REPUBLIC OF KENYA

MINISTRY OF WATER DEVELOPMENT

# SAMBURU

## WATER RESOURCES ASSESSMENT STUDY

## APPENDICES

February 1991

WATER RESOURCES
ASSESSMENT SECTION
NAIROBI, KENYA

WRAP
WATER RESOURCES
ASSESSMENT & PLANNING

TNO – INSTITUTE
OF APPLIED GEOSCIENCE
DELFT, THE NETHERLANDS

# APPENDICES

## TABLE OF CONTENTS

APPENDIX 3 - GEOPHYSICAL SURVEYS

APPENDIX 4 - DATA ON RAINFALL, EVAPORATION AND SURFACE WATER

APPENDIX 5 - DATA ON BOREHOLES, CHEMISTRY OF SPRINGS AND WELLS, WELL TESTS AND DRINKING WATER STANDARDS

Note:

*The numbers of the Appendices correspond with the respective numbers of the chapters of the Water Resources Assessment Study - Main Report.*

# APPENDIX 3

## GEOPHYSICAL SURVEYS

## APPENDIX 3

3.1 Geophysical Surveys and Results

3.2 Vertical Electrical Soundings

3.3 Em Profiles

3.4 Apex Max - Min Electromagnetic Profiles

3.5 Electrical Resistivity Profiles

# Appendix 3.1

# Geophysical Surveys and Results

## Appendix 3.1 GEOPHYSICAL SURVEYS AND RESULTS

### 1. Wamba Division

Wamba division (Figure 1) is mainly underlain by rocks of the Basement System. In the northeastern part of the investigated area some isolated basalt plains occur, whereas in the western part a relatively small elongated phonolitic ridge can be found.

### 1.1 Wamba Town

#### General

As written before, the geophysical fieldwork in Samburu District was started in Wamba Town. With its fast growing population and deficient water supply, this locality was placed at the top of the priority list for Wamba Division. The water supply from one existing borehole and a spring is far below the present demand. Moreover, the supply is frequently interrupted by mechanical breakdowns of the pump and by drying up of the spring in prolonged drought.

Wamba Town (Figure 1.1a) is situated mainly on a relatively high west-east ridge. This ridge ends promptly towards the eastern edge of the urban area. Between this edge and the Mathews range, a flat south-north running valley of about 1 km wide is situated. North of the town, this valley turns sharply to the west, reaching a width of about 5 km.

Unfortunately, no aerial photos were available for the Wamba Town area. Moreover, satellite images show cloudy patches over the same zone. Nevertheless, from drainage patterns and visual observation in the field a number of north-south and east-west trending lineations could be deduced in the exposed mountainous areas.

The valley systems seem to be formed by tectonic activity, where several inferred structures can be expected. Also, accumulation of ground water is more probable in these low-lying areas. Geophysical activities were therefore concentrated in the valleys east and north of the town.

The aim of the investigation was two fold:

First, to locate and drill one or more boreholes to cover at least the present water demand of Wamba town. Second, to point out a number of suitable structures or zones where future borehole sites can be located without extensive additional surveys.

#### Fieldwork

Initially, a brief survey was done by means of a number of vertical electrical soundings distributed around the town. The aim of the survey was to obtain a general idea of the thickness of the weathered zone.

Simultaneously, 5 RP were executed in the west-east, southwest-northeast and south-north directions in order to establish the resistivity distribution at various depths (Appendix 3.5). According to preliminary VES interpretations, the following penetration depth's (AB/2) were selected: 25 m, 50 m and 100 m. Profiling was done with a constant station interval of 25 m. The total length of the RP's amounted to 5780 m.

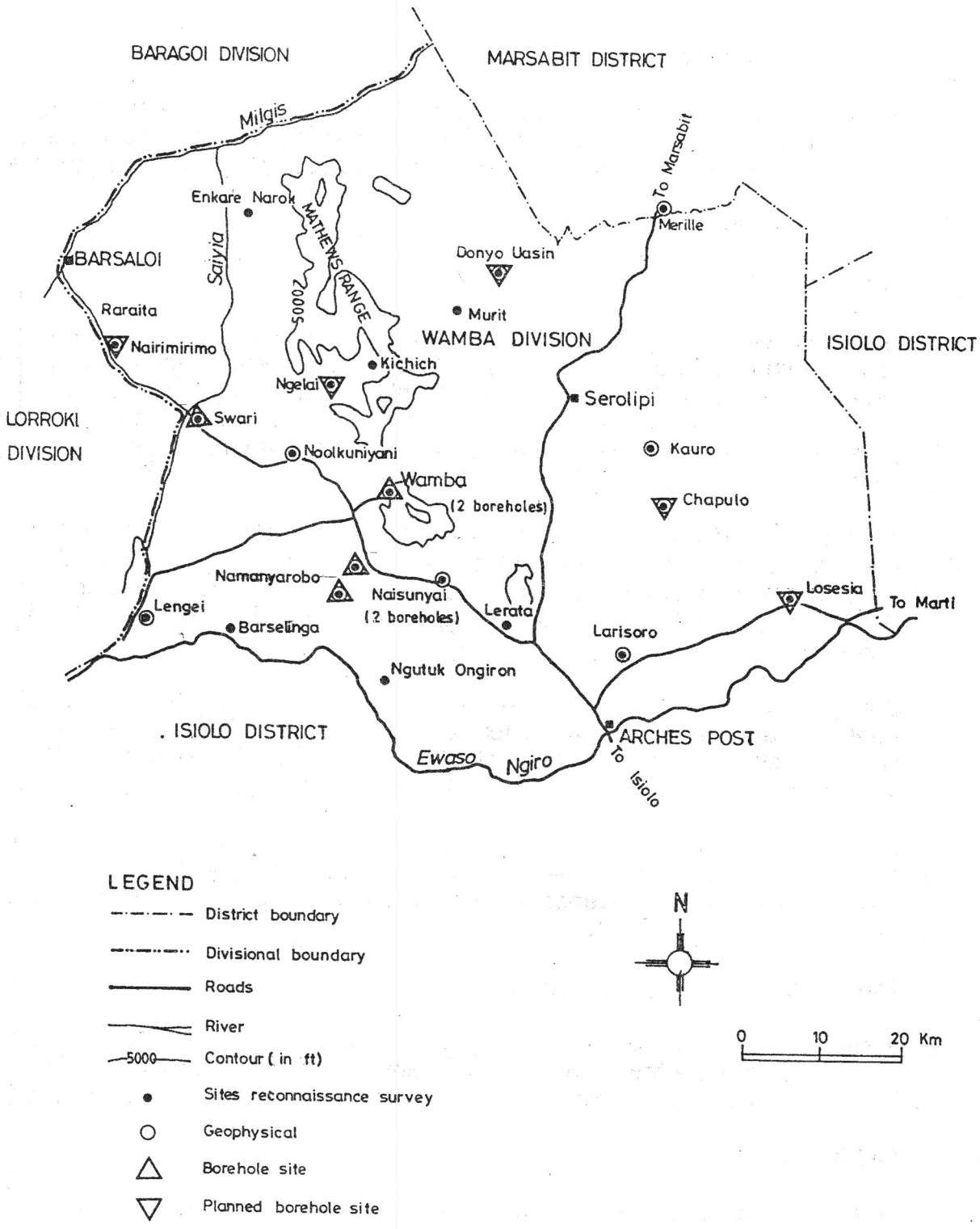
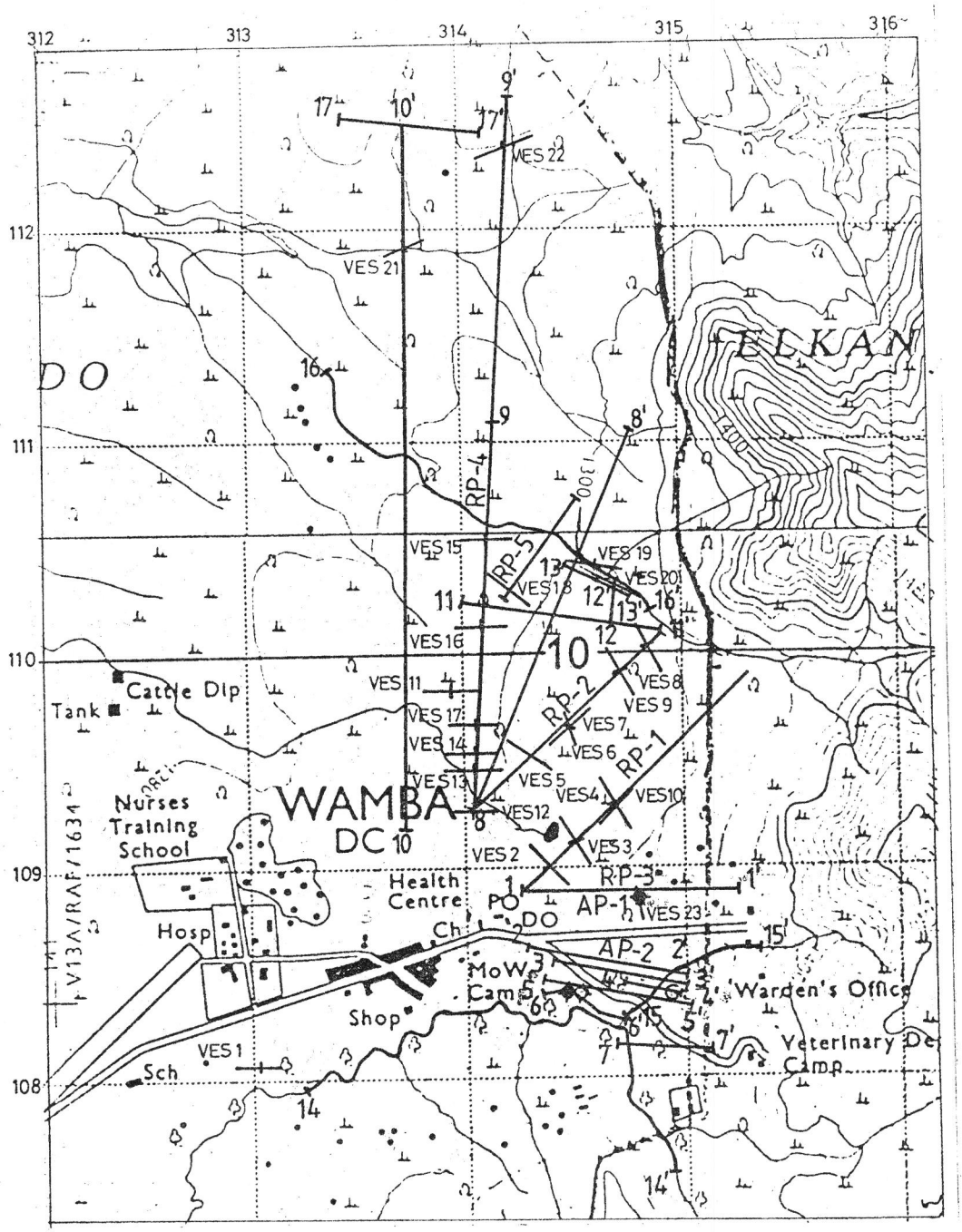



**Fig. 1 Situation Map Wamba Division**




1 Km

VES — Vert. Electrical Sounding

1 — 1' — EM-34 Profile

RP-1 — Resistivity Profile 1

AP-1 — Apex Max-Min Profile 1

Exploratory Borehole, dry

Exploratory Borehole, with water

High-Low resistivity discontinuity (fault)

Low resistivity area (fault zone, deeply weathered zone or thick alluvial cover)

**Fig. 1.1a Situation Map Wamba Town**

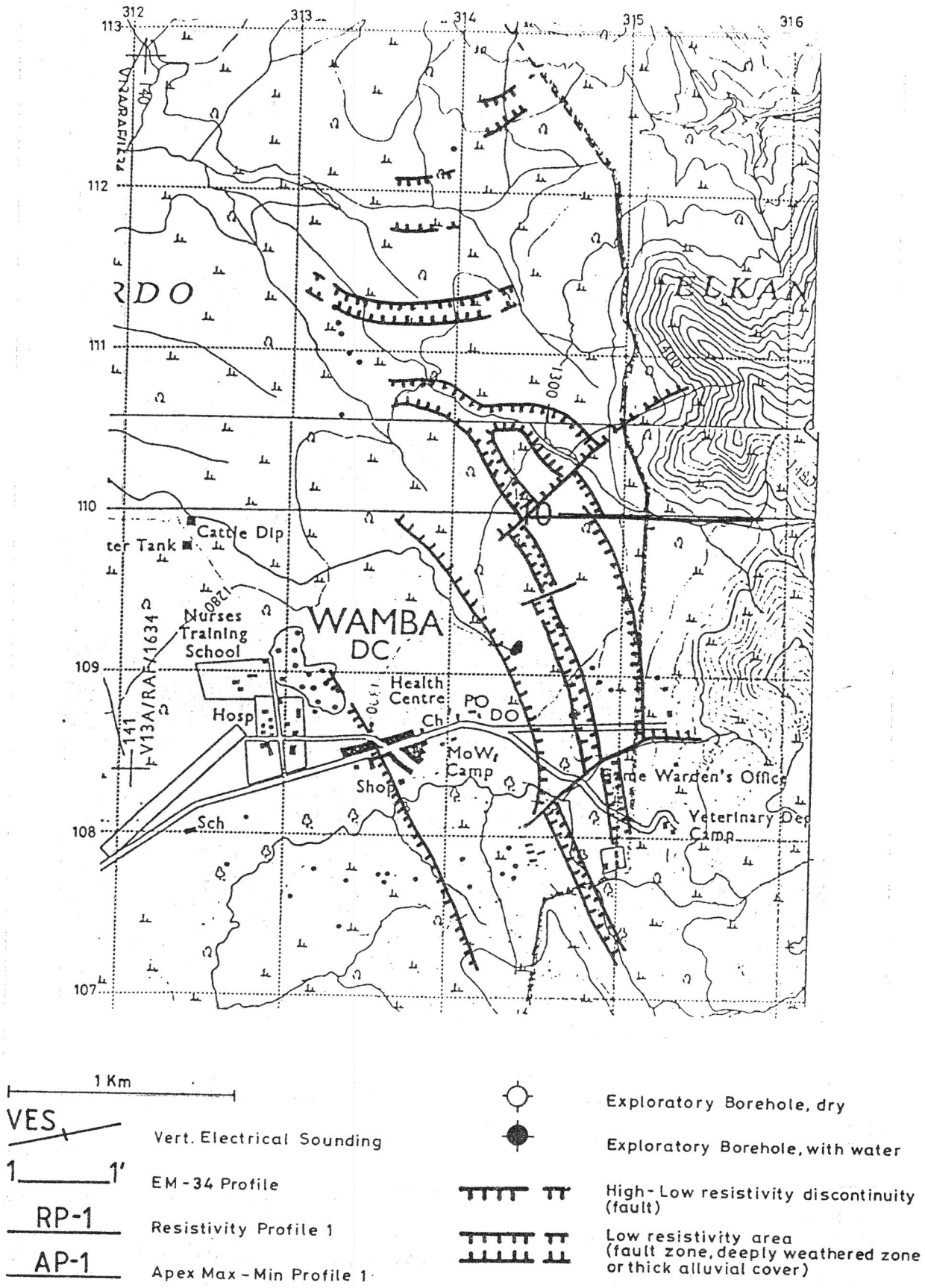



**Fig. 1.1b Structural Map Wamba**

In the western part of the area, 2 AP's were carried out. AP-1 was done along RP-3 for comparison. The total length of the APs is 1250 m (Appendix 3.4).

Next EM was introduced. This resulted in a substantial acceleration of the field data acquisition. On account of this, further profiling was extensively done by this method. Altogether, 17 EM profiles were executed, labelled W WAMBA 1 to W WAMBA 17. The total length of these profiles amounted to 18,870 m (Appendix 3.3).

Generally, coil separations of 40 m or 20 m were used. In shallow weathered zones, like river beds, the 10 m coil separation was employed. Because of the great sensitivity of the horizontal coil position to deviations from the exact horizontal position which easily could give erroneous readings, only the vertical coil array was applied. The vast majority of the profiles were done with a station distance of 20 m, which was optimum to allow a clear registration of abrupt resistivity changes.

During the survey, some complementary VES were done, mainly along the resistivity and EM profiles, in order to supply quantitative data for the interpretation of these profiles. The total number of VES executed in the survey area amounted to 23. VES graphs and interpretation results are given in Appendix 3.2.

**Results**

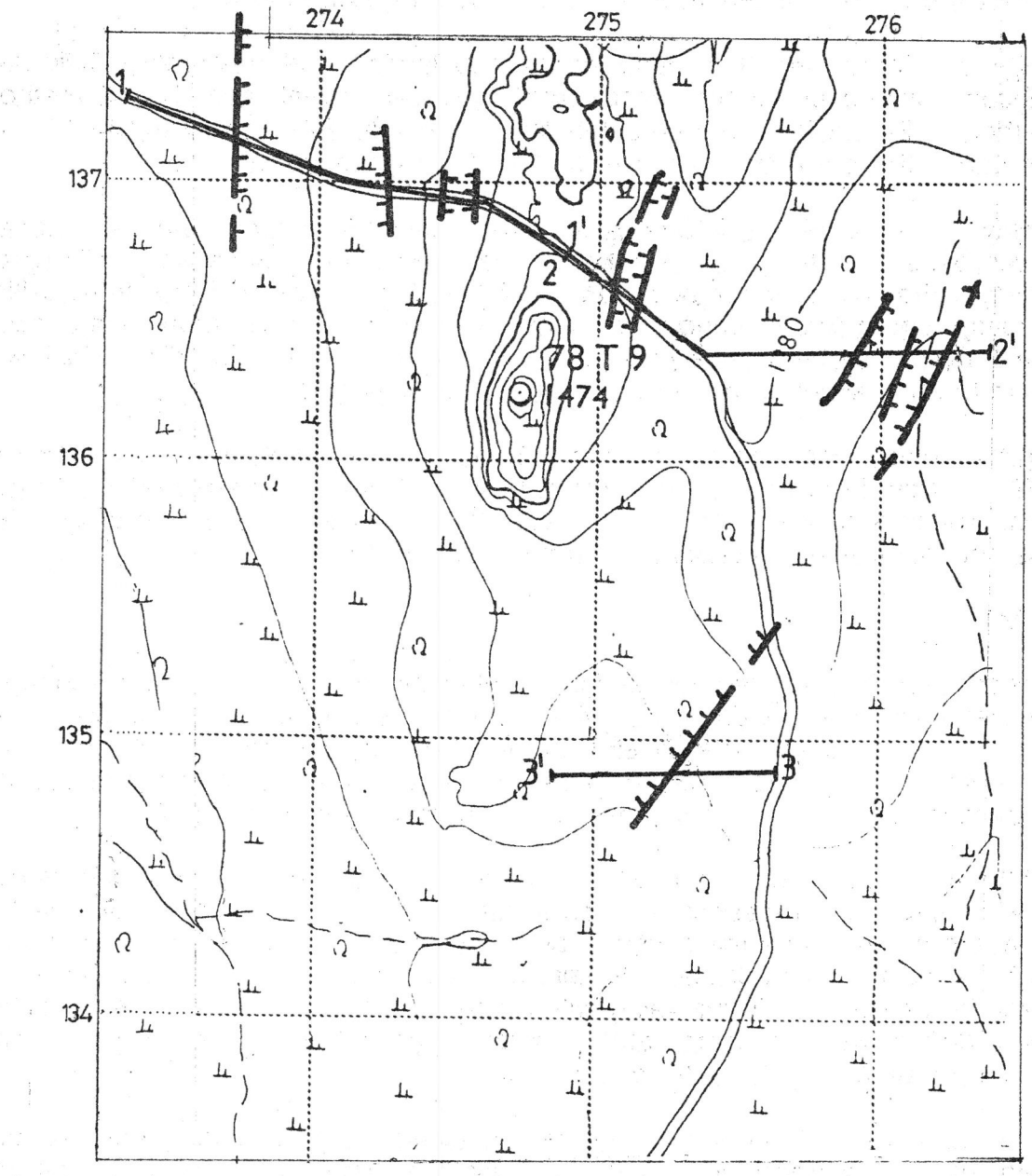
The resistivity and EM profiles show a considerable number of sharp resistivity changes (anomalies) which can be correlated with thickness differences within the weathered layer. Commonly, these differences originate from vertical movements along fault plains. Elevated parts are exposed to erosion, whereas the weathered zone of the lower ones is better preserved or even complemented by sedimentation.

Out of the anomalies, three main SE-NW running tectonic structures could be inferred (Figure 1.1b). One of these is situated at the western margin of the valley east of Wamba and seems to be the continuation of the Wamba river fault. This fault cuts through the western flank of the mountain range as a deep valley and is expected to recharge its inferred part in the valley with a continuous flow of fresh water. For this reason a drilling site was located at the eastern edge of the corresponding anomaly along EM profile W WAMBA 6 (Appendix 3.3).

The first borehole (C7909) apparently did not strike the fault zone as it was dry. Consequently, a second hole (C7910) was drilled at about 50 m from the first one towards the centre of the anomaly. In this hole, water was struck at several depths where electric resistivity logging indicated low resistivity cracked zones. However, the yield is quite low. Apparently, this relatively big fault is of a closed type preventing the accumulation of more groundwater.

A second valley-like structure runs at about 300 m distance east of the first one in the same direction. VES soundings carried out along this structure give very great depths, about 200-300 m, to the fresh basement.

A test hole C7911 drilled at station 27 of profile W WAMBA 1 penetrated a sedimentary clayey sand formation up to a total depth of 80 m. Unfortunately, drilling had to be stopped at this depth because of serious instability of the hole. A preliminary pump test during the drilling gave a yield of about 8 $m^3$/h. After well construction the yield dropped to 3 $m^3$/h. Apparently, the problems of instability and consecutive emergency measures during the well completion resulted in a deficient well construction. In future,




1 Km

VES — Vert. Electrical Sounding

1 — 1' — EM-34 Profile

RP-1 — Resistivity Profile 1

AP-1 — Apex Max-Min Profile 1

Exploratory Borehole, dry

Exploratory Borehole, with water

High-Low resistivity discontinuity (fault)

Low resistivity area (fault zone, deeply weathered zone or thick alluvial cover)

**Fig. 1.2 Situation Map Nairimirimo**

a deep well could be constructed using a more suitable drilling method to avoid caving, which will allow a better well construction.

A third structure was found along a section of the Margwe river, intersecting the second structure where this river crosses the resistivity profile RP-4. Although a borehole was located along this structure, no test drilling was included in the present program.

In future ground water programmes, all of the low resistivity anomaly zones which are indicated on the structural map could be considered for prospective drilling.

## 1.2 Nairimirimo

### General

This area extends on both sides of the Engineji Hill (see Figure 1.2). The road to Barsaloi east from the hill follows a water divide. The low ground on either side of the hill looks promising for groundwater. Faulting has been interpreted from aerial photographs in the low lying area on the western side of the hill.

The proposed borehole is expected to serve the local primary school and community.

### Fieldwork

Three EM profiles were covered in this area (W Nairimirimo 1 to 3). Profile 1 (1680 m) was done along the road on the west side of the hill. Profile 2 (1600 m) started at the end of 1 along the road for 600 m before changing the direction to west-east for about 1000 m. Profile 3 (800 m) was done 2 km south of the above profiles in west-east direction (Appendix 3.3).

### Results

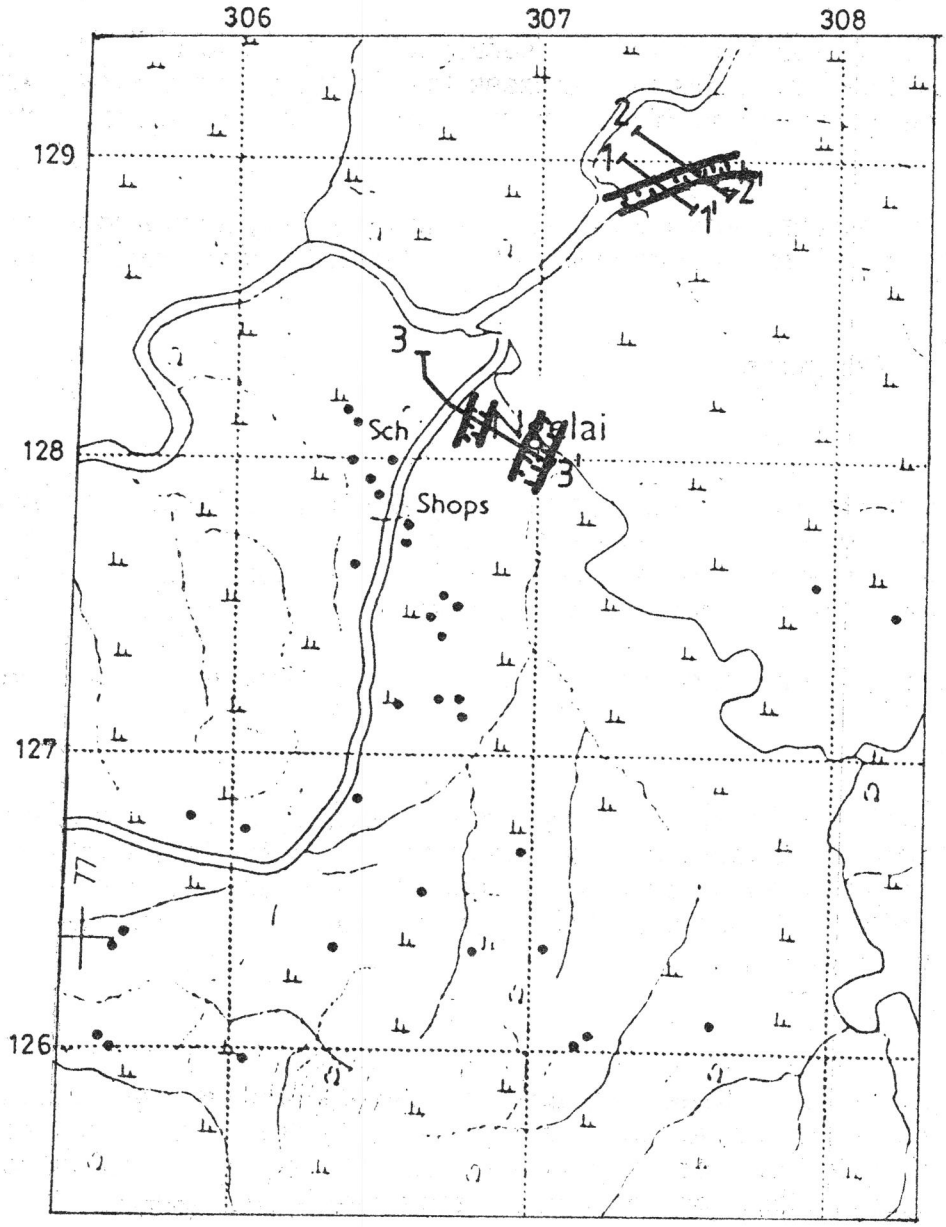
On each profile, several resistivity changes can be observed which may indicate tectonic features such as fault planes and graben - like structures. A borehole site was selected on profile 3 at station 24 on the eastern edge of a low resistivity zone where several north-south faults on both sides of the hill seem to converge. Due to delays no drilling was carried out.

## 1.3 Ngelai

### General

The area is located along the Barsaloi - Kichich road (see Figure 1.3). There are several laggas which are filled with water during the rainy season. During the dry season the laggas dry up, forcing the livestock to be moved to as far as Kichich, a tourist resort situated within a forest. This is a problem to the Forest Department as the livestock destroys the young trees. Besides this there is a primary school and a health centre under construction which need a permanent source of water.

Preliminary investigations showed the presence of several faults, the most interesting one along the Ngeny valley. This fault seems to cross another major one just below the health centre.




1 Km

VES — Vert. Electrical Sounding

1 — 1' — EM-34 Profile

RP-1 — Resistivity Profile 1

AP-1 — Apex Max-Min Profile 1

Exploratory Borehole, dry

Exploratory Borehole, with water

High-Low resistivity discontinuity (fault)

Low resistivity area (fault zone, deeply weathered zone or thick alluvial cover)

**Fig. 1.3 Situation Map Ngelai**

**Fieldwork**

Three EM profiles W Ngelai 1, (380 m) W Ngelai 2, (300 m) and W Ngelai 3 (580 m) were made in the area (Appendix 3.3). The first two were made near the abandoned mission. They were 100 m apart. The last one was made at an azimuth of 120° up to the road then changed azimuth to 320°.

**Results**

In all the three profiles low resistivity zones were picked. Correlation of these anomalies clearly shows a fault zone running in NE-SW direction parallel to the major lagga and another fault running in the same direction parallel to the former one.

A borehole can be located within the major fault zone and especially on profile 1 where recharge from the intermittent flow in the lagga is expected to be good.

## 1.4 Swuari

**General**

This area is located near the Seiya river along the Wamba - Barsaloi road (Figure 1.4). From the drainage pattern of the laggas an intricate network of southwest-northeast and southeast-northwest lineations could be inferred. The proposed borehole may serve the school and Trading Centre.

**Fieldwork**

The area is rather rugged and not easily accessible for the drilling rig. For this reason fieldwork was restricted to some sites near the road. Four EM profiles were made in this area (Appendix 3.3). Profiles W Swuari 1 (160 m) and W Swuari 2 (220 m) were done near the Seiya river in west-east direction and 80 m apart. Profile W Swuari 3 (340m) was made across the school football field in west-east direction. Profile W Swuari 4 (80 m) was made in north-south direction starting from station 1 of profile 3.

**Results**

Along profiles 3 and 4 a low-resistivity anomaly was found which may indicate a relatively small fault zone running across the school compound in southeast-northwest direction and probably crossing the main fault system of the Seiya river. However this site is at elevation of 120 m above the Seiya river, hence the water level is expected to be too deep for economic exploitation. An alternative site was selected at the low resistivity section of profile 1 near the Seiya river where the probability of striking water is considerably higher.

This site was however inaccessible to the drilling rig and hence the drilling was done at the first site (i.e school football field). The recharge in this site is expected from the Seiya river (about 2 ½ km north) and hence the aquifer was expected to be struck at a depth of more than 100 m. However on drilling the only aquifer was struck at a depth 70 m, with the total drilled depth being 130 m.

An aquifer of about 3 $m^3$/hr was struck at 70 m, containing highly mineralized water. Obviously this water does not originate from the Seya river system, but from higher regions. The high mineral content is due to the long setention time which allows the

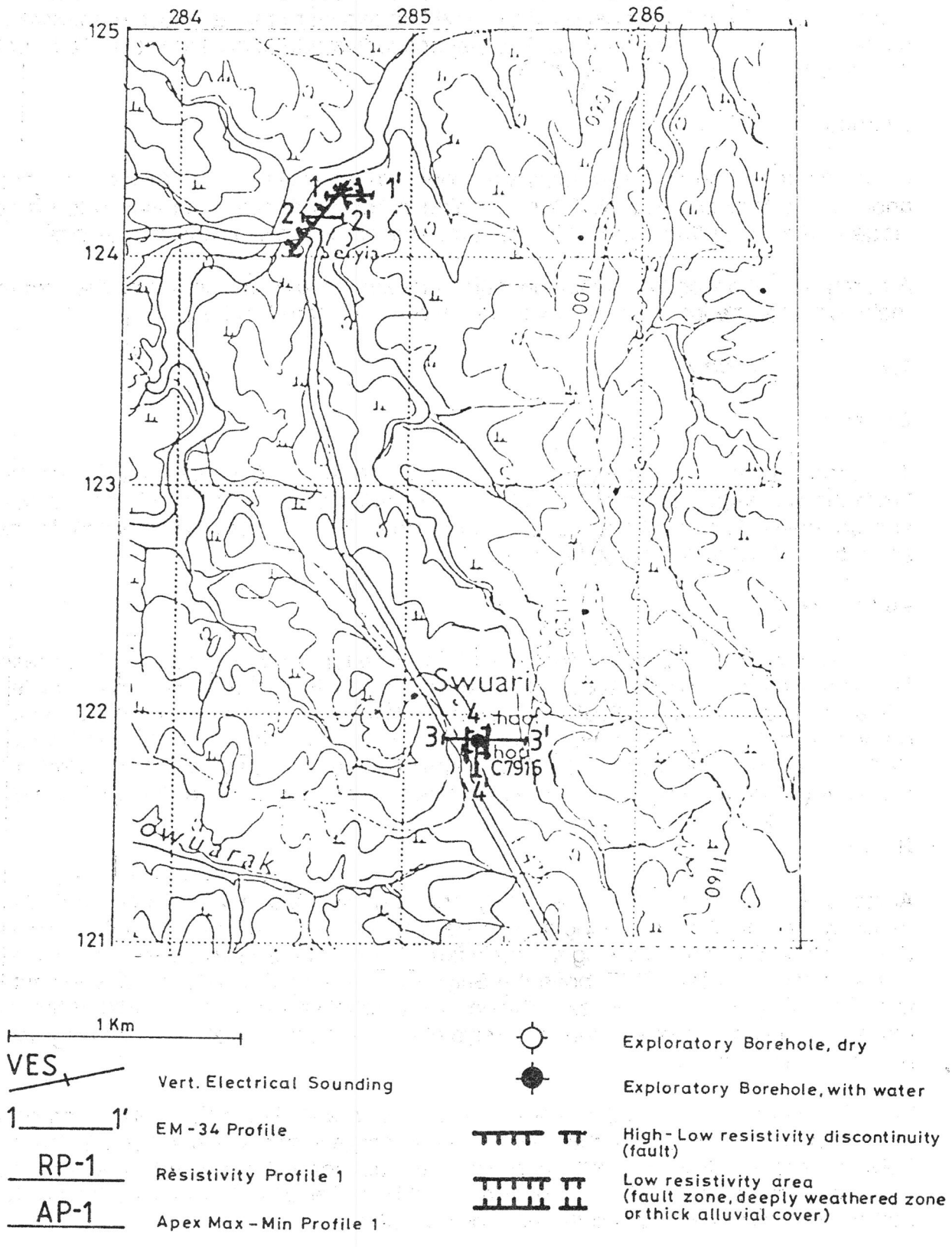



**Fig. 1.4 Situation Map Swuari**

water to dissolve salts from rocks as it passes through.

## 1.5 Naisunyai

### General

This area Figure (1.5) is geographically quite near to the Namanyarobo one (next chapter) and some of the lineaments observed in the latter also extend to the former. A permanent dam was constructed about 6 km to the east of the Kimaniki pass. Therefore geophysical fieldwork was concentrated around the pass to find a suitable site I for an alternative livestock watering point.

### Fieldwork

This area was divided into 3 sub areas and a total of 15 profiles were made (Appendix 3.3). On the western side there is a generally flat area near the dam which has been named site I. Site J is the area near a drift. Site K is on the eastern side of the drift.

At site I five EM profiles (W Naisunyai 1 to 5) were executed. Profiles 3 (1,480 m) and 5 (2,220) m were made in north-south direction 250 m apart with the former starting at the junction of the old and new road. Profiles 1 (2,540 m); 2 (1,660 m) and 4 (1,700 m) were run parallel in northwest-southeast direction and 250 m apart. The first profile started at the foot of Werikoi hill running almost parallel to the road and the other two were done south of this.

At site J three EM profiles (W Naisunyai 6 to 8) were made all starting near the drift. Profile 6 (1,520 m) runs in a southwest-northeast direction while profiles 7 (920 m) and 8 (660 m) are in northwest-southeast direction and at a distance of 250 m apart.

At site K seven EM profiles (W Naisunyai 9 to 15) were done. Profiles 9 (1,040 m), 10 (1,080 m); 11 (1,060 m) and 12 (1,080 m) were done parallel to each other in northwest-southeast direction and 500 m apart. Two other profiles 13 (1,040 m) and 14 (1,000 M) were run in west-east direction 1 km apart. Finally, profile 15 (1,020 m) was done in a southwest-northeast direction starting at the end of profile 12.

In addition, two soundings were executed near the selected borehole site (Appendix 3.2). The maximum AB/2 for VES $K_1$ is 250 m and $K_2$ is 320 m.

### Results

For the profiles at site I several contrasting resistivity changes can be observed which may indicate the presence of faults or fractures. At the other two sites very few anomalies were picked even when different coil separations were used on the same profile. Most of the profiles show constant and low resistivity values. This indicates an unusual thick weathered layer or the existence of sedimentary fill.

At site K two VES were executed in order to find the true thickness of the unconsolidated overburden. The soundings clearly show a thin dry top layer of high resistivity (165-650 ohmm) up to a depth of 4 - 7 m which overlies a layer of lower resistivity (25-28 ohmm) at a depth of 7-25 m. The third layer has a slightly higher resistivity (60-70 ohmm) at a depth of (25 - 40 m). The layer below this has a low resistivity (25 ohmm) up to a depth of 100 m, which marks the interface between loose overburden and fresh bedrock.

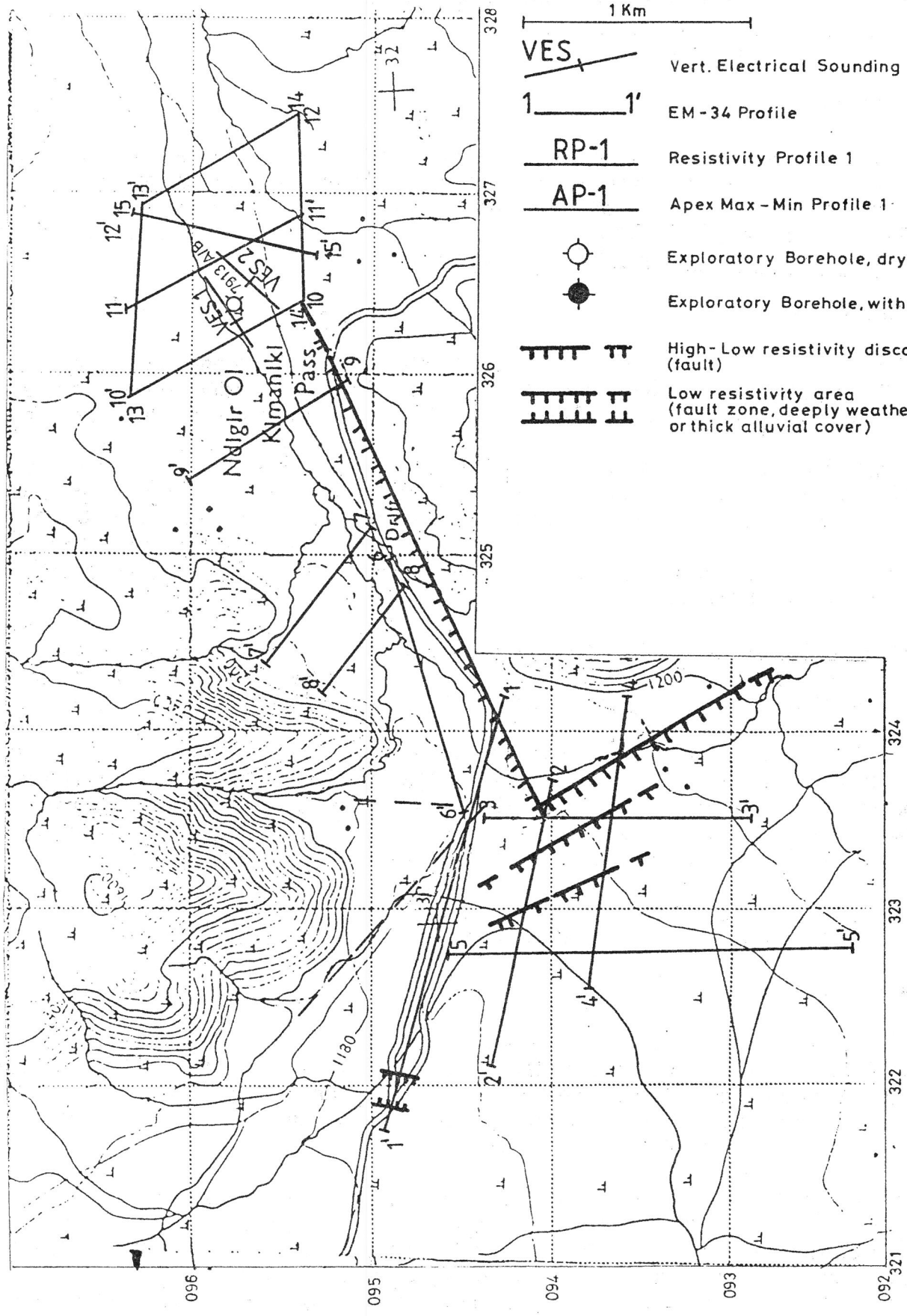



**Fig. 1.5 Situation Map Naisunyai**

A test hole (7913A) on site VES-1 penetrated loose dry sediments upto a depth of 64 m. The drilling was abandoned due to serious caving. A second attempt at a short distance reached a depth of 90 m showing identical loose dry sediments (7913B). This hole has been temporarily abandoned because of the above mentioned problem.

It concerns of an intermountaineous deep valley filled up by ill-sorted, short-range fluviatile deposits. Water inflow occur principally along the contact between these sediments and the surrounding basements rocks, whereas a considerable post of the accumulated water will probably be drained by the existent inferred faults in the basement underlying the sediments. Nevertheless, some water can be expected in the lowermost part of the sediments and the weathered basements rocks. To-be drilled therefore a future borehole is recommended by the straight-flush mud circulation system up to the fresh baserock.

## 1.6 Namanyaraboo

### General

This relatively extensive area is to the south of the bridge across the Lengusaka river on the road Archers Post to Wamba. The area is far from the existing water supplies although water from laggas is being used. Namanyaraboo dam, situated at the centre of the investigation area, is completely silted up.

From aerial photographs several lineaments can be observed most of which have a north-south trend while others run east-west. Most laggas seem to follow these lineaments although it is not easy to discern the latter in the field, especially in flat lying areas, where they are concealed below the sediments.

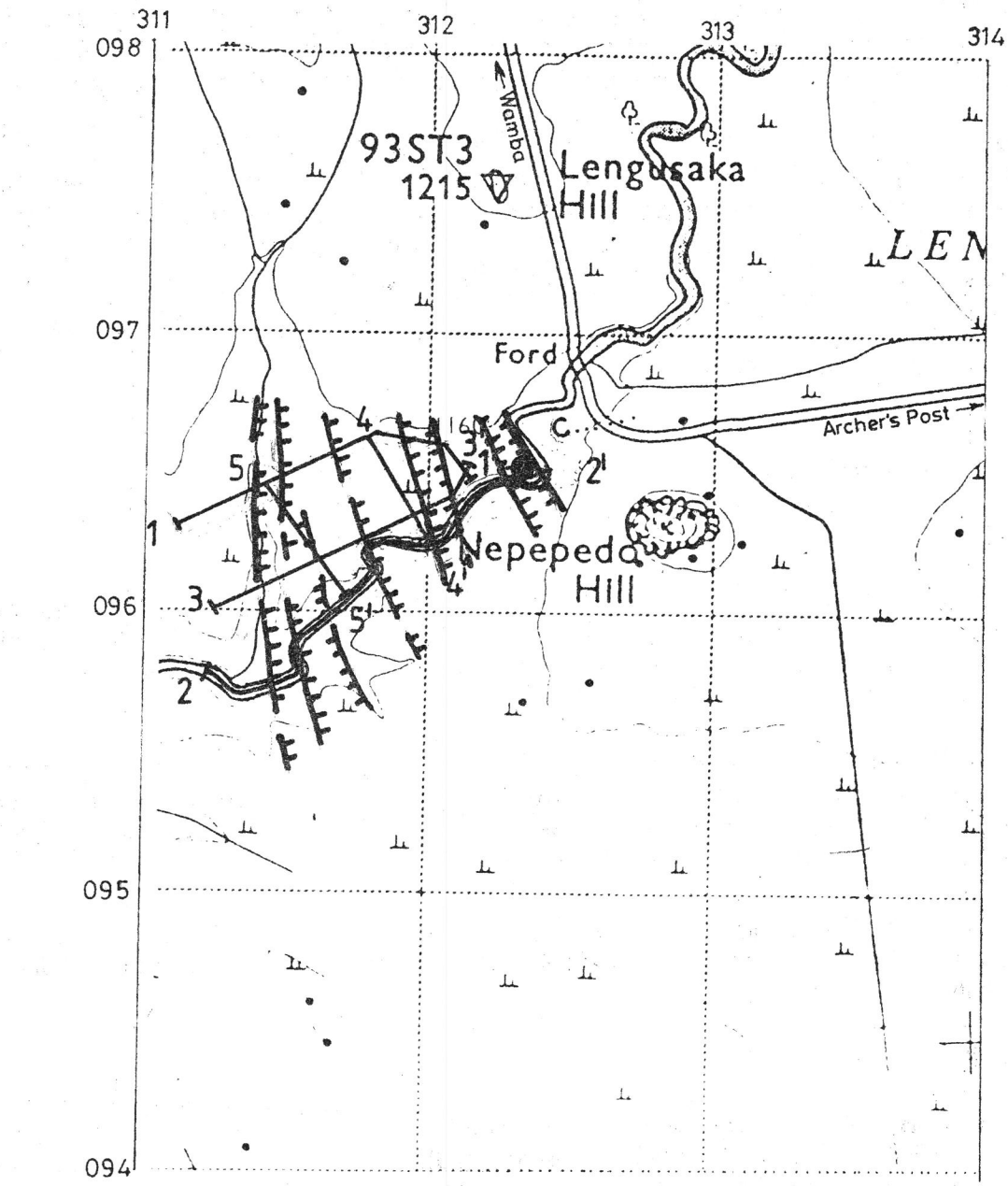
The whole area is subdivided into five sites. The figures 1.6a, 1.6b and 1.6c cover the sites A,B,C,D and E respectively. Site C was not investigated due to difficult accessibility.

### Fieldwork

Four sites (A,B,D and E) were chosen for investigation. Fourteen EM profiles were done with a total length of 12.44 km (Appendix 3.3). The station interval was 20 m for all profiles. The coil separation was 20 m in all profiles except in one (W Namanyaraboo 14) where it was 40 m. Orientation and length of profiles were variable depending on local topography and the lineaments. A few soundings were done in places where more information on depth of weathered zones was needed.

At site A, five EM profiles were done near the bridge slightly to the west of Nepepedo Hill Profile W Namanyaraboo 1 (1,240 m) was done in an azimuth of 245° a few hundred metres from Lengusaka lagga. Profile W Namanyaraboo 2 (1,800 m) was done along the lagga while 3 (1,060 m) parallel and 300 m to the south of $A_1$-$A_1$ was done close to the lagga. The remaining ones (i.e W Namanyaraboo 4 and W Namanyaraboo 5 were 400 m apart with lengths of 460 m and 520 m respectively. They crossed the other profiles, as shown on Figure 3.7, in an azimuth of 150°.

Another five profiles were made at site B, next to the dam. Only profile W Namanyaraboo 8 has a length of 420 m. Each of the others are 500 m long. Profiles W Namanyaraboo 6, W Nanyaraboo 7 and W Namanyaraboo 10 were done in a north-




1 Km

VES — Vert. Electrical Sounding

1 — 1' — EM-34 Profile

RP-1 — Resistivity Profile 1

AP-1 — Apex Max-Min Profile 1

Exploratory Borehole, dry

Exploratory Borehole, with water

High-Low resistivity discontinuity (fault)

Low resistivity area (fault zone, deeply weathered zone or thick alluvial cover)

**Fig. 1.6a Situation Map Namanyarabo Site A**

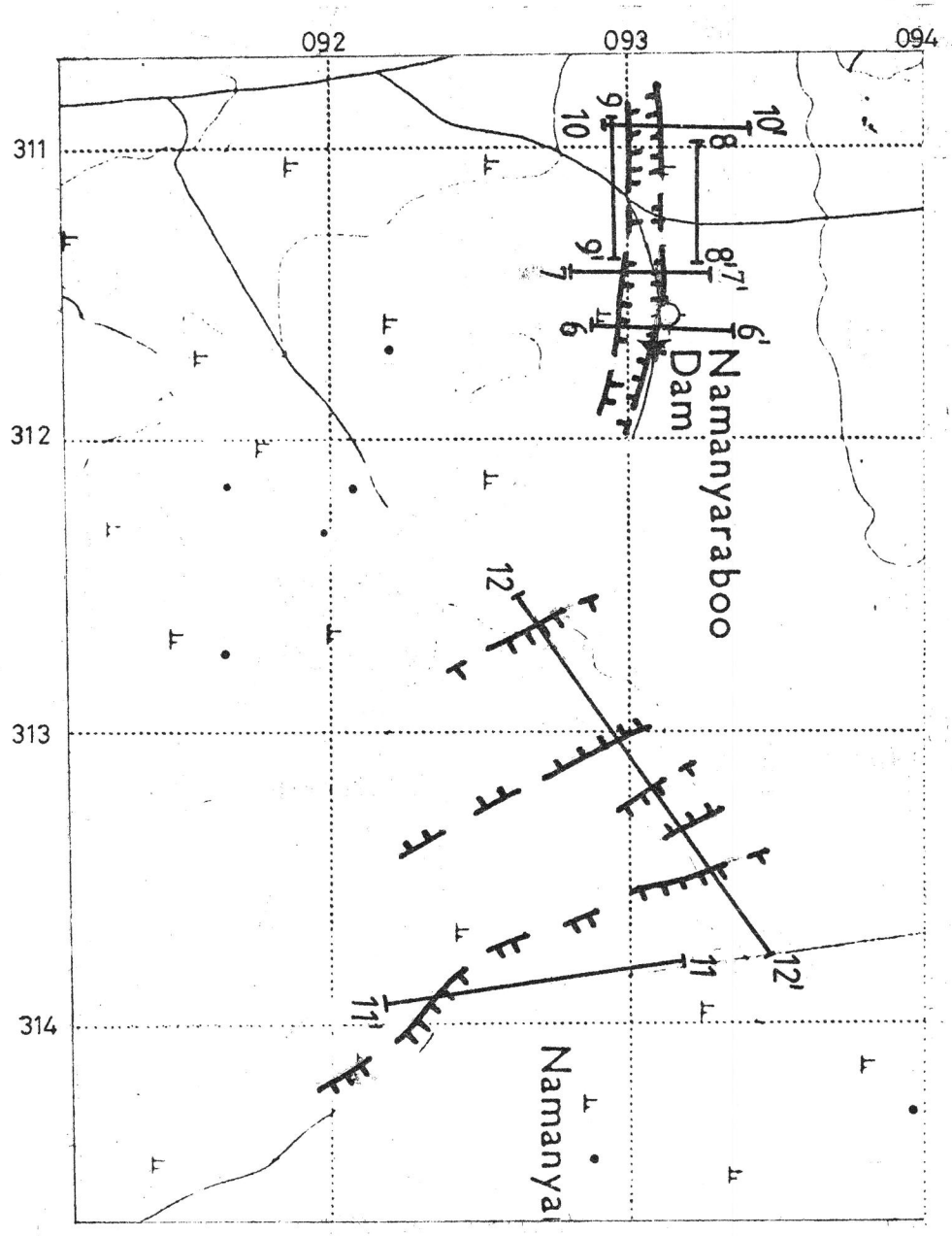
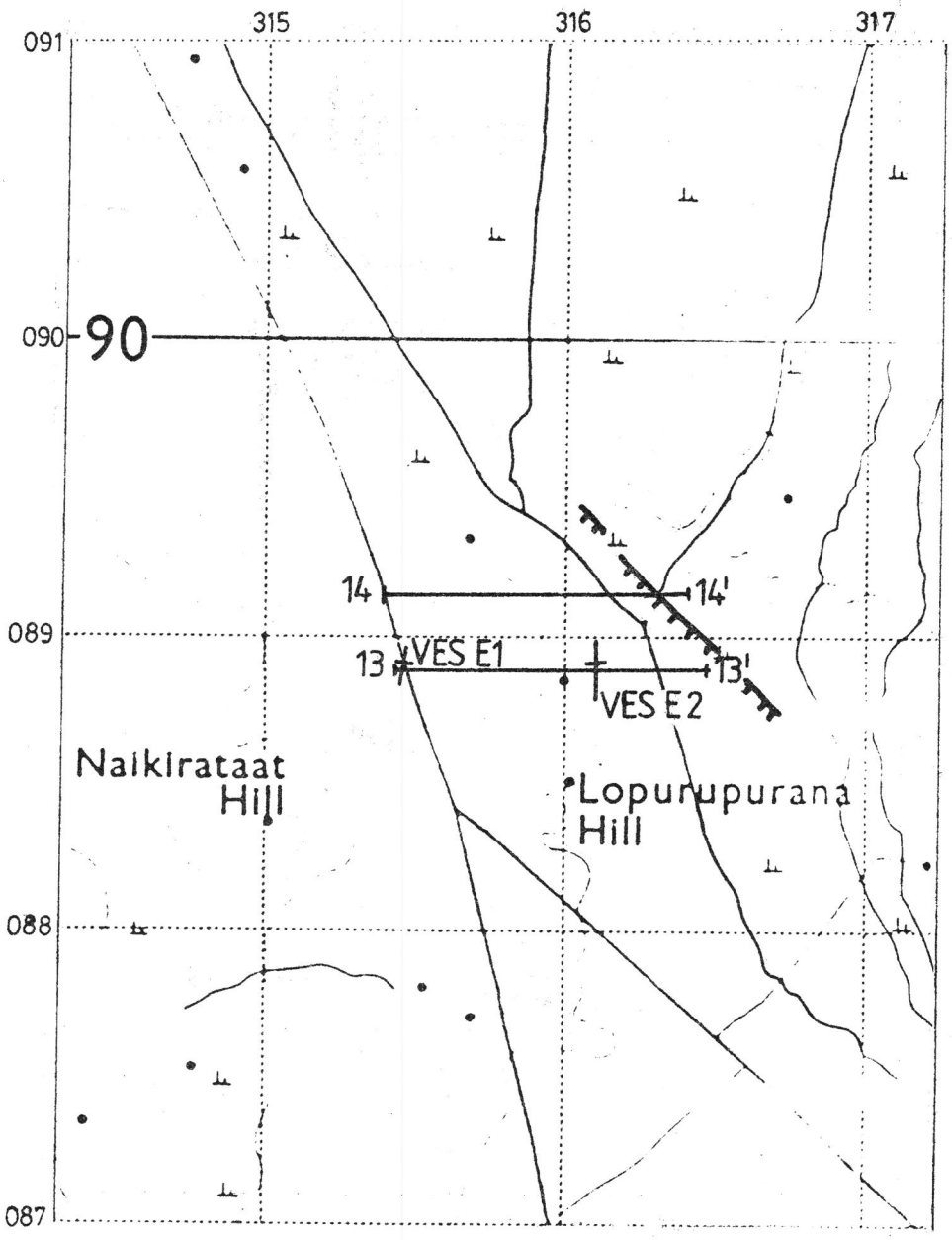



**Fig. 1.6b Situation Map Namanyarabo Sites B,C,D**




1 Km

VES — Vert. Electrical Sounding

1 — 1' — EM-34 Profile

RP-1 — Resistivity Profile 1

AP-1 — Apex Max-Min Profile 1

Exploratory Borehole, dry

Exploratory Borehole, with water

High-Low resistivity discontinuity (fault)

Low resistivity area (fault zone, deeply weathered zone or thick alluvial cover)

**Fig. 1.6c Situation Map Namanyarabo Site E**

south direction while the remaining two were in an east-west direction. One sounding (VES $B_1$) was done at station 14 of profile 6, just behind the dam (Appendix 3.2).

At site D two profiles were done both starting from the road just to the west of Namanyarobo Hill. Profiles W Namanyaraboo 11 at an azimuth of 170°E and W Nanyaraboo 12 (azimuth 235°) started 300 m to the north of the start of profile 11. Their lengths were 1,180 m and 1,580 respectively.

Further south, at site E near Lopuruparana Hill, two profiles were done, each one kilometre long. Both started at the road and were done in an easterly direction 250 m from each other (profiles W Namanyaraboo 13 and 14).

**Results**

The EM profiles show a number of low resistivity anomalies that can be interpreted to mean faults or deeply weathered zones. Generally, the anomalies correspond to the inferred lineations. The earlier observation that the dam was situated on a faultline was strengthened by the anomalies picked on the north-south profiles at site B which are in line with the dam.

The results of sounding $B_1$ near the dam shows three layers overlying the basement: a surface layer 5m thick with a resistivity of 105 ohmm, is underlain by a layer 4m thick having a resistivity of 300 ohmm, followed by another one of about 80 m thick and with resistivity of 140 ohmm.

The other two soundings ($E_1$ and $E_2$) show similar layering made up of a surface layer upto 2m thick with a resistivity of 120-300 ohmm. Before encountering the basement there is an intermediate resistivity zone between 25-40 m with a resistivity of 40-130 ohm metres.

The site of sounding $B_1$ was considered suitable for drilling as it shows a thick weathered layer (upto 90m). In addition, the various departments in Samburu District preferred that new boreholes be drilled away from any existing water points e.g laggas and dams. Despite the said thick weathered layer borehole C7912 drilled at this site turned out to be dry. Therefore another one C7914 was drilled near the lagga at the second largest anomaly (stations 86-91) of profile W Namanyaraboo 2. This borehole was successful and struck water at about 18 m below the surface.

Resistivity borehole logging shows that the water producing zones have low resistivities representing weathered basement rock.

## 1.7 Lengei

**General**

Lengei is situated on the Wamba-Maralal road about 7 km west of Lodungokwe (Figure 1.7). This being one of the areas not covered by aerial photographs, topographic maps were relied on for the preliminary findings. It seemed that there is a graben on both sides of Lengei Hill. Drainage was also thought to follow faultlines.

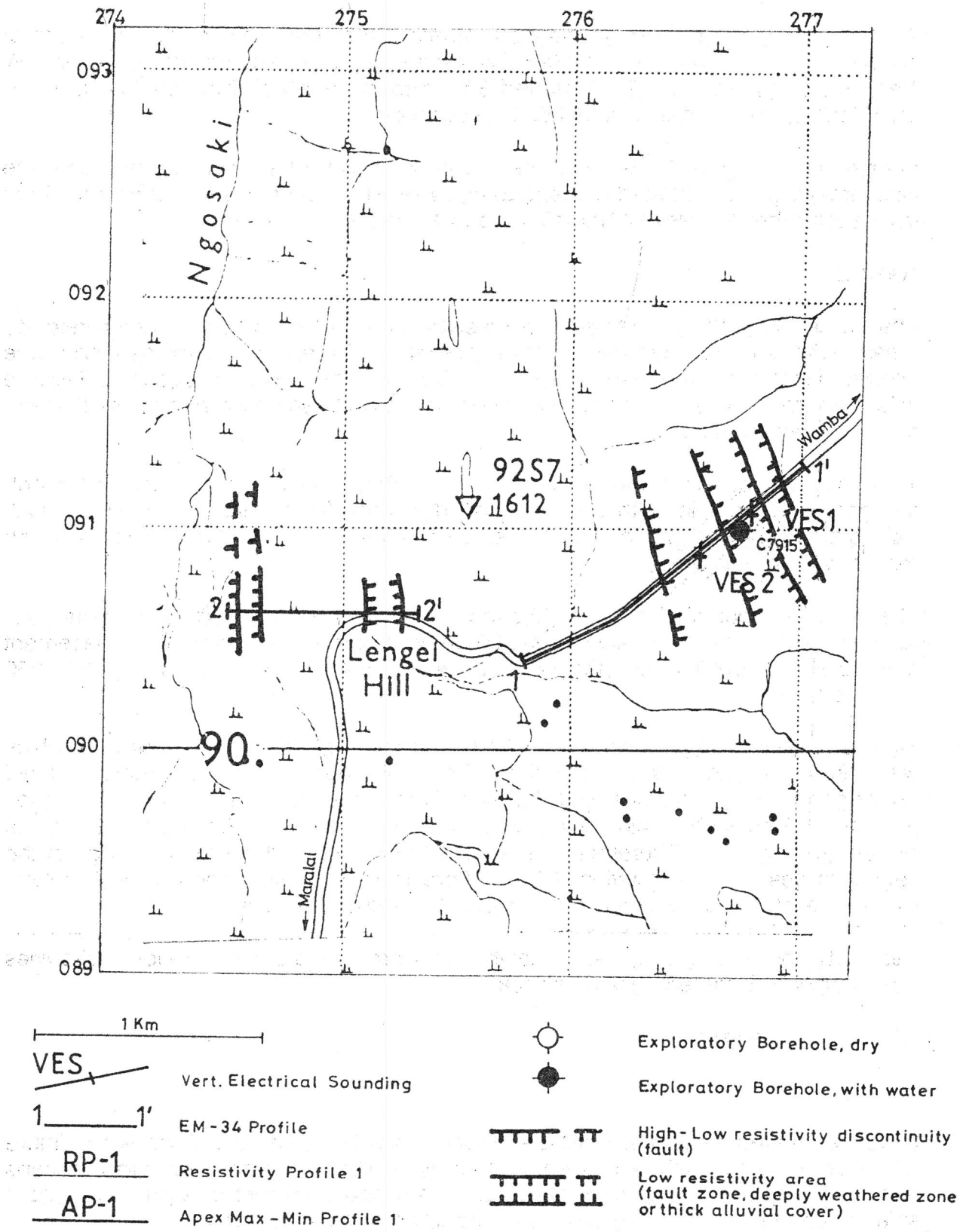



**Fig. 1.7 Situation Map Lengei**

### Fieldwork

Two EM profiles were executed. The first one was on the eastern side and the second one on the western side of Lengei Hill. Profile W Lengei 1 (1,580 m) was done along the road while W Lengei 2 (840 m) started from the road, at Lengei Hill, and ran westward (Appendix 3.3).

In addition two soundings (VES 1 and 2) were done at stations 61 and 46 respectively of profile 2 (Appendix 3.2). VES 1 had a maximum AB/2 of 160 m of 187° while VES 2 had AB/2 of 100 m.

### Results

A number of low resistivity anomalies were picked on the profiles. The notable one was on profile 1 with resistivities as low as 25 ohmm. This anomaly is about 800 m wide suggesting step faulting within a graben like structure. Profile 2 shows only the eastern edge of a graben by step-faulting similar to the situation found in the eastern valley.

The two soundings were done within the anomalous zone to procure more information about the subsurface. The soundings show similar layering in that there is a surface cover (about 2m) with a resistivity of 100-120 ohmm, underlain by a layer about 10 m deep with resistivity of 7-20 ohmm. This is followed by an intermediate zone 25-30 m below the surface with a resistivity of 30-130 ohmm before hitting the basement.

The results indicated that there was a good chance of success if drilling is done within one of these anomalous regions. A borehole C 7915 was drilled in the centre of the eastern graben to a depth of 100 m. Water was struck at 63 m.

## 1.8 Noolkuniyani

### General

Noolkuniyani is located on the Wamba - Baragoi road a few kilometers from the Wamba - Baragoi - Kichich junction (Figures 1.8a and 1.8b). Here water is needed for the planned school and Trading Centre in addition to livestock.

The preliminary investigations showed that this area lies on a water divide. The northern part of the divide has been eroded into a rugged terrain with mostly dendritic drainage. The southern divide is more level with poorly defined valleys. This made it difficult to infer any lineaments. It was therefore decided that EM profiles be done to try and locate any features of interest, particularly weathered zones.

### Fieldwork

Geophysical work was executed at two sites in Noolkuniyani. Four EM profiles were done at site A (W Noolkuniyani 1 to 4) in a west-east direction, varying in length between 480 and 860 m (Appendix 3.3). At site B, farther to the west of site A three parallel profiles were done in an azimuth of 40°, 300m from one another with respective lengths of 2,140 m, 1,620 m, and 1,560 m (profiles W Noolkuniyani 5 to 7).

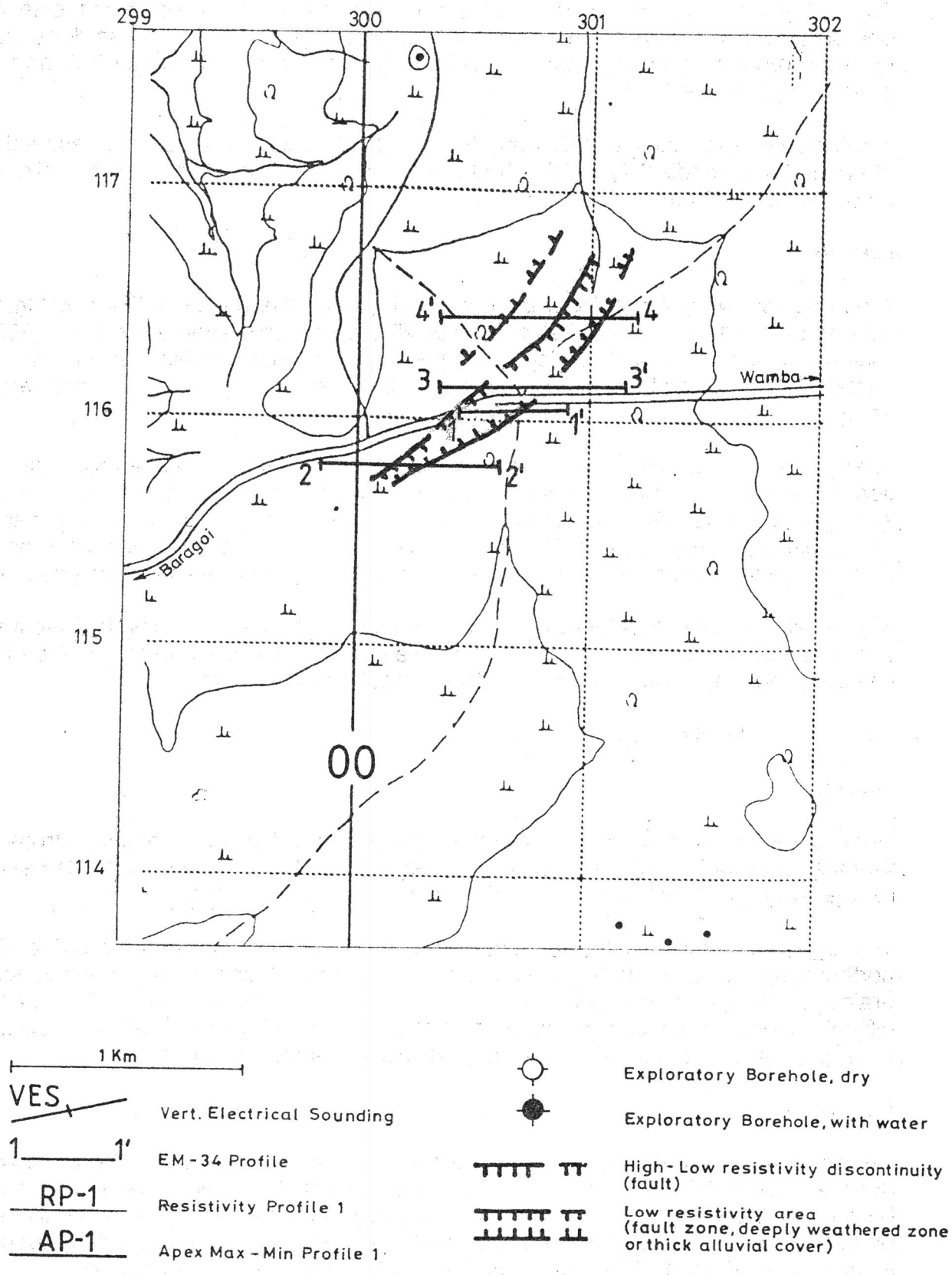



**Fig. 1.8a Situation Map Noolkuniyani, Site A**

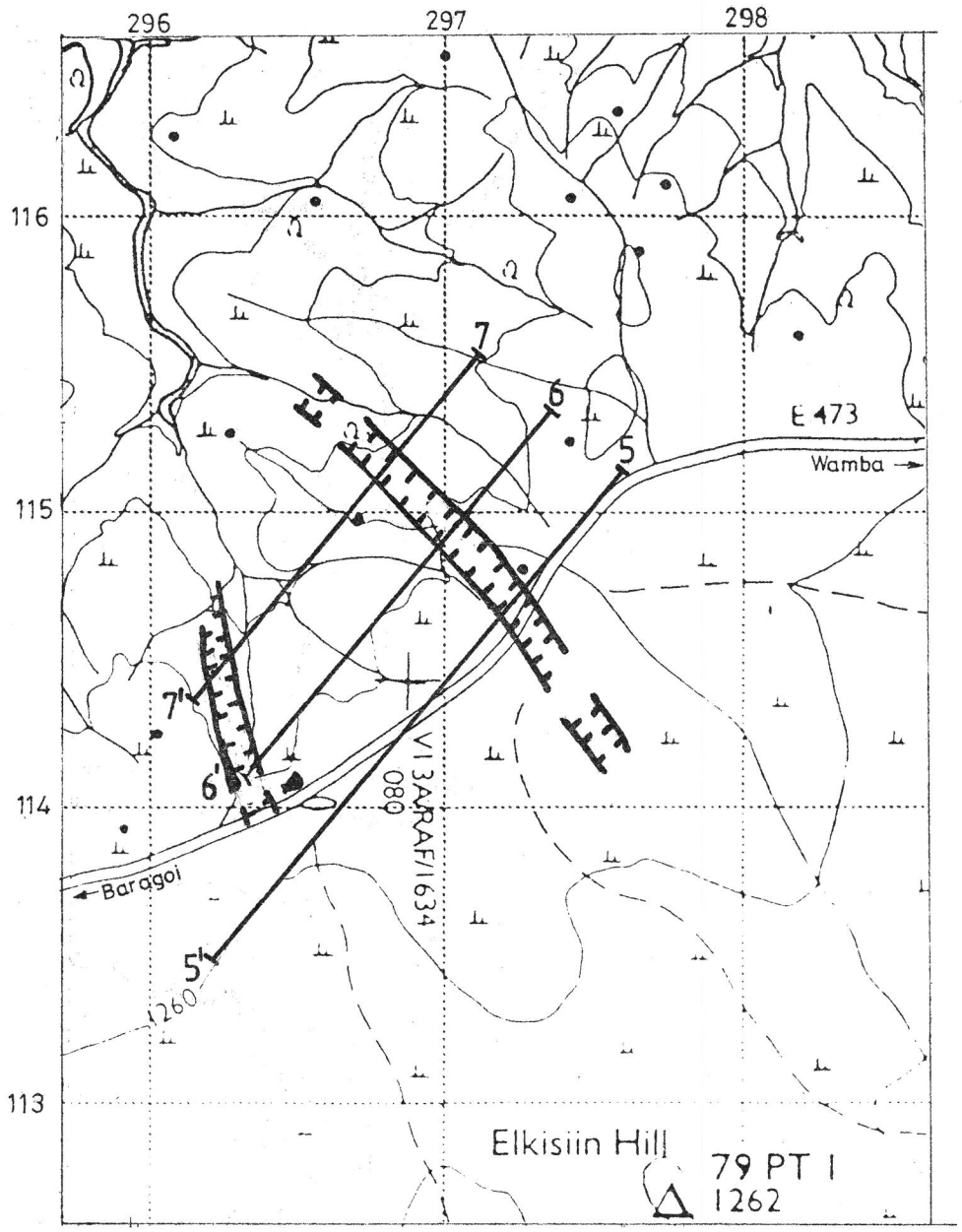



**Fig. 1.8b Situation Map Noolkuniyani, Site B**

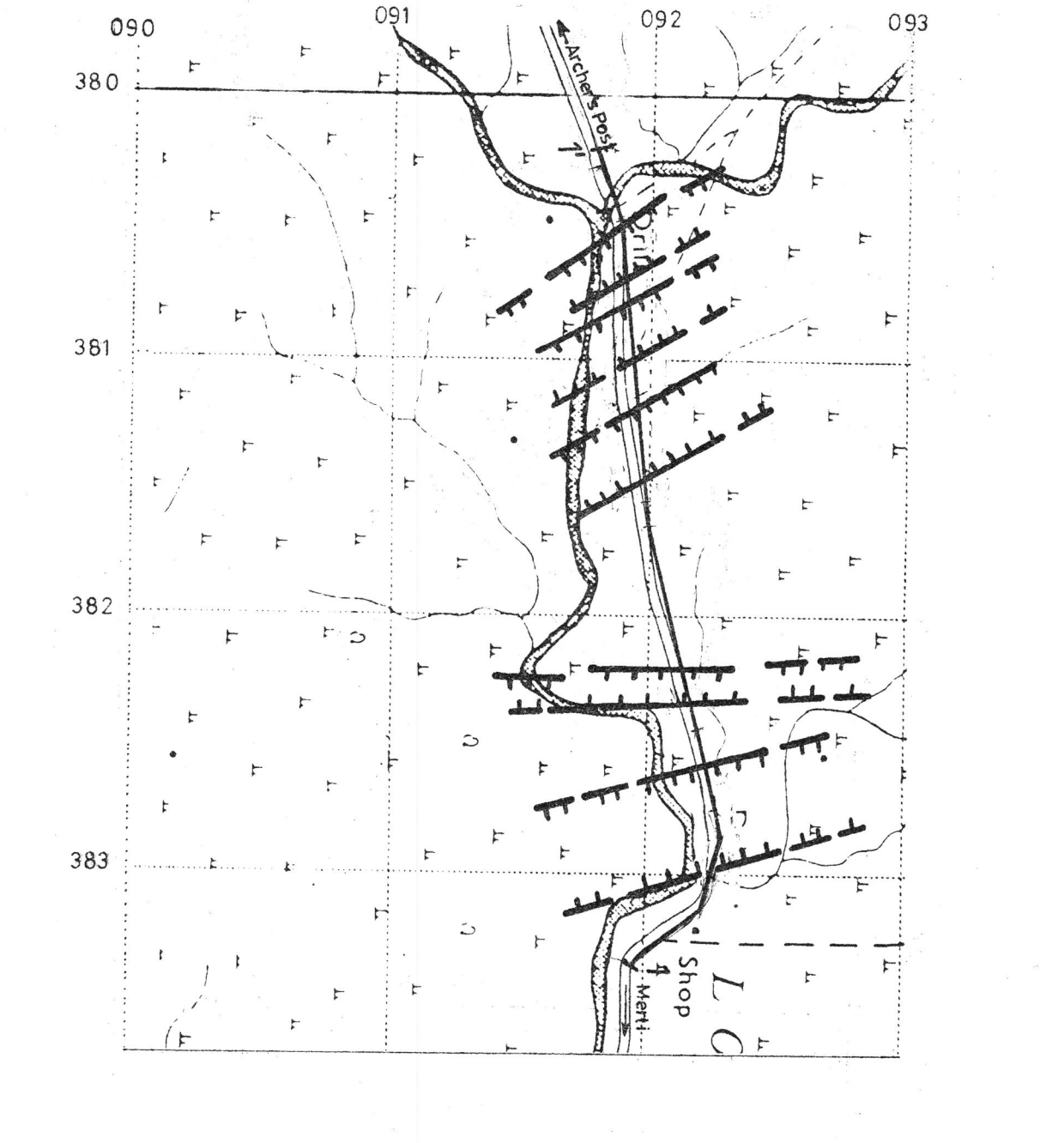



**Fig. 1.9 Situation Map Losesia**

**Results**

At site A, one pronounced resistivity anomaly (fault zone) was found, running SW-NE through the profiles. At site B, two similar zones were detected. No borehole could be drilled here due to preference given to other areas on basis of the priorities.

The future, boreholes could be located anywhere within the indicated fault zones.

## 1.9 Losesia

**General**

Losesia, situated on the Archer's Post - Merti road (Figure 1.9), has few "Manyattas" and although the map shows the presence of a shop, it seems as if the centre ceased to exist. The investigated area is close to a lagga and is intended to be a watering point for livestock and human use.

No photographs were available covering this area. From topographic maps, it was noted that Losesia lagga follows a course with sudden angular turns that suggest faulting.

**Fieldwork**

One profile (W Losesia 1) was executed along the road with a length of 3360 m (Appendix 3.3).

**Results**

Three major low resistivity anomalies were picked on the profile. An anomalous zone of about 800 m wide was detected at the western part of the profile, indicating intems faulting. Similar narrower anomalies were found at the eastern part, coinciding with sharp changes in the lagga course.

The three anomalous sites were thought to be suitable for drilling. Therefore, it was recommended that a borehole be drilled at any of the anomalous zones. However, drilling was not done at this location.

## 1.10 Merille

**General**

This is a Market Centre on the boundary between Samburu and Marsabit Districts. All shops and settlements are on the Marsabit side of river Merille which forms the boundary (Figure 1.10).

There are a number of abandoned boreholes which the available records indicate were yielding brackish water. These include borehole numbers SA 86, C3613, C3614, C3622 and C3624. It is not yet clear why the boreholes were abandoned.

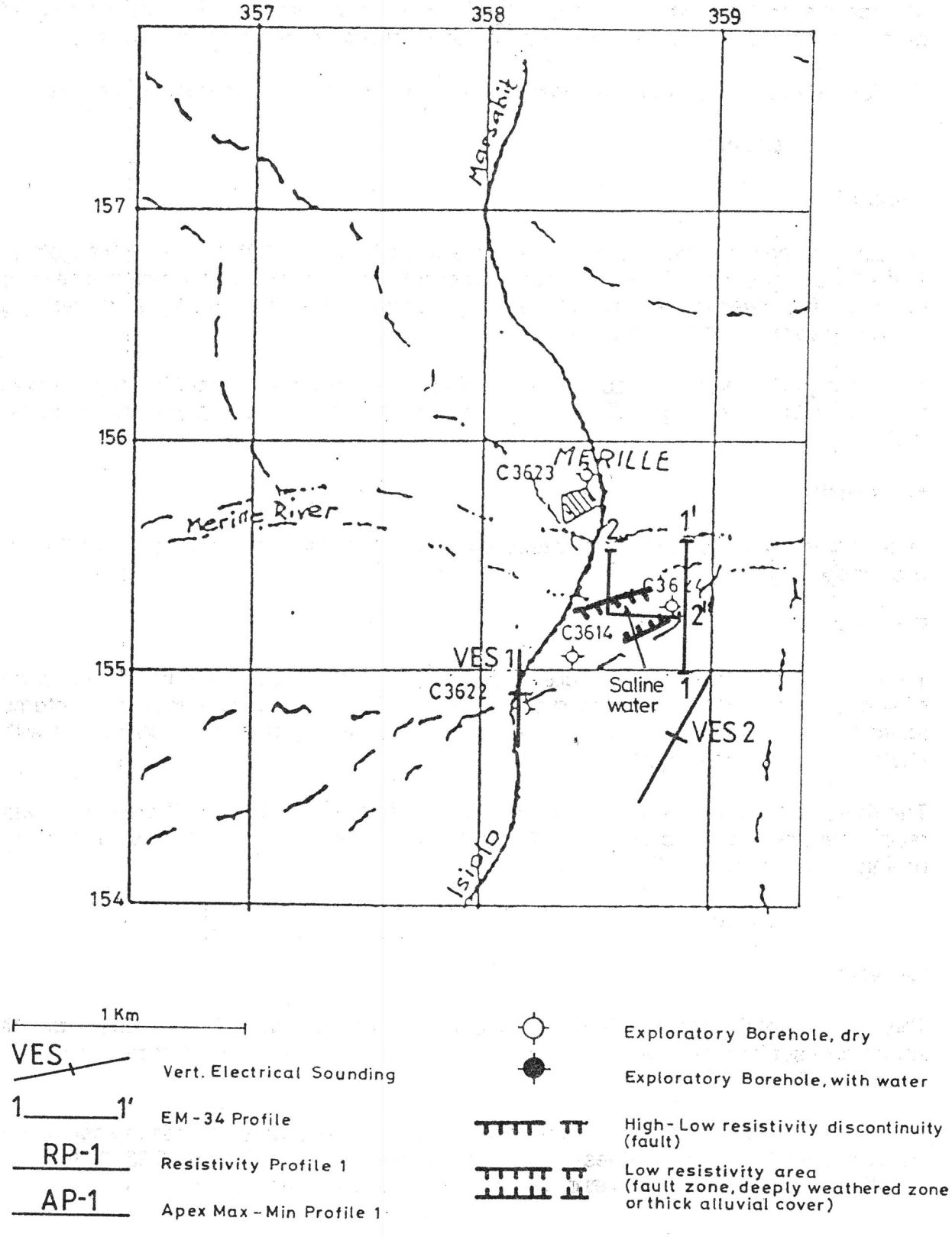



**Fig. 1.10 Situation Map Merille**

**Fieldwork**

Geophysical work was carried out on the river bed and its flood plains. Two EM profiles were executed both starting from the northern edge of the dry Merille river bed near the main bridge (Appendix 3.3). Profile W Merille 1, 580 m long, was executed in a north-south direction about 350 m east of the bridge. It passed mainly over volcanic rock (lava flow). Profile W Merille 2, 600 m long, was executed 50 m from the main bridge and parallel to the first profile for the first fourteen stations, thereafter turning east following a small lagga. It crosses the contact between basement and volcanics, running about 200 m over the latter.

In addition two soundings (VES) were executed (Appendix 3.2). VES 1 was carried out on river sediments (sandy clay) overlying basement rocks with a trend of 175° on the eastern side of the road - about 15 m away and 200 m south of Merille river. The maximum AB/2 was 200 m.

VES 2 was done on the volcanics with an azimuth of 30°E about 80 m from the end of profile W Merille 1.

**Results**

Both profiles show similar low resistivity anomalies at the southern bank of the river. The anomalies are as a result of the fine river sediments (clay or sandy clay) and saline water. There are high resistivities on the sandy river bed as well as further away from the river on the volcanics.

The soundings do not show a clear picture of the subsurface probably due to shielding by the low resistivity surface deposits.

No drilling was recommended here because no major aquifer is expected and the shallow groundwater that might exist is bound to be saline as evidenced by the abandoned boreholes, and the very low resistivity values.

## 1.11 Larisoro

**General**

This name refers to a large area north of Archers' Post. The name comes from the largest of the many seasonal laggas that pass through the area. It is mainly a grazing area though a few army camps indicate armed forces interest in the area mainly for training purposes. The area is shown in Figure 1.11.

The area is covered by basement rocks which outcrop mainly along the laggas. Sandy soils and in some areas small patches of concretional (Kunker) limestone cover most of the area.

**Fieldwork**

Seven short vertical loop electromagnetic profiles were done (W Larisoro 1 to 7). They all have station intervals of 10m and coil separations of 20m (separations of 40 m were tried but gave a very poor response). The profiles are shown in Appendix 3.3.

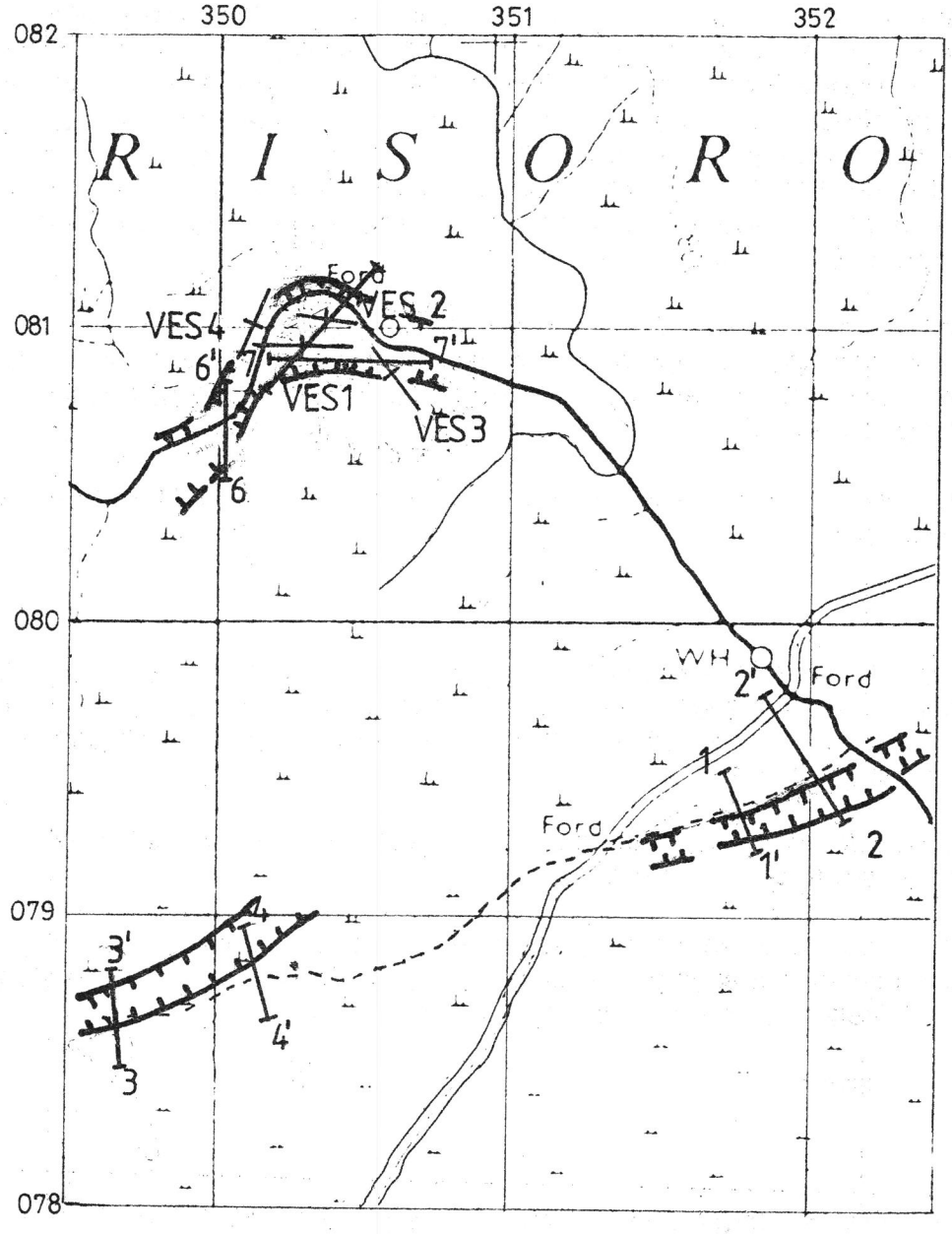



**Fig. 1.11 Situation Map Larisoro**

Four soundings (VES) were made at the locations shown on the situation map. The soundings are included in Appendix 3.2.

**Results**

The soundings indicate the alluvial and weathered layer to be confined to 6-7m thick and with a very low resistivity (12-14 ohmm) which may suggest clayey or saline conditions. This layer apparently rests on fresh basement rocks indicated by very high resistivity (3000 Ohmm)

A future borehole is recommended on the west bank of the Larisoro lagga within the anomalous zone which crosses the profiles 1 and 2. At this site, fresh water occurrence is more porbable than at the other investigated areas in Larisoro.

## 1.12 Chapulo

**General**

The name of this locality comes from a large seasonal lagga which traverses the area from the southwest to the north. Much further downstream it is called Kauro (see Chapter 1.13). The lagga forms a broad shallow valley about 2 - 3 kilometers wide while a few scattered small hills form the outer margins of the valley. The shallow valley and the hills give the impression of a tectonic origin of the valley. The area is shown in Figure 1.12.

The geology mainly consists of basement (gneisses and biotite schists) whose top layer has weathered to sandy soil. A few thin patches of Kunker limestone are scattered all along the valley. The soils also seem to have a high calcium carbonate content.

**Fieldwork**

Two soundings were done about two kilometers apart (Appendix 3.2).

**Results**

The soundings indicate the presence of a top sandy soil layer about 1 m thick with a resistivity of 60 ohmm. A weathered zone consisting of two layers of thickness of 19 and 21 m and resistivities of 25 and 100 ohmm respectively were interpreted on 1. On VES 2 only one weathered layer 5.5 m thick with a resistivity of 10 ohmm was identified. The low resistivities in both soundings indicates clayey conditions.

Groundwater was expected to be found in the weathered layer. Consequently the site of VES 1 was recommended for drilling. However, drilling was not done at this location.

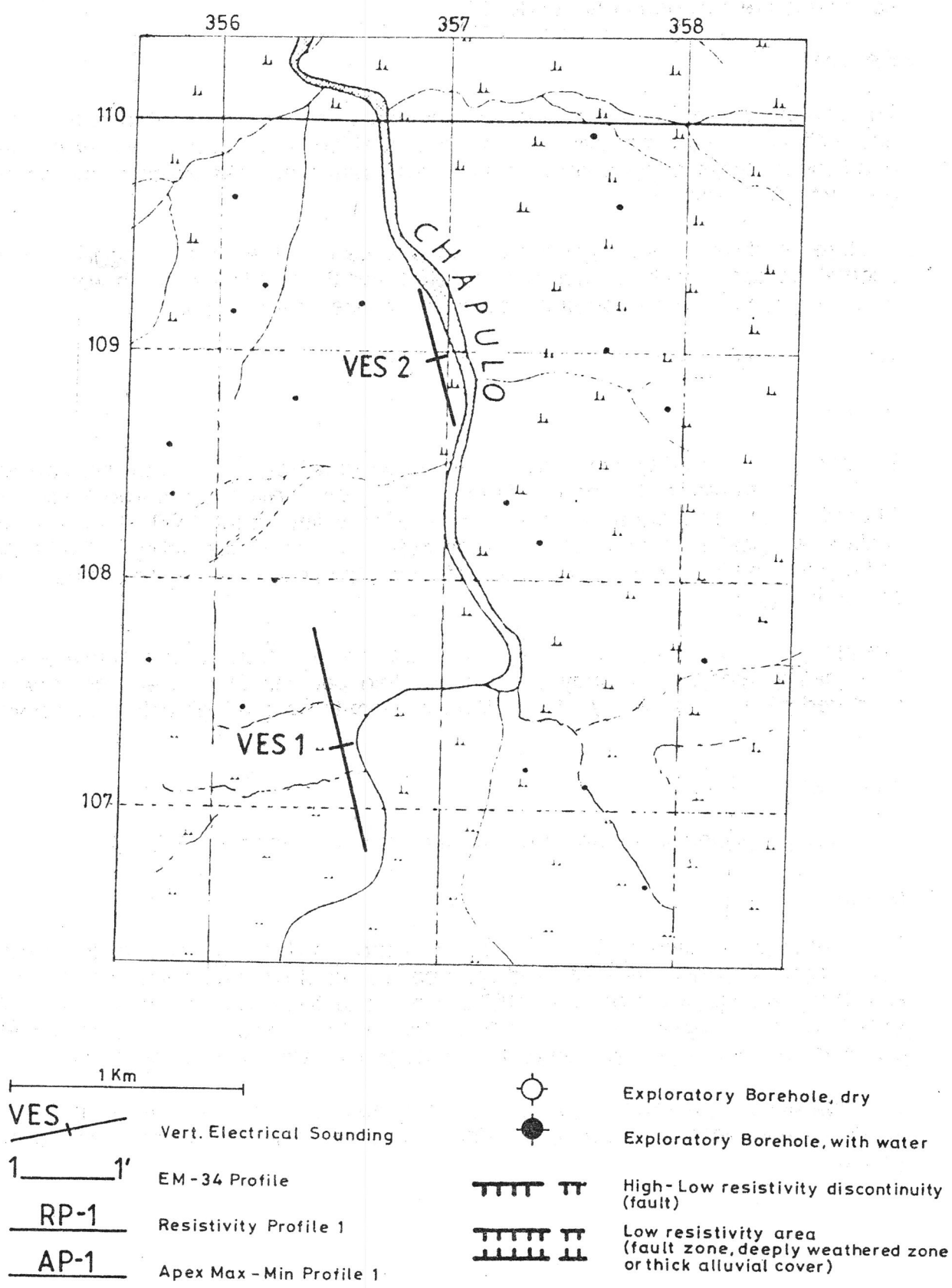



**Fig. 1.12 Situation Map Chapulo**

## 1.13 Kauro

### General

As explained before, Kauro valley is also referred to as Chapulo upstream. At Kauro however the lagga is much wider (over 100 m in some sections). There used to exist a centre by that name which was burnt down by shifta bandits. There are intentions to re-open it. The area is shown in Figure 1.13.

The geology comprises of biotite gneisses covered by sandy soils.

### Fieldwork

Three short electromagnetic profiles, in a SW-NE direction (W Kauro 1) and two in an NW-SE direction (W Kauro 2 and 3) were made (Appendix 3.3). All the profiles had coil separations of 20 m, and station intervals of 10 m. The vertical loop array was used. Five short VES were also made at various sites as shown on the situation map. These soundings are shown in Appendix 3.2.

### Results

The soundings and the profiles indicated very shallow weathering on the surface. Fresh basement was indicated to be at 2 - 5 metres in all soundings except in VES 1 where it was indicated to be at 11 m. Very low resistivities (2.5 to 5 ohmm) were observed in all the soundings which may be due to either saline water or very clayey top layers.

This site is no longer a top priority for drilling purposes. Suitable areas for further investigations have been identified further upstream.

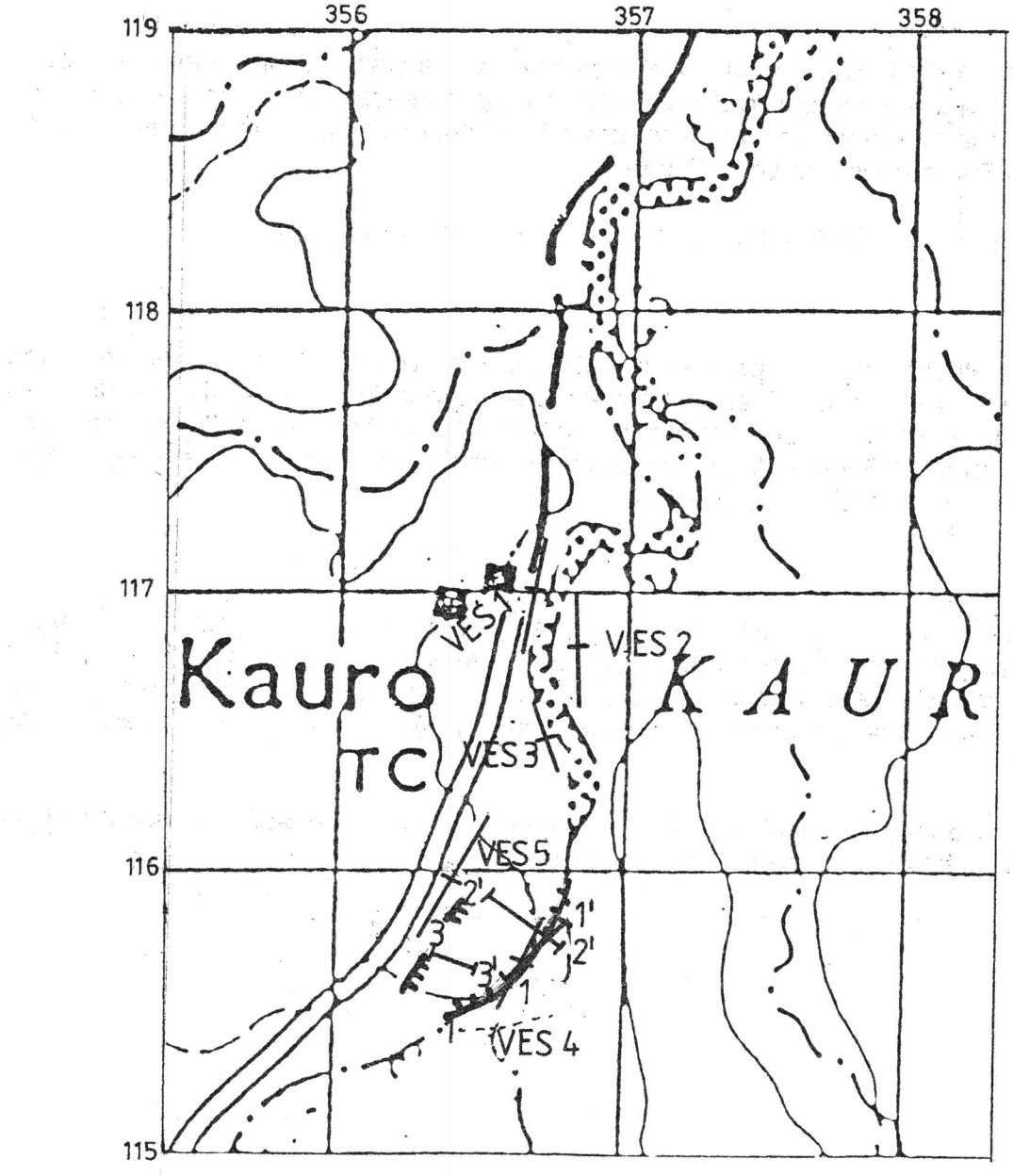



**Fig. 1.13 Situation Map Kauro**

## 2. Baragoi Division

Baragoi Division is the northernmost of the three divisions of Samburu District (Figure 2). It can be reached by road from Maralal or from Wamba over rugged terrain. The water need situation is not as acute as in Wamba Division.

Baragoi division is geologically composed of both volcanic and basement formations. The southern limits of the division which are also of higher altitude are mainly of volcanic rocks while the low lying areas in the north and west are composed of basement rocks.

Rainfall in this division is low and perennial rivers absent. Vegetation cover is also scanty. The major laggas are Seiya which forms the boundary between Baragoi and Wamba divisions, Baragoi, Barsaloi, Arsim and Milgis.

Mainly, EM profiles were carried out supplemented by a number of VES soundings. However, in volcanic formations only VES were done.

No geophysical work was done in Kawop since there was an abandoned borehole indicating the presence of groundwater. The following is a description of each site.

### 2.1 Baragoi Centre

#### General

This is the main centre of Baragoi Division (Figure 2.1). It is located about 76 km to the north of Maralal (about 103 km by road). The centre has four boreholes, one at the town water supply (C3855), two abandoned (C3456 and C3869) and one supplying the secondary school (C4417). Borehole C3855 is seriously threatened by erosion, as it is very near the bank of Baragoi Lagga. The abandoned C3456, located about 150 m west of the Town centre is reported to have had slightly saline water. The reason for the abandonment appears to be the breakdown of the reciprocating pump and rehabilitation is possible. The yield was $m^3$/hr, water was struck at levels 21 m, 43 m and 73 m. The water rest level was 14 m. This borehole has a total depth of 152 m. Borehole C4417 supplying the School is equipped with a windmill. Records show that it is only capable of producing 1.7 $m^3$/hr. Borehole C3869, which is also abandoned, had a yield of 1.4 $m^3$/hr, water was struck at 12.2 m, while the water rest level was 10.97 m. The total depth of this borehole is 94 m.

Since the town is growing, an alternative source of water to augment the present supply is necessary.

The area is composed of basement rocks with quartz-feldspathic veins running in an almost North-South direction. Some observable lineations, probably faults following the Baragoi River and its tributaries were inferred, hence geophysical investigations were concentrated around the river valleys within and close to the urban area.

#### Fieldwork

A total of 7 EM profiles and 3 soundings were carried out at Baragoi centre (Appendix 3.3). Profile B Baragoi 1 of length 740 m running $073^0$ was done east of Baragoi Secondary School with coil separation 40 m and station interval 10 m. The second one (B Baragoi 2) 980 m long and azimuth $210^0$ was carried out near the Chiefs Camp,

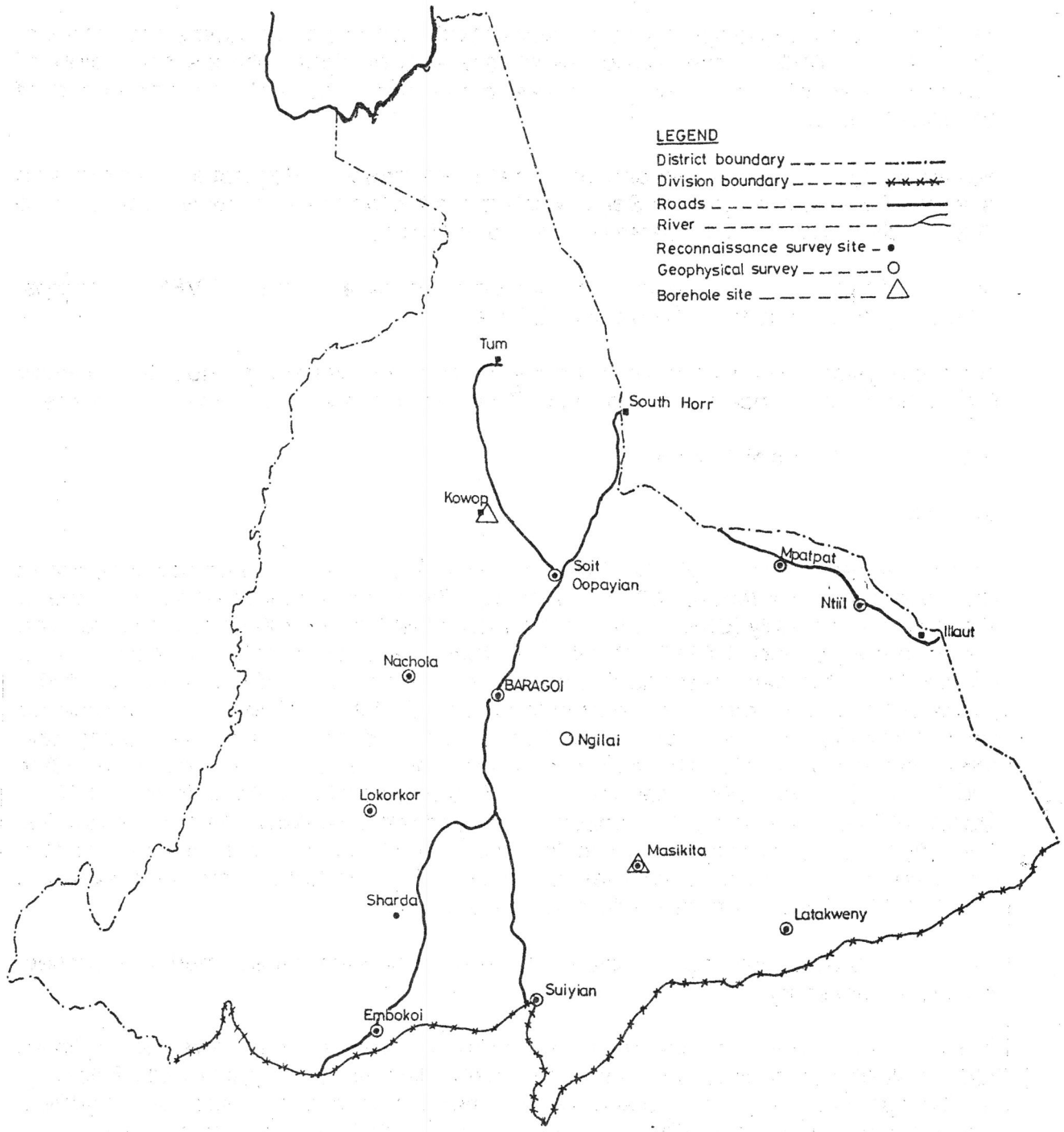
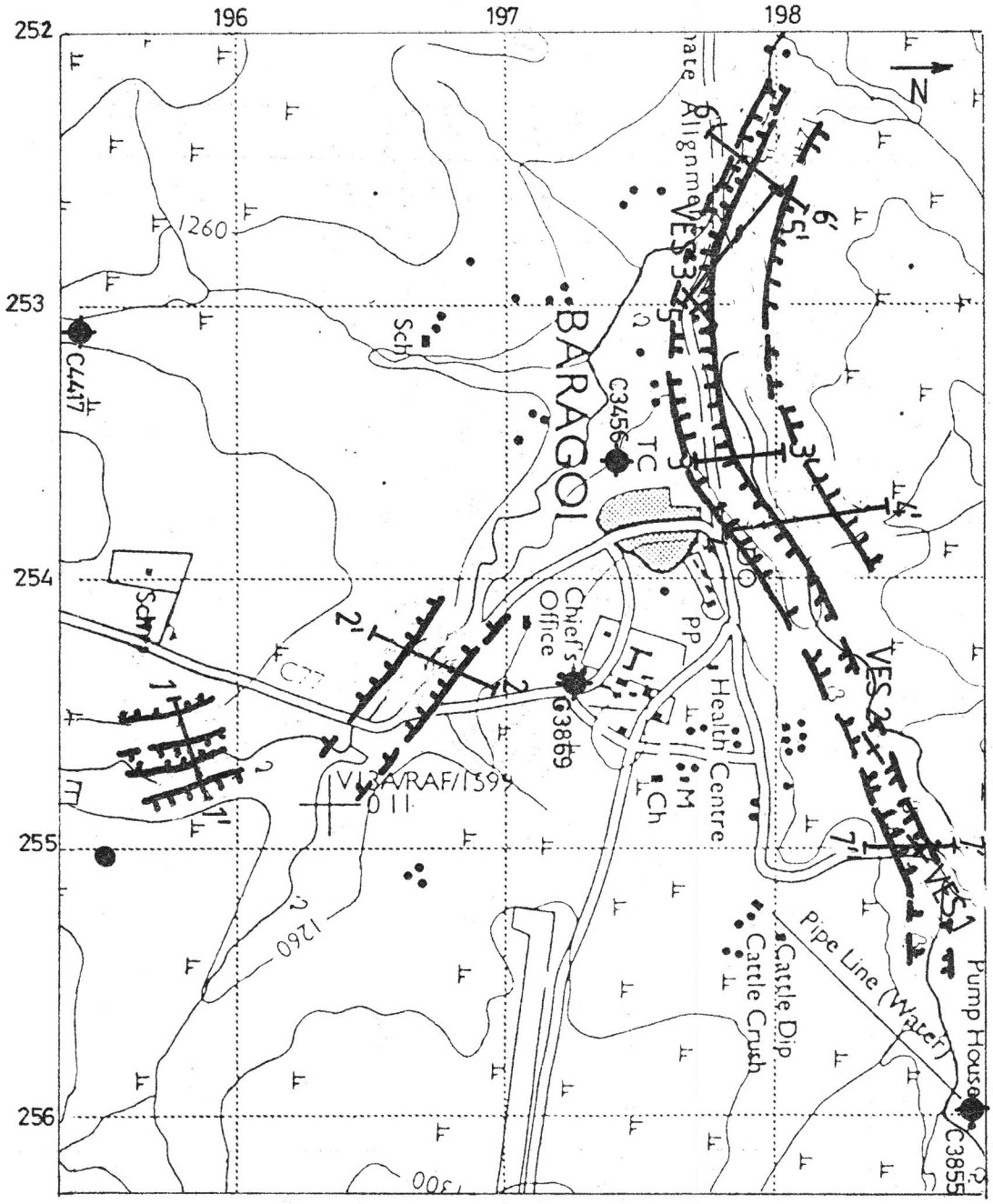



**Fig. 2 Situation Map Baragoi Division**




1 Km

VES — Vert. Electrical Sounding

1 —— 1' — EM-34 Profile

RP-1 — Resistivity Profile 1

AP-1 — Apex Max-Min Profile 1

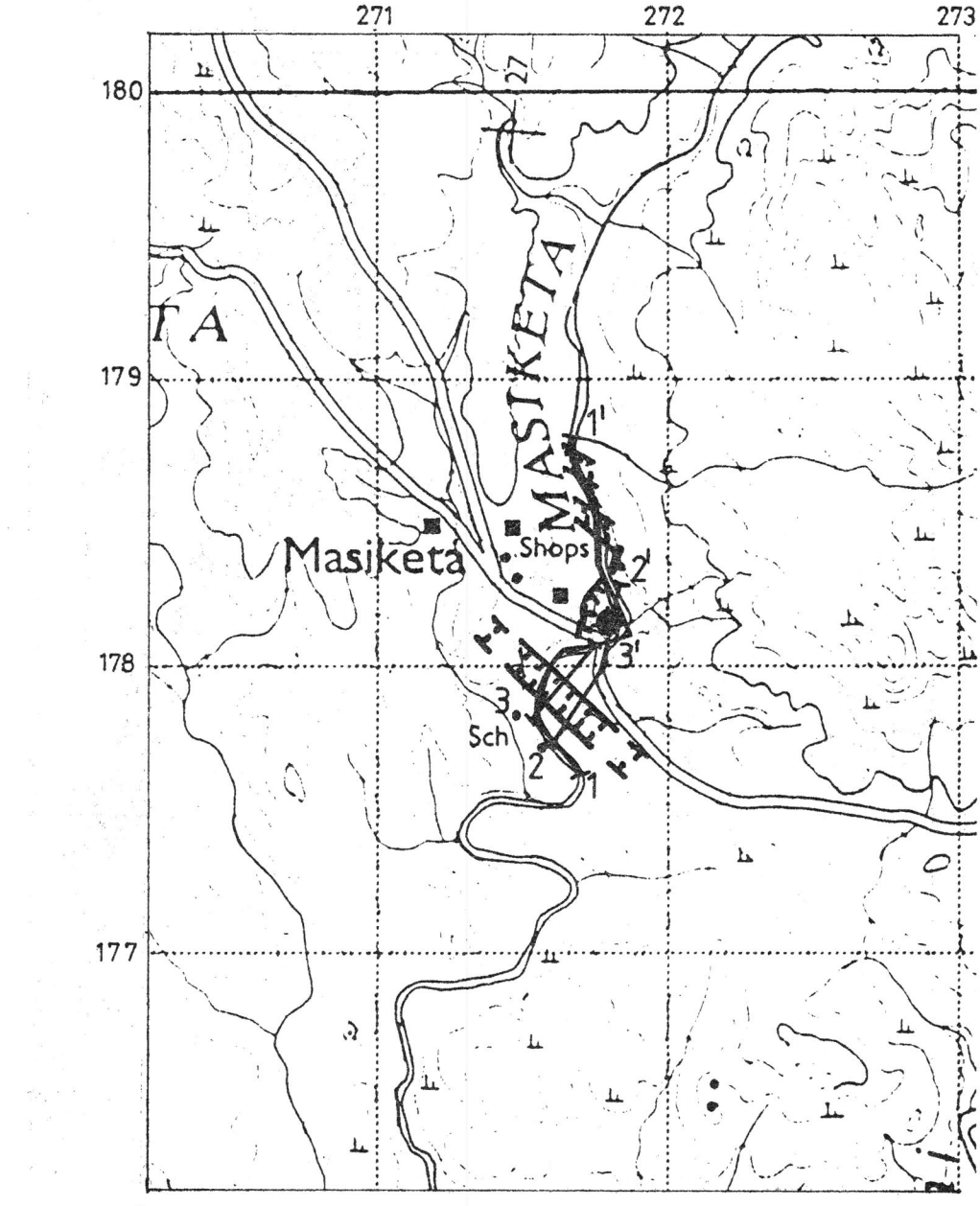
Exploratory Borehole, dry

Exploratory Borehole, with water

High-Low resistivity discontinuity (fault)

Low resistivity area (fault zone, deeply weathered zone or thick alluvial cover)

**Fig. 2.1 Situation Map Baragoi Centre**




1 Km

VES — Vert. Electrical Sounding

1 — 1' — EM-34 Profile

RP-1 — Resistivity Profile 1

AP-1 — Apex Max-Min Profile 1

Exploratory Borehole, dry

Exploratory Borehole, with water

High-Low resistivity discontinuity (fault)

Low resistivity area (fault zone, deeply weathered zone or thick alluvial cover)

**Fig. 2.2 Situation Map Masiketa**

with coil separation and station interval being 40 m and 10 m respectively. The first and second profiles run across the Epoipa tributary. Profile B Baragoi 3 600 m long and direction 343$^0$ and profile B Baragoi 4 1180 m long at 347$^0$, run across the Baragoi lagga and are almost parallel to each other. Near the confluence of the Epoipa and Baragoi rivers, profiles B Baragoi 5 with length 1020 m running at 310$^0$ and profile B Baragoi 6 460 m long with azimuth 210$^0$ were carried out, coil separation being 40 m while station interval 10 and 20 m respectively. The seventh profile (B Baragoi 7), 640 m long and running North-South was carried out from the edge of the Baragoi lagga southwards.

In addition to the profiles, 3 soundings were executed in the areas observed to show anomalies from EM profiles (Appendix 3.2). VES 1 made at station 14 of EM B Baragoi 8 near the drift of Baragoi lagga and the road to South Horr, had a maximum AB/2 of 50 m and azimuth 240$^0$ VES 2 was carried out 300 m west of VES 1 with maximum AB/2 63 m and azimuth 239$^0$ VES 3 was executed near the Baragoi-Epoipa rivers confluence at station 1 of EM B Baragoi 5, with orientation 241$^0$.

**Results**

The seven EM profiles show big variations in the resistivities, lying between 20 and 700 Ohmm. Some geophysical structures can be inferred from these variations as shown in the situation map of Baragoi centre that there could be fault lines running along them. Indications that these fault structures influence the river courses are also evident.

From the three soundings executed along the Baragoi lagga, two layers are noted to overly the basement, though shallowly, extending to a maximum depth of about 30 m only. A dry top layer of soil of varying thickness (about 1.5 m) overlies the weathered rock material of variable thickness and resistivity, which extends to the fresh bedrock. Borehole C 3855 which currently serves the Town is in the same lagga. From records, this borehole has water struck level 10.71 m and yield 1.8 m$^3$/hr. This indicates that the aquifer is at almost the same depth as that deduced from the sounding. The water is moderately hard but it is of good chemical and organic quality. A supplementary borehole for the town water supply could be drilled at any site within the low resistivity area along Baragoi lagga, which is indicated on the situation map. As observed from the records, the yield of borehole C3456 of m$^3$/hr was quite high comparatively. Should rehabilitation of this borehole be possible, it would be a better alternative source of water for the town since it is also very close to the town centre.

## 2.2 Masiketa

**General**

This small village comprises a school, a mission centre and a few houses and shops (Figure 2.2). The surrounding area is dry with very little vegetation. Presently, the water source is from dug wells along the Masiketa lagga.

Geologically, this area is situated on basement rocks close to a granitic intrusive body. The contact zone between the two formations is assumably fractured. Hence this zone may have favourable hydrogeological conditions and a fairly good recharge from the Masiketa river.

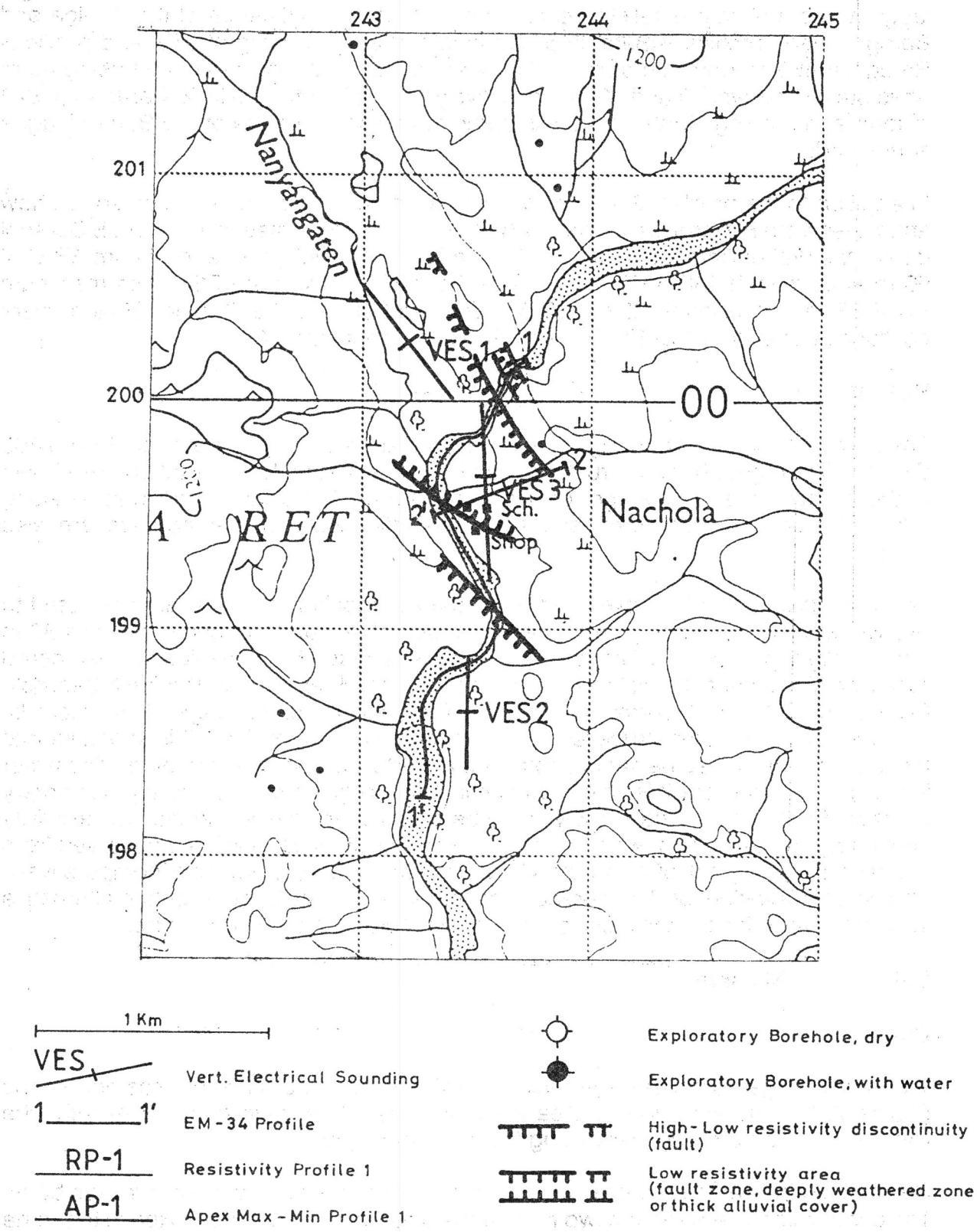



**Fig. 2.3 Situation Map Nachola**

The aim of the EM Survey was to find the most suitable place within this contact zone for the location of a borehole.

**Field Work**

Profile B Masiketa 1 (1530 m) was executed in the lagga bed. Profiles B Masiketa 2 (600 m) and B Masiketa 3 (320 m) were carried out at the eastern bank of the lagga crossing a narrow shaped basement enclosure within the granitic intrusion (Appendix 3.3).

**Results**

Several low-resistivity anomalies were found along the three profiles, indicating the most fractured parts within the contact zone.

In accordance with the EM results, a borehole (C7919) was located and drilled southeast of Masiketa centre in an area enclosed by the Baragoi road and the lagga (see situation map). Although other anomalous areas are also suitable for drilling, this site was selected for reasons of easy accessibility and central position between Masiketa centre and the school compound.

The borehole which has a depth of 100 m was quite successful, having a yield of 5 $m^3/h$ and a good water quality.

## 2.3 Nachola

**General**

This centre has a few houses, a church and a school (Figure 2.3). It lies next to the Baragoi lagga which is quite wide, at certain sections being up to about 100 m. The people get the water from the river and during dry spells, they scoop out sand from the river bed to reach water. A number of quartz dykes were observed along the road to the centre with a general North-South strike. This preferred direction of strike may indicate the general trend of fractures in the area, some of which the dykes may have filled. The main rock type observed to cover the area is basement.

The low lying former flood plains of the lagga were investigated for groundwater including the contact areas between the dykes and the host rocks.

**Fieldwork**

Two profiles and three soundings were carried out as shown in Appendix 3.3 and Appendix 3.2 respectively. Profile B Nachola 1 2060 m long ran along the Baragoi lagga while profile B Nachola 2 600 m long and azimuth $250^0$ was on the side of the lagga passing through the school. The coil separation used in both profiles was 20 m while the station interval was 10 m and 20 m respectively.

The three soundings were executed in the areas where anomalies were picked in the EM profiles. VES 1 with a maximum AB/2 320 m, was made on the western side of the lagg. VES 2 and 3 were made on the Eastern side of the lagga with AB/2 being 250 m and 400 m respectively. The orientations of the three soundings 1,2 and 3 were $138^0$, $180^0$ and $035^0$ respectively.

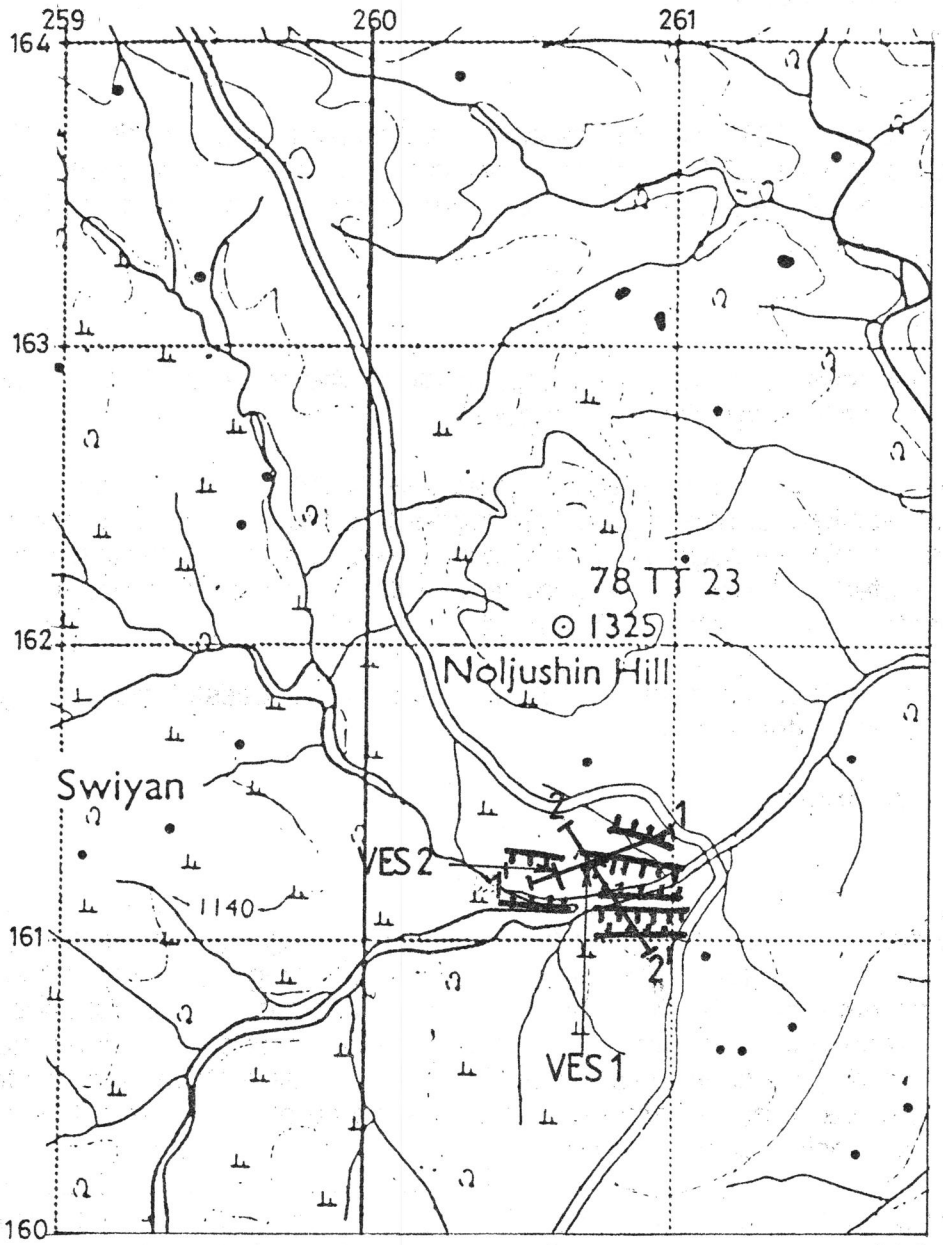



**Fig. 2.4 Situation Map Suiyan**

### Results

At the Southern part of profile B Nachola 1 low resistivity values of about 30 ohmm prevail. These indicate a relatively thick weathering or alluvial fill. VES-2, which was conducted in this zone, shows a thickness of approximately 60 m. At the central part of the profile, relatively high resistivity were found followed again by a low resistivity zone. This can be correlated with the low resistivity zone of profile B Nachola 2 which, altogether indicate a northwest - southeast running fault zone along the Nanyangaten lagga. The thickness of the weathered layer deduced from VES 2 in this zone is about 100 m, confirming the above interpretation.

A borehole is recommended in this zone for example at VES-2 where the best conditions for ground water are expected.

## 2.4 Suiyan

### General

Suiyan is located between Baragoi and Barsaloi, near Noljushin Hill. The area is composed of basement rocks with the only observable conspicuous structure being the Suiyan lagga, where geophysical investigation was carried out. Due to poor accessibility, the area of investigation was rather limited since the drilling rig would only be able to reach areas near the Baragoi - Barsaloi road (Figure 2.4).

There is a primary school with about 34 children and water is derived from the lagga bed which dries up during the dry season. Since the area is hard hit by water shortage, it merits consideration.

### Fieldwork

Two EM profiles were made near the lagga (Appendix 3.3). Profile B Suiyan 1 (940 m long) at 255° was parallel to the lagga while profile B Suiyan 2(520 m long) at 145° was carried out across the lagga, intersecting the first profile. The coil separation was 20 m fro both first and second profiles while the station interval was 10 m and 20 m respectively.

Two soundings were executed in the areas where significant anomalies were noted (Appendix 3.2). VES 1 with maximum AB/2 63 m at 250° orientation was made at station 10 of profile B Baragoi 2, while VES 2 with a maximum AB/2 of 50 m and azimuth 260° was made at station 40 of EM profile B Baragoi 1.

### Results

In both profiles, there are pronounced low resistivity anomalies. This may indicate, that the lagga is fault controlled. Hence some groundwater accumulation can be expected within the anomaly zone with an intermittent recharge from the lagga. The VES-1 and VES-2 show a shallow weathering, 15 m and 2.5 m respectively. Nevertheless, fracturing in the fault zone can be expected at much greater depths.
A borehole is recommended at the northern bank of the lagga along profile 2 within the indicated anomaly zone (see situation map).

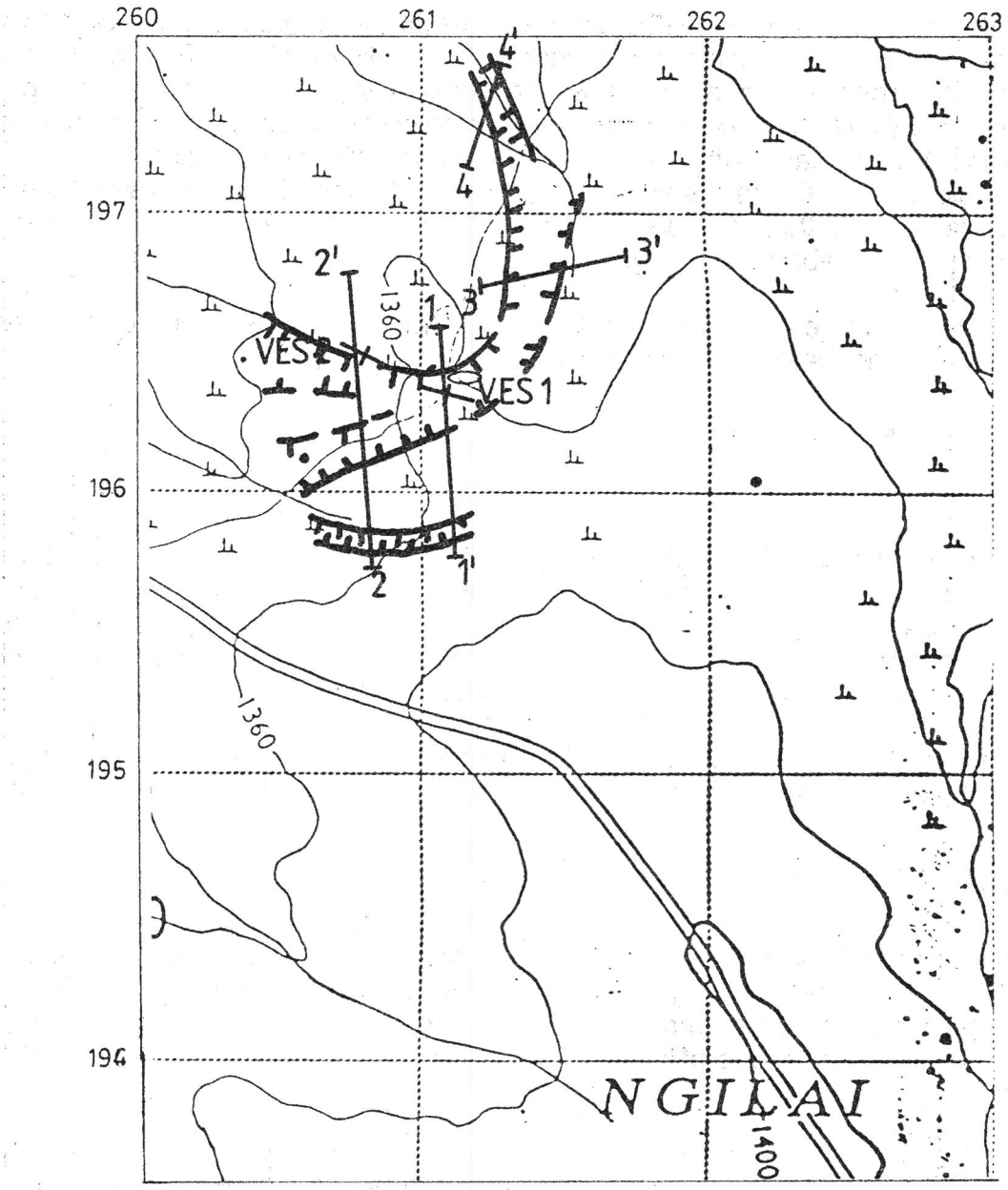



**Fig. 2.5 Situation Map Ngilai**

## 2.5 Ngilai

### General

Ngilai refers to a rather wide area to the east of Baragoi town (Figure 2.5). A shallow pan which dries up very soon after the rains exists near Ngilai Primary School. However, it is not sufficient for this vast area. As such geophysical work was done at the primary school which is just over 1 km off Baragoi-Lesirikan road. No lineaments were reported in the first reconnaissance visit.

### Fieldwork

Geophysical work was done around the school to try to establish if the laggas are due to faulting a where water is expected. Four EM profiles were done followed by two sounding at anomalous zones on the first two profiles (Appendices 3.3 and 3.2).

Profile B Ngilai 1 (800 m long) and profile B Ngilai 2 (1040 m long) were done parallel to each other and almost N-S (175). Profile 1 started from the school compound and profile 2 started 260 m to the west of it.

Profile B Ngilai 3 (520 m long) was started near the school field running almost W-E (80°E) across the lagga. Lastly profile B Ngilai 4 was done north of the school about 300 m away from the main school building with an orientation of N 20° across the same lagga as in profile 3. All the profiles had a coil separation and station interval of 20 m.

The first sounding (VES 1) was done on station 12 of profile 1, the lowest anomaly point. It has a maximum AB/2 of 100 m and orientation of 295°.

The second sounding, VES 2 was done on station 38 of profile 2 with orientation of 115° and maximum AB/2 of 100 m also.

### Results

In both profiles 1 and 2 pronounced low resistivity anomalies can be observed (see Situation map). Correlation the two profiles it can be concluded that there is a fault, much in line with the lagga.

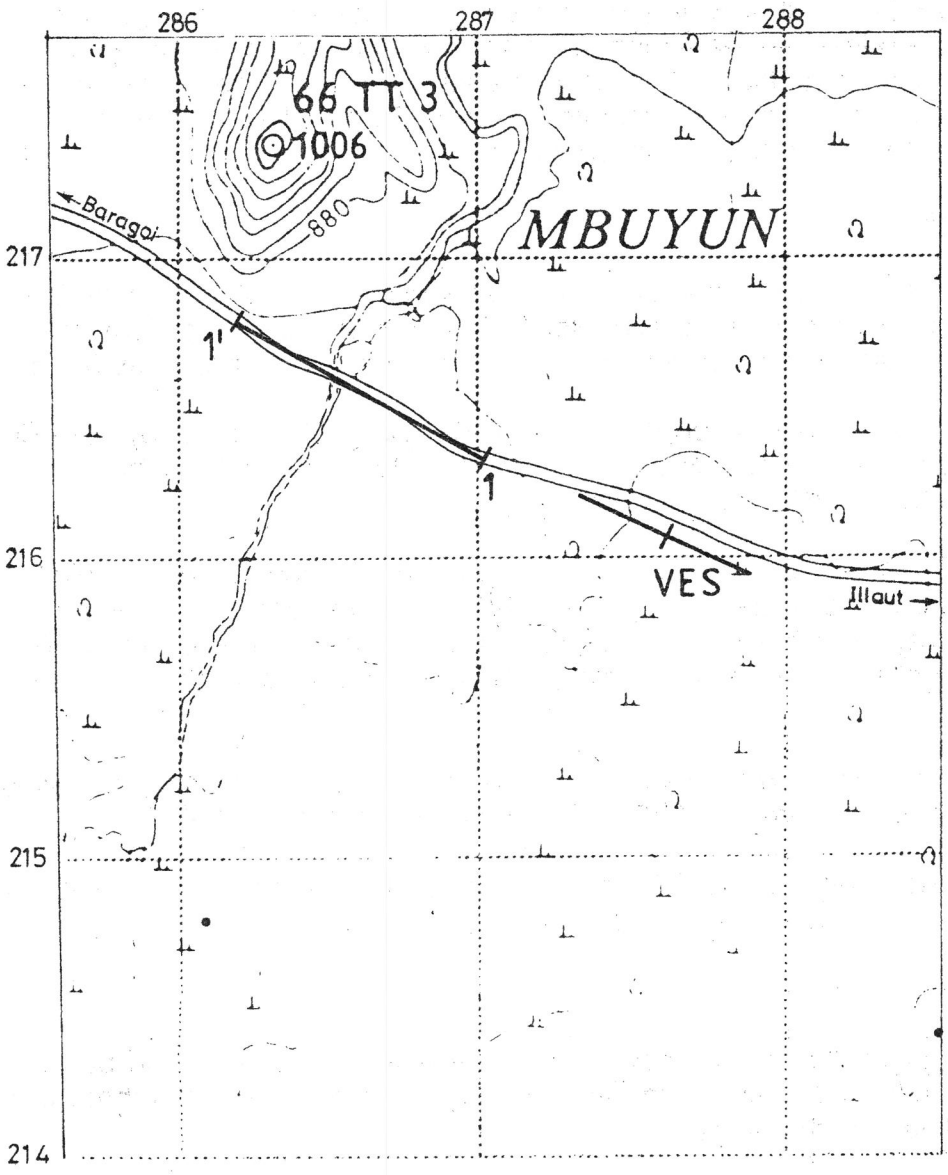
A similar observation can be made for profiles 3 and 4. These profiles are crossing the lagga which is situated to the north of the school. This suggests that this lagga also follows a faultline.

The soundings show a thin weathered layer of 10-17 m only. Nevertheless cracks can be expected also at greater depths due to faulting. Hence drilling is recommended within the anomaly zones as indicated on the situation map, especially, in the interplication of the two fault systems between profiles 1 and 3.

## 2.6 Mpatpat

### General

Mpatpat is an open area with a few Manyattas surrounding by Ndoto, Empatpat and




1 Km

VES — Vert. Electrical Sounding

1 — 1' — EM-34 Profile

RP-1 — Resistivity Profile 1

AP-1 — Apex Max-Min Profile 1

Exploratory Borehole, dry

Exploratory Borehole, with water

High-Low resistivity discontinuity (fault)

Low resistivity area (fault zone, deeply weathered zone or thick alluvial cover)

**Fig. 2.6 Situation Map Mpatpat**

Doinyo Mara Hills (Figure 2.6). This low-lying area is filled with deposits such that there are no outcrops visible. Water is expected to be found within the deposits and/or the weathered zones of the basement rocks.

### Fieldwork

Geophysical work was carried out along the road as shown on the situation map. Across the Seran lagga one EM profile of 980 m, B Mpatpat 1 was done (Appendix 3.3). The coil separation was 40 m and the station interval 20 m. To establish the depth of the weathered zone above the fresh bedrock one vertical electrical sounding was done about 1.2 km to the east of the lagga. It has a maximum AB/2 of 320 m and azimuth of 114° (Appendix 3.2).

### Results

The profile does not show any significant anomaly. This is thought to be due to the depth of overburden being greater than the penetration of the EM-instrument at the used configuration. The combined alluvial cover and weathered basement is at least 45 m thick at the VES site.

Out of these results it can be concluded that a borehole could be made anywhere within the investigated area in order to find out whether the relatively thick overburden contains water or not. For a more accurate siting some extra VES measurements are recommended.

## 2.7 Ntiil

### General

Ntiil is located to the east of Mpatpat, towards Illaut. Work was done near the junction to Arsim (Figure 2.7) which is about 1 km from Arsim lagga. This place is topographically and hydrogeologically similar to Mpatpat.

### Fieldwork

Only one EM profile was done here (B Ntiil 1) along the road (Appendix 3.3). With a length of 1800 m, it was started from one of the tributary laggas of the Arsim and ended at the junction. A coil separation of 40 m and station interval of 20 m was used.

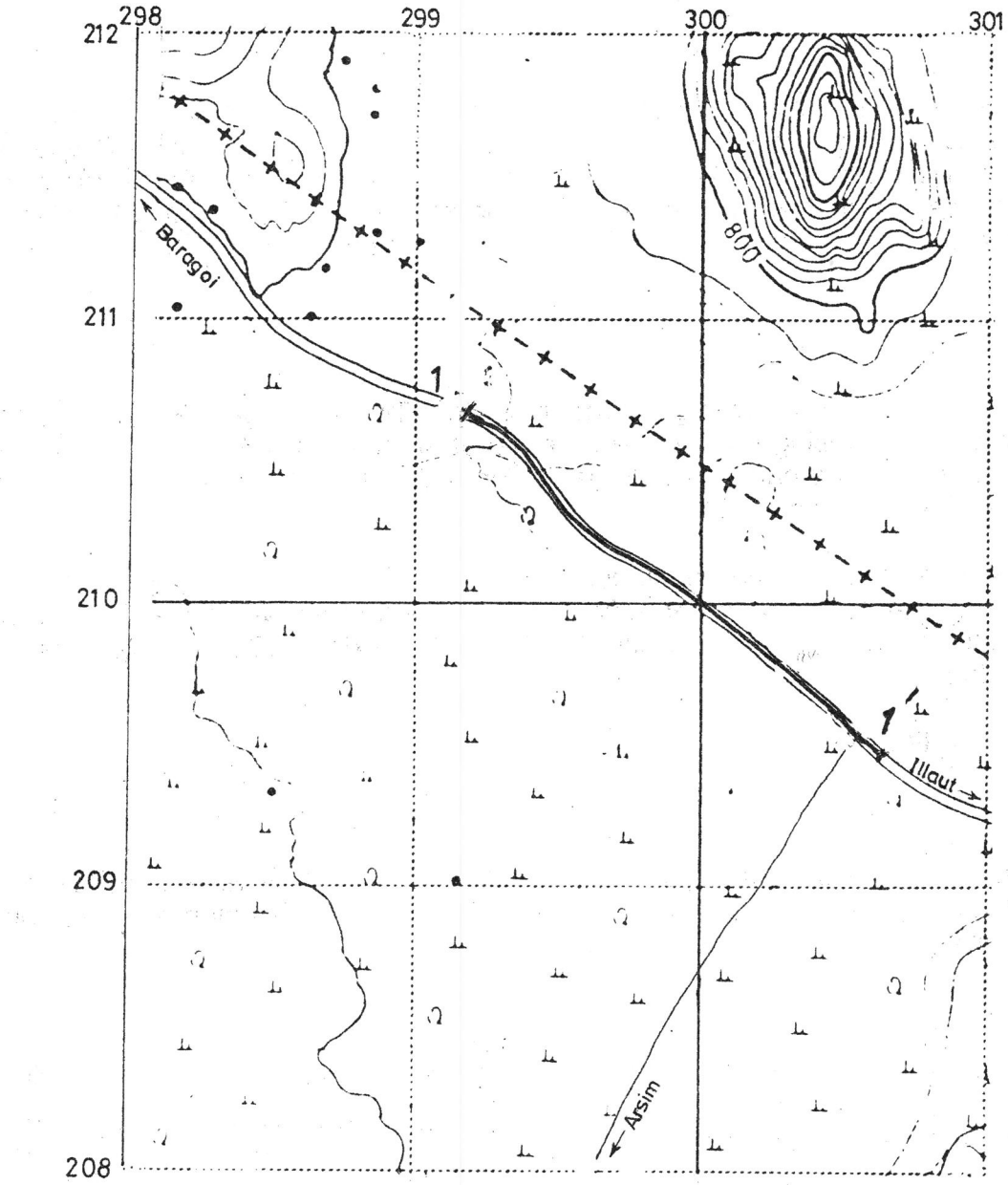
### Results

A general trend of gradually decreasing resistivities can be observed in this profile. This may indicate a proportionally increasing over-burden thickness from the west towards the Arsim river. As such it could be interesting to drill at the lowest resistivity zone between stations 61 to 73. The second alternative is between stations 46 and 52.

## 2.8 Soit Dolpayien

### General

The area is situated along the Baragoi-South Horr Road, 12 km North of Baragoi Town (Figure 2.8). The area is a low lying plain with several Manyattas distributed along the




1 Km

VES — Vert. Electrical Sounding

1 — 1' — EM-34 Profile

RP-1 — Resistivity Profile 1

AP-1 — Apex Max-Min Profile 1

Exploratory Borehole, dry

Exploratory Borehole, with water

High-Low resistivity discontinuity (fault)

Low resistivity area (fault zone, deeply weathered zone or thick alluvial cover)

**Fig. 2.7 Situation Map Ntiil**

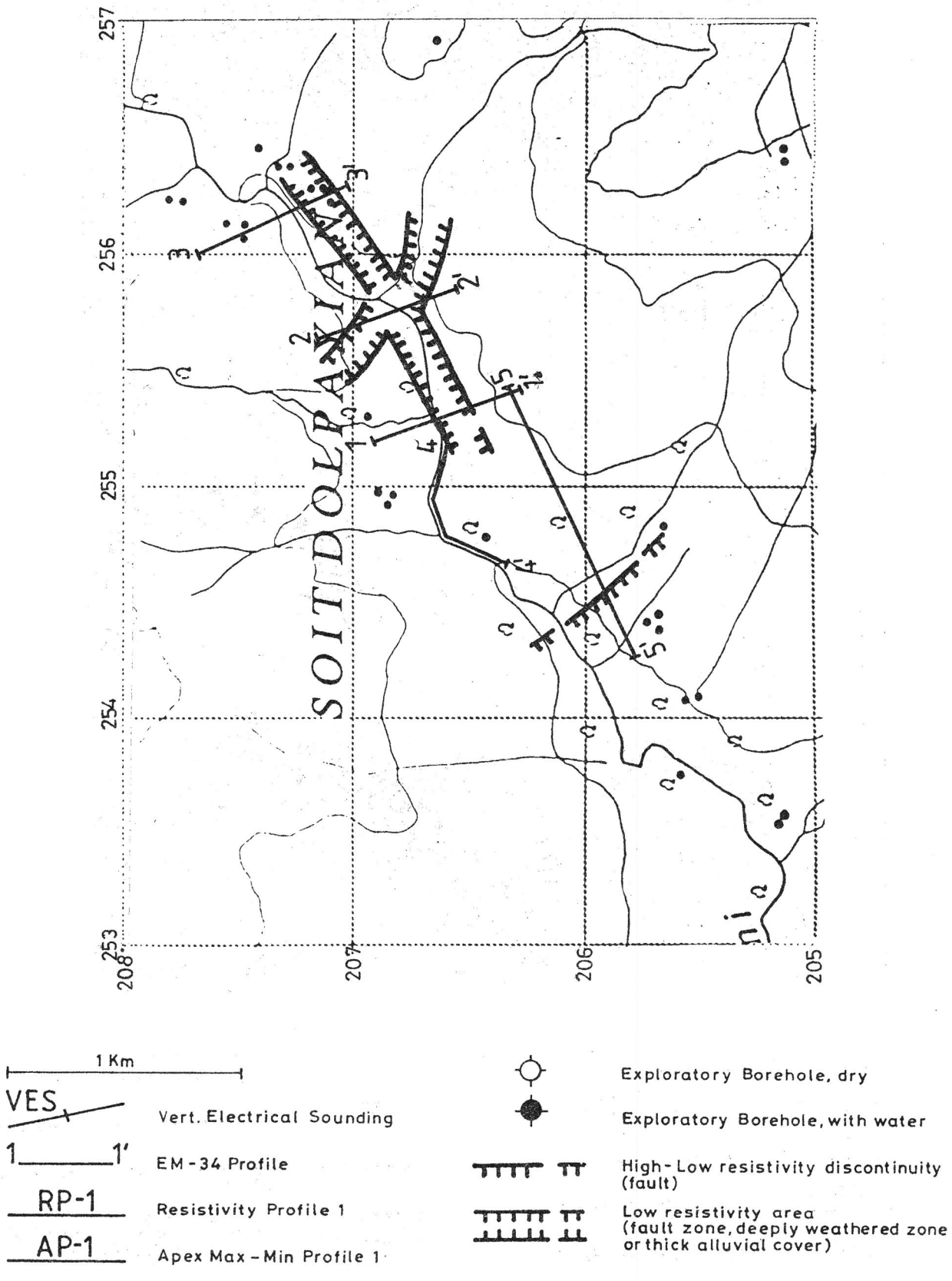



**Fig. 2.8 Situation Map Soit Dolpayian**

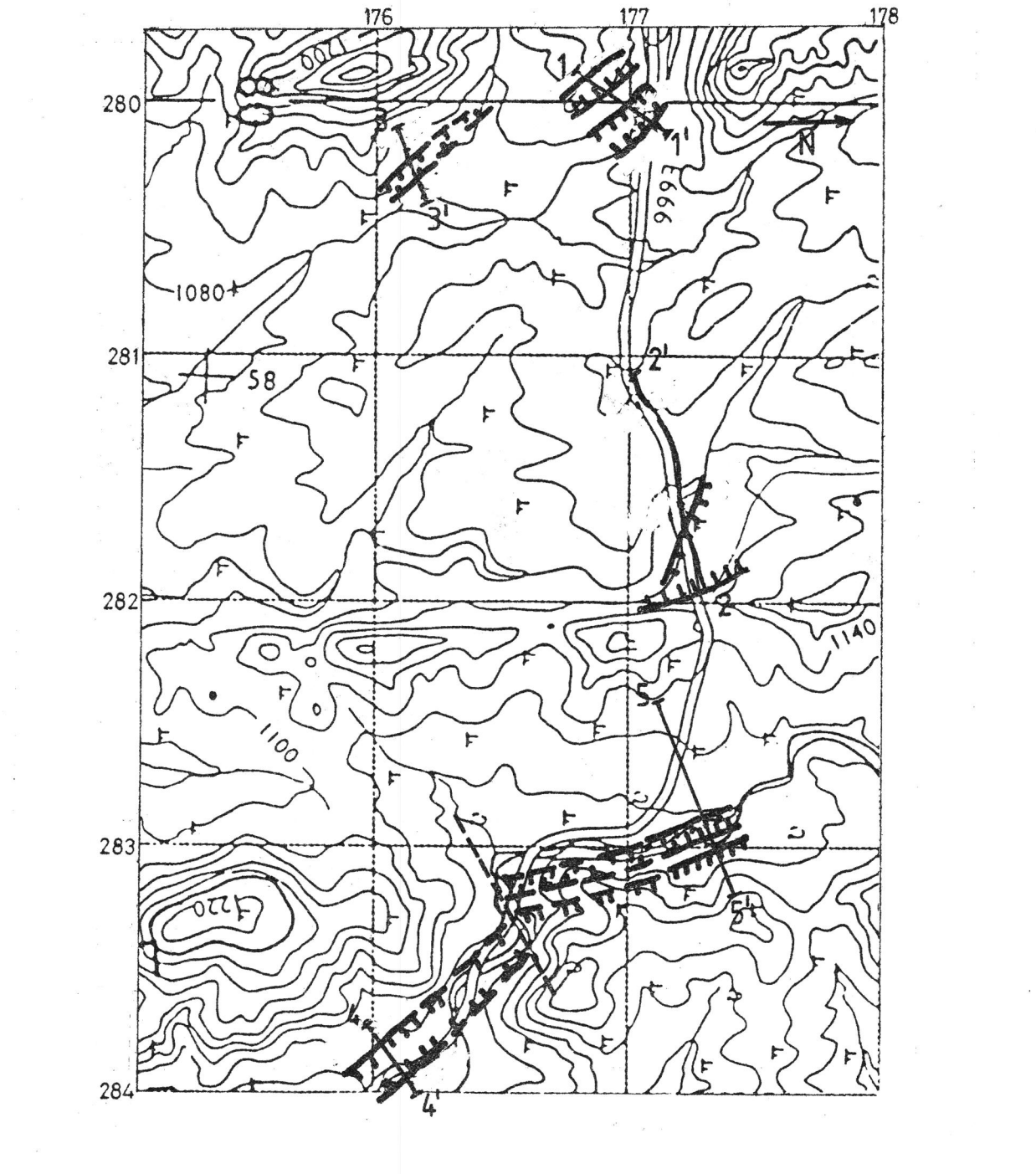



**Fig. 2.9 Situation Map Loenti**

main lagga Olwatani. There are several angular changes on the lagga which may indicate faults. The geophysical work was targeted close to the concentration of Manyattas, within the presumably faulted area.

The proposed borehole is meant to serve as a watering point for the people and livestock, especially during the dry season when the oltawani lagga dries-up.

The Ng'oroghi (Godshi) dam which had been constructed in this area has little or no water throughout the year.

**Fieldwork**

A total of 5 EM profiles (Soi Dolphayian 1 to 5) were executed in this area (Appendix 3.3). Profiles 1 (640 m); 2 (640 m) 3 (720m) were run across the lagga and parallel to each other. Profile 4 was done in the lagga starting from station 16 of profile 1 and running westwards.

On the other hand profile 5 was almost parallel to the lagga staring 20 m from station 1 of profile 1.

Coil separation was kept at 40 m, except profile 5, where the 20 m separation was used. A 20 m station interval was used throughout the whole survey.

**Results**

Profiles 1 to 3 show distinctive low resistivity anomalies. The correlation of these results in a SW-NE running low resistivity zone (see situation map) which confirms that the Oltawarin Lagga is fault controlled.

The anomaly in profile 2 is much wider than in the profiles 1 and 3. This indicates the existence of a SE-NW oriented fault which crosses the Oltawarin Lagga fault at this site.

Generally, a junction of faults is highly fractured. Therefore a borehole is recommended within this area. In case of no accessibility, drilling can be done anywhere inside the anomaly zone.

## 2.9 Loenti

**General**

Loenti located in the area between Masiketa and Latakweny along the Loindogo lagga. The topography of the area is quite uneven with many hills on either side of the lagga (Figure 2.9). The orientation of the range of hills is approximately north-south. Loenti was investigated while Latakweny was left out, since accessibility of the rig could prove difficult. No settlements were observed since the people have moved due to lack of water, hence this area merits consideration. The rivers are seasonal and even the main Loindogo lagga dries up during the dry season. The area is covered by basement rock system which shows quite some weathering on the surface.

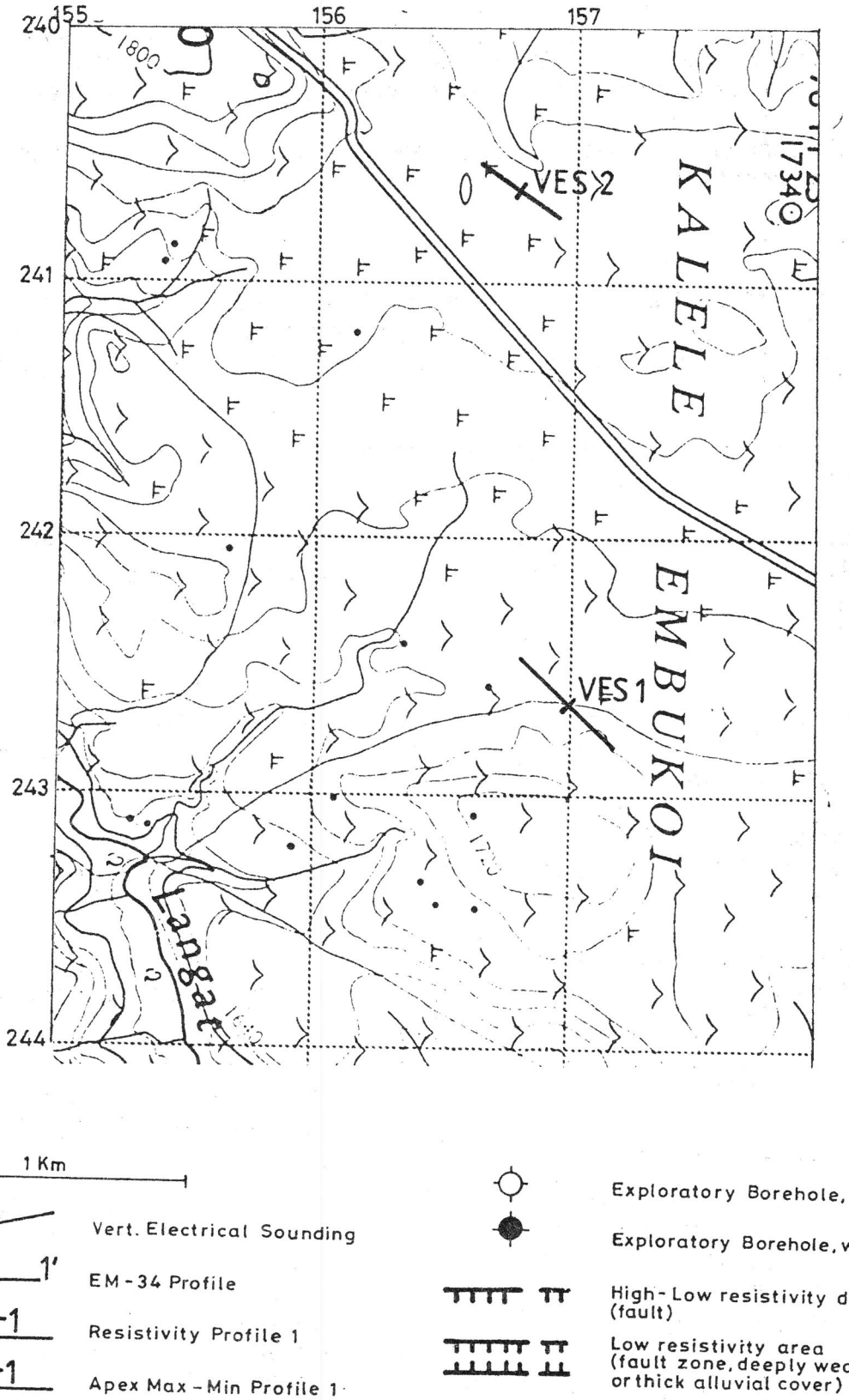



**Fig. 2.10 Situation Map Embukoi**

### Fieldwork

A total of 5 EM profiles were carried out in this area (Appendix 3.3). Profile B Loenti 1 (440 m) with azimuth 031°, profile B loenti 2 (880 m) with azimuth 270° and profile B Loenti 3 (320 m) with azimuth 063° were run across small tributaries that enter the Loenti river. Profile B Loenti 4 (340 m) with azimuth 045° and profile B loenti 5 (1140 m) with azimuth 075° were conducted across the Loindogo river. The coil separation and station interval of the profiles were 40 m and 20 m respectively.

### Results

From the five profiles executed in the area, it is evident that many fractured zones do exist and the laggas follow these zones. The variations of resistivity values are similar in the first four profiles but different for the fifth one. The difference between the highest and lowest resistivity values of profile B Loenti 5 was noted to be the greatest in the five profiles, this value being about 409 ohmm. The first four profiles have similarity in that the readings are only low in the lagga zones, but the fifth profile shows persistent low resistivity values on the eastern side of the lagga. The drop in resistivity from station 34 onwards could be indicative of faulting. These fault structures are oriented in the northwest-southeast direction and seem to be interrupted by a southwest-northeast fault midway between profiles 4 and 5, where the lagga abruptly changes its direction (see situation map). A borehole is recommended in this area between the road and the sharp lagga corner, where intensive fracturing is expected.

## 2.10 Embukoi

### General

Embukoi is situated between Marti and Morijo on the Baragoi - Maralal road (Figure 2.10). The area is mainly used as a grazing ground and there are no manyattas visible. The terrain is volcanic with a bouldery regolith. The even surface of the lava front to the south-east provides a good area for VES survey. As observed, some of the laggas in the zone seem to follow fault lines.

No aerial photos were available for identification of lineaments and structures that might be of geophysical interest. Nevertheless, vertical electrical soundings were carried out on the flat stretches.

### Fieldwork

Only two sites were investigated, each with one Vertical Electrical Sounding. Each sounding was done on either side of the major road. VES 1 with azimuth 040° and AB/2 of 250 m, was executed on the eastern side of the Maralal Baragoi road, precisely on a side road leading form the main road to the Langat tributary. VES 2 with azimuth 030° and AB/2 of 200 m was conducted on the western side, and close to the road.

### Results

The soundings executed in Embukoi show that the thickness of the volcanic rock cover is only 20-30 m. Below this, a layer of 20 ohmm with a thickness of 10-15 m has been found, which probably correlates with an old land surface of weathered basement rocks. This layer may contain some water although its situation is quite shallow for water accumulation in this topographically, high lying area.

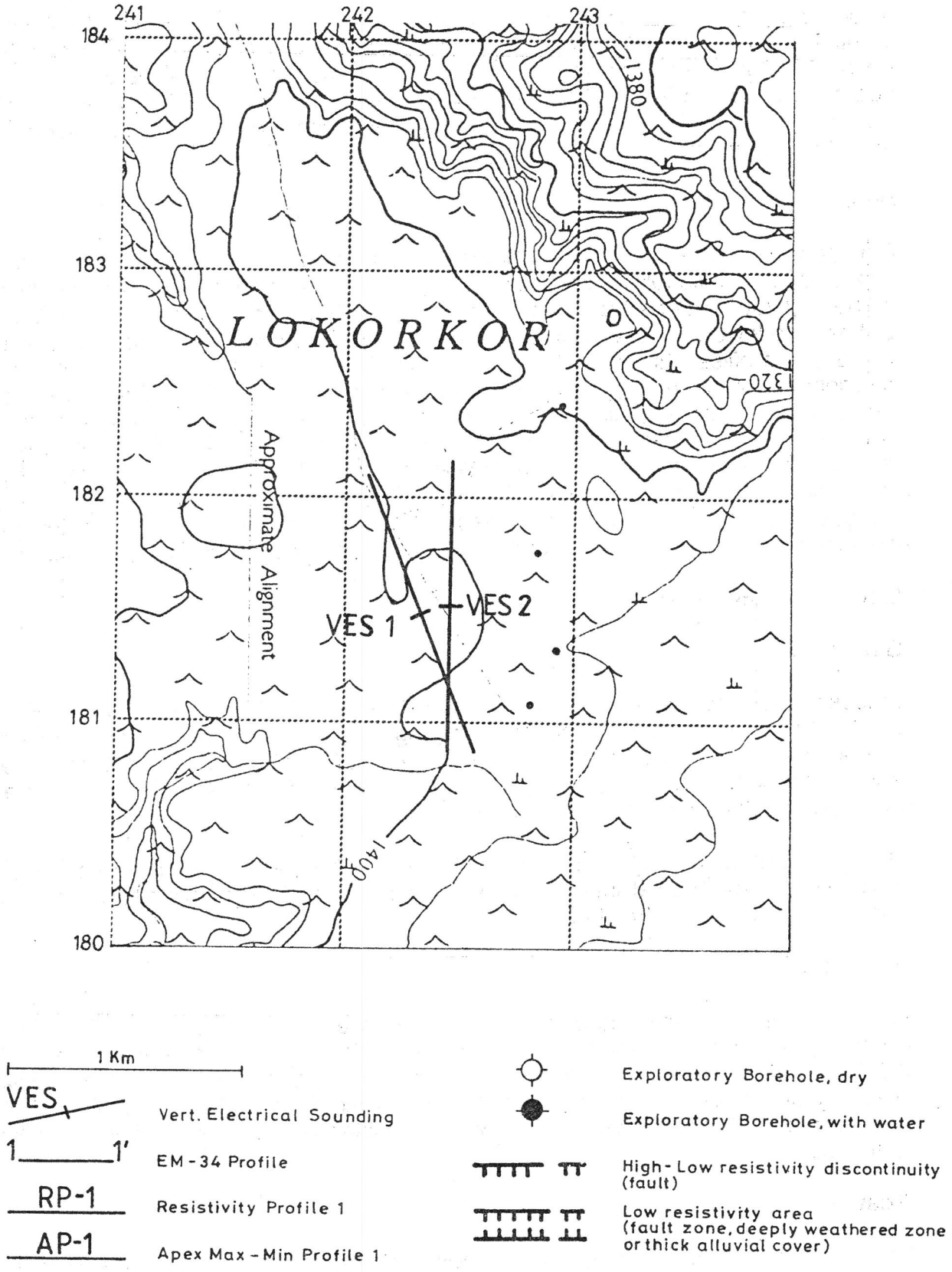



**Fig. 2.11 Situation Map Lokorkor**

## 2.11 Lokorkor

### General

This area is about 6 km to the North-west of Sharda and lies on a phonolite lava flow giving the area an almost even topography (Figure 2.11). Water is scarce and only got from small laggas during the wet season. During the dry season people have to commute all the way to Baragoi river to get water.

### Fieldwork

Only two sites were investigated using vertical electrical soundings (VES). VES 1 had a maximum AB/2 of 630 m with azimuth 155° while VES 2 had a maximum AB/2 of 500 m oriented in the North-South direction (Appendix 3.2).

### Results

The two soundings carried out in Lokorkor show a considerable thickness of volcanic rock. Both have indicated weathering near the surface just above the fresh volcanics with a thickness of about 1-2 m. Below this weathered upper part, a high resistivity 350-450 ohmm extends down to approximately 30 m. These resistivity values indicate fresh rocks without saturation. The following layer, which extends down to 110 m, has an extremely low resistivity of ohmm. Undoubtedly, this layer is saturated with groundwater with a high saline content which makes it unsuitable for human consumption.

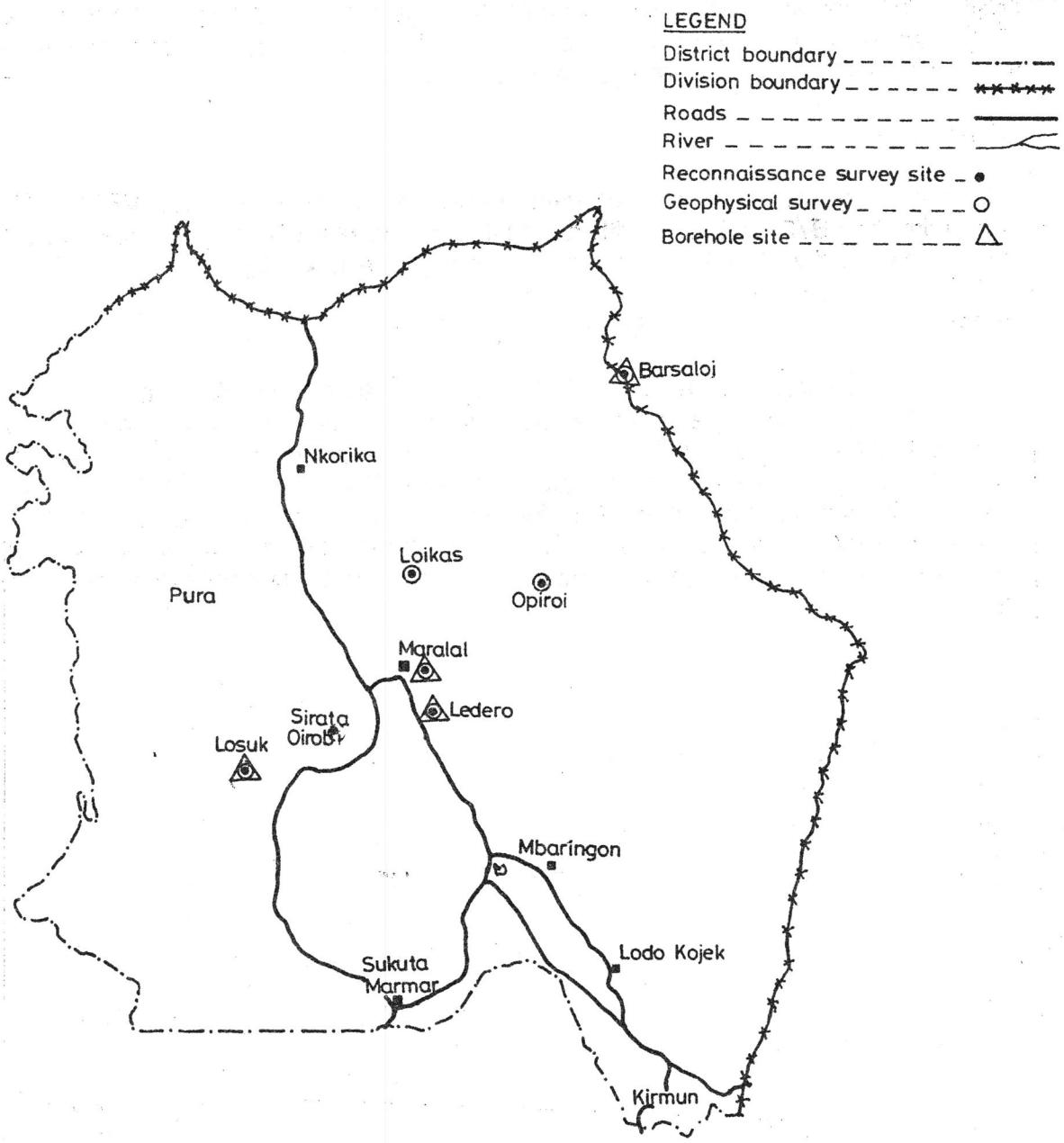



**Fig. 3 Situation Map Lorroki Division**

## 3 Lorroki Division

Lorroki is the smallest among the three divisions in Samburu district (Figure 3). It is situated in the south-west of the district and happens to be of high altitude (1500 m above sea level) and thus higher rainfall than the other two divisions. Surface water in form of springs and rivers is therefore comparatively more available.

Geologically, the division is composed of volcanic rocks to the west of Maralal. To the east and occupying about two thirds of the division are the basement formations.

Geophysical work was carried out mainly in the eastern part (i.e centres situated on basement), because here few surface water sources are available. However, work was also done at Losuk which is on volcanic rocks. Although Maralal town is currently well served by water from Nundoto dam, geophysical work was also done in and around the town. Groundwater may be considered in future as alternative source, because of an existing pollution risk of Nundoto Dam.

Five sites were investigated in Lorroki Division and their description is given here below.

### 3.1 Maralal

#### General

A reconnaissance survey at Maralal Town was made in the period 11th to 14th July 1988 following a request from the CG to WRAP. The purpose of the survey was to select sites where more detailed geophysical work could be done for the location of future wells. During the survey it was learnt that the town requires about 550 $m^3$/day of water all of which comes from the Nundoto Dam. Wheat farming up-stream of the dam had, however, resulted in serious herbicide pollution of the dam rendering the water unsuitable for human consumption.

In the past, several boreholes have been drilled, generally with poor results. Most of these wells are broken down and abandoned. The Loikas spring, with an average yield of 6 $m^3$/h, was abandoned when the Nundoto dam was constructed.

There are no aerial photographs covering the town and the structural geology could only be deduced from landsat images and geological maps. There were however on an inconvenient scale for such a small study area. Geogphysical surveys, therefore became necessary for investigating the structures in detail.

The geophysical survey was made in the period 29th August to 10th September 1988. Some additional work was done in early November. During the survey it was learnt that the rains of August had finally caused the dam to spill, diluting the pollution to torelable levels. New boreholes however are still necessary as a standby both for any such mis-hap in future or if the dam starts silting up.

Maralal town lies on basement rocks composed of Leroghi Gneisses and the Siambu Basement complex. Both of these formations haver various local variations within them. To the west and north-west of the town phonolites and basalts occur, mainly as a lava flow emanating from the Leroghi Plateau. A large quaternary alluvial patch has formed south of the town along the major laggas converging there. These laggas are the Loidongo, Loikas, Yamo and Nundoto.

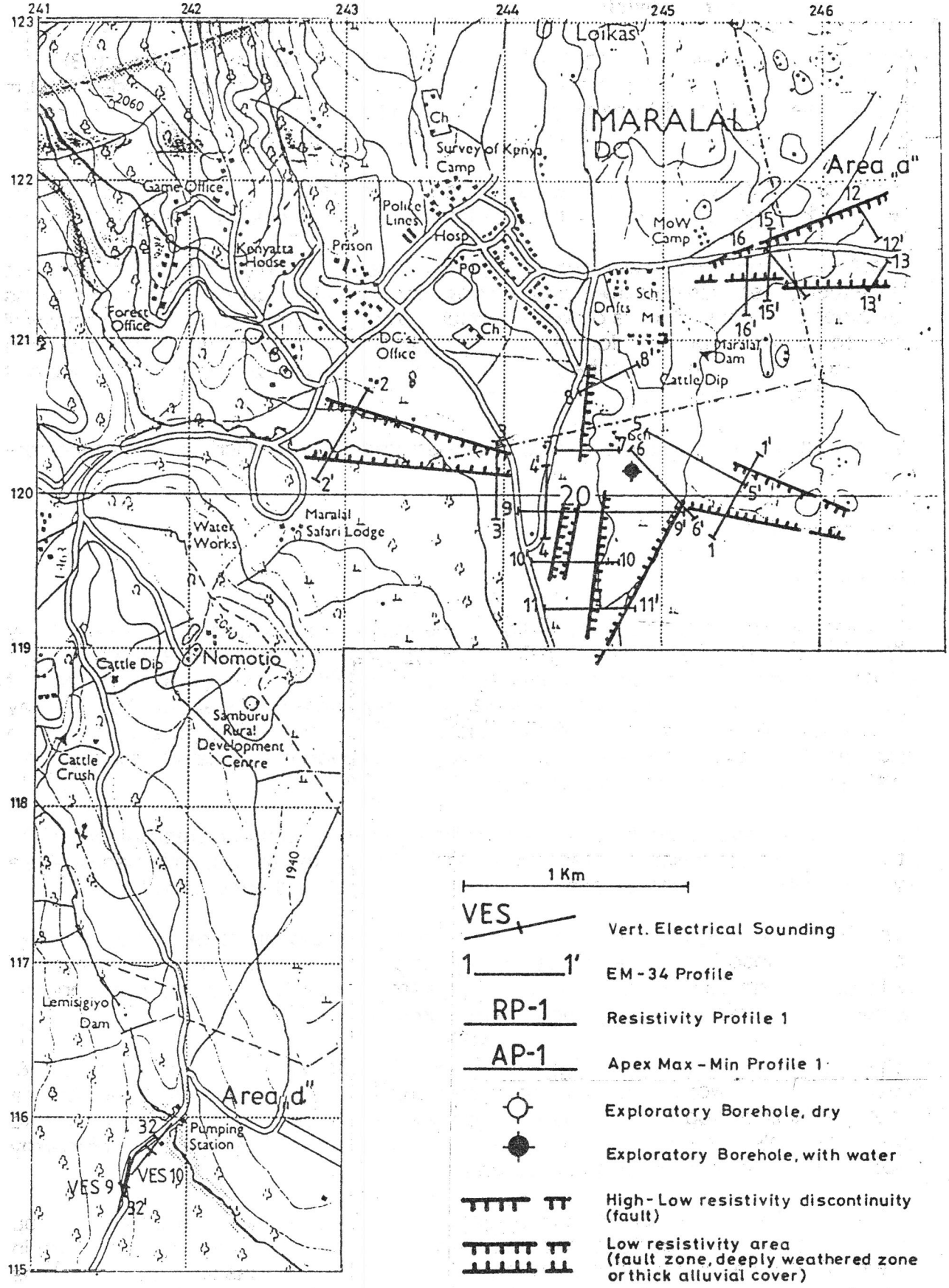



**Fig. 3.1a Situation Map Maralal Site A,D**

Groundwater accumulation can be expected in alluvial sand accumulations and cones of dejection, in the weathered top layer and faulted zones in the basement rocks.

Coarse alluvial sediments were encountered at the Loikas springs. It is expected that these course sediments are highly productive, but with a limited storage because of their restricted extension. A yield of approximately 7 $m^3/h$ was reported from the broken down wells drilled in this area. The weathered top layer of the basement is a poor aquifer because of its high clay content. Generally, the wells constructed in weathered basement material had a yield of less than 1 $m^3/h$.

Fault zones can have a relative high permeability. Also recharge is expected to be good, since laggas have developed along such structures. The borehole drilled for the Catholic Mission along a faulted zone gave initially 6 $m^3/h$.

From volcanic areas, ground water can be expected from old land surfaces between intermittent lava flows, from fractured volcanic rocks and from the weathered upper part of the basement below the volcanic cover.

In the geophysical surveys which will be described in the following sections, EM-34 profiling was applied to locate the presence and extension of deeply weathered areas, alluvial sediments, faults and faulted zones. Additionally, vertical electrical soundings were carried out to determine the thickness of the weathering and of the alluvial fill, as well as the depth to the volcanic-basement contact at one location in the volcanic area.

**Fieldwork**

Geophysical fieldwork has been carried out in four distinguished areas, a) the confluence of the Loikas, Yamo and Loidongo laggas to the east and south of the town, b) the Loikas midstream area to the north, c) the Loikas spring area at about 10 km to the north of Maralal Town and d) the area surrounding the old pump house along the Nundoto lagga (Figures 3.1a and 3.1b).

(a) In this area, sixteen EM-34 profiles were carried out (L Maralal 1 to L Maralal 16) with length's varying from 210 m to 1000 m. Aim of the survey was the determination of the area's extension of the alluvial fill - weathered and faulted complex. Additionally, five VES were done in order to quantify the thickness of the non consolidated over burden on top of the fresh basement rocks. These are VES-7, VES-8 and VES-11 to VES-13.

(b) Nine EM-34 profiles were executed in this area mainly to locate faults or faulty zones around the Loikas lagga and its main tributaries (L Maralal 17 to L Maralal 25). VES-5 and VES-6 were projected along profile L-Maralal 19, to find the thickness of the weathered layer.

(c) At the Loikas spring's area, profile L Maralal 26 was done along the eastern and L Maralal 28 along the western branch of the Loikas lagga.
Four short profiles were done crossing the above given main profiles: L Maralal 27 for the eastern and L Maralal 29 to L Maralal 31 for the western branch. The main purpose of these profiles was the detection of any change in the relative thickness of the coarse alluvial material filling the lagga bed along the investigated branches.

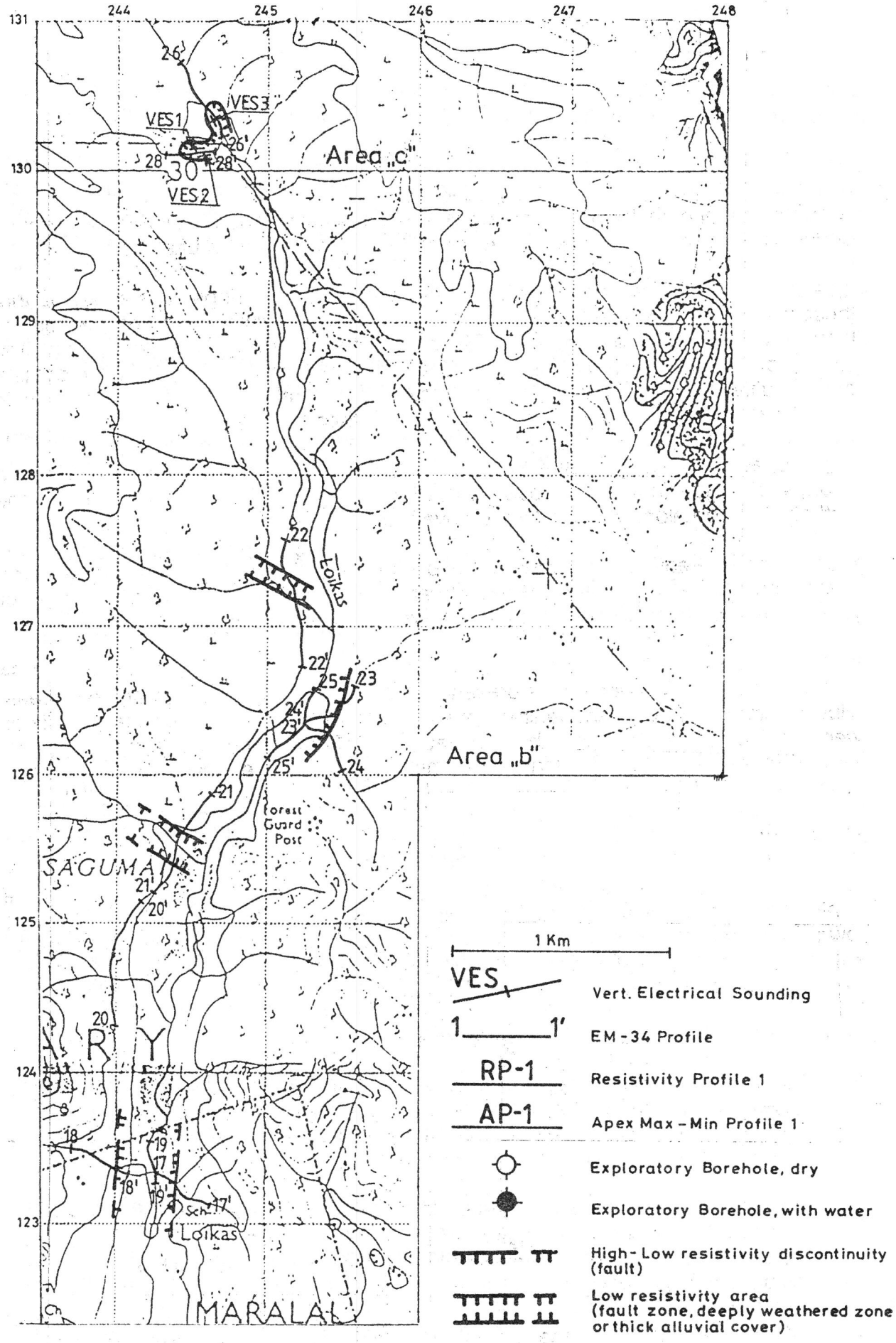



**Fig. 3.1b Situation Map Maralal Site B,C**

Two VES were carried out in each of the branches to determine the thickness of this alluvial fill from which the nos VES-1 and VES-2 in the western and VES-3 and VES-3 in the eastern branch.

(d) On this site, VES-9 and VES-10 were performed. The aim of this survey was to find the depth to the basement rocks (thickness of the volcanic cover). The survey was completed with a EM-34 profile (L Maralal 32, length 500 m), to see whether low resistivity anomalies could be found in this expectedly faulted zone. The EM and VES data are shown in Appendices 3.3 and 3.2 respectively.

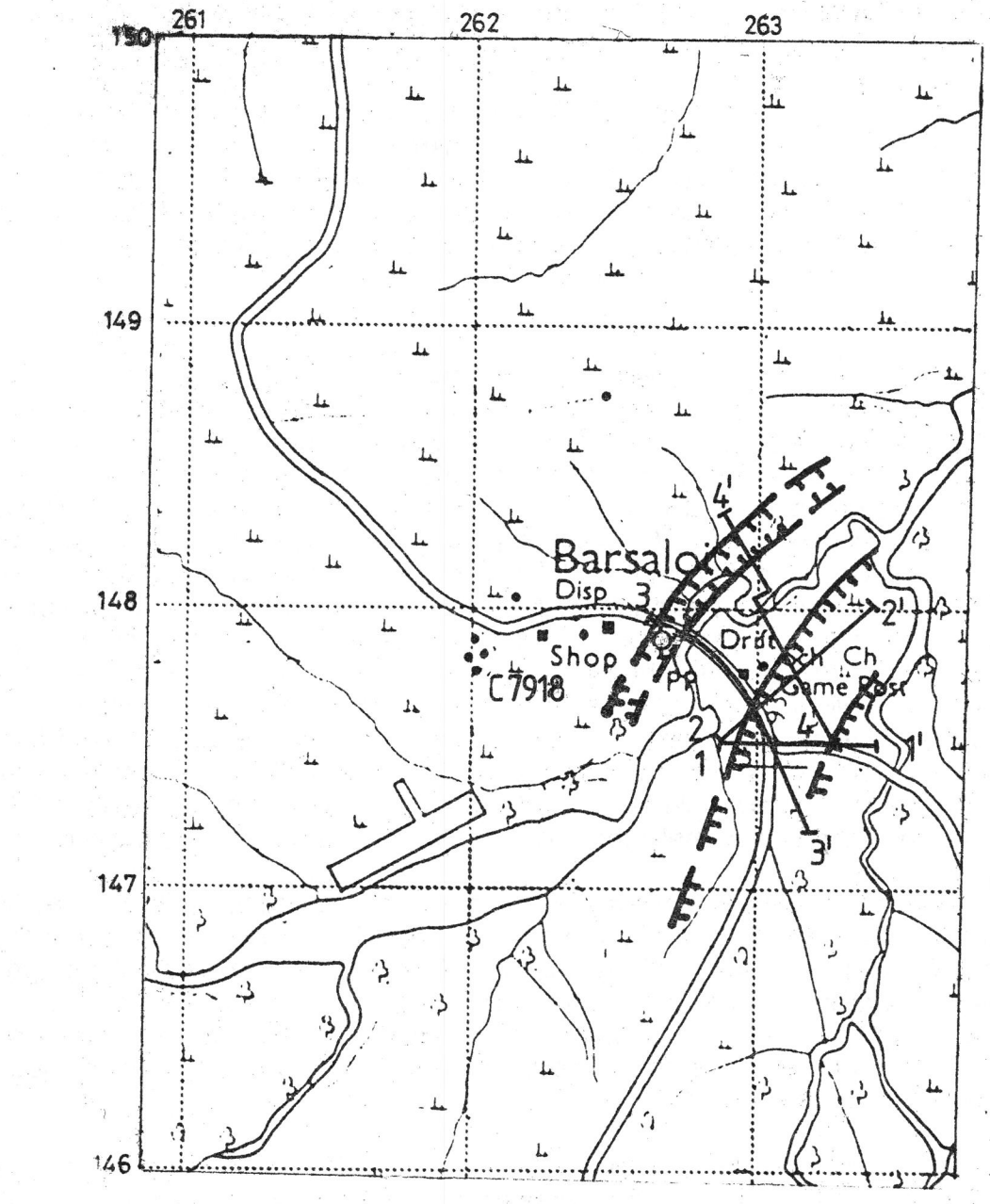
**Results**

(a) Anomalies found in the profiles confirm clearly the already adopted concept of an interception of two different fault systems in this area. The NW-SE running Yamo fault zone crosses the N-S Loikas - Loidongo fault zones. Because of the expected high grade of fracturing, this was thought to be an ideal site for ground water investigation. That is why an exploratory borehole Kirisia C7920, was located in the very centre of this low resistivity anomaly area. The result of this borehole was quite disappointing. Until 34 m a rather course sandy river deposit (terrace) was found but without saturation. From 34 until the final depth of 160 m very fine grained, decomposed augite gneiss with a high clay content was perforated. Although water bearing, this material has a low permeability with an estimated yield of only 1 $m^3/h$. Therefore, the hole was backfilled and abandoned without a well construction. Given the very fine structures of these gneisses, probably more success can be expected at a less fractured and weathered site, for example along the Yamo to the west from the main road, but within the indicated anomaly zone, or elsewhere outside of the central area.

(b) In several profiles sharp low resistivity anomalies were found, indicating faulting along the Loikas lagga and its main tributaries. Especially the resistivity drop from 200 ohmm to 30 ohmm in profile 23 from the east towards the lagga is very remarkable. Hence a borehole could be projected at the western, low resistivity site of the on the situation map indicated fault. Drilling could be done within the anomaly zones of the tributaries (profiles 21 and 22) as well, though less recharge is expected.

(c) A coarse sand and gravel alluvial fill of about 20-30 m thickness is expected within the indicated low resistivity area to the west (western branch) and to the north west (eastern branch) from the Loikas springs. A borehole site was selected in the eastern branch since pumping from a well at the western branch would directly affect the yield of the springs. Unfortunately, drilling could not be carried out because of delays in the drilling program.

(d) The contact between the basement rocks volcanic rocks is about 2 km East of this area. Hence the thickness of the volcanic cover was expected to be shallow. Surprisingly VES 9 and 10 (especially VES 10) indicate volcanic cover of upto 250 m. A borehole was drilled at VES 10 to a depth of 200 m and is semi-artesian, with water struck log at 112 m and water rest level at 1 m. The geological shows volcanic material upto the total 200 m drilled, thus conforming the VES results. The most likely sequence of events to explain the unusual volcanic thickness is down-throw faulting of the basement, followed by filling of the depression by later episodes of volcanic lava flows.




1 Km

VES — Vert. Electrical Sounding

1 — 1' — EM-34 Profile

RP-1 — Resistivity Profile 1

AP-1 — Apex Max-Min Profile 1

Exploratory Borehole, dry

Exploratory Borehole, with water

High-Low resistivity discontinuity (fault)

Low resistivity area (fault zone, deeply weathered zone or thick alluvial cover)

**Fig. 3.2 Situation Map Barsaloi**

Taking the four areas together (i.e a,b,c,d), it is recommended that future boreholes be located within the volcanics where they are expected to have high yields. A good example is the Losuk borehole (12 km south-east of area d) which has a yield of 12.5 $m^3/h$ at a drawdown of 25 m.

Nevertheless boreholes for local use also can be drilled in the indicated zones of the basement complex where resistive low yields (1-5 $m^3/h$) are to be expected.

## 3.2 Barsaloi

### General

This centre is situated at the conjunction of the three divisions of Samburu (Figure 3.2). Although it belongs administratively to Lorroki Division, its accessibility for survey purposes is much better from Baragoi.

Lagga bed wells are the present source of water. Although the Catholic Mission has a productive well in the western bank of the lagga, its yield is far below the total demand of the rapidly increasing population and the expanding school society.

On the geological map, several fault lines can be observed, which are converging near Barsaloi centre. Also a contact zone between basement rocks and a granitic inlier is situated at a short distance to the east from the lagga. Both structure types are generally suitable for the accumulation of groundwater.

### Fieldwork

Field work was concentrated within the township area. Four EM profiles were executed (Figure 3.2). Profiles L Barsaloi 1 (560 m) and L Barsaloi 2 (720 m) were done near the school compound in W-E, and SW-NE directions respectively. Both profiles were aimed to cross the basement - granite inlier contact zone. Profiles L Barsaloi 3 (1000 m) and L Barsaloi 4 (900 m) were projected more or less perpendicular to the former ones, crossing the Barsaloi lagga.

### Results

All profiles show at their eastern part a low resistivity (30-40 ohmm) zone indicating the presence of the contact zone. The relatively low resistivity values suggest that this zone is highly fractured.

Profiles L Barsaloi 3 and 4 show, west of the lagga, a narrow but very pronounced anomaly. A drilling site was located along this anomaly, also being at a central position between the township centre and the school compound. The borehole, C7918, penetrates about 21 m of fine to very coarse river deposits. Obviously, it concerns of a filled-up, abandoned course of the Barsaloi river. Especially the lower most part of this alluvial fill is very coarse consisting of gravel and boulders. Consequently, the yield of the well is quite high (about 7 $m^3/h$). From 21 m to the final depth of 40 m slightly weathered augite gneisses of the basement complex have been found, which do not contribute significantly to the total yield.

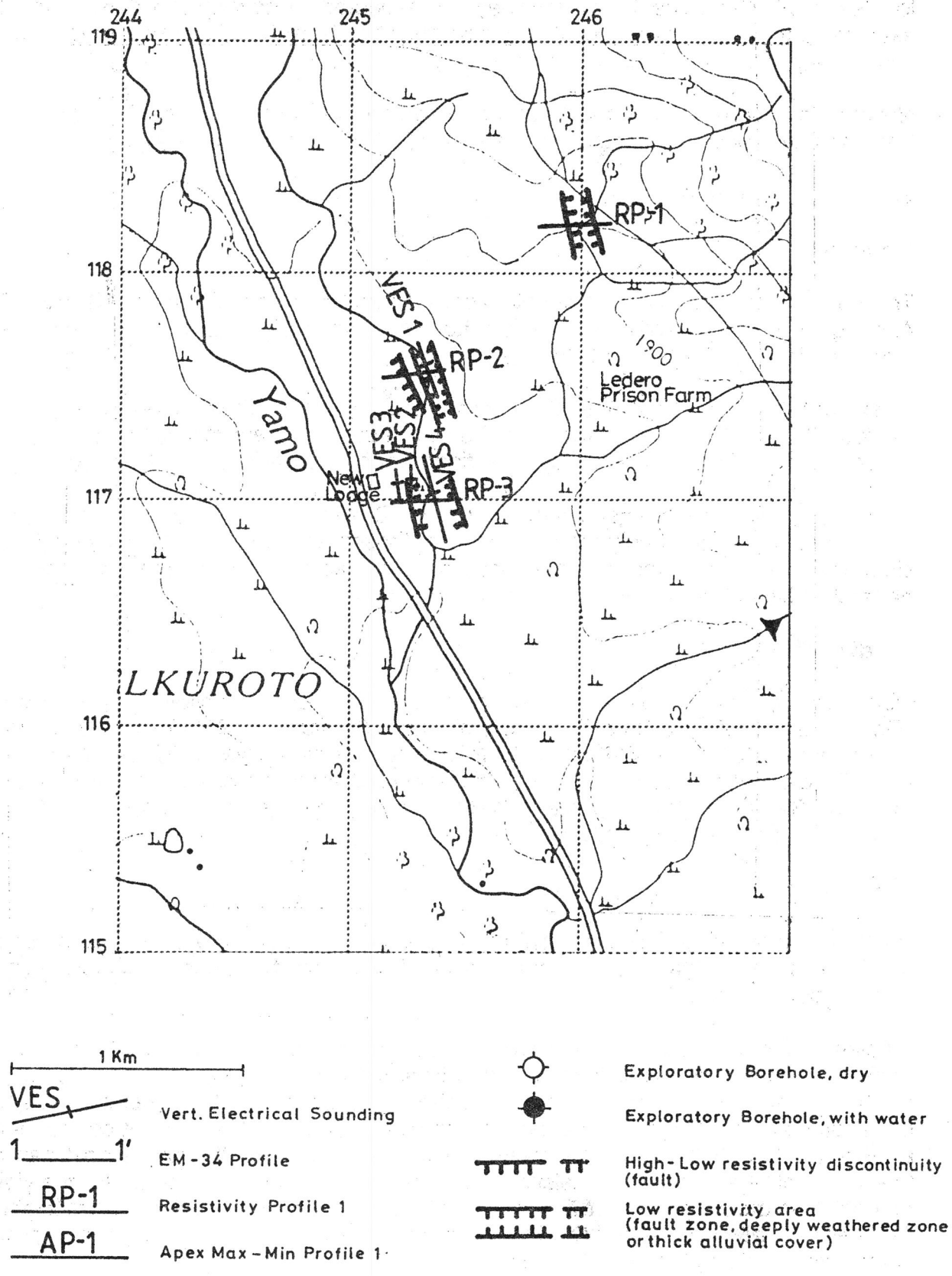



**Fig. 3.3a Situation Map Ledero Site 1**

## 3.3 Ledero

### General

Ledero is situated about 10 km south of Maralal along the Maralal - Rumuruti road. The name refers to a large area which also has a prison experimental farm and a primary school. There are a few scattered Manyattas, lying on grass-covered rolling hills which gives the area an uneven topography. Towards the east and north-east lies the Karissia Hills which are forested. The area lies on basement rock system. Geophysical survey was done in this locality, mainly to get a suitable site for commissioning the WRAP drilling rig.

Although two sites in this locality were investigated (Figure 3.3a and 3.3b), the first one, at the prison farm was abandoned for two reasons. First, the site was said to be in a private ground and secondly, priority was to be given to the Ledero School which needed water badly, hence a site near the school was identified and investigated.

### Fieldwork

The first investigated site is near the Ledero Prison Farm, while the other is near the Ledero School.

Three different geophysical survey methods were used in Ledero. These were, vertical Electrical Soundings (VES), Resistivity Profiles (RP) and Electro-Magnetic Profiles (EM).

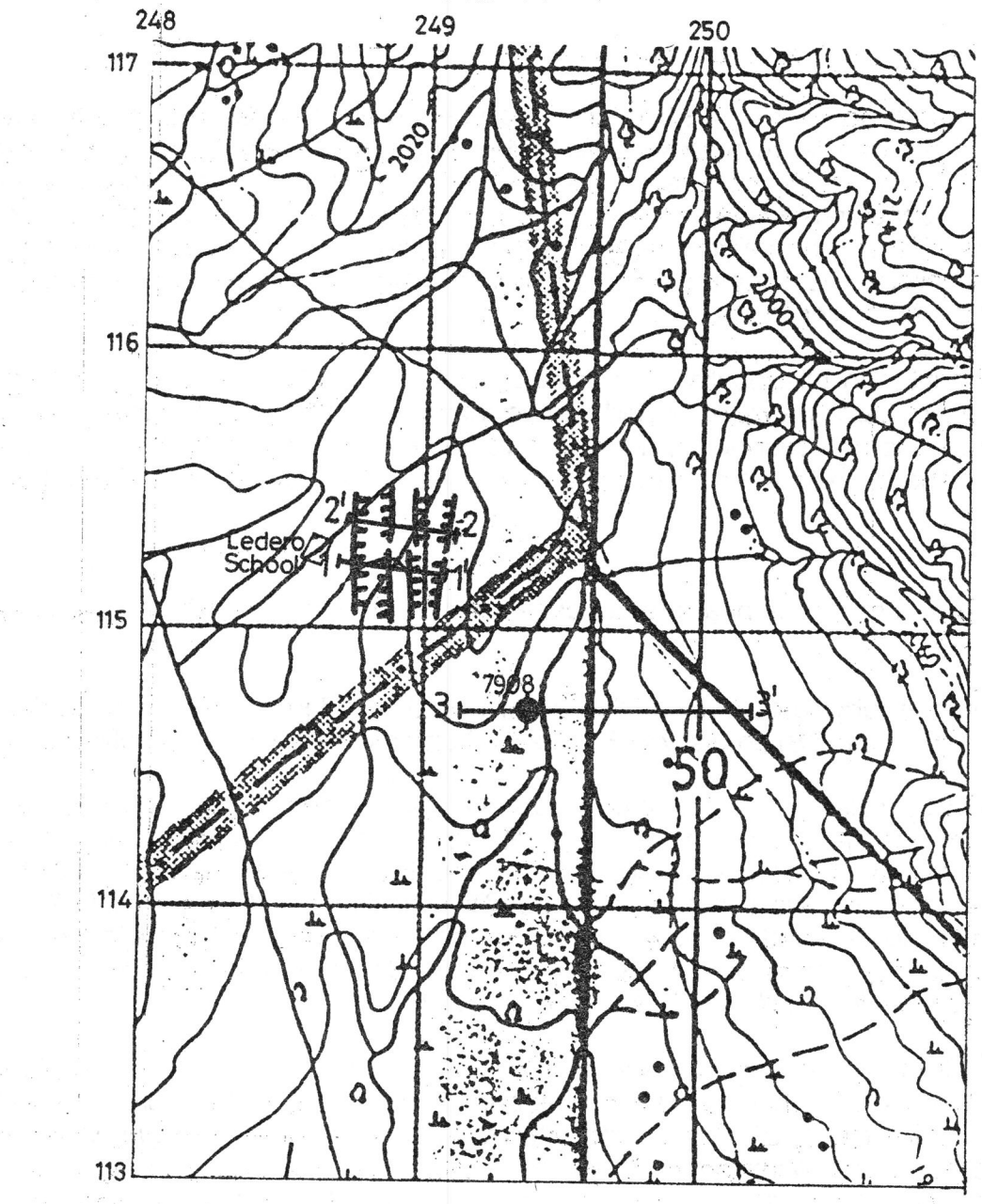
Three resistivity profiles were conducted near the Ledero Prison farm, which is located about 4 km from Maralal Town on the road to Rumuruti (Appendix 3.4). All the profiles were oriented in the east-west direction. Four soudings were then executed in the areas where anomalies were observed (Appendix 3.2). Hence VES 1 with AB/2 130 m and azimuth northwest-Southeast was made on RP2 VES 2 and 3 were done with the half schumberger array both running in the north direction and VES 4 with AB/2 of 200 m and direction north-south, were done on RP3.

There were three EM profiles executed at the Ledero school site (Appendix 3.3). Profiles L Ledero 1 and L Ledero 2 starting about 150 m east of the School centre with azimuth approximately 100°, had station interval of 20 m and coil separation 40 m. Each profile covered a distance of 380 m. Profile L Ledero 3 running east-west, with the same station interval and coil separation, covered a distance of 1280 m. This profile is about 1.2 km north-east of the School centre.

### Results

Although the first geophysical survey done at the Ledero Prison farm area yielded good results and a suitable site for drilling was selected, it had to be abandoned for reasons already mentioned.

Nevertheless, interpretation of the resistivity profiles (RP) and VES curves of the abandoned site have been made. The resistivity profiles showed anomalies at certain sections of the profiles, vertical electrical soundings were then executed at these anomaly areas to obtain qualitative data about the thickness of the weathered layer. The first sounding done on RP2 showed shallower weathering of up to 15 m while the second, third and fourth soundings done on RP3 showed deeper weathering of 30-40m. These results, indicated that the sites on RP3 are promising areas for drilling.




1 Km

VES — Vert. Electrical Sounding

1 — 1' — EM-34 Profile

RP-1 — Resistivity Profile 1

AP-1 — Apex Max-Min Profile 1

Exploratory Borehole, dry

Exploratory Borehole, with water

High-Low resistivity discontinuity (fault)

Low resistivity area (fault zone, deeply weathered zone or thick alluvial cover)

**Fig. 3.3b Situation Map Ledero Site 2**

Results obtained from the three EM profiles done at the other site, were quite positive. Anomalies were observed in all the profiles, but it was more distinct in the third one, between stations 6 and 26. From 2500 ohmm, at the beginning of the profile, the resistivity dropped to 147 ohmm at station 16. The borehole was located near the western edge of the low resistivity zone at station 12 of this profile. This borehole was drilled (C7908) and the total depth is approximately 70 m. The yield is about 1.2 $m^3$/hr.

## 3.4 Losuk

### General

Losuk is a medium sized centre with a number of shops and a primary school (Figure 3.4). In addition it has a game scout house. It is situated about 20km from Maralal passed Sirata Oirobi. This centre lies on volcanic formations making the topography predominantly flat. However, to the north of the centre a fault can be inferred from which a number of shallow wells have been dug. In one of these wells is a broken down handpump.

Since the area is volcanic, groundwater is expected to be found at interfaces of the various volcanic episodes, at the upper, weathered part of the basement below and in fractured fault zones.

### Fieldwork

To try to locate the depth to the basement below the volcanics, 3 vertical electrical sounding were executed (Appendix 3.2).

In addition, two EM profiles (L Losuk 1 and L Lusuk 2, of 310 m respectively) were done parallel to each other across the inferred fault and ran N-S. Both had a coil separation of 40m and station interval of 10m (Appendix 3.3).

### Results

Two of the three soundings are quite irregular due probably to the many boulders at the surface which impede a good contact between the electrodes and the soil. However, the soundings show clearly that there is a very thick cover of volcanics (>600m) at Losuk, since none of them encountered basement rocks.

The EM profiles show only very small anomalies at the lagga (wells) which, as mentioned above, was thought to be a fault line. The very small anomalies make it very difficult to conclude as to the existence of the fault. One possibility is that the small anomalies could be caused by the water present in the upper part of the rocks at this lagga.

Drilling was done near the inferred fault. A semi artesian aquifer was struck at 58 m. The water rest level was 1 m below surface. The pump test gave 25 m of drawdown at a yield of 12,5 $m^3$/h, which guarantees a safe yield of at least 18 $m^3$/h.

## 3.5 Opiroi

### General

Opiroi is a small centre situated along the Maralal-Barsaloi road, 30 km East of Maralal

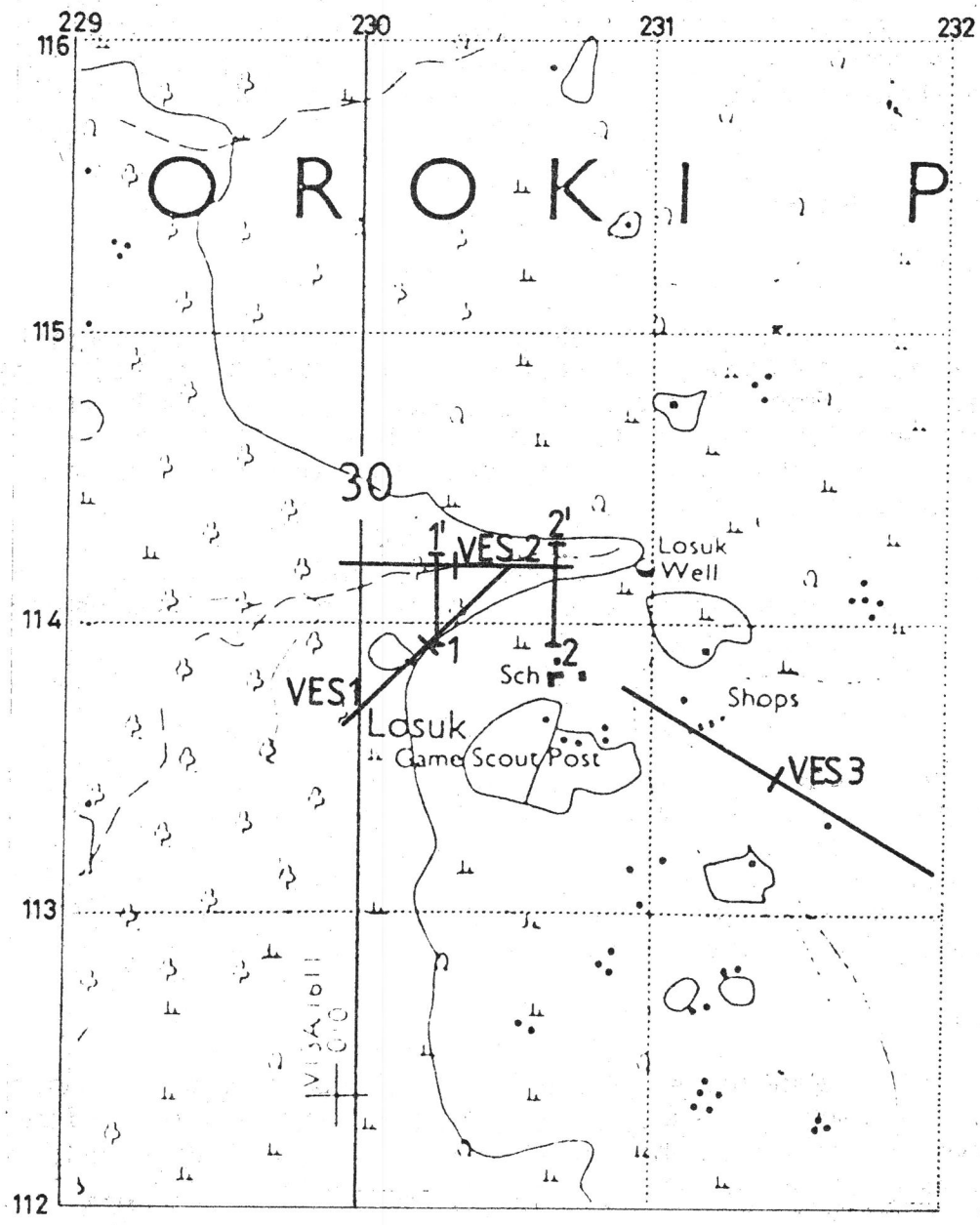



**Fig. 3.4 Situation Map Losuk**

town. It is located at the foot of the Karissia hills on the Northern edge of Lorroki forest. It has a school, a church and a few shops (Figure 3.5).

The centre experiences acute shortage of water during the dry months when the main Opiroi Lagga dries up. There are several faults which seemingly determine the course of the Opiroi lagga and of its tributaries.

**Field work**

Geophysical work was targeted to the laggas which had been inferred to be fault controlled.

Two EM Profiles were executed in this area (Appendix 3.3). Profile L Opiroi 1 (1020 m) runs along the road starting 400 m north of the church and heading to the south. At its end this profile crosses the main tributary of the Opiroi lagga.

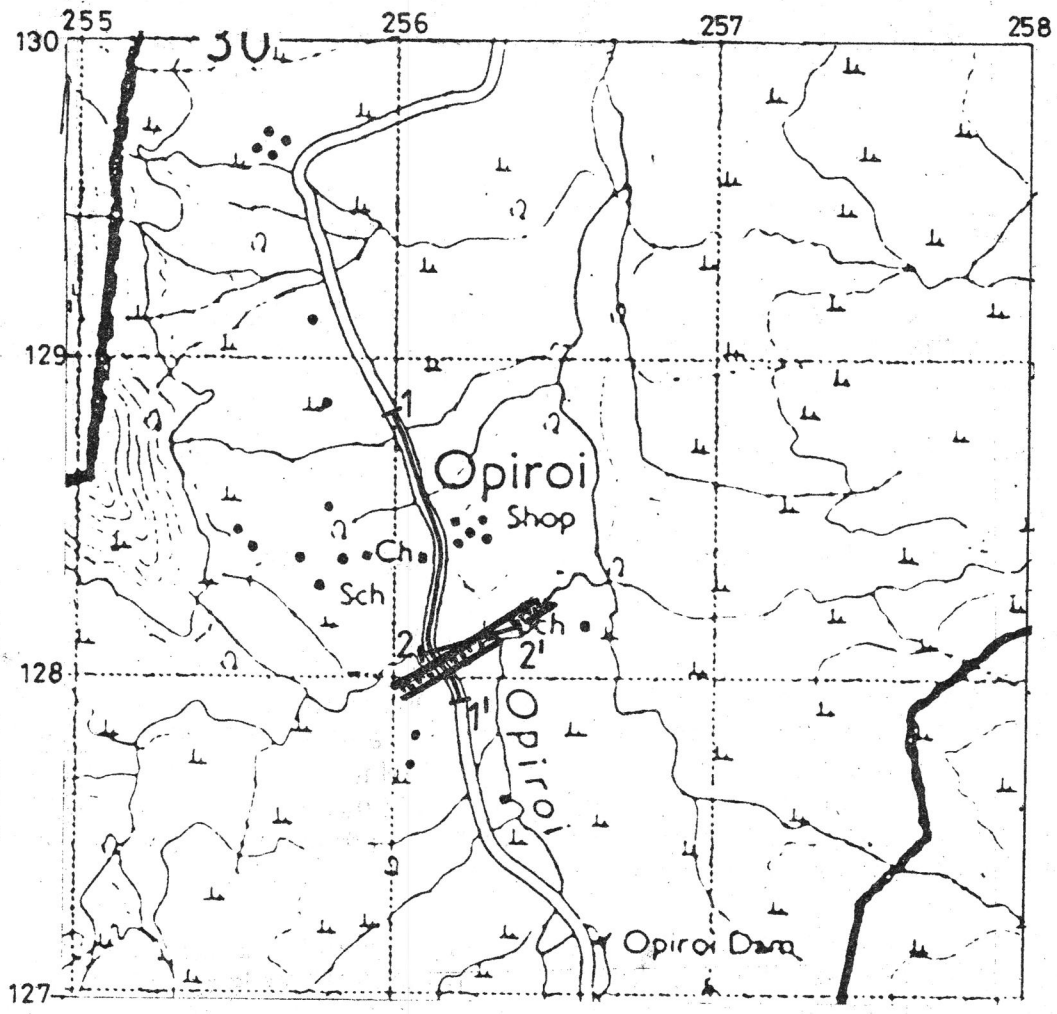
The second profile L Opiroi 2 (440 m) was done in this tributary starting at sation 45 of profile 1.

In both profiles a coil separation of 20 m and a station interval of 20 m was used.

**Results**

In both profiles, some minor resistivity changes (anomalies) were observed. In profile 1 a small anomaly was picked between stations 44 and 49, 40 m south of the lagga. Unfortunately more profiles could not be run parallel to it, to determine the orientation of the anomaly due to thick bushes on both sides of the road. The second profile did pick a similar anomaly, just before the tributary meets the Opiroi Lagga. This confirms the above view that the lagga is fault controlled.

Hence, a borehole is recommended as near as possible to the confluence of the two laggas, where intense fracturing and an adequate recharge is to be expected. The relatively thick coars alluvial cover deposited in this area can also contribute to the succes of a borehole.




1 Km

VES — Vert. Electrical Sounding

1 — 1' — EM-34 Profile

RP-1 — Resistivity Profile 1

AP-1 — Apex Max-Min Profile 1

Exploratory Borehole, dry

Exploratory Borehole, with water

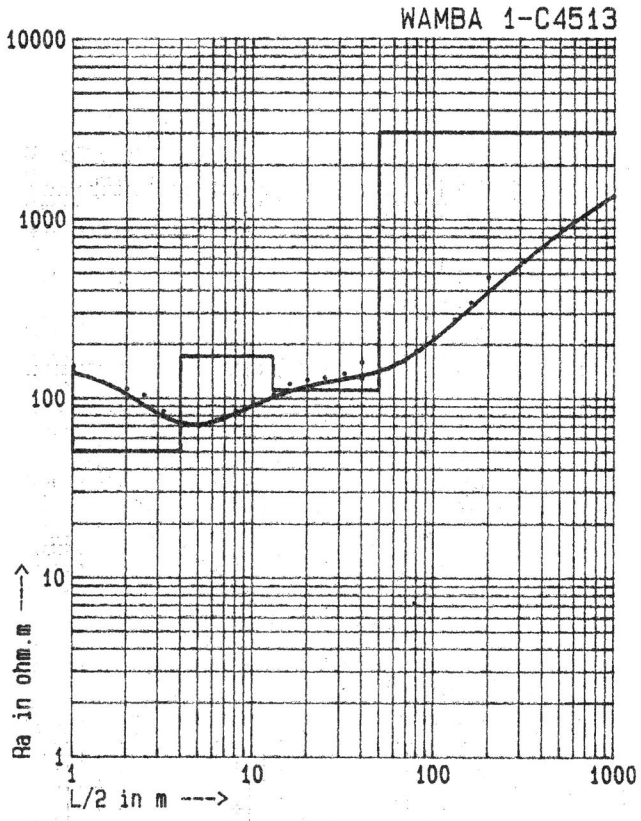
High-Low resistivity discontinuity (fault)

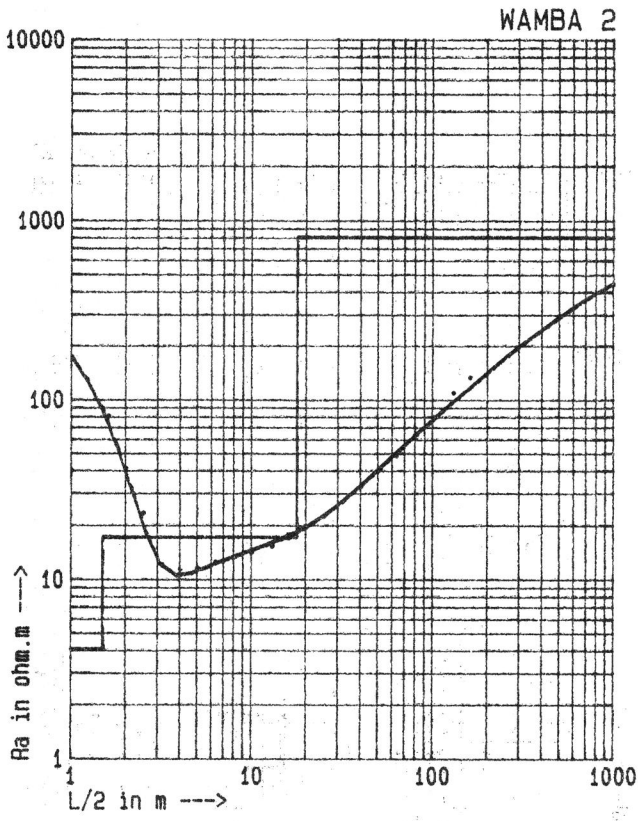
Low resistivity area (fault zone, deeply weathered zone or thick alluvial cover)

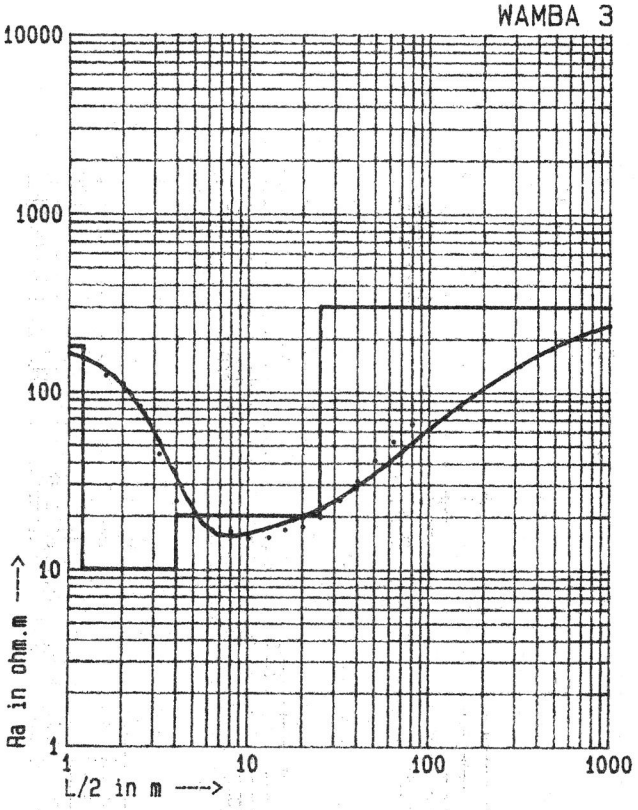
**Fig. 3.5 Situation Map Opiroi**

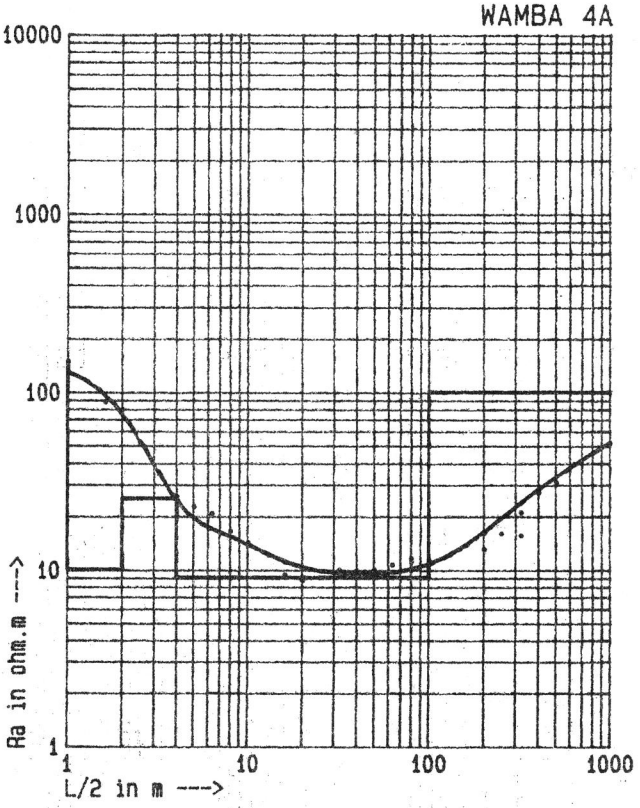
# Appendix 3.2

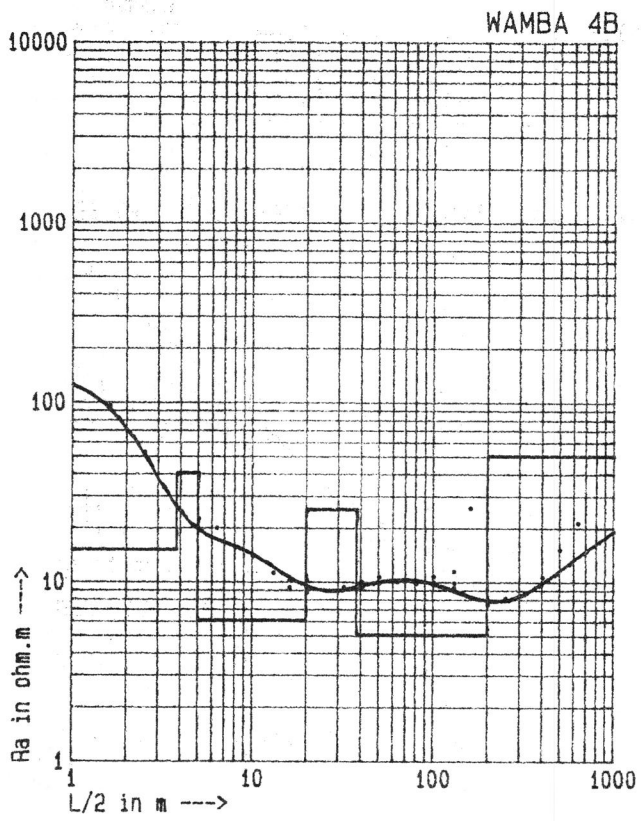
## Vertical Electrical Soundings

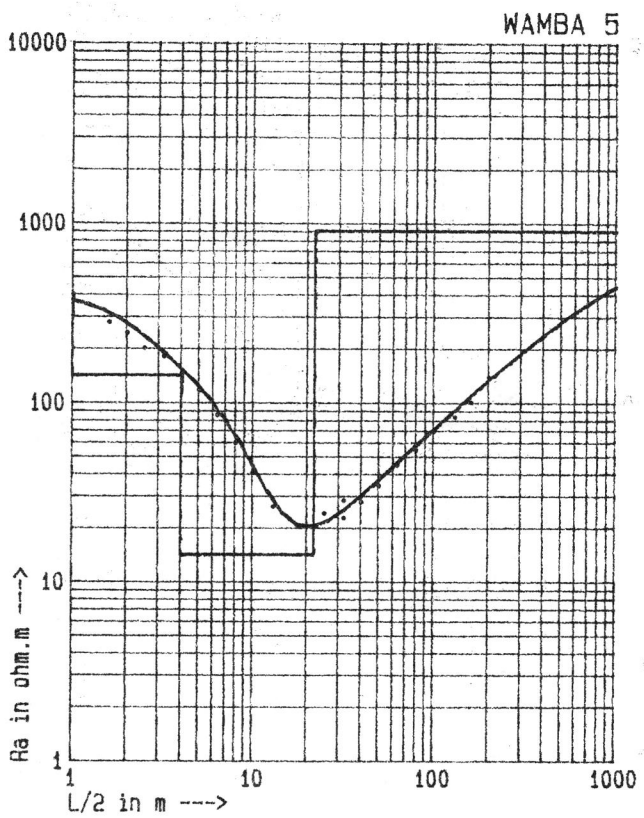

WAMBA 1-C4513
10000
1000
100
10
1
Ra in ohm.m ---->
1
10
100
1000
L/2 in m --->

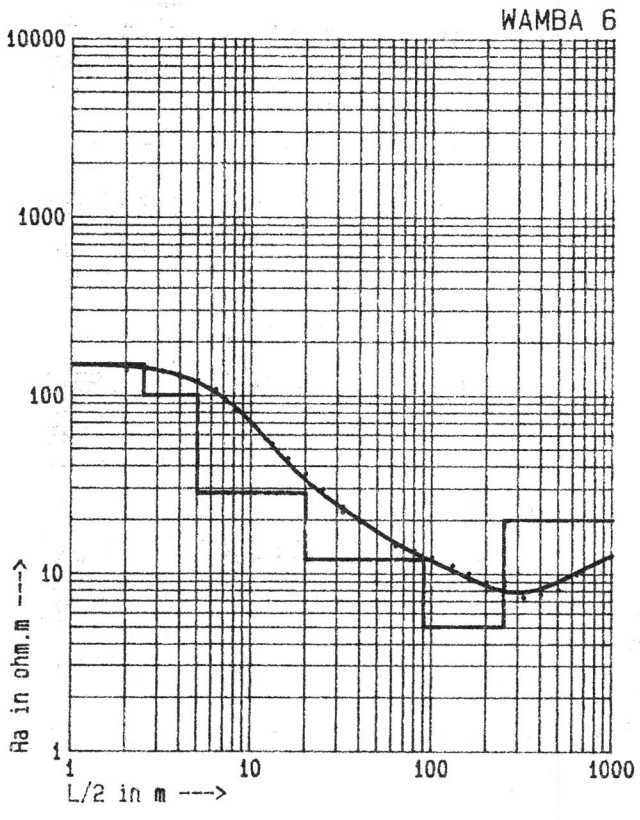

WAMBA 2
10000
1000
100
10
1
Ra in ohm.m ---->
1
10
100
1000
L/2 in m --->

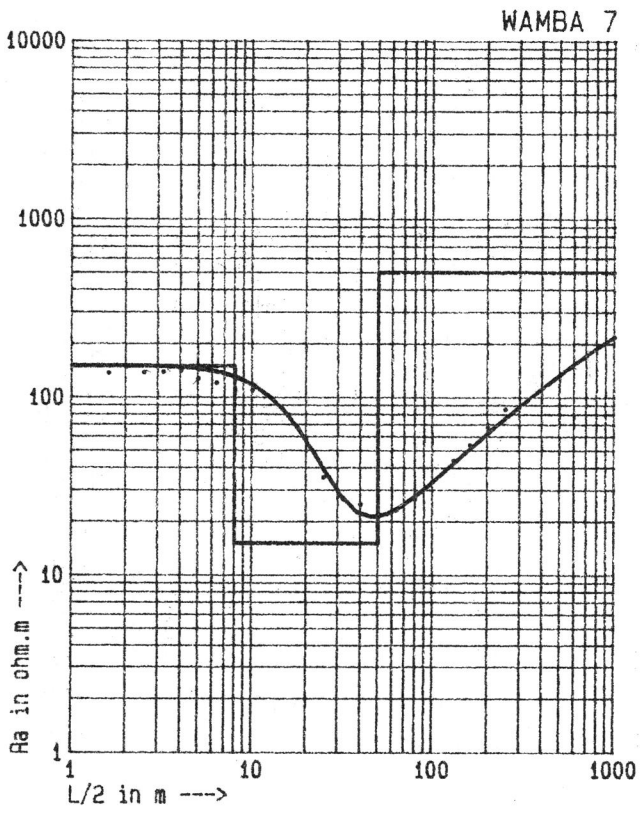

WAMBA 3
10000
1000
100
10
1
Ra in ohm.m ---->
1
10
100
1000
L/2 in m ---->

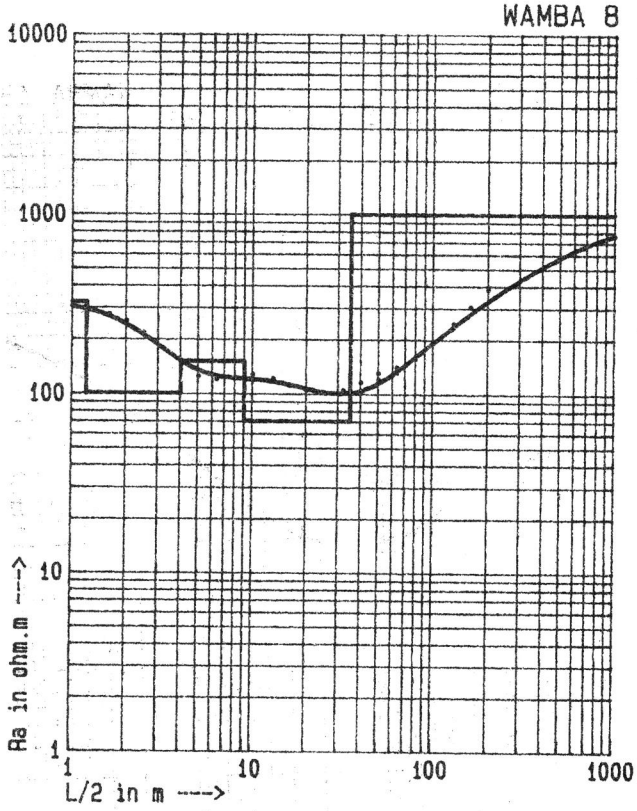

WAMBA 4A
10000
1000
100
10
1
Ra in ohm.m ---->
1
10
100
1000
L/2 in m ---->

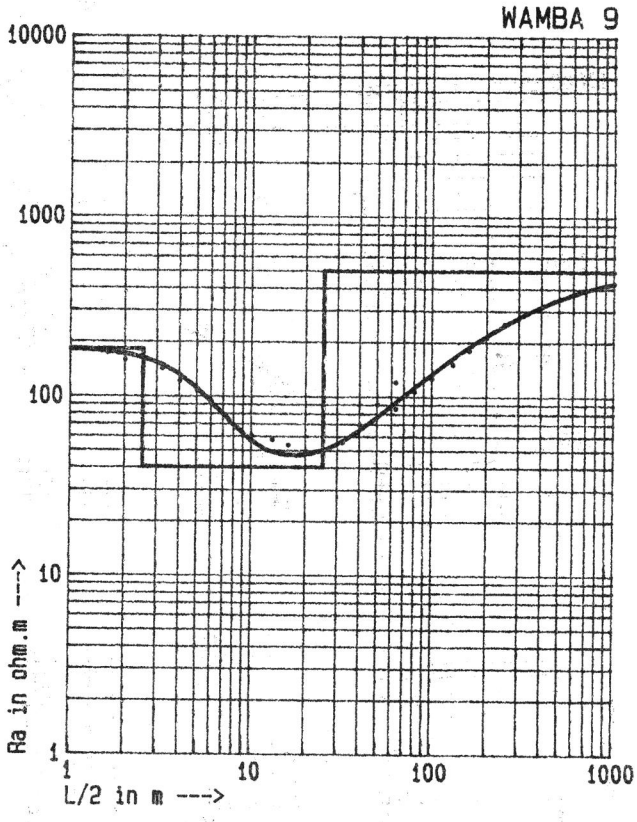

WAMBA 4B
10000
1000
100
10
1
Ra in ohm.m --->
1
10
100
1000
L/2 in m --->

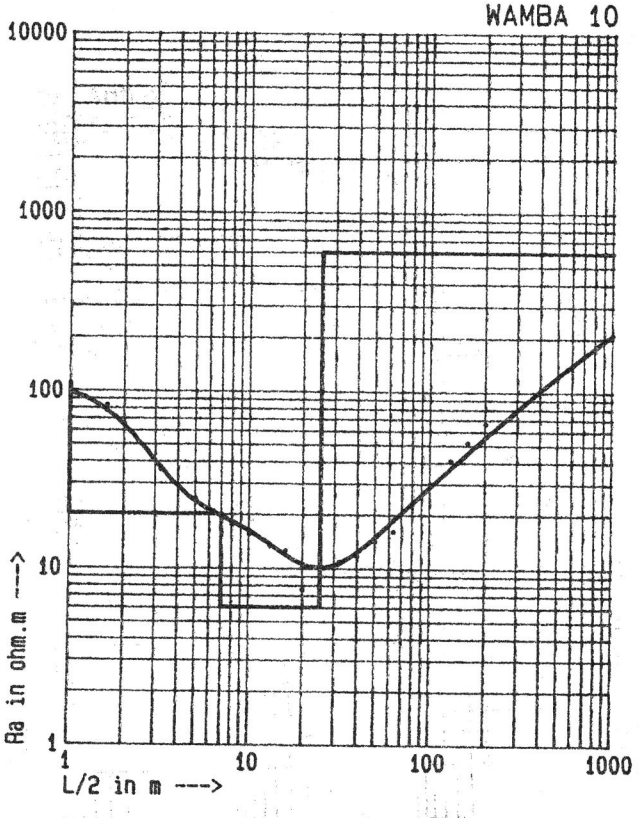

WAMBA 5
10000
1000
100
10
1
Ra in ohm.m --->
1
10
100
1000
L/2 in m --->

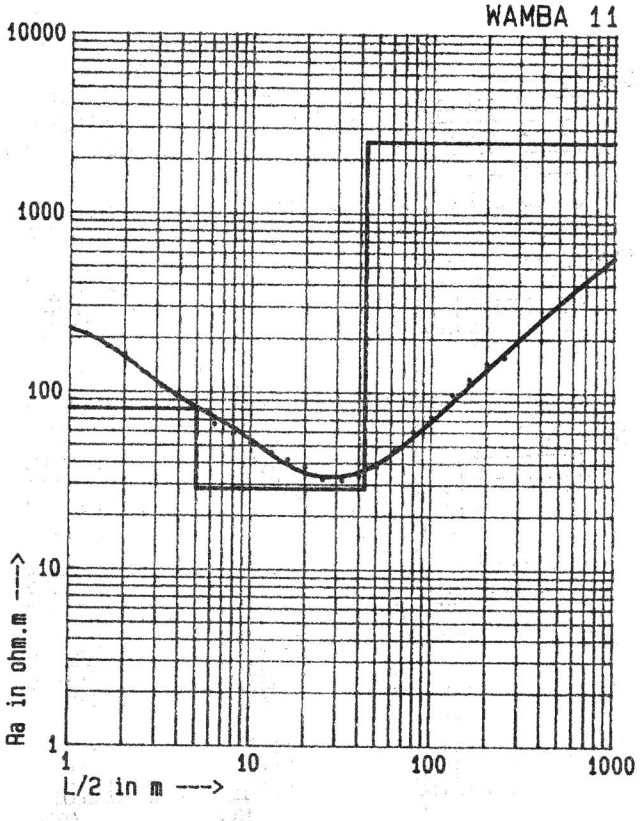

WAMBA 6
10000
1000
100
10
1
Ra in ohm.m --->
1
10
100
1000
L/2 in m --->

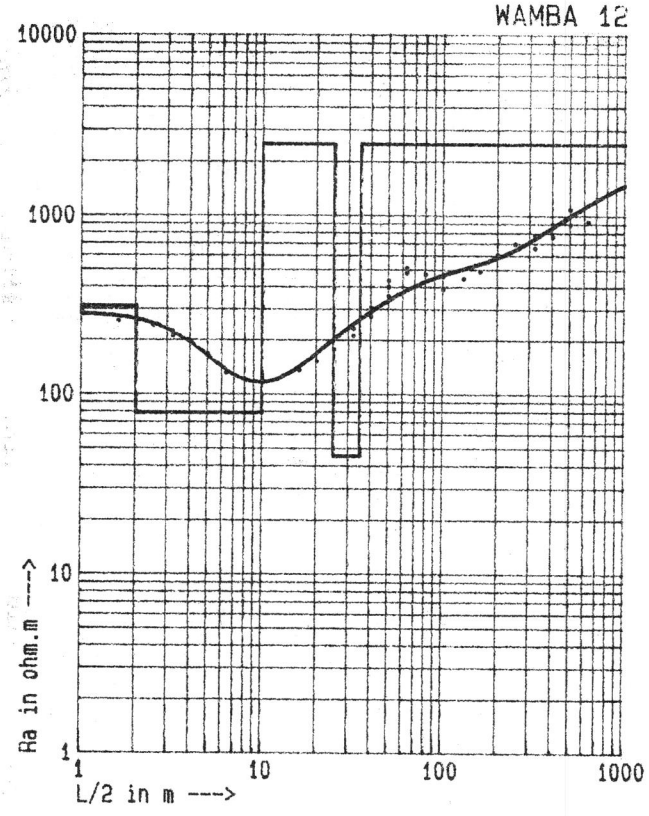

WAMBA 7
10000
1000
100
10
1
Ra in ohm.m --->
1
10
100
1000
L/2 in m --->

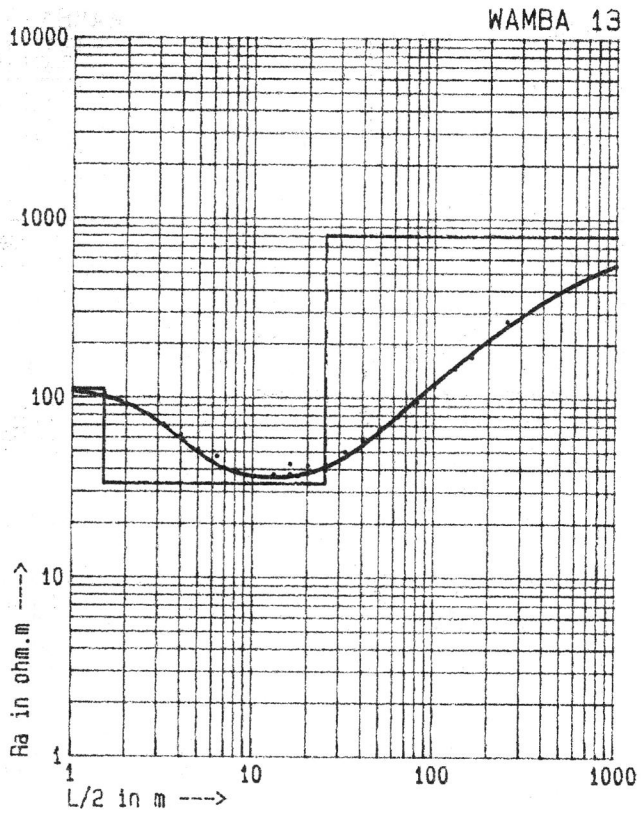

WAMBA 8
10000
1000
100
10
1
Ra in ohm.m --->
1
10
100
1000
L/2 in m --->

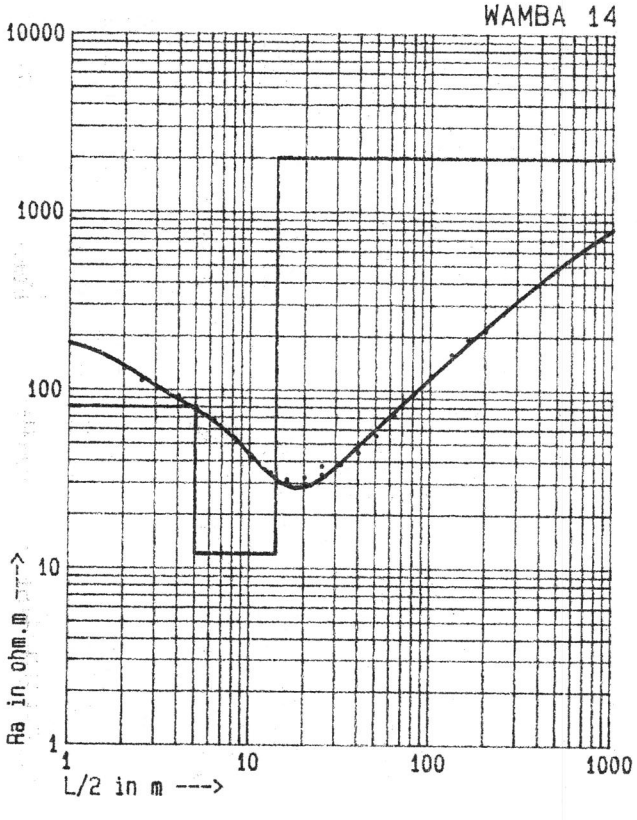

WAMBA 9
10000
1000
100
10
1
Ra in ohm.m --->
1
10
100
1000
L/2 in m --->

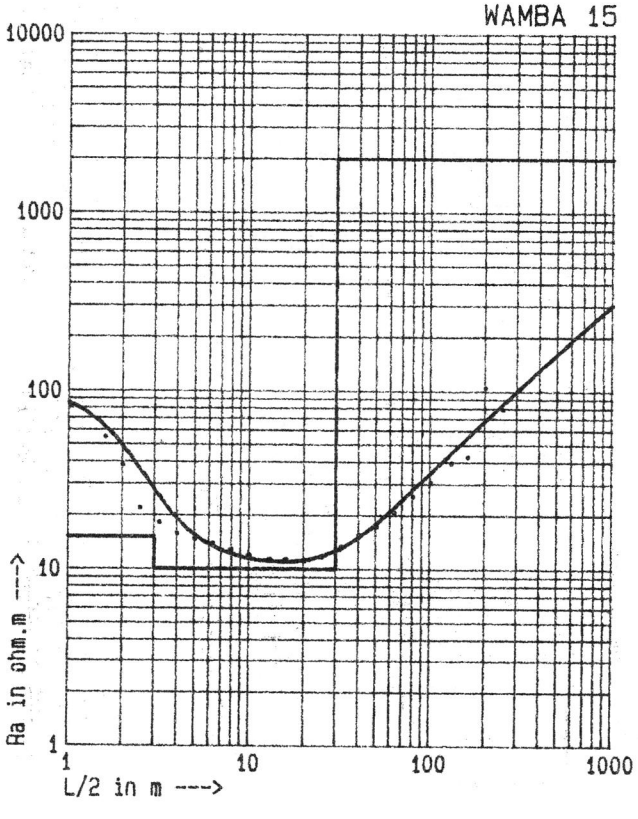

WAMBA 10
10000
1000
100
10
1
Ra in ohm.m --->
1
10
100
1000
L/2 in m --->

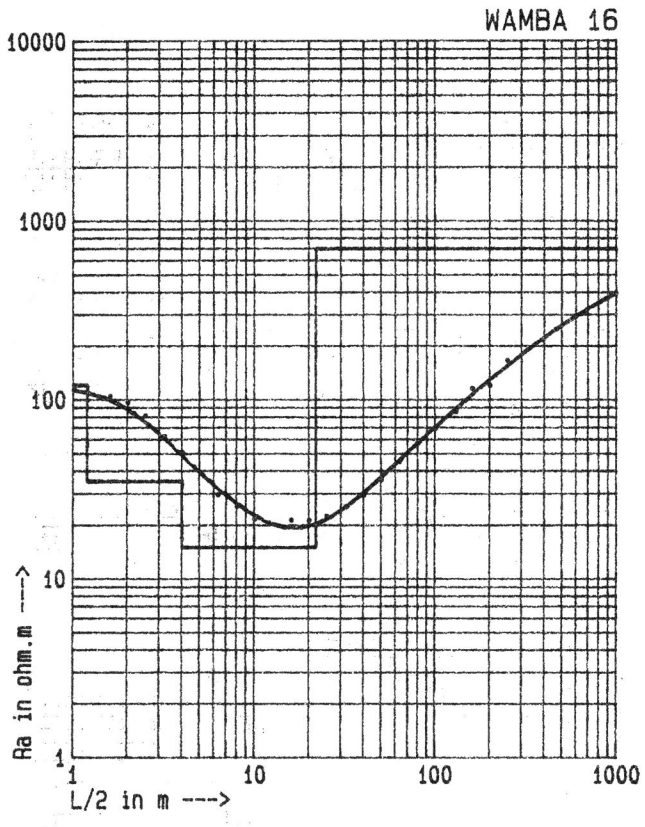

WAMBA 11
10000
1000
100
10
1
Ra in ohm.m --->
1
10
100
1000
L/2 in m --->

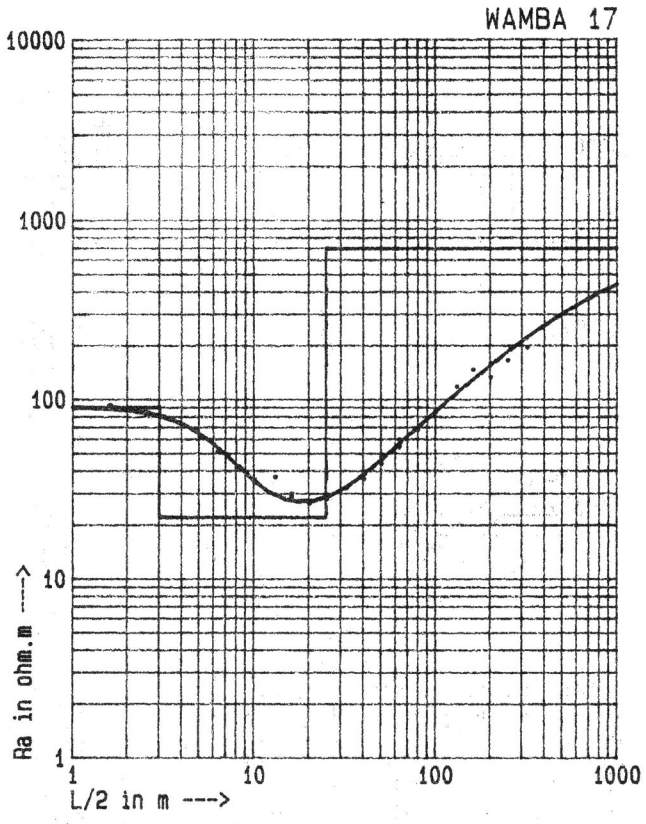

WAMBA 12
10000
1000
100
10
1
Ra in ohm.m --->
1
10
100
1000
L/2 in m --->

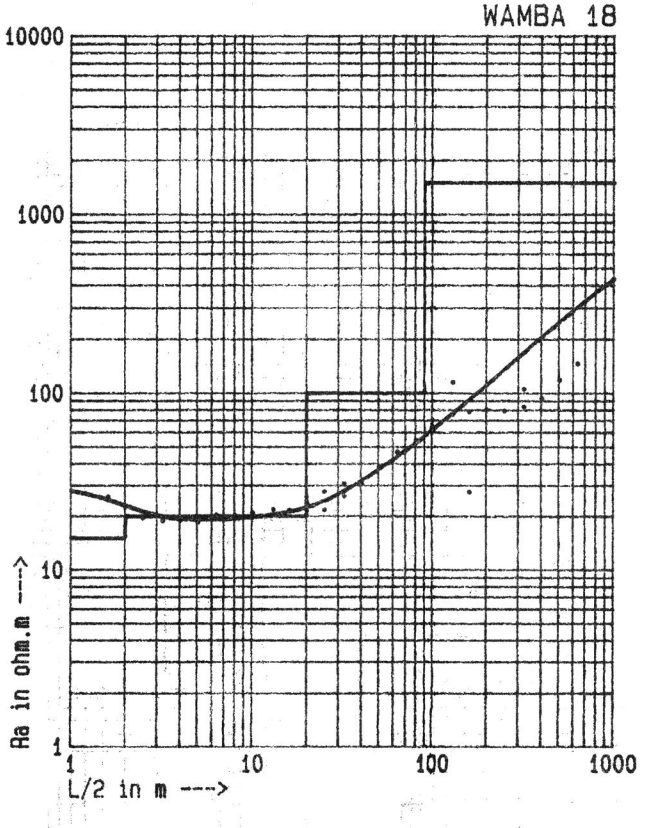

WAMBA 13
10000
1000
100
10
1
Ra in ohm.m --->
1
10
100
1000
L/2 in m --->

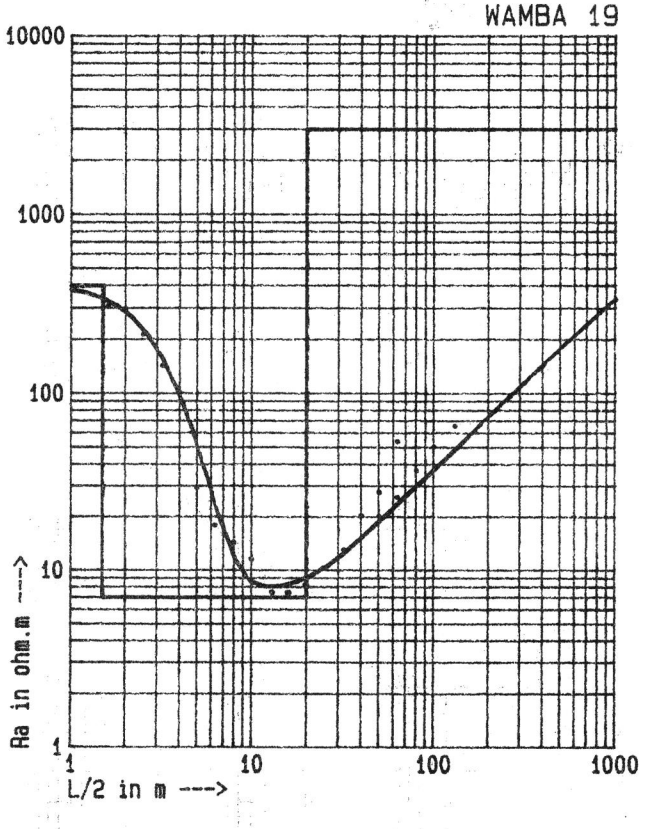

WAMBA 14
10000
1000
100
10
1
Ra in ohm.m --->
1
10
100
1000
L/2 in m --->

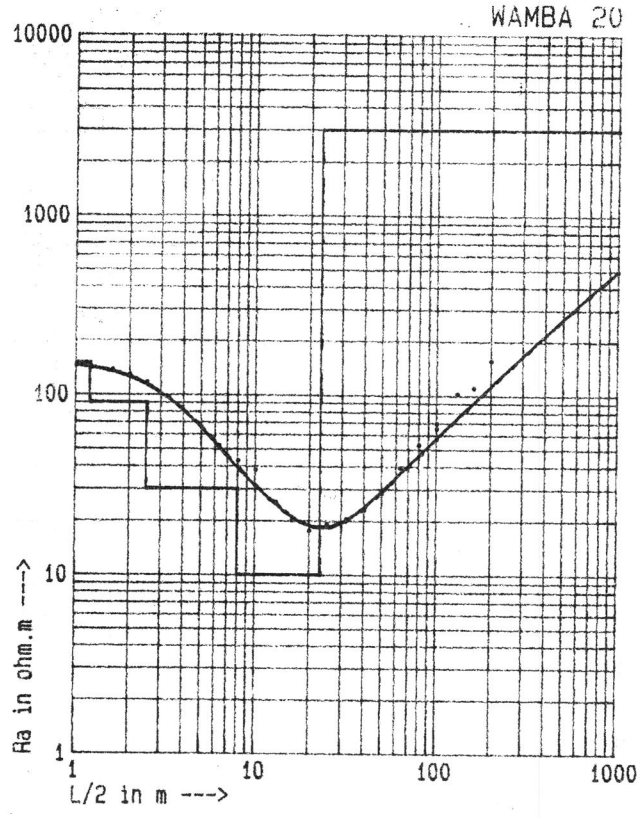

WAMBA 15
10000
1000
100
10
1
Ra in ohm.m --->
1
10
100
1000
L/2 in m --->

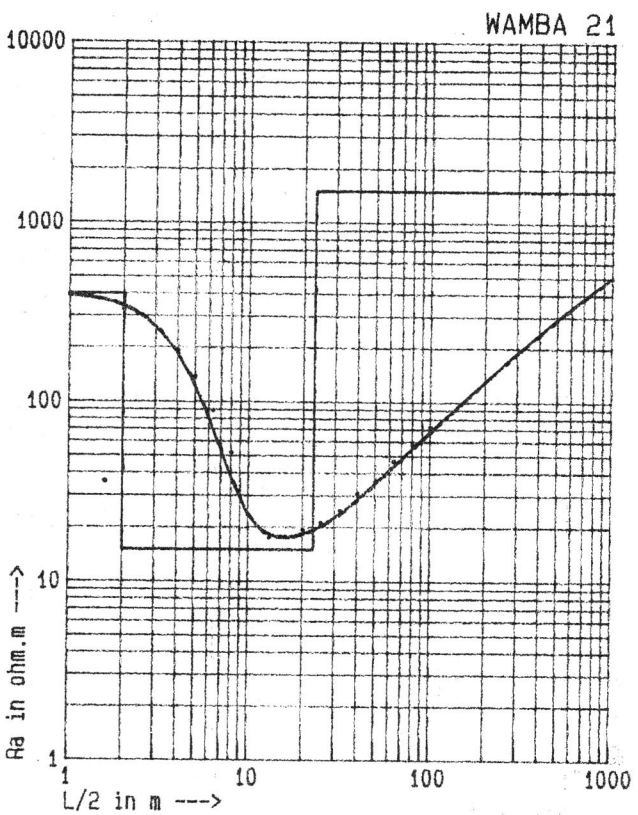

WAMBA 16
10000
1000
100
10
1
Ra in ohm.m --->
1
10
100
1000
L/2 in m --->

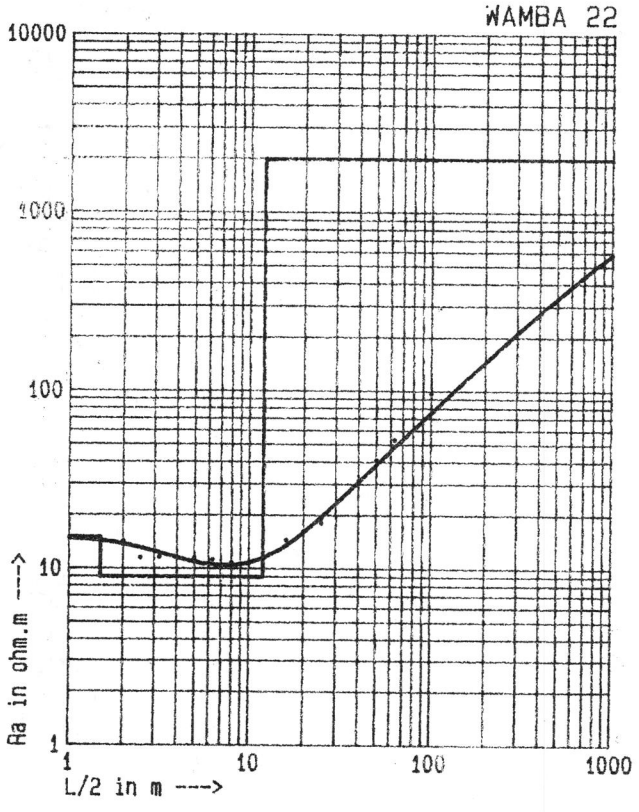

WAMBA 17
10000
1000
100
10
1
Ra in ohm.m --->
1
10
100
1000
L/2 in m --->

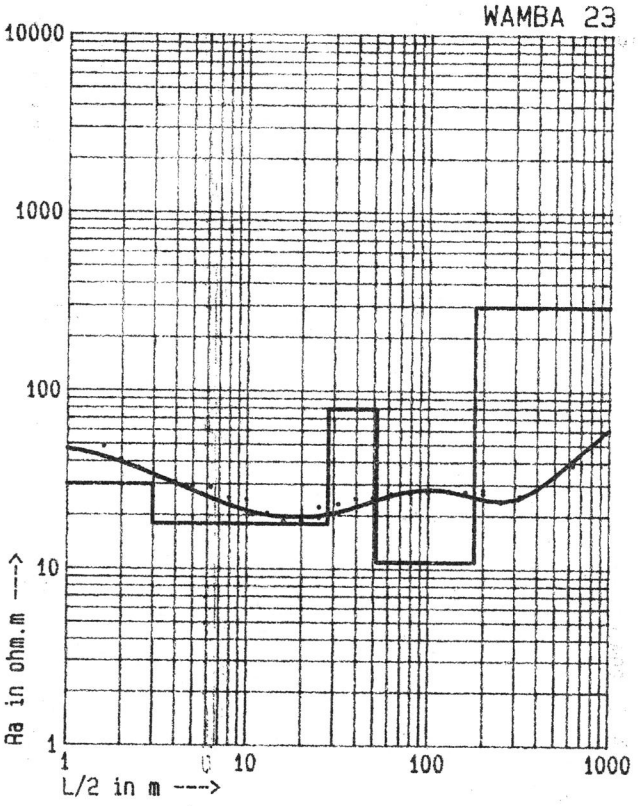

WAMBA 18
10000
1000
100
10
1
Ra in ohm.m --->
1
10
100
1000
L/2 in m --->

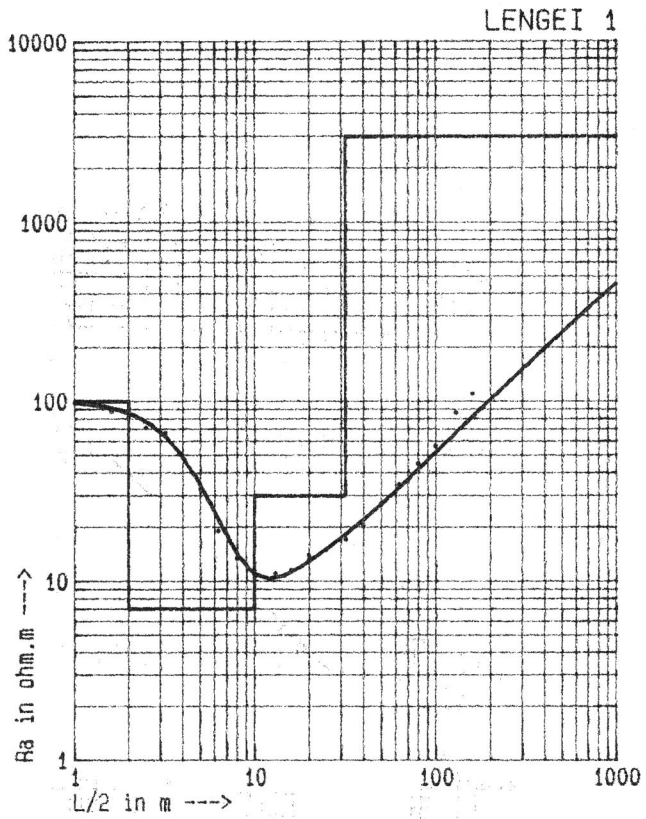

WAMBA 19
10000
1000
100
10
1
Ra in ohm.m --->
1
10
100
1000
L/2 in m --->

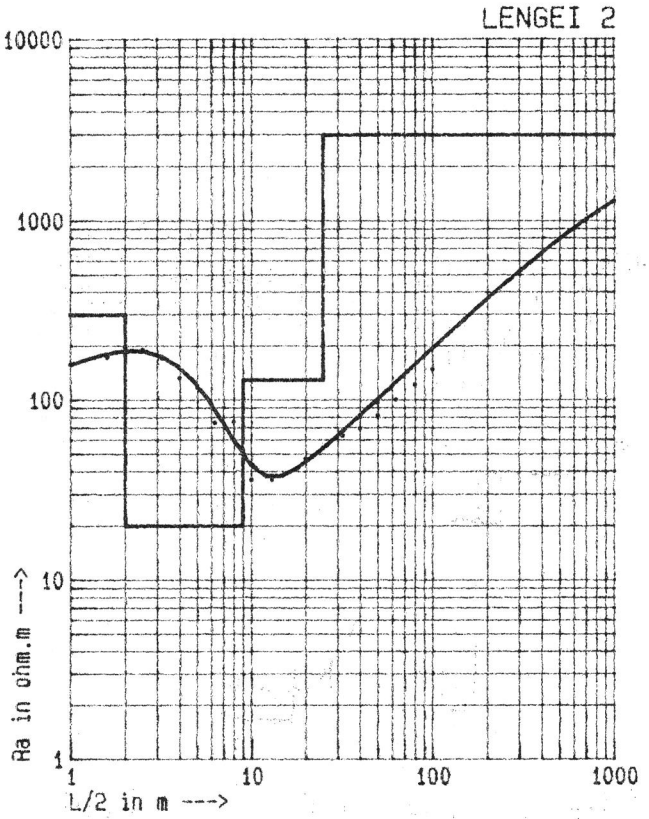

WAMBA 20
10000
1000
100
10
1
Ra in ohm.m --->
1
10
100
1000
L/2 in m --->

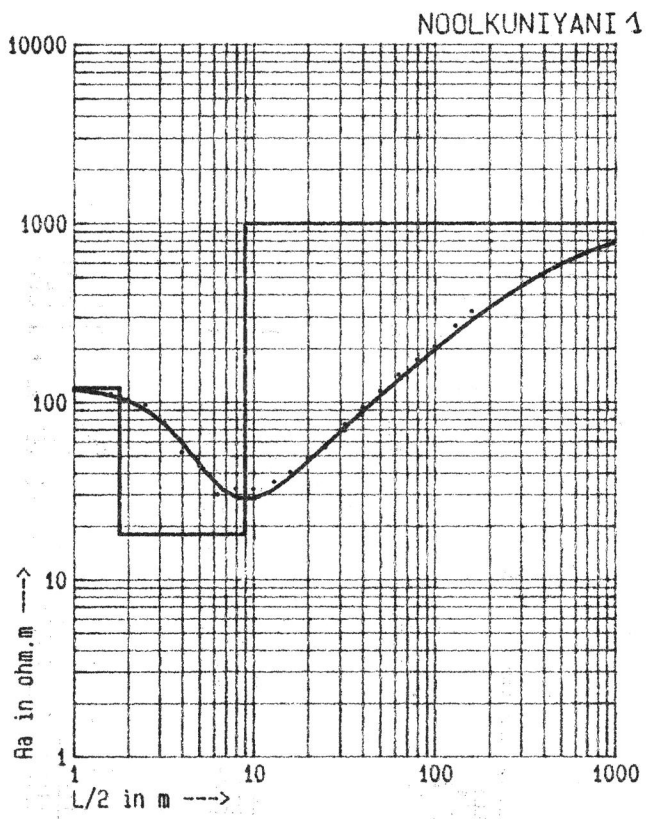

WAMBA 21
10000
1000
100
10
1
Ra in ohm.m --->
1
10
100
1000
L/2 in m --->

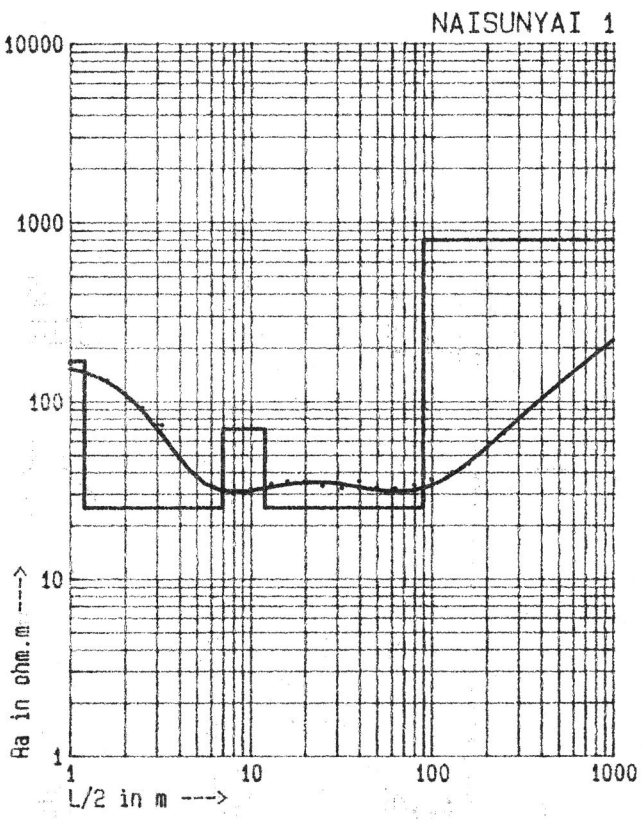

WAMBA 22
10000
1000
100
10
1
Ra in ohm.m --->
1
10
100
1000
L/2 in m --->

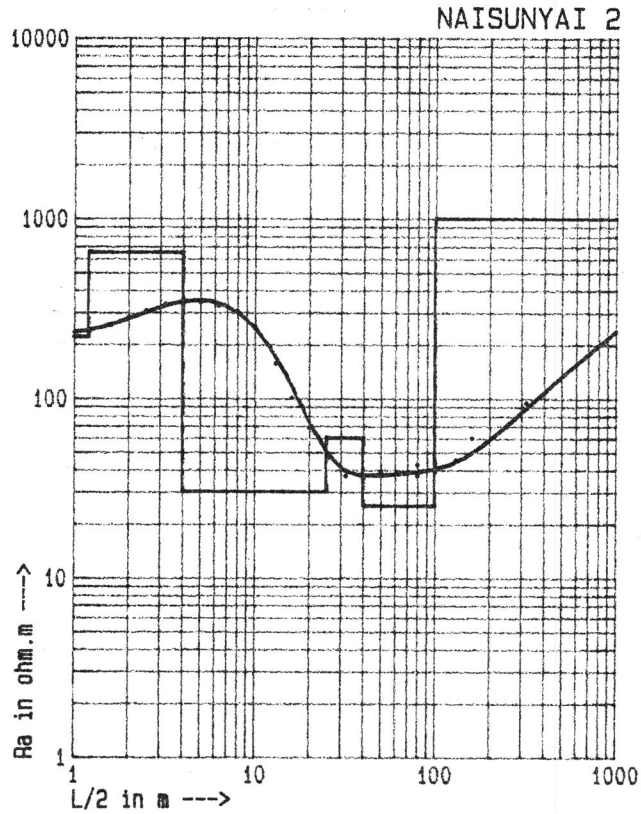

WAMBA 23
10000
1000
100
10
1
Ra in ohm.m --->
1
10
100
1000
L/2 in m --->

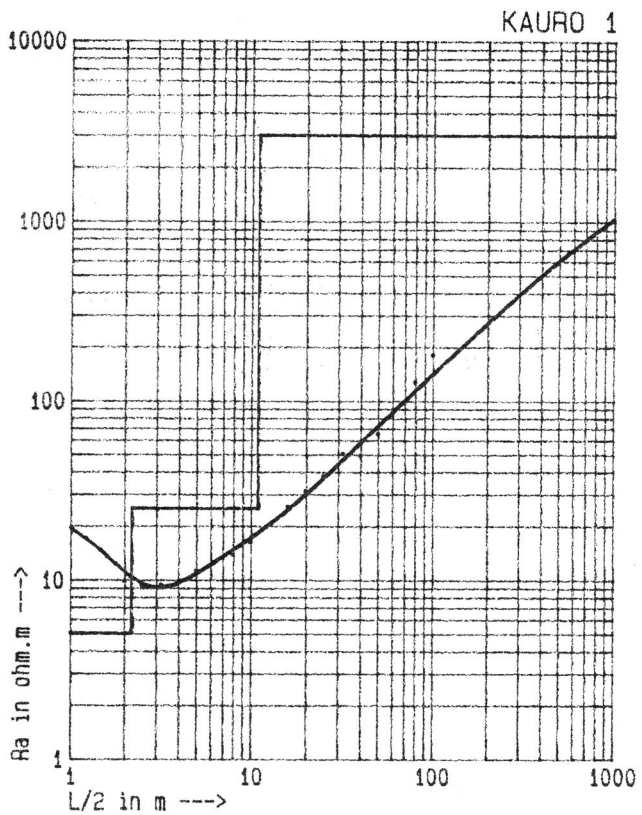

LENGEI 1
10000
1000
100
10
1
Ra in ohm.m --->
1
10
100
1000
L/2 in m --->

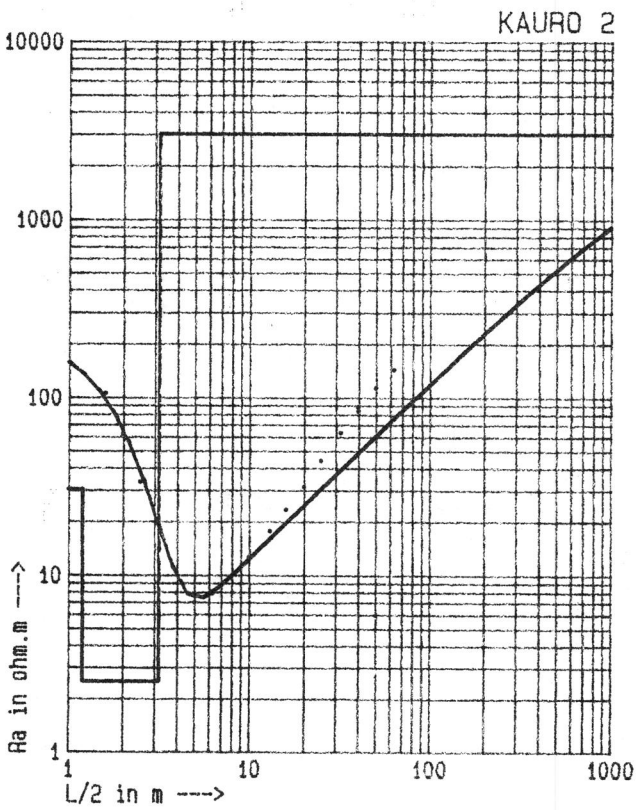

LENGEI 2
10000
1000
100
10
1
Ra in ohm.m --->
1
10
100
1000
L/2 in m --->

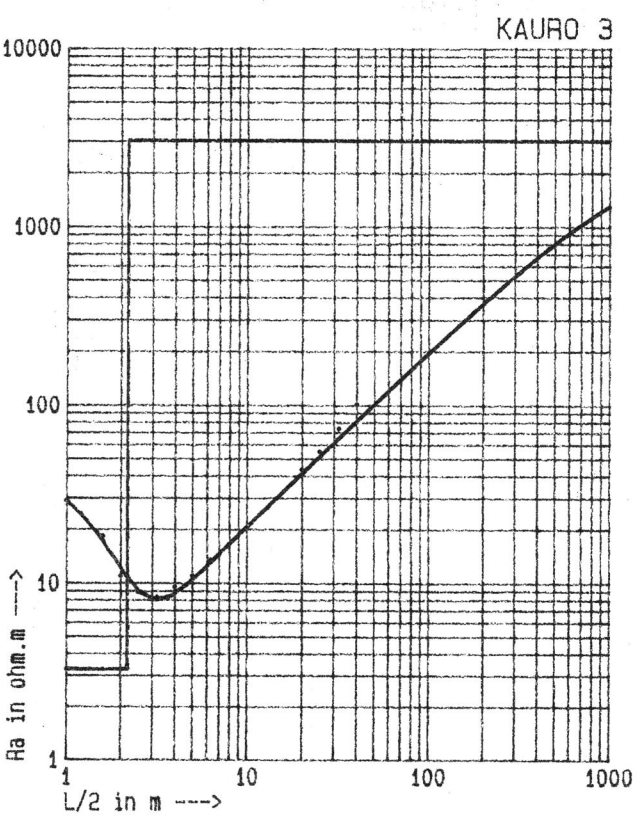

NOOLKUNIYANI 1
10000
1000
100
10
1
Ra in ohm.m --->
1
10
100
1000
L/2 in m --->

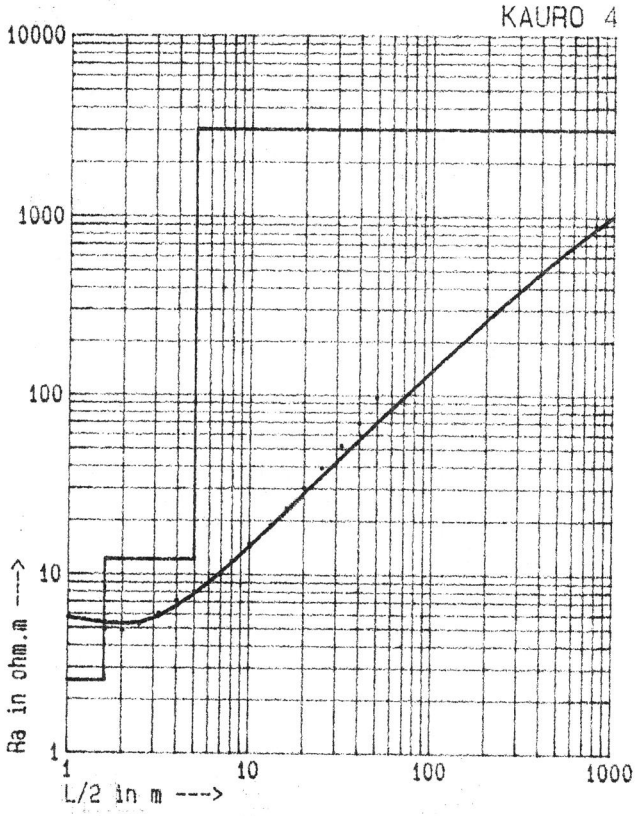

NAISUNYAI 1
10000
1000
100
10
1
Ra in ohm.m --->
1
10
100
1000
L/2 in m --->

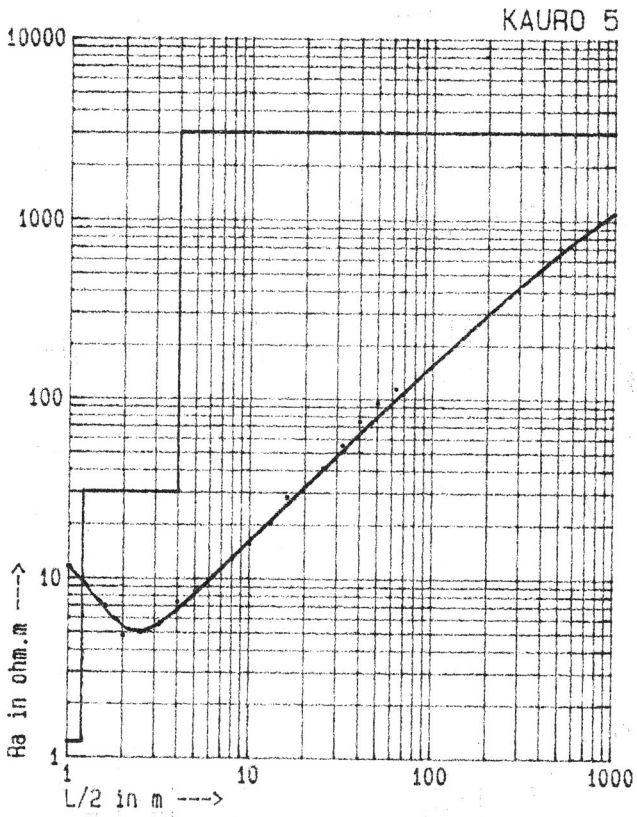

NAISUNYAI 2
10000
1000
100
10
1
Ra in ohm.m --->
1
10
100
1000
L/2 in m --->

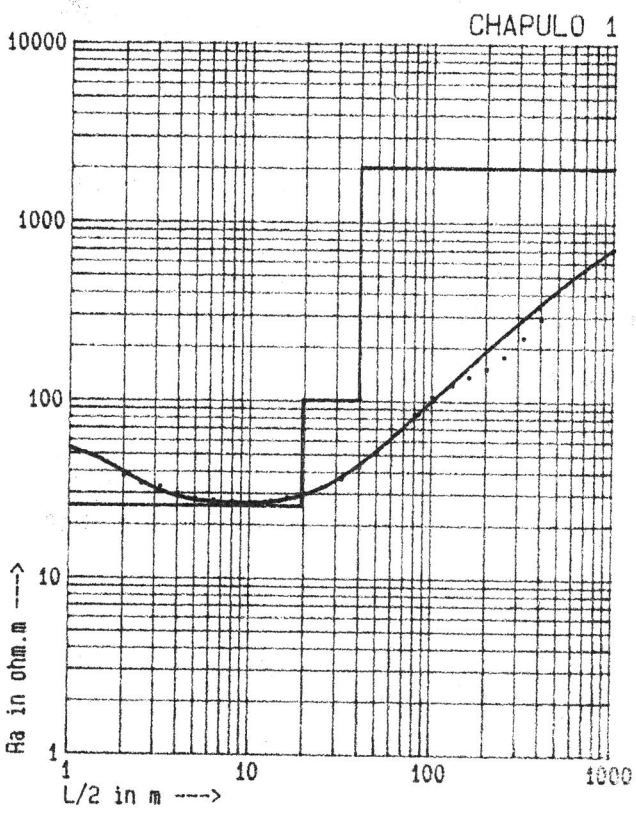

KAURO 1
10000
1000
100
10
1
Ra in ohm.m --->
1
10
100
1000
L/2 in m --->

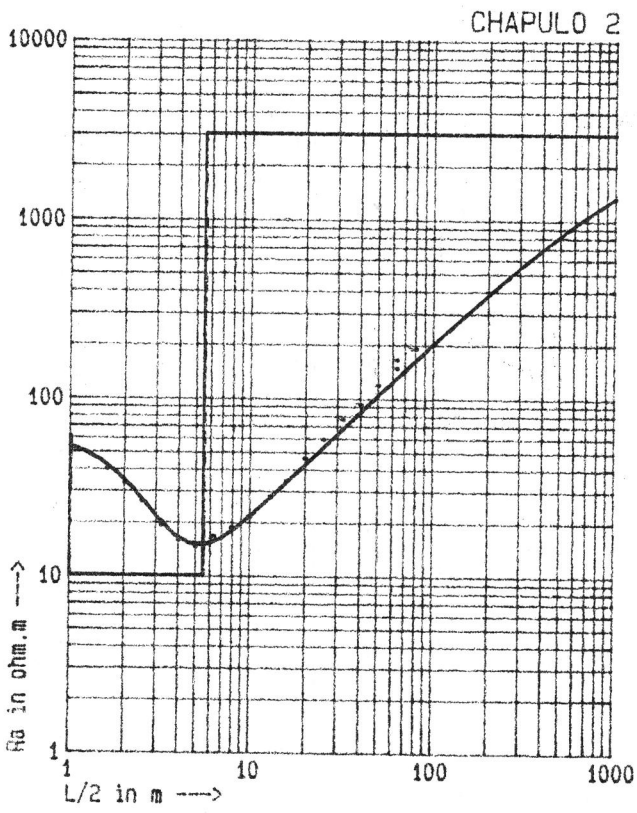

KAURO 2
10000
1000
100
10
1
Ra in ohm.m --->
1
10
100
1000
L/2 in m --->

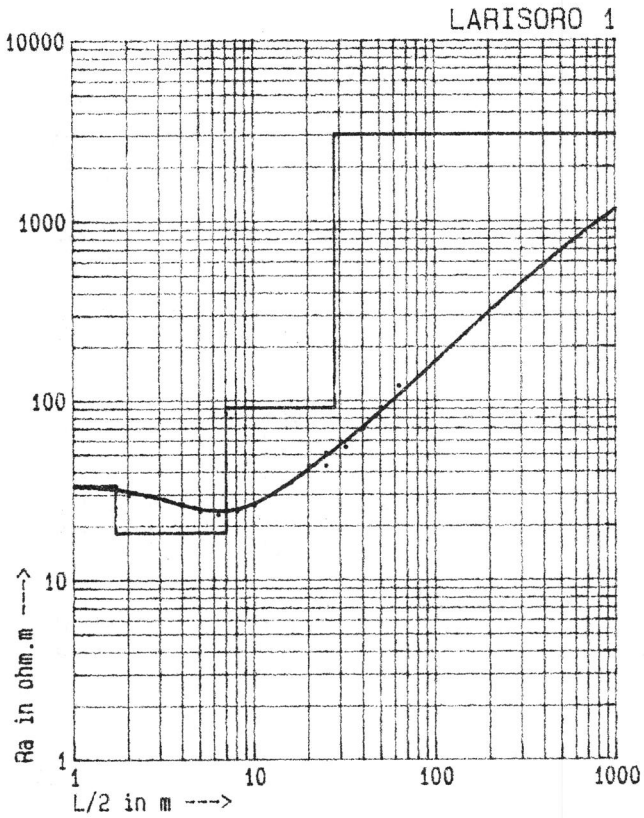

KAURO 3
10000
1000
100
10
1
Ra in ohm.m --->
1
10
100
1000
L/2 in m --->

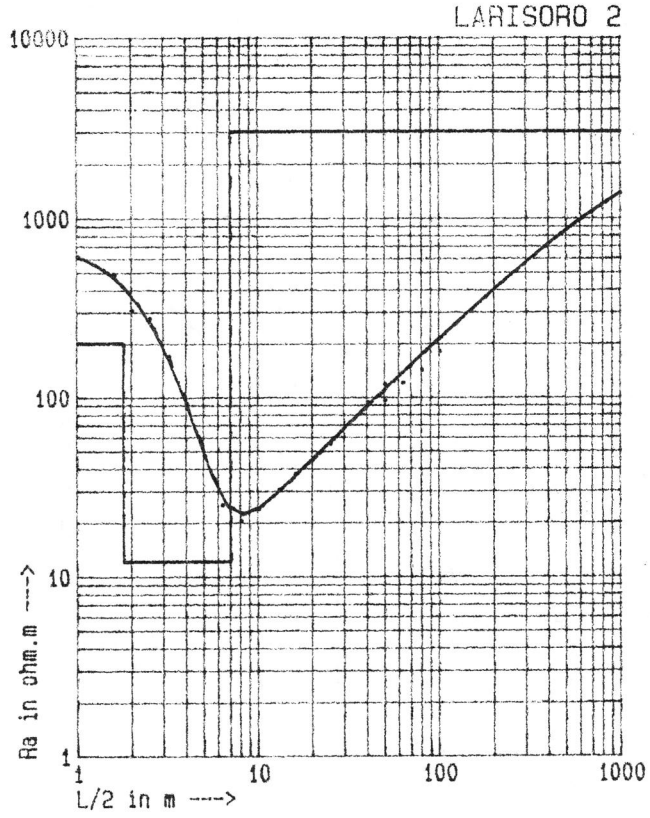

KAURO 4
10000
1000
100
10
1
Ra in ohm.m ---->
1
10
100
1000
L/2 in m ---->

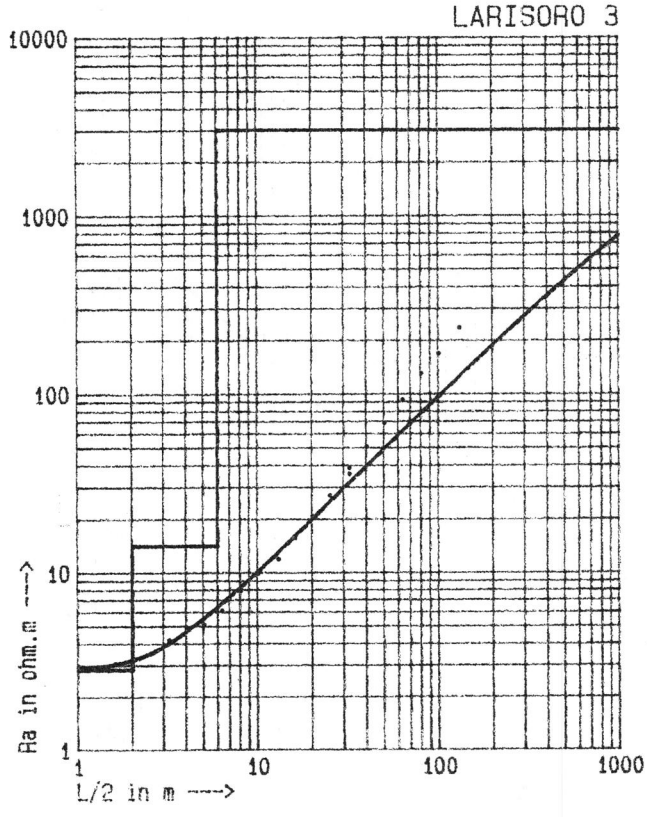

KAURO 5
10000
1000
100
10
1
Ra in ohm.m ---->
1
10
100
1000
L/2 in m ---->

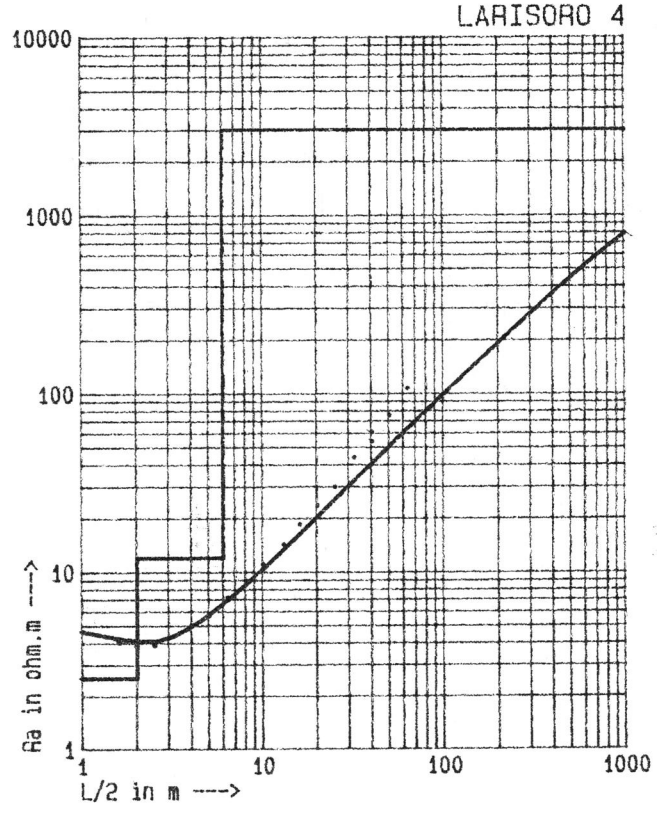

CHAPULO 1
10000
1000
100
10
1
Ra in ohm.m ---->
1
10
100
1000
L/2 in m ---->

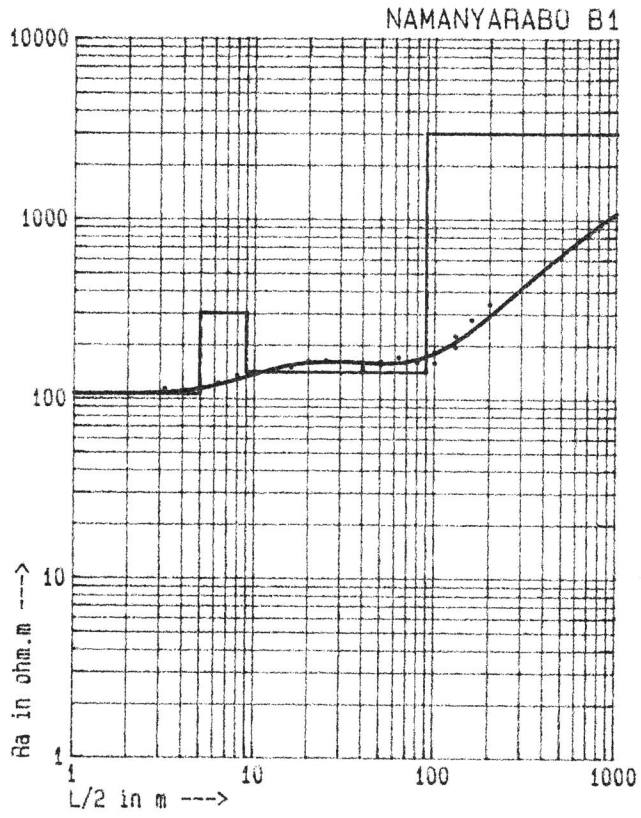

CHAPULO 2
10000
1000
100
10
1
Ra in ohm.m ---->
1
10
100
1000
L/2 in m ---->

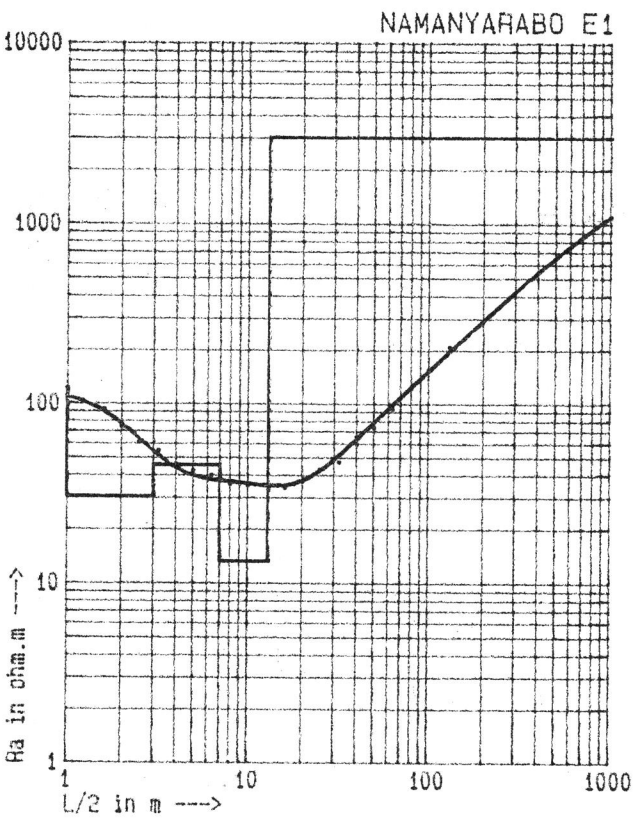

LARISORO 1
10000
1000
100
10
1
Ra in ohm.m ---->
1
10
100
1000
L/2 in m ---->

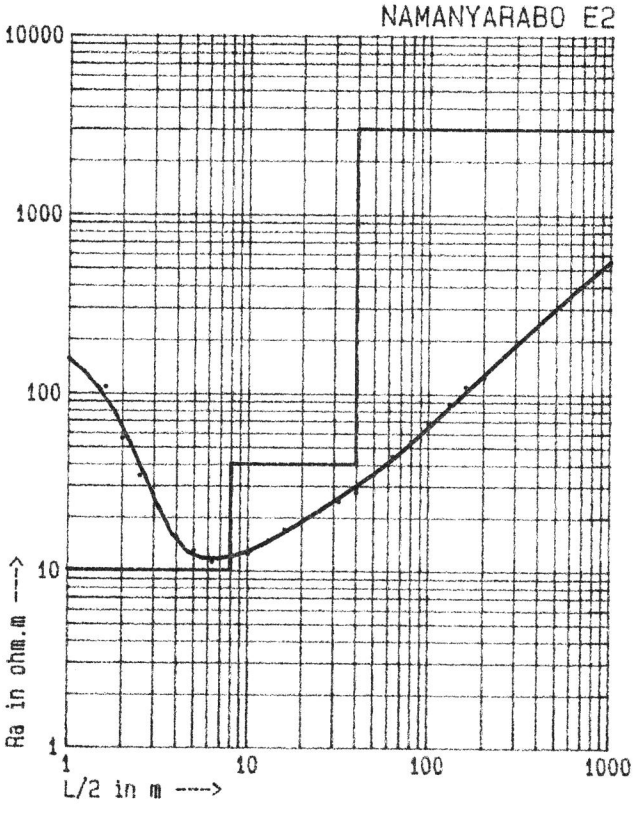

LARISORO 2
10000
1000
100
10
1
Ra in ohm.m ---->
1
10
100
1000
L/2 in m ---->

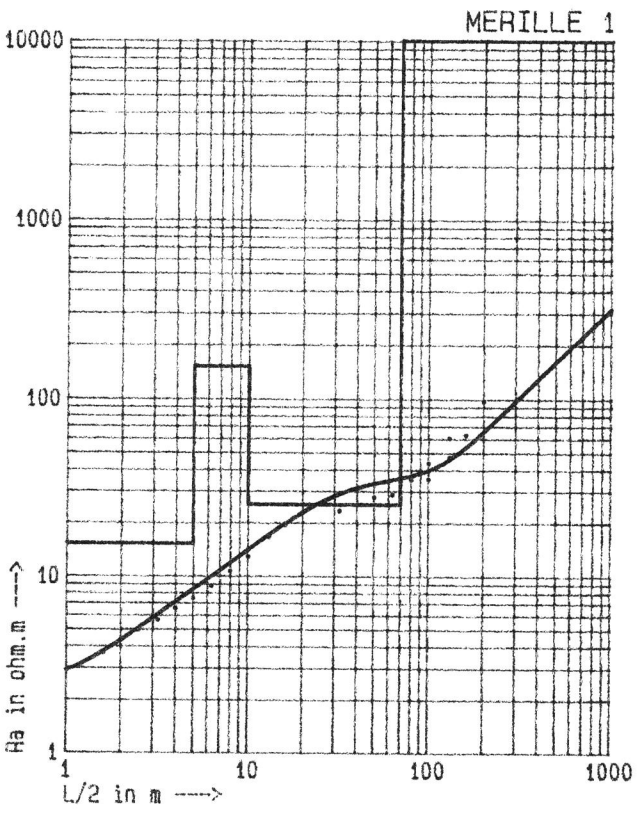

LARISORO 3
10000
1000
100
10
1
Ra in ohm.m ---->
1
10
100
1000
L/2 in m ---->

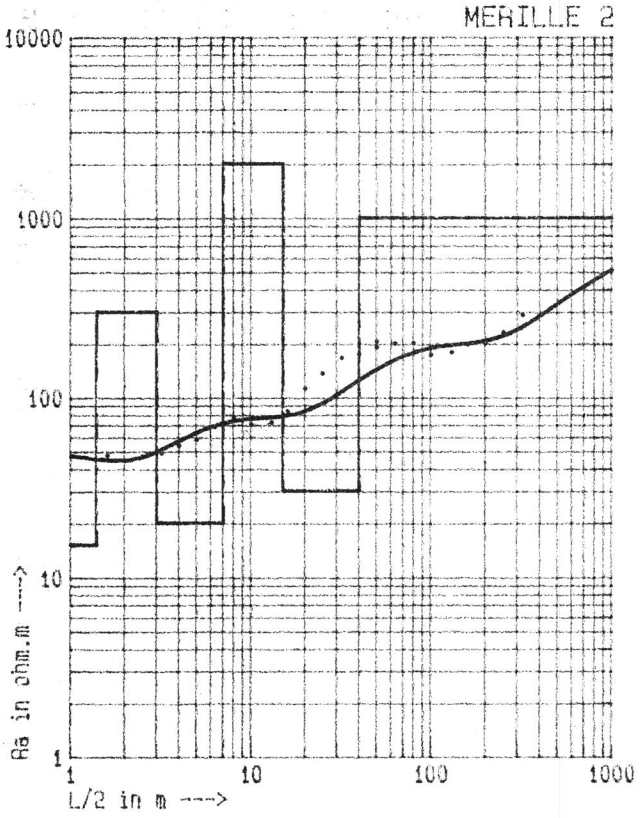

LARISORO 4
10000
1000
100
10
1
Ra in ohm.m ---->
1
10
100
1000
L/2 in m ---->

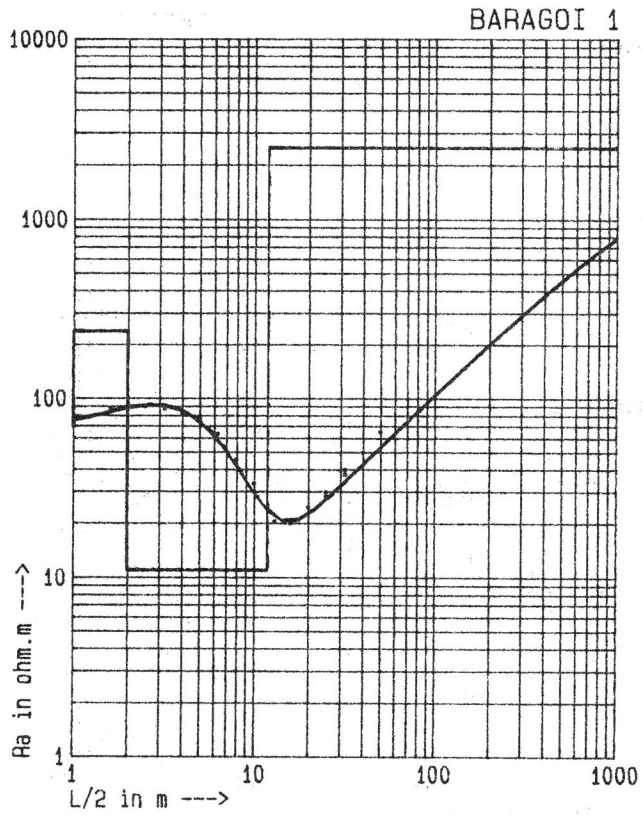

NAMANYARABO B1
10000
1000
100
10
1
Ra in ohm.m ---->
1
10
100
1000
L/2 in m ---->

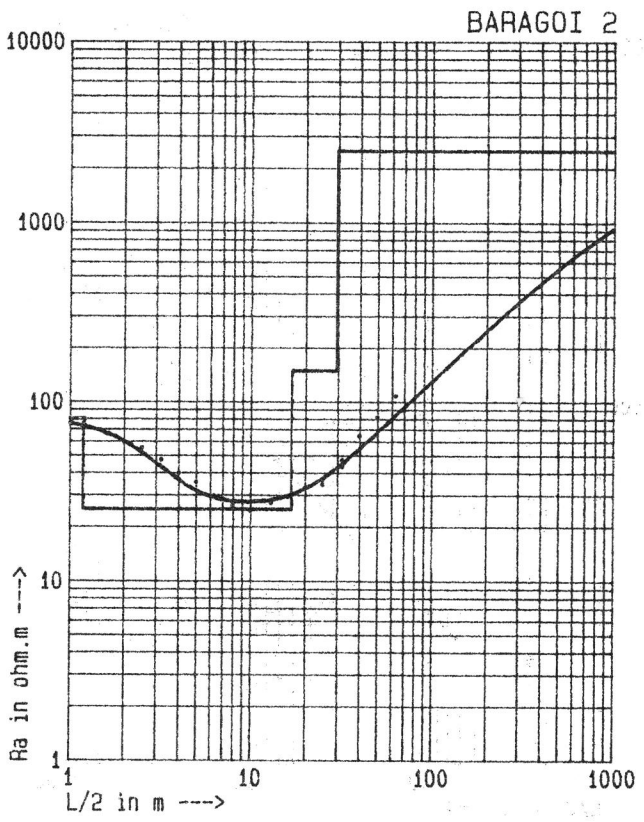

NAMANYARABO E1
10000
1000
100
10
1
Ra in ohm.m ---->
1
10
100
1000
L/2 in m ---->

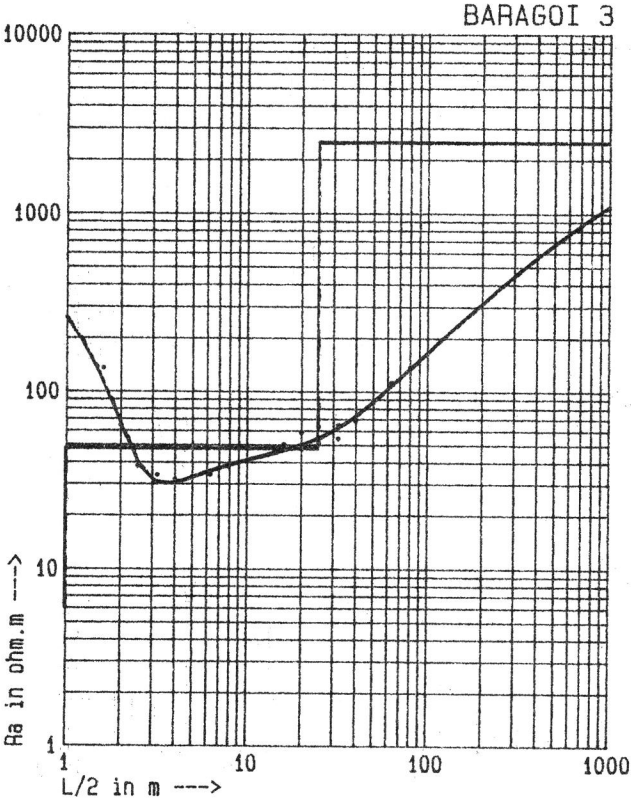

NAMANYARABO E2
10000
1000
100
10
1
Ra in ohm.m ---->
1
10
100
1000
L/2 in m ---->

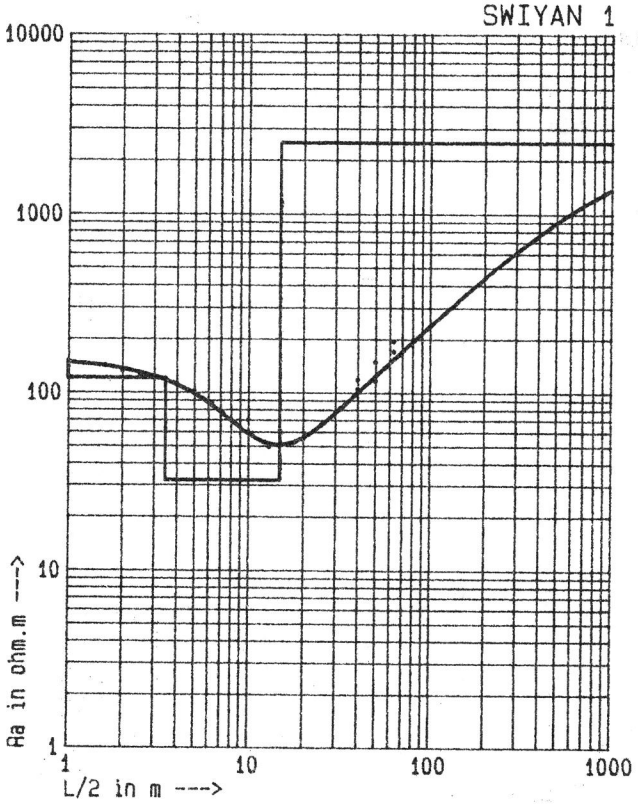

MERILLE 1
10000
1000
100
10
1
Ra in ohm.m ---->
1
10
100
1000
L/2 in m ---->

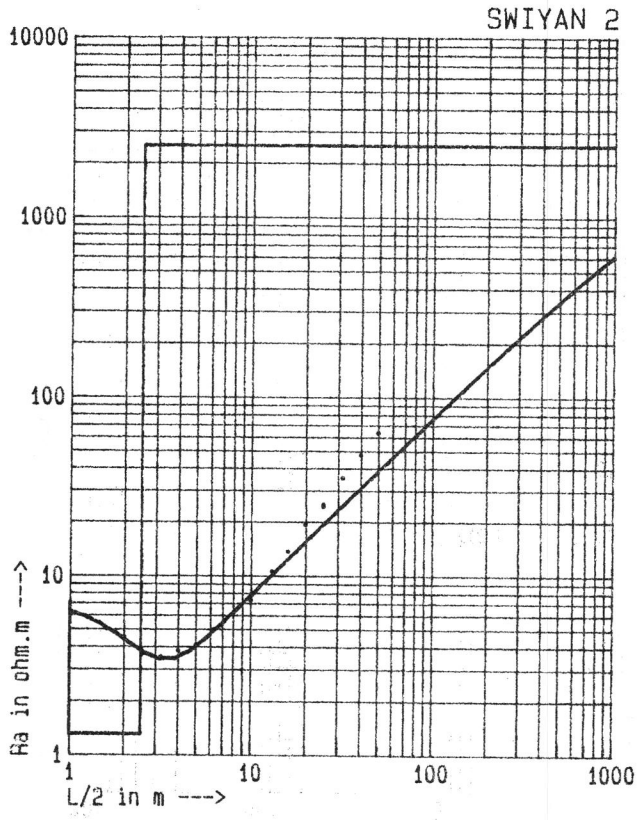

MERILLE 2
10000
1000
100
10
1
Ra in ohm.m ---->
1
10
100
1000
L/2 in m --->

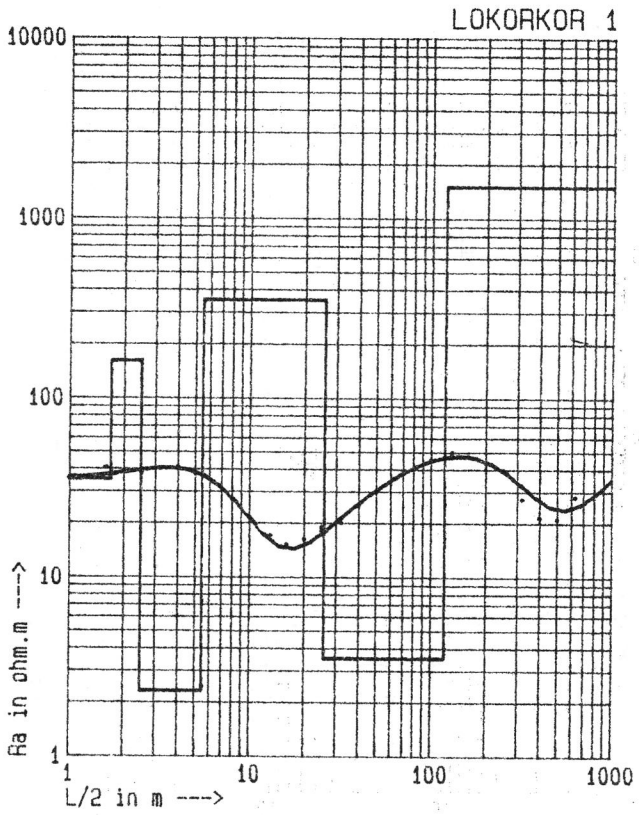

BARAGOI 1
10000
1000
100
10
1
Ra in ohm.m --->
1
10
100
1000
L/2 in m --->

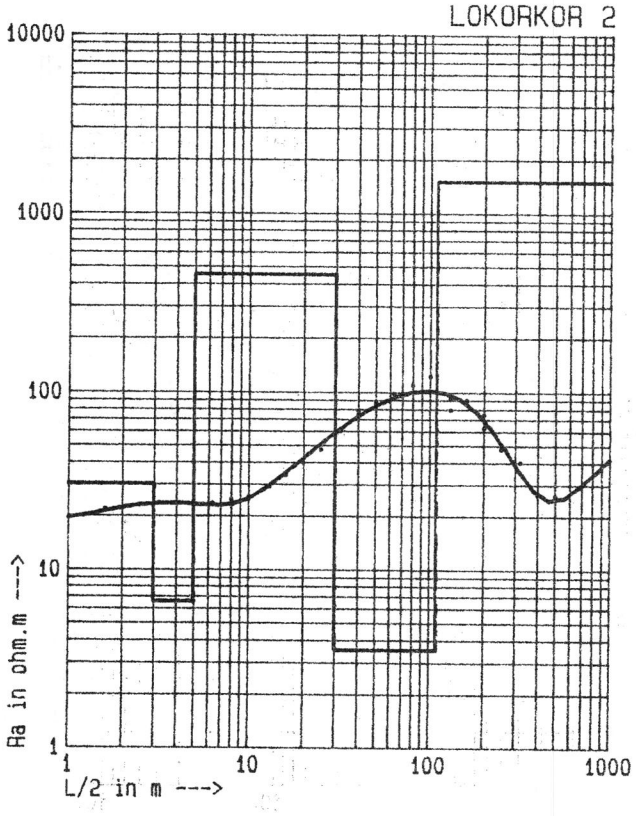

BARAGOI 2
10000
1000
100
10
1
Ra in ohm.m --->
1
10
100
1000
L/2 in m --->

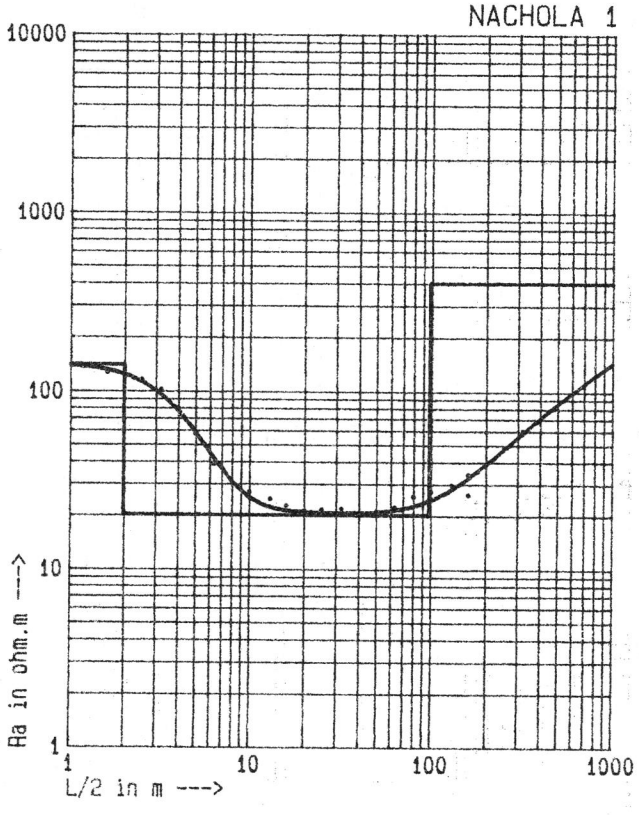

BARAGOI 3
10000
1000
100
10
1
Ra in ohm.m --->
1
10
100
1000
L/2 in m --->

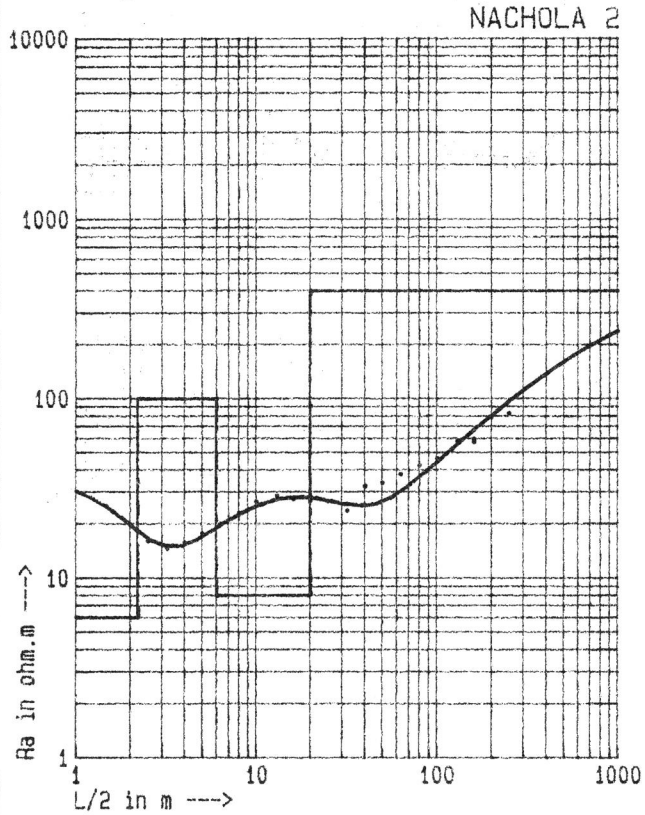

SWIYAN 1
10000
1000
100
10
1
Ra in ohm.m --->
1
10
100
1000
L/2 in m --->

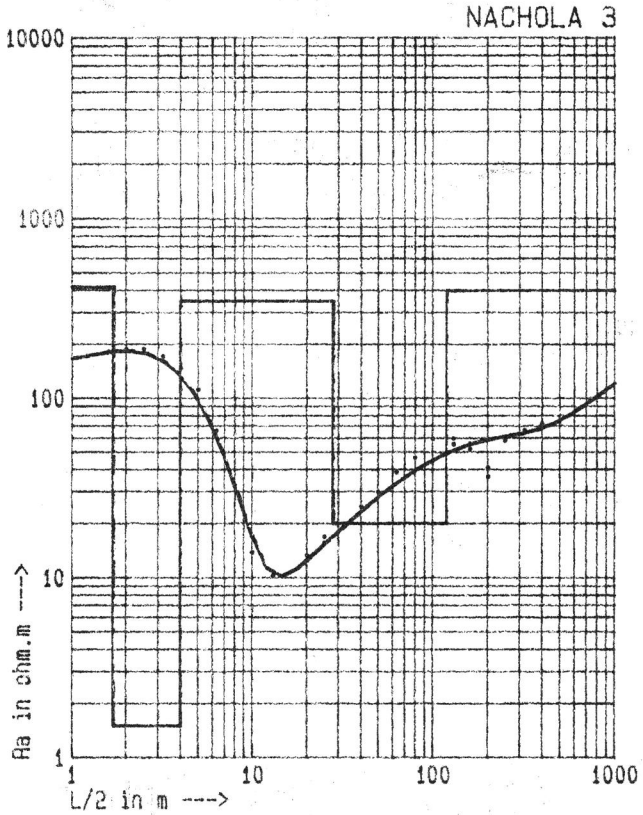

SWIYAN 2
10000
1000
100
10
1
Ra in ohm.m --->
1
10
100
1000
L/2 in m --->

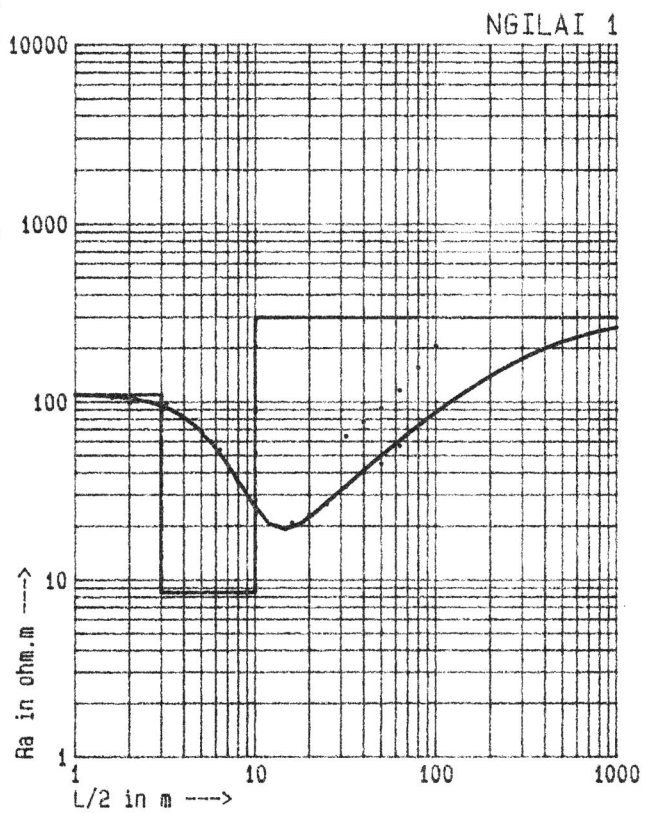

LOKORKOR 1
10000
1000
100
10
1
Ra in ohm.m --->
1
10
100
1000
L/2 in m --->

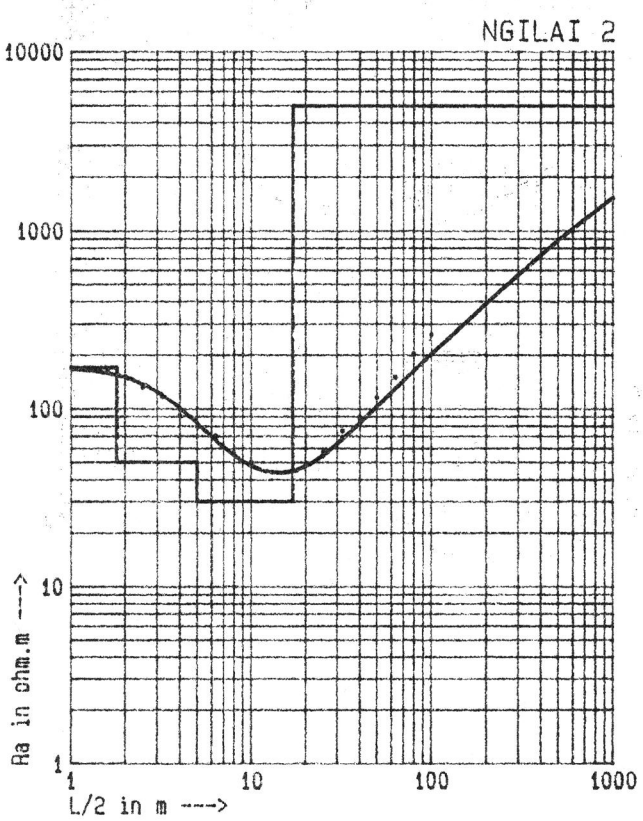

LOKORKOR 2
10000
1000
100
10
1
Ra in ohm.m --->
1
10
100
1000
L/2 in m --->

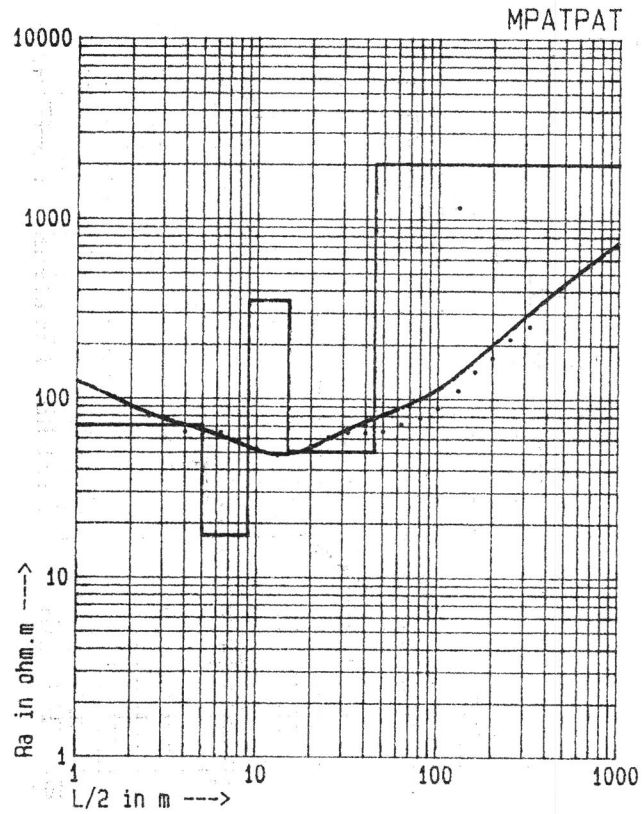

NACHOLA 1
10000
1000
100
10
1
Ra in ohm.m --->
1
10
100
1000
L/2 in m --->

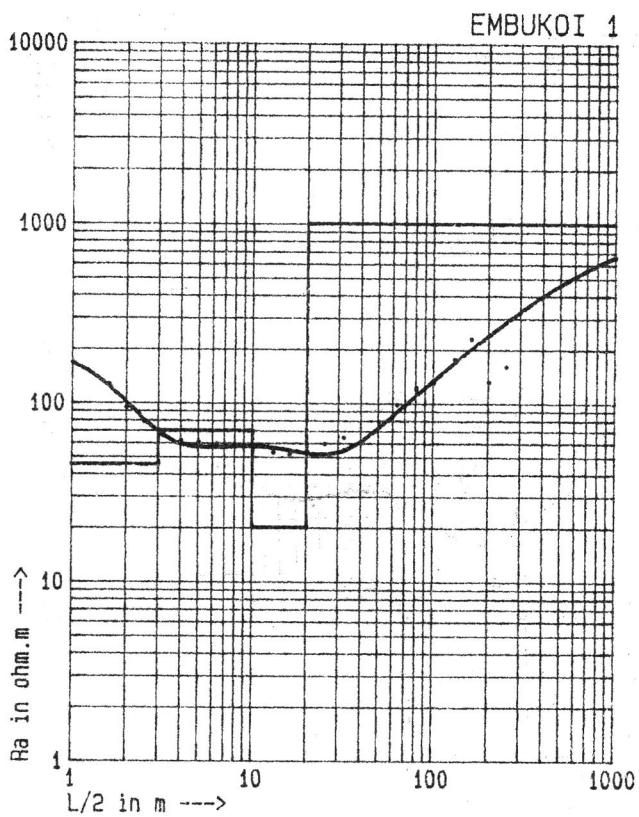

NACHOLA 2
10000
1000
100
10
1
Ra in ohm.m ---->
1
10
100
1000
L/2 in m --->

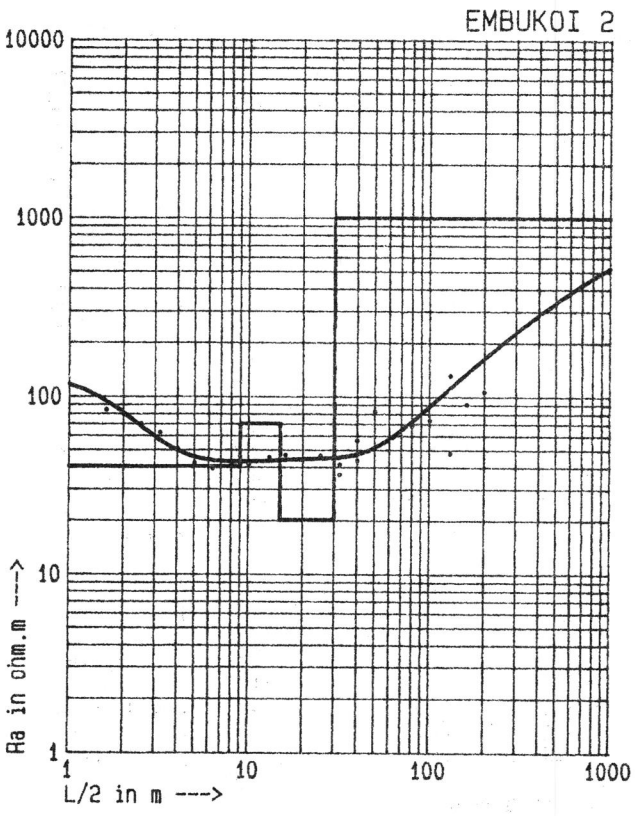

NACHOLA 3
10000
1000
100
10
1
Ra in ohm.m ---->
1
10
100
1000
L/2 in m ---->

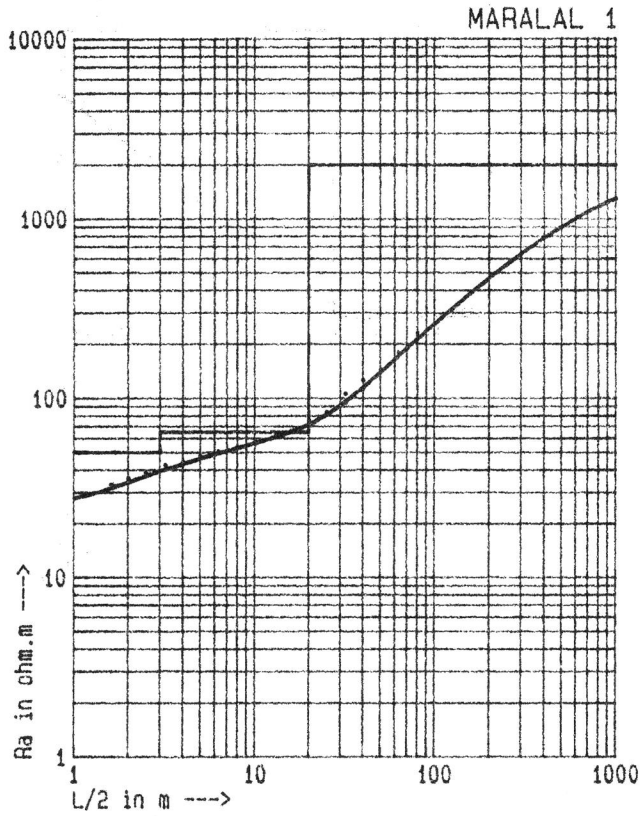

NGILAI 1
10000
1000
100
10
1
Ra in ohm.m ---->
1
10
100
1000
L/2 in m ---->

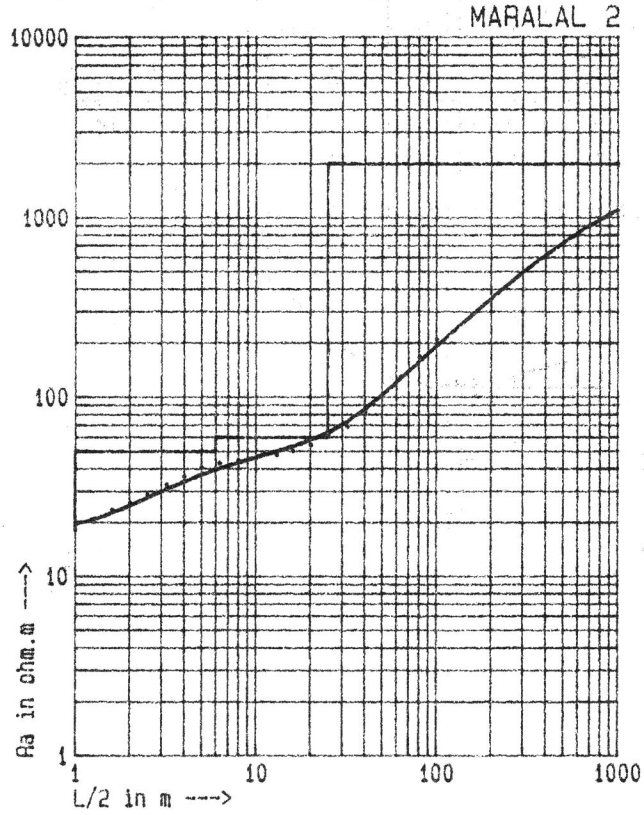

NGILAI 2
10000
1000
100
10
1
Ra in ohm.m ---->
1
10
100
1000
L/2 in m ---->

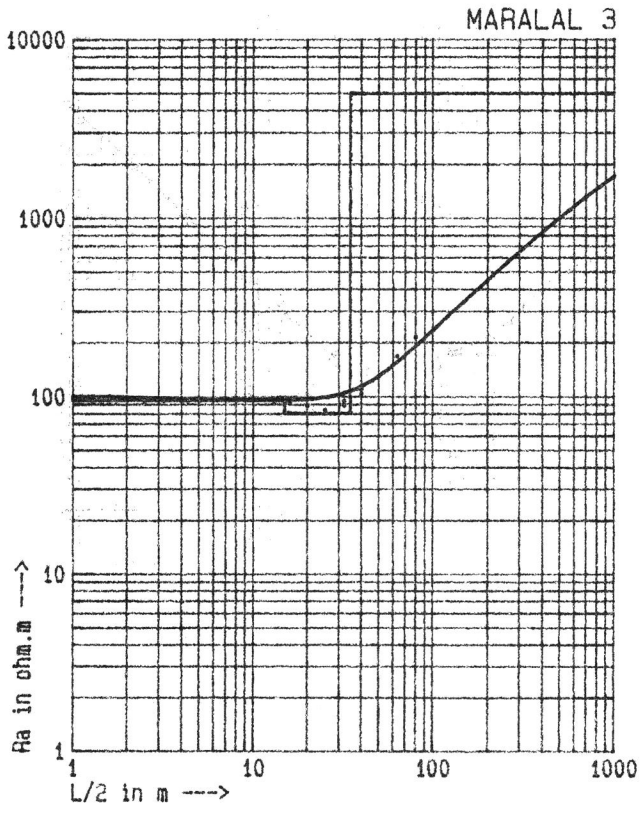

MPATPAT
10000
1000
100
10
1
Ra in ohm.m --->
1
10
100
1000
L/2 in m --->

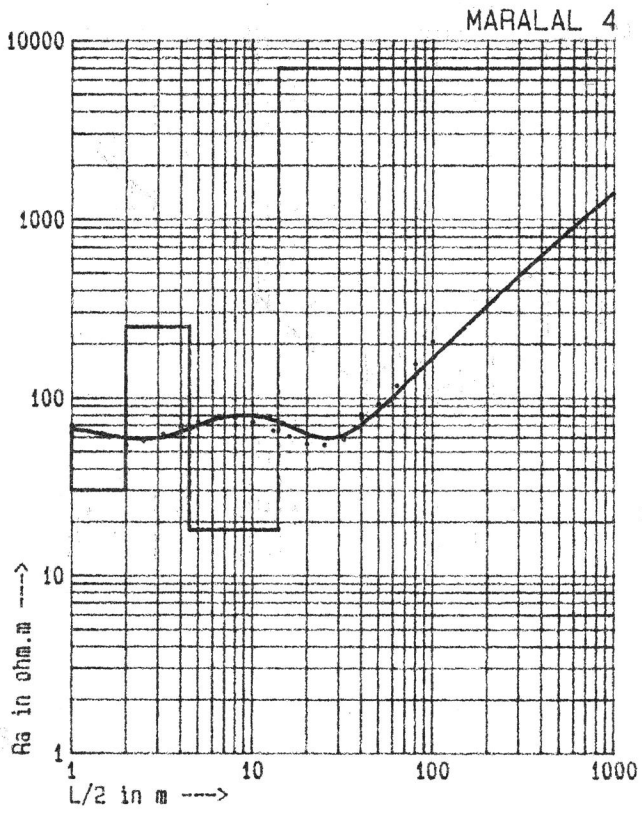

EMBUKOI 1
10000
1000
100
10
1
Ra in ohm.m --->
1
10
100
1000
L/2 in m --->

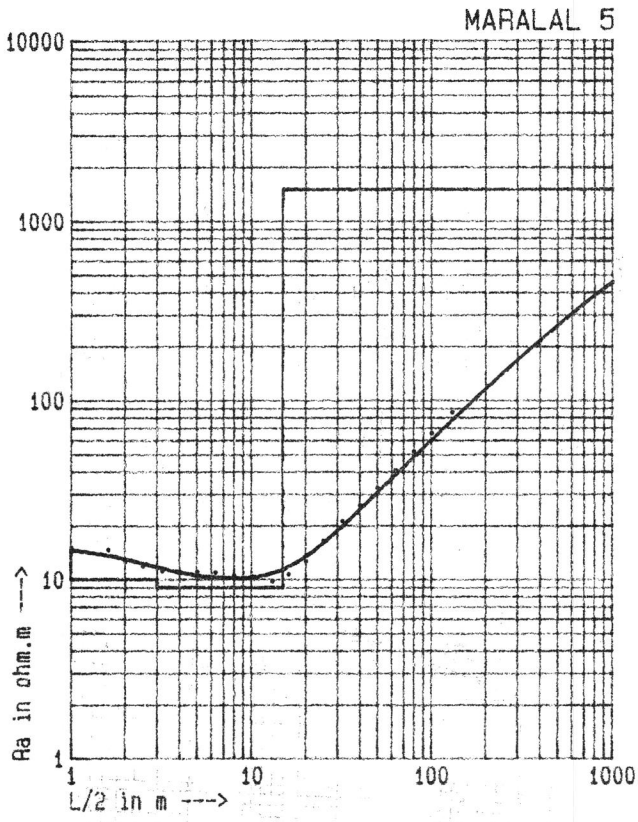

EMBUKOI 2
10000
1000
100
10
1
Ra in ohm.m --->
1
10
100
1000
L/2 in m --->

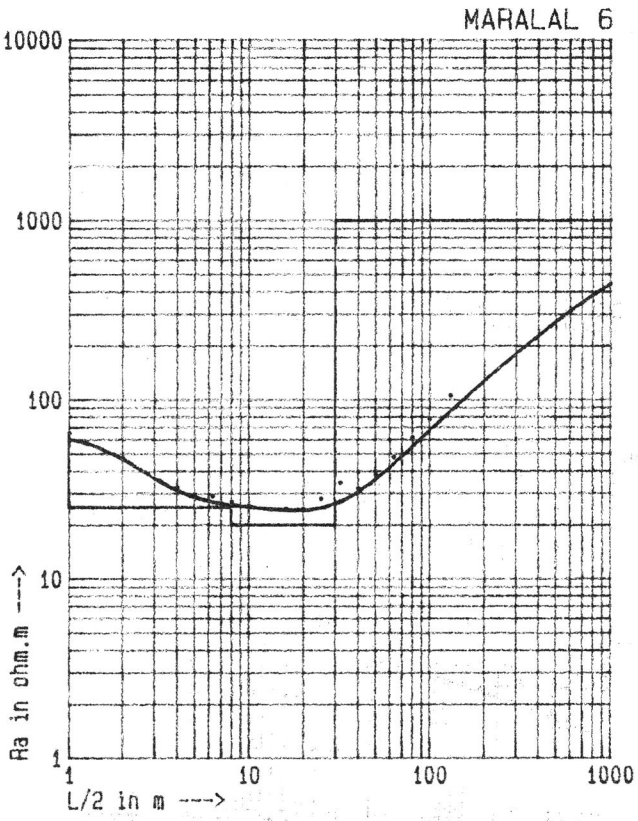

MARALAL 1
10000
1000
100
10
1
Ra in ohm.m ---->
1
10
100
1000
L/2 in m ---->

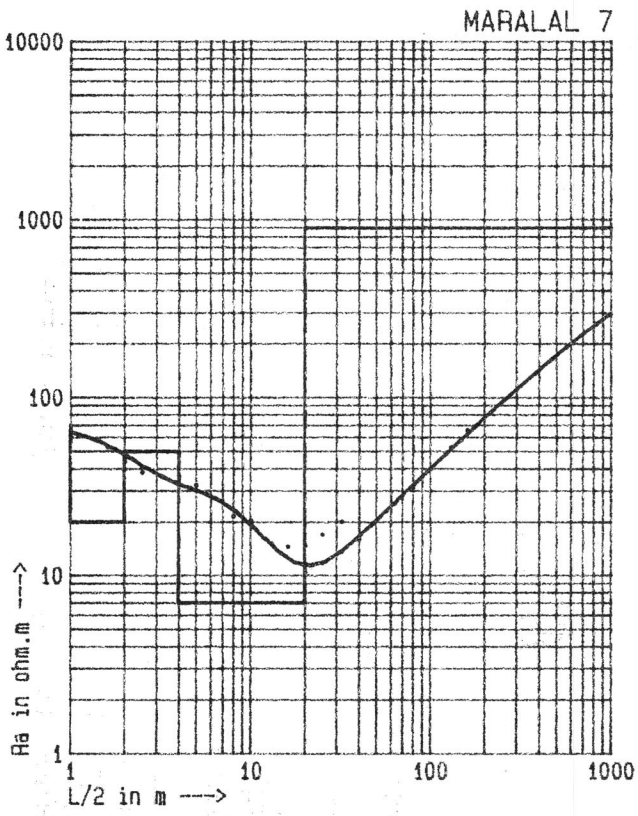

MARALAL 2
10000
1000
100
10
1
Ra in ohm.m ---->
1
10
100
1000
L/2 in m ---->

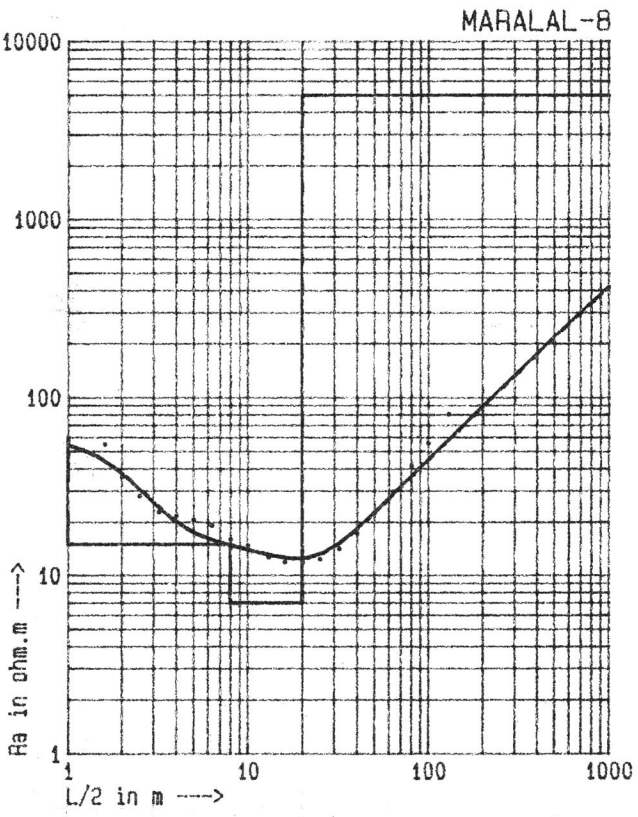

MARALAL 3
10000
1000
100
10
1
Ra in ohm.m ---->
1
10
100
1000
L/2 in m ---->

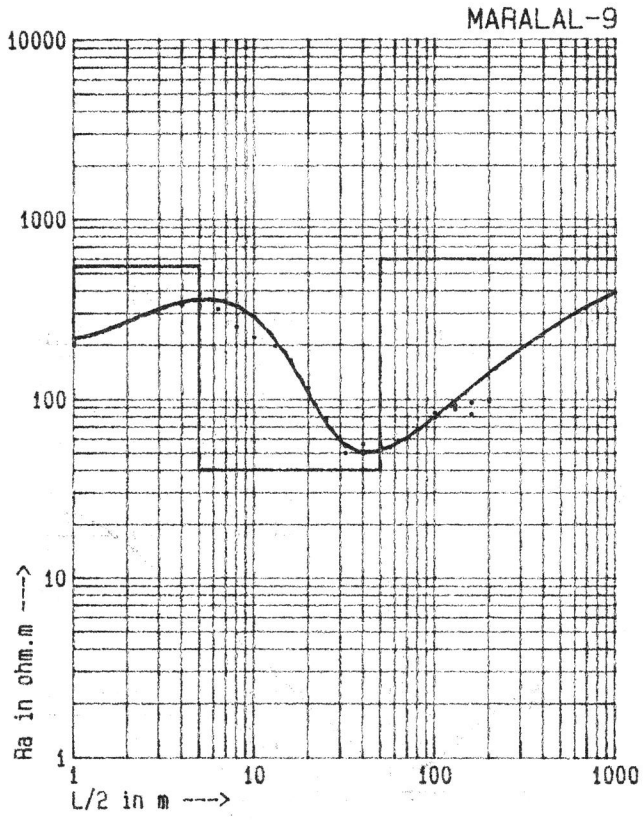

MARALAL 4
10000
1000
100
10
1
Ra in ohm.m ---->
1
10
100
1000
L/2 in m ---->

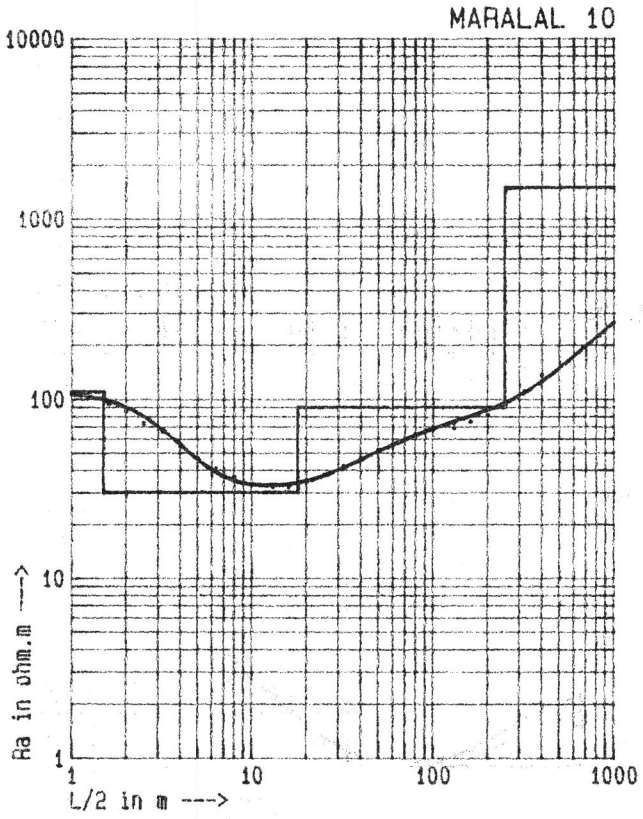

MARALAL 5
10000
1000
100
10
1
Ra in ohm.m ---->
1
10
100
1000
L/2 in m ---->

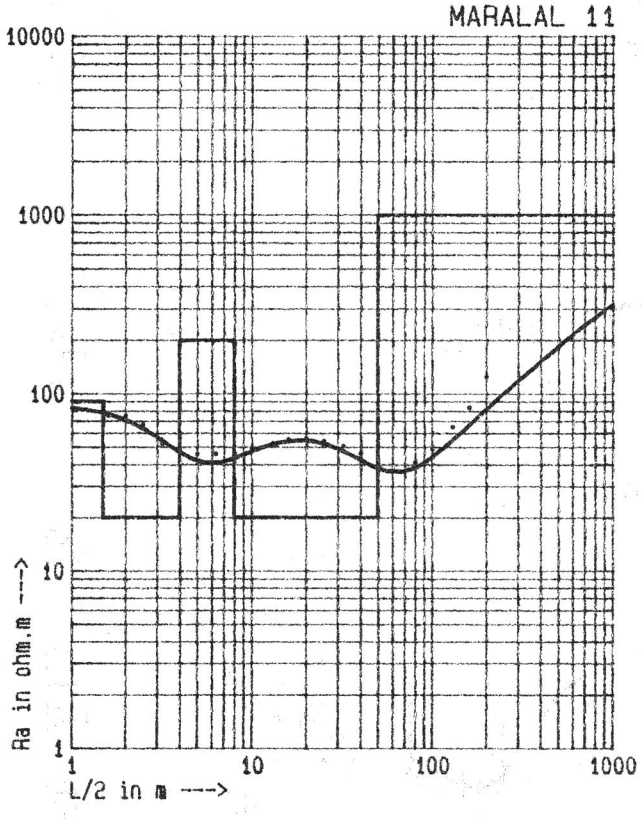

MARALAL 6
10000
1000
100
10
1
Ra in ohm.m ---->
1
10
100
1000
L/2 in m ---->

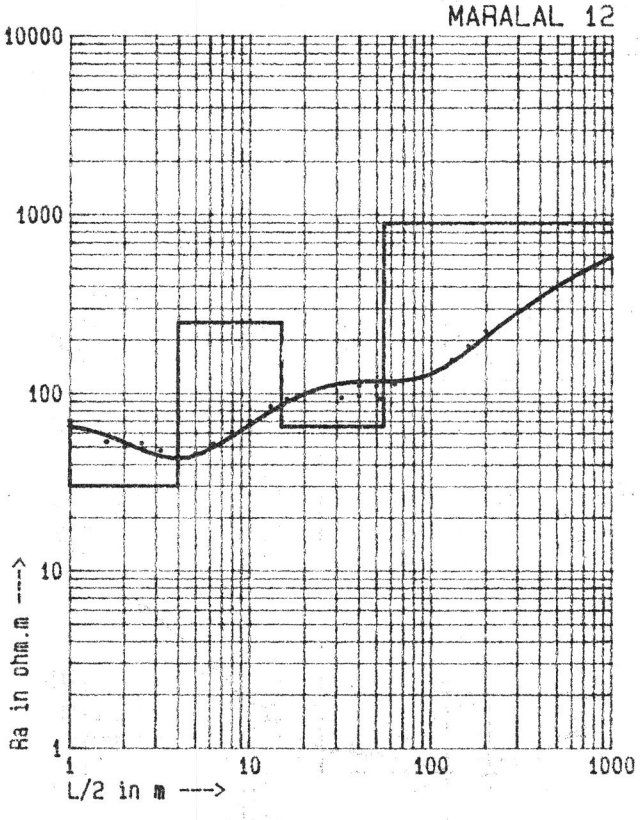

MARALAL 7
10000
1000
100
10
1
Ra in ohm.m ---->
1
10
100
1000
L/2 in m ---->

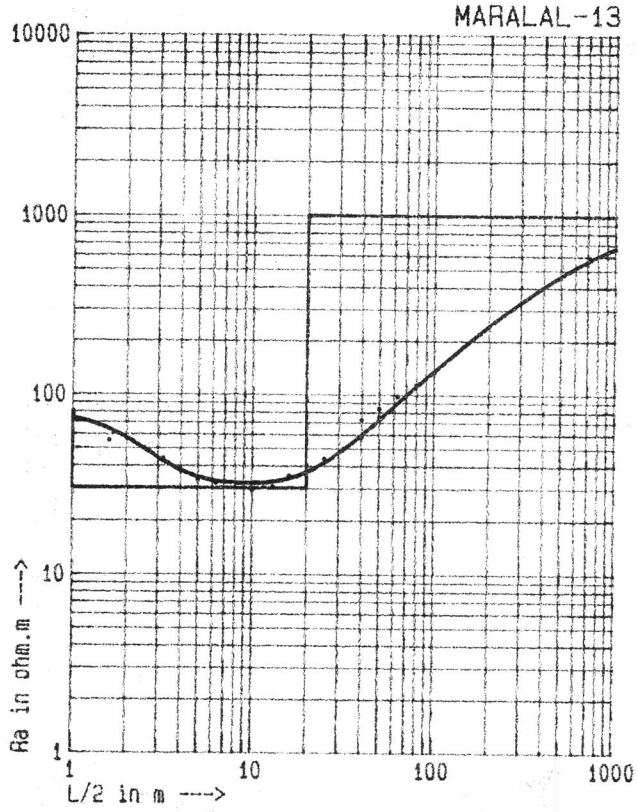

MARALAL-8
10000
1000
100
10
1
Ra in ohm.m ---->
1
10
100
1000
L/2 in m ---->

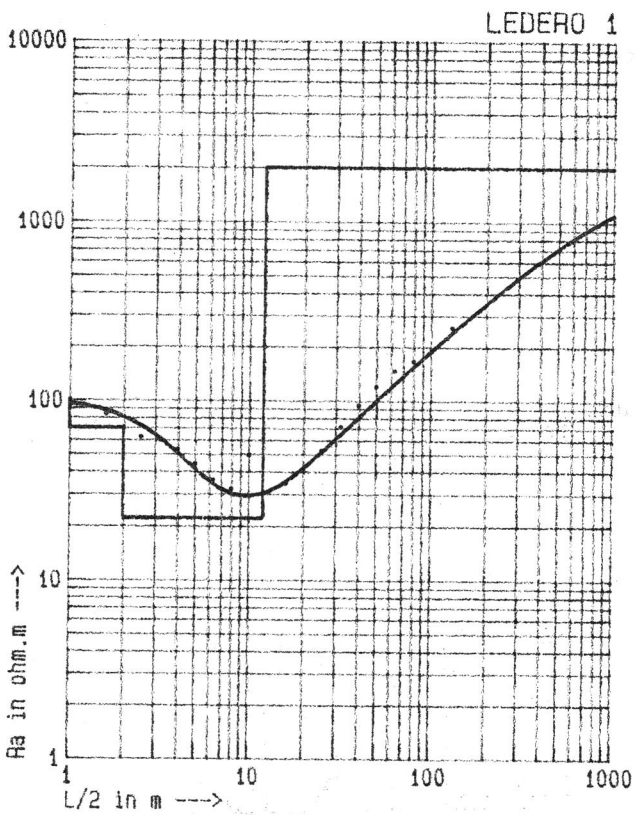

MARALAL-9
10000
1000
100
10
1
Ra in ohm.m ---->
1
10
100
1000
L/2 in m --->

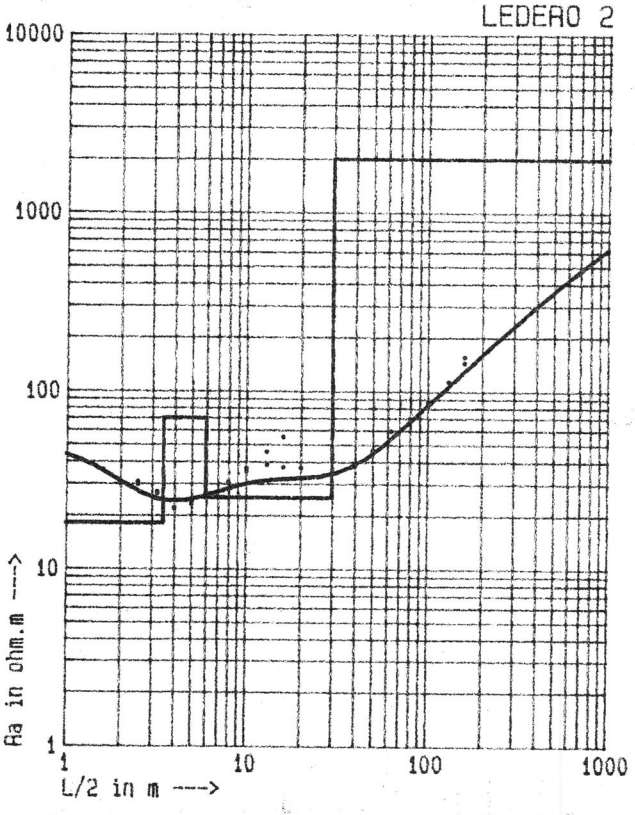

MARALAL 10
10000
1000
100
10
1
Ra in ohm.m ---->
1
10
100
1000
L/2 in m --->

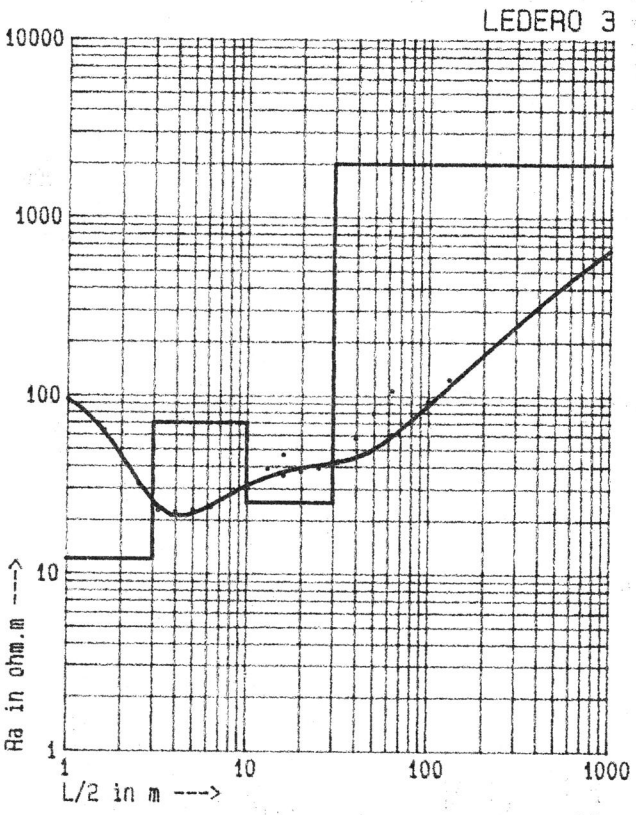

MARALAL 11
10000
1000
100
10
1
Ra in ohm.m ---->
1
10
100
1000
L/2 in m ---->

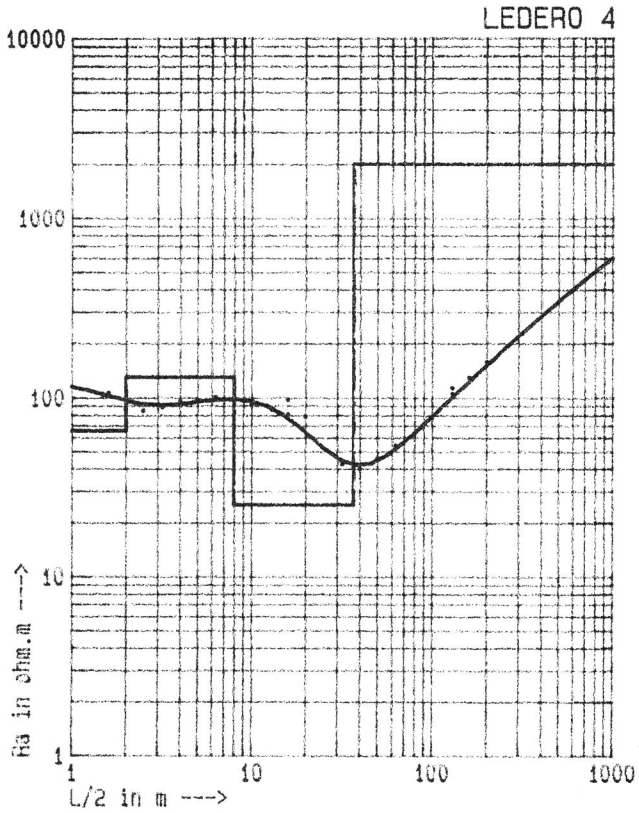

MARALAL 12
10000
1000
100
10
1
Ra in ohm.m ---->
1
10
100
1000
L/2 in m ---->

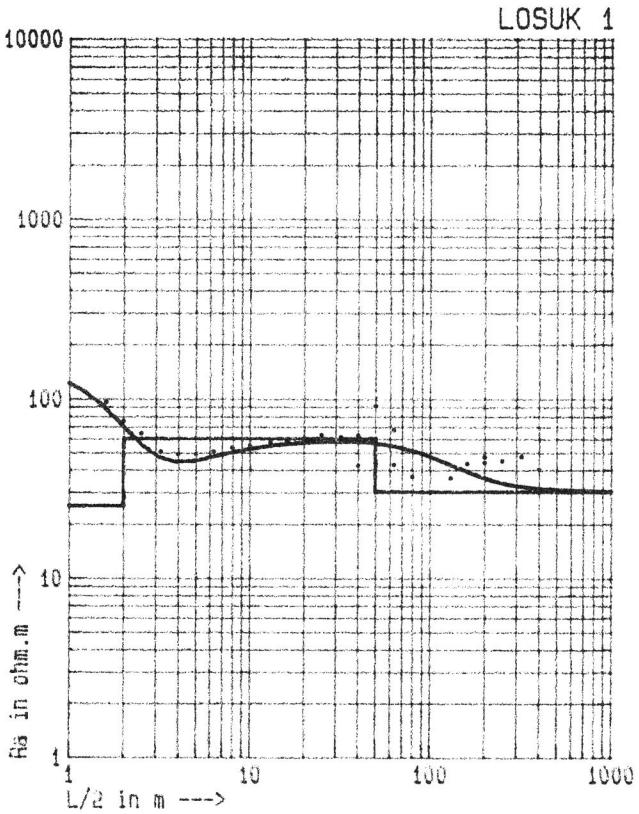

MARALAL-13
10000
1000
100
10
1
Ra in ohm.m --->
1
10
100
1000
L/2 in m --->

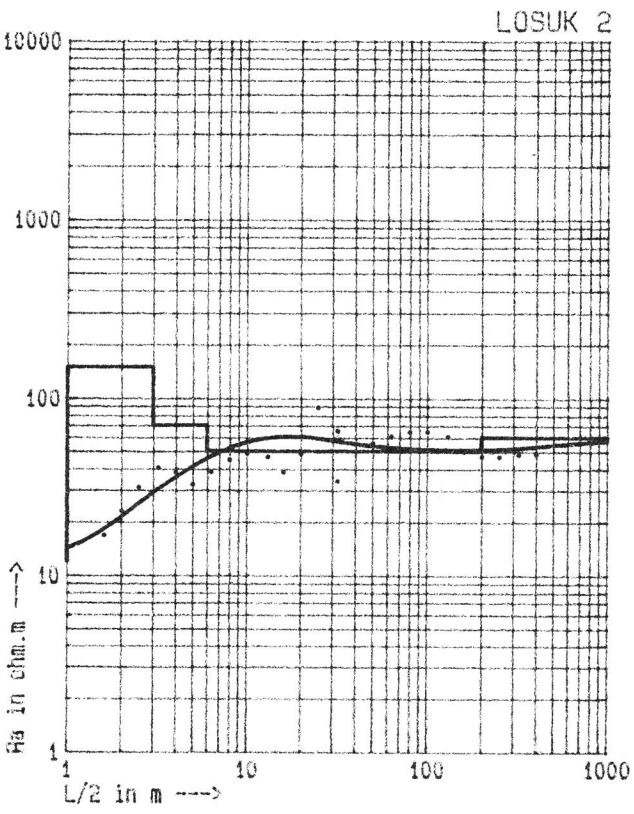

LEDERO 1
10000
1000
100
10
1
Ra in ohm.m --->
1
10
100
1000
L/2 in m --->

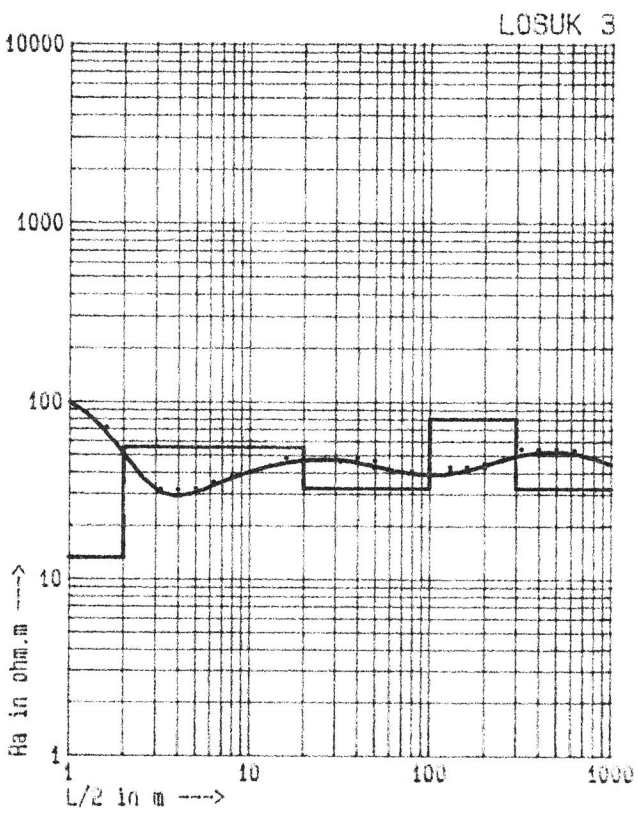

LEDERO 2
10000
1000
100
10
1
Ra in ohm.m --->
1
10
100
1000
L/2 in m --->


LEDERO 3
10000
1000
100
10
1
Ra in ohm.m --->
1
10
100
1000
L/2 in m --->


LEDERO 4
10000
1000
100
10
1
Ra in ohm.m --->
1
10
100
1000
L/2 in m --->


LOSUK 1
10000
1000
100
10
1
Ra in ohm.m --->
1
10
100
1000
L/2 in m --->


LOSUK 2
10000
1000
100
10
1
Ra in ohm.m --->
1
10
100
1000
L/2 in m --->


LOSUK 3
10000
1000
100
10
1
Ra in ohm.m --->
1
10
100
1000
L/2 in m --->

# Appendix 3.3

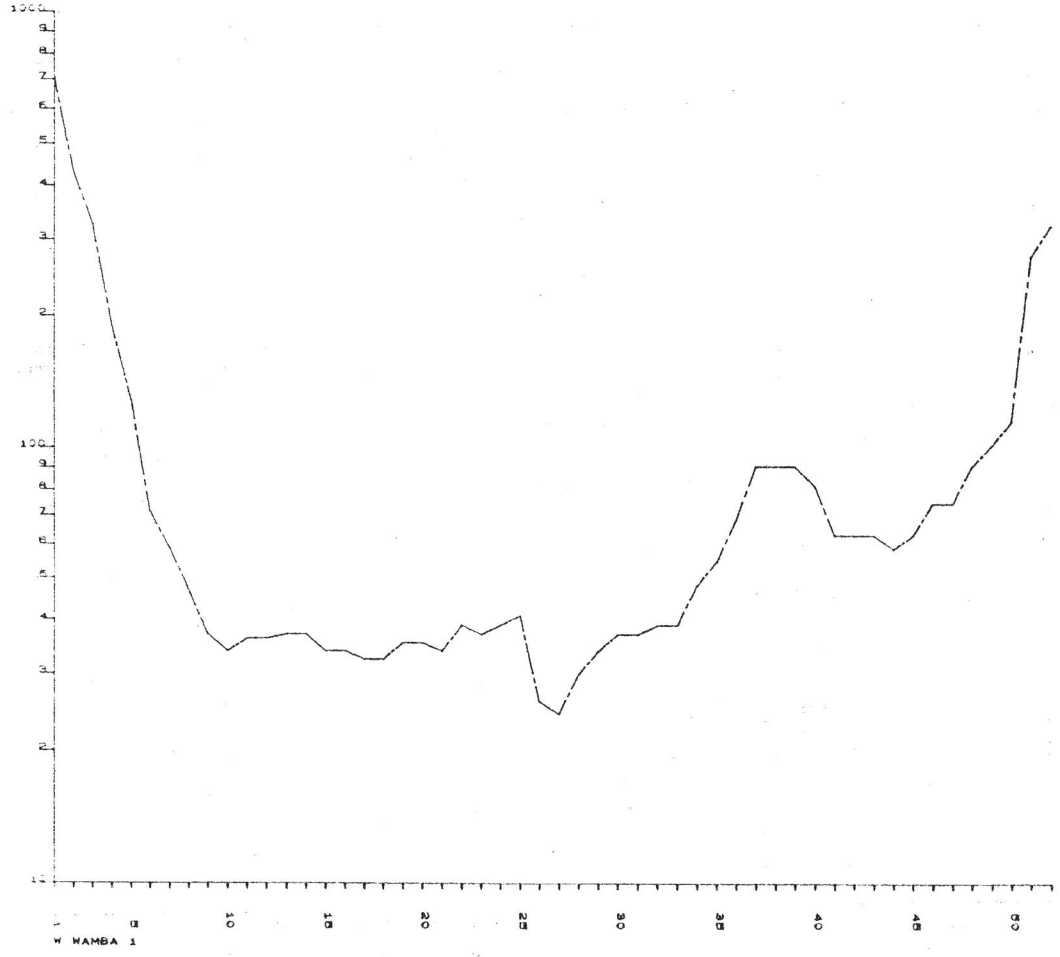
# Em Profiles

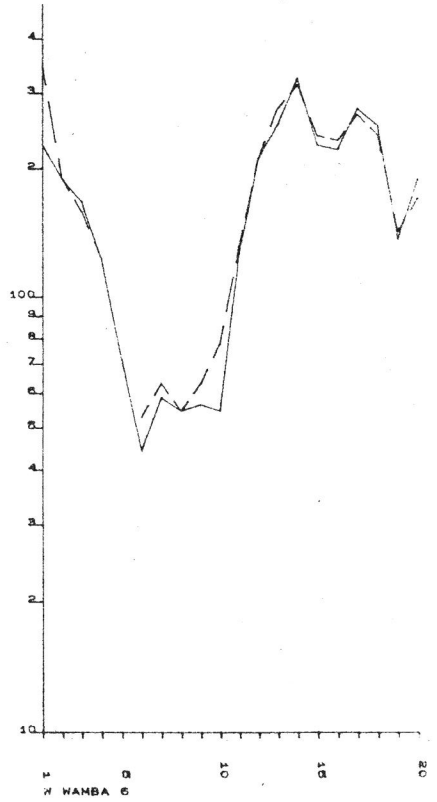
## Appendix 3.3 EM Profiles

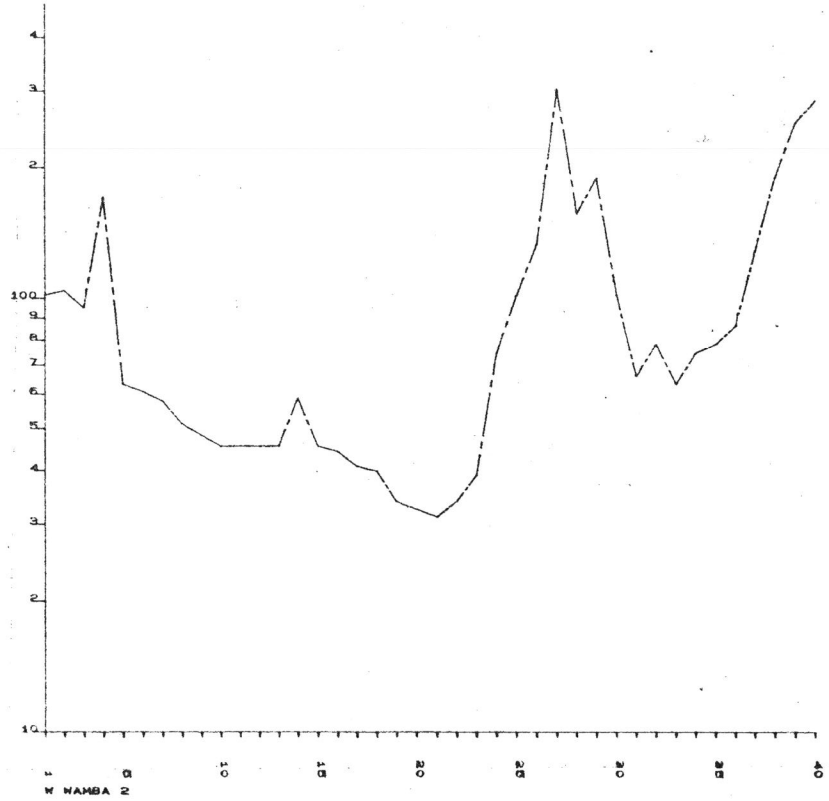
1. W Wamba 1,6
2. W Wamba 2,5
3. W Wamba 3,4,7
4. W Wamba 8
5. W Wamba 9
6. W Wamba 10
7. W Wamba 11,12
8. W Wamba 13,17
9. W Wamba 15
10. W Wamba 16
11. W Wamba 14
12. W Nairimirimo 1
13. W Nairimirimo 2
14. W Nairimirimo 3
15. W Ngelai 1,2
16. W Ngelai 3
17. W Swuari 1,2
18. W Swuari 3
19. W Naisunyai 1
20. W Naisunyai 2
21. W Naisunyai 3
22. W Naisunyai 4
23. W Naisunyai 5
24. W Naisunyai 6
25. W Naisunyai 7
26. W Naisunyai 8,9
27. W Naisunyai 10
28. W Naisunyai 11
29. W Naisunyai 12
30. W Naisunyai 13
31. W Naisunyai 14
32. W Naisunyai 15
33. W Namanyarabo 1
34. W Namanyarabo 2
35. W Namanyarabo 3,4
36. W Namanyarabo 5,6
37. W Namanyarabo 7,8
38. W Namanyarabo 9,10
39. W Namanyarabo 11
40. W Namanyarabo 12
41. W Namanyarabo 13
42. W Namanyarabo 14
43. W Lengei 1
44. W Lengei 2
45. W Noolkuniyani 1,2
46. W Noolkuniyani 3
47. W Noolkuniyani 4
48. W Noolkuniyani 5
49. W Noolkuniyani 6
50. W Noolkuniyani 7

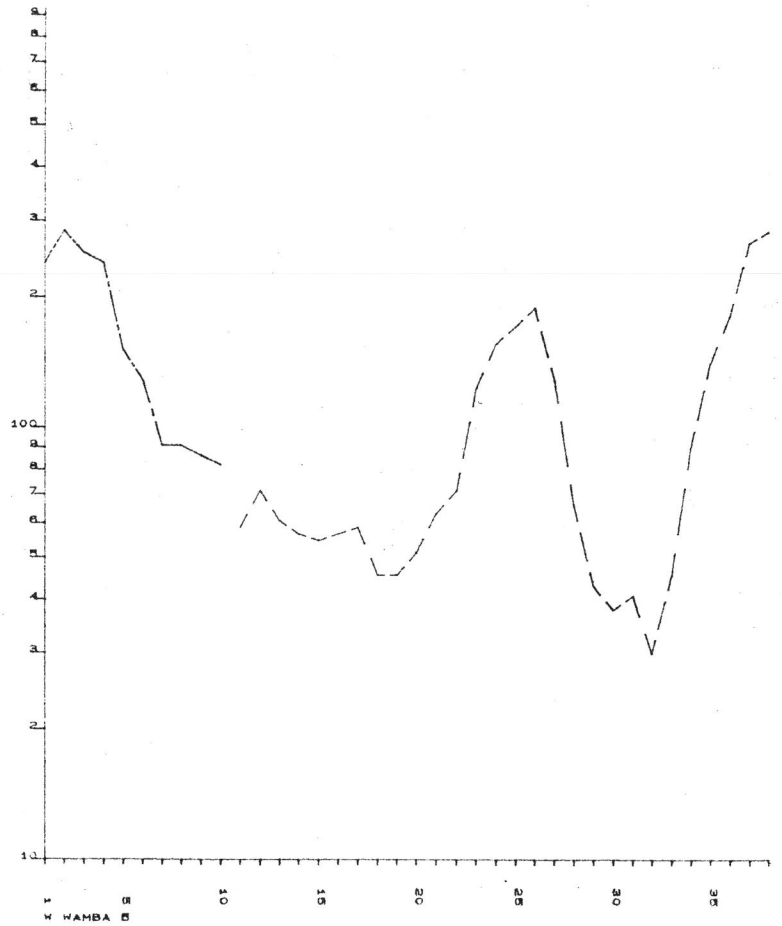
**Appendix 3.3 (Cont.) EM Profiles**

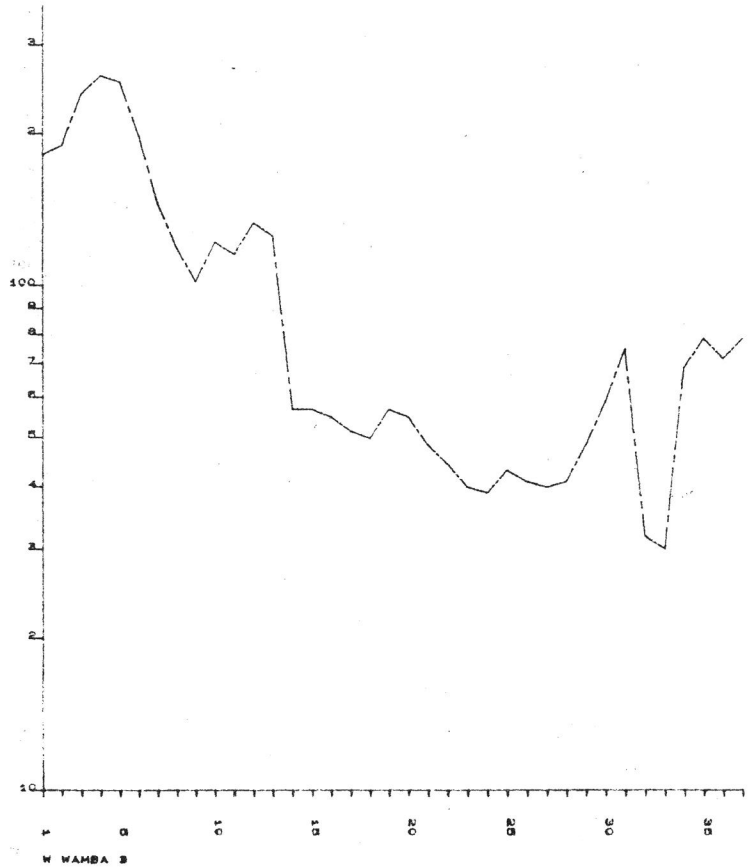
51. W Losesia 1
52. W Merille 1,2
53. W Larisoro 1,2
54. W Larisoro 3,6
55. W Larisoro 4,5
56. W Larisoro 7
57. W Kauro 1,2,3
58. B Baragoi 1,3
59. B Baragoi 2
60. B Baragoi 4
61. B Baragoi 5
62. B Baragoi 6,7
63. B Masiketa 1
64. B Masiketa 2
65. B Masiketa 3
66. B Nachola 1
67. B Nachola 2
68. B Suiyan 1,2
69. B Ngilai 1,3
70. B Ngilai 2,4
71. B Mpatpat 1
72. B Ntiil 1
73. B Soit Dol Payien 1,2
74. B Soit Dol Payien 3,4
75. B Soit Dol Payien 5
76. B Loenti 1,2
77. B Loenti 3,4
78. B Loenti 5
79. L Maralal 1
80. L Maralal 2
81. L Maralal 3
82. L Maralal 4
83. L Maralal 5
84. L Maralal 6
85. L Maralal 7,8
86. L Maralal 9,10
87. L Maralal 11,12
88. L Maralal 13,32
89. L Maralal 14,15
90. L Maralal 16,17,18
91. L Maralal 19,20
92. L Maralal 21,22
93. L Maralal 23,24
94. L Maralal 26,28
95. L Barsaloi 1,3
96. L Barsaloi 2,4
97. L Ledero 1,2
98. L Ledero 3
99. L Opiroi 1, L Losuk 1
100. L Opiroi 2, L Losuk 2

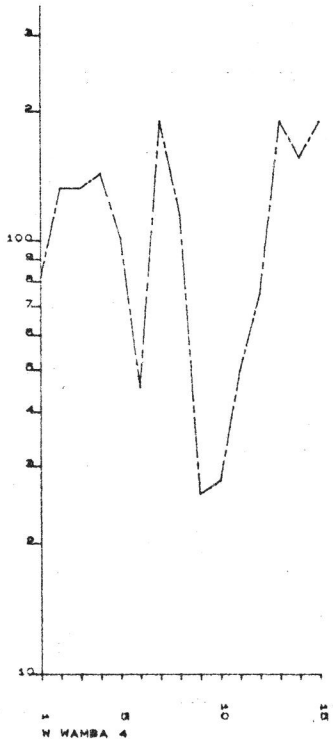

W WAMBA 1

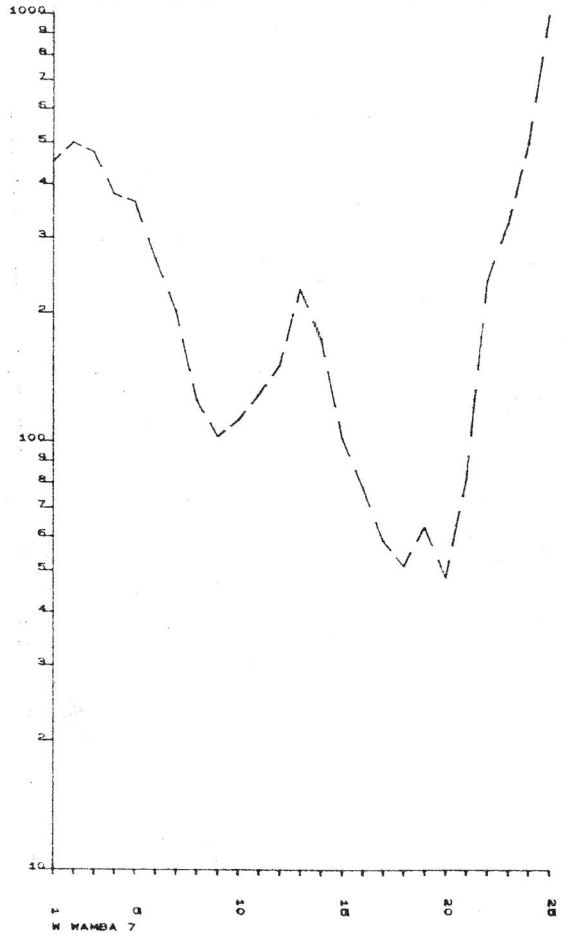

W WAMBA 6


100
10
1
5
10
15
20
25
30
35
40
W WAMBA 2


100
10
1
5
10
15
20
25
30
35
W WAMBA 5

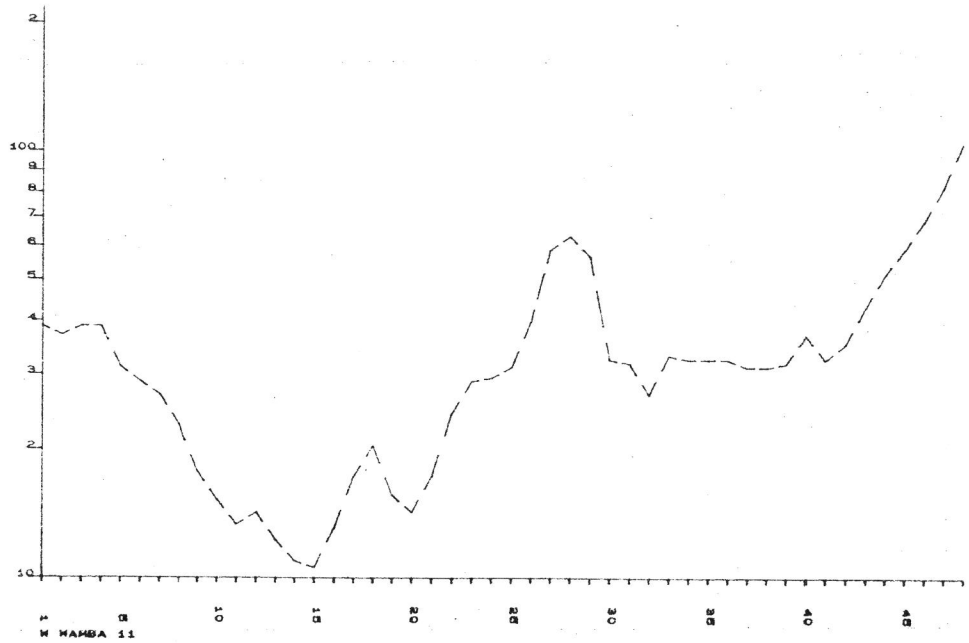

100
10
1
5
10
15
20
25
30
35
W WAMBA 3

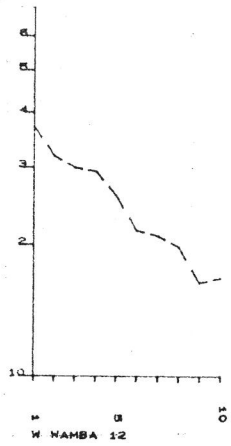

100
10
1
5
10
15
W WAMBA 4

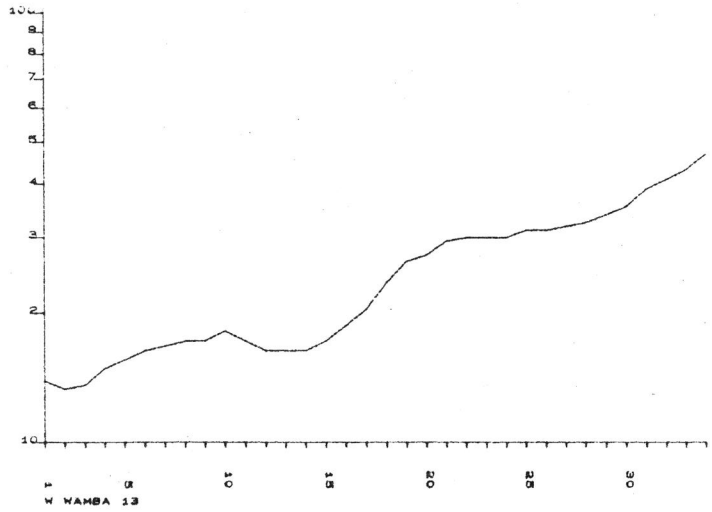

1000
100
10
1
5
10
15
20
25
W WAMBA 7

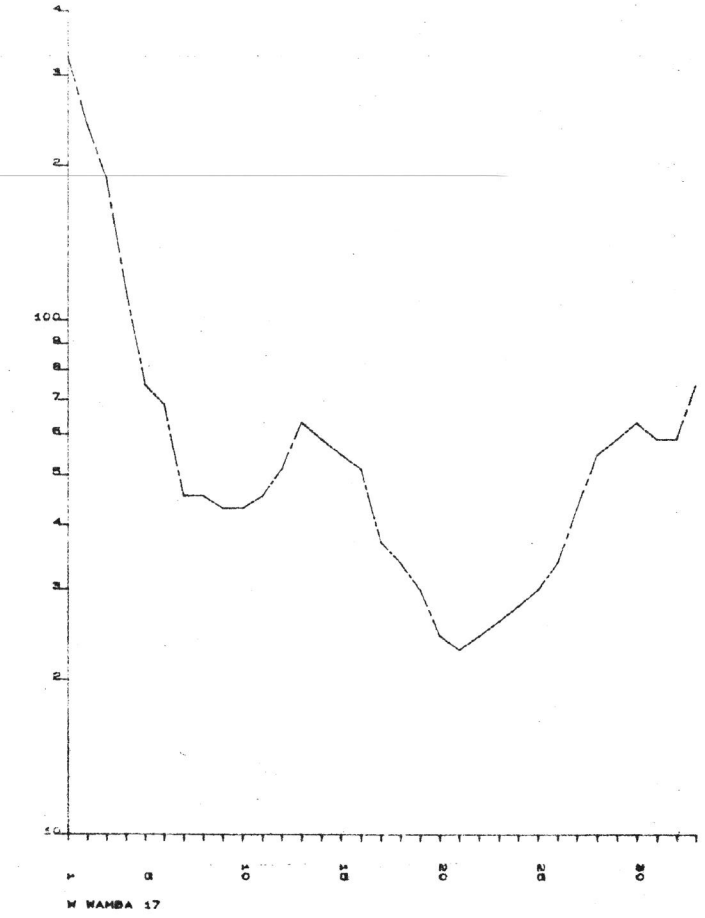
5
4
3
2
100
9
8
7
6
5
4
3
2
10
1
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
W MAMBA 6

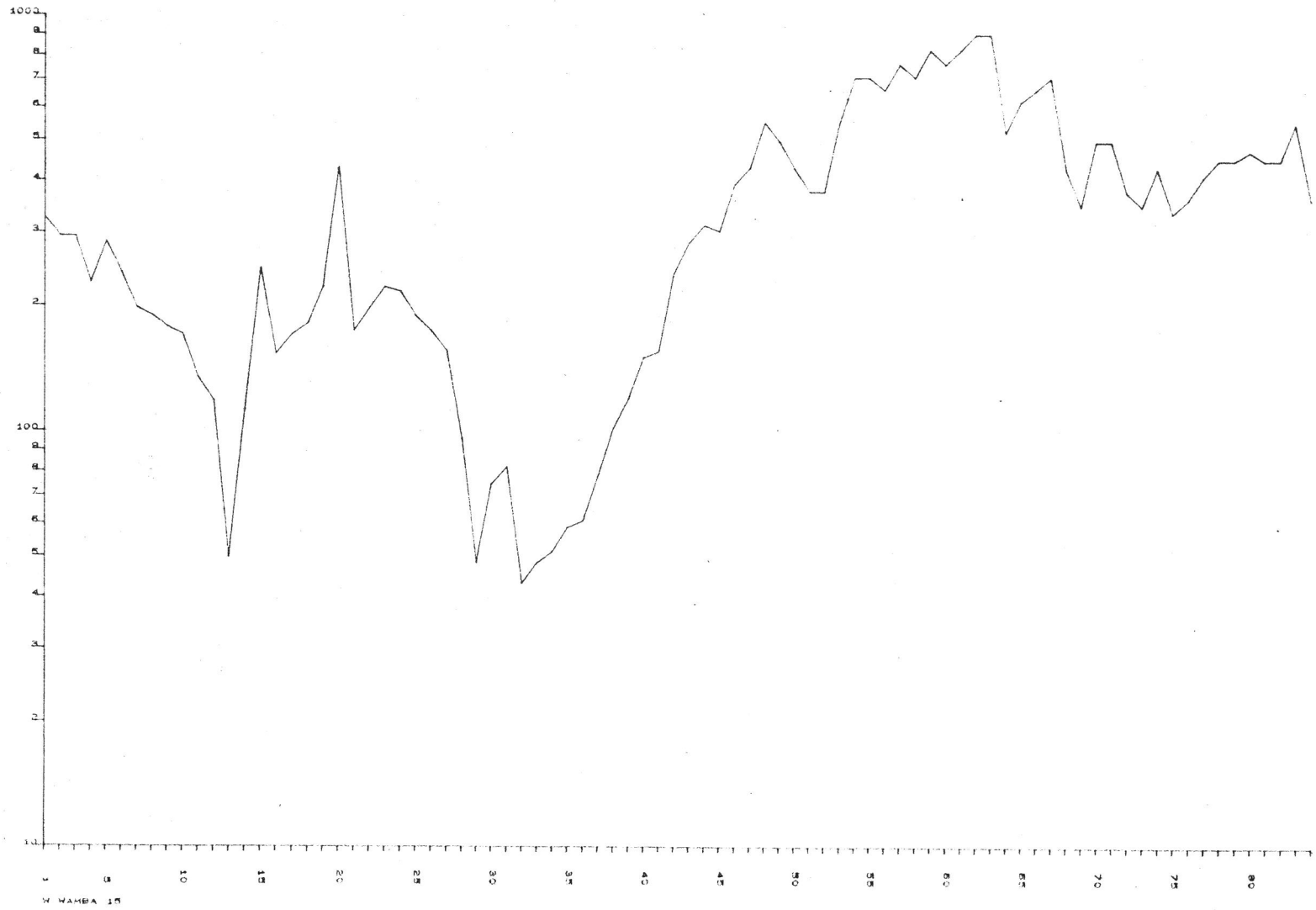
1000
100
10
1
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
W MANDA 9


W NAMBA 11


W NAMBA 12

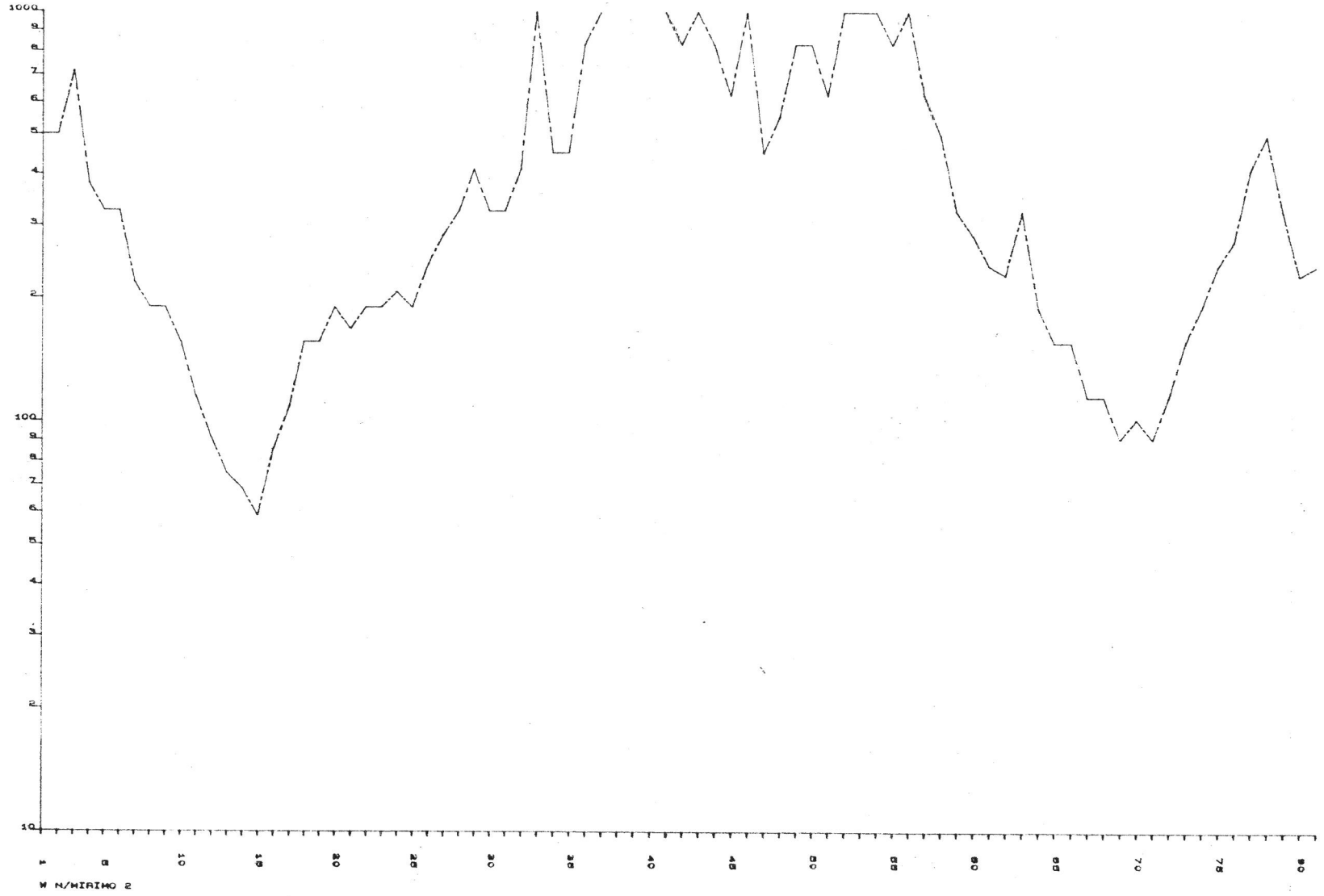

W WAMBA 13


W WAMBA 17

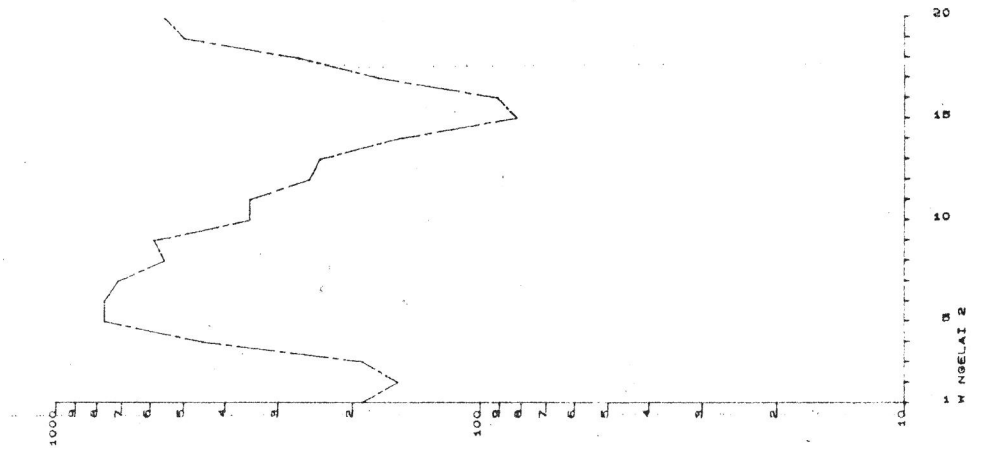

1000
100
10
1
W WAMBA 15

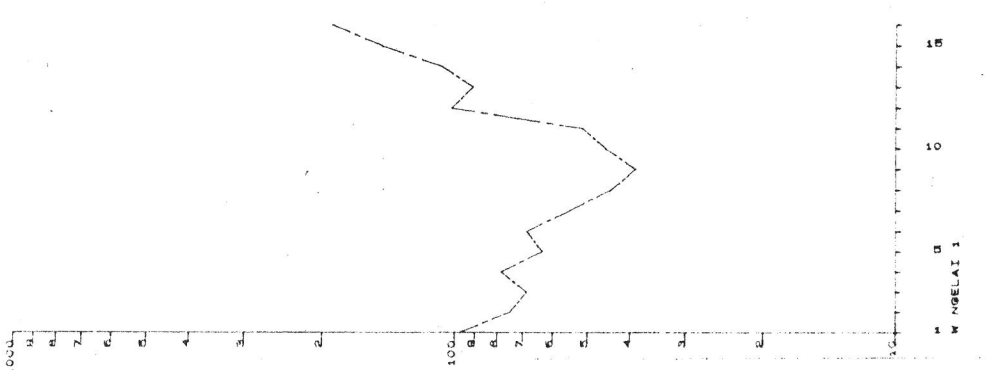
M MAMBA 85

W NAIROBI

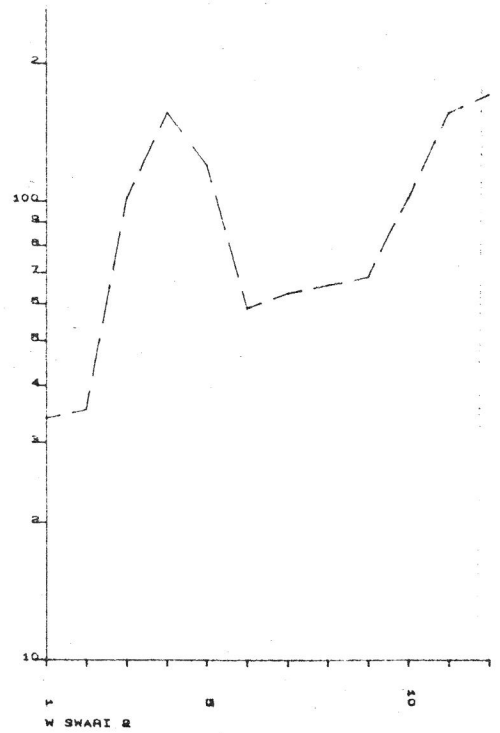

1000
100
10
1
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
W N/MIRIMO 2

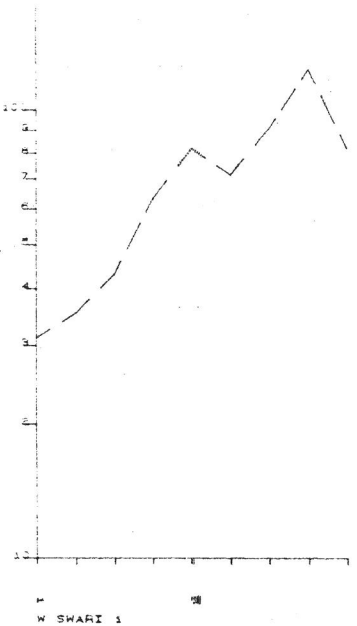
3
2
100
9
8
7
6
5
4
3
2
10
1
5
10
15
20
25
30
35
40
N.MINIMO 3


1000
100
10
1
5
10
15
20
W NGELAI 2


1000
100
10
1
5
10
15
W NGELAI 1

100
1
5
10
15
20
25
30
W NGELAI B

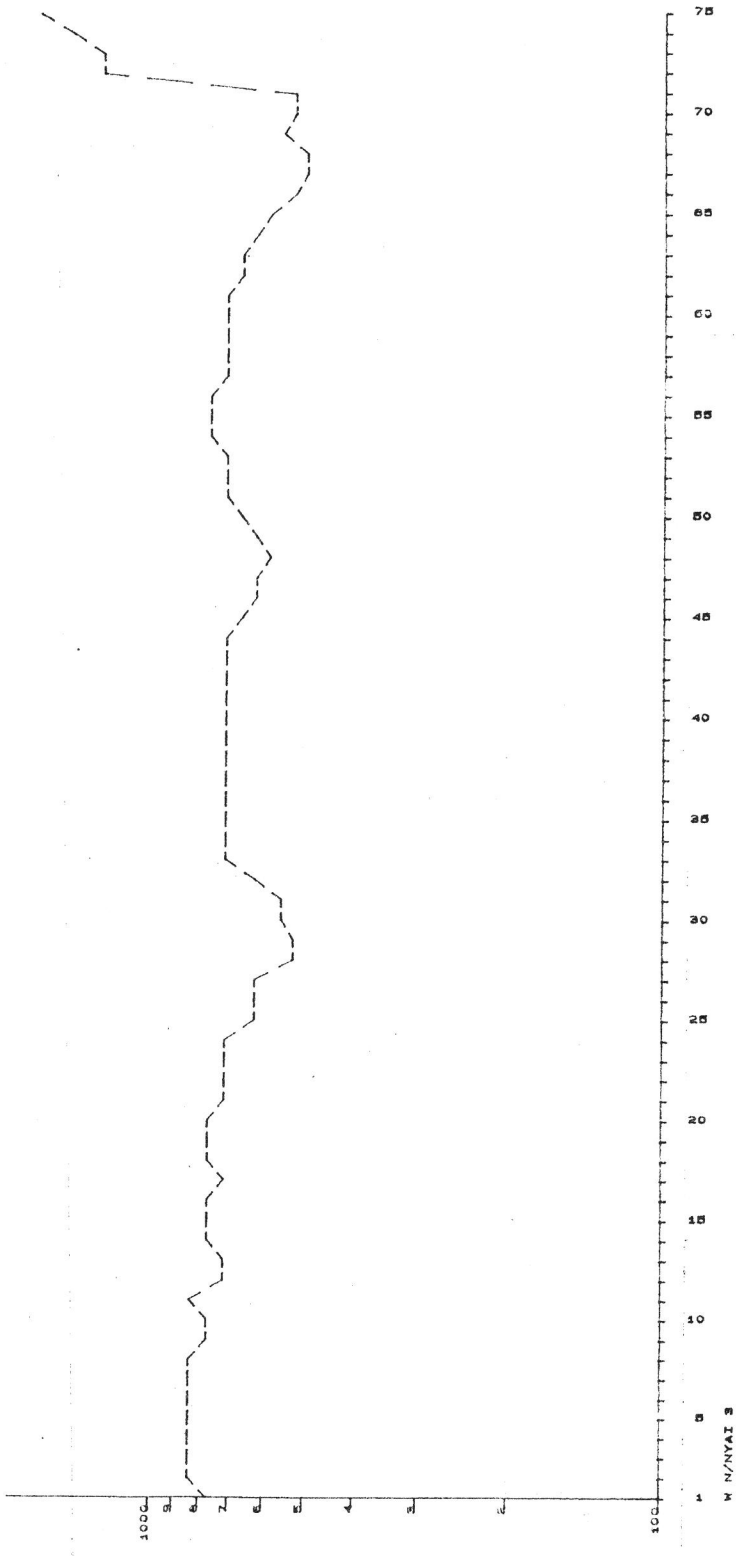

W SWARI 2

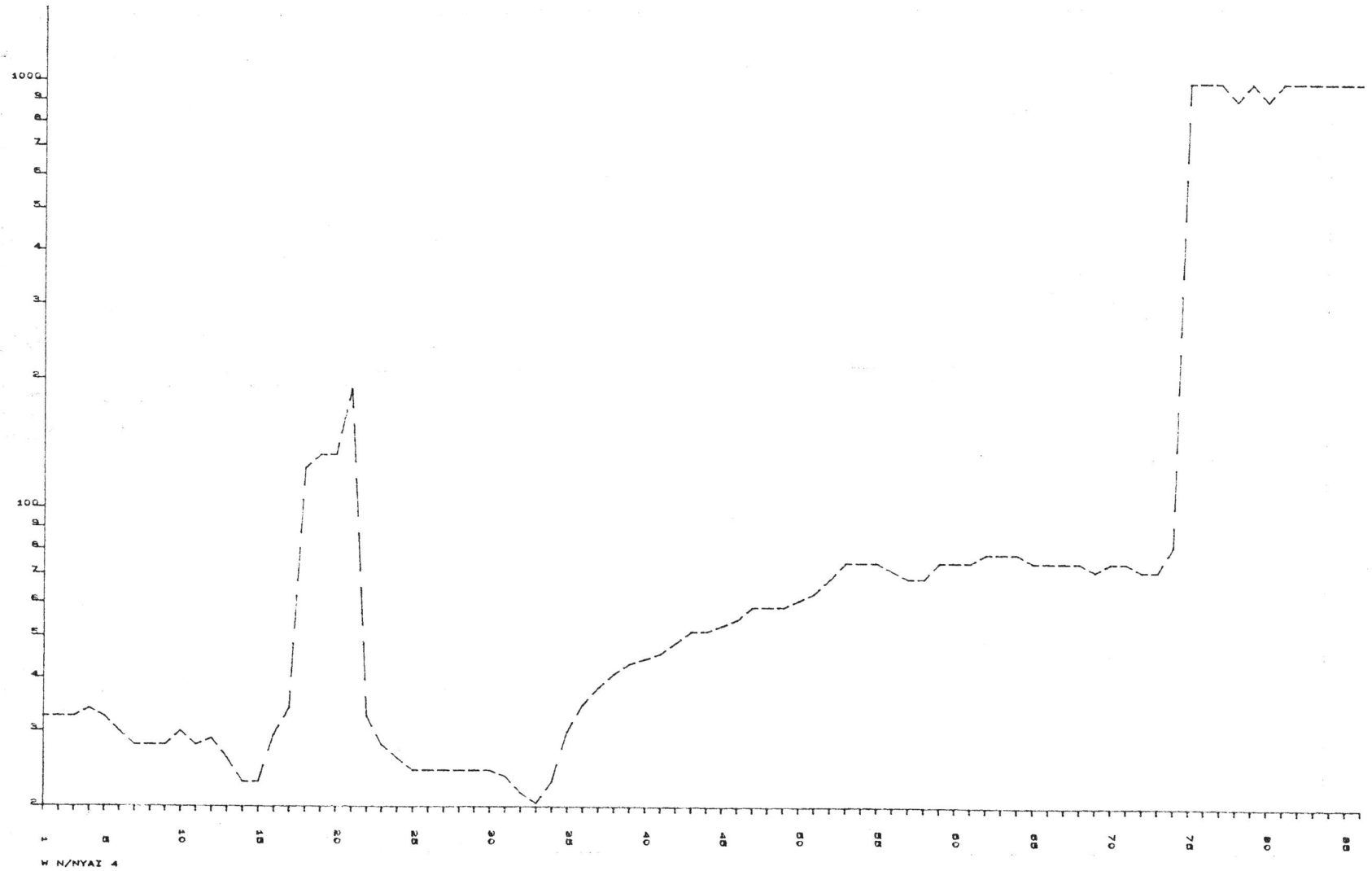

W SWARI 1

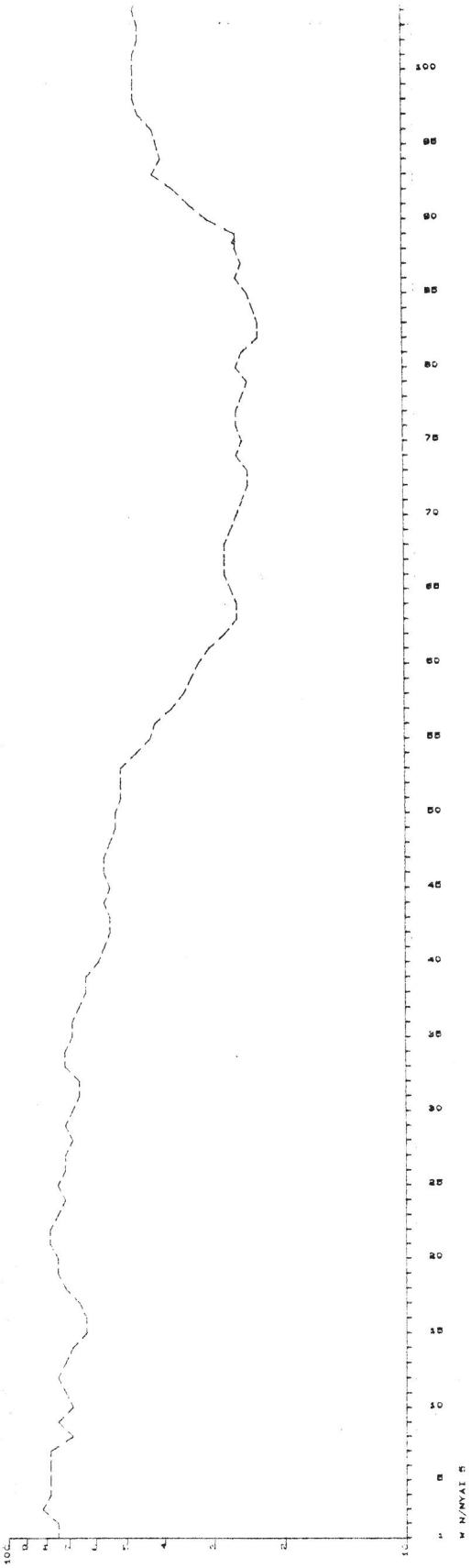
100
9
8
7
6
5
4
3
2
1
0
5
10
15
20
M SHARI 3

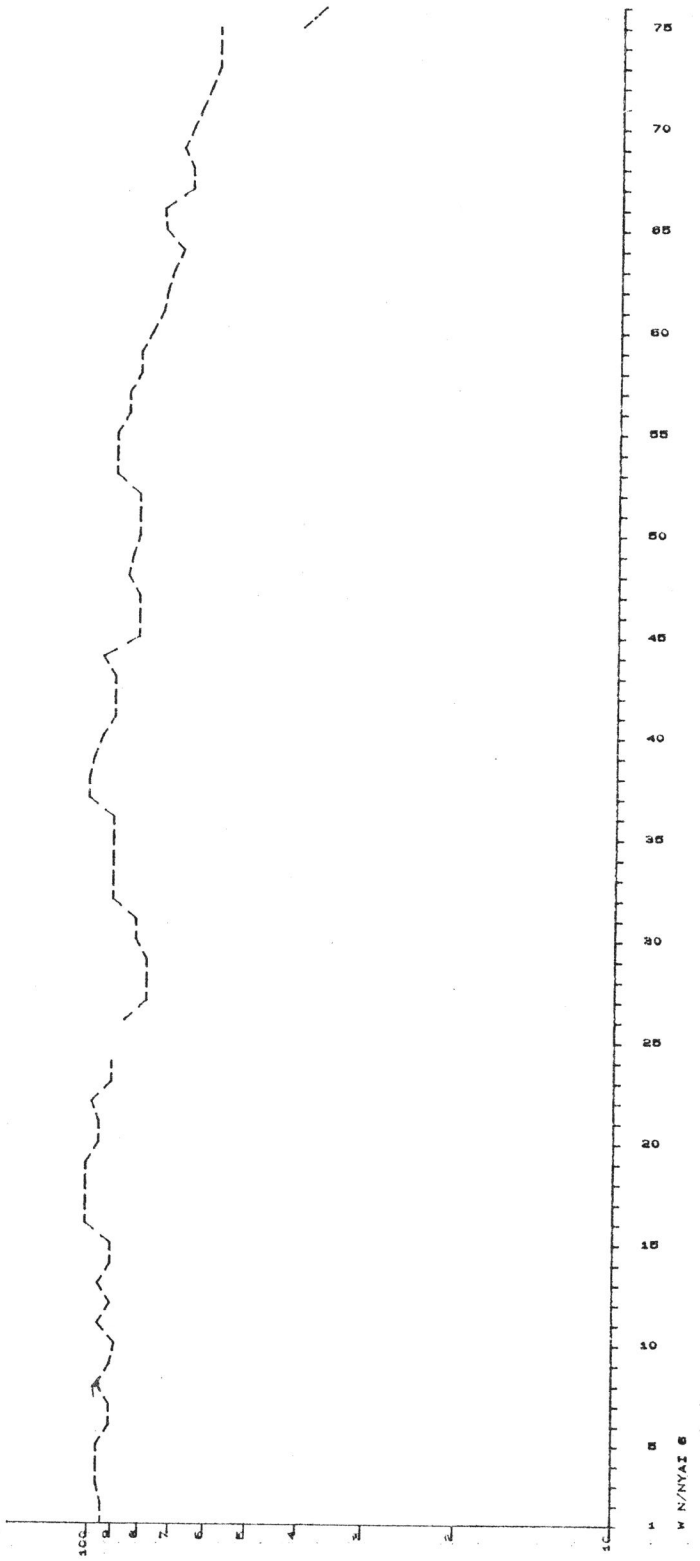
105
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
1

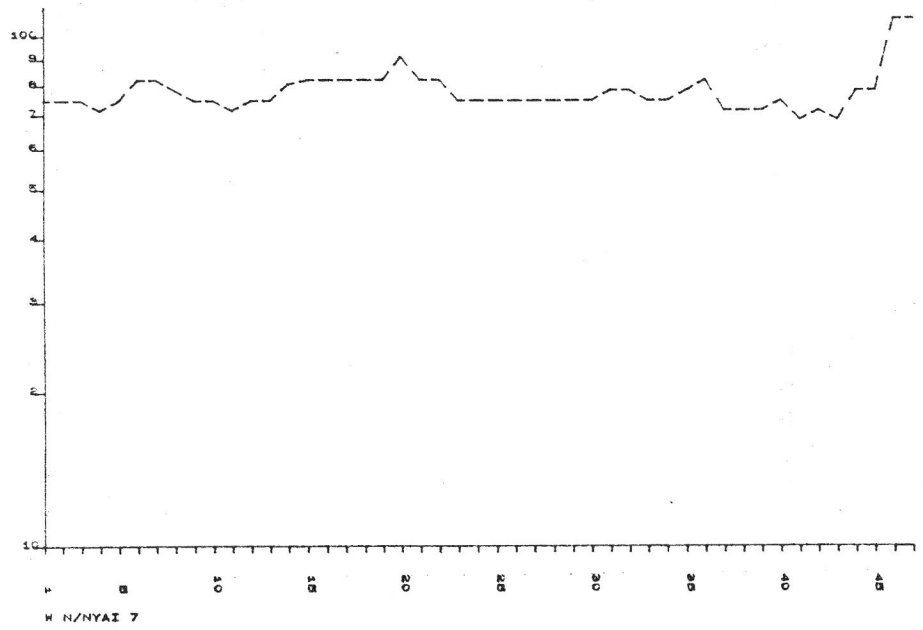
1000
100
10
1 W N/NYAI 2
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80

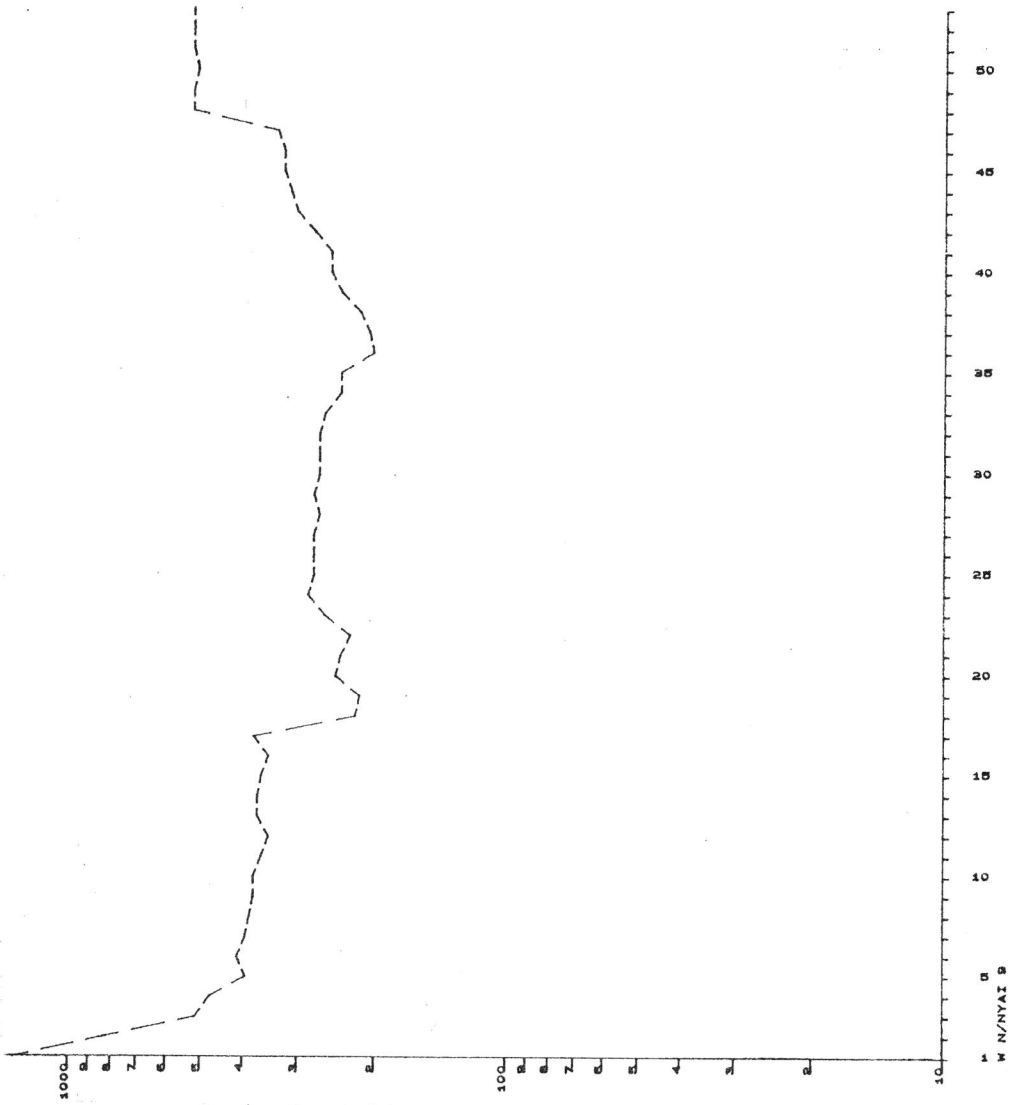

1000
100
1
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75

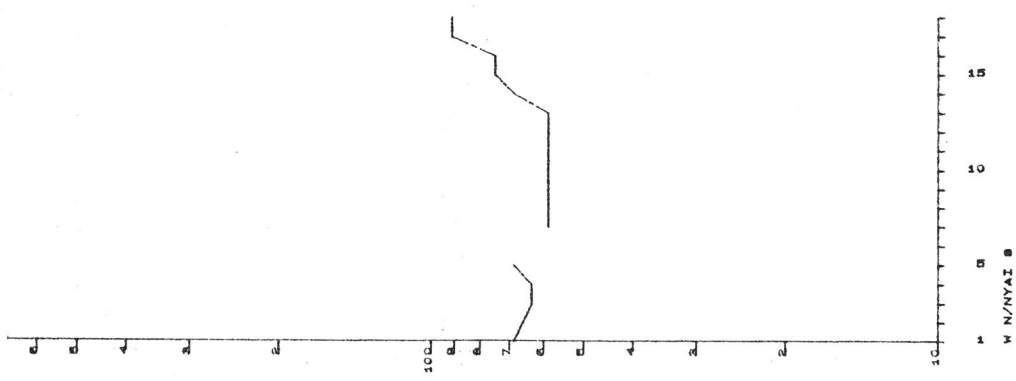

1000
100
10
1
1
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
W N/NYAI 4


100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
1
M N/MYAT 25


100
90
80
70
60
50
40
30
20
10
1
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75

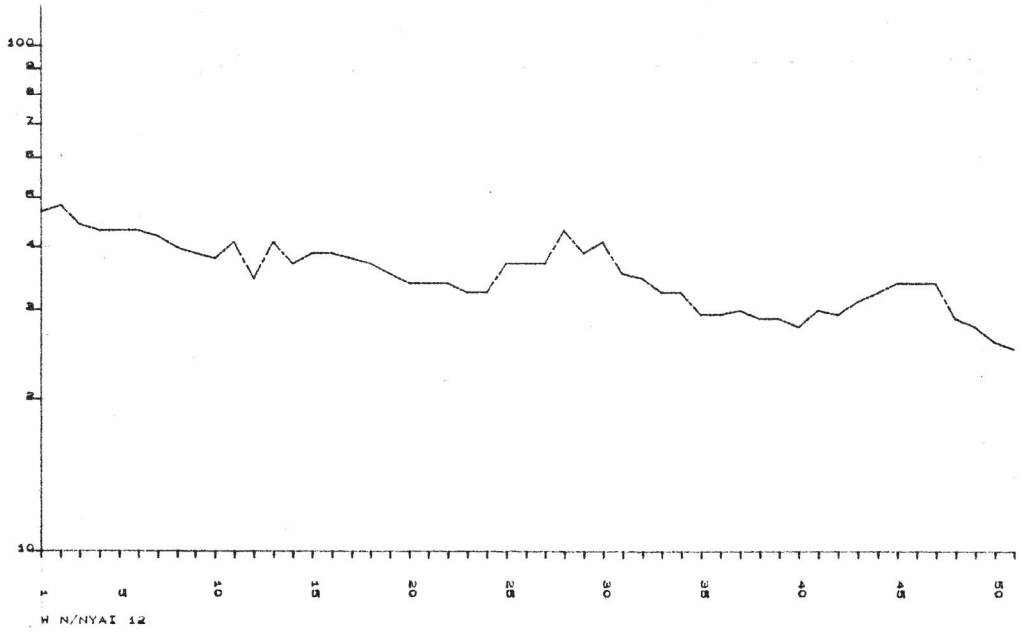

100
90
80
70
60
50
40
30
20
10
1
5
10
15
20
25
30
35
40
45
N/NYAI 7


1000
100
10
1
5
10
15
20
25
30
35
40
45
50
W N/NYAI S

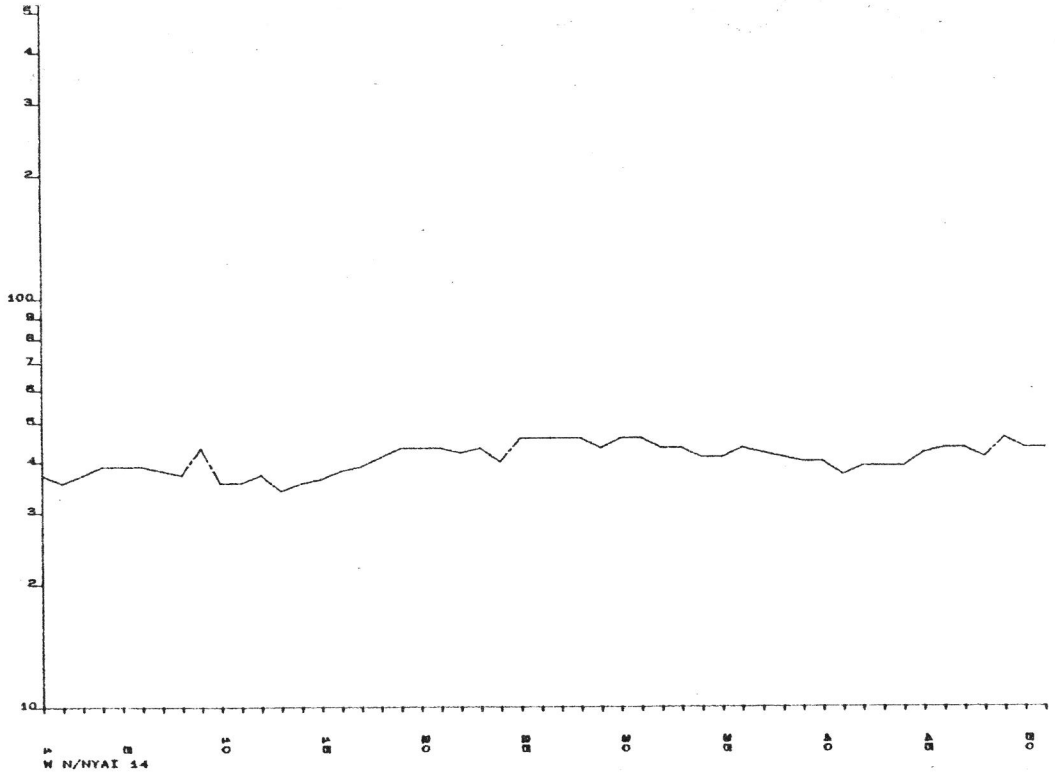

100
10
1
5
10
15
W N/NYAI S

5
4
3
2
100
9
8
7
6
5
4
3
2
10
1
5
10
15
20
25
30
35
40
45
50
55
M N/NYAI 10

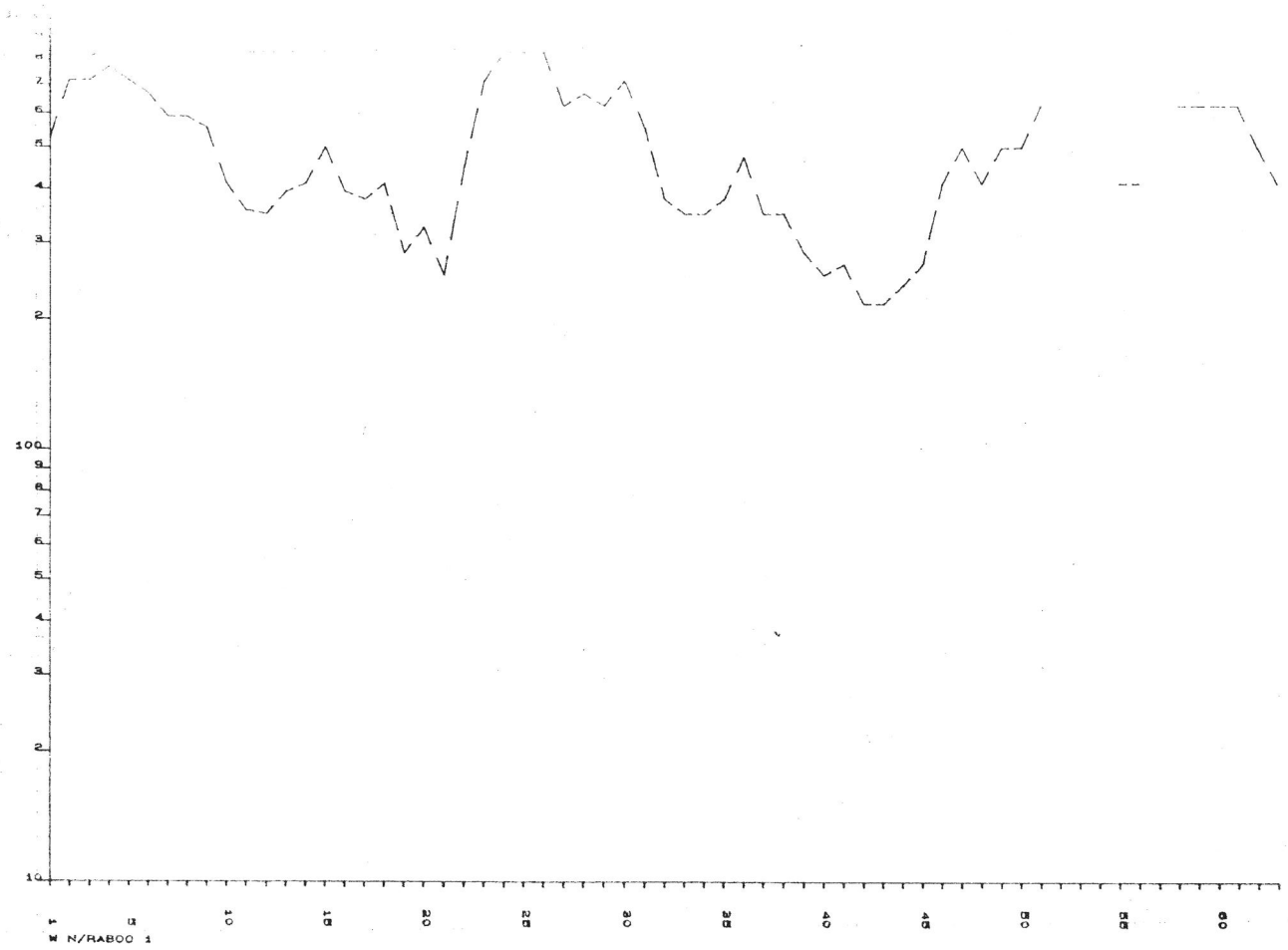
7
6
5
4
3
2
1
0
5
10
15
20
25
30
35
40
45
50
M N/NYAI 11

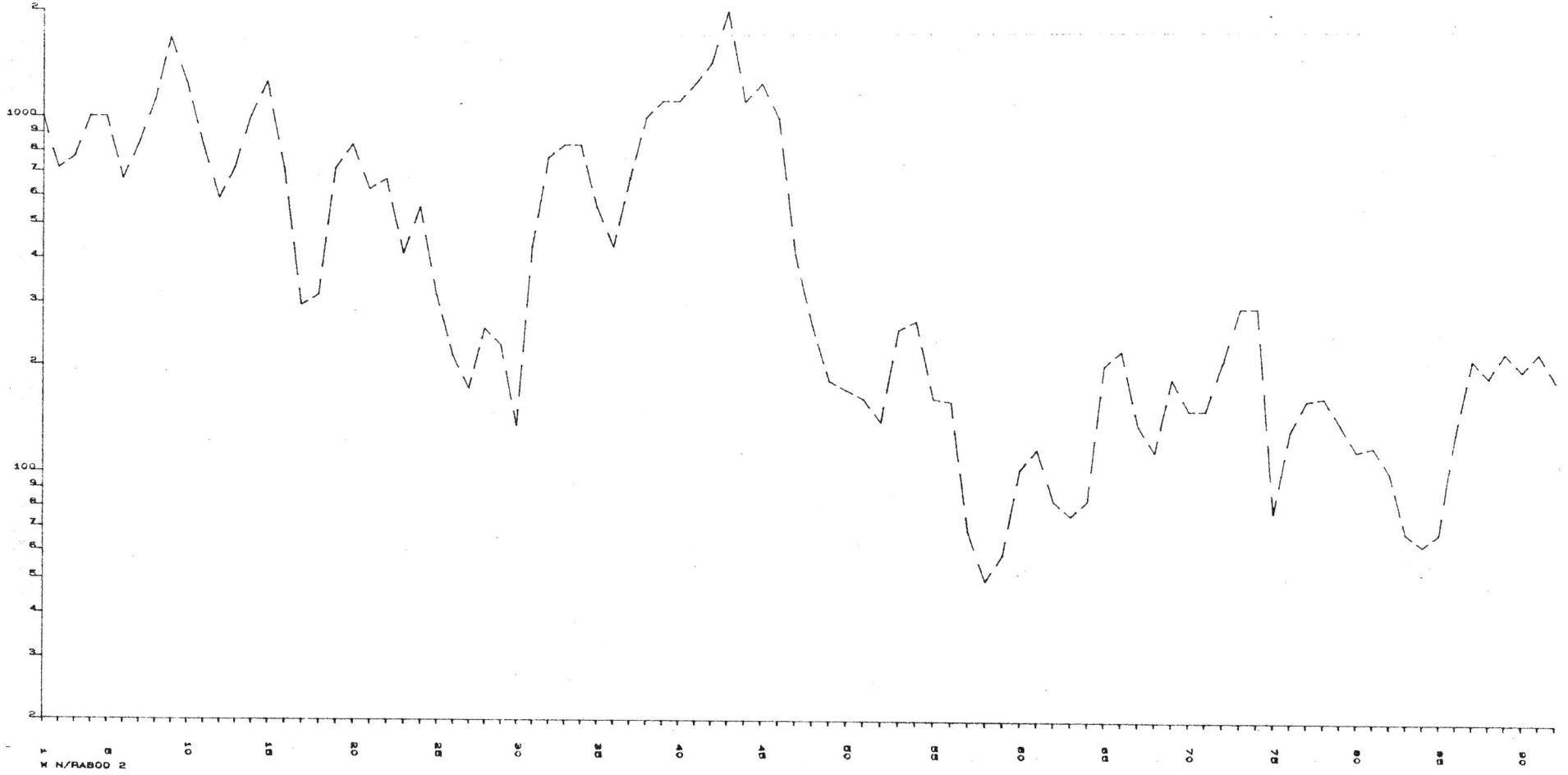

100
4
2
10
1
5
10
15
20
25
30
35
40
45
50
H N/NYAI 12

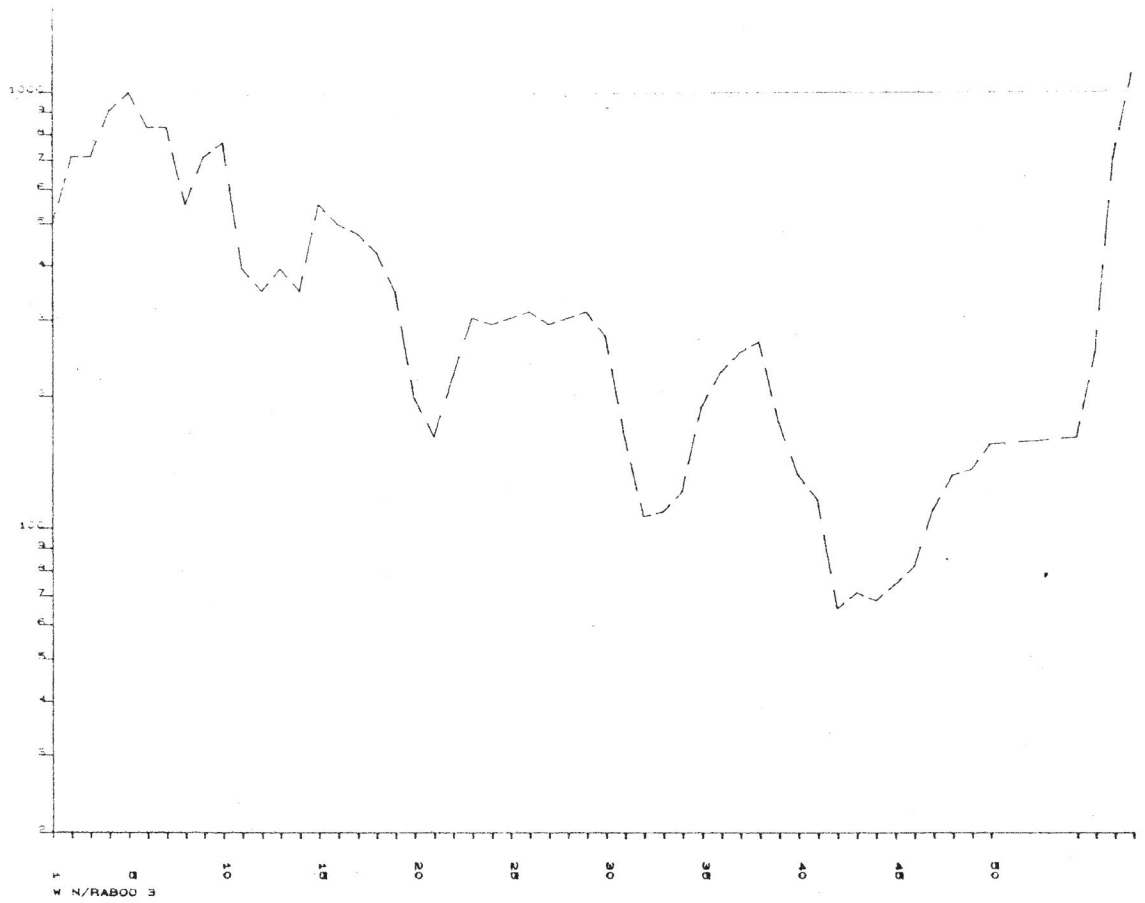
100
1
5
10
15
20
25
30
35
40
45
50
N/NYAI 13

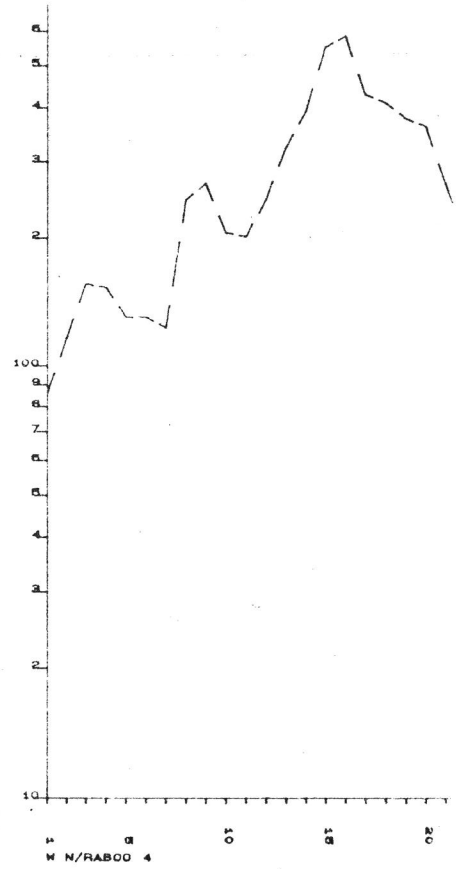

5
4
3
2
100
9
8
7
6
5
4
3
2
10
1
5
10
15
20
25
30
35
40
45
50
W N/NYAI 14

5
4
3
2
1
1
5
10
15
20
25
30
35
40
45
50
M N/NYAT 15


100
10
1
5
10
15
20
25
30
35
40
45
50
55
60
N/RABOO 1

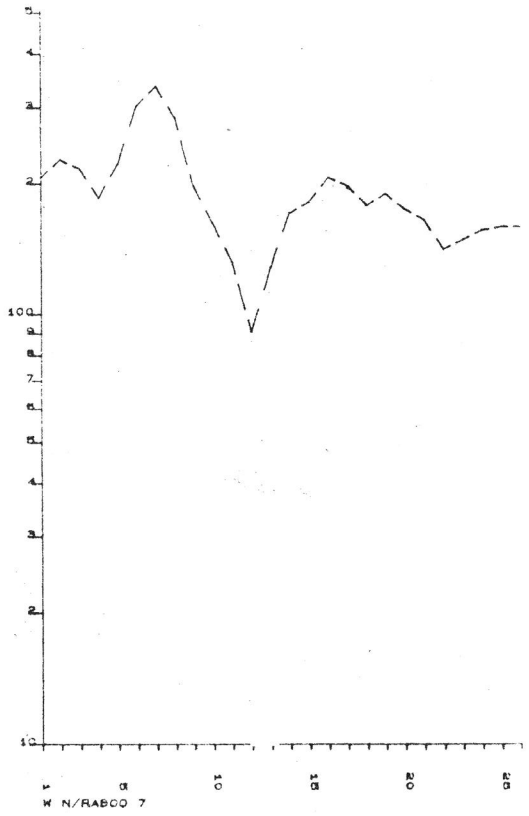

1000
100
X N/RABOD 2

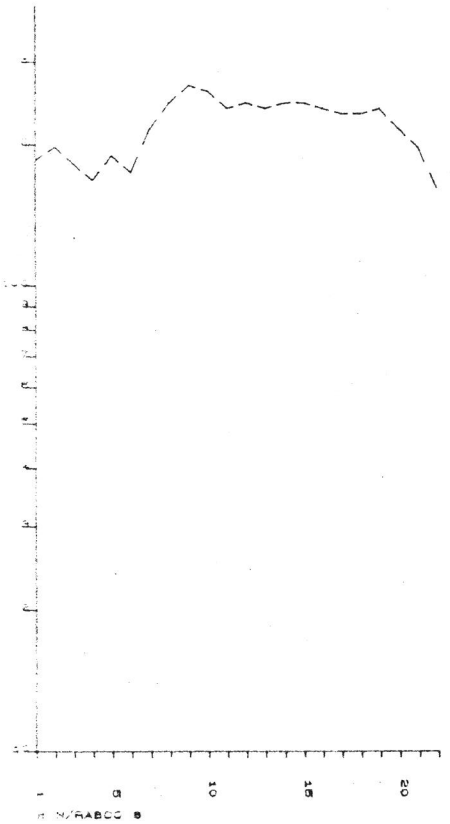

W N/RABOO 3

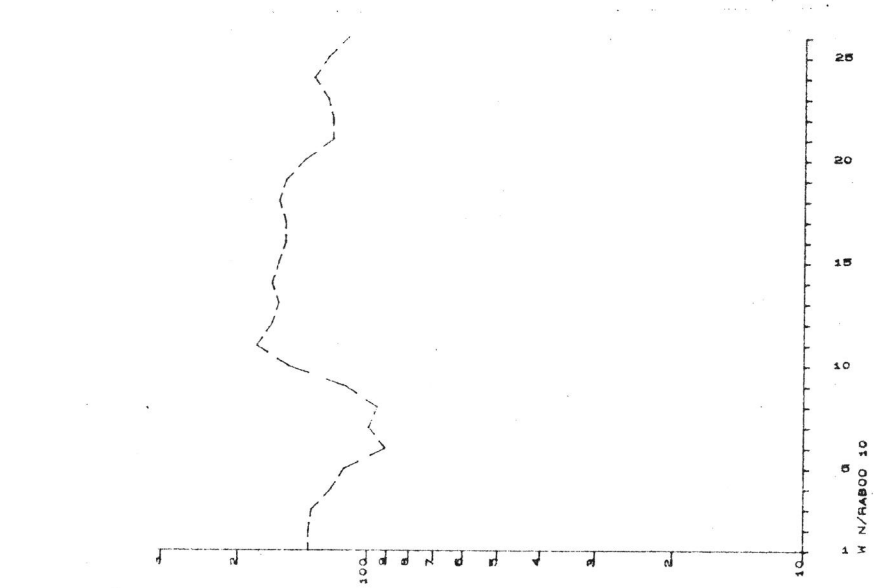

W N/RABOO 4

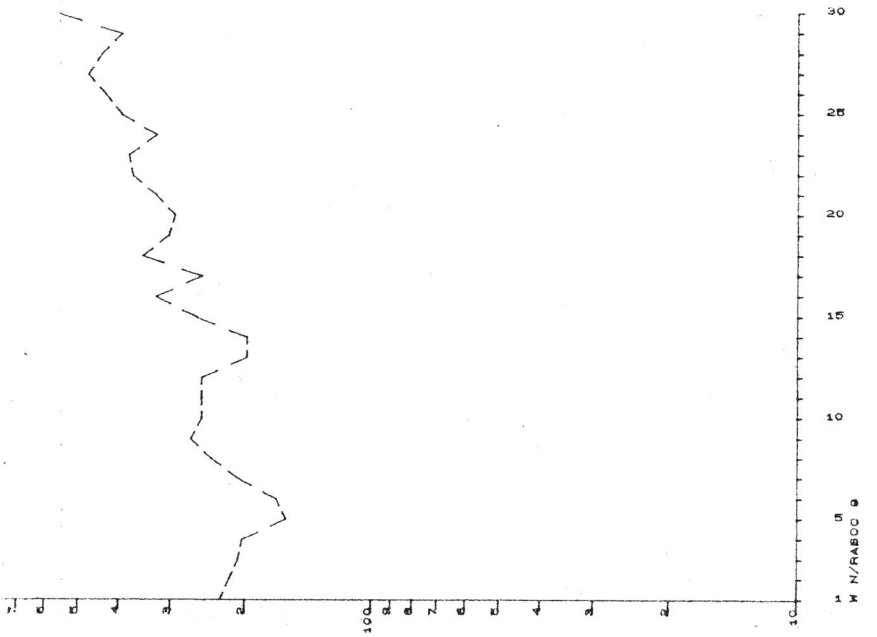
7
6
5
4
3
2
100
9
8
7
6
5
4
3
2
1
5
10
15
20
25
N/RABOO 6

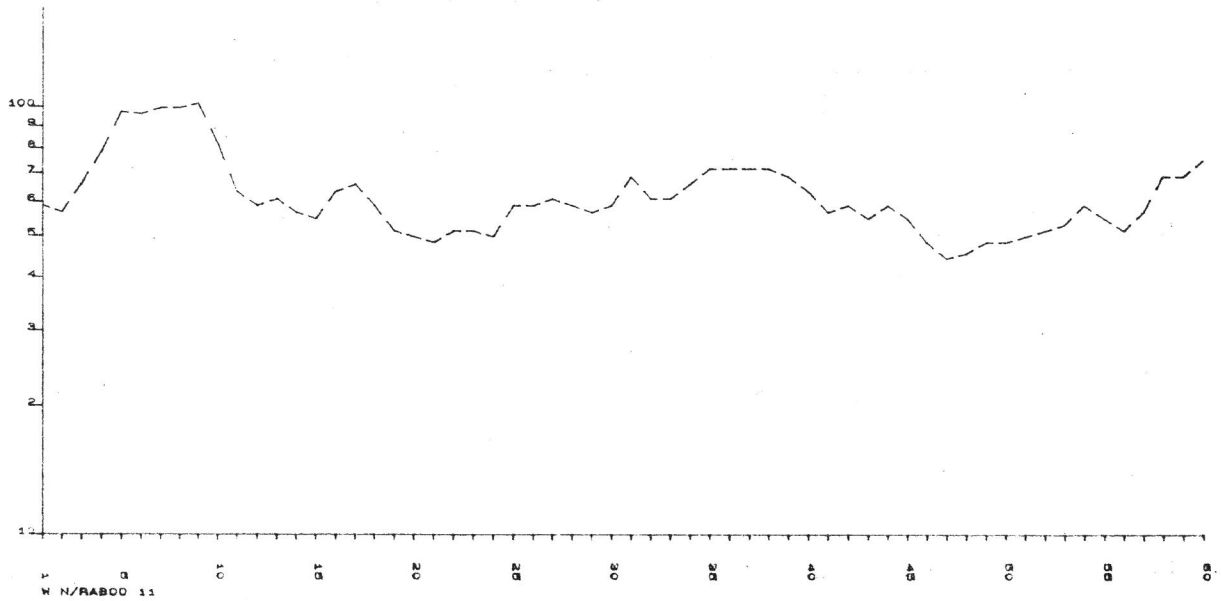

7
6
5
4
3
2
100
9
8
7
6
5
4
3
2
1
5
10
15
20
25
N/RABOO 5


W N/RABOO 7

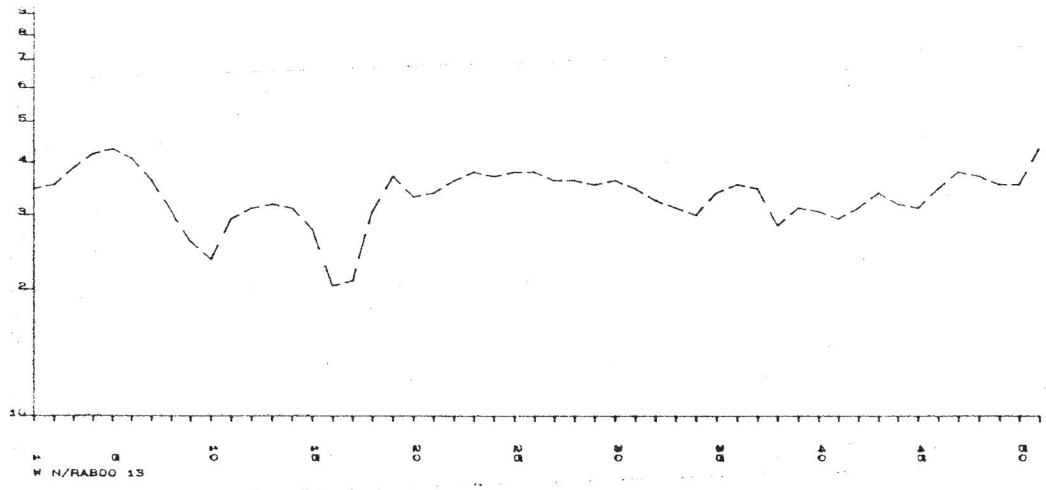


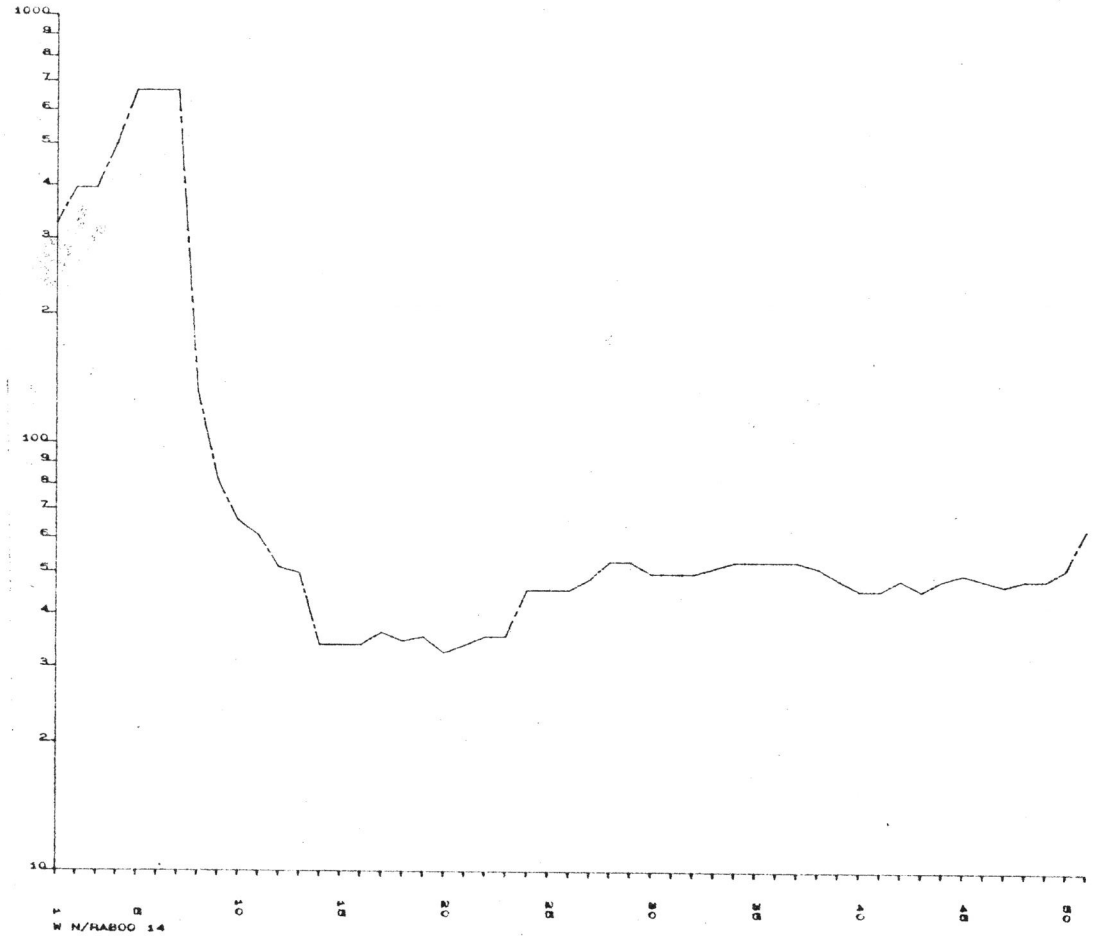

W N/RABOO 10

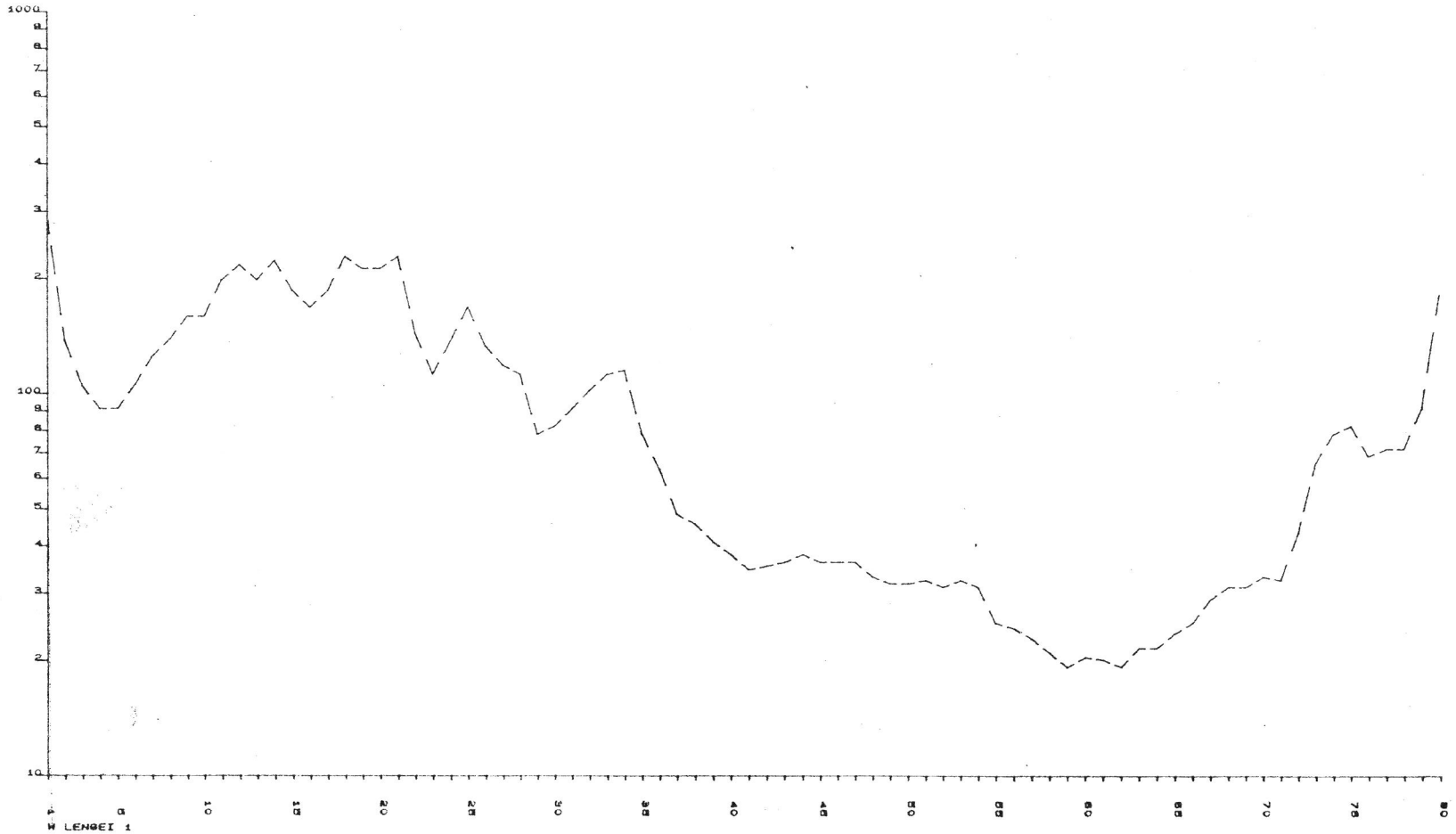

W N/RABOO 9

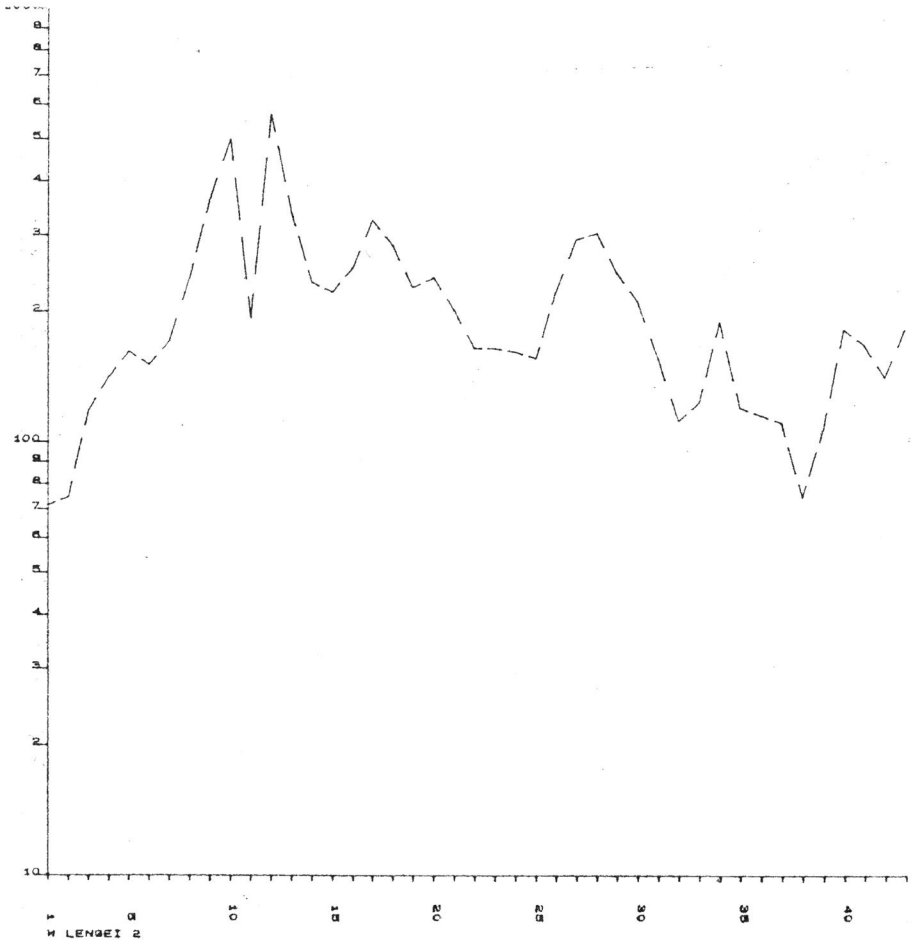

100
10
1
0
5
10
15
20
25
30
35
40
45
50
55
60
W N/RA800 11

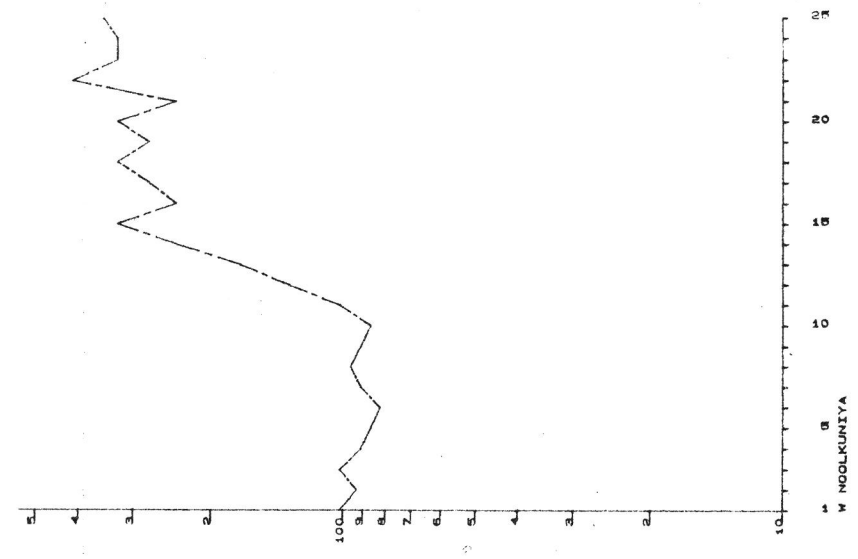
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
1
W N/RABOO 12
100
9
8
7
6
5
4
3
2
10
2

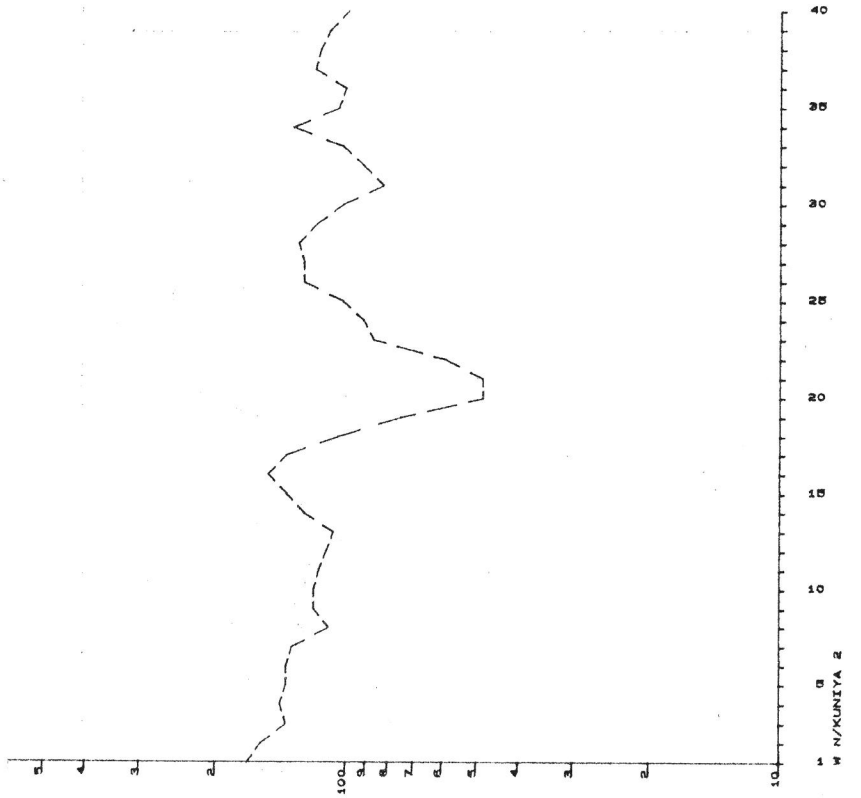

10
5
4
3
2
1
1
5
10
15
20
25
30
35
40
45
50
W N/RAB00 13


1000
9
8
7
6
5
4
3
2
100
9
8
7
6
5
4
3
2
10
1
5
10
15
20
25
30
35
40
45
50
W N/RABOO 14

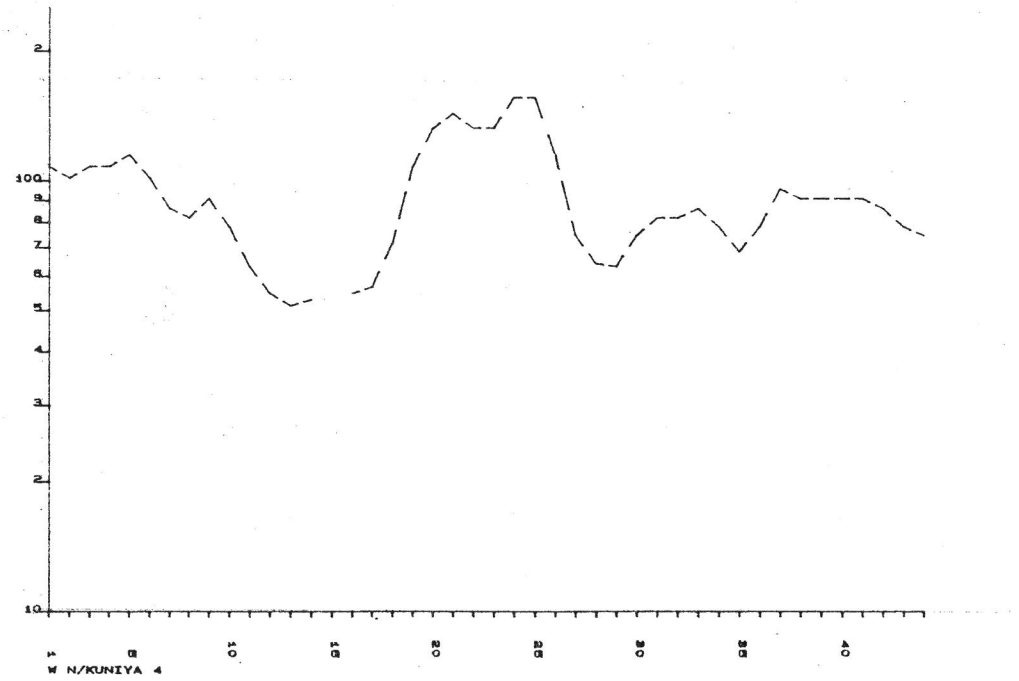

1000
100
10
W LENGEI 1


1
5
10
15
20
25
30
35
40
M LENGEI 2


W MOOLKUNIYA


W N/KUNIYA 2

2
100
9
8
7
6
5
4
3
2
10
1
5
10
15
20
25
30
35
40
W N/KUNIYA 3

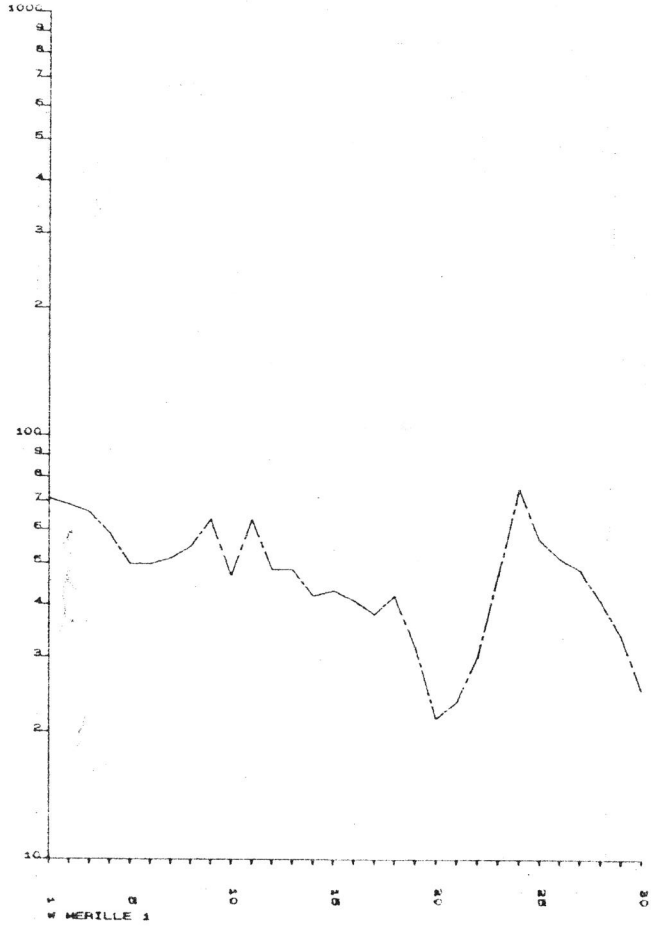

2
100
9
8
7
6
5
4
3
2
10
1
5
10
15
20
25
30
35
40
W N/KUNIYA 4

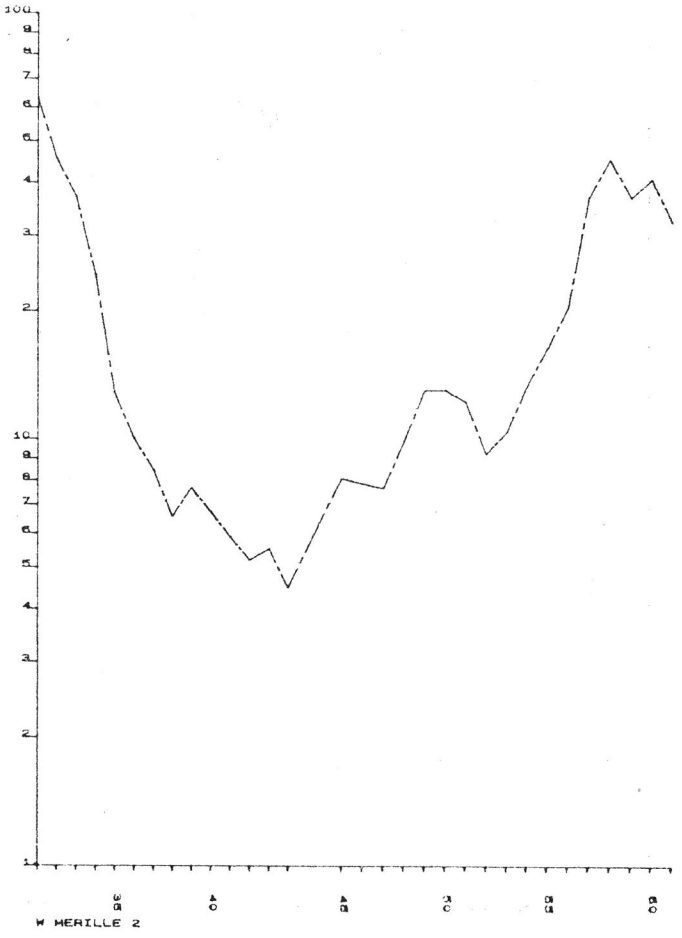
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
1
M N/KUNIYA S

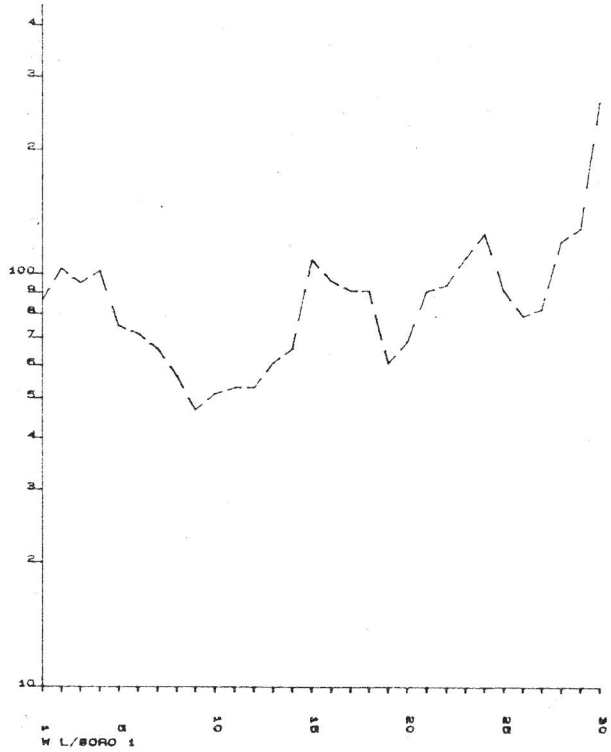

W N/KUNIYA 6

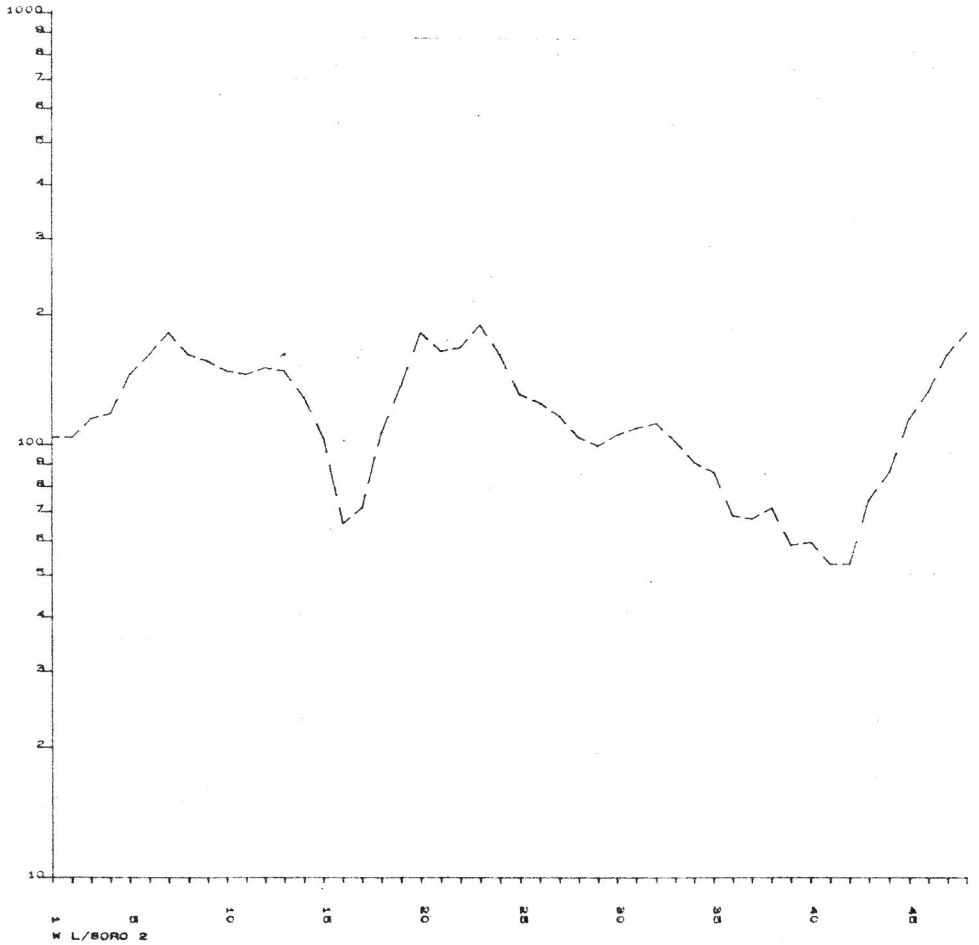
W N/KUNIYA 7

W LOSEBIA 1


W MERILLE 1


W MERILLE 2


100
10
1
5
10
15
20
25
30
W L/BORO 1

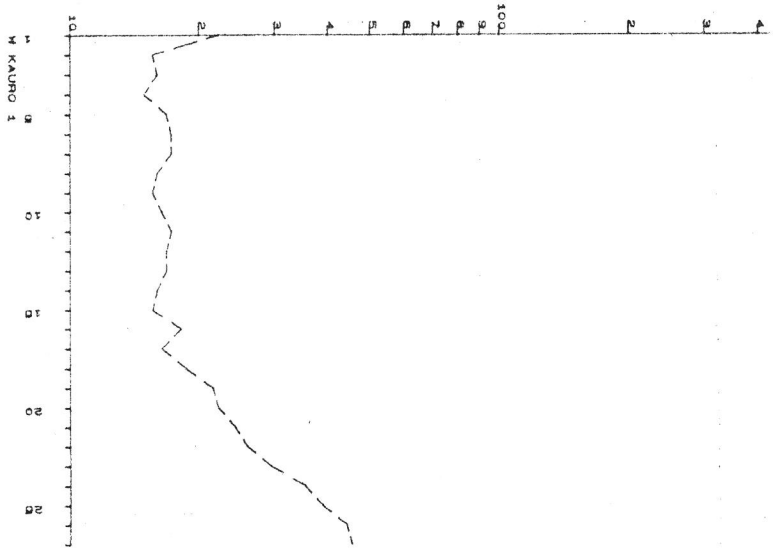

1000
100
10
1
5
10
15
20
25
30
35
40
45
W L/BORO 2

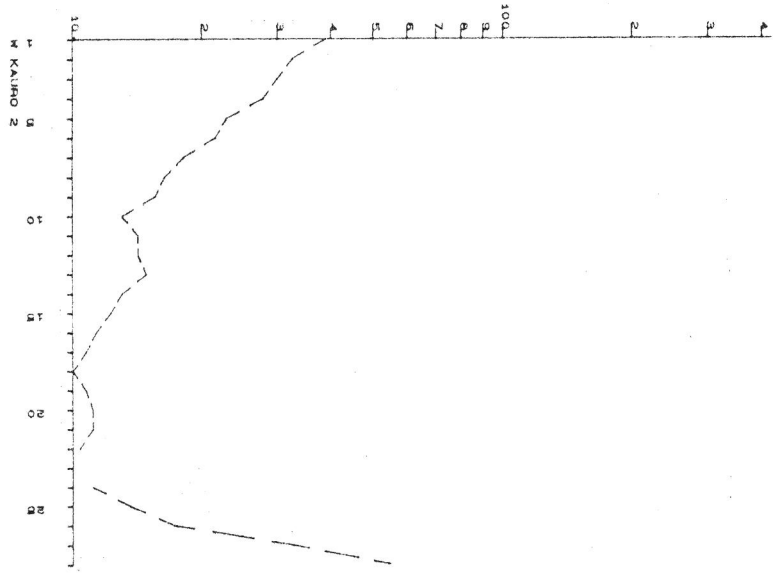
1

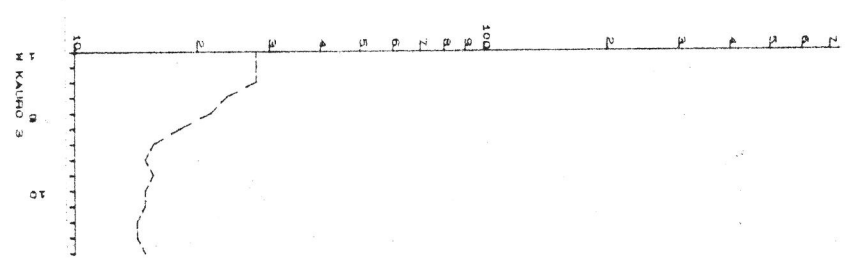
W L/SORO 5

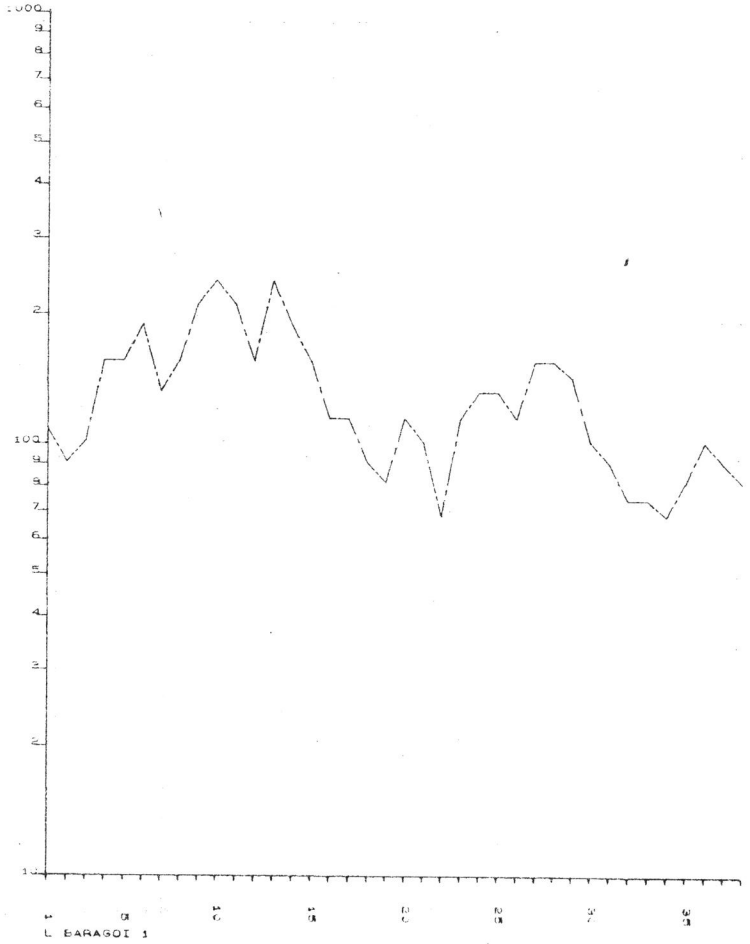

W L/SORO 4

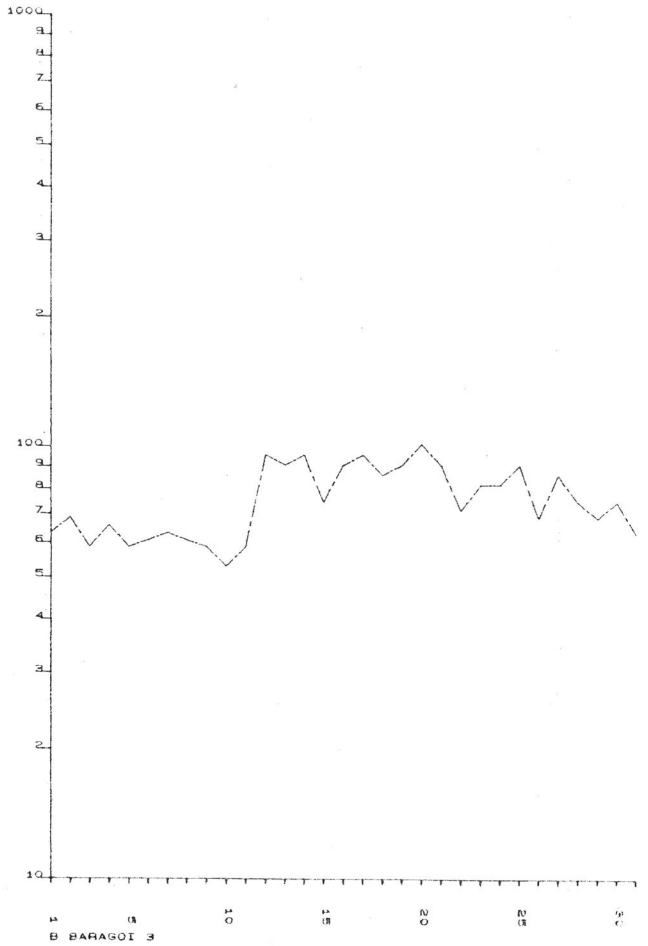
6
5
4
3
2
10
9
8
7
6
5
4
3
2
1
1
5
10
15
20
25
30
35
40
45
W L/SOAD 7

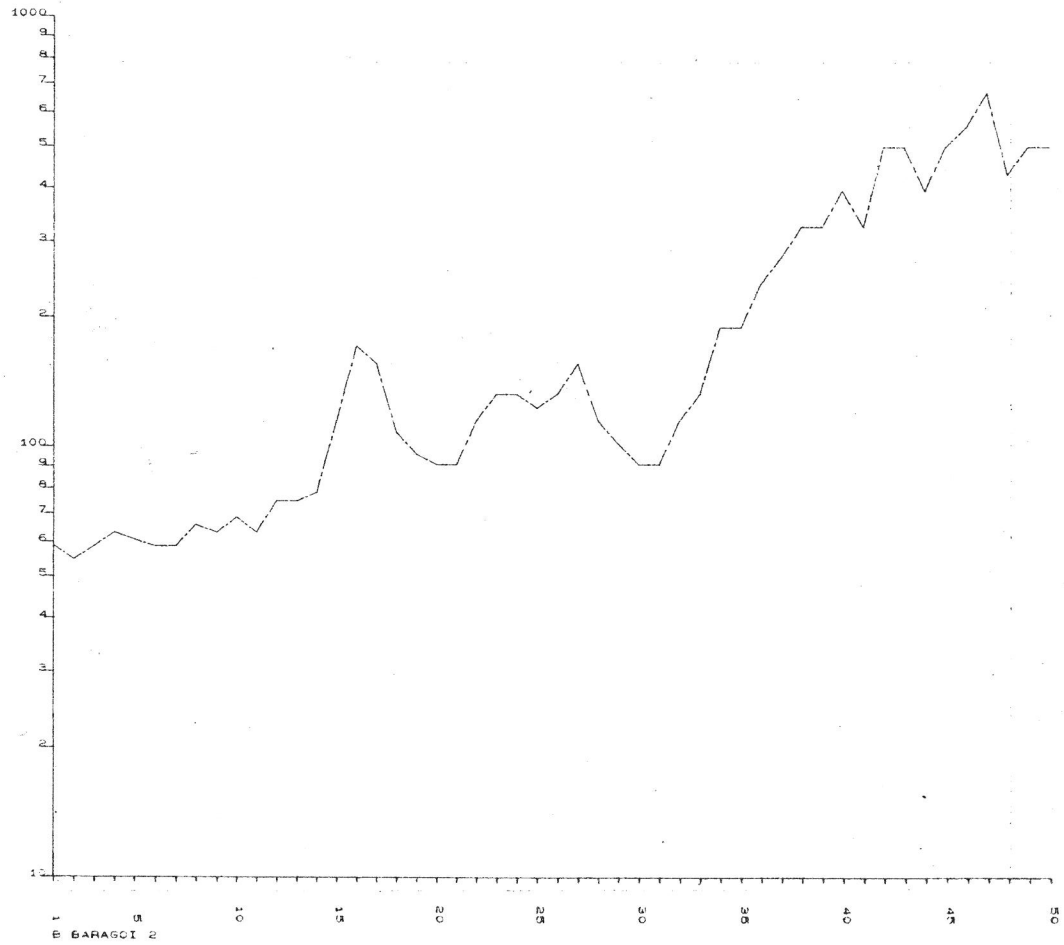

M KAURO 1


M KAURO 2

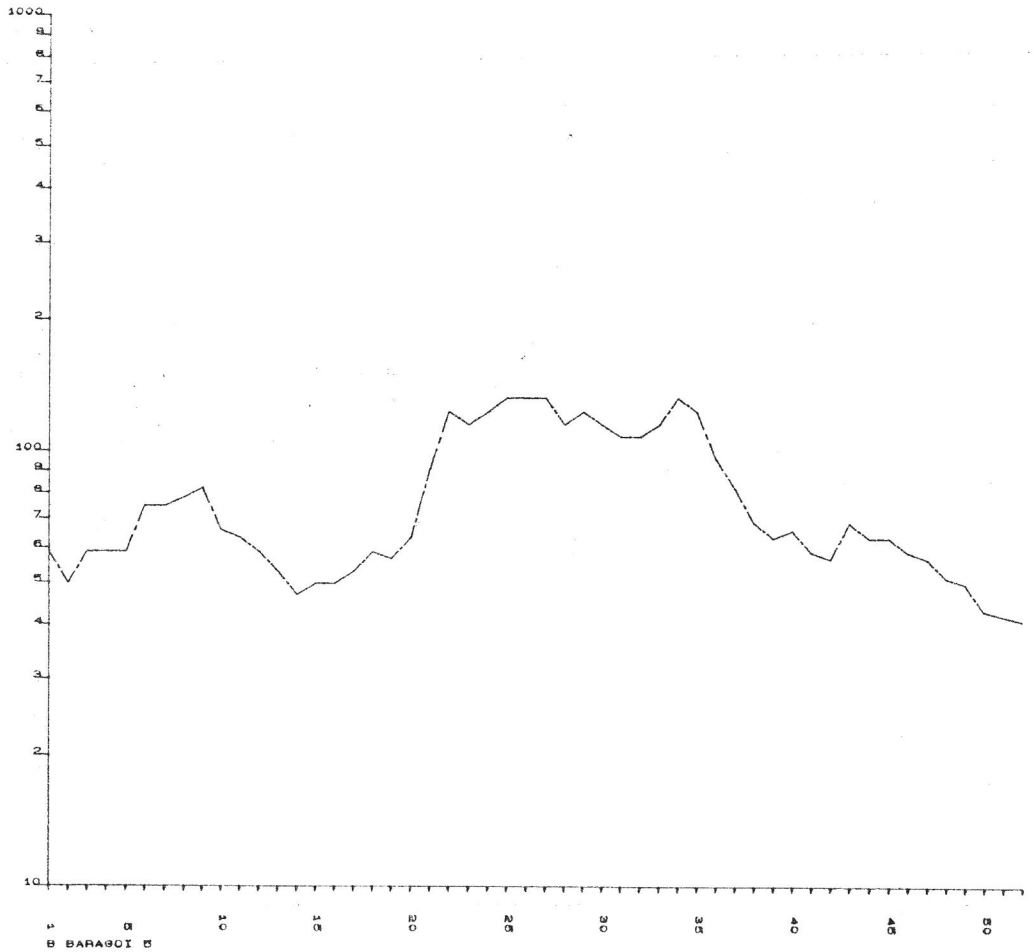

M KAURO 3

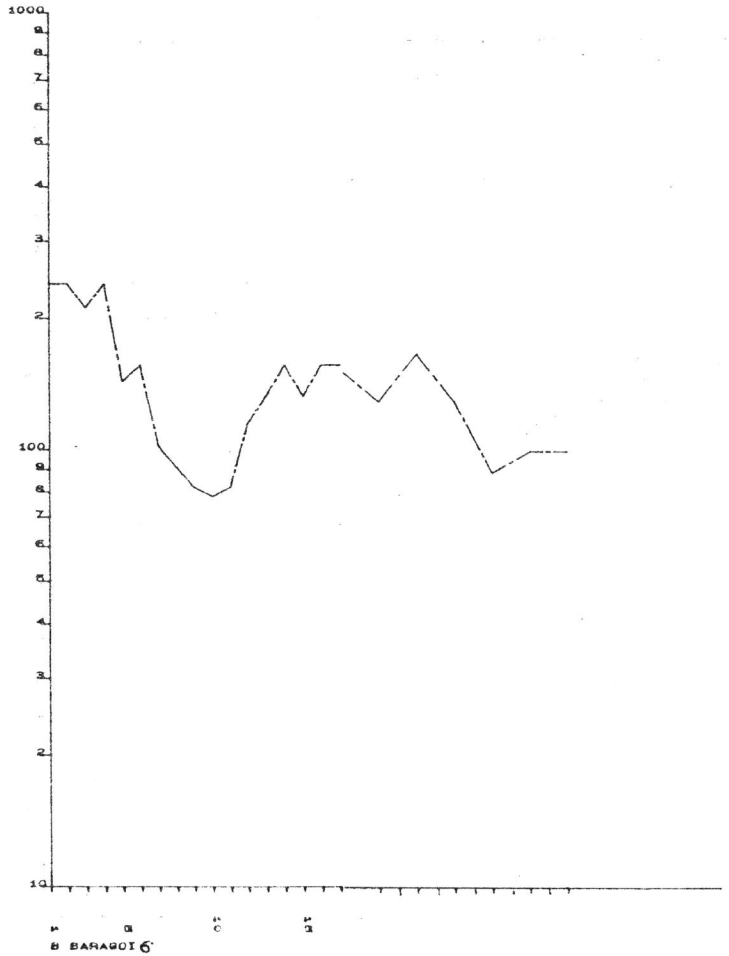

L BARAGOI 1

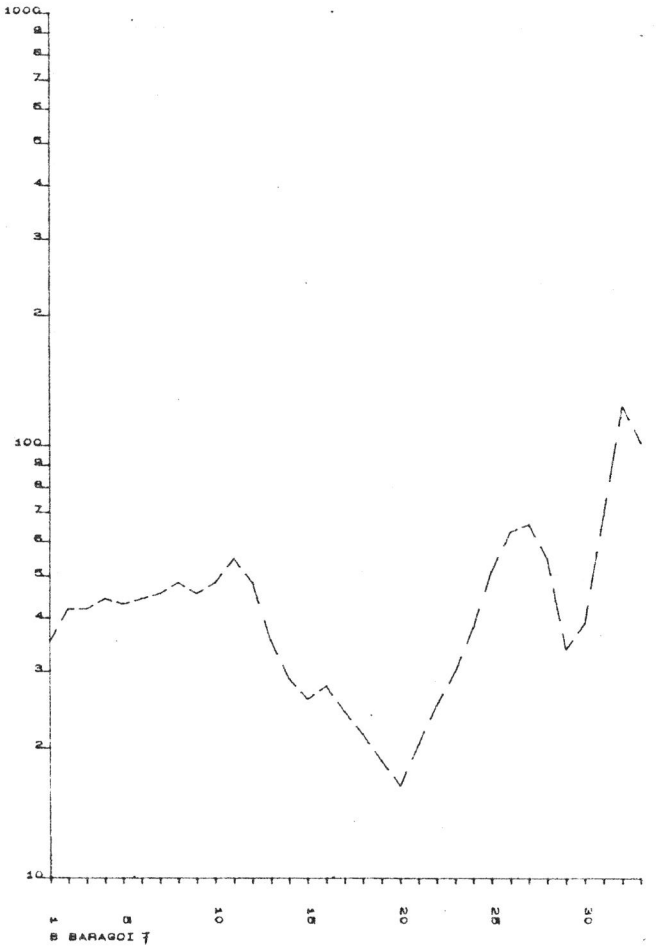

B BARAGOI 3

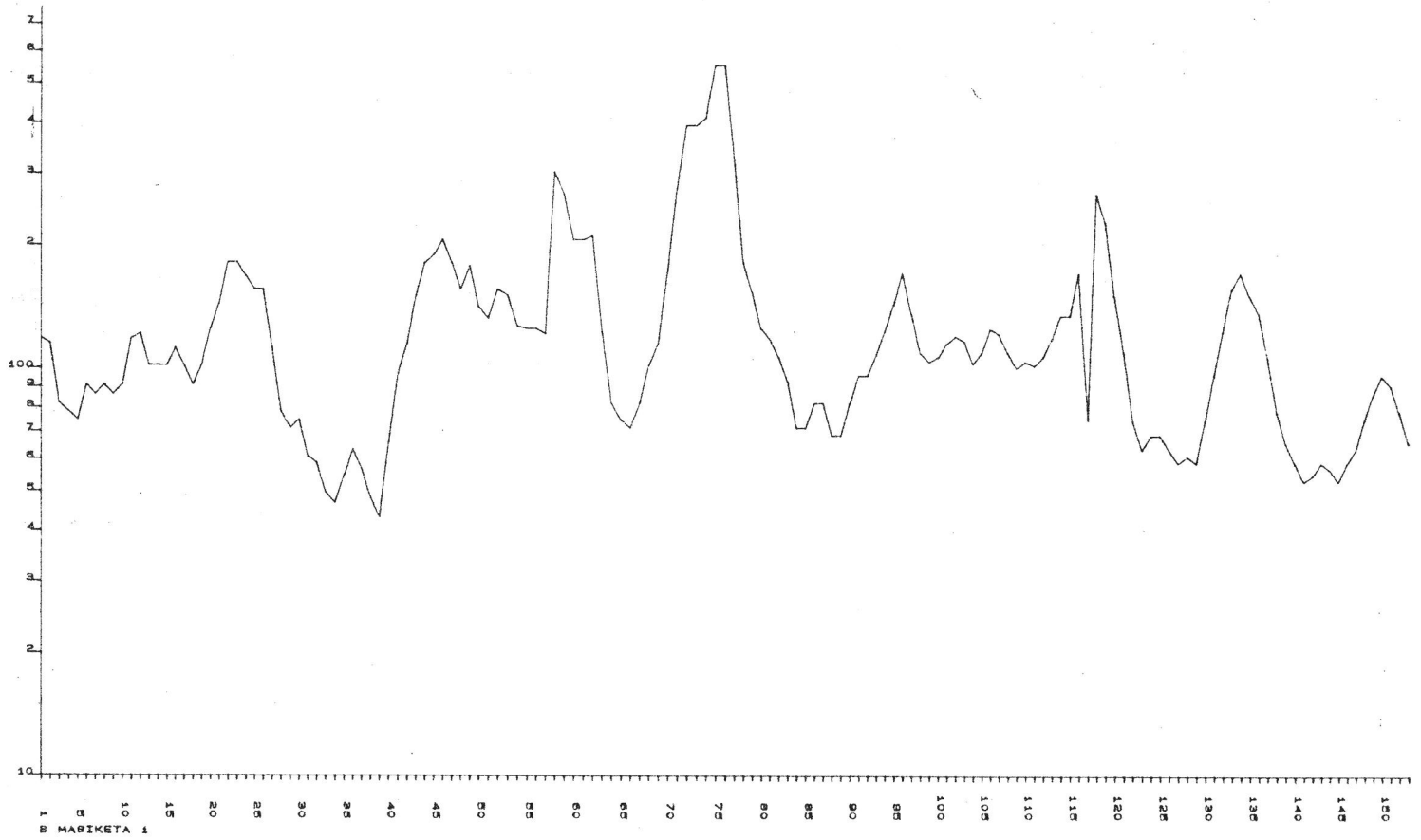

1000
100
10
1
5
10
15
20
25
30
35
40
45
50
B BARAGOI 2

100
9
8
7
6
5
4
3
2
1
0
1
5
10
15
20
25
30
35
40
45
50
55
60
E BARAGOI 4

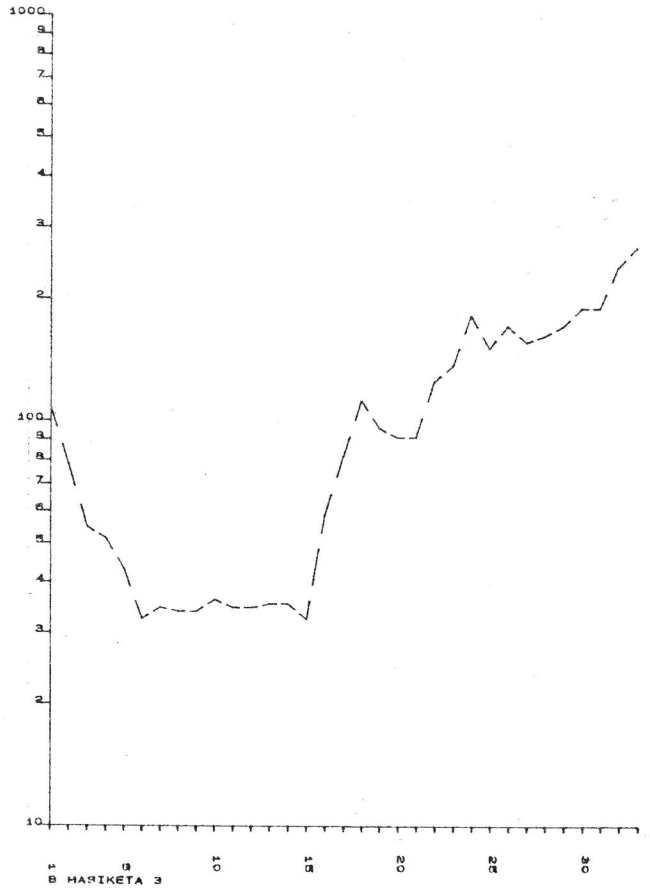

1000
100
10
1
5
10
15
20
25
30
35
40
45
50
B BARAGOI B

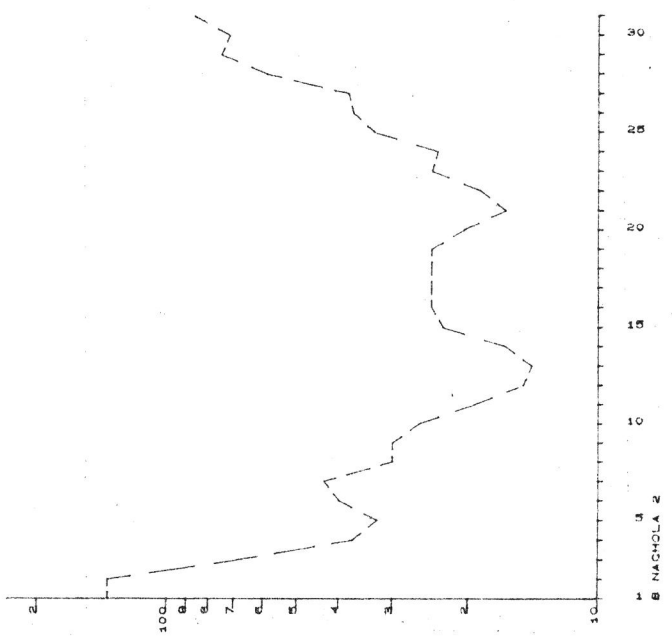

1000
100
10
1
5
10
15
B BARAGOI 6

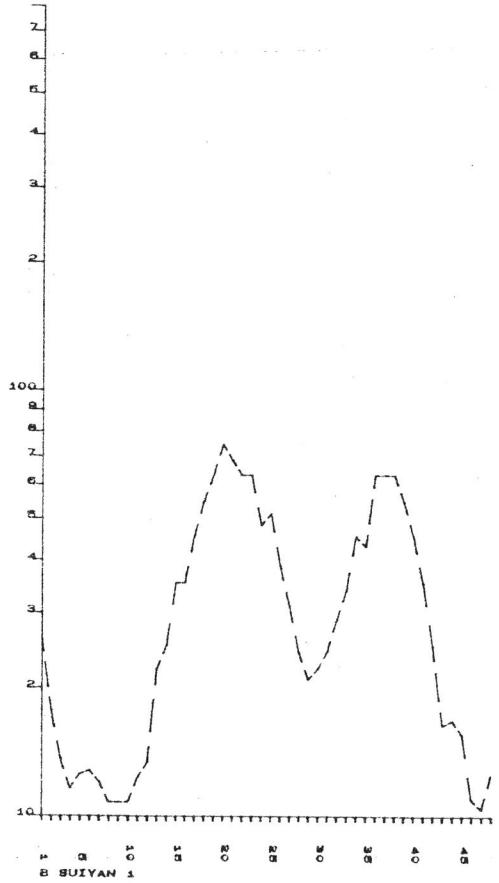

1000
100
10
1
5
10
15
20
25
30
B BARAGOI 7

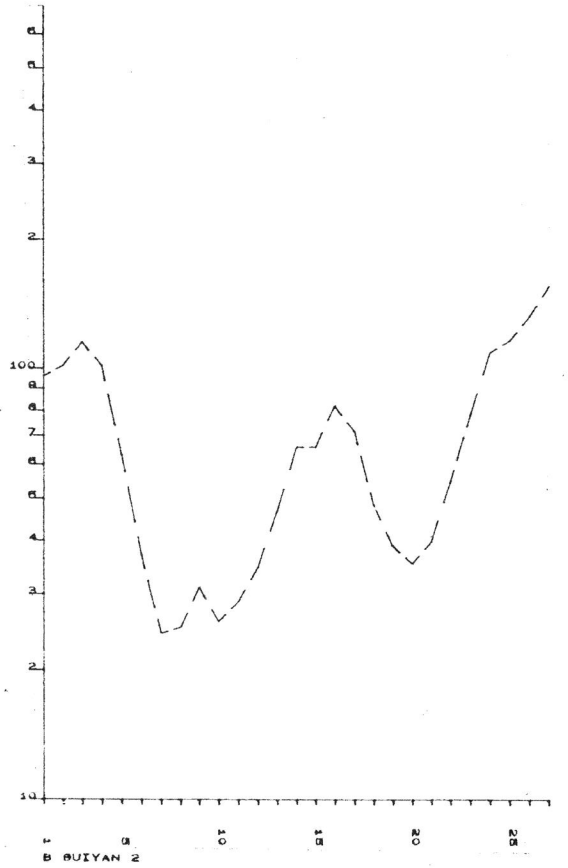

B MABIKETA 1

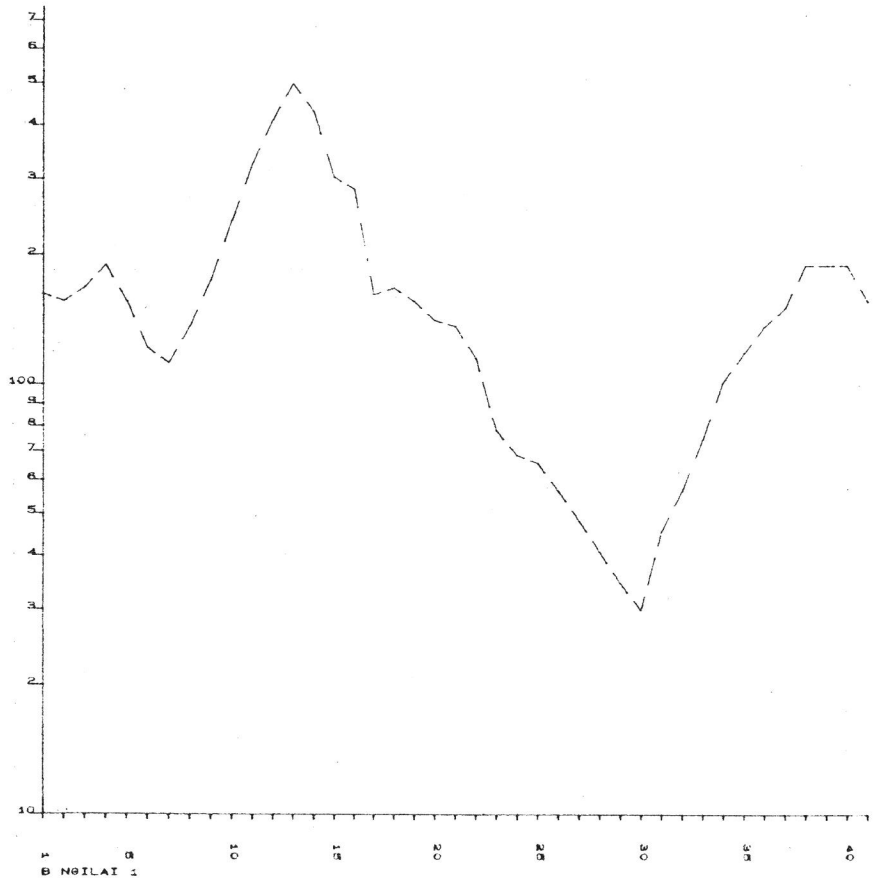
100
9
8
7
6
5
4
3
2
1
0
1
5
10
15
20
25
30
35
40
45
50
55
60
MASIKETA 2

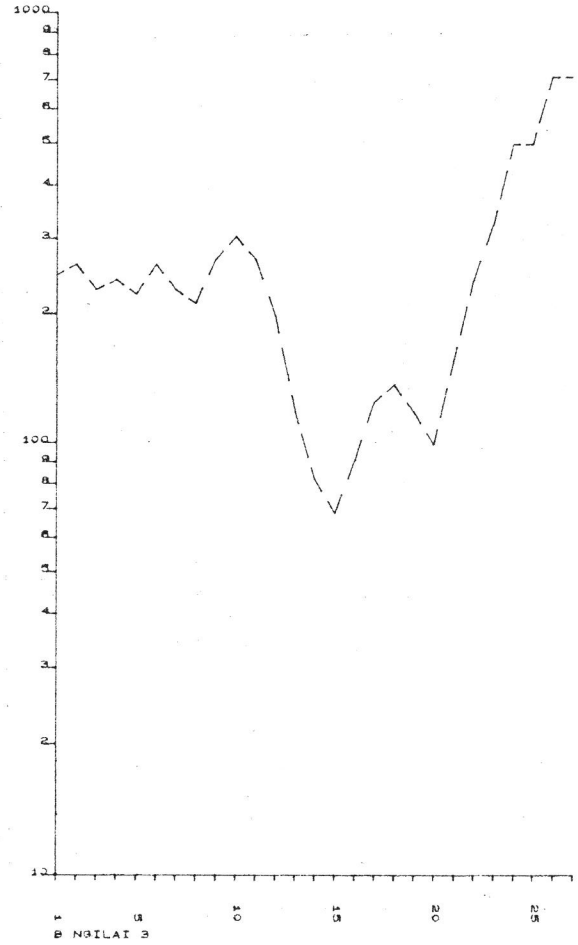

1000
100
10
1
5
10
15
20
25
30
B MARKETA 3

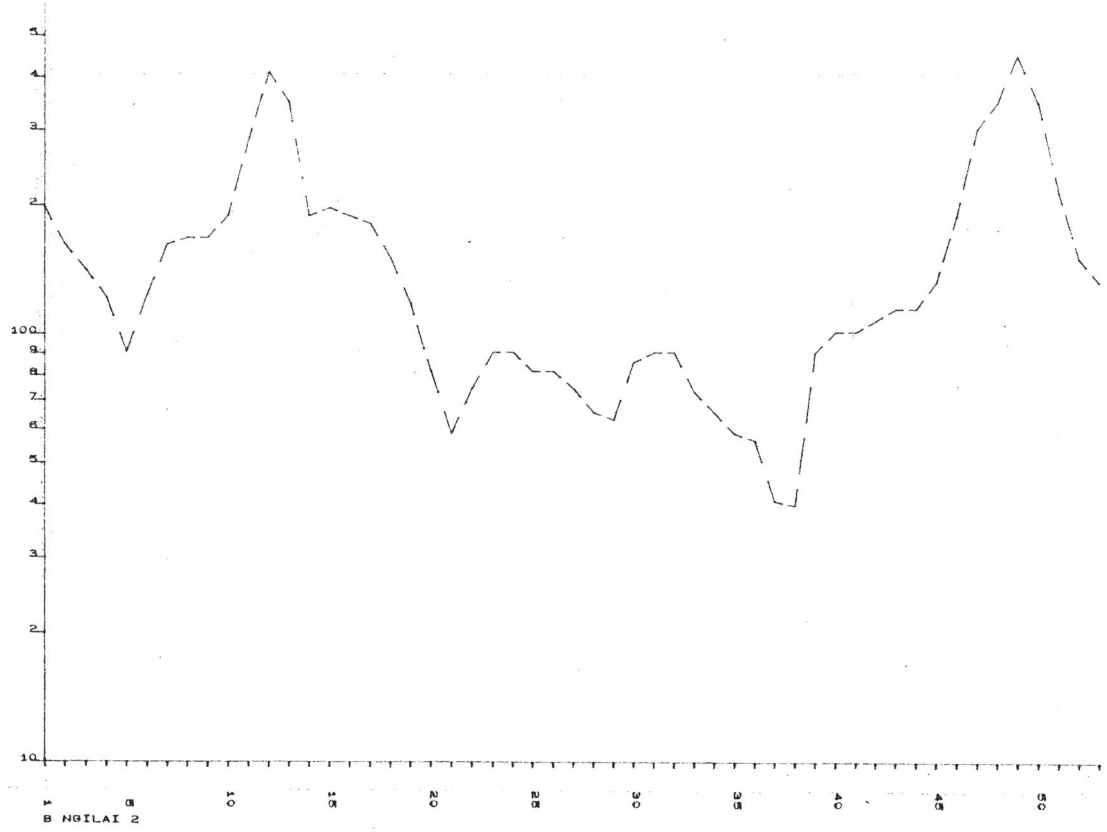

100
9
8
7
6
5
4
3
2
10
1
5
10
15
20
25
30
8 NAGHOLA 2

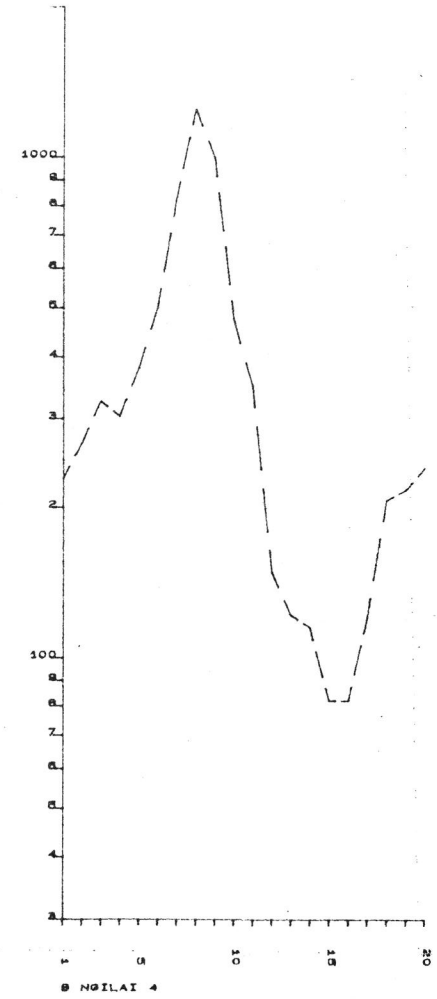

B BUIYAN 1

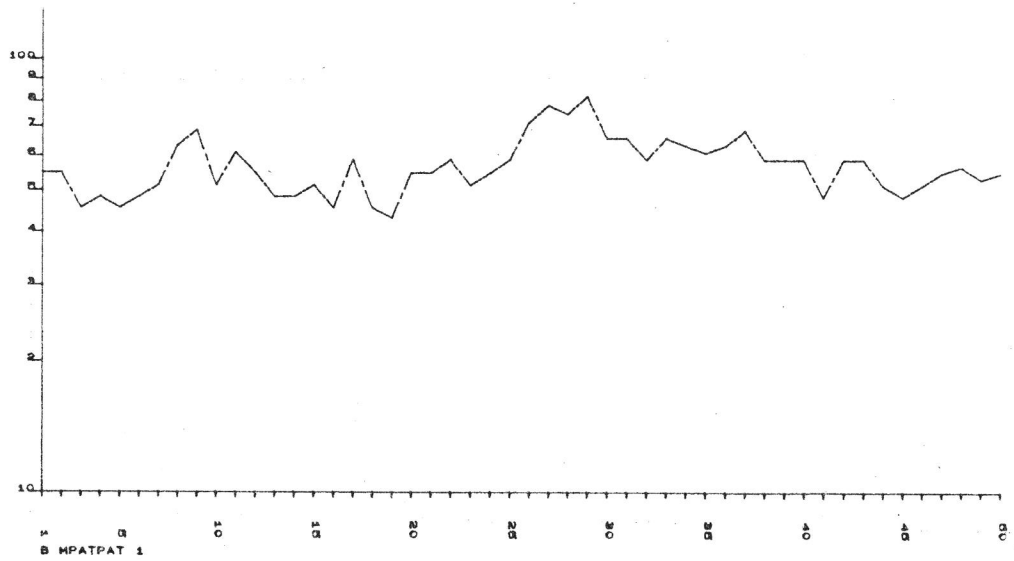

B BUIYAN 2


100
1
5
10
15
20
25
30
35
40
B NGILAI 1

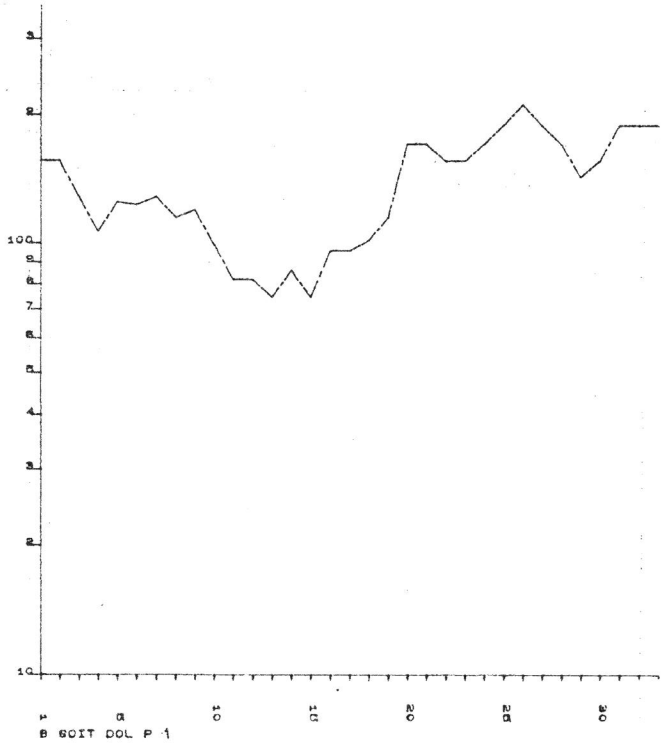

1000
100
1
5
10
15
20
25
B NGILAI 3

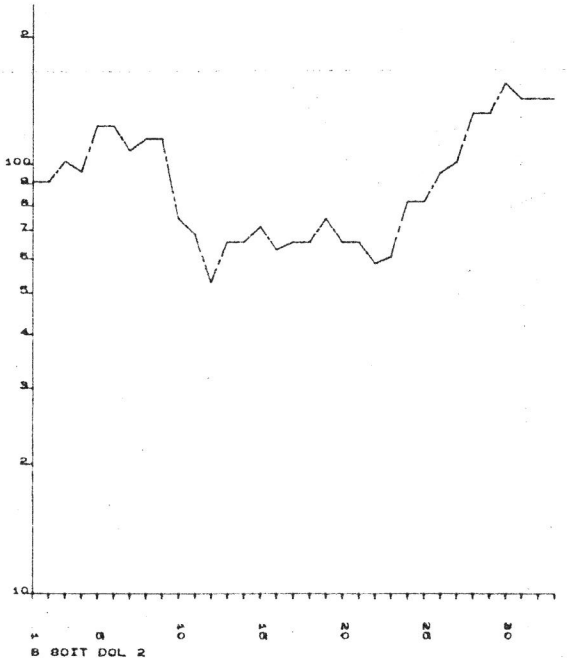

1000
100
10
1
5
10
15
20
25
30
35
40
45
50
B NGILAI 2

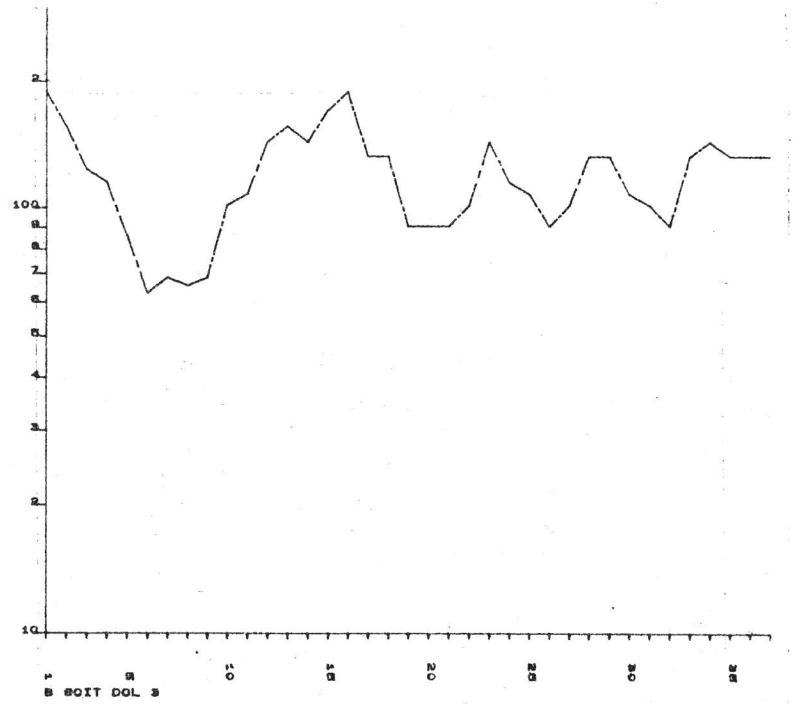

1000
100
1
5
10
15
20
B NGILAI 4

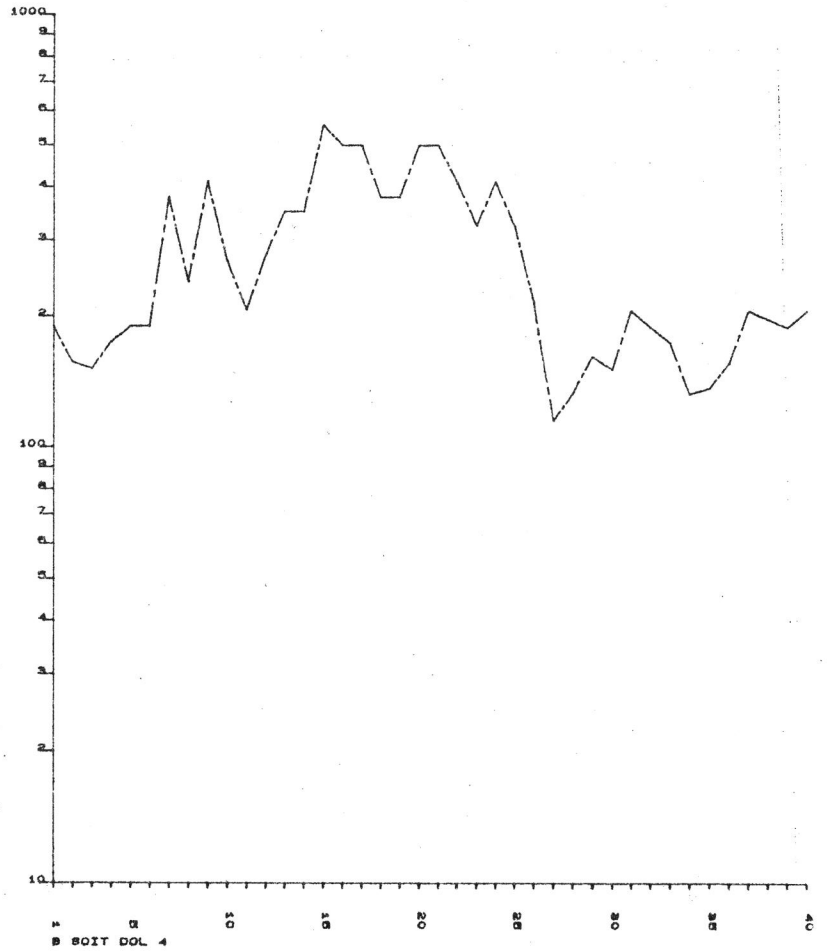

100
90
80
70
60
50
40
30
20
10
1
5
10
15
20
25
30
35
40
45
50
В МРАТРАТ 1

130
125
120
115
110
105
100
95
90
85
80
75
70
65
60
55
10
2
3
4
5
6
7
8
9
100
B NTIL 1

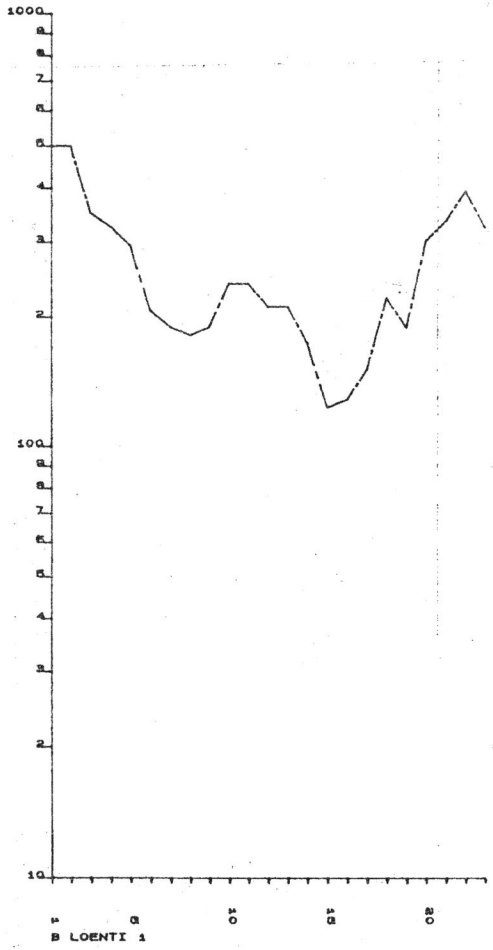

100
1
5
10
15
20
25
30
B GOIT DOL P 1

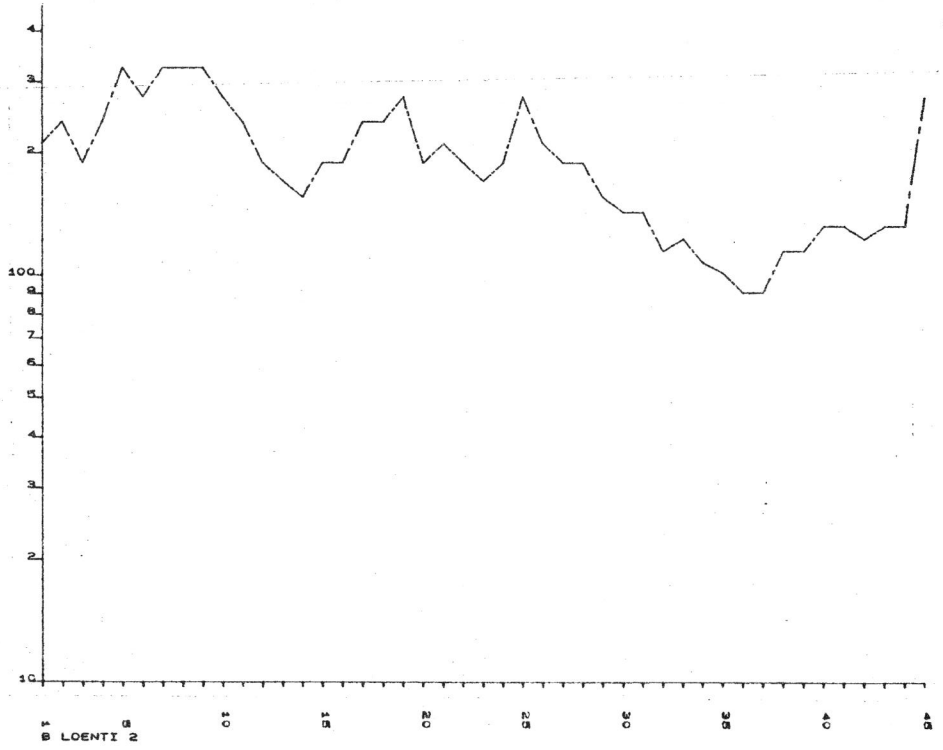

100
1
5
10
15
20
25
30
B GOIT DOL 2

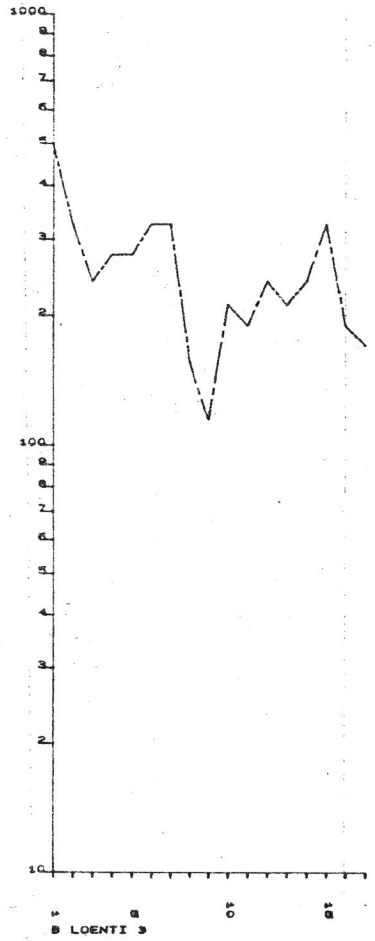

100
10
1
5
10
15
20
25
30
35
B SOIT DOL 3

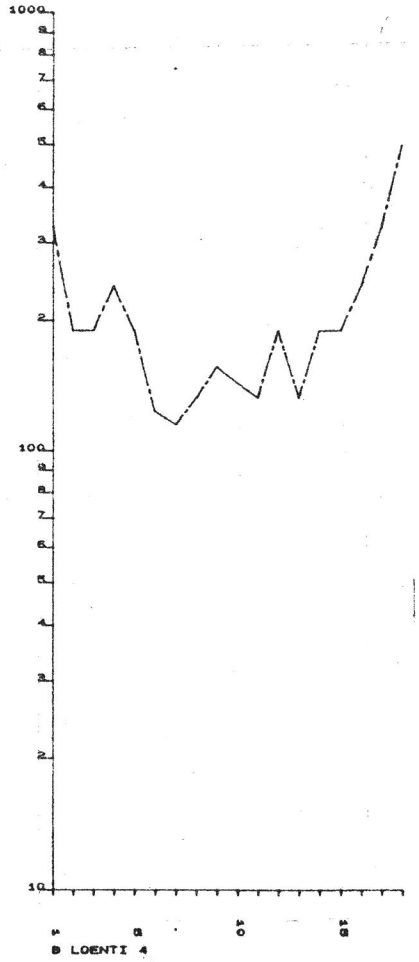

1000
100
10
1
5
10
15
20
25
30
35
40
B SOIT DOL 4

1
E SOIT COL 5


1000
100
10
1
5
10
15
20
B LOENTI 1

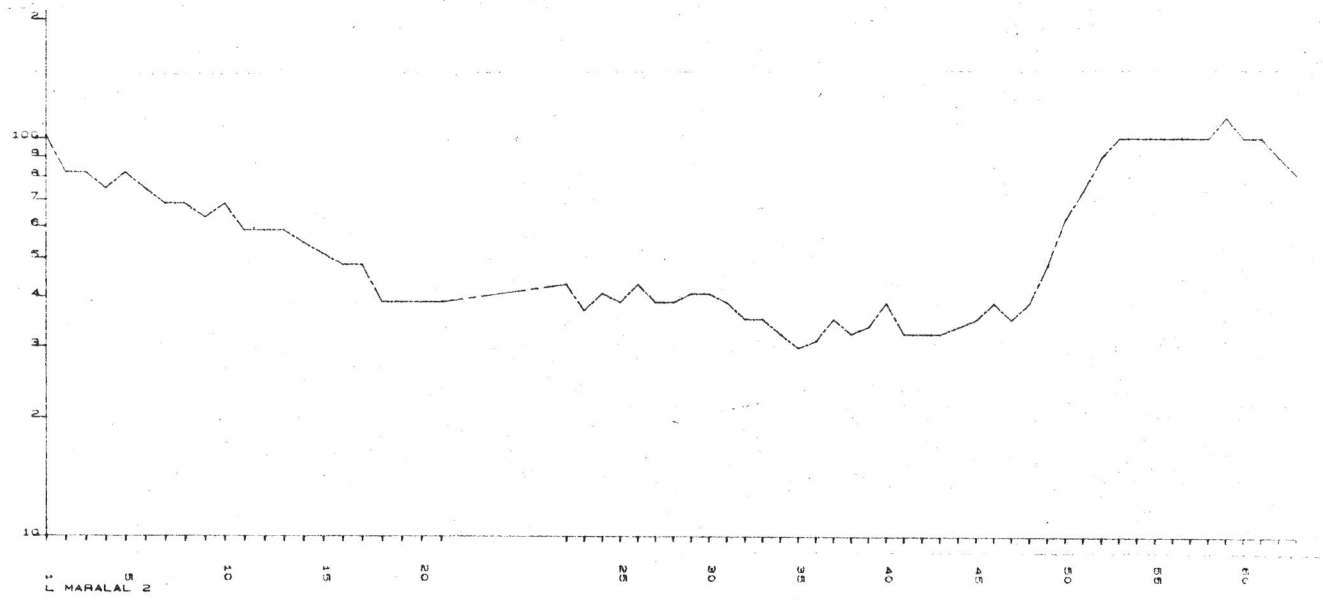

100
10
1
5
10
15
20
25
30
35
40
45
B LOENTI 2

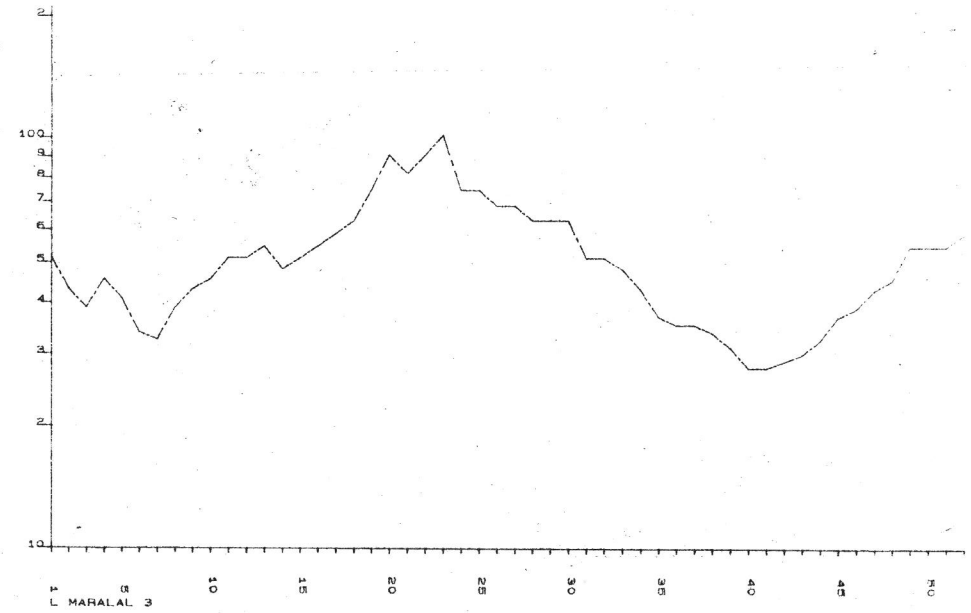

1000
100
10
B LOENTI 3


1000
100
10
B LOENTI 4

6
5
4
3
2
100
9
8
7
6
5
4
3
2
10
1
5
10
15
20
25
30
35
40
45
50
55
LOENTI

L MARALAL 1

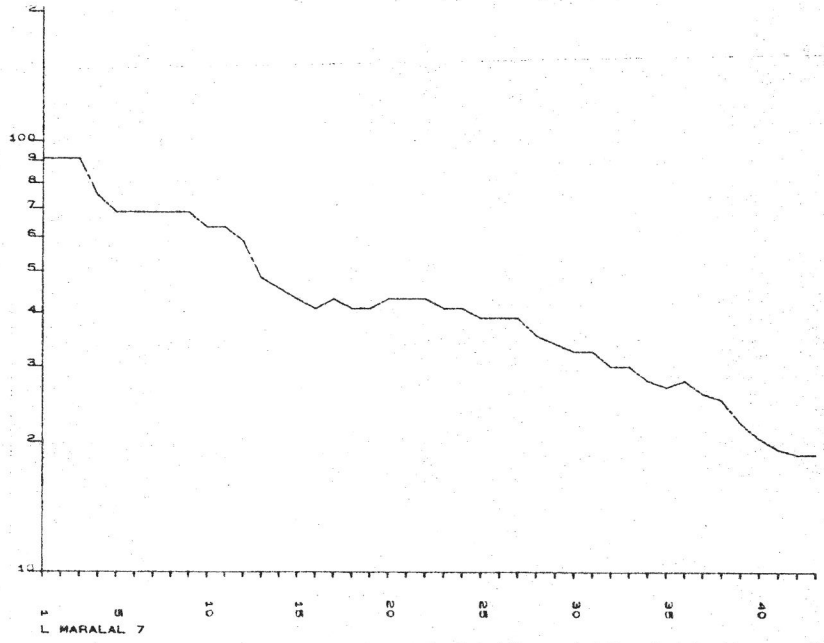

2
100
9
8
7
6
5
4
3
2
10
1
5
10
15
20
25
30
35
40
45
50
55
60
L MARALAL 2

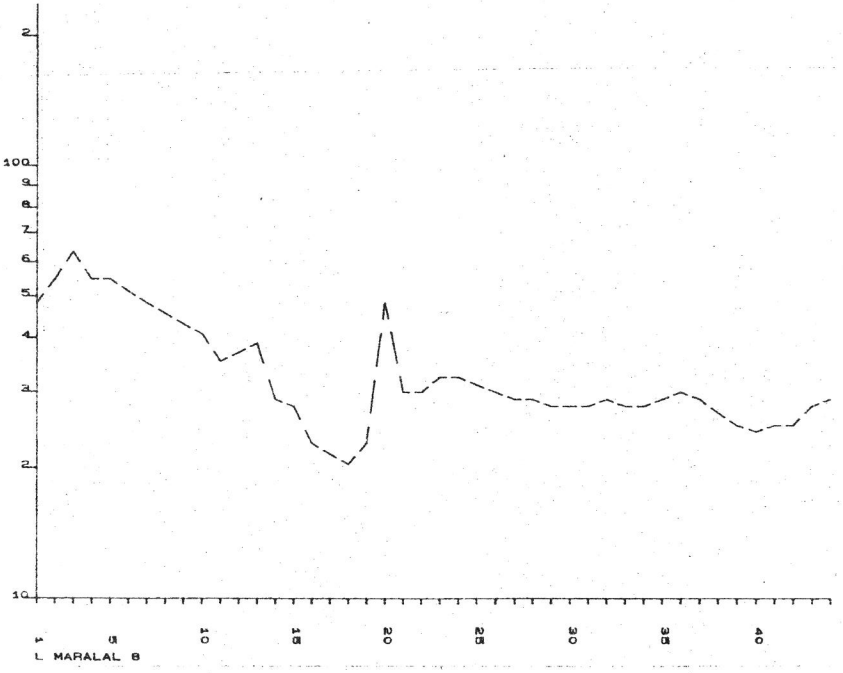

2
100
9
8
7
6
5
4
3
2
10
1
5
10
15
20
25
30
35
40
45
50
L MARALAL 3

L MARALAL 4

100
9
8
7
6
5
4
3
2
1
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
MARALAL 5

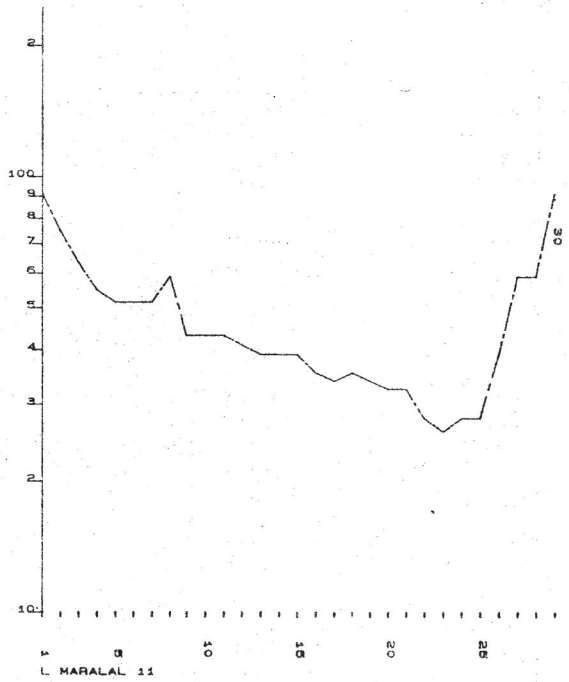
100
9
8
7
6
5
4
3
2
1
1
5
10
15
20
25
30
35
40
45
50
55
60
65
70
L MARALAL 6


100
9
8
7
6
5
4
3
2
10
1
5
10
15
20
25
30
35
40
L MARALAL 7

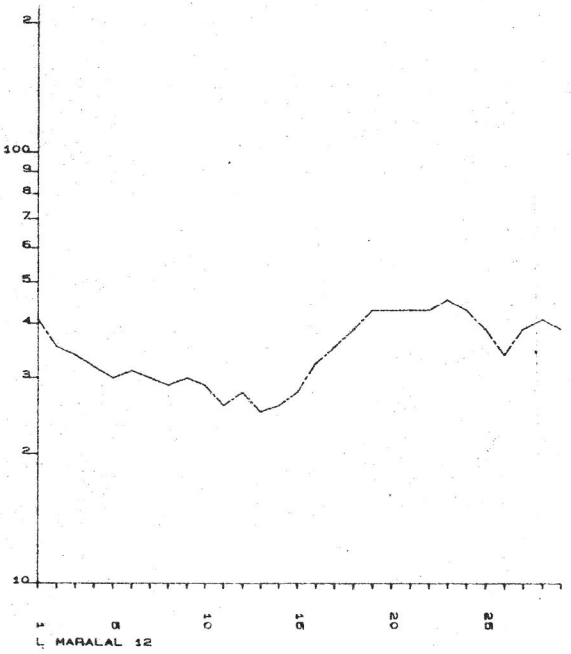

2
100
9
8
7
6
5
4
3
2
10
1
5
10
15
20
25
30
35
40
L MARALAL 8

L MARALAL 9

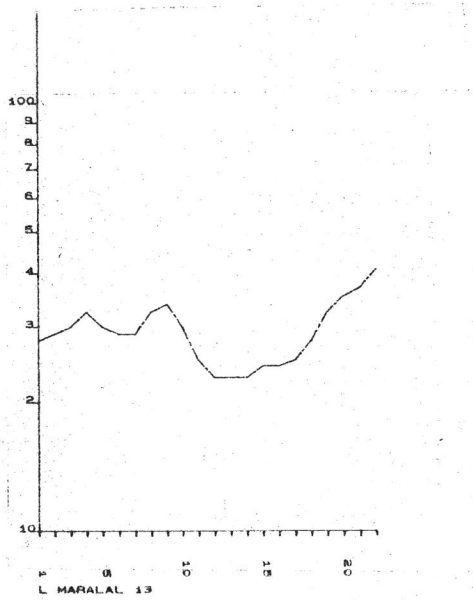

L MARALAL 10

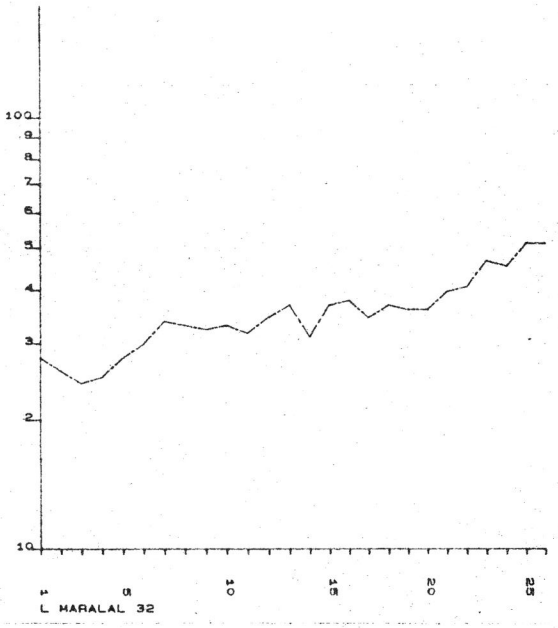


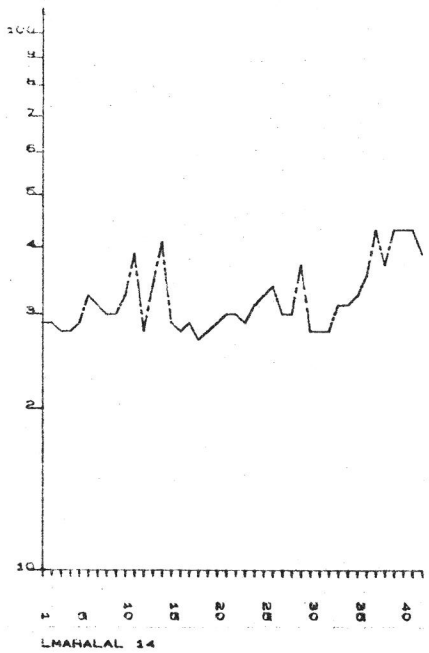

L MARALAL 11

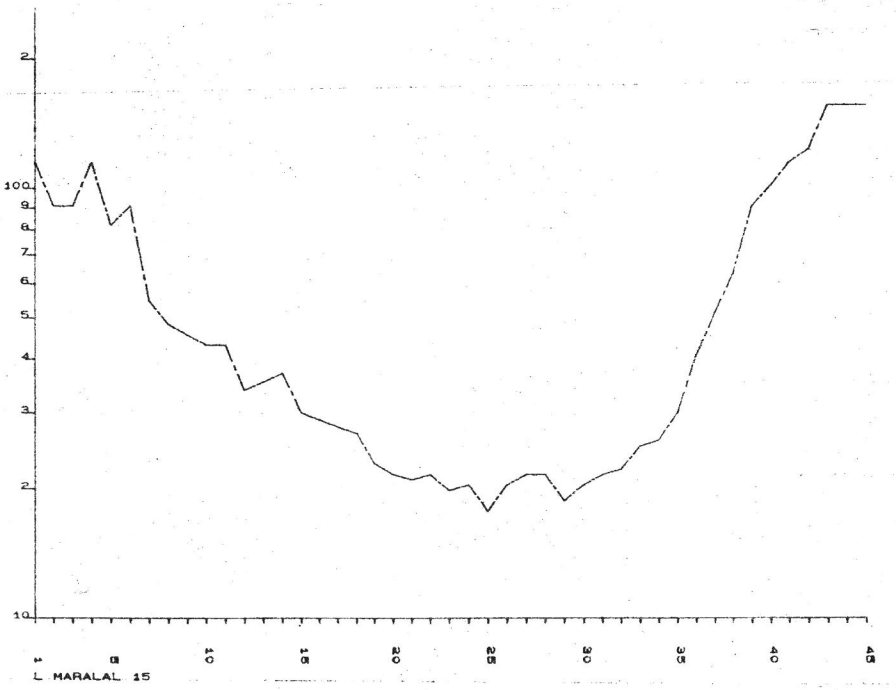



L MARALAL 12

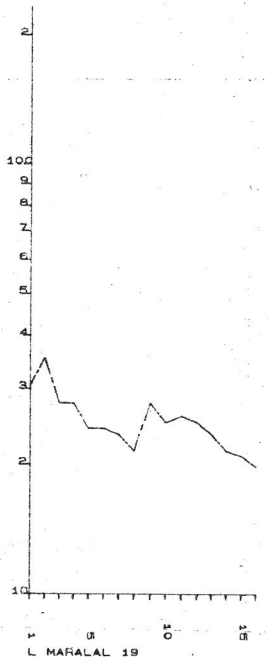

100
9
8
7
6
5
4
3
2
10
L MARALAL 13

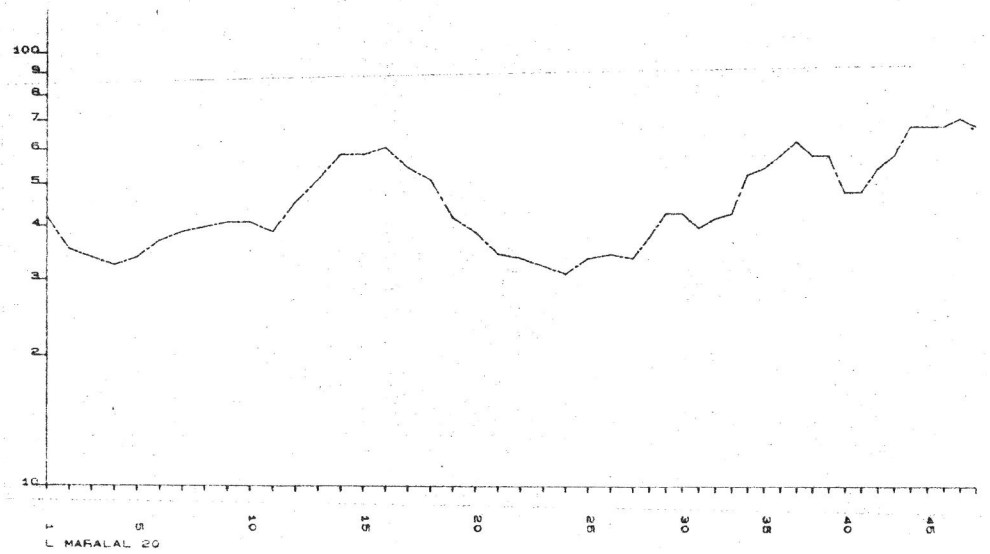

100
9
8
7
6
5
4
3
2
10
L MARALAL 32

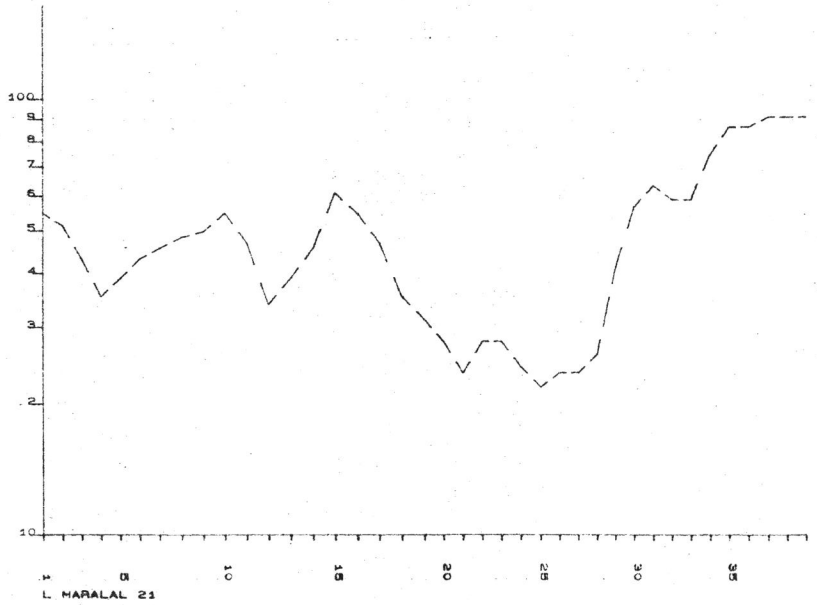

LMARALAL 14

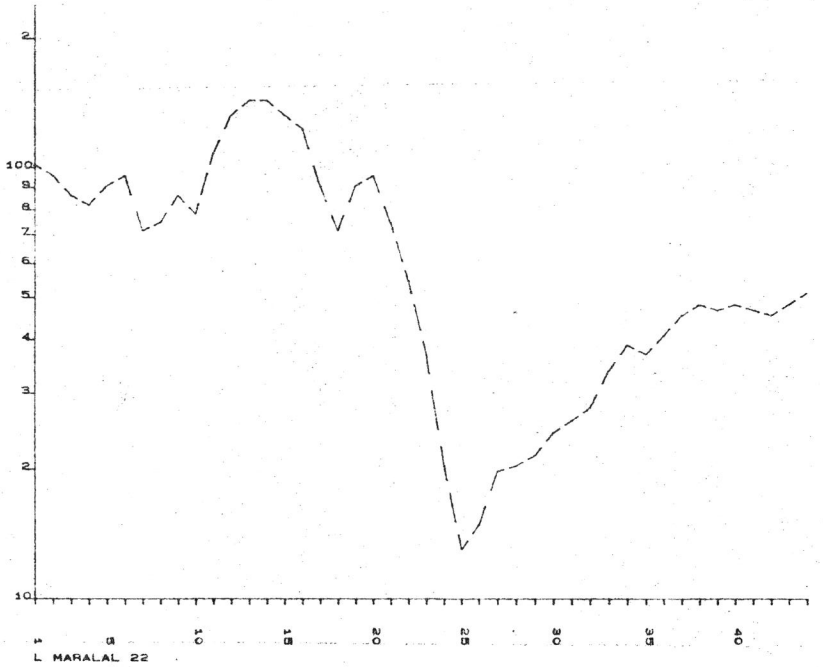

L MARALAL 15

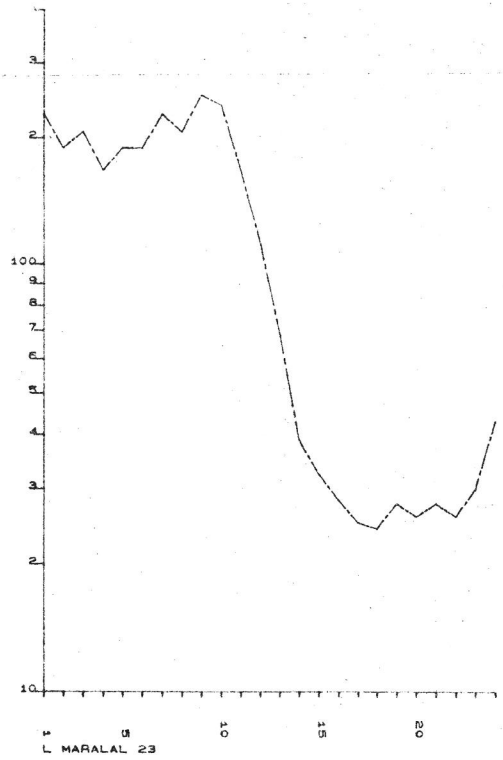
L MARALAL 16
L MARALAL 17
L MARALAL 18


L MARALAL 19

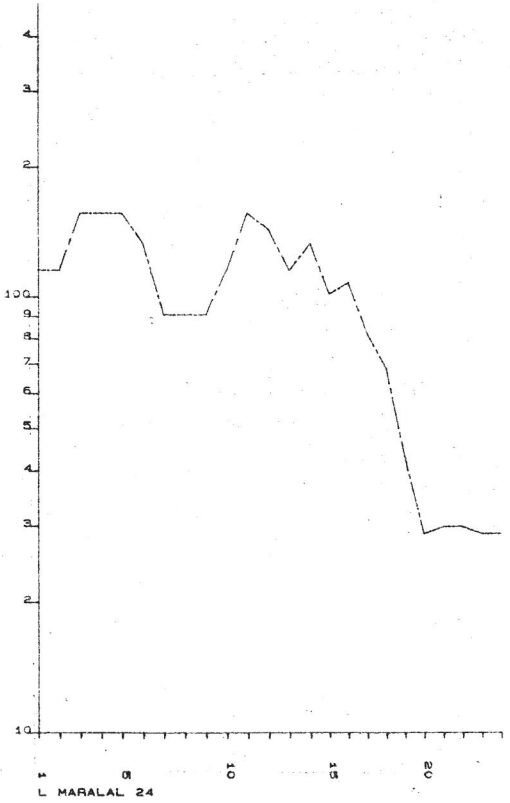

L MARALAL 20


100
90
80
70
60
50
40
30
20
10
1
5
10
15
20
25
30
35
L MARALAL 21


100
90
80
70
60
50
40
30
20
10
1
5
10
15
20
25
30
35
40
L MARALAL 22




L MARALAL 23



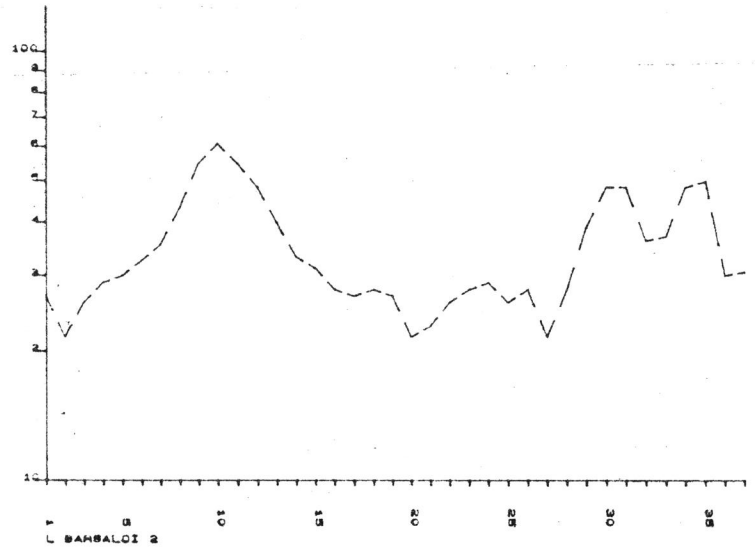

L MARALAL 24

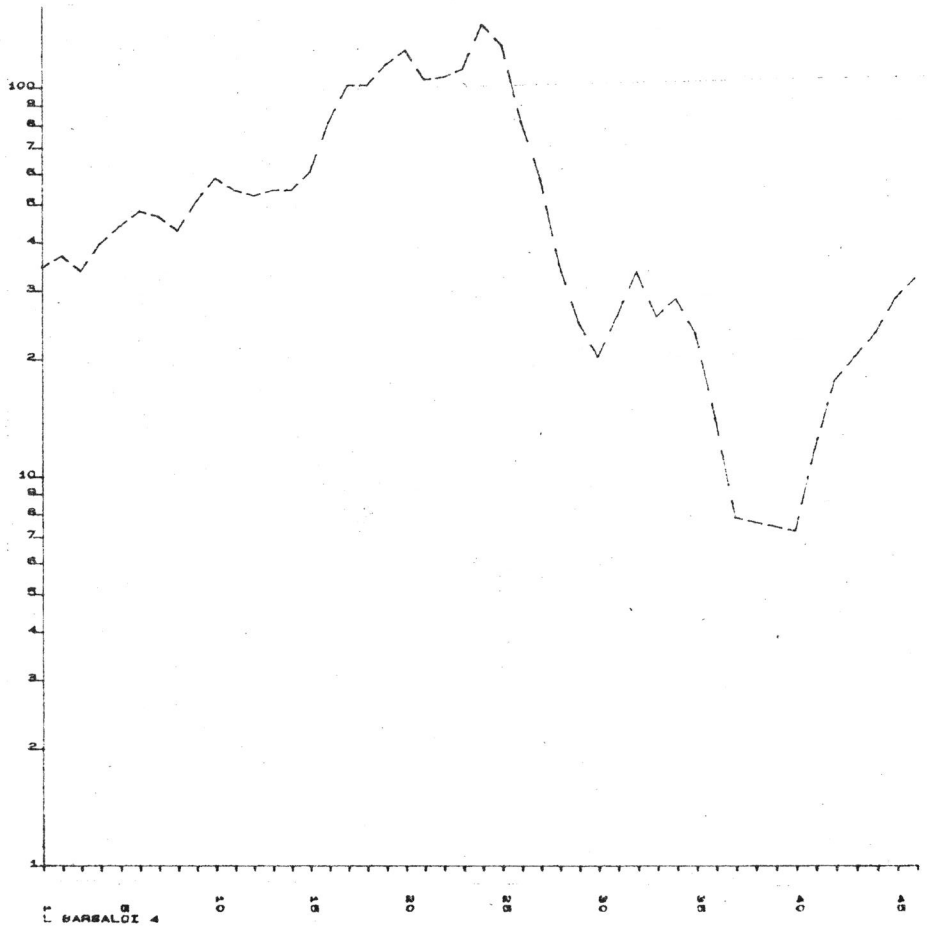
100
9
8
7
6
5
4
3
2
10
1
5
10
15
L MARALAL 28

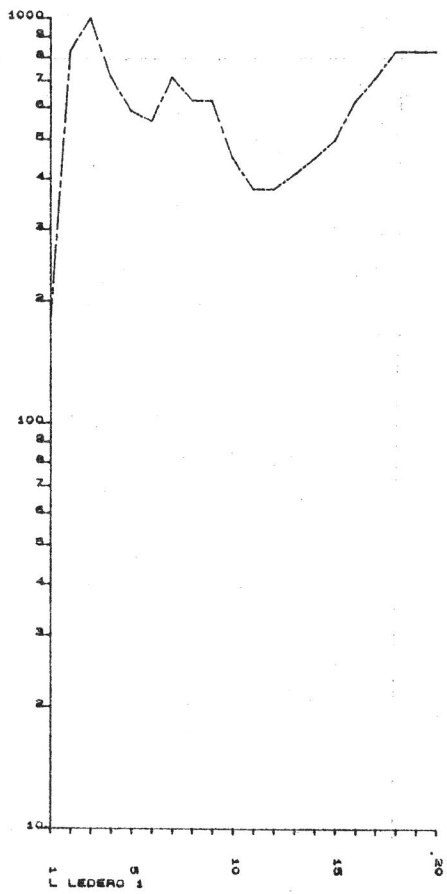

2
100
9
8
7
6
5
4
3
2
10
1
5
10
15
20
25
30
L MARALAL 26

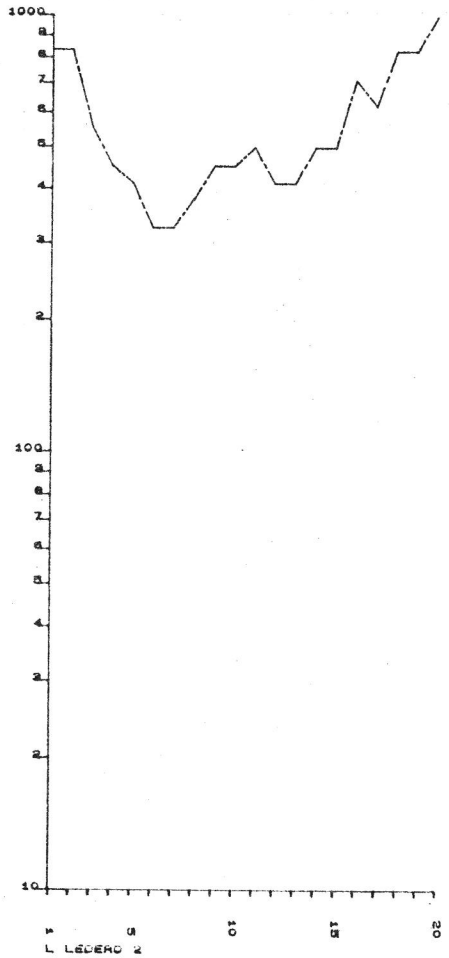
L BARBALOI 3


L BARBALOI 1


100
1
L BARBALOI 2


100
1
L BARBALOI 4

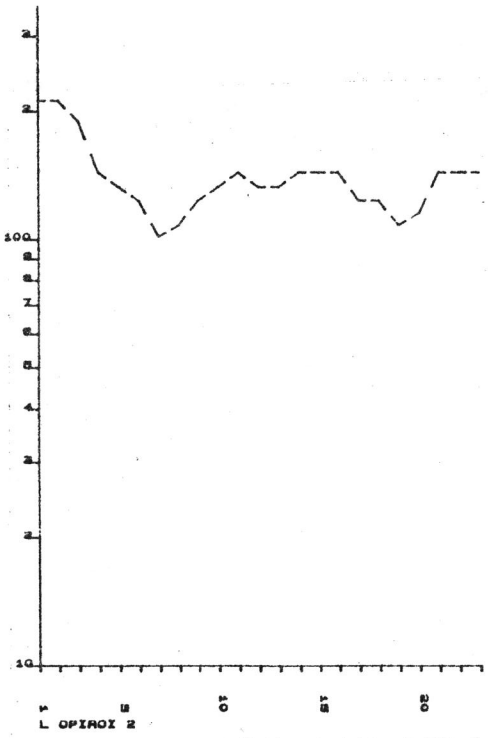

1000
100
10
1
5
10
15
20
L LEDERO 1

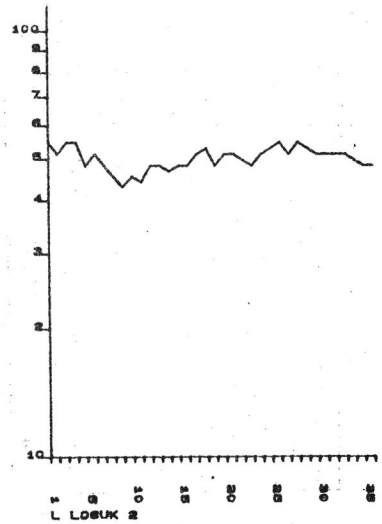

1000
100
10
1
5
10
15
20
L LEDERO 2

1000
100
L. LEDERO 3

L LOBUK 1


L OPIROI 1


L OPIROI 2

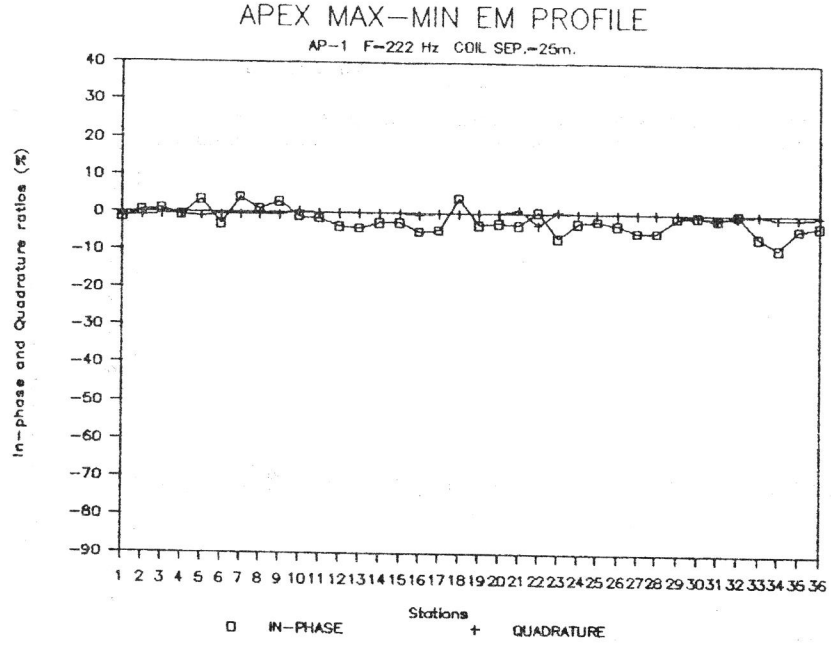

L LOGUK 2

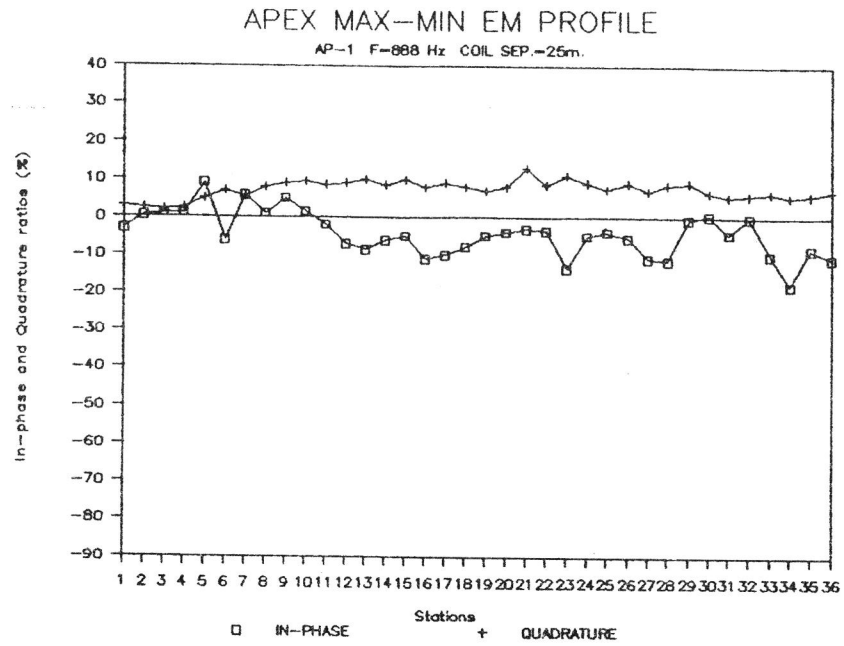
# Appendix 3.4

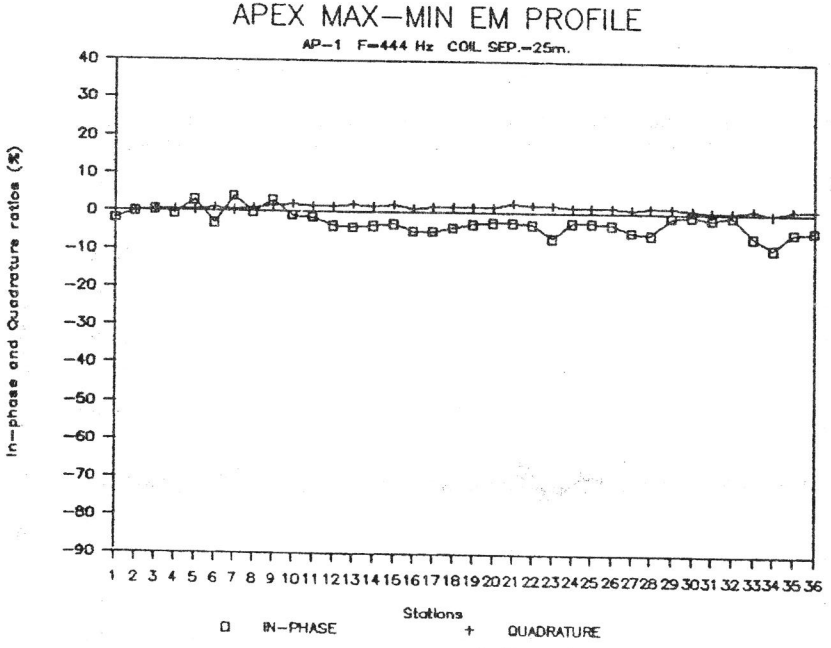
## Apex Max - Min Electromagnetic Profiles

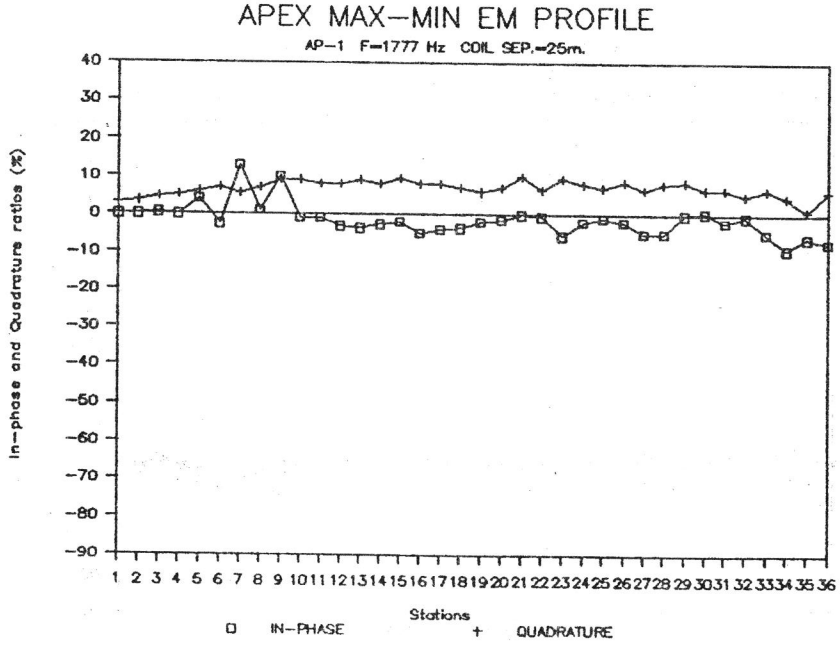
## Appendix 3.4 Apex Max - Min Electromagnetic Profiles (Wamba Town)

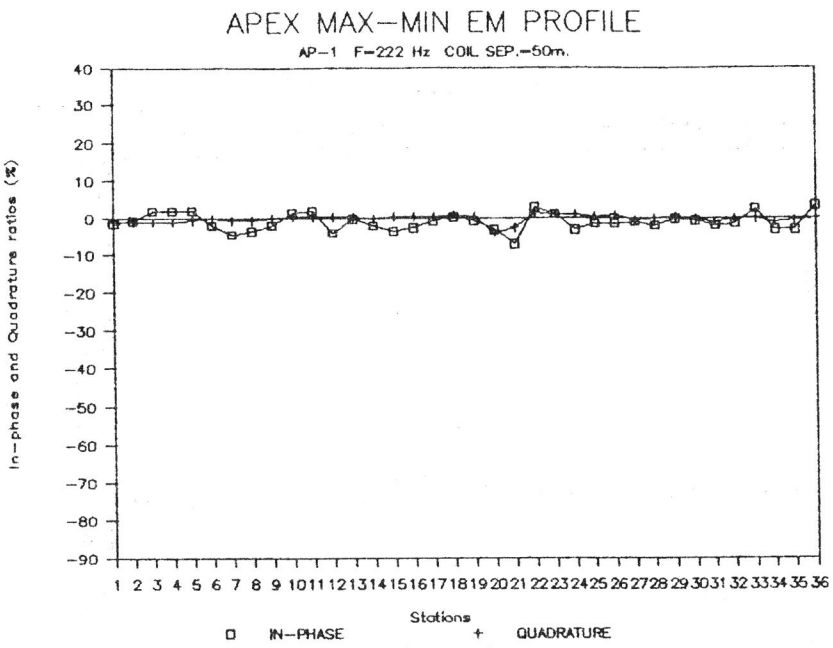
| | AP | Coil Seperation (m) | Frequencies (Hz) |
|---|---|---|---|
| 1. | AP - 1 | 25 | 222, 444, 888, 1777 Hz |
| 2. | AP - 1 | 25 | 3555 |
| | | 50 | 222, 444 |
| 3. | AP - 1 | 50 | 888, 1777, 3555 |
| 4. | AP - 1 | 100 | 222, 444, 888, 1777 |
| 5. | AP - 1 | 100 | 3555 |
| | AP - 2 | 50 | 888, 1777 |
| 6. | AP - 2 | 50 | 3555 |
| | | 100 | 888, 1777, 3555 |
| 7. | AP - 2 | 100 | 3555 |

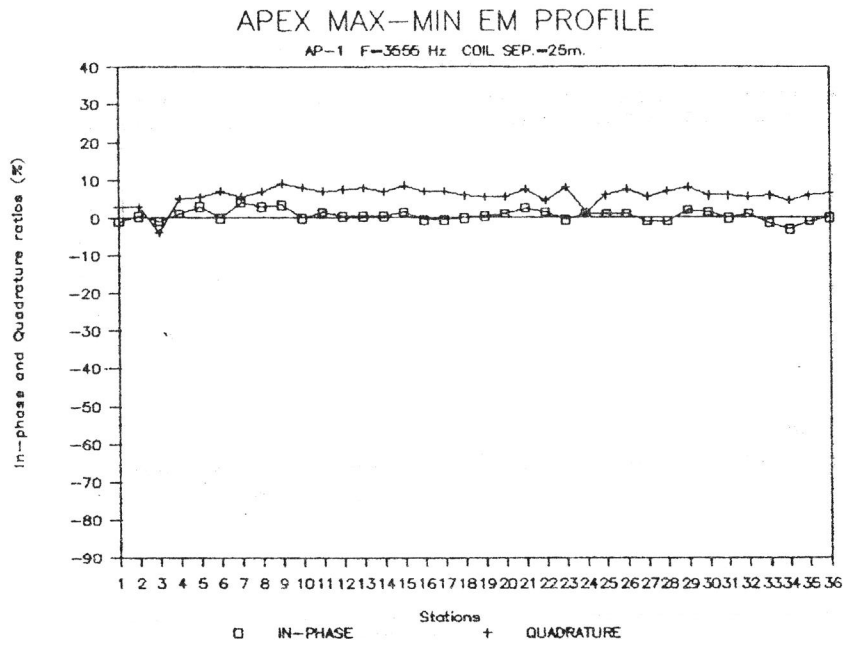

APEX MAX–MIN EM PROFILE
AP–1 F=222 Hz COIL SEP.=25m.
In–phase and Quadrature ratios (%)
Stations
IN–PHASE
QUADRATURE

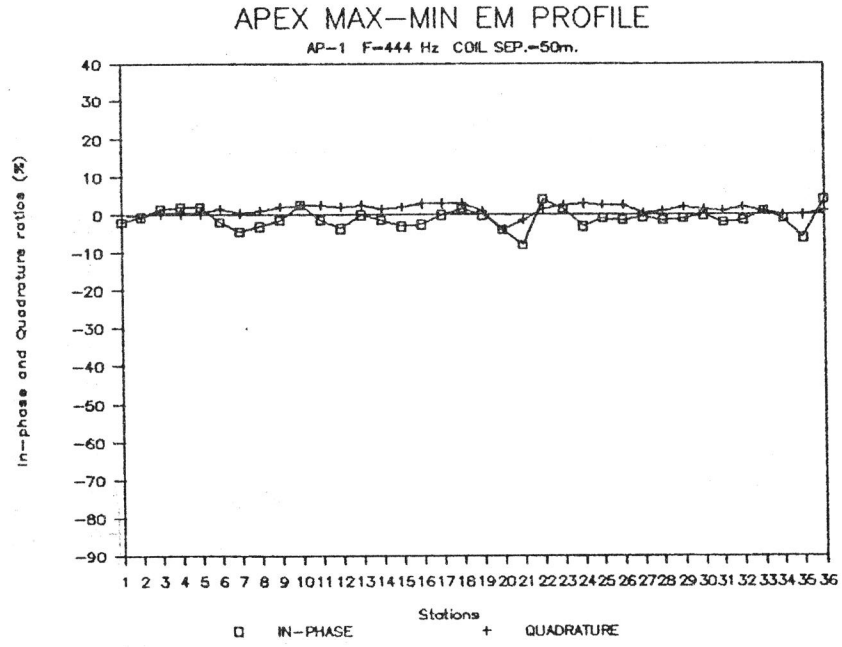

APEX MAX–MIN EM PROFILE
AP–1 F=888 Hz COIL SEP.=25m.
In–phase and Quadrature ratios (%)
Stations
IN–PHASE
QUADRATURE

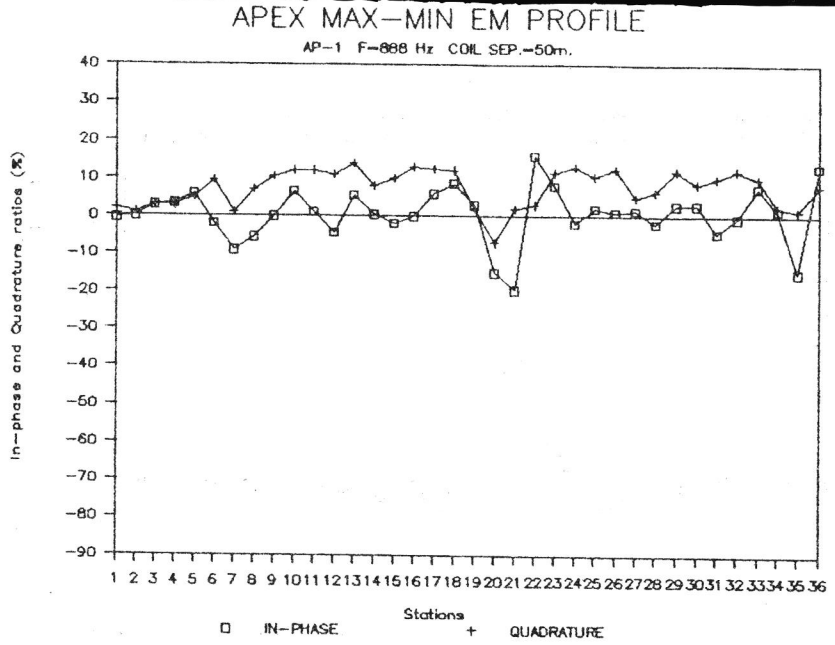

APEX MAX–MIN EM PROFILE
AP–1 F=444 Hz COIL SEP.=25m.
In–phase and Quadrature ratios (%)
Stations
IN–PHASE
QUADRATURE

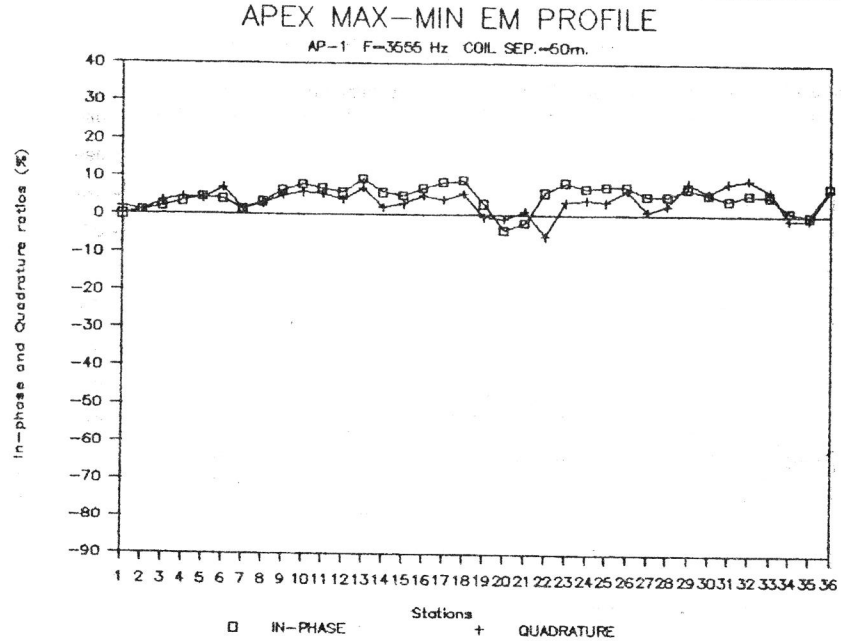

APEX MAX–MIN EM PROFILE
AP–1 F=1777 Hz COIL SEP.=25m.
In–phase and Quadrature ratios (%)
Stations
IN–PHASE
QUADRATURE

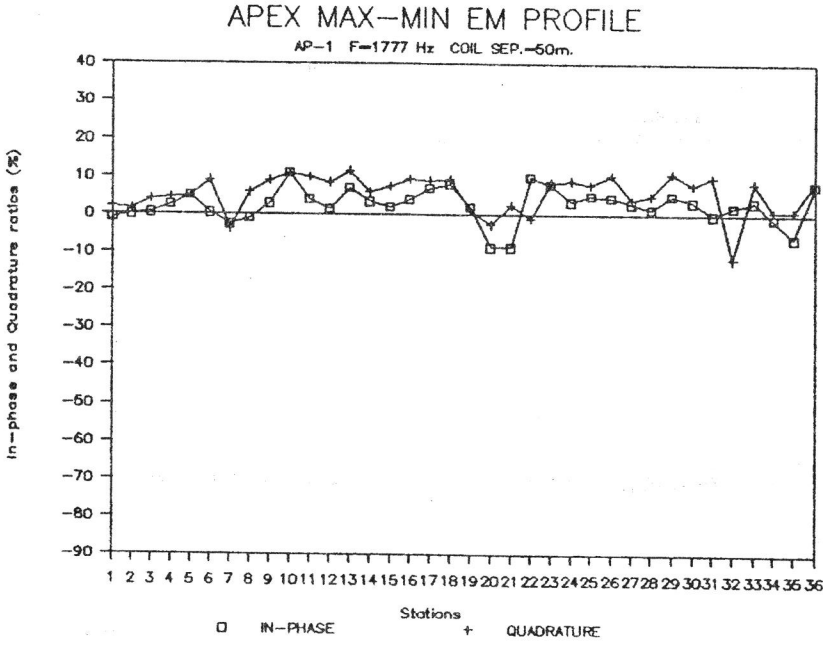

APEX MAX–MIN EM PROFILE
AP–1 F=222 Hz COIL SEP.=50m.
In–phase and Quadrature ratios (%)
Stations
IN–PHASE
QUADRATURE

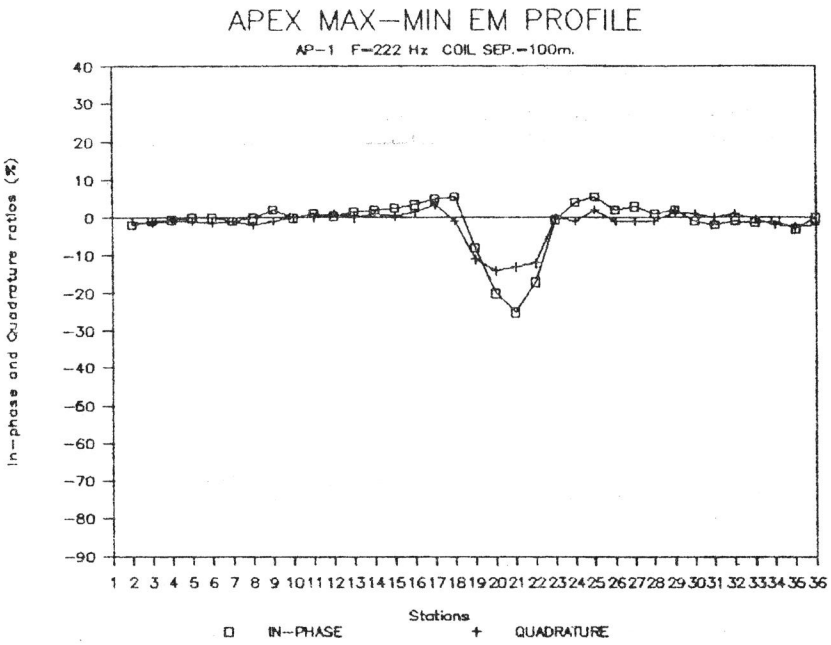

APEX MAX–MIN EM PROFILE
AP–1 F=3556 Hz COIL SEP.=25m.
In–phase and Quadrature ratios (%)
Stations
IN–PHASE
QUADRATURE

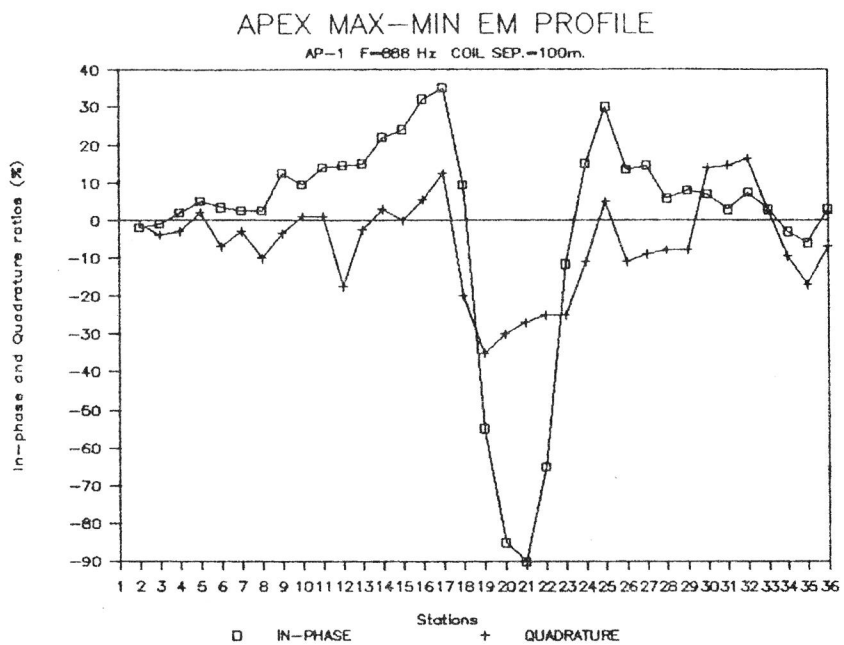

APEX MAX–MIN EM PROFILE
AP–1 F=444 Hz COIL SEP.=50m.
In–phase and Quadrature ratios (%)
Stations
IN–PHASE
QUADRATURE

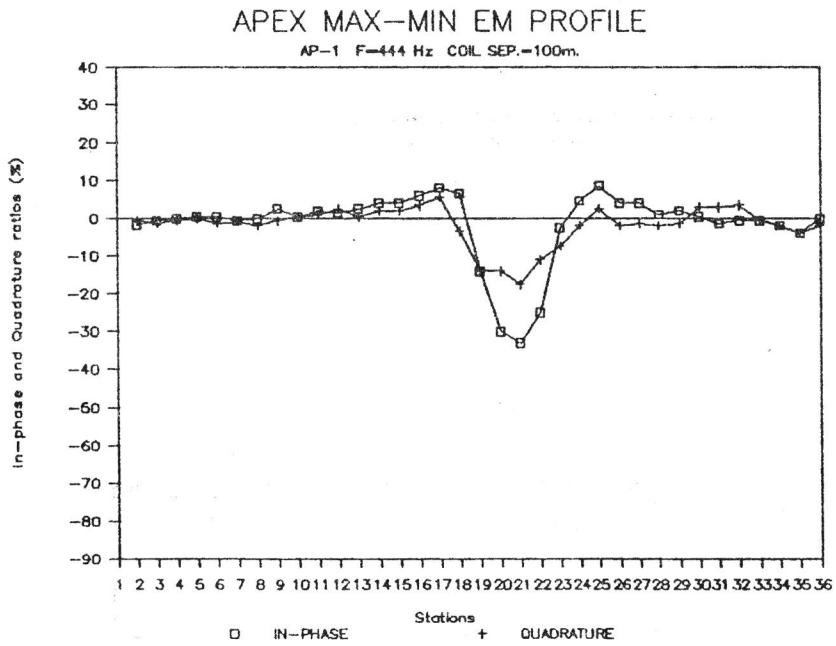

APEX MAX–MIN EM PROFILE
AP–1 F=888 Hz COIL SEP.=50m.
In–phase and Quadrature ratios (%)
Stations
IN–PHASE
QUADRATURE

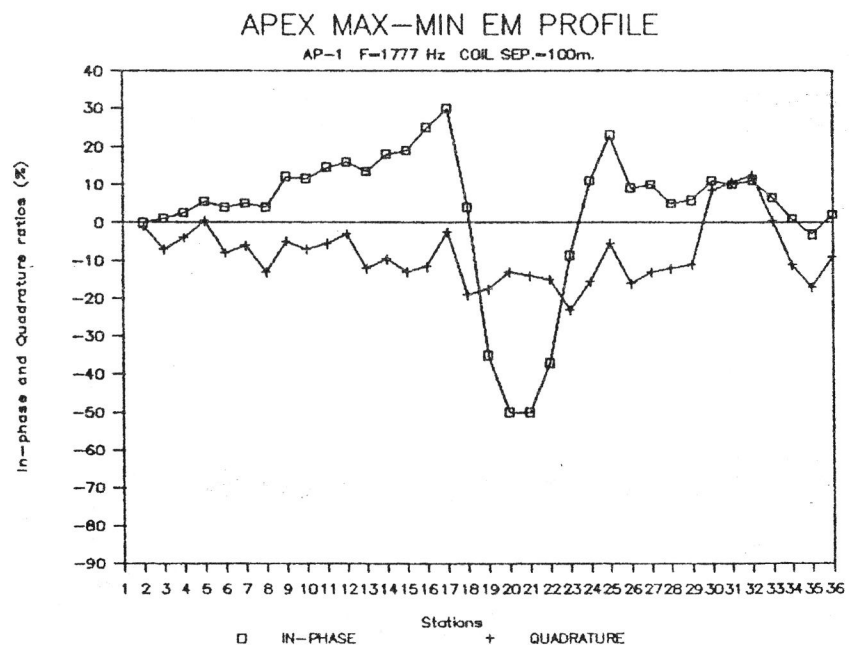

APEX MAX–MIN EM PROFILE
AP–1 F=3555 Hz COIL SEP.=50m.
In–phase and Quadrature ratios (%)
Stations
IN–PHASE
QUADRATURE

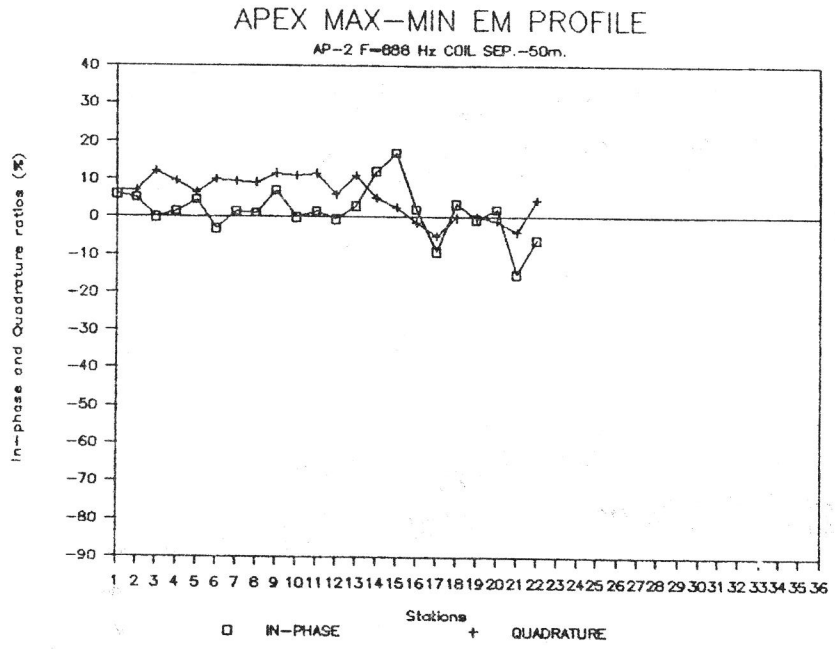

APEX MAX–MIN EM PROFILE
AP–1 F=1777 Hz COIL SEP.=50m.
In–phase and Quadrature ratios (%)
Stations
IN–PHASE
QUADRATURE

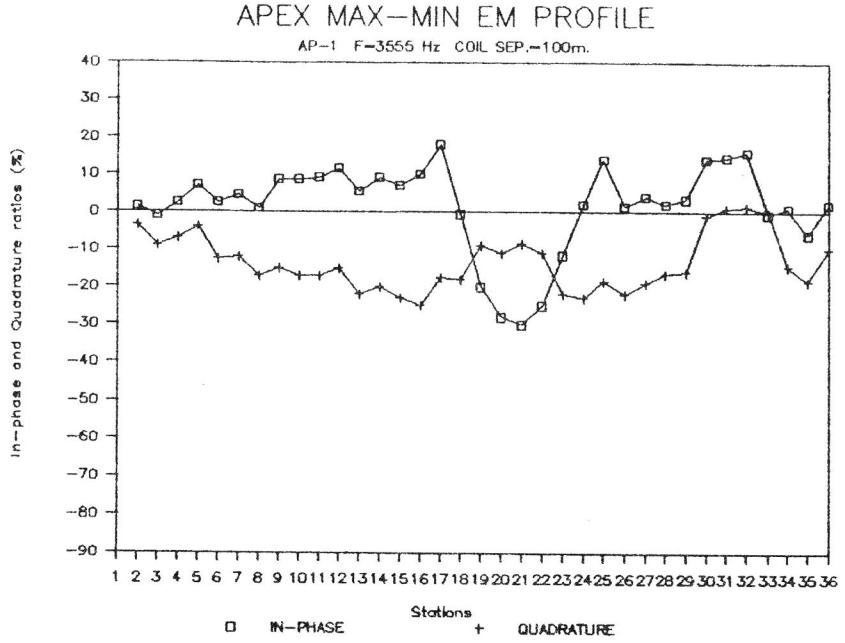

APEX MAX–MIN EM PROFILE
AP–1 F=222 Hz COIL SEP.=100m.
In–phase and Quadrature ratios (%)
Stations
IN–PHASE
QUADRATURE

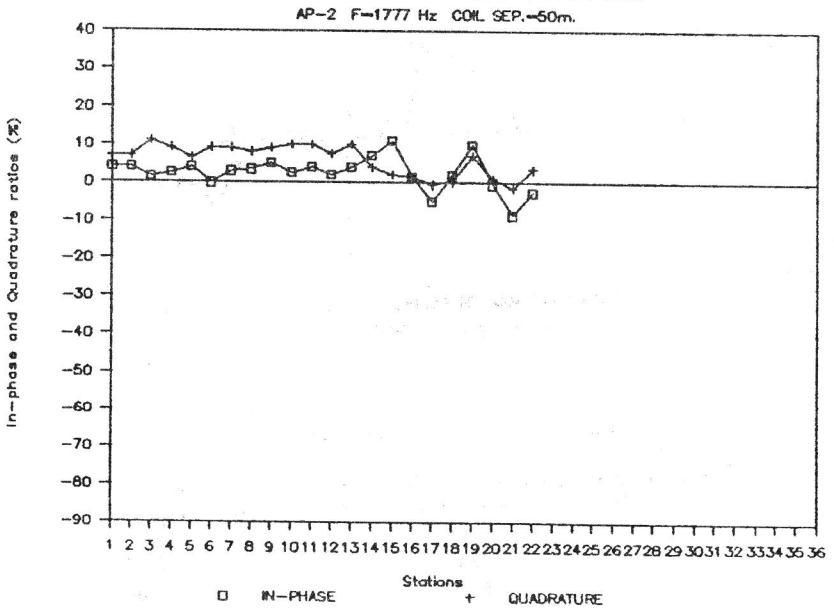

APEX MAX–MIN EM PROFILE
AP–1 F=888 Hz COIL SEP.=100m.
In–phase and Quadrature ratios (%)
Stations
IN–PHASE
QUADRATURE

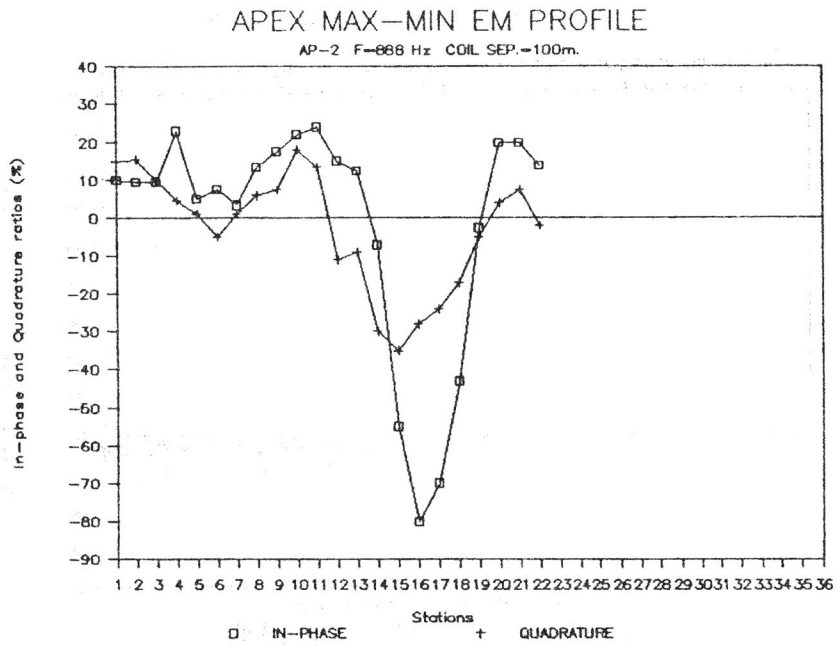

APEX MAX–MIN EM PROFILE
AP–1 F=444 Hz COIL SEP.=100m.
In–phase and Quadrature ratios (%)
Stations
IN–PHASE
QUADRATURE

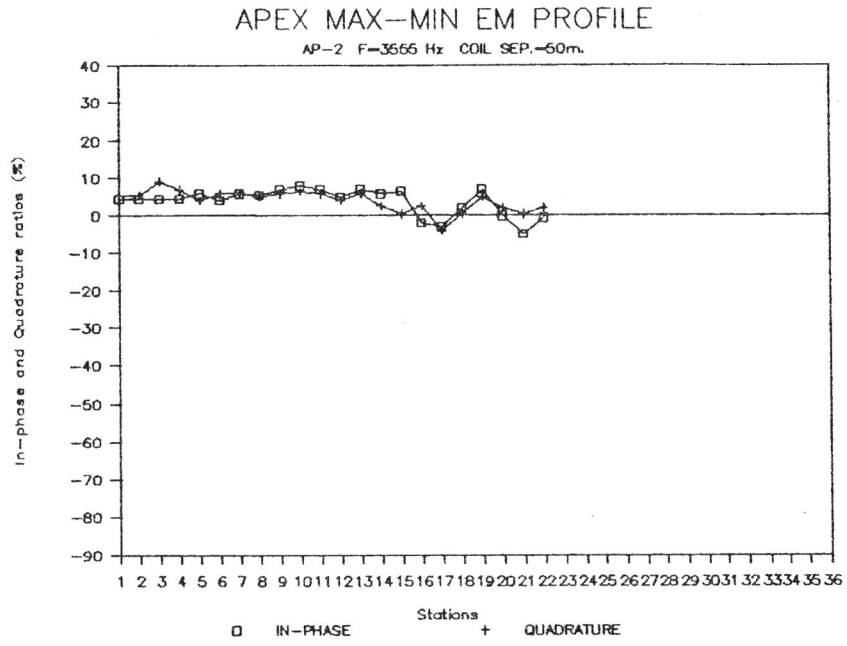

APEX MAX–MIN EM PROFILE
AP–1 F=1777 Hz COIL SEP.=100m.
In–phase and Quadrature ratios (%)
Stations
IN–PHASE
QUADRATURE

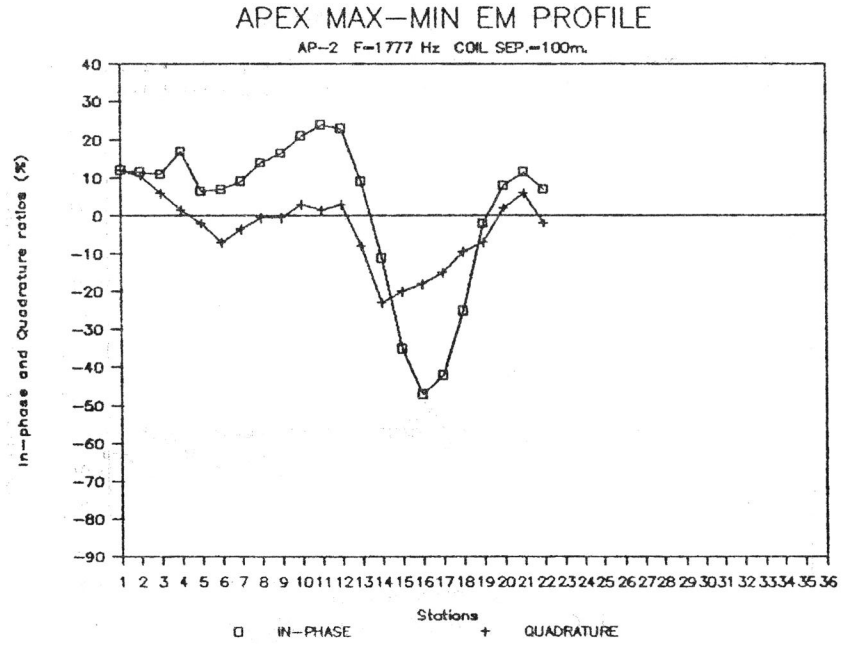

APEX MAX–MIN EM PROFILE
AP–2 F=888 Hz COIL SEP.–50m.
In–phase and Quadrature ratios (%)
Stations
IN–PHASE
QUADRATURE

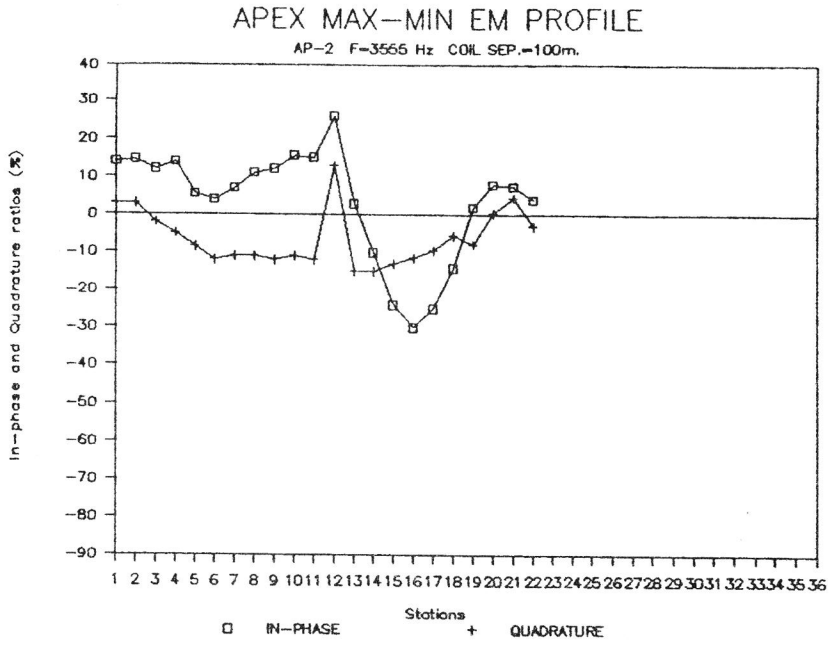

APEX MAX–MIN EM PROFILE
AP–1 F=3555 Hz COIL SEP.–100m.
In–phase and Quadrature ratios (%)
Stations
IN–PHASE
QUADRATURE


APEX MAX–MIN EM PROFILE
AP–2 F=1777 Hz COIL SEP.–50m.
In–phase and Quadrature ratios (%)
Stations
IN–PHASE
QUADRATURE


APEX MAX–MIN EM PROFILE
AP–2 F=888 Hz COIL SEP.=100m.
In–phase and Quadrature ratios (%)
Stations
IN–PHASE
QUADRATURE

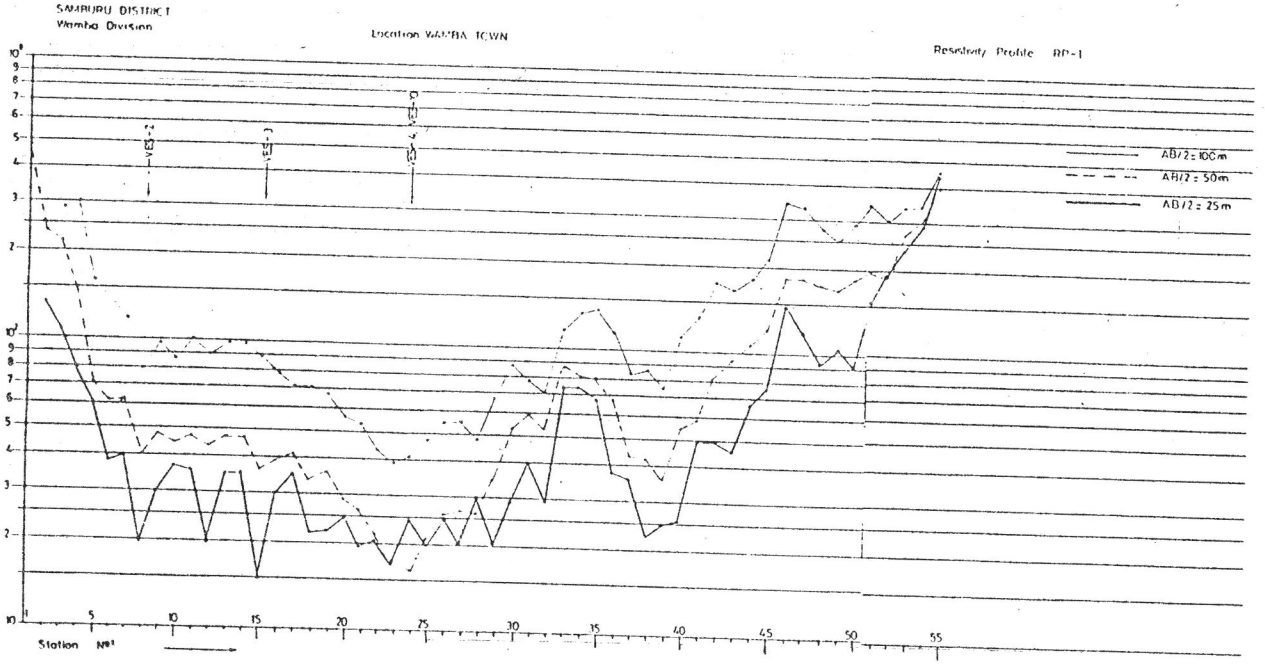

APEX MAX–MIN EM PROFILE
AP–2 F=3555 Hz COIL SEP.=50m.
In–phase and Quadrature ratios (%)
Stations
IN–PHASE
QUADRATURE


APEX MAX–MIN EM PROFILE
AP–2 F=1777 Hz COIL SEP.=100m.
In–phase and Quadrature ratios (%)
Stations
IN–PHASE
QUADRATURE


APEX MAX-MIN EM PROFILE
AP-2 F=3565 Hz COIL SEP.=100m.
In-phase and Quadrature ratios (%)
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36
Stations
IN-PHASE
QUADRATURE

# Appendix 3.5

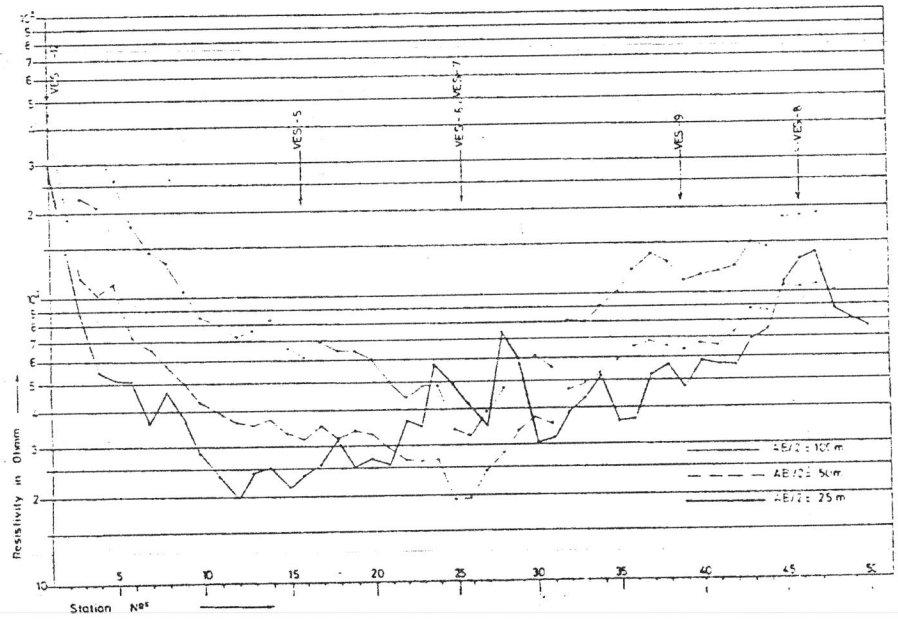
## Electrical Resistivity Profiles

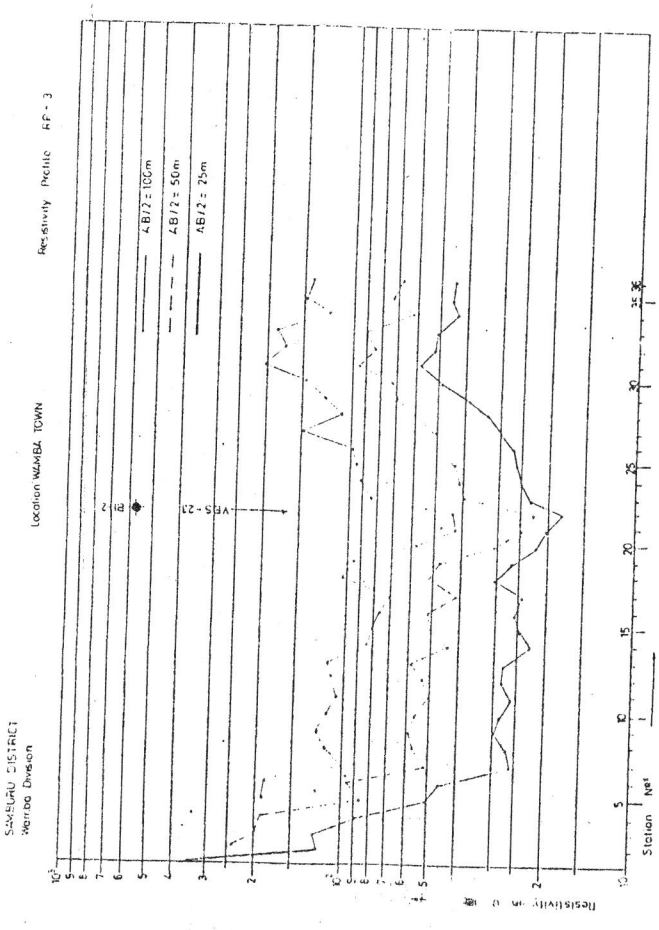

SAMBURU DISTRICT
Wamba Division
Location WAMBA TOWN
Resistivity Profile RP-1
AB/2 = 100m
AB/2 = 50m
AB/2 = 25m
Station Nº
1
5
10
15
20
25
30
35
40
45
50
55

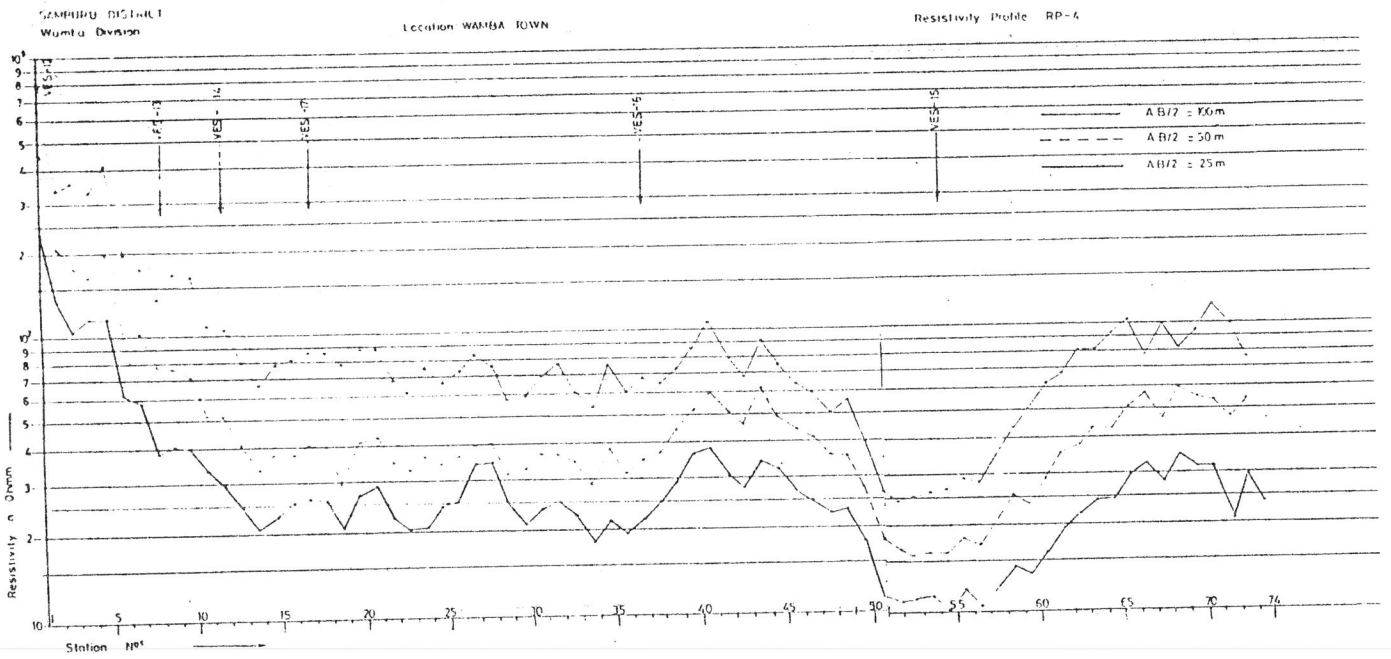
SAMBUR DISTRICT
Wamba Division

Location WAMBA TOWN

Resistivity Profile RP-2



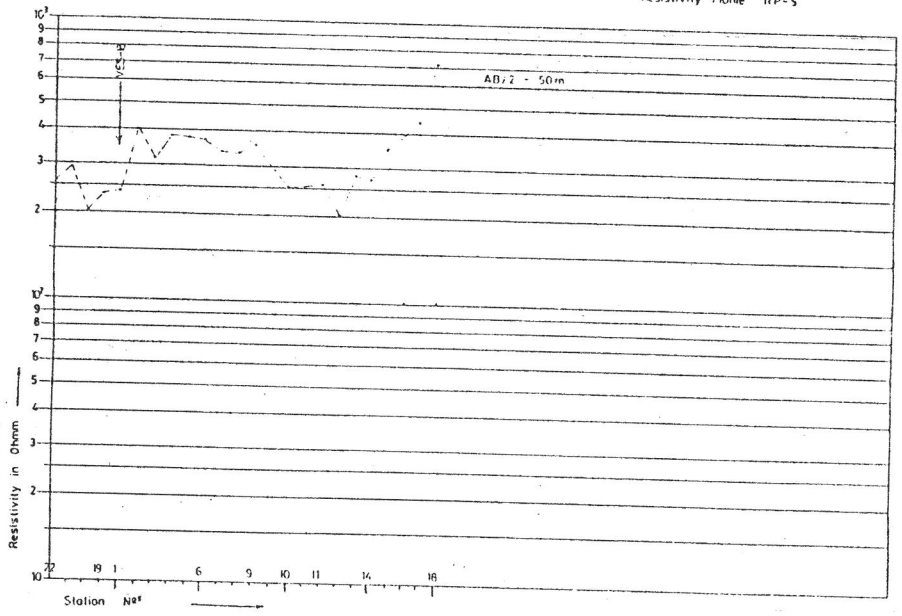

SAMBURU DISTRICT
Wamba Division
Location WAMBA TOWN
Resistivity Profile RP - 3
AB/2 = 100m
AB/2 = 50m
AB/2 = 25m
VES - 23
Resistivity in Ω m
Station No.


ZAMBIA DISTRICT
Wumlu Division
Location WAMBA TOWN
Resistivity Profile RP-4
VES-13
VES-14
VES-15
VES-16
VES-17
AB/2 = 100m
AB/2 = 50m
AB/2 = 25m
Resistivity ρ Ohmm
Station No's

SAMBURU DISTRICT
Wamba Division

Location WAMBA TOWN

Resistivity Profile RP-5



# APPENDIX 4

## DATA ON RAINFALL, EVAPORATION AND SURFACE WATER

## APPENDIX 4


4.1 List of Rainfall Station

4.2 List of Evaporation Pan Stations

4.3 Runoff Station

4.4 Mean Monthly Rainfall Data

4.5 Mean Monthly Rainfall Graphs

4.6 Monthly and Annual Evaporation Graphs

4.7 Annual Rainfall

4.8 Annual Rainfall Variation

4.9 Annual Rainfall Frequency Distribution

4.10 Annual Maximum Daily Rainfall

4.11 Stage and Discharge Hydrograph

4.12 Flow duration, Rating Curves and Monthly Flow Distribution

4.13 Miscellaneous Discharge Measurements

4.14 Discharge Measurements at Amaya RGS

4.15 Discharge Measurements at S. Horr RGS

4.16 Chemical Data, Surface Water

# Appendices 4.1, 4.2, 4.3 and 4.4

## Appendix 4.1 List of Rainfall Stations

| STATION NUMBER | LOCATION (NORTHINGS) | LATITUDE (EASTINGS) | LONGITUDE (METRES) | ALTITUDE PERIOD | RECORD |
|---|---|---|---|---|---|
| 87.36.00 | * South Horr | 2° 06' | 36° 54' | 1006 | 1962-63,1973-1985 |
| 87.36.01 | * Tuum Primary School | 2° 09' | 36° 47' | 1676 | 1973-78,1980-1988 |
| 88.36.00 | * Maralal D.C. | 1° 05' | 36° 42' | 1951 | 1935-55,57,1959-1988 |
| 88.36.01 | * Maralal El Barta | 1° 47' | 36° 48' | 914 | 1939-1988 |
| 88.36.02 | Maralal Samburu BCM | 1° 01' | 36° 45' | 1829 | 1939-1964 |
| 88.36.03 | Poror Forest Station | 1° 14' | 36° 36' | 2408 | 1971-1988 |
| 88.36.04 | Maralal Agriculture Office | 0° 05' | 36° 41' | 1874 | |
| 88.36.05 | Kowop Borehole | 1° 59' | 36° 46' | 1371 | 1973-1977 |
| 88.36.06 | * Merti Maralal | 1° 29' | 36° 43' | 1372 | 1960-1966,73,75,1982 |
| 88.36.07 | * Barsaloi Primary School | 1° 20' | 36° 52' | 1143 | 1973-1977, 1979, 1988 |
| 88.36.08 | B.cms Maralal Town | 1° 07' | 36° 42' | 1951 | 1964-1975 |
| 88.36.12 | Sirata Primary School | 1° 03' | 36° 49' | 1981 | 1973-1977 |
| 88.36.13 | Lesirikan Training Centre | 1° 47' | 36° 57' | 1551 | 1977-1981 |
| 88.36.14 | * Losuk primary School | 1° 02' | 36° 35' | 1981 | 1973-76,1978,1983-1985,1988 |
| 88.36.15 | * Bauwa Primary School | 1° 02' | 36° 49' | 2103 | 1974-1988 |
| 88.36.16 | * Opiroi Primary School | 0° 10' | 36° 49' | 1676 | |
| 88.36.17 | * Mirijo Primary School | 1° 20' | 36° 37' | 1981 | 1974-1976,1988 |
| 88.37.00 | * Illauti Training Centre | 1° 51' 10" | 37° 15' 05" | 762 | 1973-1983,1986,1988 |
| 88.37.01 | Latakwen | 1° 33' | 37° 07' 15" | 1067 | 1974 |
| 88.37.02 | Nkoromit | 1° 44' | 37° 18' | 853 | 1960-1964 |
| 88.37.03 | Maralal Kauro | 1° 03' | 37° 43' | 745 | |
| 88.37.06 | * Swari N. School | 1° 14' | 37° 12' | 1189 | 1973-1977,1988 |
| 88.37.07 | * Serulevi Police Post | 1° 08' | 37° 38' | 732 | 1973-77,1979-1986,1988 |
| 88.37.08 | Ngilai Primary School | 0° 08' | 37° 15' | 1524 | |
| 88.37.09 | * Kichichi Game Park | 1° 09' 40" | 37° 20' | 1524 | |
| 89.36.19 | Tangulbei | 0° 38' | 36 18' | 1280 | 1939-62,1964-71,1973-1986 |
| 89.36.60 | Sosian Ranch | 0° 38' | 36° 48' | 1737 | 1963-1986 |
| 89.36.61 | Samburu Ranch | 0° 49' | 36° 40' | 1585 | |
| 89.36.74 | * Suguta Murmar | 0° 50' | 38° 41' | 1896 | 1973-1974,1976-1988 |
| 89.36.75 | Kisima APS Post | 0° 57' | 36° 46' | 1801 | 1973-74, 1979-1981 |
| 89.36.77 | Karimun Police Post | 0° 45' | 36° 53' | 1768 | 1974-77, 1979-1981 |
| 89.36.78 | * Longewan Shops | 0° 50' | 36° 33' | 1981 | 1974-1975,1988 |
| 89.36.79 | * Lodo Kejek Chiefs | 0° 51' | 36° 52' | 1676 | 1974-1988 |
| 89.37.18 | * Wamba D.O | 0° 59' | 37° 19' 50" | 1315 | 1938-62,1966-86 |
| 89.37.35 | * Archer's Post | 0° 38' | 37° 40' | 864 | 1946-88 |
| 89.37.63 | Samburu Lodge | 0° 35' | 37° 33' | 914 | 1963-1985 |
| 89.37.69 | * Wamba Game Department | 0° 58' 45" | 37° 20' 25 | 1360 | 1974-1988 |
| 89.37.79 | * Lerata Borehole | 0° 49' | 37° 27' 45" | 914 | 1973-1980,1988 |
| 89.37.93 | * Lodungukwe Game Camp | 0° 52' | 37° 00' | 1310 | 1974-1987 |
| 89.37.102 | Kipsing | 0° 37' | 37° 15' | 1036 | 1978,1980-1985 |
| 98.37.103 | Longopito Longopito | 0° 42' | 37° 08' | 1150 | 1978-1985 |
| | ** Amaya Centre | 0° 52' | 36° 28' | 1676 | 1987- |
| | ** Poro Chief's Centre | 1° 12' | 36° 32' 40" | 2149 | 1987- |

* = Rainfall Stations Rehabilitated by the Project.

Rehabilitation involved supply of measuring cylinder, some components of the raingauge, and in some cases the entire raingauge.

** = New rainfall stations installed by the project.

## Appendix 4.2 List of Evaporation Pan Stations

| STATION NAME | LONGITUDE | LATITUDE | ALTITUDE (M) | RECORDS | REMARKS |
|---|---|---|---|---|---|
| Archer's Post<br>W.D. No. 1 | 37 39 50 E | 00 38 20 N | 864 | 1946-86 | Old Station<br>Pan replaced by WRAP |
| Amaya Centre<br>W.D. No. 56 | 36 27 55 E | 00 52 05 N | 1676 | 1987- | New Station<br>Installed by WRAP<br>(7/10/1987) |
| South Horr<br>W.D. No 68 | 36 53 35 E | 02 05 45 N | 1219 | 1987- | New Station<br>Installed by WRAP<br>(9/10/1987) |
| Maralal Water Supply<br>W.D. No. 69 | 36 40 45 E | 01 03 15 N | 1951 | 1987- | New station Installed<br>by WRAP<br>(13/10/1987) |
| Wamba Game Department<br>W.D. No. 57 | 37 20 28 E | 00 57 25 N | 1360 | 1987 | New station Installed<br>by WRAP<br>(15/10/87) |

**Note:** W D. No ..... Water Department Number given by Surface Water Division
WRAP ..... Water Resources Assessment Project

## Appendix 4.3 Runoff Stations

| River | Latitude | Longitude | Catchment Area Sq. km | Type | Opened |
|---|---|---|---|---|---|
| Amaya | 0 52 00 | 36 37 50 | 113 | Staff gauge | 10/10/87 |
| South Horr | 2 05 15 | 36 53 35 | 12 | Staff gauge | 08/11/87 |
| Nundoto dam | 1 03 41 | 36 40 45 | 52 | Staff gauge | 04/11/87 |

# Appendix 4.4 Mean Monthly Rainfall in mm.

| Rainfall Station<br>K.M.D No.<br>Altitude | Records | | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Poror Forest<br>88.36.03<br>2408 | 1971-88 | x<br>cv<br>% | 14.3<br>1.49<br>2.6 | 15.2<br>1.29<br>2.8 | 26.7<br>1.38<br>4.8 | 70.9<br>0.73<br>12.9 | 52.5<br>0.68<br>9.5 | 63.6<br>0.91<br>11.5 | 85.7<br>0.71<br>15.5 | 71.7<br>0.84<br>13 | 45.9<br>0.79<br>8.3 | 32.2<br>1.11<br>5.8 | 51.9<br>1.01<br>9.4 | 20.8<br>1.03<br>3.8 | 551 |
| Maralal DC<br>88.36.00<br>1951 | 1935-55<br>1957<br>1959-88 | x<br>cv<br>% | 13.8<br>1.55<br>2.3 | 18.9<br>1.69<br>3.1 | 36.3<br>1.06<br>6 | 88.5<br>0.64<br>14.7 | 64.1<br>0.63<br>10.6 | 56.2<br>0.69<br>9.3 | 89.4<br>0.65<br>14.8 | 87.2<br>0.61<br>14.5 | 35.8<br>0.93<br>5.9 | 39.6<br>0.92<br>6.6 | 51.5<br>0.97<br>8.5 | 21.8<br>1.21<br>3.6 | 603 |
| Nundoto Dam<br>WD.656<br>1900 | 1977-84<br>1986<br>1988 | x<br>cv<br>% | 15.3<br>1.67<br>2.9 | 15.5<br>1.38<br>2.9 | 37.3<br>1.67<br>7.0 | 79.4<br>1.13<br>14.9 | 32.1<br>0.82<br>6.0 | 45.5<br>0.78<br>8.5 | 71.3<br>0.85<br>13.3 | 68.2<br>0.76<br>12.8 | 53.3<br>1.22<br>10.0 | 46.7<br>1.23<br>8.7 | 54.0<br>1.41<br>10.1 | 15.5<br>1.00<br>2.9 | 534 |
| Sukuta armar<br>89.36.7<br>1896 | 1973-74<br>1976-88 | x<br>cv<br>% | 18.0<br>1.60<br>2.9 | 22.4<br>1.66<br>3.6 | 31.9<br>1.10<br>5.2 | 65.4<br>0.66<br>10.6 | 55.0<br>0.81<br>8.9 | 67.0<br>0.59<br>10.9 | 149.6<br>1.48<br>24.3 | 31.7<br>0.99<br>5.2 | 34.5<br>0.99<br>5.6 | 36.0<br>0.75<br>5.9 | 66.0<br>1.05<br>10.7 | 37.1<br>0.94<br>6.0 | 615 |
| Sosian<br>89.36.60<br>1737 | 1963-86 | x<br>cv<br>% | 14.1<br>1.88<br>2.9 | 14.3<br>1.49<br>2.9 | 36.1<br>1.19<br>7.4 | 109.8<br>1.18<br>22.5 | 61.6<br>0.85<br>12.6 | 34.3<br>1.05<br>7.0 | 38.1<br>0.98<br>7.8 | 44.5<br>0.96<br>9.1 | 24.0<br>1.29<br>4.9 | 20.7<br>0.99<br>4.2 | 55.3<br>0.76<br>11.3 | 34.6<br>1.16<br>7.1 | 487 |
| Lodokejek<br>89.36.79<br>1676 | 1974-88 | x<br>cv<br>% | 23.5<br>2.21<br>3.3 | 8.7<br>1.44<br>1.2 | 51<br>1.40<br>7.3 | 180.8<br>0.53<br>25.8 | 75.4<br>0.70<br>10.7 | 44.7<br>1.42<br>6.4 | 43.9<br>0.78<br>6.3 | 26.1<br>0.98<br>3.7 | 20.8<br>1.10<br>3.0 | 59.6<br>1.04<br>8.5 | 104.1<br>0.34<br>14.8 | 63.1<br>0.86<br>9.0 | 702 |
| Tangulbei<br>89.36.19<br>1524 | 1939-62<br>1964-71<br>1973-86 | x<br>cv<br>% | 18.7<br>1.54<br>2.7 | 20.7<br>1.66<br>3.0 | 45.9<br>0.96<br>6.6 | 91.9<br>0.71<br>13.1 | 110.6<br>0.68<br>15.8 | 62.9<br>0.60<br>9.0 | 94.2<br>0.74<br>13.5 | 99.7<br>0.71<br>14.2 | 46.8<br>0.76<br>6.7 | 30.2<br>0.77<br>4.3 | 49.9<br>1.50<br>7.1 | 28.0<br>1.07<br>4.0 | 700 |
| Wamba Game<br>89.37.69<br>1360 | 1974-88 | x<br>cv<br>% | 28.7<br>1.65<br>3.7 | 6.6<br>1.37<br>0.8 | 85.2<br>1.07<br>10.9 | 209.3<br>0.56<br>26.9 | 91.7<br>0.82<br>11.8 | 13.6<br>1.50<br>1.7 | 12.6<br>1.47<br>1.6 | 4.2<br>2.13<br>0.5 | 7.6<br>1.33<br>1.0 | 83.0<br>1.42<br>10.7 | 168.2<br>0.67<br>21.6 | 67.7<br>0.76<br>8.7 | 778 |
| Wamba DO<br>89.37.18<br>1315 | 1938-62<br>1966-88 | x<br>cv<br>% | 21.4<br>1.41<br>3.0 | 18.5<br>2.19<br>2.6 | 75.8<br>0.98<br>10.7 | 192.9<br>0.61<br>27.1 | 54.8<br>0.77<br>7.7 | 7.0<br>1.77<br>1.0 | 11.5<br>1.46<br>1.6 | 4.5<br>2.16<br>0.6 | 3.6<br>2.03<br>0.5 | 72.0<br>1.17<br>10.1 | 180.6<br>0.85<br>25.4 | 67.8<br>1.20<br>9.5 | 710 |
| Lodungukwe<br>89.37.93<br>1310 | 1974-87 | x<br>cv<br>% | 22.4<br>1.77<br>4.5 | 13.8<br>1.44<br>2.8 | 35.1<br>1.02<br>7.1 | 77.1<br>0.67<br>15.6 | 57.9<br>0.72<br>11.7 | 22.0<br>1.32<br>4.5 | 25.5<br>1.79<br>5.2 | 17.0<br>1.56<br>3.4 | 12.8<br>1.74<br>2.6 | 43.2<br>1.15<br>8.7 | 94.2<br>0.63<br>19.0 | 74.0<br>0.73<br>14.9 | 495 |
| South Horr<br>87.36.00<br>1006 | 1962-63<br>1973-86 | x<br>cv<br>% | 27.5<br>1.39<br>6.3 | 5.7<br>1.94<br>1.3 | 42.5<br>1.38<br>9.7 | 118.8<br>1.06<br>27.0 | 48.6<br>0.93<br>11.1 | 5.5<br>2.30<br>1.3 | 9.5<br>1.48<br>2.2 | 7.1<br>2.14<br>1.6 | 4.2<br>3.01<br>1.0 | 34.4<br>1.27<br>7.8 | 93.3<br>1.19<br>21.2 | 42.0<br>1.11<br>9.6 | 439 |
| Baragoi DO<br>88.36.01<br>914 | 1938-88 | x<br>cv<br>% | 23.6<br>1.27<br>4.4 | 34.2<br>1.04<br>6.4 | 64.3<br>0.73<br>12.1 | 112.4<br>0.45<br>21.2 | 54.3<br>0.55<br>10.2 | 20.9<br>1.61<br>3.9 | 22.0<br>1.34<br>4.1 | 20.1<br>1.52<br>3.8 | 11.0<br>2.37<br>2.1 | 55.0<br>0.71<br>10.4 | 79.0<br>0.66<br>14.9 | 34.7<br>0.76<br>6.5 | 532 |
| Samburu Lodge<br>89.37.63<br>914 | 1964<br>1967-70<br>1973-85 | x<br>cv<br>% | 19.5<br>1.90<br>4.6 | 28.2<br>1.33<br>6.7 | 42.3<br>0.97<br>10.0 | 104.0<br>0.70<br>24.5 | 41.6<br>0.69<br>9.8 | 2.1<br>2.10<br>0.5 | 2.7<br>2.20<br>0.6 | 4.0<br>2.33<br>0.9 | 6.2<br>1.84<br>1.5 | 40.8<br>0.79<br>9.6 | 96.6<br>0.99<br>22.8 | 35.9<br>1.14<br>8.5 | 424 |
| Archer's Post<br>89.37.35<br>864 | 1946-88 | x<br>cv<br>% | 9.3<br>1.78<br>2.7 | 9.1<br>2.17<br>2.6 | 33.8<br>1.02<br>3.7 | 84.1<br>0.66<br>24.1 | 40.6<br>0.91<br>11.6 | 3.4<br>2.49<br>1.0 | 3.8<br>2.05<br>1.1 | 3.3<br>2.91<br>1.0 | 3.4<br>1.40<br>1.0 | 29.8<br>1.13<br>8.5 | 89.6<br>1.09<br>25.6 | 39.4<br>1.11<br>11.3 | 350 |

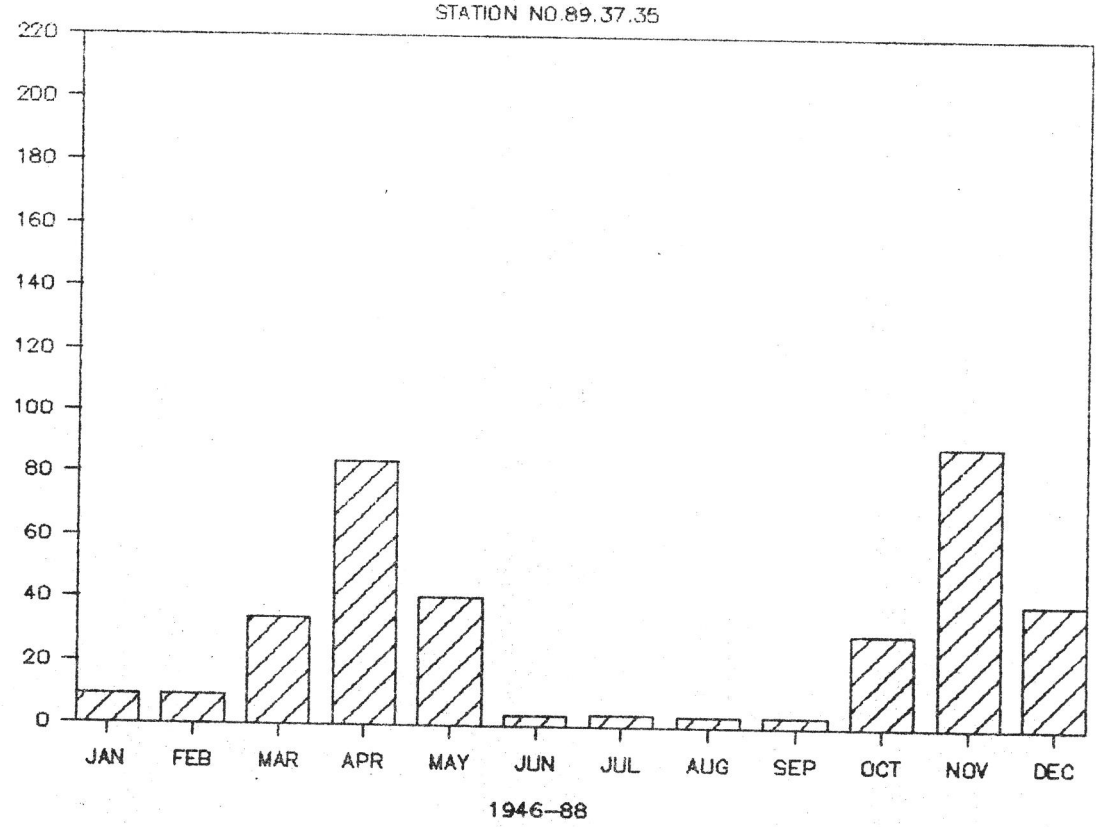
x .....Mean Monthly rainfall
cv.....Coefficient of variation
% .....Monthly mean as percentage of annual mean

# Appendix 4.5

## Mean Monthly Rainfall Graphs

## MEAN MONTHLY RAINFALL AT ARCHER'S POST

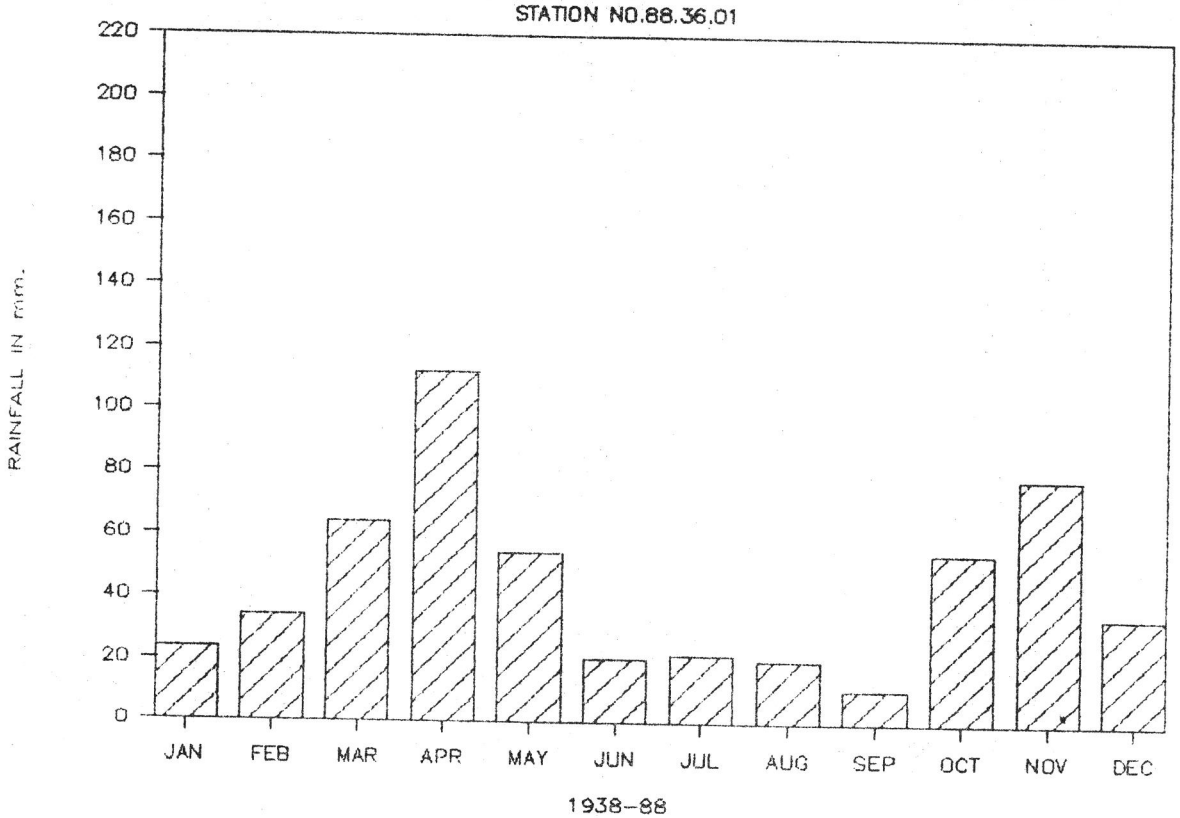
STATION NO.89.37.35




1946–88

## MEAN MONTHLY RAINFALL AT BARAGOI DO

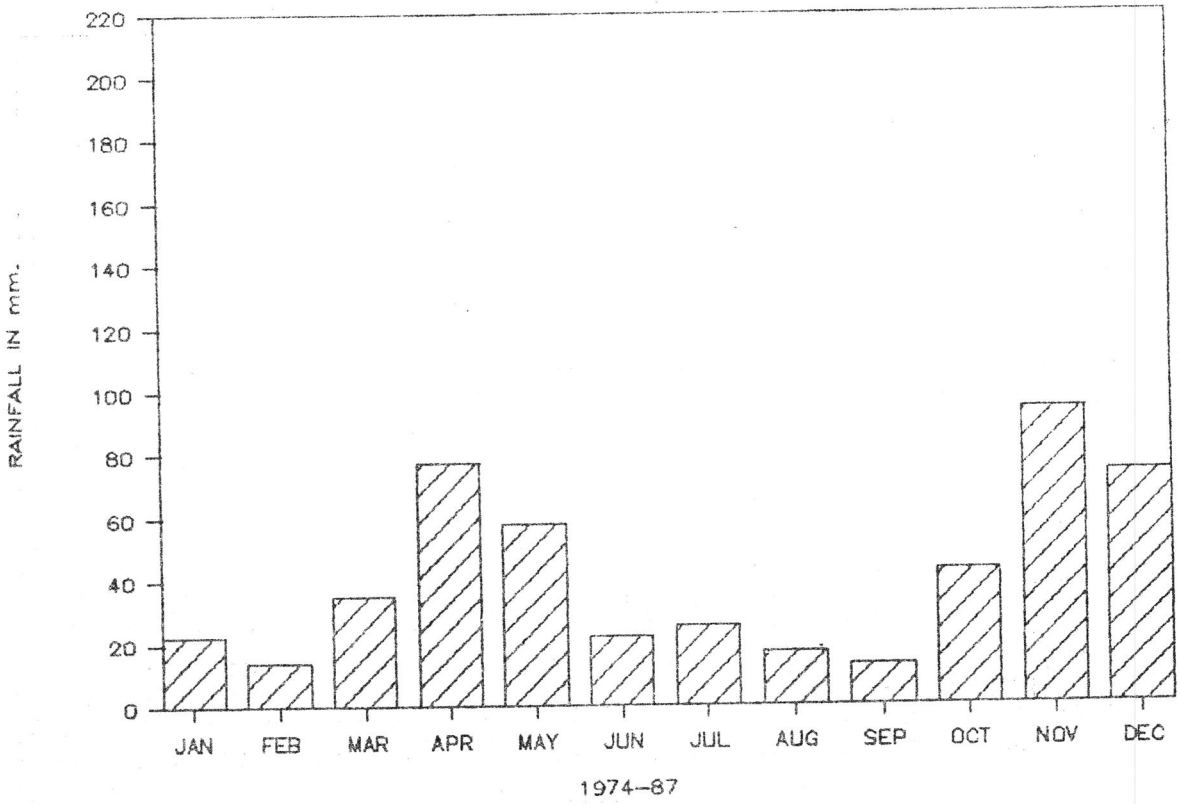
STATION NO.88.36.01




1938–88

## MEAN MONTHLY RAINFALL AT LODUNGUKWE

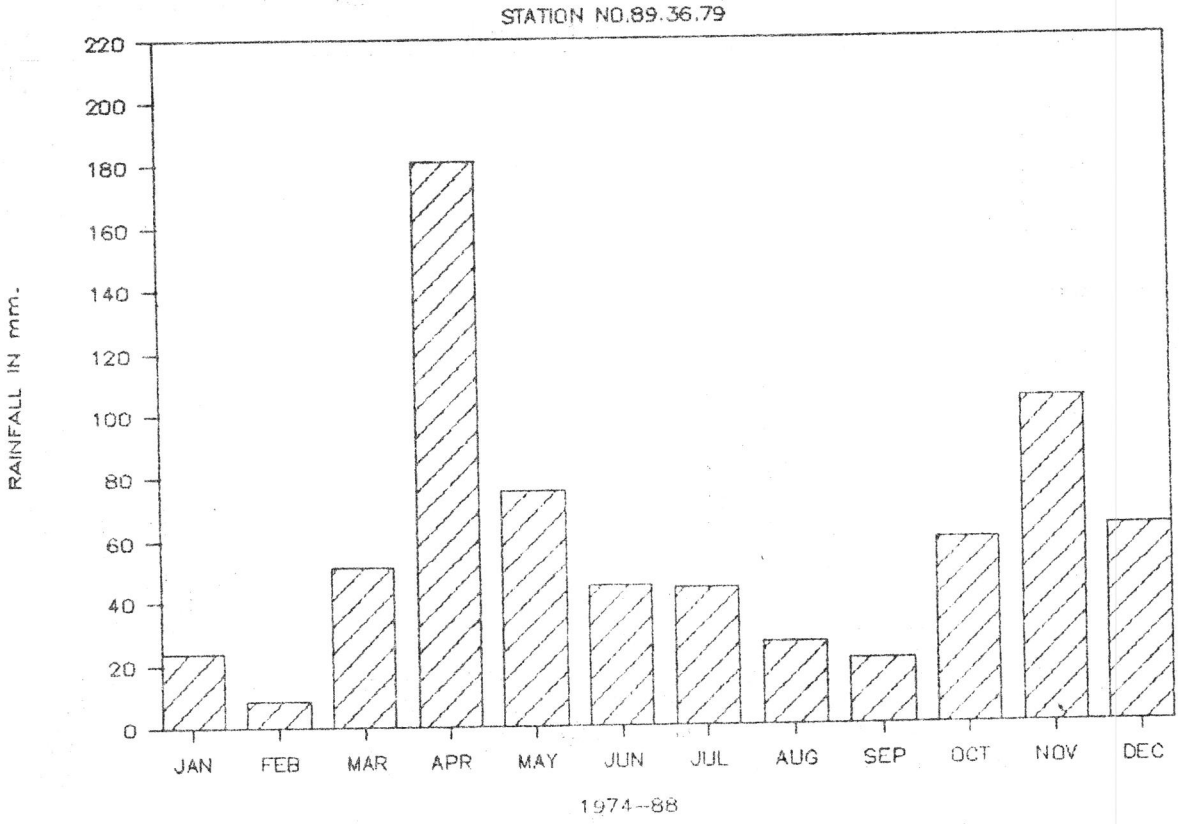
STATION NO.89.37.93




1974–87

## MEAN MONTHLY RAINFALL AT LODOKEJEK

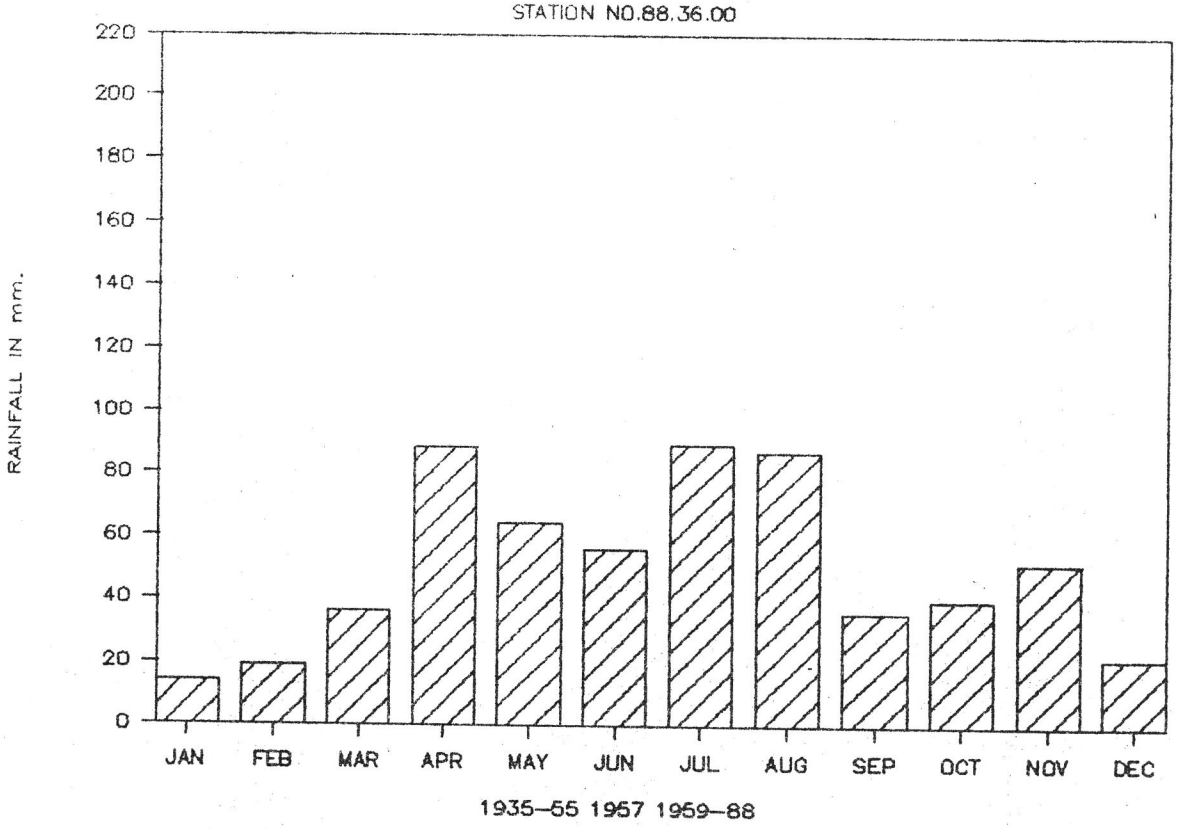
STATION NO.89.36.79




1974–88

## MEAN MONTHLY RAINFALL AT MARALAL DC

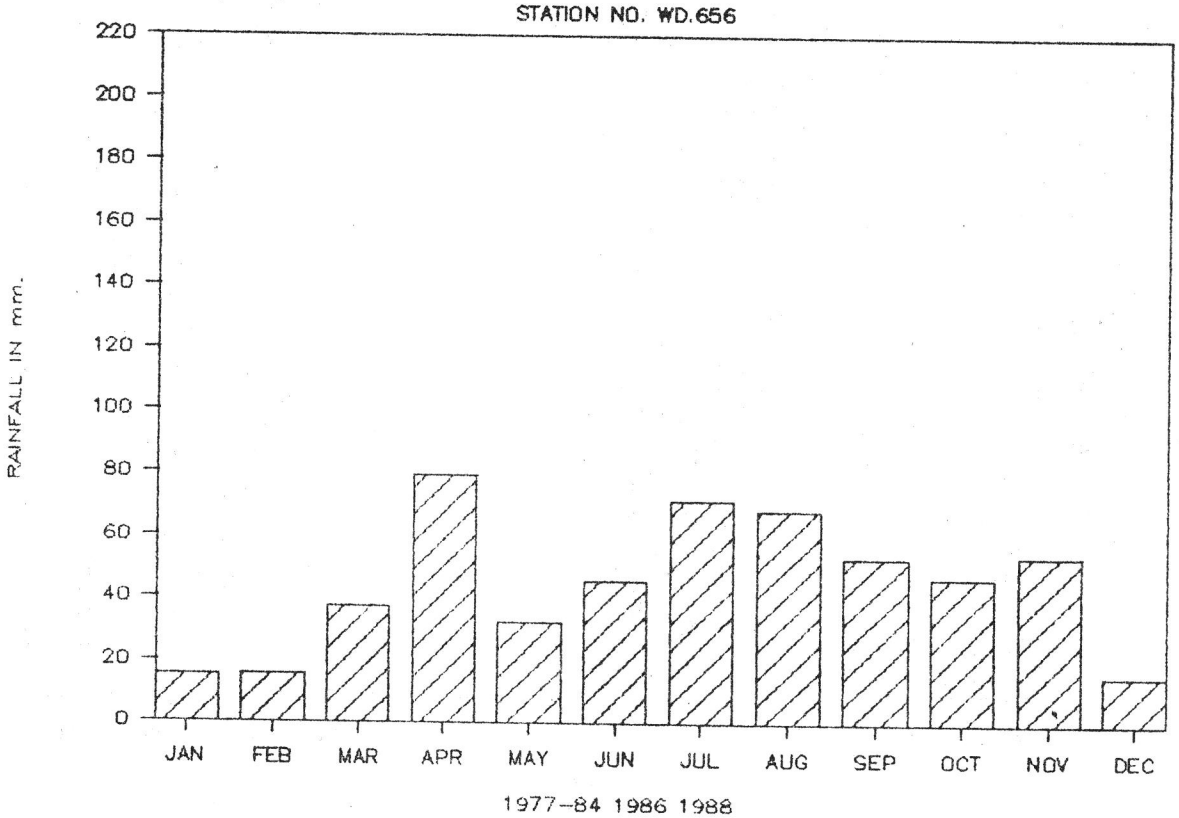
STATION NO.88.36.00




1935–55 1957 1959–88

## MEAN MONTHLY RAINFALL AT NUNDOTO DAM

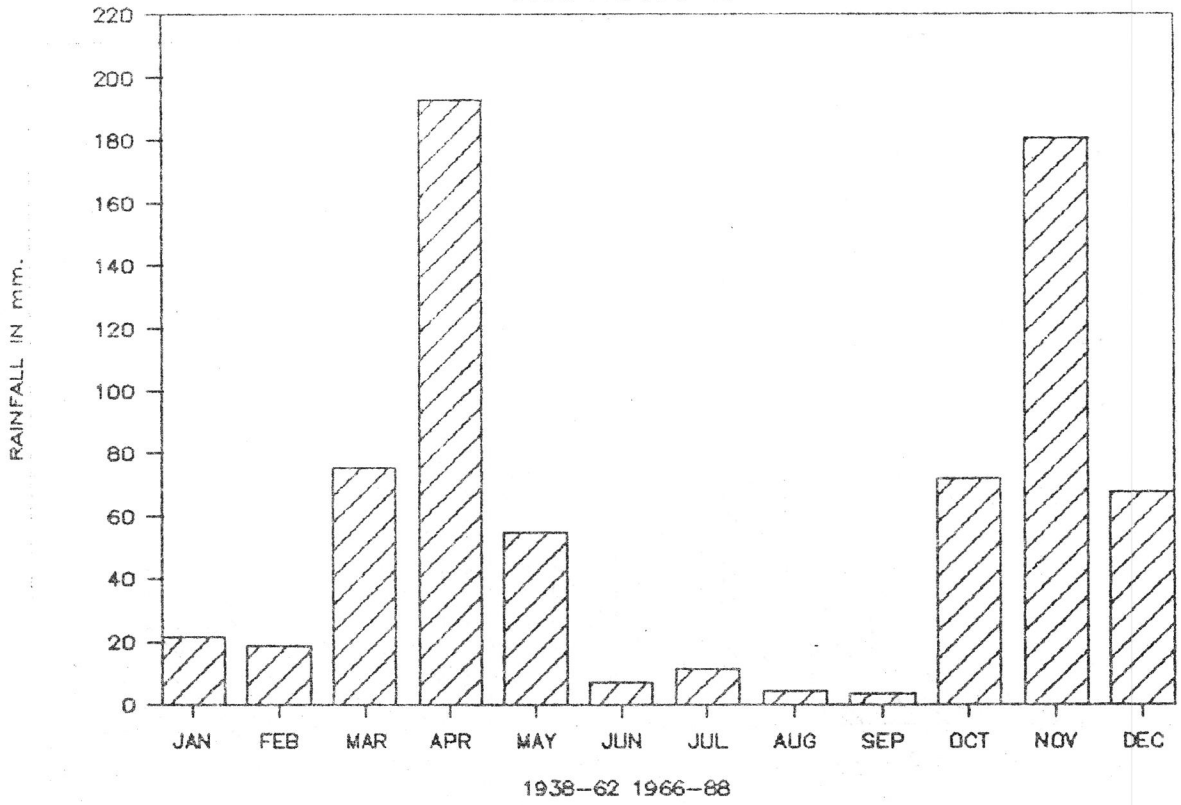
STATION NO. WD.656




1977–84 1986 1988

## MEAN MONTHLY RAINFALL AT WAMBA DO

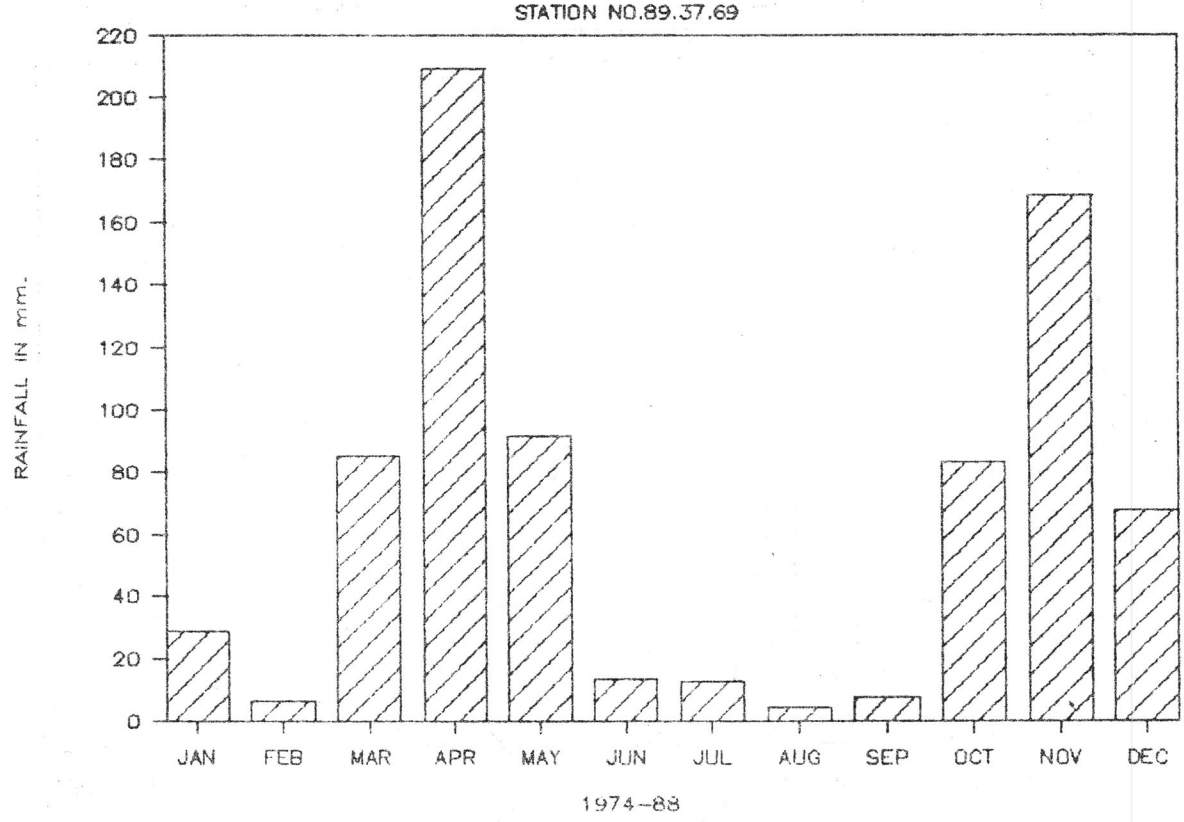
STATION NO.89.37.18




1938–62 1966–88

## MEAN MONTHLY RAINFALL AT WAMBA GAME

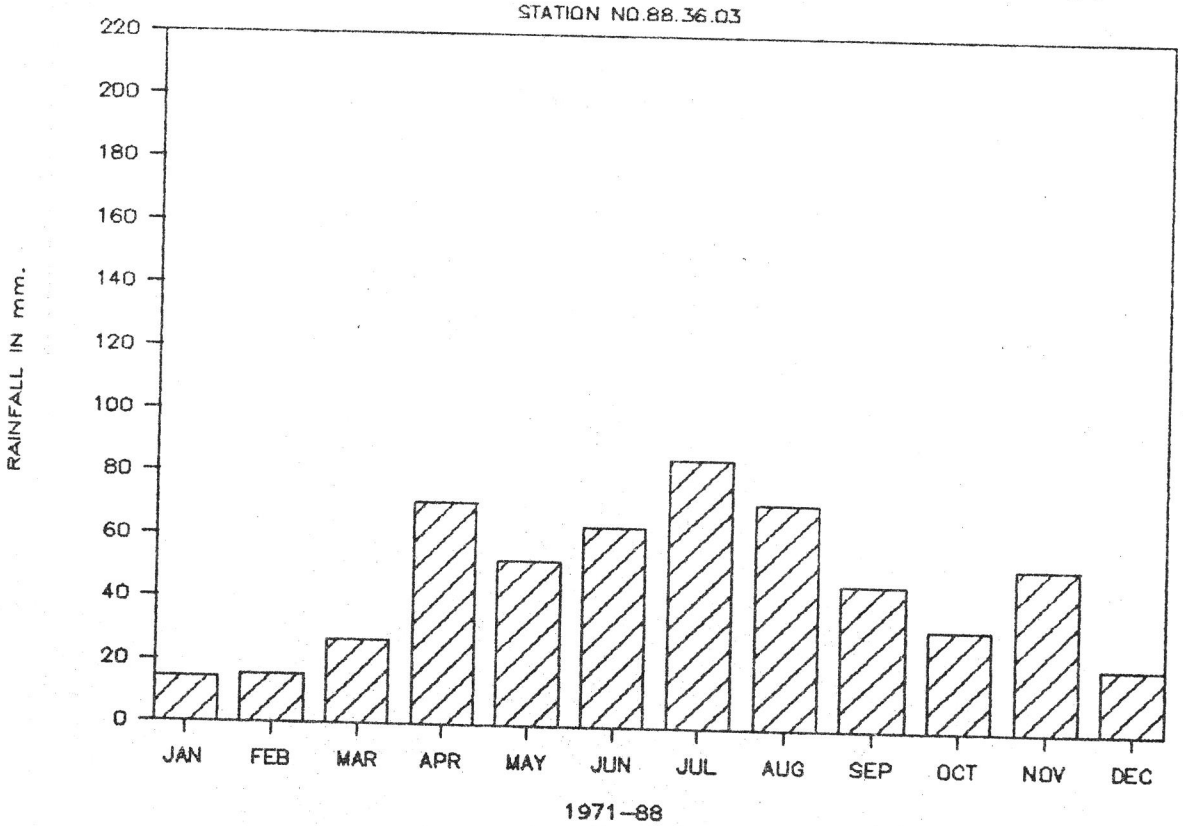
STATION NO.89.37.69




1974–88

## MEAN MONTHLY RAINFALL AT PORORR FOREST

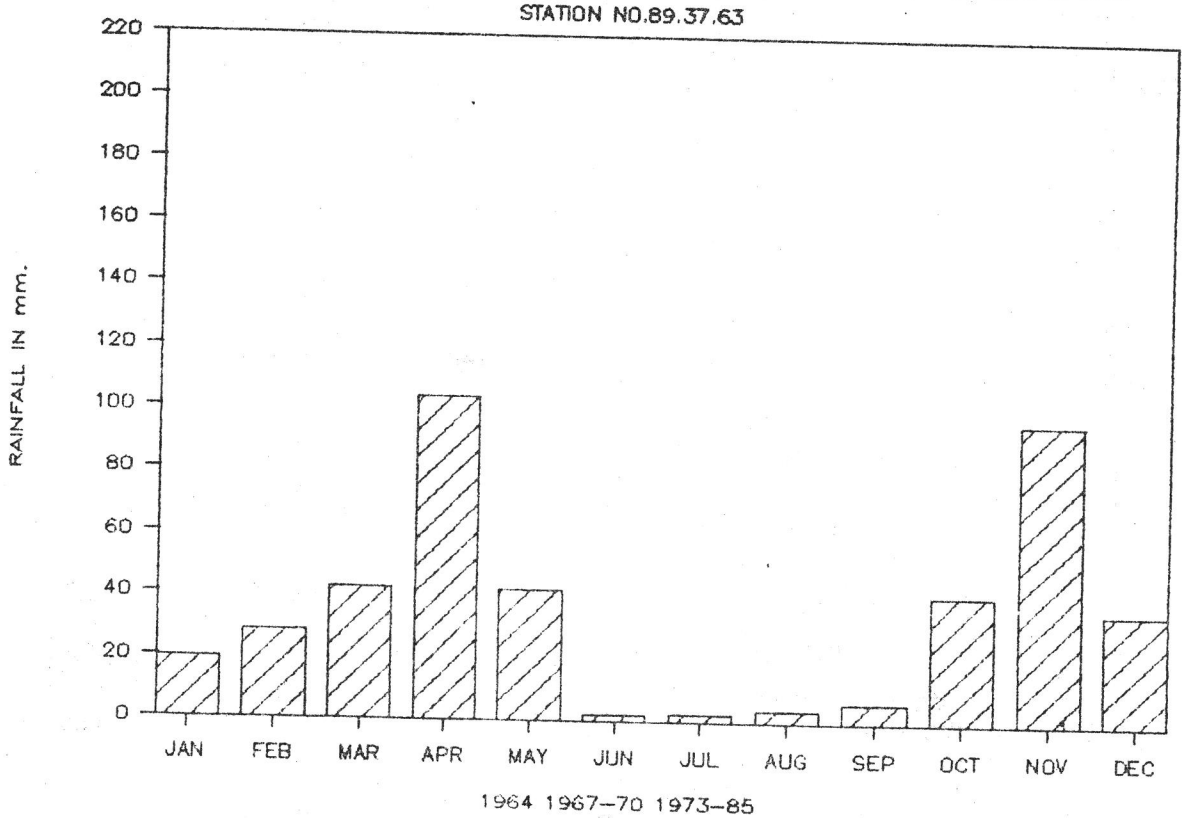
STATION NO.88.36.03




1971–88

## MEAN MONTHLY RAINFALL AT SAMBURU LODGE

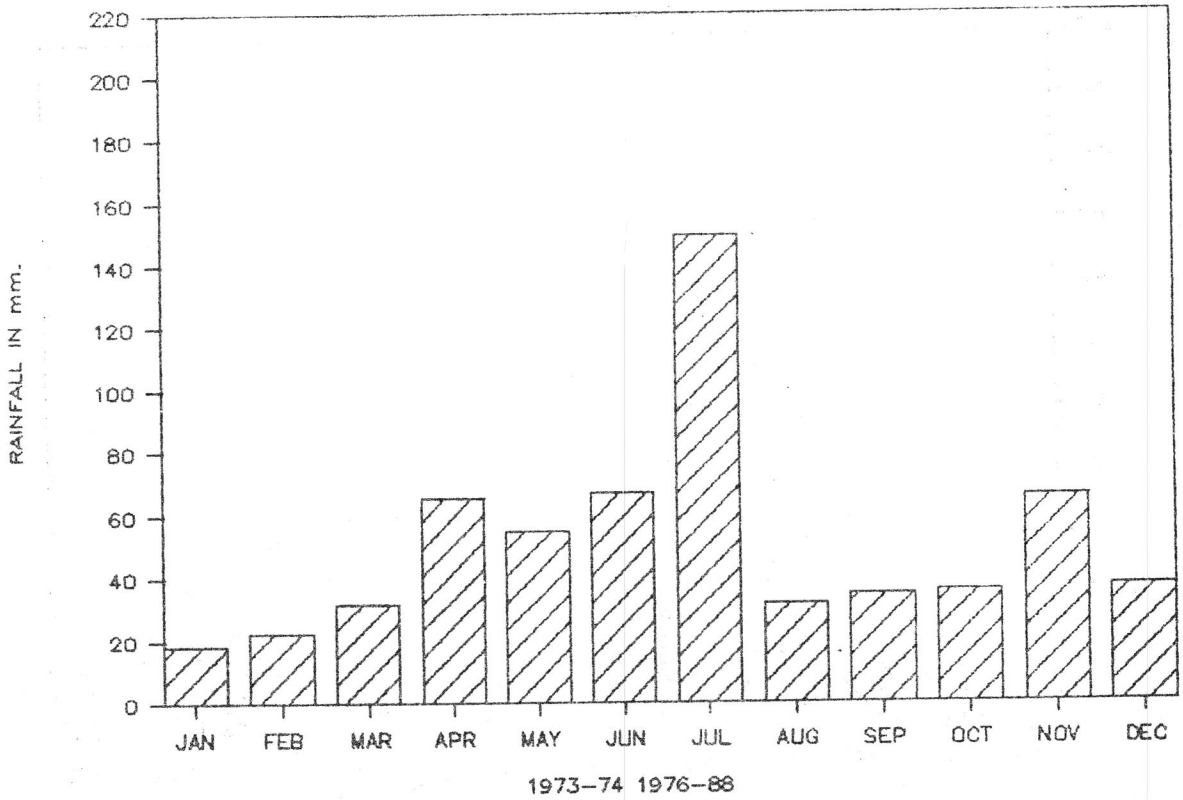
STATION NO.89.37.63




1964 1967–70 1973–85

## MEAN MONTHLY RAINFALL AT SUKUTA MARMAR

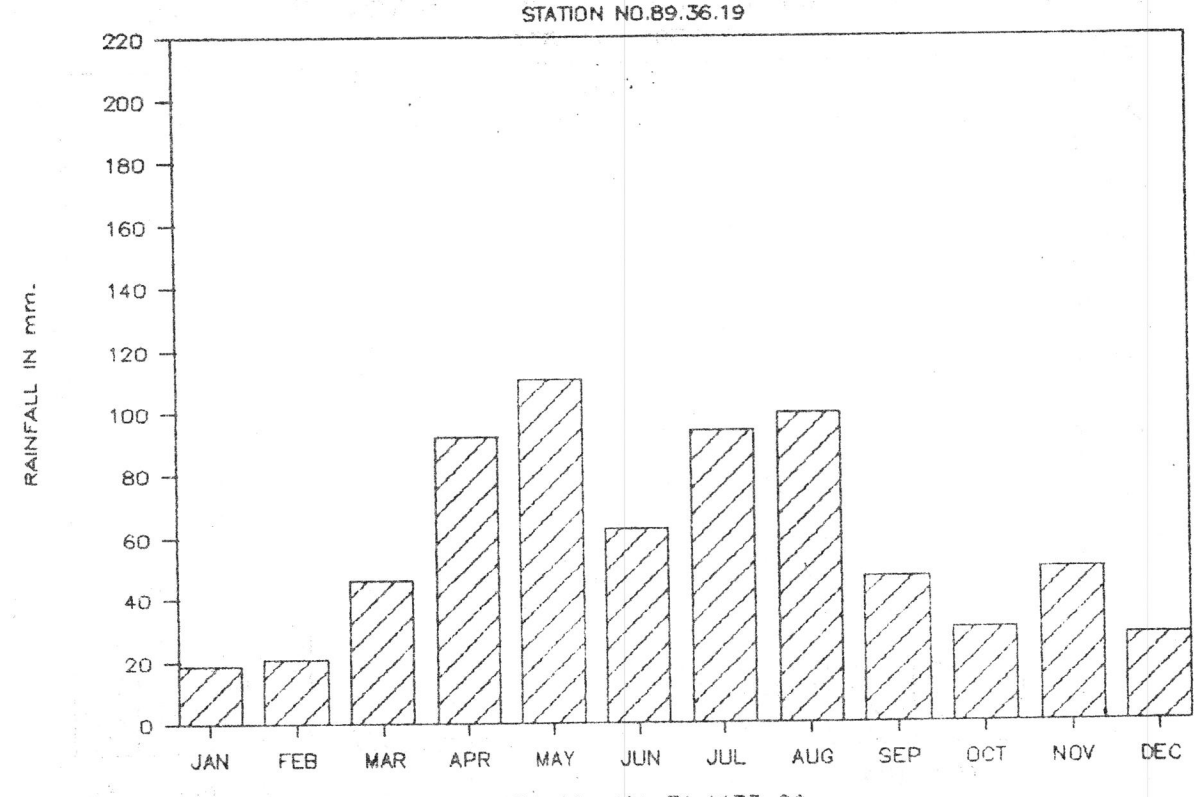
STATION NO.89.36.74




1973–74 1976–88

## MEAN MONTHLY RAINFALL AT TANGULBEI

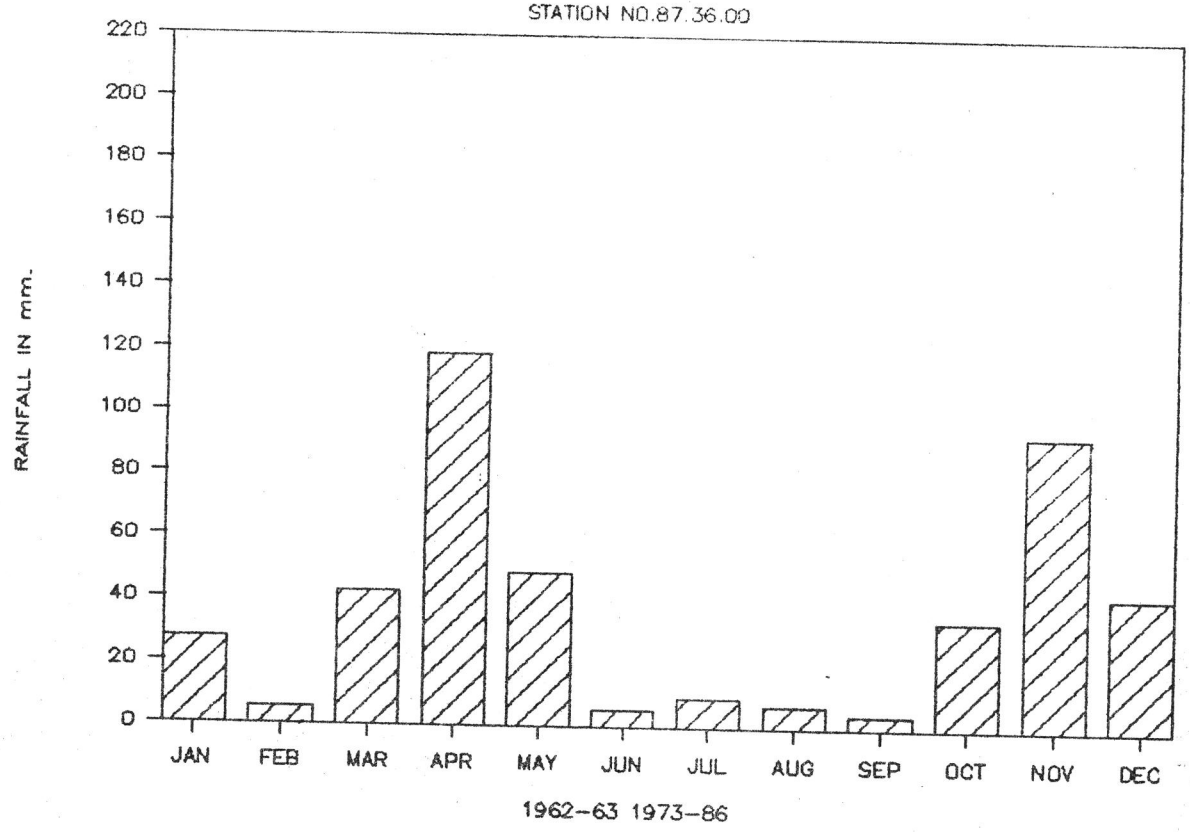
STATION NO.89.36.19




1939–62 1964–71 1973–86

## MEAN MONTHLY RAINFALL AT SOUTH HORR

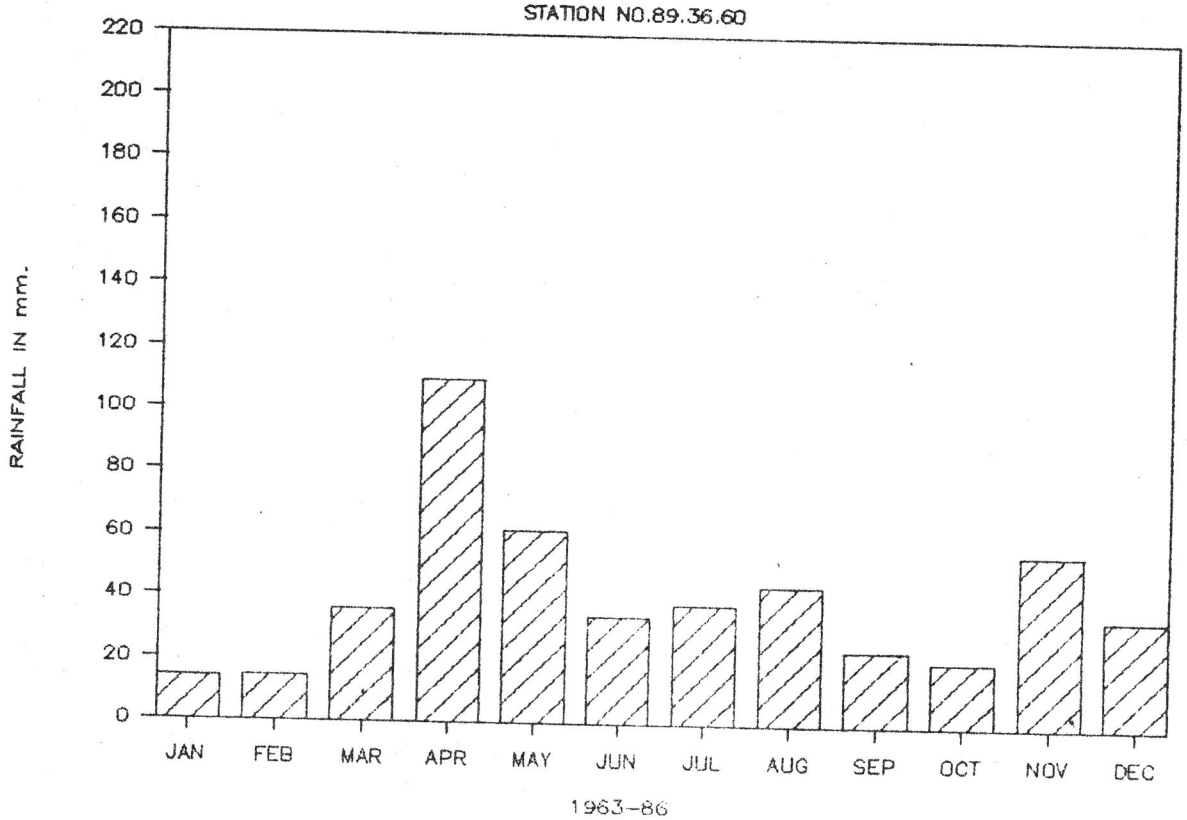
STATION NO.87.36.00




1962–63 1973–86

## MEAN MONTHLY RAINFALL AT SOSIAN

STATION NO.89.36.60



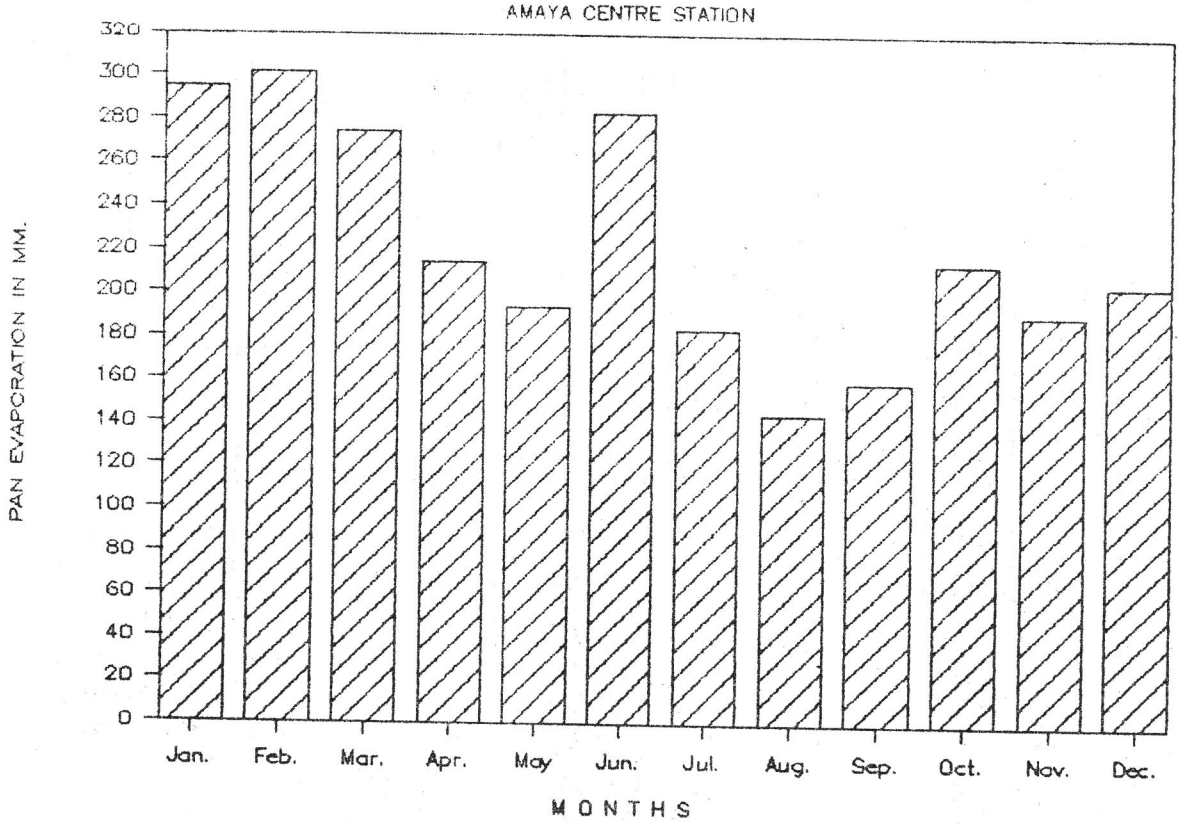

1963–86

# Appendix 4.6

## Monthly and Annual Evaporation Graphs

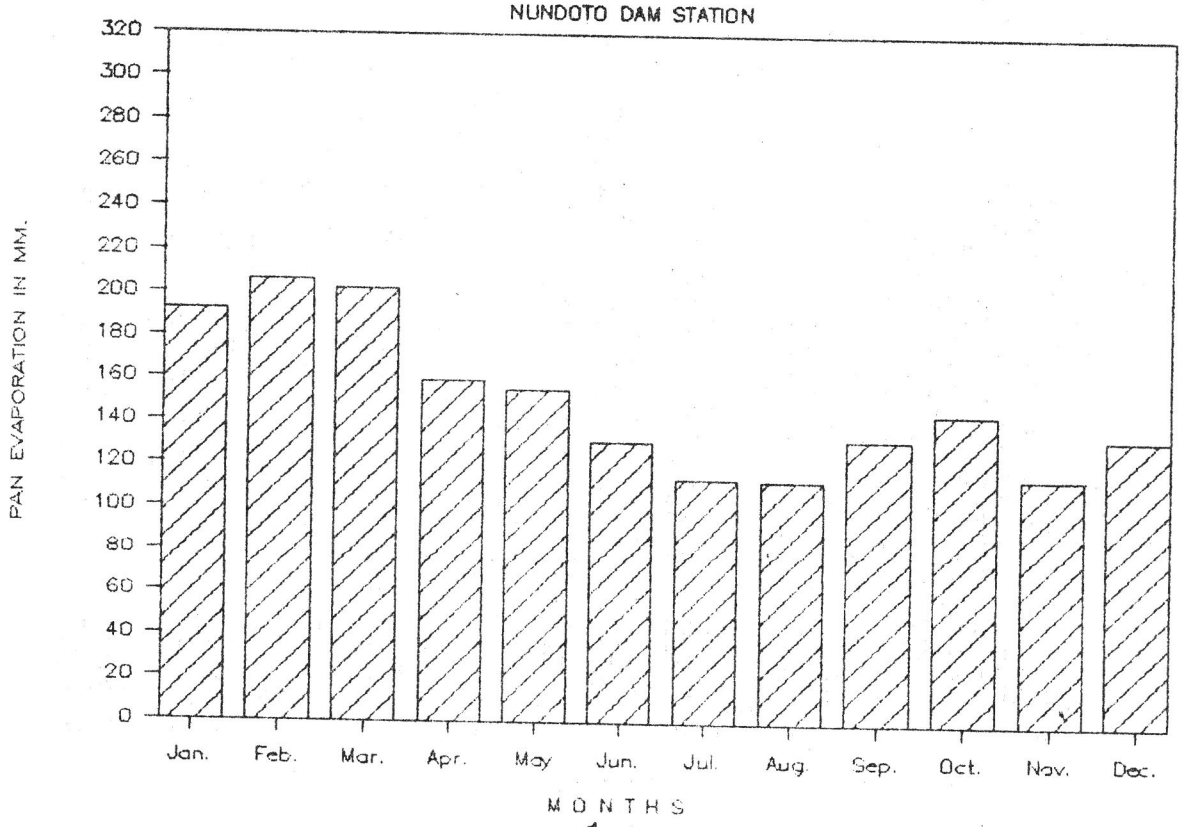
# MONTHLY EVAPORATION DISTRIBUTION..1988

AMAYA CENTRE STATION



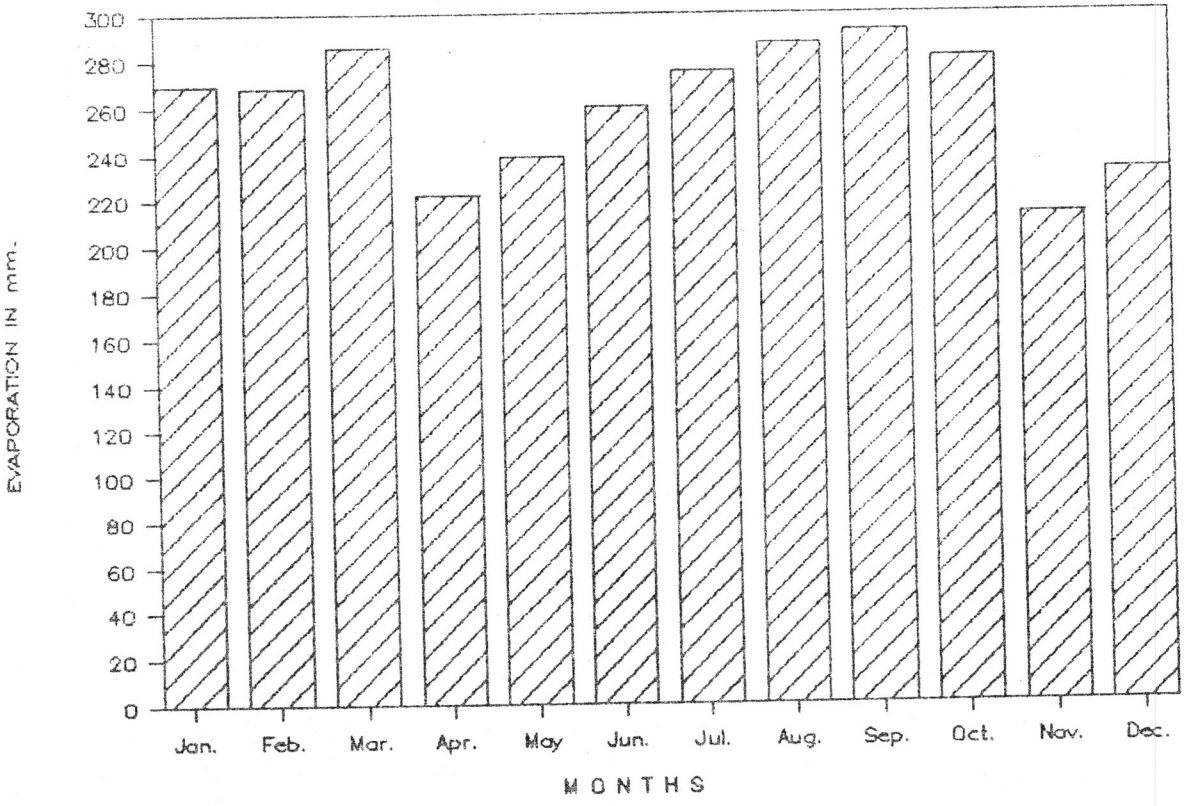

# MONTHLY EVAPORATION DISTRIBUTION..1988

NUNDOTO DAM STATION

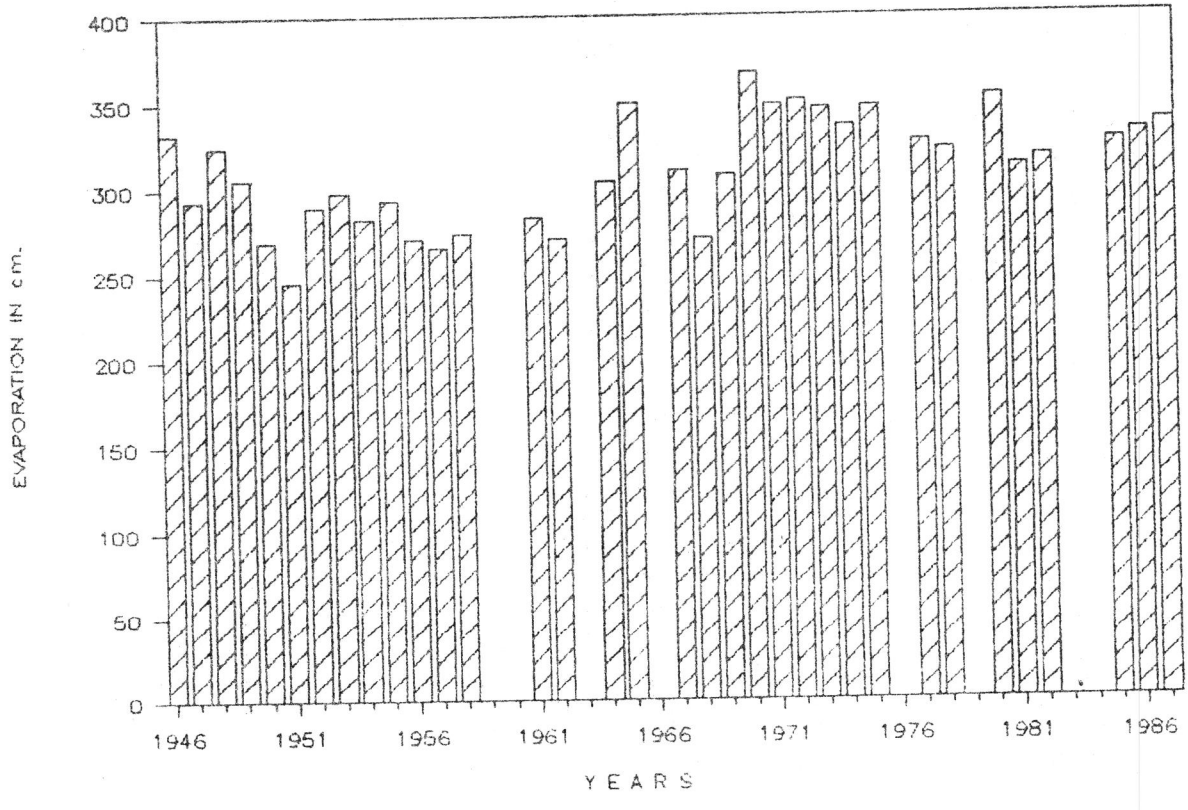


## MEAN MONTHLY PAN EVAPORATION..1946–88

ARCHER'S POST STATION NO. WD.1

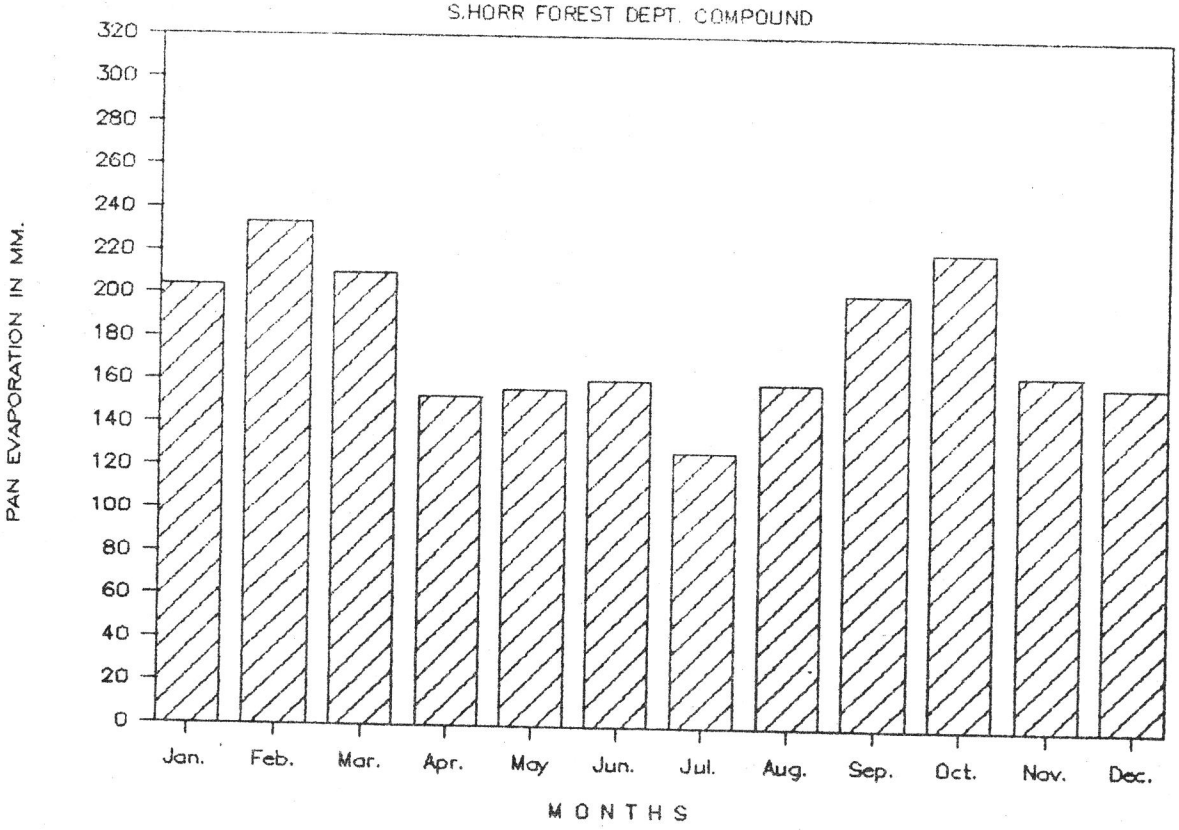



## ANNUAL PAN EVAPORATION AT ARCHER'S POST



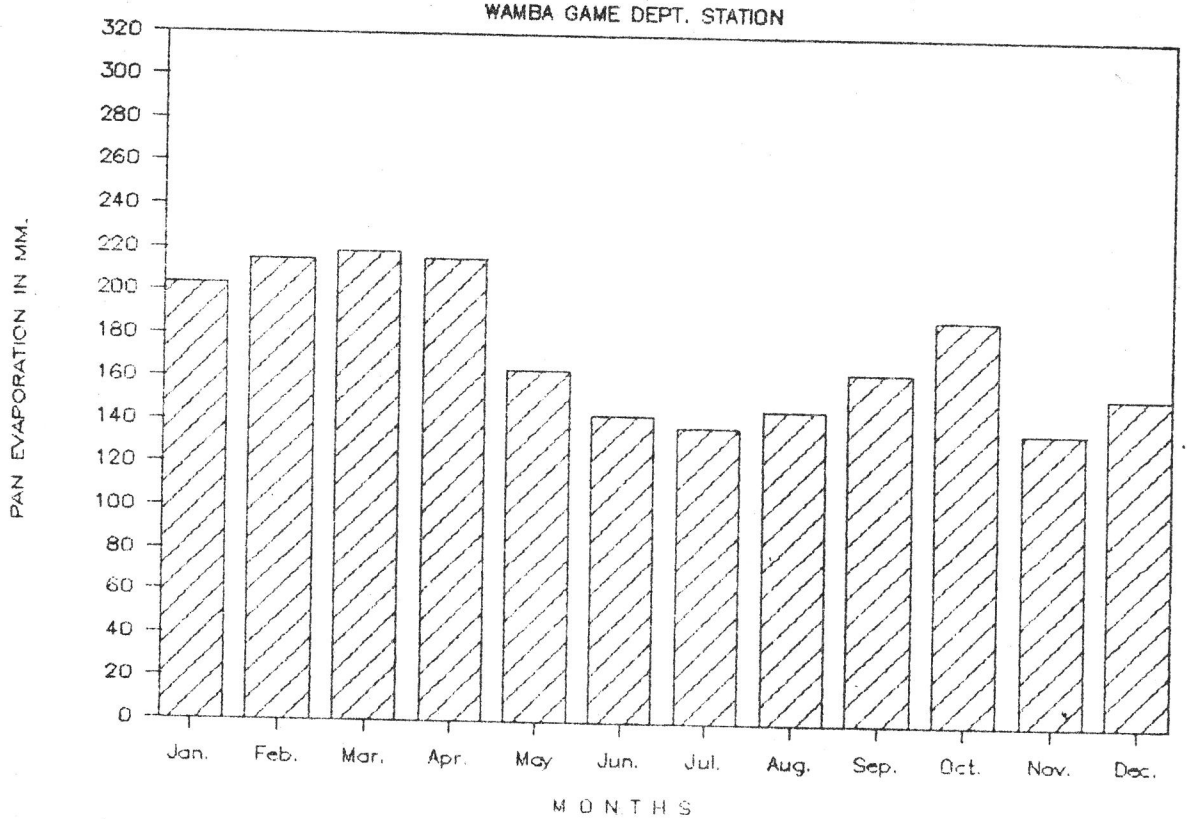
## MONTHLY EVAPORATION DISTRIBUTION..1988

S.HORR FOREST DEPT. COMPOUND



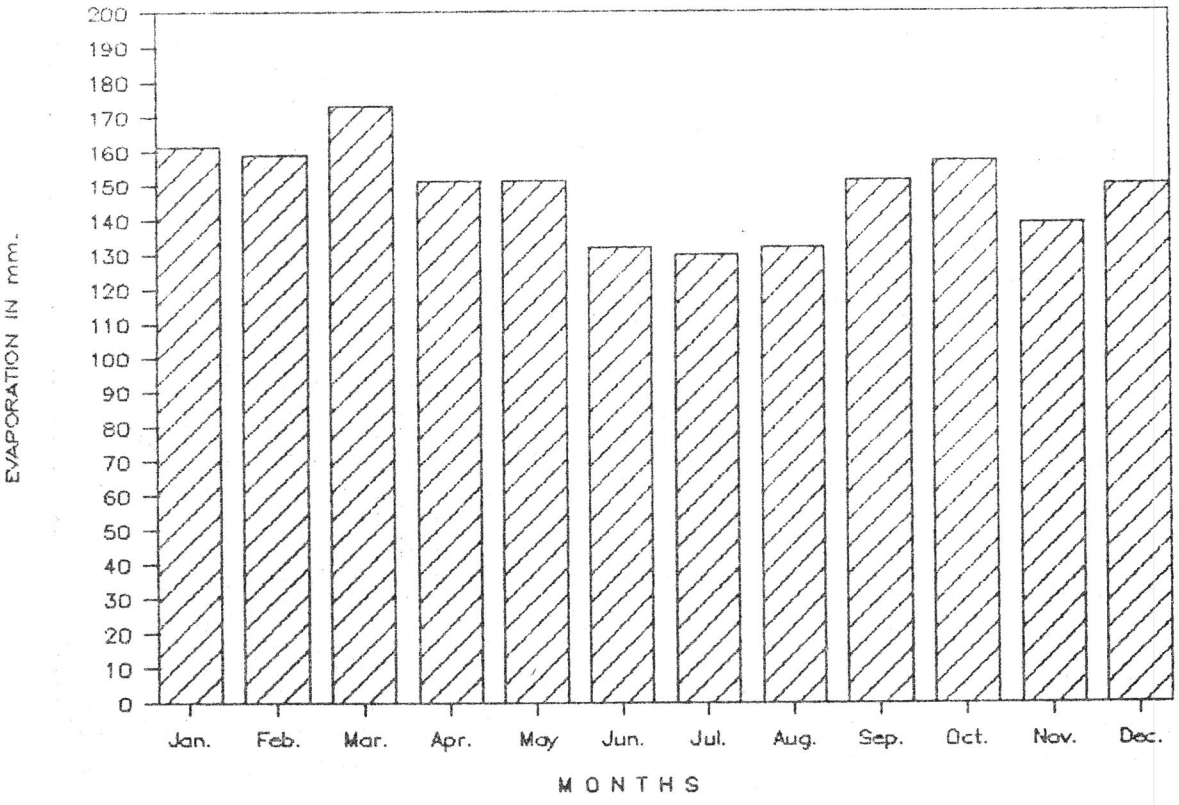

## MONTHLY EVAPORATION DISTRIBUTION..1988

WAMBA GAME DEPT. STATION



# MEAN MONTHLY POTENTIAL EVAPORATION

MARALAL PENMAN ESTIMATE (1946–56)



# Appendix 4.7

# Annual Rainfall

## ANNEX 4.7 ANNUAL AND SEASONAL RAINFALL

*(summary of main conclusions from 'Climate of Samburu District, Kenya' by R. Jaetzold)*

### Methodology

The report contains nine rainfall maps for Samburu District with contour lines of median rainfalls. A median value is the middle value in a group of numbers which have been arranged in ascending or descending order. This value is exceeded by 50% of the other values.

The report mentions as main advantage of the use of medians (instead of means) that, given a rather short series of observations, an extreme wet year might have no effect on the median value. But the average will be substantially lifted. Vegetation reflects much more the median rainfall than the average as extreme values have no major, permanent influence on it. In the absence of adequate coverage of rainfall stations, vegetation can be used as an indicator for median rainfall. The continuous contour lines on the rainfall maps are based on interpolations from rainfall stations while the dotted lines are based on vegetational information.

Using these techniques, contour maps of the annual median rainfall, and of the seasonal (long and short) rains are produced and attached to this report as Plates 4.2 to 4.4 through. For other valuable maps, notably those about reliability of rainy seasons, growing periods, production risks and eco-climatic zones reference is made to the afore mentioned report.

*(The difference between the median and mean is not as big as is suggested by the report: in Samburu District, the average is about 10% higher than the median, and this is almost the same as the error of estimate of an individual raingauge in a remote area -WRAP Editor)*

### Variability

The variability of the rainfall increases with decreasing means or medians, and time: i.e the variability in the arid areas in the East and the North is much greater than in the West while the variability of seasonal rainfalls is also much greater than of annual rains. Seasonal droughts are rather common.

In the higher parts of the District, the long rains are usually good but the short rains poor.

### Droughts

Droughts are defined in terms of forage production rates. Very low or zero rates during a critical period means a drought. Details are contained in the report.

The main conclusion is that severe droughts occur more frequently in semi-arid lowlands than in the higher (more humid parts) of the District. Furthermore, they occur more often during the second half of the year when the short rains fail.

For more information on rainfall reference is made to the original report by Jaetzold. This report contains a lot of additional information in the form of tables, graphs and maps on seasonal and annual rainfalls.

# Appendix 4.7 Annual rainfall in mm.

| Station : | Poror Forest | Maralal DC | Nundoto Dam | Sukuta Marmar | Sosian | Tangulbei | Wamba Game | Wamba DO | Lodungukwe | S.Horr | Samburu Lodge | Baragoi DO | Archer's Post |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Reg No. | 883603 | 883600 | WD.656 | 893674 | 893660 | 893619 | 893769 | 893718 | 893793 | 873600 | 893763 | 883601 | 893735 |
| Alt.(m.) | 2408 | 1951 | 1900 | 1896 | 1737 | 1524 | 1360 | 1315 | 1310 | 1006 | 914 | 914 | 864 |
| 1936 | | 899 | | | | | | | | | | | |
| 1937 | | 628 | | | | | | | | | | | |
| 1938 | | 545 | | | | | | | | | | | |
| 1939 | | 582 | | | | | | | | | | | |
| 1940 | | 547 | | | | | | 384 | | | | | |
| 1941 | | 658 | | | | 707 | | 500 | | | | 350 | |
| 1942 | | 700 | | | | | | 784 | | | | 496 | |
| 1943 | | 480 | | | | 777 | | 385 | | | | 386 | |
| 1944 | | 591 | | | | 996 | | 350 | | | | 384 | |
| 1945 | | 607 | | | | 792 | | 463 | | | | 469 | |
| 1946 | | 463 | | | | 743 | | 379 | | | | 678 | |
| 1947 | | 695 | | | | | | 322 | | | | 479 | |
| 1948 | | 586 | | | | 896 | | 891 | | | | 491 | 144 |
| 1949 | | 496 | | | | 661 | | 1744 | | | | 607 | 358 |
| 1950 | | 544 | | | | 425 | | 549 | | | | 426 | 318 |
| 1951 | | 756 | | | | 569 | | 602 | | | | 382 | 180 |
| 1952 | | 478 | | | | | | 1542 | | | | 446 | 228 |
| 1953 | | 460 | | | | 496 | | 475 | | | | 558 | 669 |
| 1954 | | 714 | | | | 400 | | 639 | | | | 586 | 119 |
| 1955 | | 693 | | | | 701 | | 467 | | | | 487 | 171 |
| 1956 | | 684 | | | | | | 643 | | | | 562 | 246 |
| 1957 | | 503 | | | | | | 884 | | | | 517 | 170 |
| 1958 | | 739 | | | | 822 | | 849 | | | | 541 | 410 |
| 1959 | | 518 | | | | 981 | | 508 | | | | 574 | 422 |
| 1960 | | 688 | | | | 667 | | 574 | | | | 730 | 317 |
| 1961 | | 986 | | | | 380 | | 649 | | | | 511 | 446 |
| 1962 | | 671 | | | | 1245 | | 1282 | | | | 552 | 243 |
| 1963 | | 632 | | | | 605 | | 727 | | 410 | | 1087 | 847 |
| 1964 | | 718 | | | 679 | | | 1268 | | | | 714 | 755 |
| 1965 | | 336 | | | 604 | 1075 | | 796 | | | | 528 | 713 |
| 1966 | | 640 | | | 171 | 526 | | 555 | | | | 502 | 366 |
| 1967 | | 599 | | | 289 | | | 619 | | | | 281 | 189 |
| 1968 | | 637 | | | 581 | 1124 | | 1433 | | | 771 | 710 | 478 |
| 1969 | | 530 | | | | 939 | | 1435 | | | 1024 | 555 | 539 |
| 1970 | | 683 | | | 255 | 708 | | 816 | | | 467 | 465 | 683 |
| 1971 | 734 | 724 | | | 200 | 1050 | | 595 | | | | 345 | 380 |
| 1972 | 370 | 478 | | | 430 | 902 | | 690 | | | | 414 | 218 |
| 1973 | 577 | 543 | | | 446 | | | 551 | | | | 442 | 288 |
| 1974 | 576 | 565 | | | 316 | 630 | | 674 | | 317 | 201 | 483 | 349 |
| 1975 | 829 | 708 | | | 353 | 551 | 612 | 591 | | 364 | 96 | 545 | 276 |
| 1976 | 390 | 459 | | 419 | 385 | 837 | 748 | 670 | | 261 | 303 | 523 | 189 |
| 1977 | 1018 | 1052 | 1228 | 959 | 512 | 524 | 521 | 568 | 261 | 114 | 254 | 647 | 276 |
| 1978 | 722 | 817 | 637 | 1586 | 859 | 661 | 1302 | 1070 | 896 | 1227 | 602 | 461 | 151 |
| 1979 | 473 | 481 | 504 | | | | 1159 | 1047 | 693 | | | 688 | 404 |
| 1980 | 332 | 314 | 306 | 401 | | 302 | 851 | 610 | 573 | 431 | 467 | 663 | 478 |
| 1981 | 495 | 789 | 1141 | 547 | | 436 | 355 | 266 | 301 | 450 | 205 | 491 | 264 |
| 1982 | 473 | 385 | 320 | 418 | | 588 | 777 | 646 | 492 | 509 | 286 | 381 | 226 |
| 1983 | 797 | 552 | 259 | 619 | 598 | 637 | 1111 | 955 | 592 | 452 | 401 | 365 | 342 |
| 1984 | 263 | 214 | 109 | 227 | 276 | 259 | 453 | 362 | 546 | | 301 | 453 | 482 |
| 1985 | 564 | 496 | | 625 | | | 459 | 447 | 219 | 340 | 169 | 690 | 196 |
| 1986 | 436 | 552 | 242 | 445 | | | 754 | 498 | | | | 438 | 223 |
| 1987 | 213 | 403 | | 415 | | | 685 | 672 | 439 | | | 598 | 272 |
| 1988 | 663 | 852 | 956 | 865 | | | 531 | 427 | 527 | | | 748 | 320 |
| | | | | | | | 1363 | 856 | | | | 524 | 304 |
| | | | | | | | | | | | | 634 | 389 |
| n .... | 18 | 53 | 10 | 12 | 16 | 35 | 15 | 50 | 11 | 11 | 14 | 50 | 43 |
| x .... | 551 | 605 | 570 | 627 | 435 | 703 | 779 | 714 | 504 | 443 | 396 | 532 | 350 |
| cv .... | 0.37 | 0.26 | 0.67 | 0.56 | 0.43 | 0.34 | 0.40 | 0.46 | 0.37 | 0.61 | 0.62 | 0.25 | 0.50 |

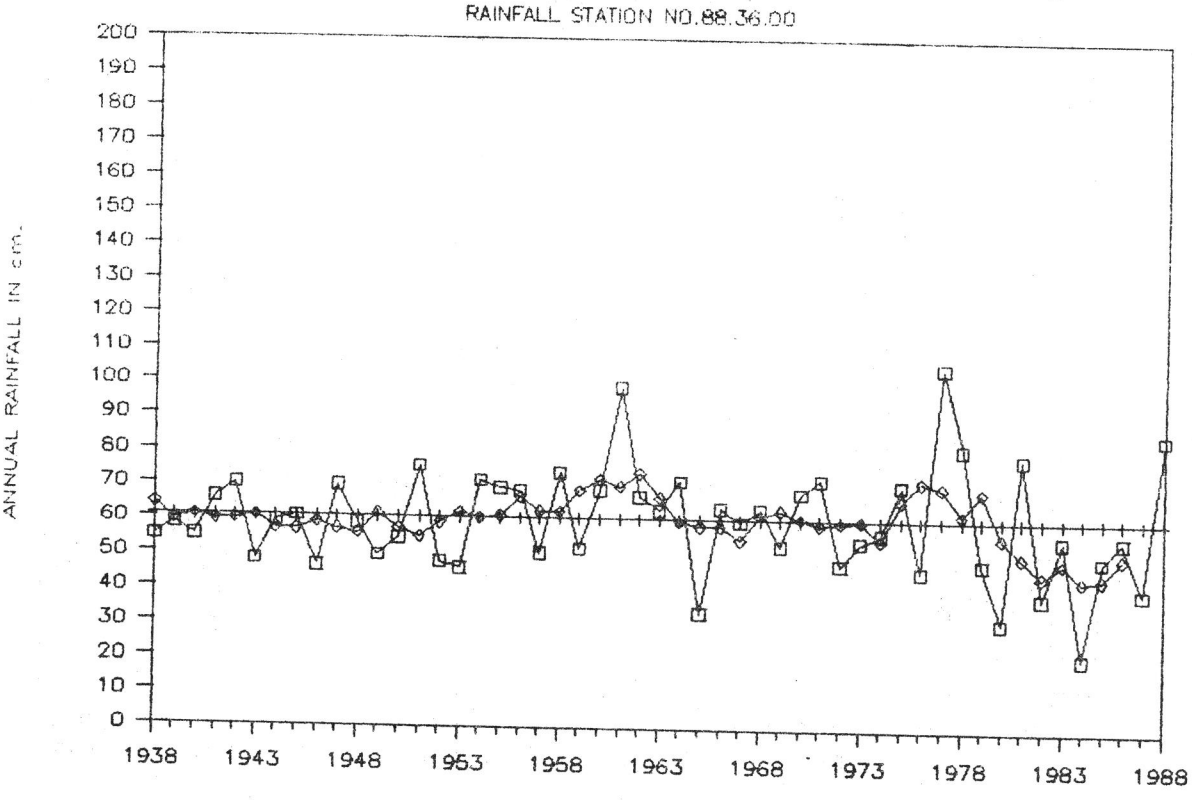
n ..... Number of years of complete record
x ..... Average annual rainfall
cv ..... Variation coefficient

# Appendix 4.8

# Annual Rainfall Variation

# ANNUAL RAINFALL VARIATION MARALAL DC

RAINFALL STATION NO.88.36.00



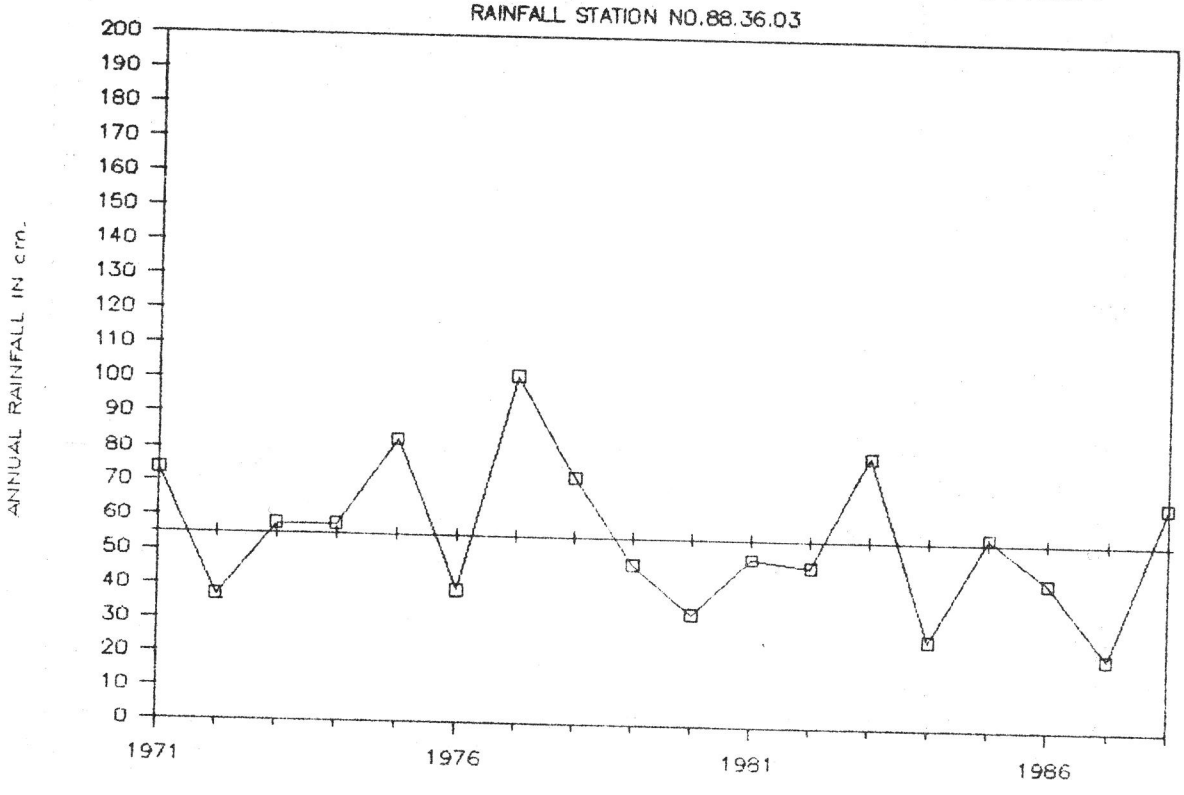

ANNUAL AVG.605 mm.(53 YEARS).

□ OBSERVED ANNUAL RF.

◇ 5 YR MOVING AVERAGE

# ANNUAL RAINFALL VARIATION PORORFOREST

RAINFALL STATION NO.88.36.03



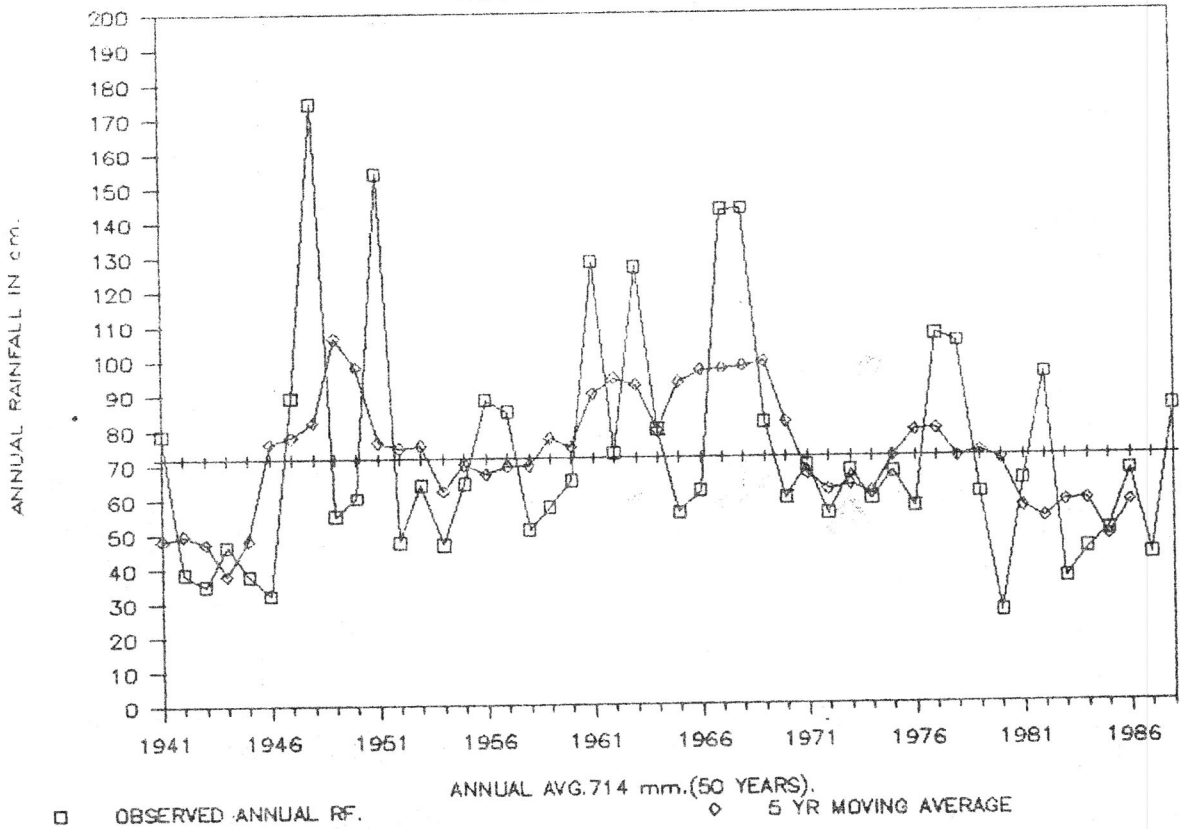

ANNUAL AVG.551 mm.(18 YEARS)

□ OBSERVED ANNUAL RF.

+ AVERAGE ANNUAL RF.

# ANNUAL RAINFALL VARIATION WAMBA DO HQ

RAINFALL STATION NO.89.37.18

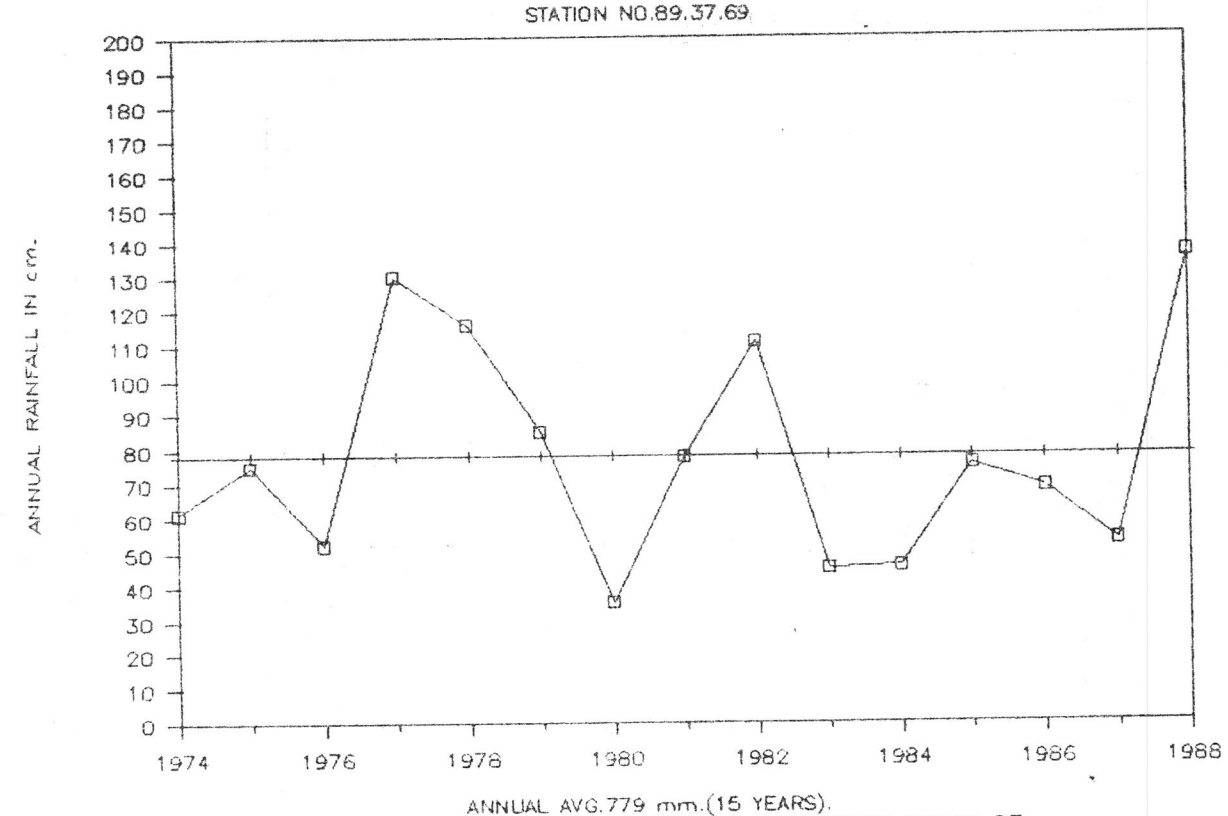



ANNUAL AVG.714 mm.(50 YEARS).

□ OBSERVED ANNUAL RF. ◇ 5 YR MOVING AVERAGE

# ANNUAL RAINFALL VARIATION WAMBA GAME

STATION NO.89.37.69

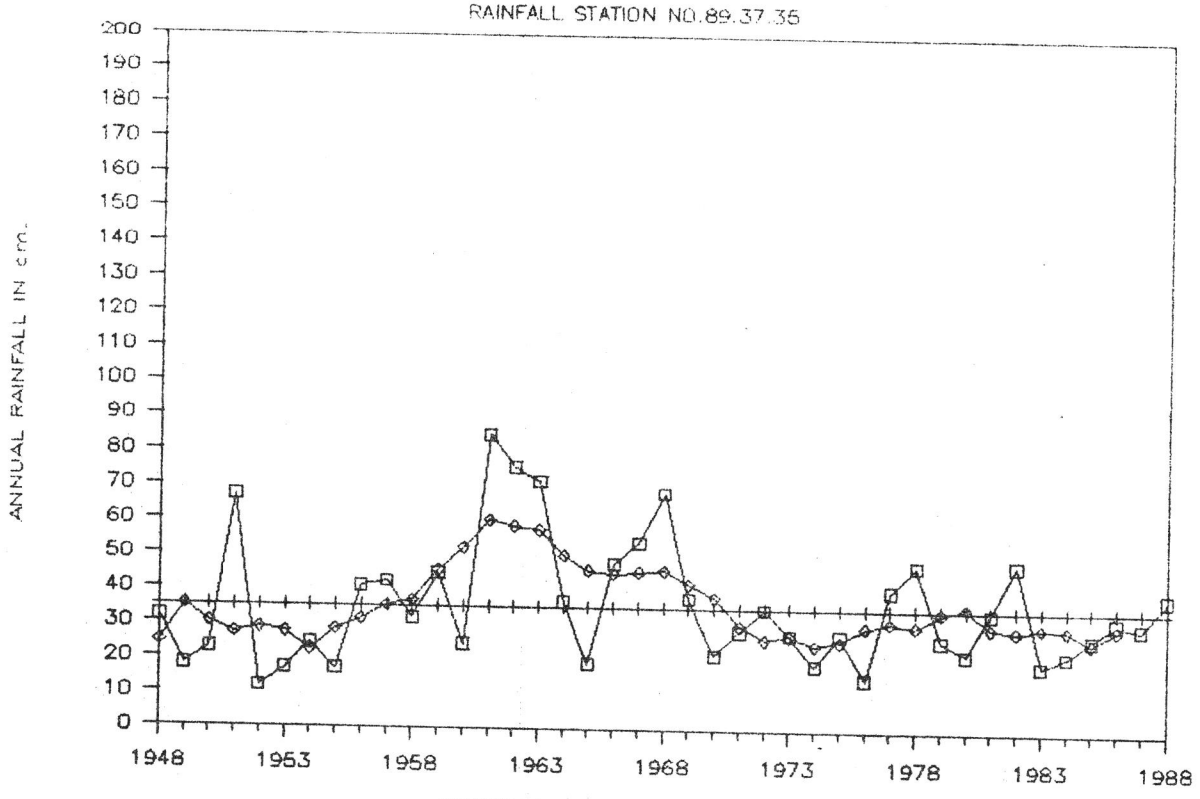



ANNUAL AVG.779 mm.(15 YEARS).

□ OBSERVED ANNUAL RF. + AVERAGE ANNUAL RF.

# ANNUAL RAINFALL VARIATION ARCHER'S POST

RAINFALL STATION NO.89.37.35

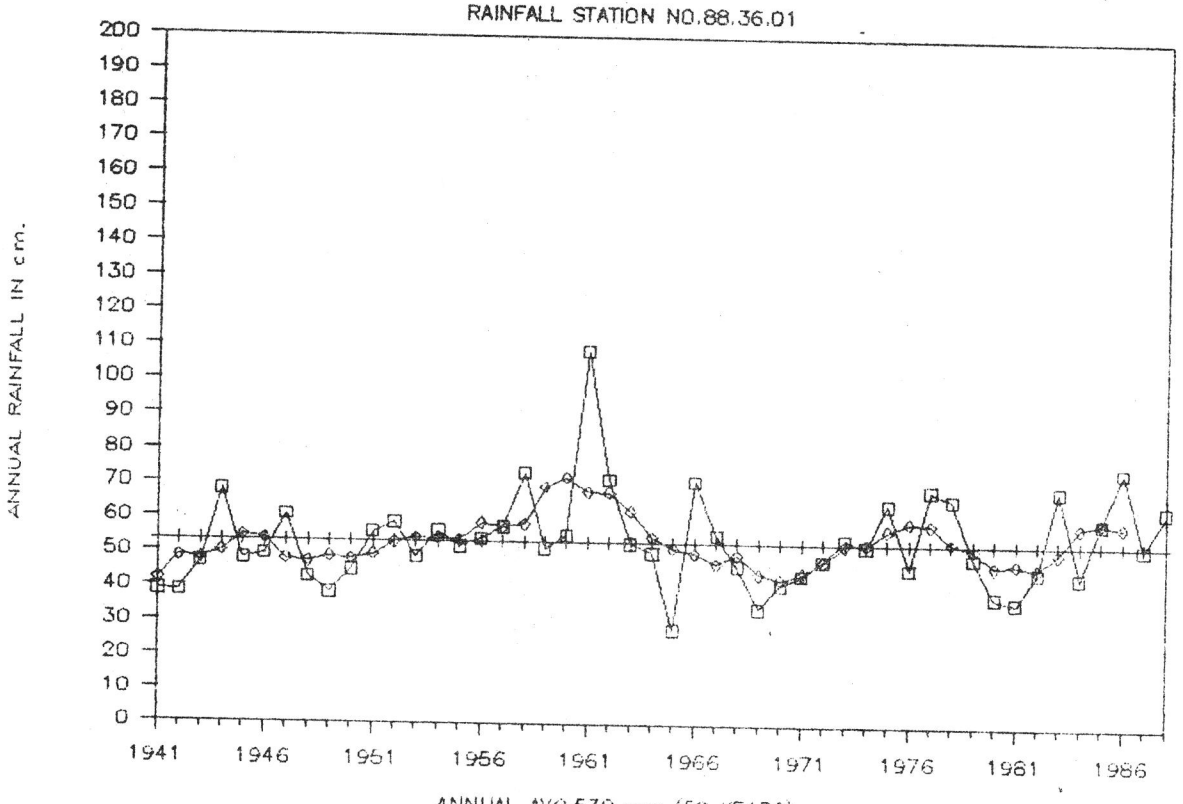



ANNUAL AVG.350 mm.(43 YEARS).

□ OBSERVED ANNUAL RF. ◇ 5 YR MOVING AVERAGE

# ANNUAL RAINFALL VARIATION BARAGOI DO HQ

RAINFALL STATION NO.88.36.01




ANNUAL AVG.532 mm.(50 YEARS).

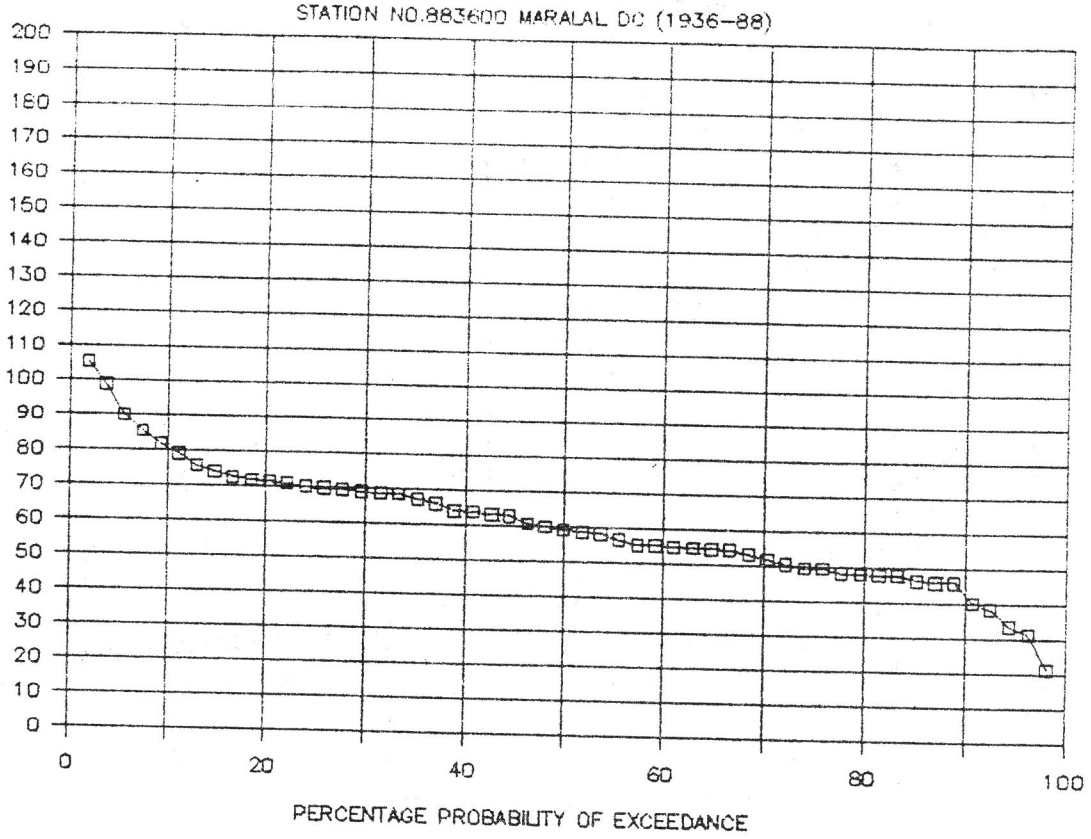
□ OBSERVED ANNUAL RF. ◇ 5 YR MOVING AVERAGE

# Appendix 4.9

## Annual Rainfall Frequency Distribution

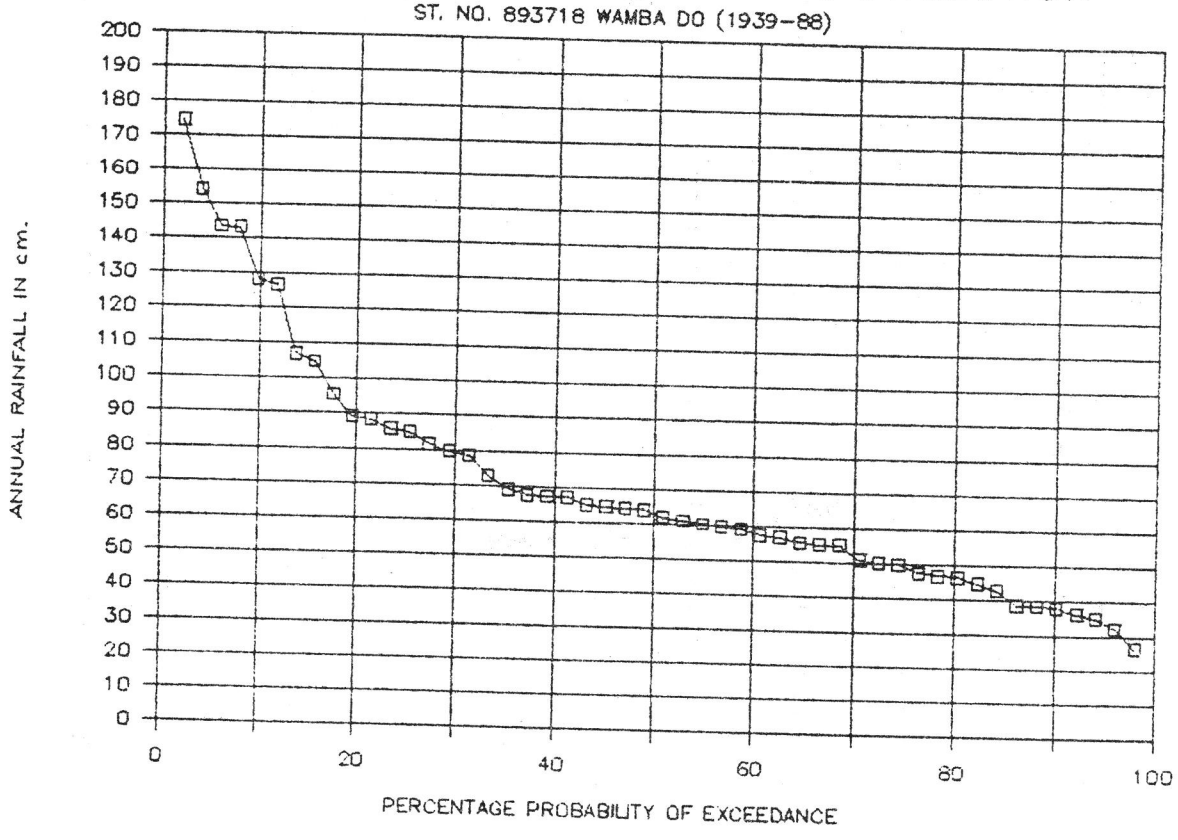
# ANNUAL RAINFALL FREQUENCY DISTRIBUTION

STATION NO.883600 MARALAL DO (1936–88)



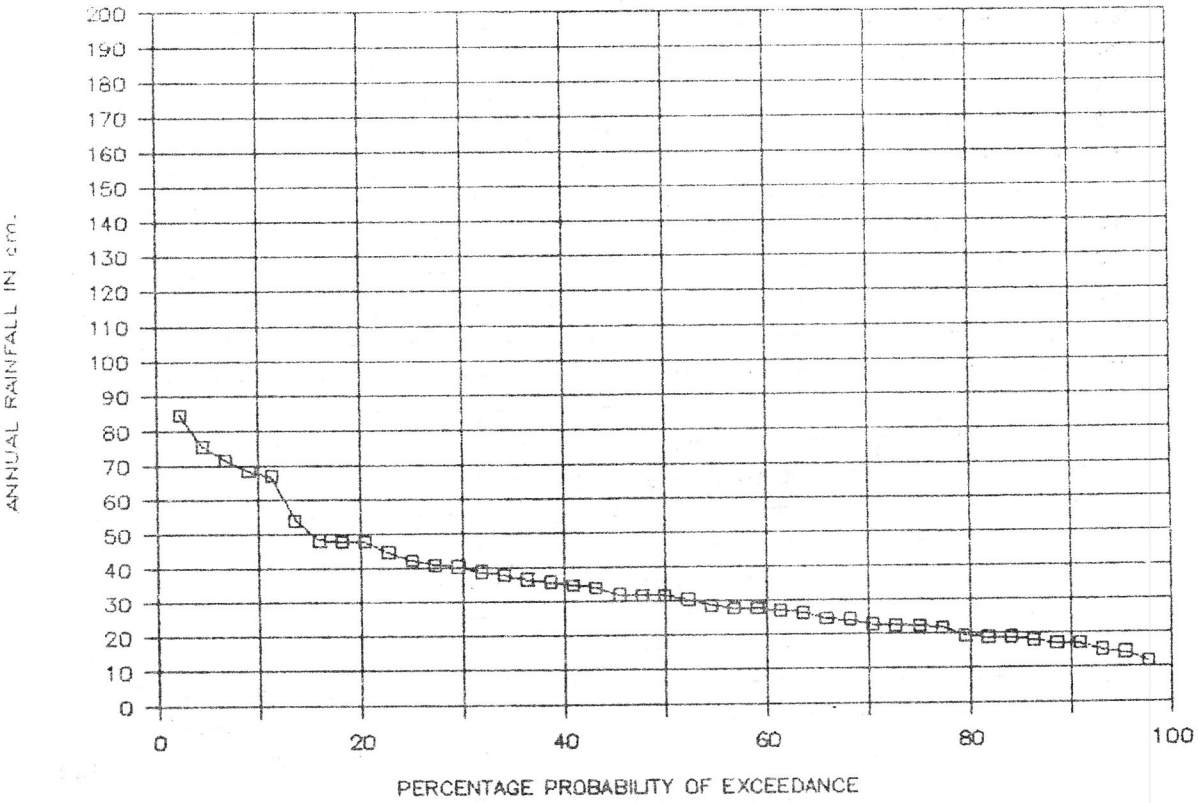

# ANNUAL RAINFALL FREQUENCY DISTRIBUTION

ST. NO. 893718 WAMBA DO (1939–88)



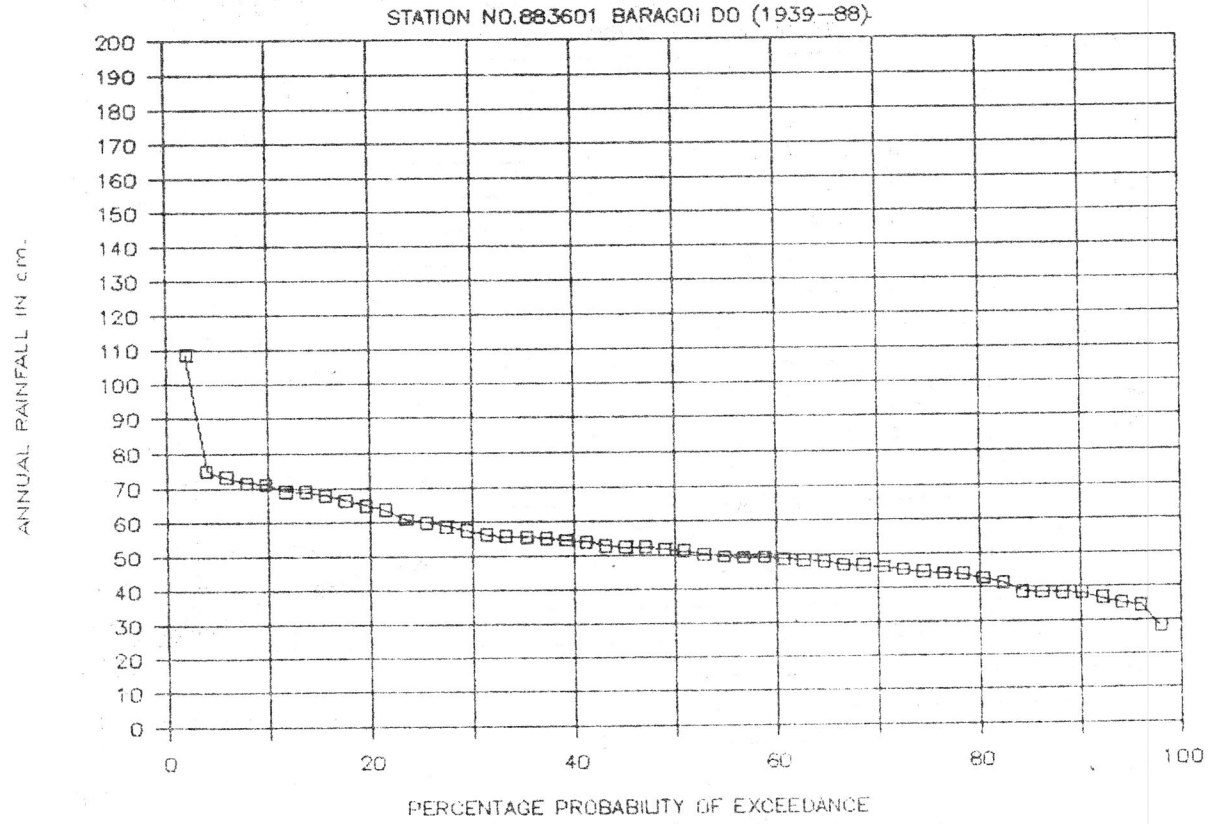
# ANNUAL RAINFALL FREQUENCY DISTRIBUTION

ST.NO. 893735 ARCHER'S POST (1946--88)




# ANNUAL RAINFALL FREQUENCY DISTRIBUTION

STATION NO.883601 BARAGOI DO (1939--88)



# Appendix 4.10

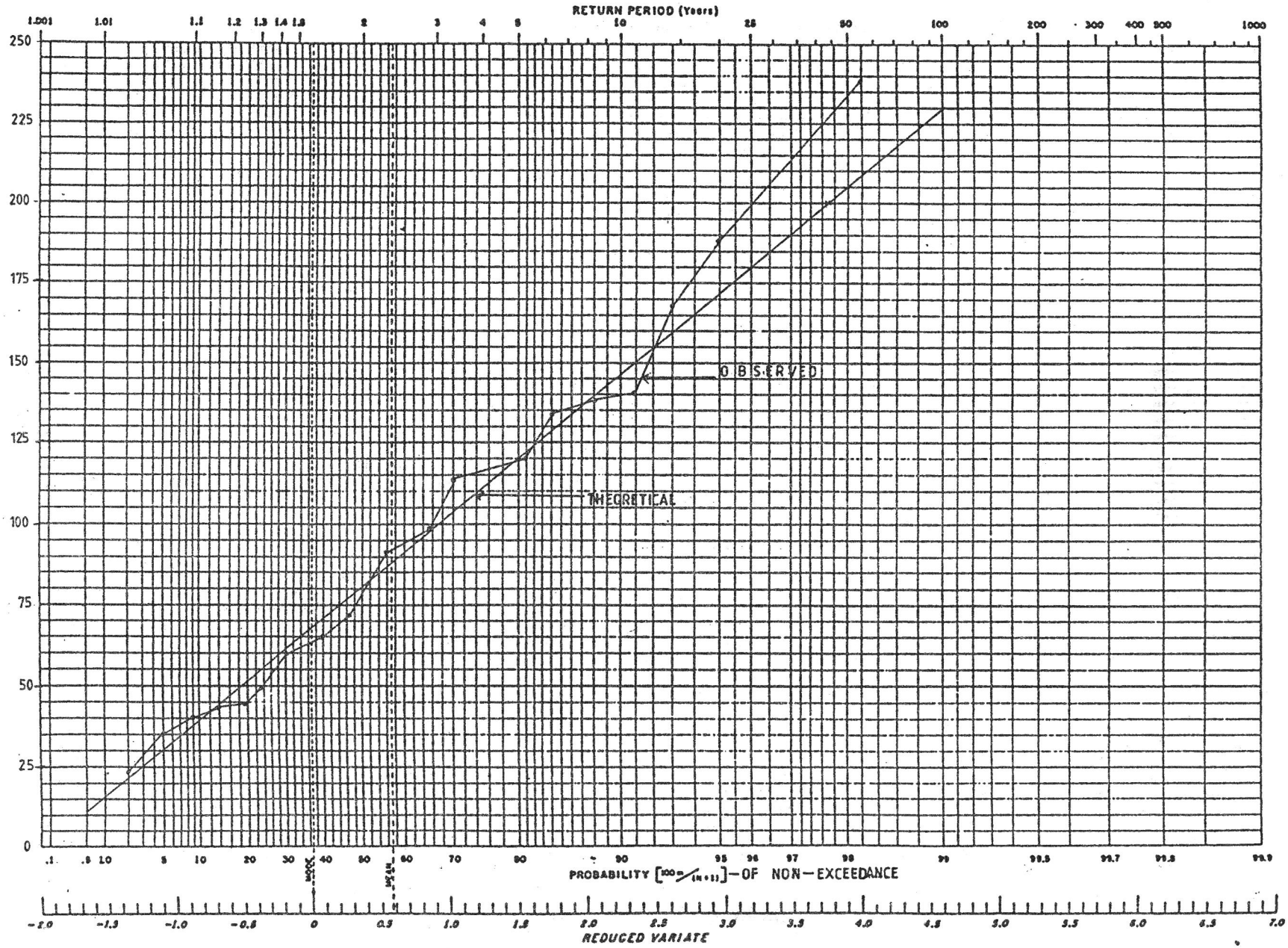
## Annual Maximum Daily Rainfall

(1-56)

U. S. DEPARTMENT OF COMMERCE, WEATHER BUREAU

Wamba D.O. Rainfall Station No. 89.37.18

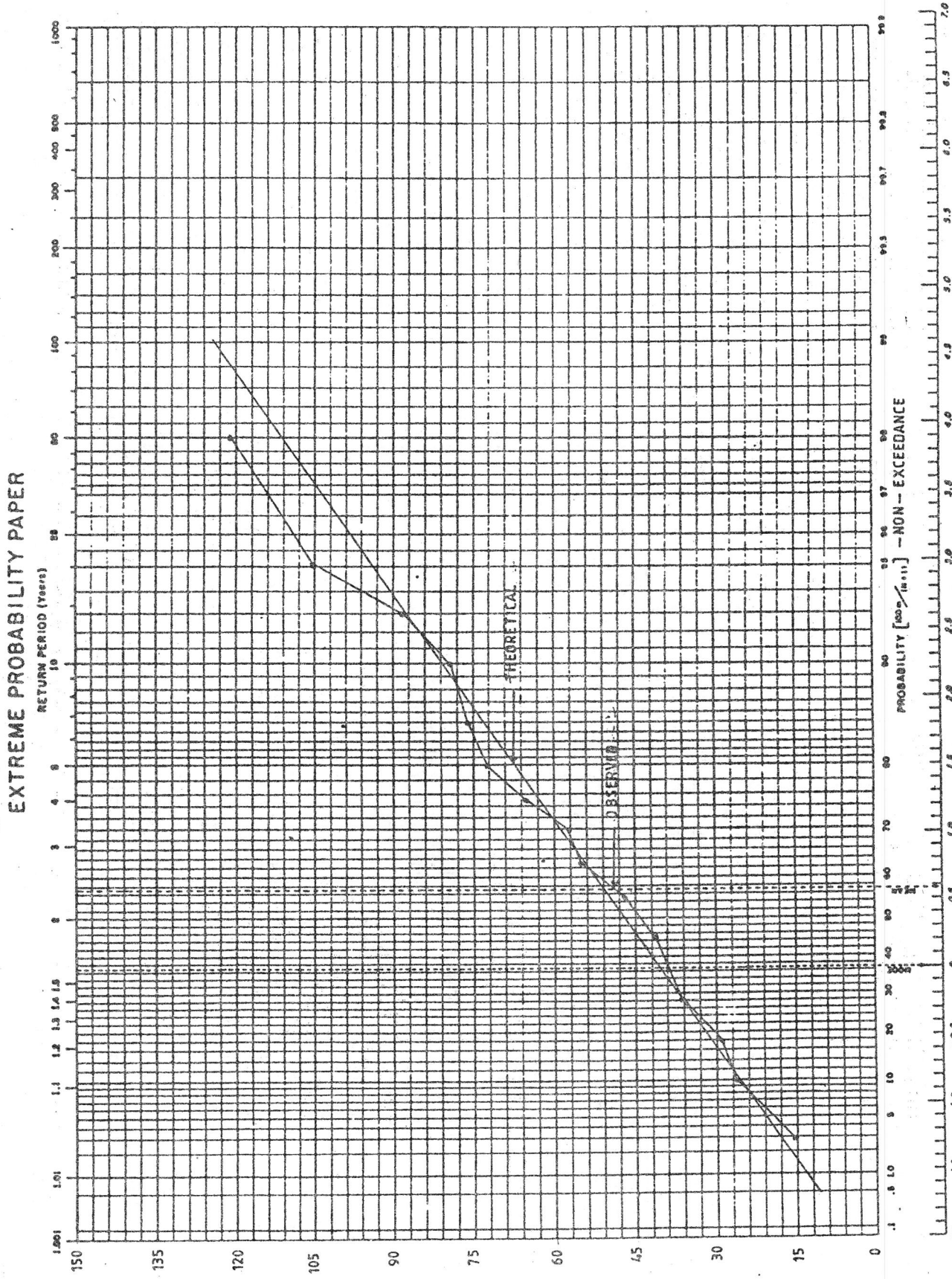
# EXTREME PROBABILITY PAPER



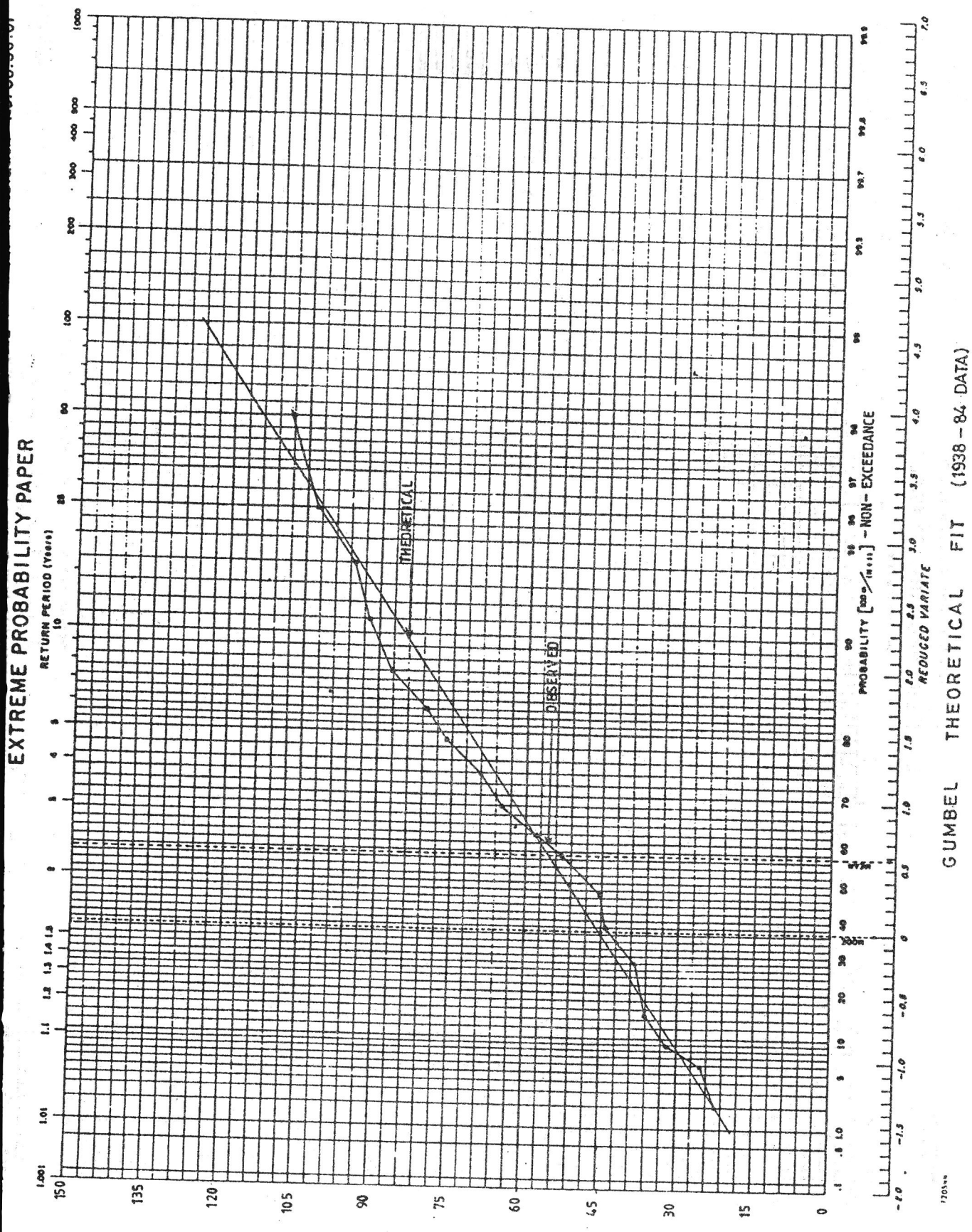

ANNUAL MAXIMUM DAILY RAINFALL (in mm)

GUMBEL THEORETICAL FIT (1939–84 DATA)

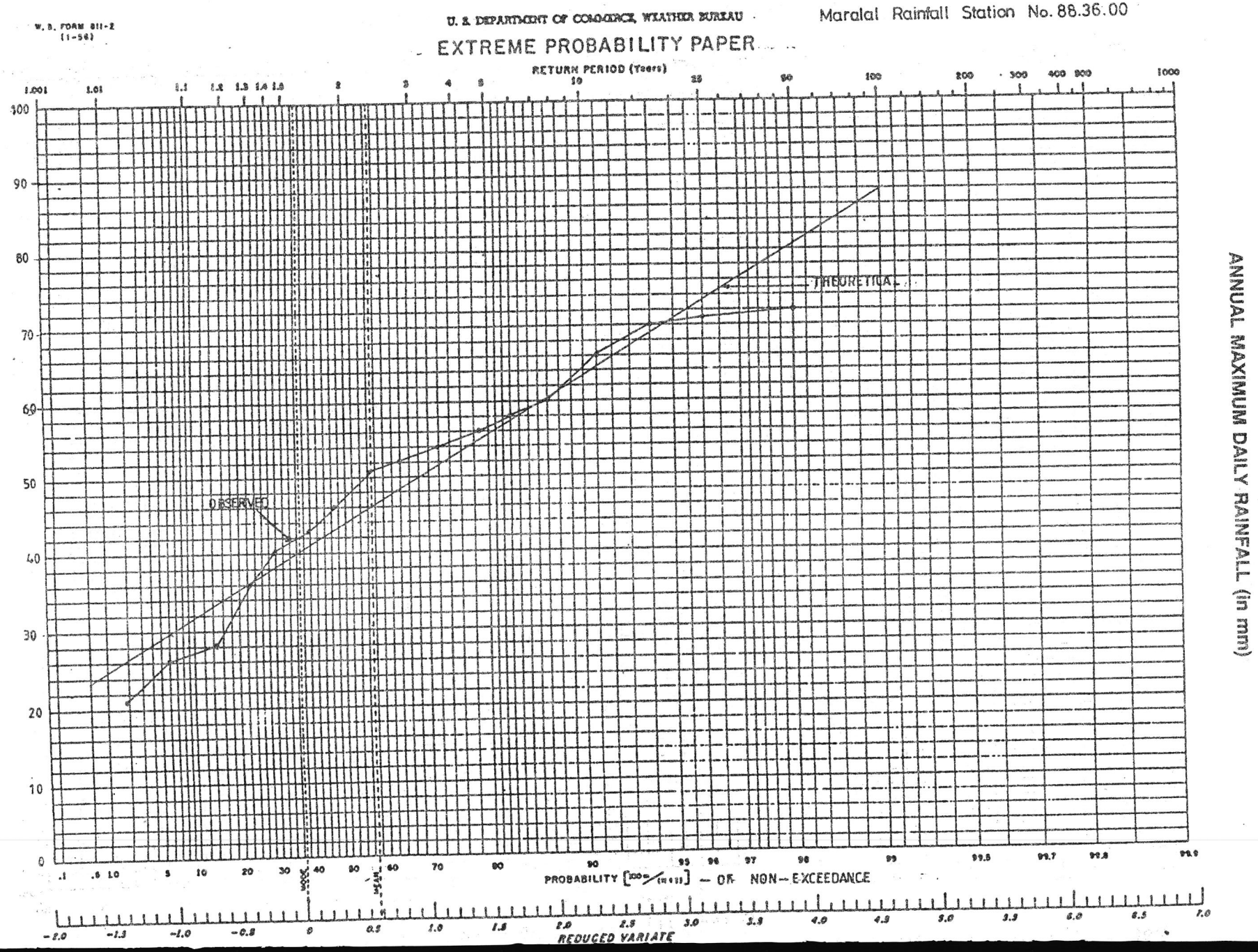
## ANNUAL MAXIMUM DAILY RAINFALL (in mm)



## ANNUAL MAXIMUM DAILY RAINFALL (in mm)




GUMBEL THEORETICAL FIT (1938 – 84 DATA)

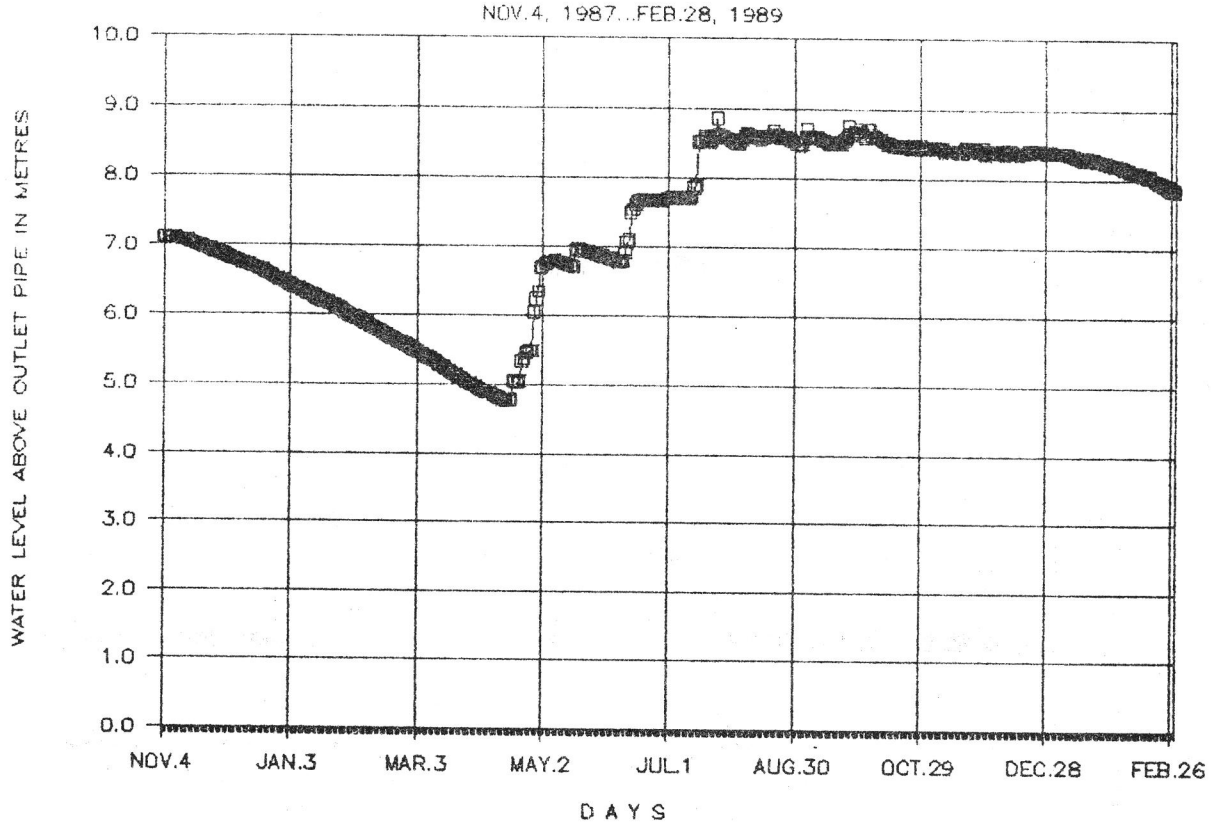

W. B. FORM 811-2 (1-56)
U. S. DEPARTMENT OF COMMERCE, WEATHER BUREAU
Maralal Rainfall Station No. 88.36.00
EXTREME PROBABILITY PAPER
RETURN PERIOD (Years)
1.001 1.01 1.1 1.2 1.3 1.4 1.5 2 3 4 5 10 25 50 100 200 300 400 500 1000
100 90 80 70 60 50 40 30 20 10 0
OBSERVED
THEORETICAL
.1 .5 1.0 5 10 20 30 40 50 60 70 80 90 95 96 97 98 99 99.5 99.7 99.8 99.9
PROBABILITY [100/(N+1)] — OR NON-EXCEEDANCE
MODE
MEAN
-2.0 -1.5 -1.0 -0.5 0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0 6.5 7.0
REDUCED VARIATE
ANNUAL MAXIMUM DAILY RAINFALL (in mm)

# Appendix 4.11

## Stage and Discharge Hydrograph

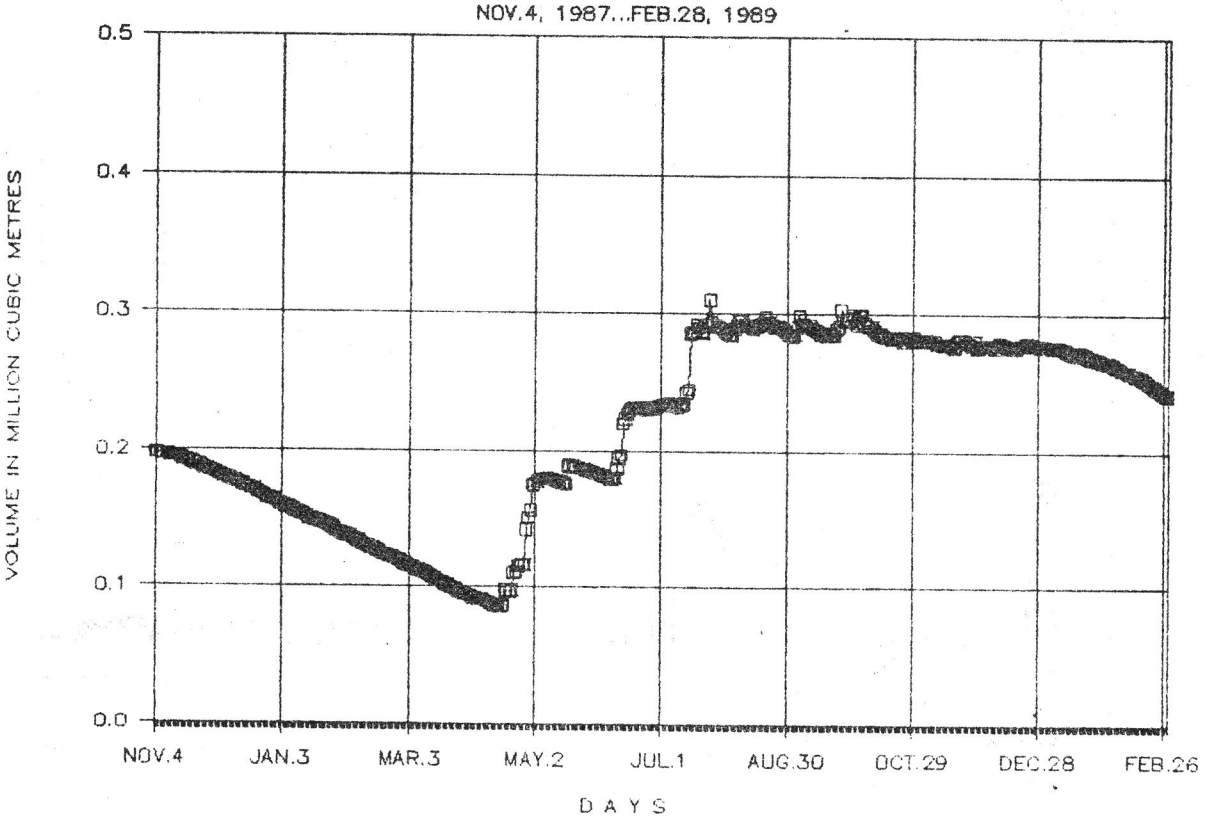
# NUNDOTO DAM WATER LEVELS

NOV.4, 1987...FEB.28, 1989



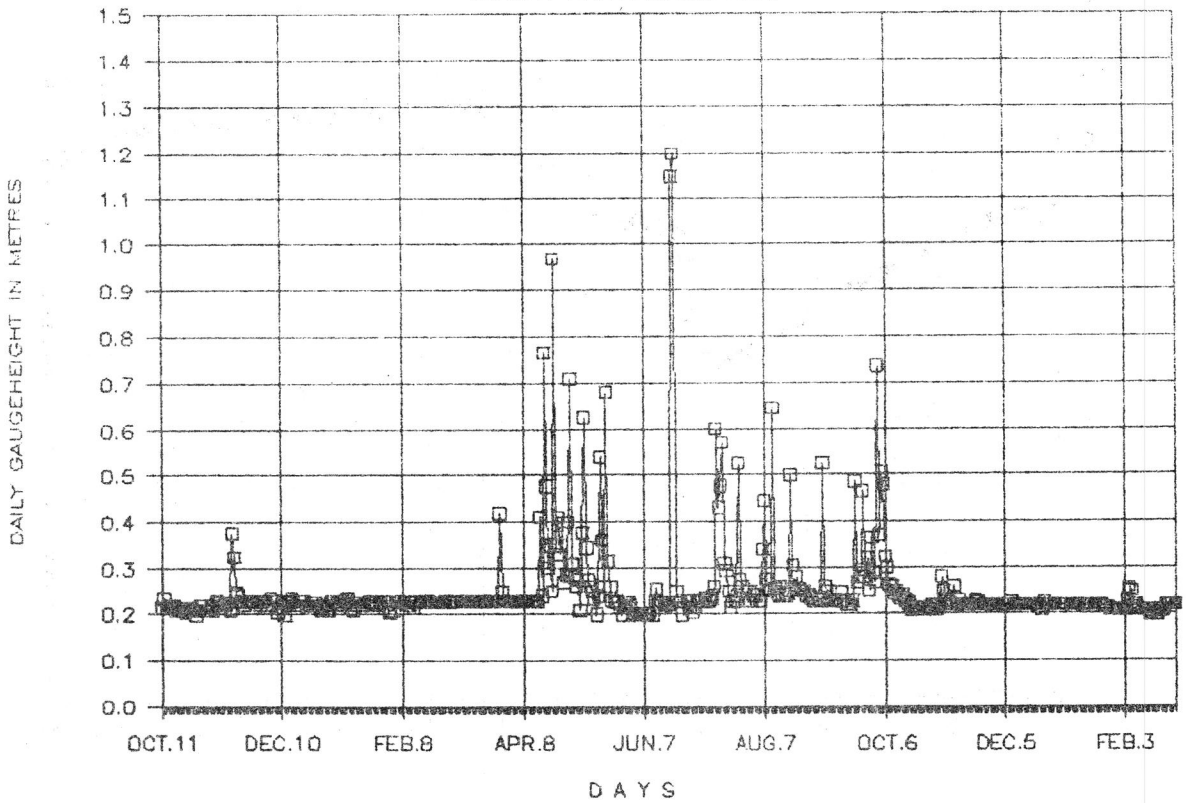

# NUNDOTO DAM STORAGE VOLUME

NOV.4, 1987...FEB.28, 1989



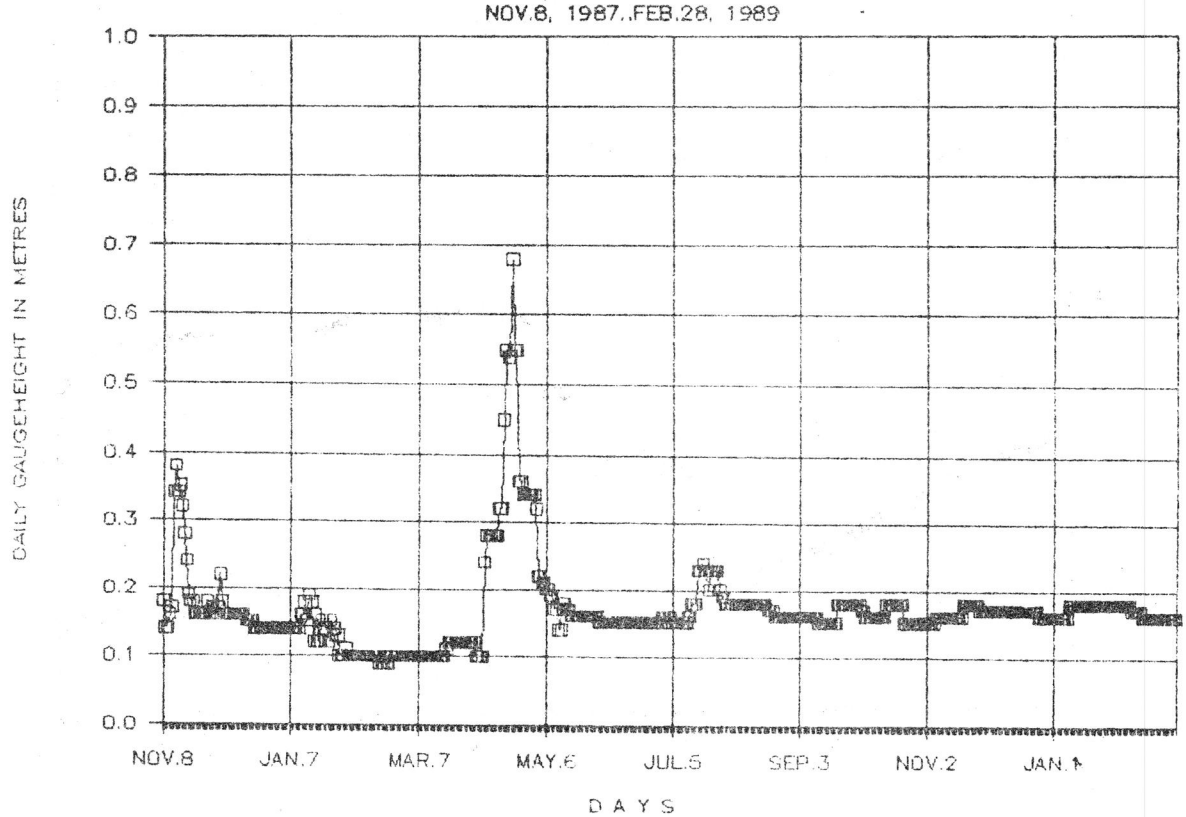
# AMAYA STREAM STAGE HYDROGRAPH

OCT.11, 1987..FEB.28, 1989



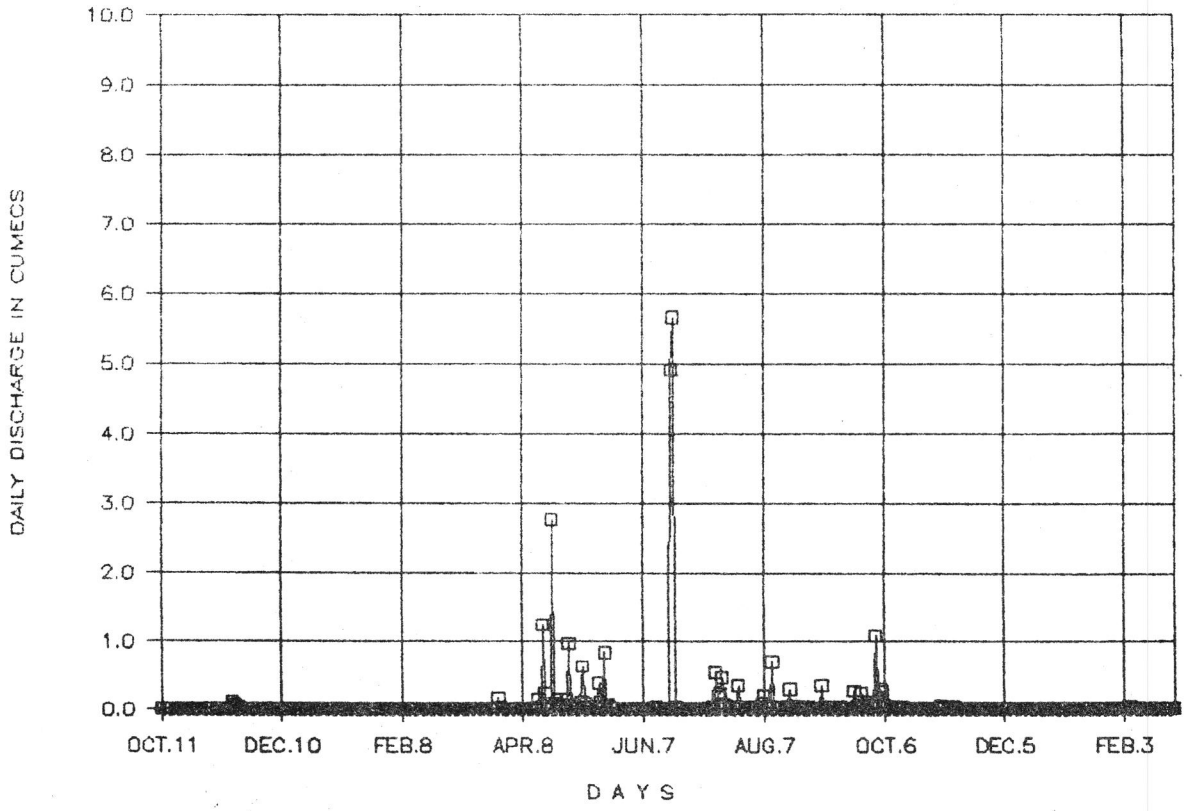

# SOUTH HORR STREAM STAGE HYDROGRAPH

NOV.8, 1987..FEB.28, 1989



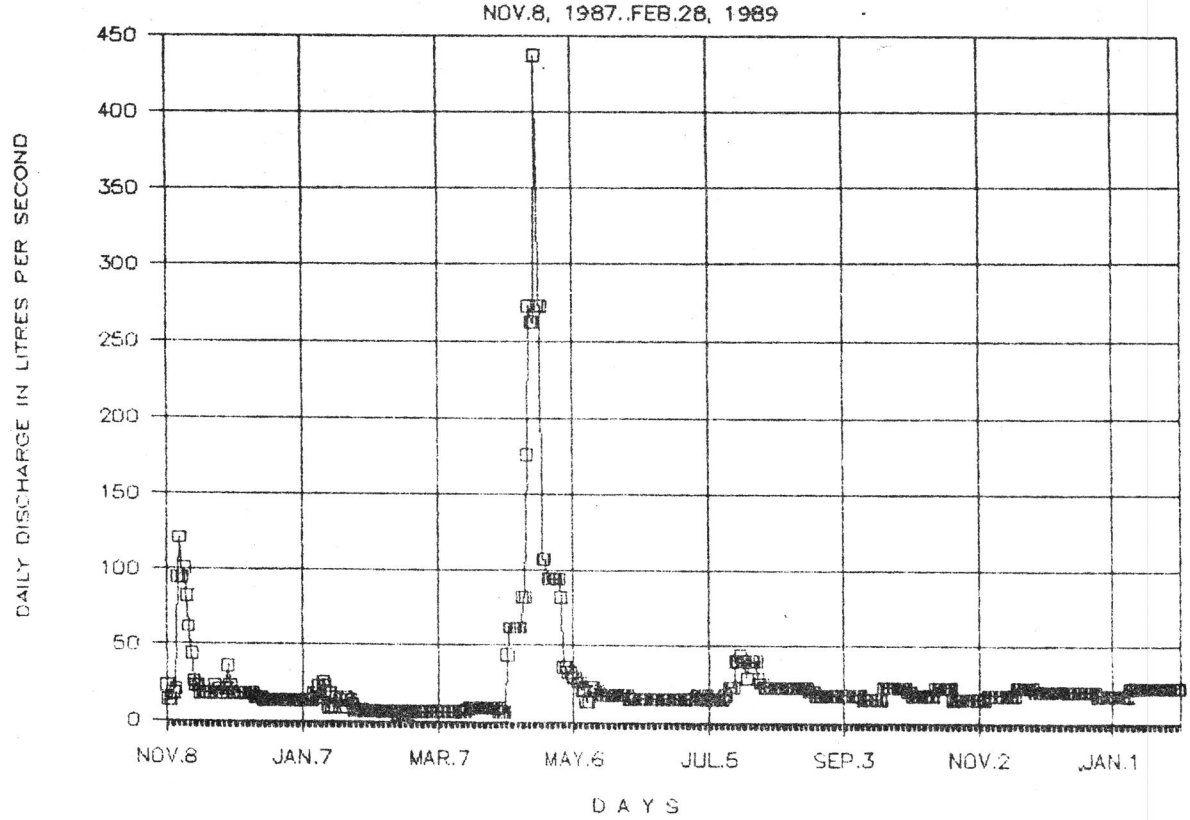
# AMAYA STREAM DISCHARGE HYDROGRAPH

OCT.11, 1987..FEB.28, 1989




# SOUTH HORR STREAM DISCHARGE HYDROGRAPH

NOV.8, 1987..FEB.28, 1989

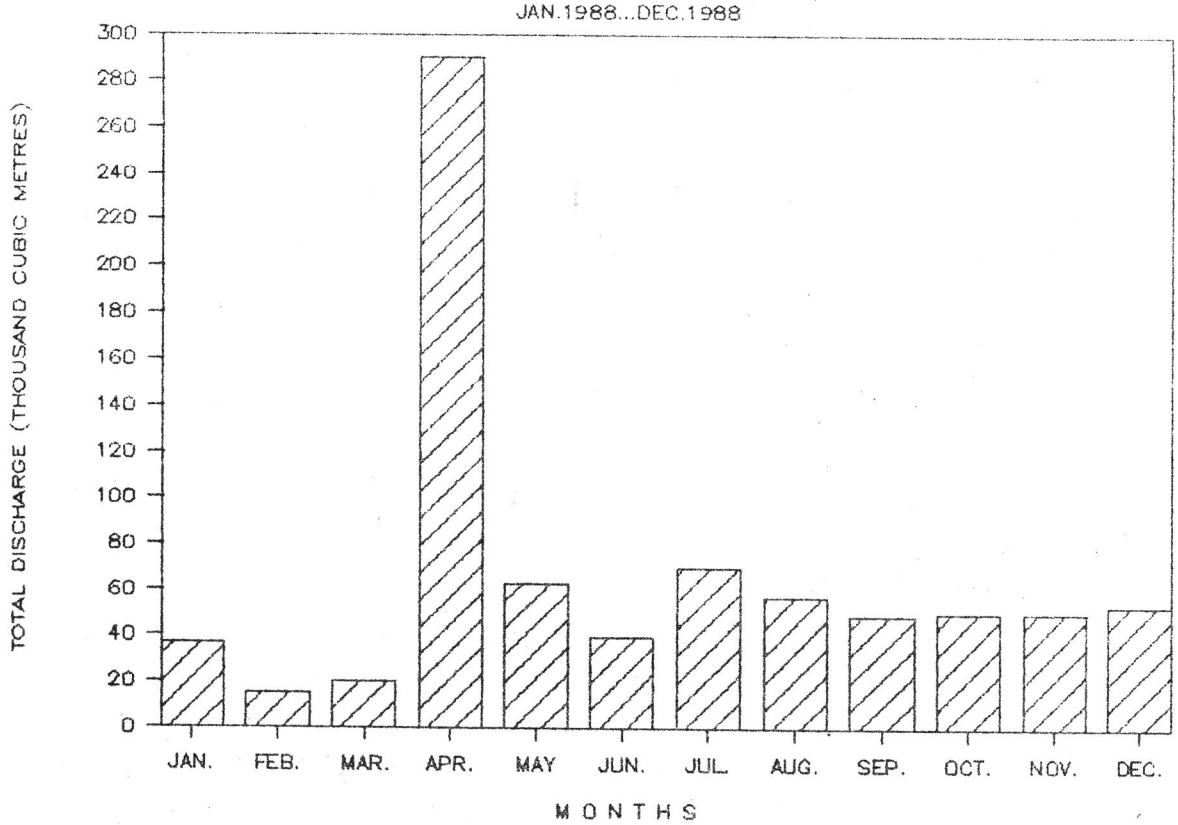


# Appendix 4.12

## Flow duration, Rating Curves and Monthly Flow Distribution

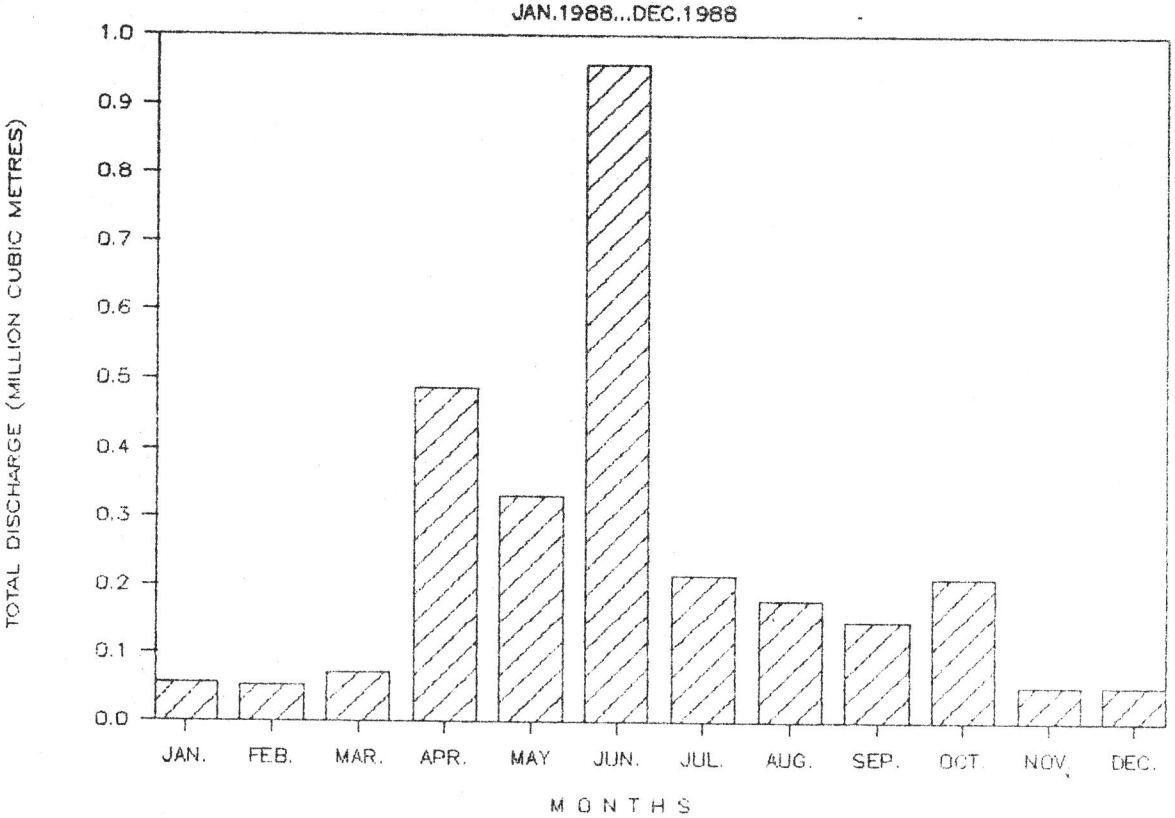
# S.HORR STREAM MONTHLY FLOW DISTRIBUTION

JAN.1988...DEC.1988



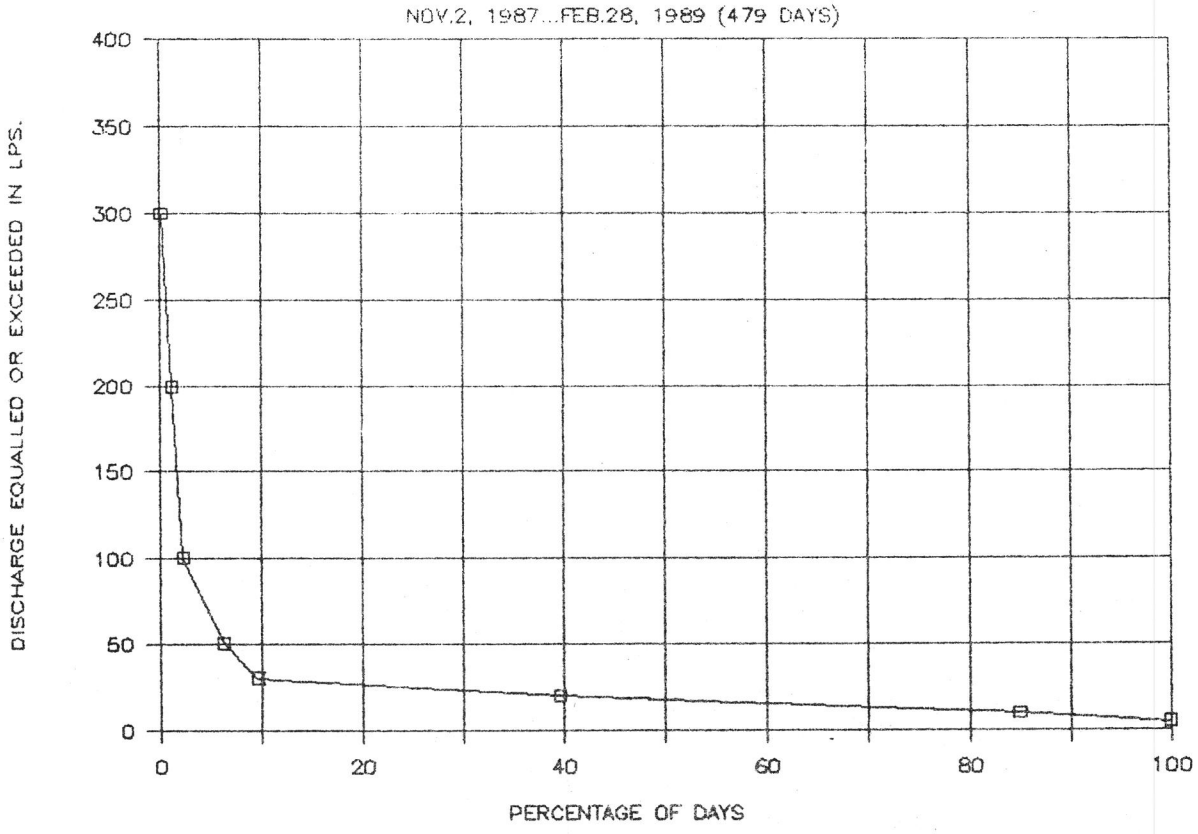

# AMAYA STREAM MONTHLY FLOW DISTRIBUTION

JAN.1988...DEC.1988



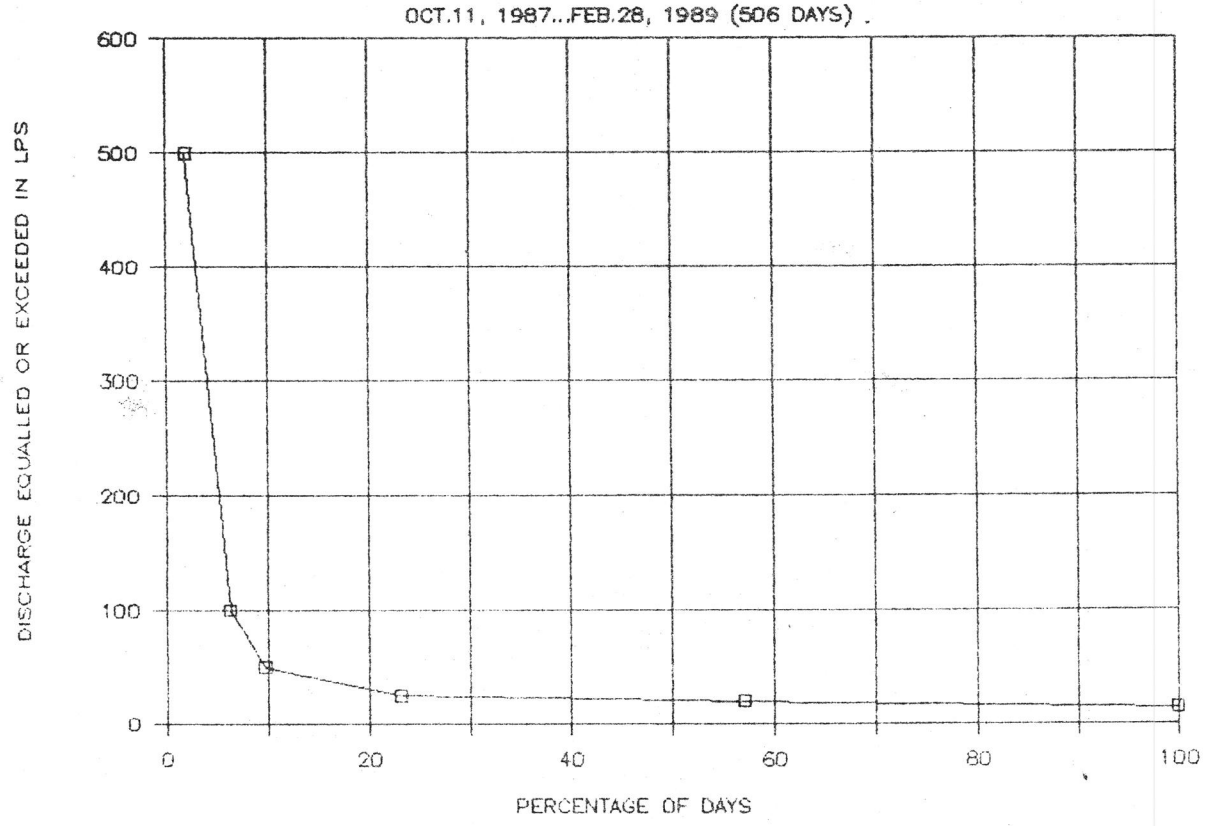
# FLOW DURATION CURVE...S.HORR STREAM

NOV.2, 1987...FEB.28, 1989 (479 DAYS)



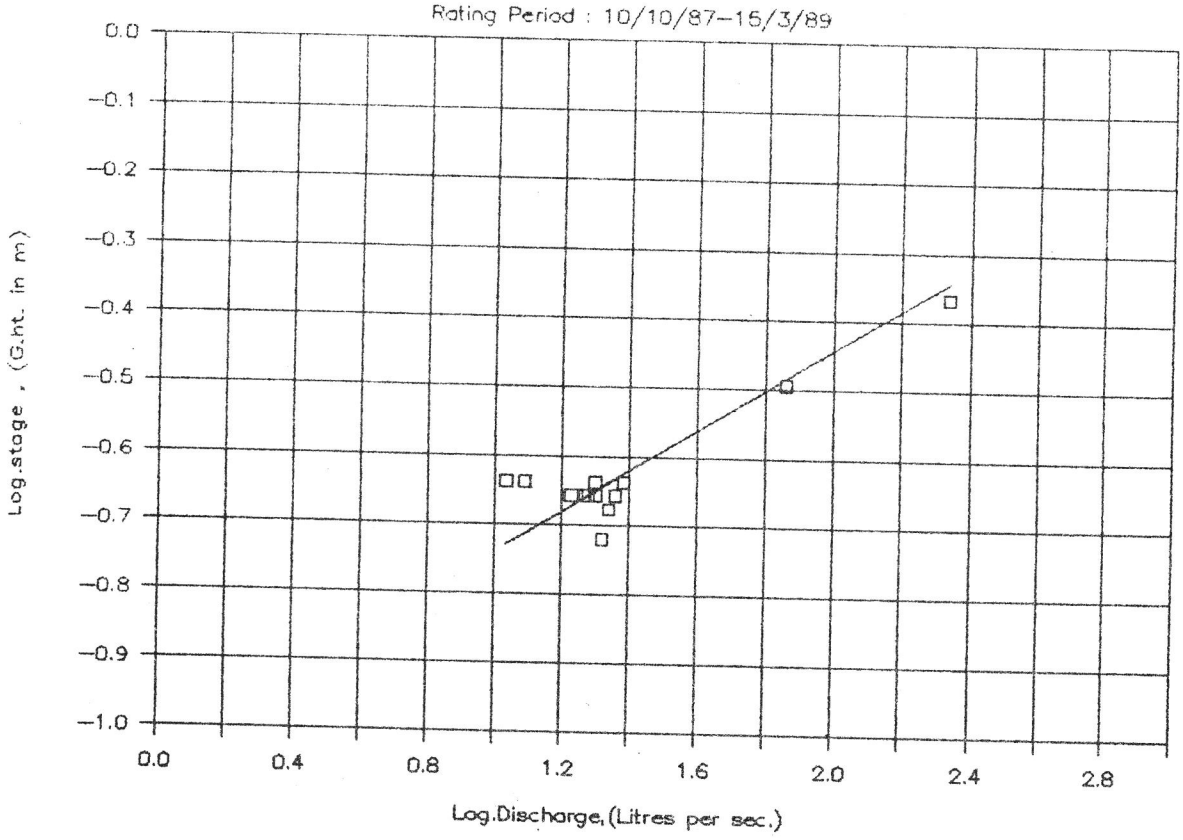

# FLOW DURATION CURVE...AMAYA STREAM

OCT.11, 1987...FEB.28, 1989 (506 DAYS) .



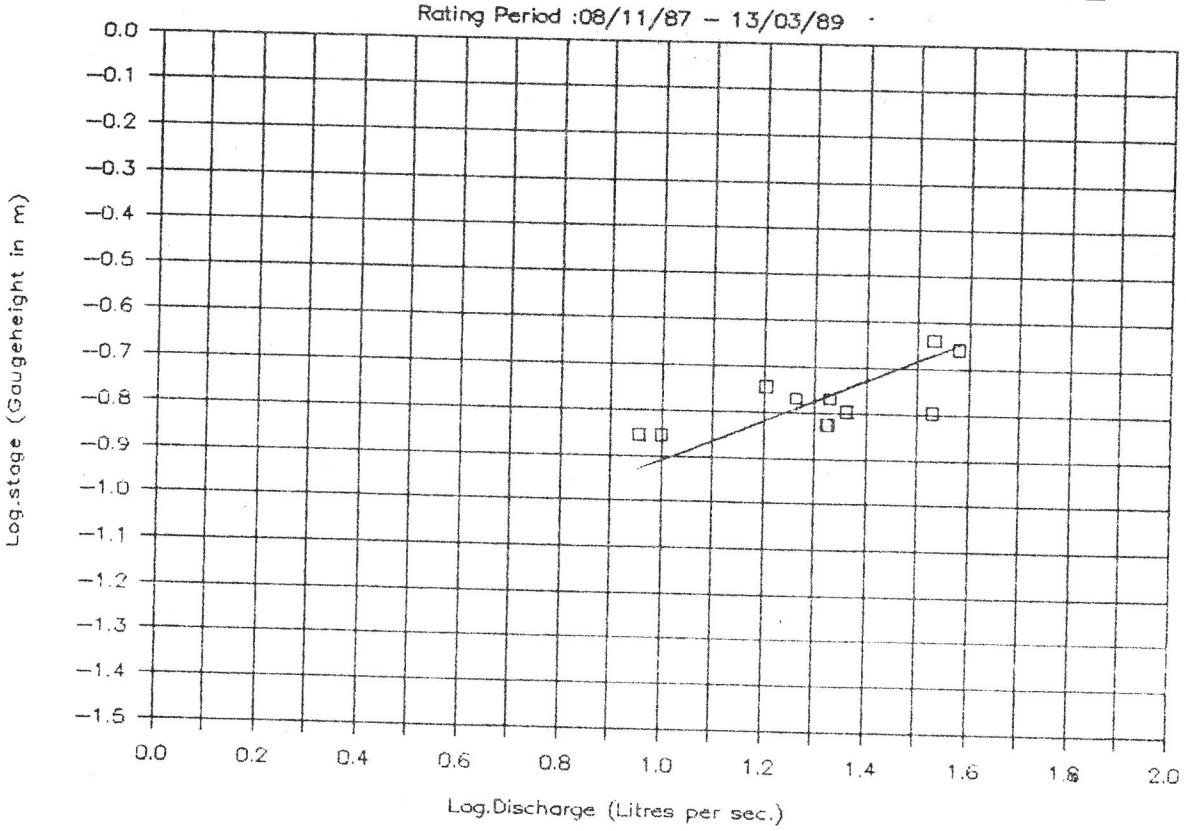
# STAGE DISCHARGE RATING CURVE – AMAYA

Rating Period : 10/10/87–15/3/89




# S.HORR STAGE – DISCHARGE RATING CURVE

Rating Period :08/11/87 – 13/03/89



Appendices 4.13, 4.14, 4.15 and 4.16

## Appendix 4.13 Miscellaneous Discharge Measurements

| Date | River | Discharge (cumecs) | Remarks |
|---|---|---|---|
| 28/04/88 | Wamba River | 0.084 | Opposite Game camp house |
| 12/05/89 | Wamba River | 0.030 | Opposite Game camp house |
| 05/11/88 | Enkare Narok | 0.050 | d/s bridge, Kisima - Sukuta Marmar road |
| 22/09/88 | Enkare Narok | 1.000 | d/s bridge, Kisima - Sukuta Marmar road |
| 20/09/88 | Enkare Narok | 0.300 | d/s bridge, Maralal - Amaya road |
| 05/11/88 | Enkare Narok | 0.060 | d/s bridge, Maralal - Amaya road |
| 13/05/89 | Seiya | 0.240 | Near Lodokejek Centre U/S road crossing |
| 22/09/88 | Seiya | 0.510 | Near Lodokejek Centre U/S road crossing |
| 15/09/88 | Seiya | 1.580 | Near Lodokejek Centre U/S road crossing |
| 21/09/88 | Nundoto River | 0.160 | Upstream of new dam |
| 19/09/88 | Nundoto River | 0.270 | Upstream of new dam |
| 05/11/88 | Nundoto River | 0.030 | Upstream of new dam |
| 05/11/88 | Nundoto River | 0.020 | New dam spillway |
| 21/09/88 | Nundoto River | 0.100 | New dam spillway |
| 19/09/88 | Nundoto River | 0.250 | New dam spillway |
| 19/09/88 | Nundoto River | 0.200 | Between new and old Nundoto dams at old RGS site |
| 21/09/88 | Nundoto River | 0.090 | Between new and old Nundoto dams at old RGS site |
| 19/09/88 | Nundoto River | 0.180 | d/s bridge Amya - Maralal road |
| 21/09/88 | Nundoto River | 0.110 | d/s bridge Amya - Maralal road |

**Source:** Water Resources Assessment Project

**Note:** Cumecs = cubic metres per second
d/s = downstream
u/s = upstream
RGS = Regular Gauging Station

## Appendix 4.14 Discharge Measurements by WRAP at Amaya stream Gauging station

| 14/05/89 | Gauge Height (m) | Discharge (lps) |
|---|---|---|
| 10/10/87 | 0.23 | 24.3 |
| 10/11/87 | 0.22 | 18.7 |
| 05/12/87 | 0.23 | 12.3 |
| 07/12/87 | 0.23 | 10.8 |
| 14/01/88 | 0.22 | 17.0 |
| 19/02/88 | 0.22 | 23.0 |
| 29/04/88 | 0.30 | 72.6 |
| 10/06/88 | 0.22 | 19.0 |
| 15/07/88 | 0.43 | 218.0 |
| 20/09/88 | 0.23 | 21.0 |
| 04/11/88 | 0.22 | 21.0 |
| 30/01/89 | 0.21 | 22.0 |
| 15/03/89 | 0.22 | 21.0 |
| 14/05/89 | 0.34 | 110.0 |

## Appendix 4.15 Discharge Measurements by WRAP at S. Horr Stream Gauging station

| 14/05/89 | Gauge Height (m) | Discharge (lps) |
|---|---|---|
| 09/10/87 | - | 13.4 |
| 08/11/87 | 0.16 | 33.9 |
| 09/11/87 | 0.15 | 21.2 |
| 03/12/87 | 0.17 | 21.4 |
| 04/12/87 | 0.17 | 18.3 |
| 18/01/88 | 0.16 | 23.0 |
| 24/02/88 | 0.10 | 20.4 |
| 02/05/88 | 0.22 | 38.1 |
| 12/06/88 | 0.15 | 21.0 |
| 17/07/88 | 0.23 | 34.0 |
| 16/09/88 | 0.14 | 9.0 |
| 07/11/88 | 0.14 | 10.0 |
| 31/01/89 | 0.18 | 16.0 |
| 13/03/89 | 0.14 | 10.0 |

# Appendix 4.16 Chemical Data Surface Water

| LOCATION | DATE OF SAMPLING | pH | color | Turb FTU. | KMnO4 value | E.C. uS/cm | Fe | Mn | Ca | Mg | Na | K | Total Hard | Total Alk | HCO3 | Cl | F | NO3 | NO2 | SO4 | PO4 | Free CO2 | TDS | SUM CATIONS | SUM ANIONS | IONIC BALANCE | Suit. for Domes. use | SAR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | mg/l | | | | | | | | | | | | | | | | | meq/l | meq/l | % | | |
| South Horr | 14/09/87 | 6.3 | 5 | 1.7 | 3.3 | 136 | 0.8 | <0.1 | 5.5 | 4.0 | 12 | - | 35 | 26 | 32 | 13 | 0.15 | - | 0.01 | 12 | 0.02 | 6 | 81 | 1.1 | 1.1 | -0.5 | Yes | 1.0 |
| South Horr | 07/12/87 | 6.5 | 10 | 3.5 | 13 | 168 | - | - | 12 | 4.5 | 1.6 | 3.1 | 48 | 30 | 37 | 17 | 0.21 | - | <0.01 | 15 | <0.01 | 4 | 100 | 1.1 | 1.4 | -10.9 | Yes | 0.1 |
| Amaya intake | 13/09/87 | 7.6 | <5 | 12 | 0.60 | 715 | 0.7 | <0.1 | 0.7 | 0.4 | 120 | - | 9.3 | 234 | 285 | 25 | 1.0 | - | 0.01 | 3.5 | 0.02 | 2 | 429 | 5.3 | 5.5 | -1.6 | Yes | 28.3 |
| Amaya Tap Water | 13/09/87 | 7.3 | 30 | 13 | 1.50 | 676 | 0.7 | <0.1 | 0.2 | 0.3 | 120 | - | 7.4 | 220 | 268 | 25 | 0.95 | - | <0.01 | 4.1 | 0.04 | 4 | 405 | 5.3 | 5.2 | 0.6 | Yes | 39.6 |
| Nundoto Dam | 13/09/87 | 7.0 | cloudy | 120 | 11 | 201 | 7.5 | 0.1 | 2.0 | 4.5 | 12 | - | 50 | 60 | 73 | 13 | 0.24 | - | <0.01 | <0.3 | <0.01 | 8 | 120 | 1.0 | 1.6 | -22.4 | No * | 1.1 |
| Nundoto Dam | 09/12/87 | 6.9 | brown | 110 | 15 | 228 | - | - | 16 | 5.0 | 17 | 12 | 62 | 74 | 90 | 12 | 0.4 | - | <0.01 | <0.3 | <0.01 | 4 | 136 | 2.3 | 1.8 | 10.8 | No * | 1.0 |
| Lake Turkana | 14/12/87 | 9.8 | <5 | 26 | 20 | 4200 | - | - | 5.6 | 1.5 | 929 | 24 | 20 | 1212 | - | 470 | 11 | - | 1.0 | 29 | 1.6 | nil | 2520 | 41.4 | 38.1 | 4.2 | No | 90.0 |
| Ewaso Ngiro 5E3 | 18/12/85 | 8.1 | 40 | 110 | 4 | 320 | 2.2 | 0.18 | 28 | 15 | - | - | 130 | 164 | 200 | 8 | 0.22 | - | - | <0.3 | - | - | 192 | 2.6 | 3.5 | -14.2 | No * | - |
| Ewaso Ngiro 5E3 | 21/09/86 | 7.7 | cloudy | 190 | 4.9 | 185 | 2.8 | 1.8 | 2.8 | 4.8 | 11 | 11 | 34 | 70 | 85 | 9 | 0.31 | 0.61 | <0.01 | 0.3 | - | 7 | 112 | 1.3 | 1.7 | -12.3 | No * | 0.9 |
| Ewaso Ngiro 5E3 | 19/11/86 | 7.8 | muddy | muddy | 13 | 270 | 140 | 5.5 | 20 | 35 | 18 | 24 | 140 | 178 | 217 | 8 | 0.28 | 0.95 | - | 0.03 | - | 4 | 161 | 5.3 | 3.8 | 16.5 | No * | 0.6 |
| Ewaso Ngiro at Samburu Lodge | 27/01/87 | 7.8 | cloudy | 210 | 4.1 | 260 | 55 | 1.4 | 7.3 | 19 | 16 | 16 | 94 | 110 | 134 | 9 | 0.3 | 0.81 | 0.05 | <0.3 | - | 2 | 156 | 3.0 | 2.5 | 10.6 | No * | 0.7 |

HCO3 Concentration is Calculated from the Total Alkalinity (for pH <8.3)

* = Suitable for Domestic Consumption after treatment

# APPENDIX 5

DATA ON BOREHOLES

CHEMISTRY OF SPRINGS AND WELLS

WELL TESTS AND

DRINKING WATER STANDARDS

## APPENDIX 5

5.1 List of Boreholes Drilled in Samburu

5.2 Chemical Data Springs and Wells

5.3 Chemical Data Boreholes

5.4 Wells Tests

5.5 Drinking Water Standards for Kenya

# Appendix 5.1

## List of Boreholes Drilled in Samburu

Appendix 5.1 List of Boreholes Drilled in Samburu

| B/H NO. | LOCATION | COORDINATES | SHEET NO. | SURFACE ELEVATION m + msl | TOTAL DEPTH (m) | COMPLETION DATE | STRUCK LEVEL DEPTH (m) | STRUCK LEVEL ELEV. m+msl | REST LEVEL DEPTH | REST LEVEL ELEV. | YIELD m3/HR | A | B | C | PRESENT STATE | TDS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SA91 | Serolevi | 01 09'32"N 37 35'19"E | 80 | 750 | 53 | 08-04-41 | | | | | 0.5 | No | No | No | Not traced | |
| C444 | Maralal | 01 05'46"N 36 41'42"E | 78/3 | 1940 | 122 | 31-07-46 | 46 | 1849 | 28 | 1912 | 0.38 | No | No | No | Abandoned | |
| | | | | | | | 91-122 | | | | | | | | | |
| C479 | Maralal | 01 03'56"N 36 40'29"E | 78/3 | 1940 | 90 | 31-10-46 | 55,69 | 1871 | 11 | 1929 | 0.41 | No | No | No | Abandoned | |
| C1450 | Serolevi | 01 09'08"N 37 35'27"E | 80 | 747 | 84 | 12-06-51 | 18 | 729 | 12 | 735 | 3.6 | No | No | No | Not traced | |
| C1500 | Serolevi | 01 12'00"N 37 33'41"E | 80 | 790 | 45 | 12-07-51 | 19,26 | 764 | 16 | 774 | 3.4 | No | No | No | Not traced | |
| C1505 | Maralal | 01 06'10"N 36 41'58"E | 78/3 | 1945 | 105 | 09-08-51 | 26 | 1919 | 23 | 1922 | 0.73 | No | No | No | Abandoned | |
| C1520 | Lerata | 00 46'36"N 37 31'55"E | 94/1 | 914 | 106 | 06-08-51 | - | - | - | | Nil | No | No | No | Dry Hole | |
| C1533 | Lerata | 00 46'17"N 37 33'28"E | 94/1 | 914 | 118 | 09-09-51 | - | - | | | Nil | No | No | No | Dry Hole | |
| C1552 | Lerata | 00 46' 26N 37 32 37"E | 94/1 | 906 | 49 | 20-09-51 | - | | - | | Nil | No | No | No | Dry Hole | |
| C1553 | Marti | 01 37'02"N 36 44'04"E | 65/3 | 1475 | 136.00 | 10-10-51 | 70 | 1405 | 59.00 | 1416 | 0.68 | No | No | No | Not traced | 2575 |
| C1613 | Kowop | 01 59'17"N 36 46'32"E | 65/2 | 1330 | 120 | 24-11-51 | 69 | 1261 | 65.00 | 1265 | 3.18 | No | No | No | Operational | |
| C1639 | Marti | 01 29'00"N 36 42'23"E | 78/1 | 1600 | 102 | 11-01-52 | 69 | 1531 | 60 | 1540 | 4.3 | No | No | No | Operational | |
| C1723 | Maralal | 01 05'29"N 36 41'41"E | 78/3 | 1940 | 122.00 | 23-02-52 | 35 | 1905 | 30.00 | 1910 | 0.51 | No | No | No | Abandoned | |
| C1776 | Barsalinga | 00 54'16"N 37 06'23"E | 93/1 | 1180 | 107 | 24-04-52 | 62,101 | 1079 | 46 | 1134 | 4.0 | No | No | No | Abandoned | |
| C1806 | Naibor Keju | 00 57'23"N 36 48'20"E | 92/2 | 1800 | 76 | 20-03-52 | 23,38 | 1762 | 14.00 | 1786 | 0.91 | No | No | No | Not in use | |
| C2434 | Lonkewan | 00 51'46"N 36 32'37"E | 92/1 | 2080 | 183 | 05-09-55 | 169 | 1911 | 146.00 | 1934 | 2.50 | No | No | No | Operational | |
| C2847 | Lonkewan | 0 55'02"N 36 33'32"E | 92/1 | 2020 | 180.00 | 31-11-58 | 110.00 | 1910.00 | 71.00 | 1949 | 2.10 | No | No | No | Not in use | |
| C2972 | Lonkewan | 00 51'26"N 36 36'15"E | 92/1 | 2000 | 259 | 15-11-59 | 46,174 | 1826 | 49.00 | 1951 | 1.20 | No | No | No | Blocked | |
| C3114 | Rarait | 01 16'22"N 36 47'08"E | 78/2 | 1380 | 122 | 19-03-61 | 29-30 | 1316 | 24.00 | 1356.00 | 4.10 | No | No | No | Blocked | |
| | | | | | | | 46-52 | | | | | No | No | No | | |
| | | | | | | | 64-110 | | | | | No | No | No | | |
| C3456 | Baragoi | 01 47'04"N 36 47'06"E | 65/2 | 1240 | 152 | 28-08-67 | 21,43 | 1142 | 14.00 | 1226.00 | 3.55 | No | No | No | Not in use | |
| | | | | | | | 73,98 | | | | | No | No | No | | |
| C3505 | Lerata | 00 47'00"N 37 31'01"E | 94/1 | 930 | 41.00 | 27-07-68 | 20.00 | 910 | 16.00 | 914 | 2.3 | No | No | No | Operational | |

Cont. Appendix 5.1 List of Boreholes Drilled in Samburu

| B/H NO. | LOCATION | COORDINATES | SHEET NO. | SURFACE ELEVATION m + msl | TOTAL DEPTH (m) | COMPLETION DATE | STRUCK LEVEL DEPTH (m) | STRUCK LEVEL ELEV. m+msl | REST LEVEL DEPTH | REST LEVEL ELEV. | YIELD m3/HR | A | B | C | PRESENTATION | TDS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C3556 | Lerata | 00 46'20"N 37 34'06"E | 94/1 | 890 | 43.00 | 17-03-69 | unknown | - | 14.00 | 876 | 0.7 | No | No | No | Operational | |
| C3557 | Lerata | 00 46'33'N 37 34'05"E | 94/1 | 890 | 21 | 26-03-69 | - | - | - | | Nil | No | No | No | Dry Hole | |
| C3558 | Lerata | 00 46'23'N 37 32'47"E | 94/1 | 906 | 34 | 04-04-69 | - | - | - | - | Nil | No | No | No | Dry Hole | |
| C3560 | Lerata | 00 46'30'N 37 34'16"E | 94/1 | 890 | 44 | 15-04-69 | - | | - | | Nil | No | No | No | Dry Hole | |
| C3565 | Serolevi | 01 08'08"N 37 35'58"E | 80 | 732 | 16 | Unknown | 4 | 728 | 3 | 729 | 18.2 | No | No | No | Not in use | 1200 |
| C3575 | Serolevi | 01 08'12"N 37 36'11"E | 80 | 732 | 15.00 | 17-05-69 | 4 | 728 | 12.00 | 720 | 5.50 | No | No | No | Operational | 4900 |
| C3586 | Loijuk Swamp | 00 45'55"N 37 21'58"E | 93/2 | 1050 | 92 | 16-08-69 | 66,82 | 968 | 39 | 1011 | 3.9 | No | No | No | Blocked | |
| C3599 | Serolevi | 01 08'12"N 37 36'03"E | 80 | 732 | 24 | 27-05-69 | 5-15 | 727 | 11 | 721 | 21.8 | No | No | No | Not in use | |
| C3600 | Serolevi | | 80 | | 17.00 | 30-05-69 | 4 | | 9.00 | | 6.20 | No | No | No | Not Traced | |
| C3604 | Loijuk Swamp | 00 45'47"N 37 22'03"E | 93/2 | 1050 | 124 | 02-08-69 | 41<br>52-55<br>67-108 | 983 | 36 | 1014 | 2.5 | No | No | No | Blocked | |
| C3609 | Maralal | 01 05'39"N 36 42'32"E | 78/3 | 1920 | 71 | 26-08-69 | 38,42 | 1878 | 35 | 1885 | 6.00 | No | No | No | Working | |
| C3613 | Merille | 01 23'55"N 37 43'16"E | 80 | 610 | 20 | 19-08-69 | - | | - | | Nil | No | No | No | Dry Hole | |
| C3614 | Merille | 01 24'24"N 37 43'37"E | 80 | 610 | 25 | 23-08-69 | 4 | 606 | 10 | 600 | 12.7 | No | No | No | Brackish Water Abandoned | |
| C3622 | Merille | 01 24'18"N 37 43'28"E | 80 | 610 | 30 | 02-09-69 | 6.00 | 604 | 20.00 | 590 | 18.20 | No | No | No | Brackish Water Abandoned | |
| C3624 | Merille | 01 24'34"N 37 43'50"E | 80 | 610 | 52 | 15-09-69 | 2 | 608 | 2 | 608 | 1.8 | No | No | No | Brackish Water Abandoned | |
| C3651 | Lesirikan | 01 47'04"N 36 57'35"E | 65/2 | 1518 | 64.00 | 15-12-69 | 55.00 | 1463 | 45.00 | 1473 | 5.50 | No | No | No | Operational | |
| C3692 | Maralal | 01 04'09"N 36 42'11"E | 78/3 | 1880 | 49 | 08-07-70 | - | | | | Nil | No | No | No | Working | |
| C3808 | Wamba | 00 58'56"N 37 19'06"E | 93/2 | 1290 | 61 | ?-10-70 | 15 | 1275 | 15 | 1275 | 1.4 | No | No | No | Not in use | 1810 |
| C3810 | Archer's Post | 00 38'29"N 37 40'05"E | 94/3 | 838 | 198 | 12-02-72 | 14,18<br>72,158 | 680 | 9 | 829 | 1.5 | No | No | No | Operational | |

Cont. Appendix 5.1 List of Boreholes Drilled in Samburu

| B/H NO. | LOCATION | COORDINATES | SHEET NO. | SURFACE ELEVATION m + msl | TOTAL DEPTH (m) | COMPLETION DATE | STRUCK LEVEL DEPTH (m) | STRUCK LEVEL ELEV. m+msl | REST LEVEL DEPTH | REST LEVEL ELEV. | YIELD m3/HR | A | B | C | PRESENTATION | TDS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C3827 | Wamba | 00 58'48"N 37 19'06"E | 93/2 | 1290 | 73 | 13-05-72 | 18,55 | 1235 | 14 | 1276 | 2.4 | No | No | No | Operational | 570 |
| C3832 | Lodungokwe | 00 53'47"N 36 59'46"E | 92/2 | 1200 | 128 | 25-04-72 | 17.00 | 1183 | 8 | 1192 | 4.1 | No | No | No | Operational | 2125 |
| C3833 | Sirata Oirobi | 01 03'19"N 36 39'26"E | 78/3 | 1960 | 123 | 03-06-72 | 38 | 1922 | 12 | 1948 | 2.20 | No | No | No | Operational | |
| C3855 | Baragoi Township | 01 47'50"N 36 48'25"E | 65/2 | 1260 | 183 | 28-07-72 | 22 | 1238 | 11 | 1249 | 1.80 | No | No | No | Operational | 335 |
| C3869 | Baragoi Township | 01 47'01"N 36 47'32"E | 65/2 | 1260 | 91 | 28-09-72 | 12.00 | 1248 | 11 | 1249 | 1.40 | No | No | No | Operational | |
| C4296 | Wamba | 00 58'56"N 37 19'11"E | 93/2 | 1290 | 129 | 11-09-76 | 58 | 1232 | 29 | 1261 | 0.2 | No | No | No | Operational | |
| C4297 | Wamba | 00 58'30"N 37 18'47"E | 93/2 | 1290 | 104 | 09-11-76 | 35.00 | 1255 | 23.00 | 1267 | 1.0 | No | No | No | Abandoned | |
| C4315 | Wamba | 00 58'52"N 37 19'15"E | 93/2 | 1290 | 94.5 | 28-02-77 | 40,82 | 1208 | 21 | 1269 | 4.8 | No | No | No | Operational | |
| C4316 | Bauwa | 01 01'48"N 36 48'13"E | 78/4 | 1850 | 101 | 17-05-77 | 35,98 | 1752 | 25 | 1825 | | No | No | No | Operational | |
| C4417 | Baragoi | 01 46'03"N 36 46'51"E | 65/2 | 1260 | 120 | 21-11-77 | 33,66 | 1194 | 31 | 1229 | 10.00 | No | No | No | Operational | 1470 |
| C4449 | Kowop | 01 58'48"N 36 48'13"N | 62/2 | 1360 | 83 | 03-01-78 | - | - | - | | Nil | No | No | No | Dry Hole | |
| C4513 | Wamba (MoWD) | 00 58'37"N 37 19'19"E | 93/2 | 1280 | 120 | 05-06-78 | 7,40 | 1240 | 7 | 1273 | 6.80 | No | No | No | Operational | |
| C4530 | Barsaloi | 01 20'00"N 36 51'54"E | 78/2 | 1120 | 120 | 24-07-78 | 6,56 | 1064 | 6.00 | 1114 | 12.00 | No | No | No | Blocked | |
| C4895 | Maralal | 01 05'52"N 36 43'05"E | 78/3 | 1920 | 83 | 15-11-81 | 24,34 | 1886 | 19 | 1901 | 1.50 | No | No | No | Not in use | |
| C5898 | Loikas | 01 10'34"N 36 42'20"E | 78/3 | 2060 | 24 | 06-09-84 | 10 | 2050 | 5 | 2055 | 2.5 | No | No | No | Not in use | |
| C6021 | Loikas | 01 10'35"N 36 42'19"E | 78/3 | 2060 | 32 | 28-09-84 | 5,18 | 2042 | 4 | 2056 | 3.6 | No | No | No | Not in use | |
| C6022 | Loikas | 01 10'42"N 36 42'20"E | 78/3 | 2060 | 26 | 16-10-84 | 6 | 2054 | 3 | 2057 | 7.9 | No | No | No | Not in use | |
| C6023 | Loikas | 01 10'39"N 36 42'21"E | 78/3 | 2060 | | No Records Available | | | | | | No | No | No | Not in use | |
| C6796 | Wamba | 00 58'50"N 37 19'07"E | 93/2 | 1290 | 152 | - | | | 43 | 1247 | 0.5 | No | No | No | Not in use | |
| C6797 | Wamba | 00 58'56"N 37 19'03"E | 93/2 | 1290 | 152 | - | | | 32 | 1258 | 2.7 | No | No | No | Operational | |
| C7191 | Lodokejek | 00 51'03"N 36 51'07"E | 92/2 | 1680 | 60 | - | 16,28 | 1652 | 7 | 1673 | 1.2 | No | No | No | Operational | |
| C7908 | Ledero | 01 02'53"N 36 45'11"E | 78/4 | 1970 | 80 | -03-88 | - | | 24 | 1946 | 1.2 | Yes | Yes | Yes | Not in use | 389 |
| C7909 | Wamba | 00 58'40"N 37 20'32"E | 93/2 | 1305 | 93 | 12-04-88 | 14 | 1291 | 10 | 1295 | - | No | No | Yes | Abandoned | |
| C7910 | Wamba | 00 58'44"N 37 20'00"E | 93/2 | 1305 | 120 | 21-04-88 | 26,68 | 1237 | 25 | 1280 | 1.2 | Yes | Yes | Yes | Not in use | |
| C7911 | Wamba | 00 59'17"N 37 21'52"E | 93/2 | 1320 | 76 | 28-05-88 | 52 | 1268 | 27 | 1293 | 3.2 | Yes | Yes | Yes | Not in use | 2100 |

Cont. Appendix 5.1 List of Boreholes Drilled in Samburu

| B/H NO. | LOCATION | COORDINATES | SHEET NO. | SURFACE ELEVATION m + msl | TOTAL DEPTH (m) | COMPLETION DATE | STRUCK LEVEL DEPTH (m) | STRUCK LEVEL ELEV. m+msl | REST LEVEL DEPTH | REST LEVEL ELEV. | YIELD m3/HR | A | B | C | PRESENTATION | TDS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C7912 | Namanyarobo | 00 50'30"N 37 18'32"E | 93/2 | 1130 | 100 | 02-06-88 | - | | - | | Nil | No | No | No | Dry Hole | |
| C7913A | Kimaniki Pass | 00 52'00"N 37 26'29"E | 93/2 | 1085 | 64 | 07-06-88 | - | | - | | Nil | No | No | No | Site Abandoned | |
| C7913B | Kimaniki Pass | 00 52'00"N 37 26'32"E | 93/2 | 1085 | 92 | 12-06-88 | - | | - | | Nil | No | No | No | Site Abandoned | |
| C7914 | Lengusaka | 00 52'23"N 37 18'45"E | 93/2 | 1150 | 70 | 20-06-88 | 18 | 1132 | 3 | 1147 | 1.1 | Yes | Yes | Yes | Not in use | 1740 |
| C7915 | Lengei | 00 49'12"N 36 59'29"E | 92/2 | 1370 | 100 | 25-06-88 | 54,63 | 1307 | 39 | 1331 | 1.8 | Yes | Yes | Yes | Not in use | 1200 |
| C7916 | Swuari | 01 06'11"N 37 04'13"E | 79/3 | 1120 | 130 | 20-07-88 | 70 | 1050 | 63 | 1057 | 2.8 | Yes | Yes | No | Very salty Water | 5184 |
| C7917 | Kowop | 01 59'10"N 36 46'30"E | 65/2 | 1320 | 150 | 14-12-88 | 123 | 1197 | 56 | 1264 | 2.0 | Yes | Yes | No | Not in use | 2120 |
| C7918 | Barsaloi | 01 20'13"N 36 52'02"E | 78/2 | 1120 | 40 | 06-02-89 | 16 | 1104 | 9 | 1111 | 7.2 | Yes | Yes | No | Not in use | 356 |
| C7919 | Masiketa | 01 36'37"N 36 56'57"E | 65/4 | 1160 | 100 | 28-01-89 | 16,70 | 1090 | 5 | 1155 | 5.2 | Yes | Yes | No | Not in use | 933 |
| C7920 | Kirisia | 01 05'08"N 36 42'22"E | 78/3 | 1915 | 160 | 15-04-89 | 34 | 1881 | 33 | 1882 | - | Yes | Yes | No | Site Abandoned | - |
| C7921 | Losuk | 01 01'56"N 36 34'43"E | 78/3 | 1995 | 100 | 21-04-89 | 26,58 | 1937 | 1 | 1994 | 12 | Yes | Yes | No | Not in use | 432 |
| C7922 | Nondoto | 01 02'48"N 36 40'48"E | 78/3 | 1890 | 200 | 08-05-89 | 112 | 1778 | 14 | 1876 | 6 | Yes | Yes | No | Not in use | 612 |

KEY: A = Chemical Analysis B = Test Pumping C = Geophysical Logging

# Appendix 5.2

## Chemical Data Springs and Wells

Appendix 5.2 CHEMICAL DATA SPRINGS (Samples collected by WRAP)

SAMBURU DISTRICT

| LOCATION | MAIN AQUIFER V-vocanics B-basement | DATE OF SAMPLING | pH | color | Turb FTU. | KMn04 value | E.C. uS/cm | Fe | Mn | Ca | Mg | Na | K | Total Hard | Total Alk | HCO3 | Cl | F | NO3 | NO2 | SO4 | PO4 | Free CO2 | TDS | SUM CATIONS | SUM ANIONS | IONIC BALANCE | Suitable for domestic use | SAR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | mg/l | | | | | | | | | | | | | | | | | meq/l | meq/l | % | | |
| Amaya | V | 28/03/89 | 7.9 | 5 | 5 | - | 570 | 0.1 | 0 | 1.6 | 0.7 | 143.5 | 3.7 | 7 | 320 | 390 | 5 | 1.4 | 0 | 0 | 8 | - | - | 400 | 6.5 | 6.7 | -1.7 | Yes | 23.8 |
| Sukuta Marmar | V | 28/03/89 | 7.3 | 5 | 0 | - | 680 | - | 0 | 2.4 | 0.5 | 157 | 3.4 | 8 | 310 | 378 | 14 | - | 1.1 | 0 | 20 | - | - | 480 | 7.1 | 7.0 | 0.5 | Yes | 24.1 |
| Bauwa | B | 25/02/89 | 7.5 | 10 | 9.5 | 9.9 | 559 | 0.1 | 0.5 | 50 | 16 | 50 | 147 | 188 | 180 | 219 | 37 | - | - | 0.1 | 53 | 0.2 | 10 | 335 | 9.7 | 5.7 | 25.8 | No | 1.6 |
| Barsaloi | B | 03/03/89 | 8.1 | 5 | 5 | 2.8 | 585 | 0.1 | 0.1 | 63 | 19 | 25 | 8.4 | 234 | 236 | 288 | 15 | - | - | 0.1 | 23 | 0.08 | 18 | 351 | 6.0 | 5.6 | 3.4 | Yes | 0.7 |
| Ngurunit | B | 03/04/89 | 7.4 | 5 | 1 | 4 | 204 | 0.1 | 0.1 | 14 | 5.3 | 18 | 11 | 56 | 58 | 71 | 11 | - | - | <0.01 | 14 | 0.06 | 2 | 123 | 2.2 | 1.8 | 11.1 | Yes | 1.0 |
| Arsim | B | 04/04/89 | 7.2 | 5 | 1.9 | 7.1 | 261 | 0.1 | 0.1 | 14 | 5.8 | 11 | 11 | 58 | 60 | 73 | 14 | - | - | <0.01 | 13 | 0.02 | 10 | 157 | 1.9 | 1.9 | 1.9 | Yes | 0.6 |
| Tuum | B | 21/04/89 | 6.9 | 5 | 0 | - | 300 | 0.0 | 0 | 30.4 | 8.2 | 23 | 4.4 | 110 | 126 | 154 | 18 | 0.2 | 0 | 0 | 10 | - | - | 210 | 3.3 | 3.2 | 1.1 | Yes | 1.0 |
| Kurungu | B | 07/04/89 | 7.2 | 5 | 19 | 9.5 | 197 | 0.1 | 0.1 | 14 | 4.4 | 6.3 | 15 | 58 | 48 | 59 | 11 | - | - | <0.01 | 10 | 0.08 | 12 | 111 | 1.7 | 1.5 | 7.5 | No | 0.4 |
| South Horr | B | 08/04/89 | 7.3 | 5 | 11 | 7.1 | 111 | 0.1 | 0.1 | 8 | 3.4 | 4.2 | 4 | 34 | 36 | 44 | 6 | - | - | <0.01 | 7 | 0.04 | 6 | 71 | 1.0 | 1.0 | -3.5 | No | 0.3 |
| Kichichi | B | 10/04/89 | 7.2 | 5 | 2.5 | 4.1 | 73 | 0.1 | 0.1 | 4 | 1.9 | 5.3 | 4.3 | 18 | 24 | 29 | 4 | - | - | <0.01 | 5.2 | <0.01 | 4 | 44 | 0.7 | 0.7 | -0.3 | Yes | 0.5 |

HCO3 concentration is calculated from the Total Alkalinity (for pH <8.3)

(Samples might have been taken at some distance downstream from the spring)

CHEMICAL DATA WELLS

| LOCATION | MAIN AQUIFER V-vocanics B-basement | DATE OF SAMPLING | pH | color | Turb FTU. | KMn04 value | E.C. uS/cm | Fe | Mn | Ca | Mg | Na | K | Total Hard | Total Alk | HCO3 | Cl | F | NO3 | NO2 | SO4 | PO4 | Free CO2 | TDS | SUM CATIONS | SUM ANIONS | IONIC BALANCE | Suitable for domestic use | SAR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | mg/l | | | | | | | | | | | | | | | | | meq/l | meq/l | % | | |
| Illaut | B | 01/04/89 | 7.8 | 5 | 1.8 | 2.4 | 1686 | 0.1 | <0.1 | 64 | 26 | 110 | 11 | 268 | 486 | 592 | 141 | - | - | 0.1 | 81 | 0.1 | 20 | 1017 | 10.4 | 15.4 | -19.3 | No | 2.9 |
| Lairarai | V | 23/02/89 | 7.3 | 5 | 2.6 | 6.7 | 650 | 0.3 | <0.1 | 22 | 7.8 | 105 | 13 | 88 | 250 | 305 | 40 | - | - | 0.3 | 4.1 | 0.02 | 36 | 390 | 6.6 | 6.2 | 3.3 | No | 4.9 |
| Lairarai | V | 23/02/89 | 7.2 | Brown | 120 | 12 | 741 | 2 | 0.2 | 30 | 8.8 | 95 | 22 | 114 | 288 | 351 | 39 | - | - | 0.5 | 10 | 0.02 | 76 | 444 | 6.9 | 7.1 | -1.1 | No | 3.9 |
| Morijo | V | 28/02/89 | 7.3 | 5 | 9 | 2.8 | 572 | 0.2 | 1.6 | 47 | 11 | 76 | 11 | 160 | 218 | 266 | 22 | - | - | 0.05 | 12 | <0.01 | 48 | 343 | 6.8 | 5.2 | 13.4 | No | 2.6 |
| Kisima | B | 24/02/89 | 8.0 | 5 | 3.2 | 2.8 | 949 | 0.2 | <0.1 | 0.8 | 5.8 | 154 | 1.9 | 26 | 248 | 302 | 94 | - | - | <0.01 | 42 | 0.04 | 0 | 569 | 7.3 | 8.5 | -7.7 | Yes | 13.2 |
| Mbaringon | B | 24/02/89 | 6.8 | cloudy | 8.4 | 134 | 377 | 5 | 0.4 | 18 | 4.7 | 29 | 46 | 72 | 328 | 400 | 16 | - | - | <0.01 | 5.3 | 0.4 | 60 | 226 | 3.7 | 7.1 | -31.3 | No | 1.6 |
| Loikas | B | 24/02/89 | 7.3 | 5 | 20 | 5.9 | 481 | 0.5 | <0.1 | 37 | 19 | 36 | 6.3 | 148 | 168 | 205 | 26 | - | - | 0.05 | 10 | 0.2 | 38 | 289 | 5.1 | 4.3 | 8.9 | No | 1.2 |
| Lesodo | V | 25/02/89 | 8.2 | 5 | 14 | 5.9 | 611 | <0.1 | <0.1 | 39 | 11 | 84 | 15 | 142 | 272 | 332 | 18 | - | - | 0.3 | 6.7 | 0.08 | 10 | 366 | 6.9 | 6.1 | 6.2 | No | 3.1 |
| Losuk | V | 26/02/89 | 7.5 | 30 | 22 | 7.5 | 793 | 0.5 | 1.1 | 57 | 15 | 80 | 21 | 204 | 362 | 441 | 21 | - | - | 0.5 | 10 | 0.02 | 46 | 476 | 8.1 | 8.0 | 0.4 | No | 2.4 |

# Appendix 5.3

# Chemical Data Boreholes

Appendix 5.3 Chemical Data Boreholes

| Borehole Location | BH No. | Sampling Date | pH | colou N.T.U | Turb | KMnO4 value | EC uS/cm | Fe | Mn | Ca | Mg | Na | K | Total Hard | Total Alk | HCO3 | Cl | F | NO3 | SO4 | PO4 | Free CO2 | TDS | SUM CATIONS | SUM ANIONS | IONIC BALANCE | Suitable for domestic use | SAR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | mg/l | | | | | | | | | | | | | | | | meq/l | | % | | |
| Maralal | C6796 | 23/08/86 | 7.2 | 5 | 6 | 3.1 | 814 | 0.2 | 0.18 | 61 | 17 | 86 | 9 | 228 | 196 | 239 | 43 | 0.77 | 0.87 | 175 | 0.02 | 20 | 488 | 8.4 | 8.8 | -2.2 | yes | 2.2 |
| Wamba | C6797 | 28/08/86 | 7.4 | <5 | 4 | <0.1 | 2810 | 0.2 | 0.22 | 191 | 91 | 260 | 18 | 892 | 468 | 570 | 565 | 1.2 | 0.94 | 273 | 0.02 | 42 | 1686 | 28.8 | 31.0 | -3.7 | no | 3.6 |
| Maralal | C6799 | 06/09/86 | 8.3 | <5 | 2.7 | <0.1 | 918 | 0.2 | <0.01 | 15 | 36 | 149 | 11 | 200 | 226 | 275 | 149 | 0.61 | 0.89 | 48 | 0.02 | 4 | 551 | 10.5 | 9.7 | 3.7 | yes | 5.3 |
| Lodokojek | - | 09/12/86 | 8.0 | <5 | 10 | <0.1 | 1560 | 0.5 | 0.04 | 2.5 | 3.9 | 370 | 8.6 | 50 | 580 | 707 | 97 | 15.7 | 0.03 | 35.3 | 0.01 | 6 | 940 | 16.8 | 15.1 | 5.3 | no | 36.0 |
| Sarolepi | - | 09/01/87 | 8.2 | 5 | 15 | 0.47 | 3360 | 2 | 0.10 | 84 | 84 | 560 | 16 | 634 | 393 | 479 | 925 | 1.7 | <0.01 | 327 | 0.11 | 32 | 2016 | 35.9 | 40.8 | -6.4 | no | 10.3 |
| Ledero | C7908 | 21/10/88 | 7.0 | <5 | 1.1 | - | 648 | 0.1 | <0.1 | 42 | 15 | 56 | 4.7 | 38 | 192 | 234 | 73 | 0.68 | - | 17 | 0.06 | 94 | 389 | 5.9 | 6.2 | -3.0 | yes | 1.7 |
| Wamba | C7910 | 21/06/88 | 6.9 | <5 | 9 | 0.2 | 1330 | 0.1 | 0.50 | 118 | 47 | 92 | 10 | 486 | 168 | 205 | 113 | 0.7 | - | 306 | 0.01 | 20 | 798 | 14.0 | 12.9 | 4.1 | no | 1.6 |
| Wamba | C7911 | 10/06/88 | 6.3 | 5.0 | 9.0 | 0.59 | 3500 | 0.1 | 1.00 | 244 | 132 | 294 | 21 | 1156 | 246 | 300 | 311 | 2.0 | - | 950 | 0.02 | 120 | 2100 | 36.4 | 33.5 | 4.2 | no | 3.5 |
| Lengusaka | C7914 | 16/07/88 | 7.3 | <5 | 0.3 | 9.5 | 2900 | 0.2 | 0.50 | 108 | 124 | 325 | 40 | 778 | 198 | 241 | 516 | 2.5 | - | 374 | 0.06 | 53 | 1740 | 30.8 | 26.3 | 7.8 | no | 5.1 |
| Lengei | C7915 | 21/07/88 | 7.1 | 5.0 | 1.7 | 3.6 | 2000 | 0.1 | <0.1 | 9.1 | 139 | 103 | 19 | 800 | 326 | 397 | 220 | 0.85 | - | 268 | 0.02 | 80 | 1200 | 16.9 | 18.3 | -4.1 | yes | 2.3 |
| Swuari | C7916 | 16/10/88 | 7.1 | <5 | 1.2 | 11 | 8640 | <0.1 | <0.1 | 14.4 | 1050 | 378 | 52 | 4360 | 534 | 651 | 37 | 0.8 | - | 58 | 0.1 | 158 | 5184 | 104.9 | 12.9 | 78.1 | no | 3.2 |
| Kowop | C7917 | 17/04/89 | 7.2 | 5 | 1.1 | 4.7 | 3653 | <0.1 | 0.20 | 87 | 390 | 221 | 36 | 1820 | 216 | 263 | 285 | 3 | - | 1322 | <0.01 | 38 | 2120 | 47.0 | 39.9 | 8.2 | no | 2.6 |
| Barsaloi | C7918 | 24/04/89 | 7.2 | 15 | 2.5 | 6.3 | 594 | <0.1 | 0.20 | 76 | 17 | 27 | 8.3 | 260 | 230 | 280 | 25 | 1.1 | - | 26 | 0.04 | 18 | 356 | 6.6 | 5.8 | 5.9 | no | 0.6 |
| Masikita | C7919 | 21/04/89 | 7.2 | 15 | 6 | 4.7 | 1554 | <0.1 | <0.1 | 75 | 67 | 154 | 32 | 460 | 346 | 422 | 115 | 1.8 | - | 210 | <0.01 | 36 | 933 | 16.8 | 14.5 | 7.2 | no | 3.1 |
| Losuk | C7921 | 27/05/89 | 7.0 | <5 | 1.8 | 6.3 | 720 | <0.1 | 0.1 | 55 | 12 | 63 | 17 | 186 | 278 | 339 | 21 | 1.0 | - | 11 | 0.02 | 14 | 432 | 6.9 | 6.4 | 4.0 | yes | 1.7 |
| Nondoto | C7922 | 29/05/89 | 7.3 | <5 | 2 | 2.4 | 1020 | <0.1 | <0.1 | 18 | 4.9 | 176 | 5.7 | 64 | 200 | 244 | 101 | 7.0 | - | 74 | 0.01 | 12 | 612 | 9.1 | 8.4 | 4.1 | no | 8.2 |

HCO3 Concentration is calculated from the total alkalinity (for pH <8.3)

# Appendix 5.4

# Wells Tests

## Appendix 5.4 Well tests

| BH No. | Location | Aquifer Lithology | Transmissivity (from recovery phase) $m^2$/day | Specific Capacity $m^2$/day |
|---|---|---|---|---|
| C7908 | Ledero | Weathered Metamorphics * | 5.8 | 2.0 |
| C7910 | Wamba | Weathered Basement | 0.4 | 0.8 |
| C7911 | Wamba | Sandy Micaceous Sediments | 6.3 | 2.9 |
| C7914 | Lengusaka | Weathered gneiss | 5.0 | 1.1 |
| C7915 | Lengei | Weathered Gneiss | 0.7 | 0.9 |
| C7916 | Swuari | Weathered biotite gneiss | 6.1 | 1.4 |
| C7917 | Kowop | Weathered gneiss | 5.9 | 2.0 |
| C7918 | Barsaloi | Sandy sediments/some gravel/pebbles, weathered metamorphics | 8.4 | 17.5 |
| C7919 | Masiketa | Weathered unconsolidated gneissic materials | 7.7 | 1.7 |
| C7921 | Losuk | Unconsolidated weathered phonolites/some clay | 14.8 | 11.2 |
| C7922 | Nondoto | Weathered Volcanics | 0.6 | 1.8 |

* For Basement (metamorphic area) sites, fracture/fault zone is generally implied

## Appendix 5.4 Well Tests

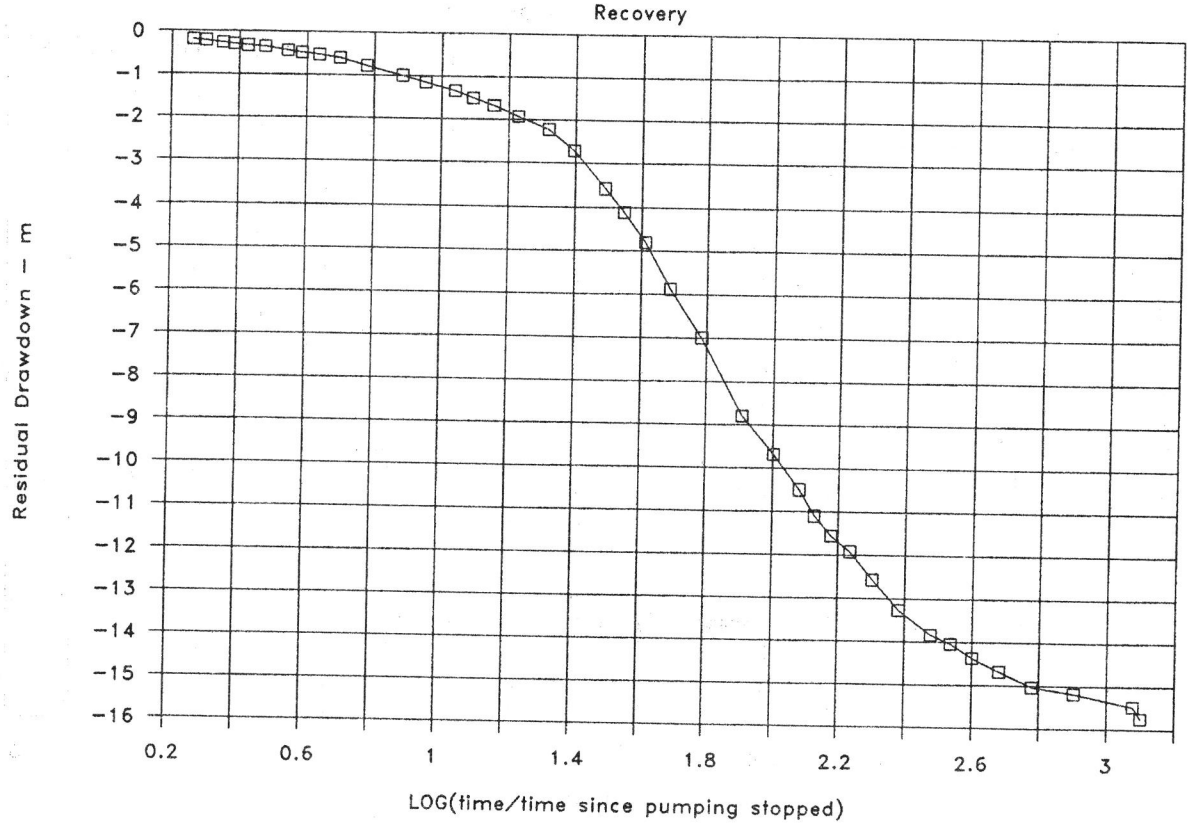
| BH No. | Location | Aquifer Lithology | Step-drawdown Test | | | | Step-drawdown Equation s = AQ + BQc | | | Estimated Sustained Yield $m^3$/day | Tested Yield $m^3$/day | Pumping Time and Corrected Pumping Time Minutes | Transmissibility Based on Recovery $m^2$/day |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Q1<br>Ql/s1 | Q2<br>Q2/s2 | Q3<br>Q3/s3 | Mean Q<br>Q/s | A | B | C | | | | |
| C7908 | Ledero | Weathered Metamorphics | 16.3<br>3.68 | 20.2<br>2.88 | 28.3<br>2.75 | 25.7<br>1.63 | 8.73 | -0.0338 | -10.02 | 22 | 29 | 1260<br>1250 | 0.42 |
| C7910 | Wamba | Wheathered Basement | 21.8<br>2.34 | 43.2<br>1.33 | 53.4<br>0.71 | 65<br>1.00 | 9.99 | 0.823 | -4.00 | 24 | 29 | 480<br>432 | 0.10 |
| C7911 | Wamba | Sand, Some gravel | 26.4<br>6.3 | 45.1<br>6.3 | 90.5<br>5.65 | 73.4<br>2.0 | 3.81 | 2.51 Exp-5 | 8.30 | 40 | 77 | 405<br>319 | 0.84 |
| C7914 | Lengusaka | Weathered gneiss | 15.6<br>2.81 | 19.0<br>2.52 | 25.2<br>2.54 | 26.5<br>1.10 | 9.68 | -1.53 Exp-2 | -9.0 | 12 | 26 | 1440<br>1395 | 0.36 |
| C7915 | Lengei | Weathered gneiss | 31.7<br>9.27 | 42.7<br>7.74 | 51.4<br>7.32 | 40.8<br>1.15 | 3.63 | 1.91 | -1.22 | 18 | 43 | 1560<br>1548 | 0.93 |
| C7916 | Swuari | Wethered biotite gneiss | | no data | | 67.0<br>1.79 | | no data | | 18 | 67 | 300 | 0.23 |
| C7917 | Kowop | Weathered gneiss | 26.4<br>3.08 | 39.6<br>3.07 | 48.2<br>2.96 | 48.3<br>1.99 | 7.79 | 2.27 Exp-5 | 14.65 | 40 | 48 | 1440<br>1383 | 0.65 |
| C7918 | Barsaloi | Sands, gravel, pebbles<br>Weathered Metamorphics | 110<br>40.7 | 76.6<br>31.2 | 172<br>25.8 | 170<br>19.5 | 0.462 | 1.34 Exp-3 | 3.98 | 170 | 173 | 1440<br>1395 | 4.15 |
| C7919 | Masiketa | Semi-pelitic gneiss is contact zone of intrusion | 80.9<br>11.4 | 112<br>9.02 | 136<br>3.04 | 123<br>1.71 | 2.09 | 6.45 Exp-9 | 12.9 | 72 | 125 | 1440<br>1397 | 0.20 |
| C7921 | Losuk | Old landsurface rocks | 174<br>15.1 | 230<br>15.0 | 298<br>14.0 | 290<br>10.6 | 1.59 | 8.82 Exp-11 | 9.37 | 200 | 288 | 1440<br>1389 | 14.0 |
| C7922 | Nondoto | Weathered volcanics | 86.2<br>5.35 | 117<br>4.09 | 136<br>3.69 | 133<br>1.69 | 5.14 | 1.12 Exp-3 | 5.10 | 100 | 144 | 720<br>609 | 0.50 |

### 5.4.1 Ledero C7908

**Appendix 5.4.1**

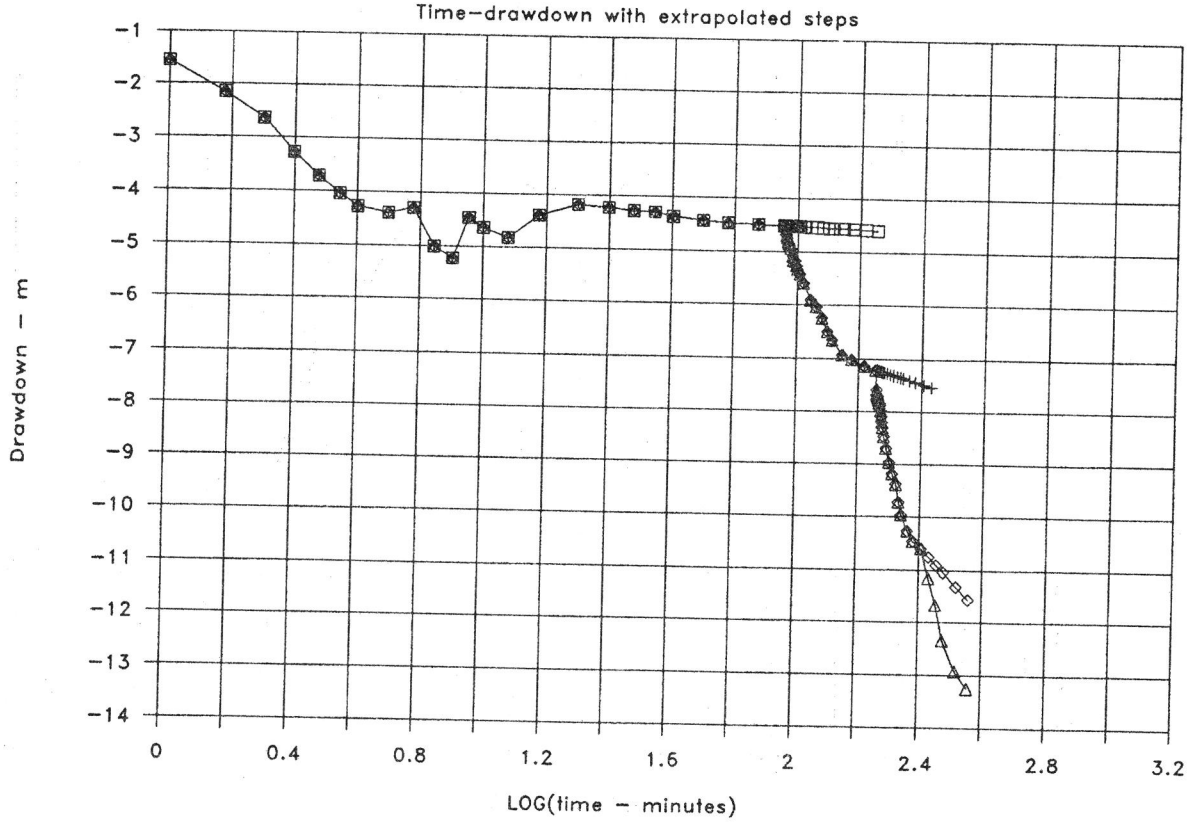
# LEDERO C7908 PUMPTEST

Recovery




# LEDERO C7908 PUMPTEST

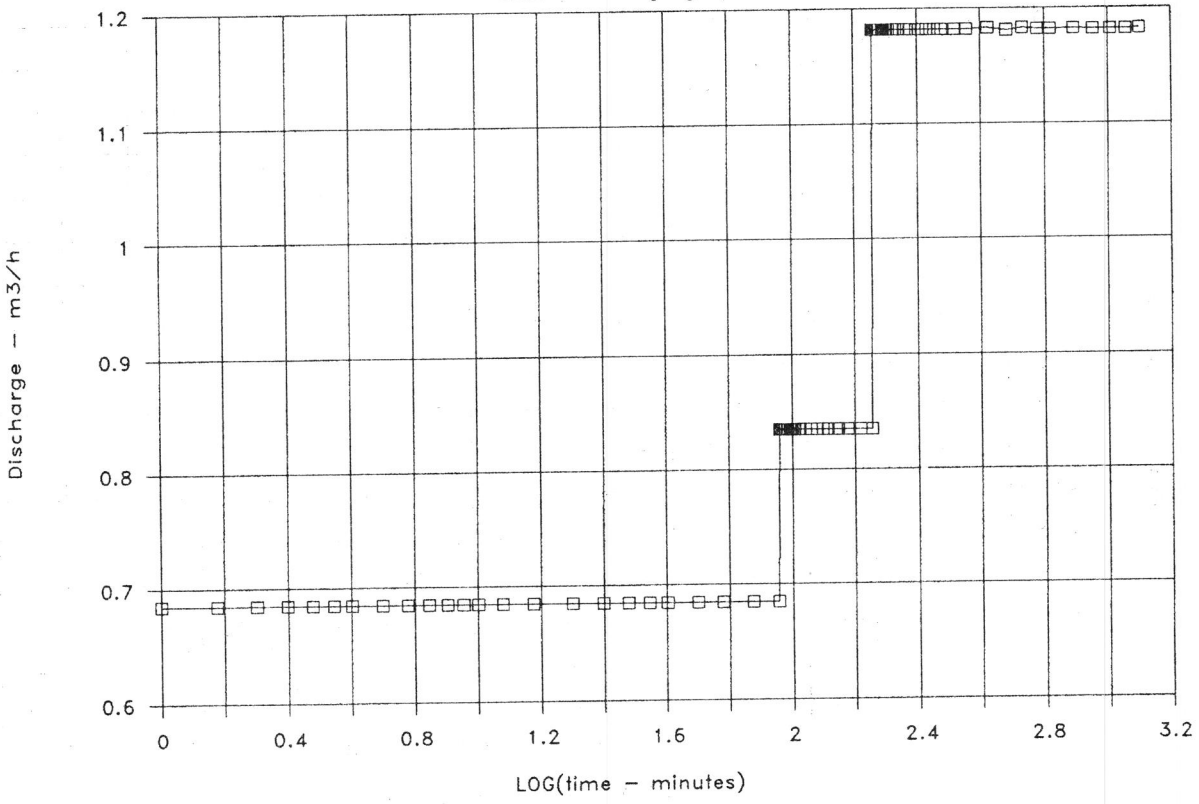
Time-drawdown with extrapolated steps



**Appendix 5.4.1**

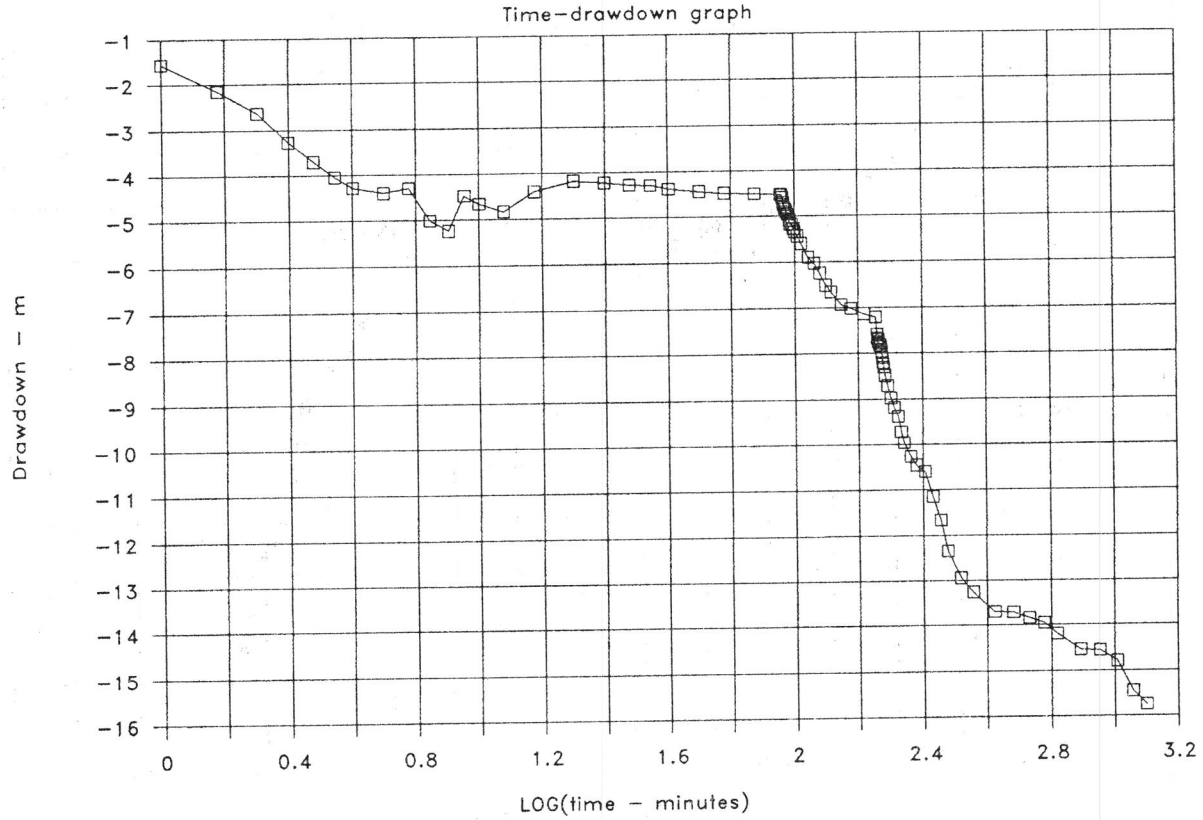
# LEDERO C7908 PUMPTEST

Time–discharge graph



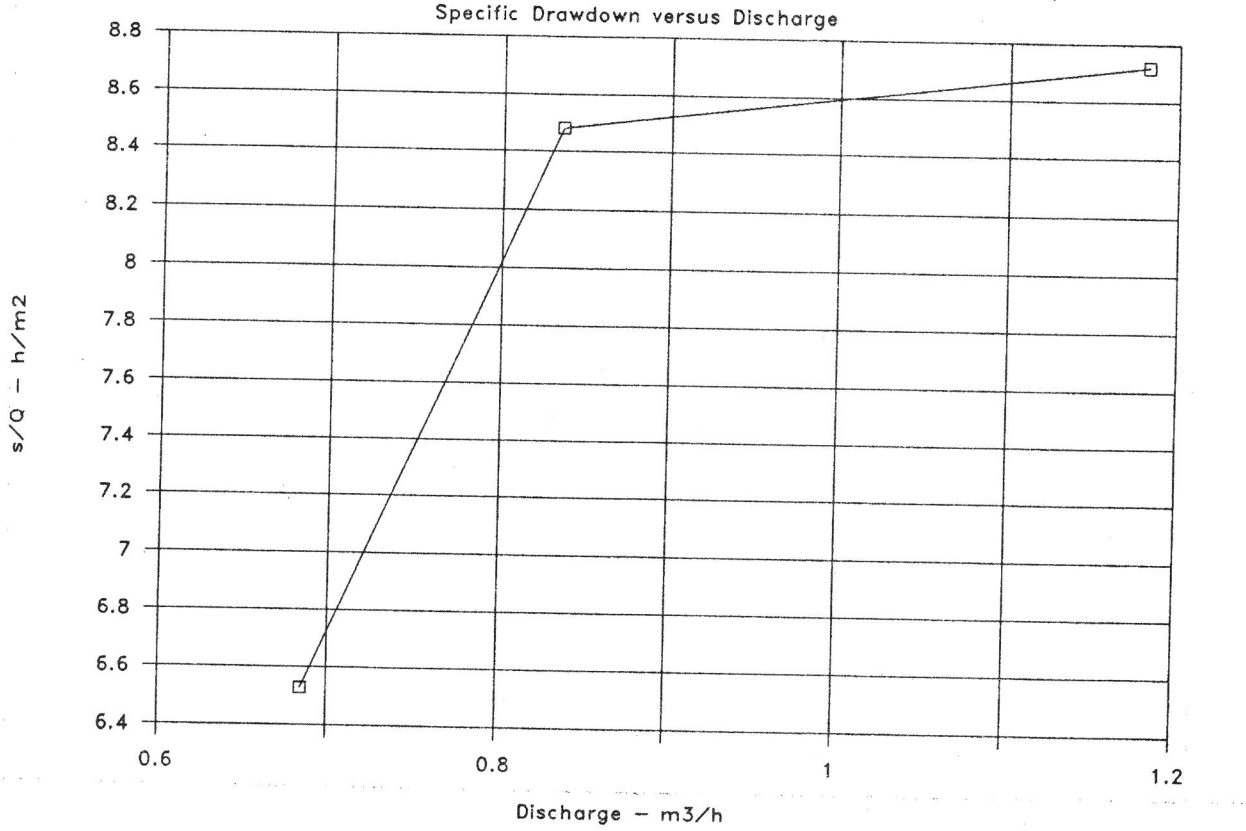

# LEDERO C7908 PUMPTEST

Time–drawdown graph



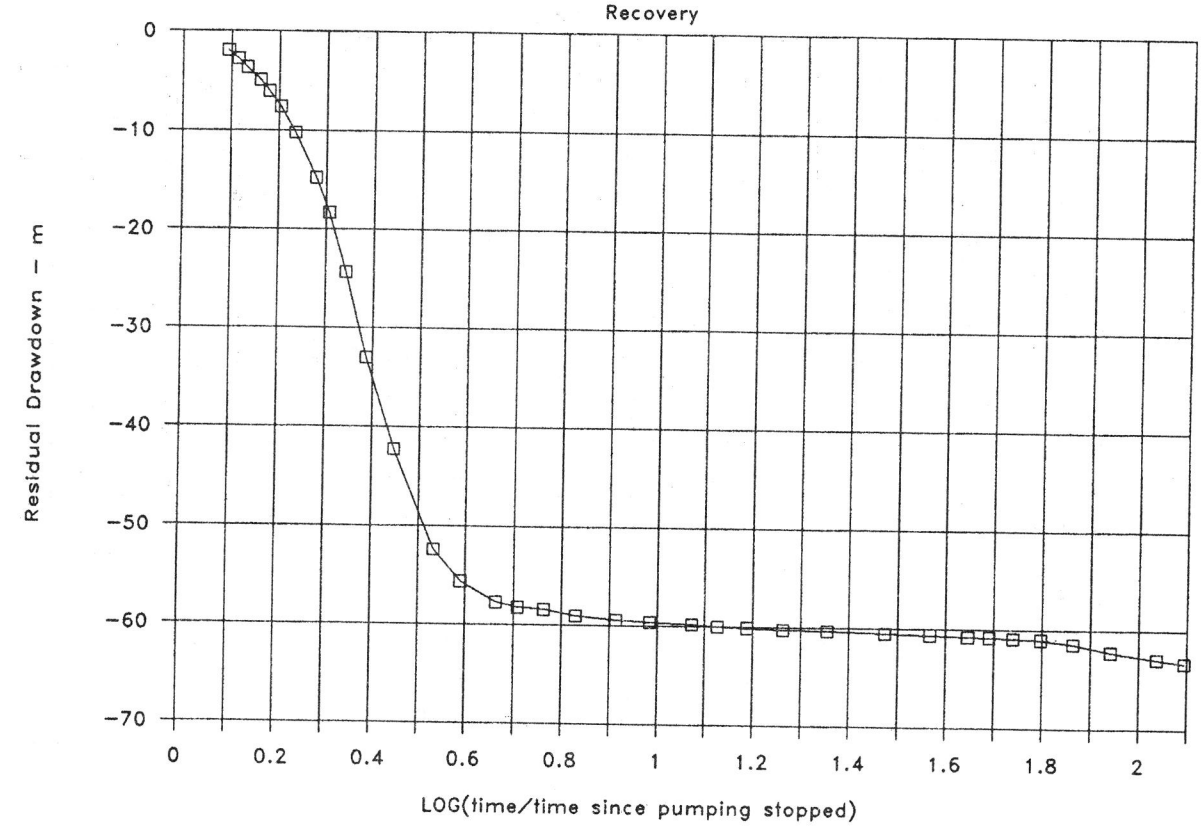
# LEDERO C7908 PUMPTEST

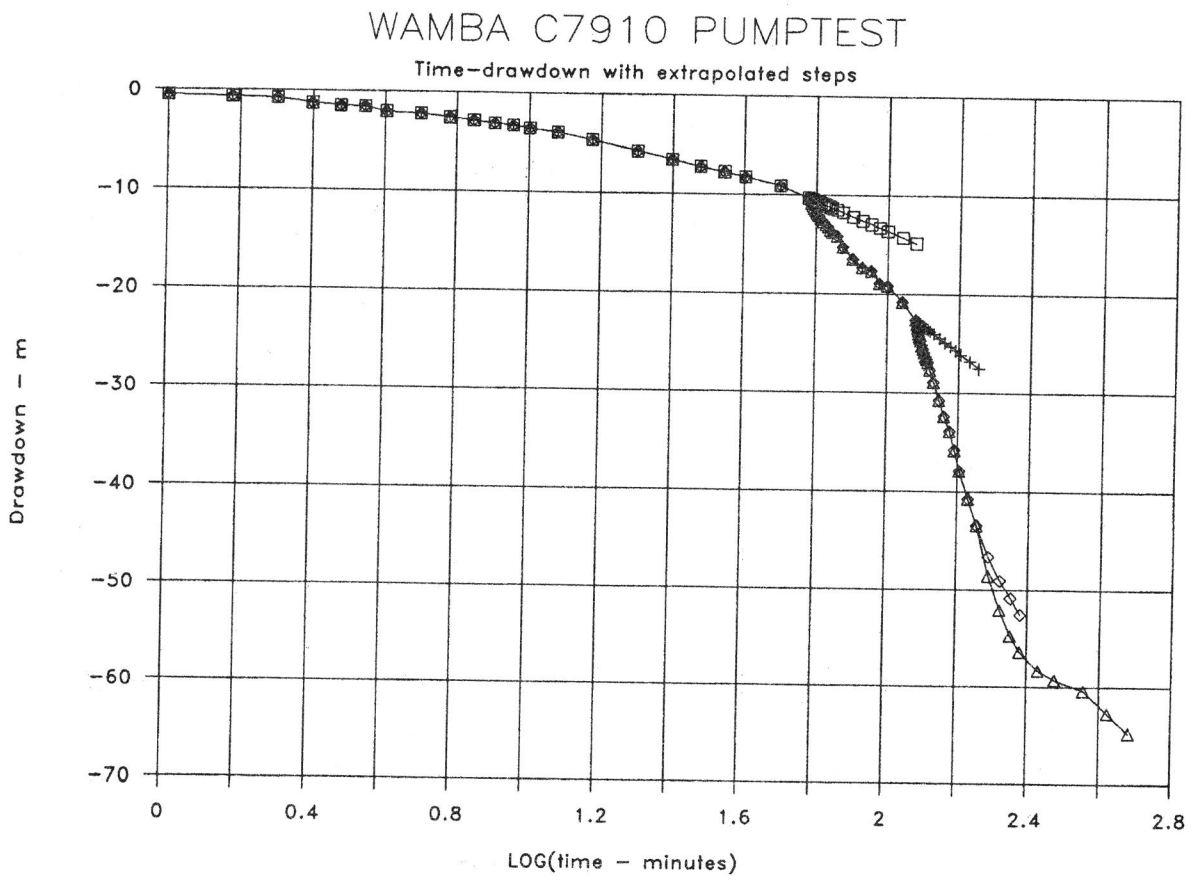
**Appendix 5.4.1**



### 5.4.2 Wamba C7910

**Appendix 5.4.2**

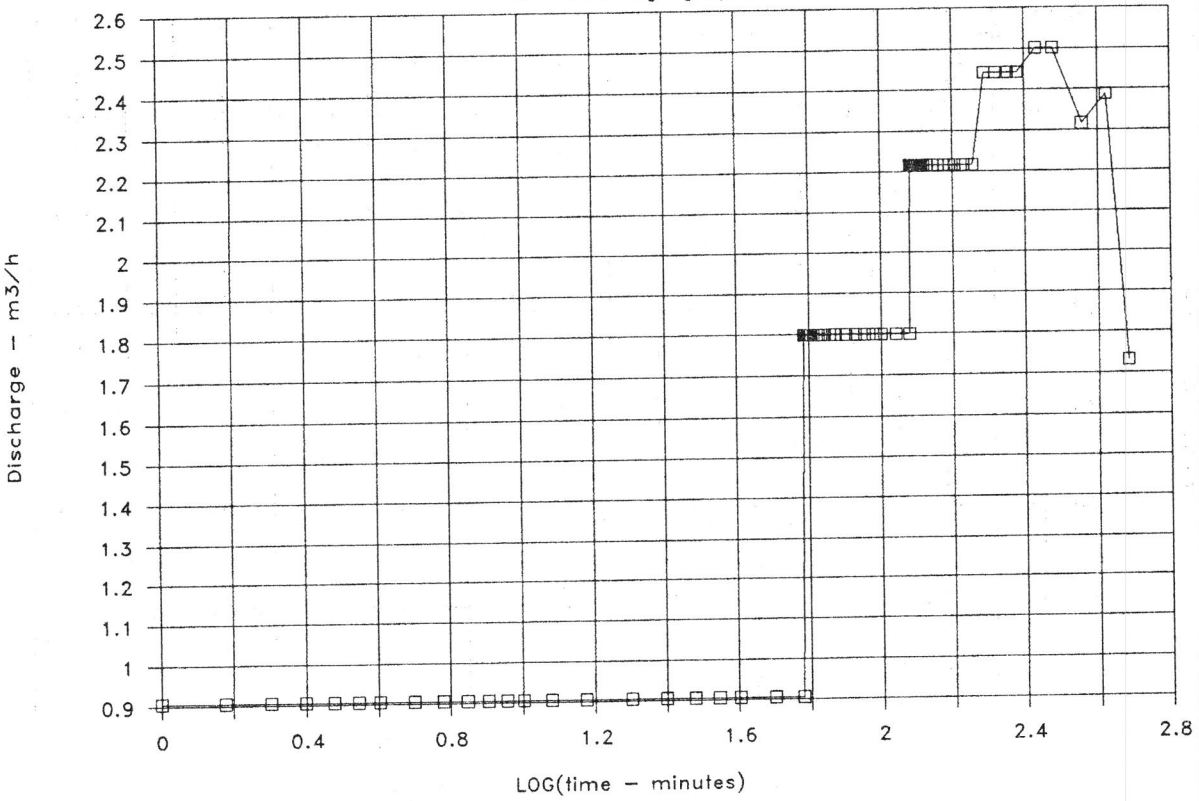


**Appendix 5.4.2**

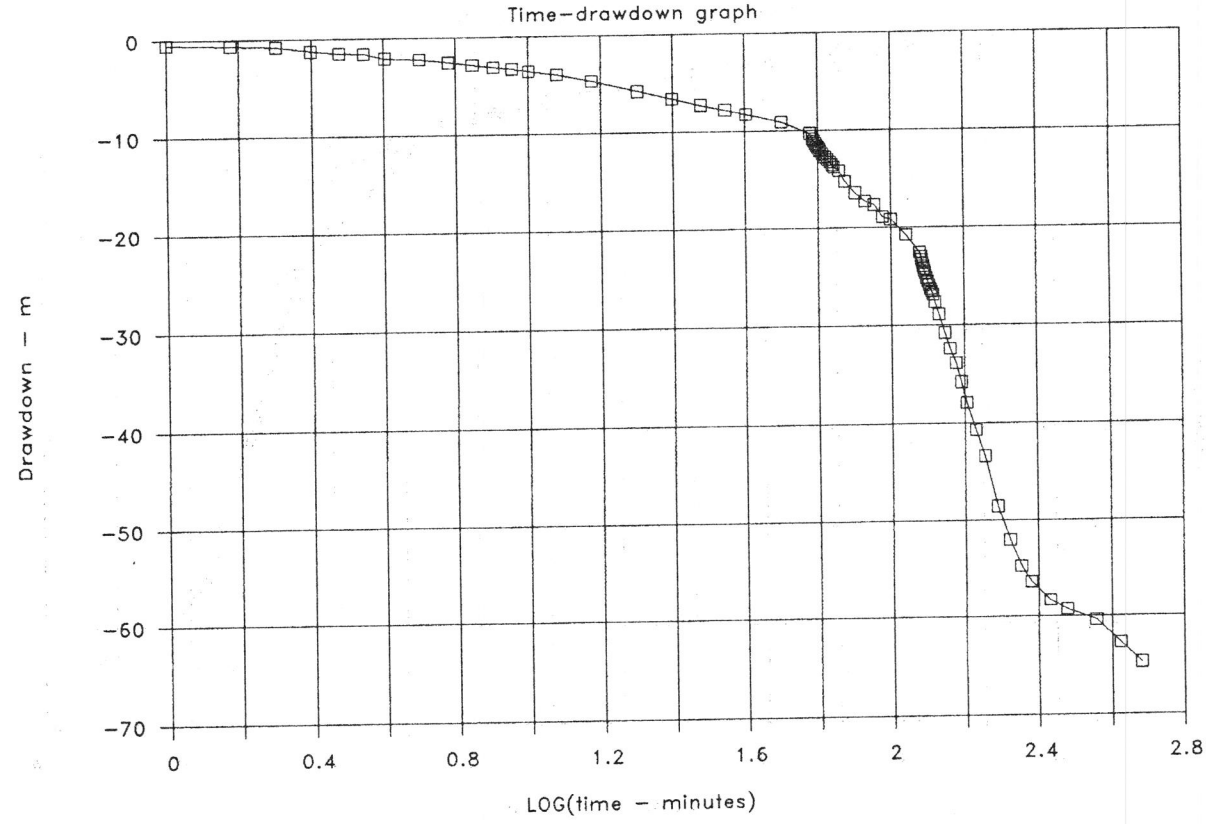
## WAMBA C7910 PUMPTEST

Time–discharge graph



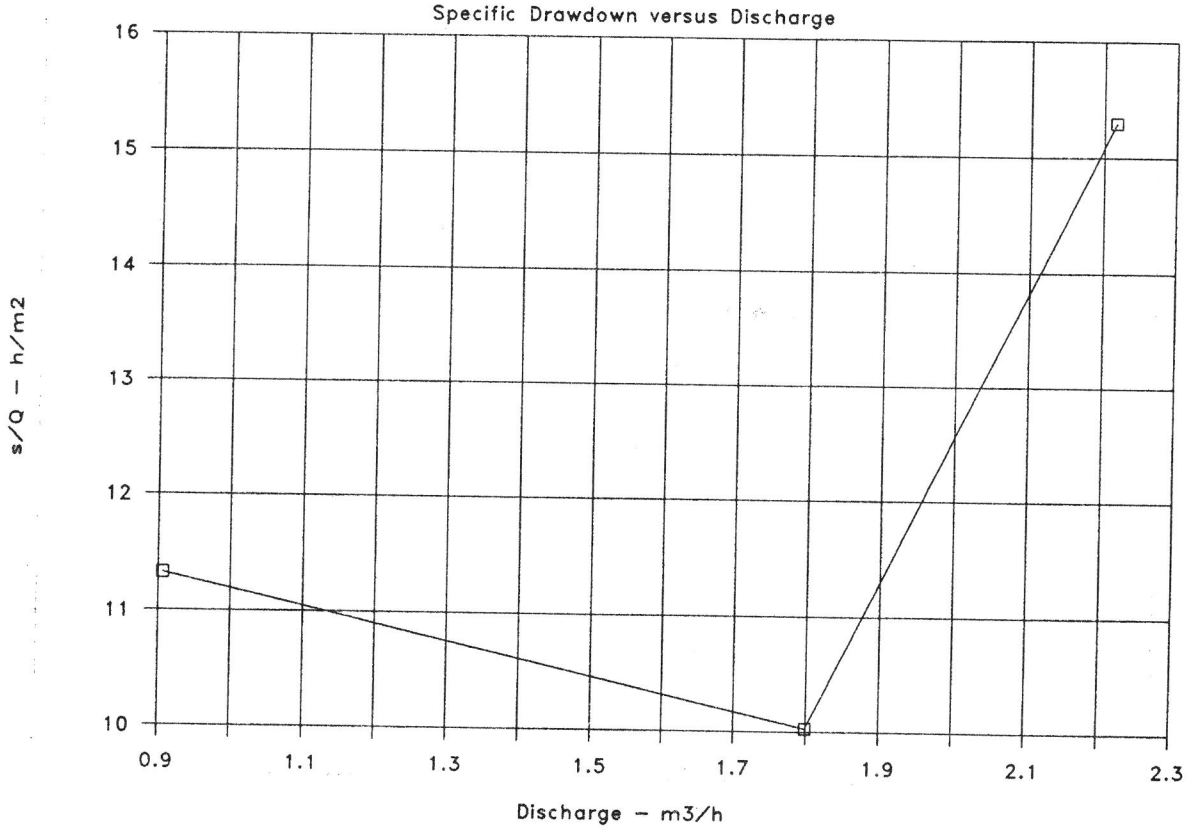

## WAMBA C7910 PUMPTEST

Time–drawdown graph



# WAMBA C7910 PUMPTEST

**Appendix 5.4.2**

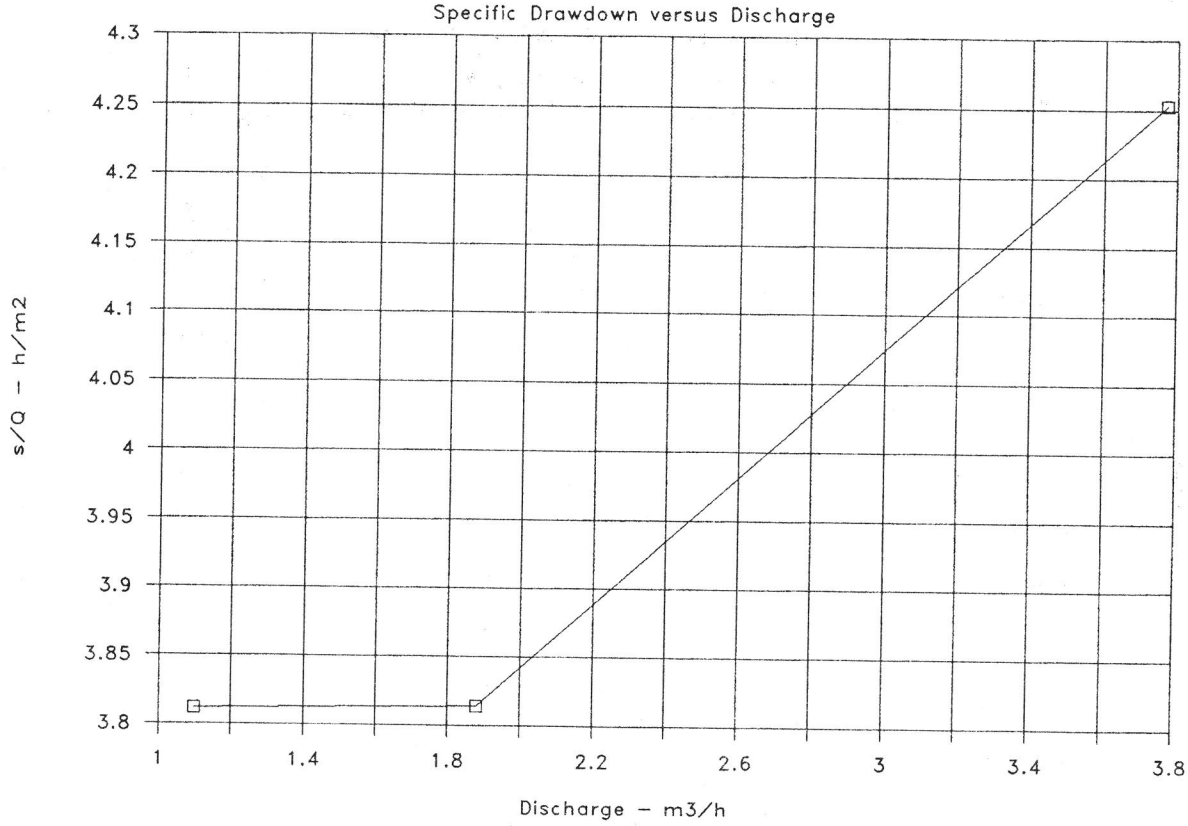


### 5.4.3 Wamba, C7911

**Appendix 5.4.3**

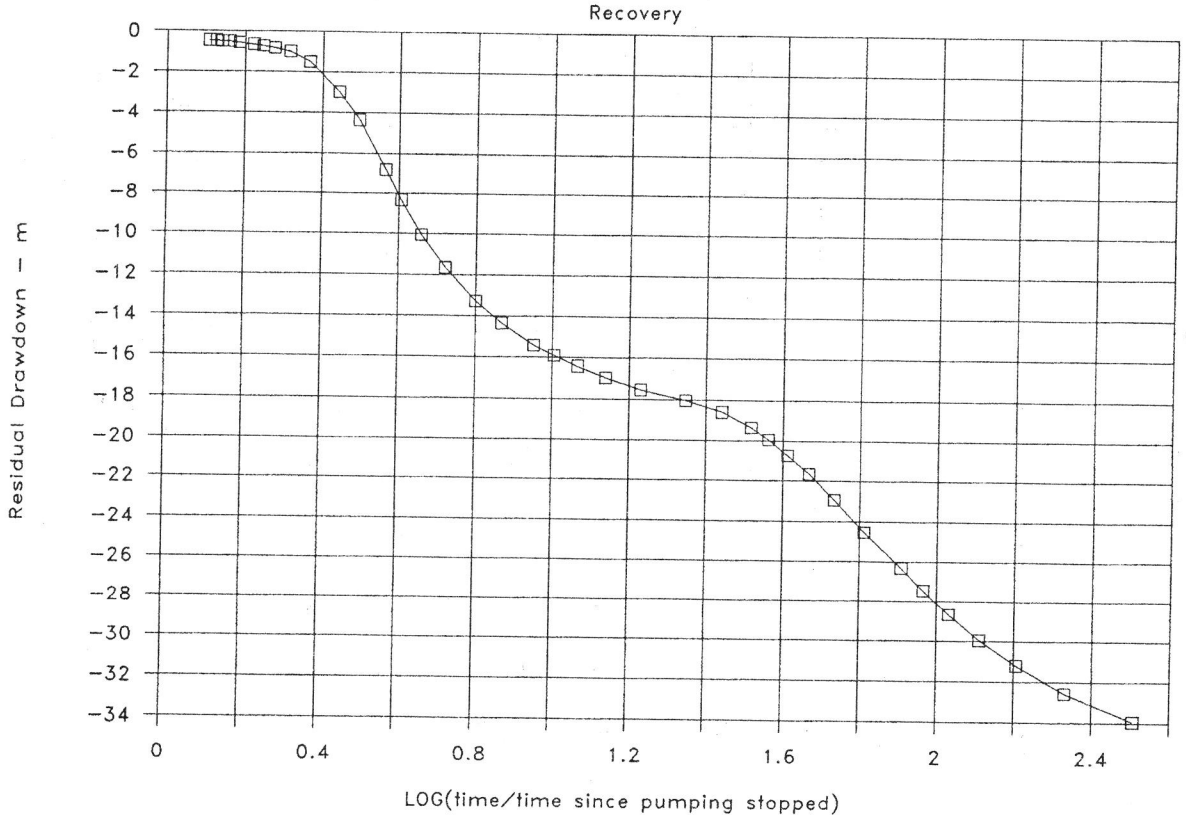
# WAMBA C7911 PUMPTEST

Specific Drawdown versus Discharge

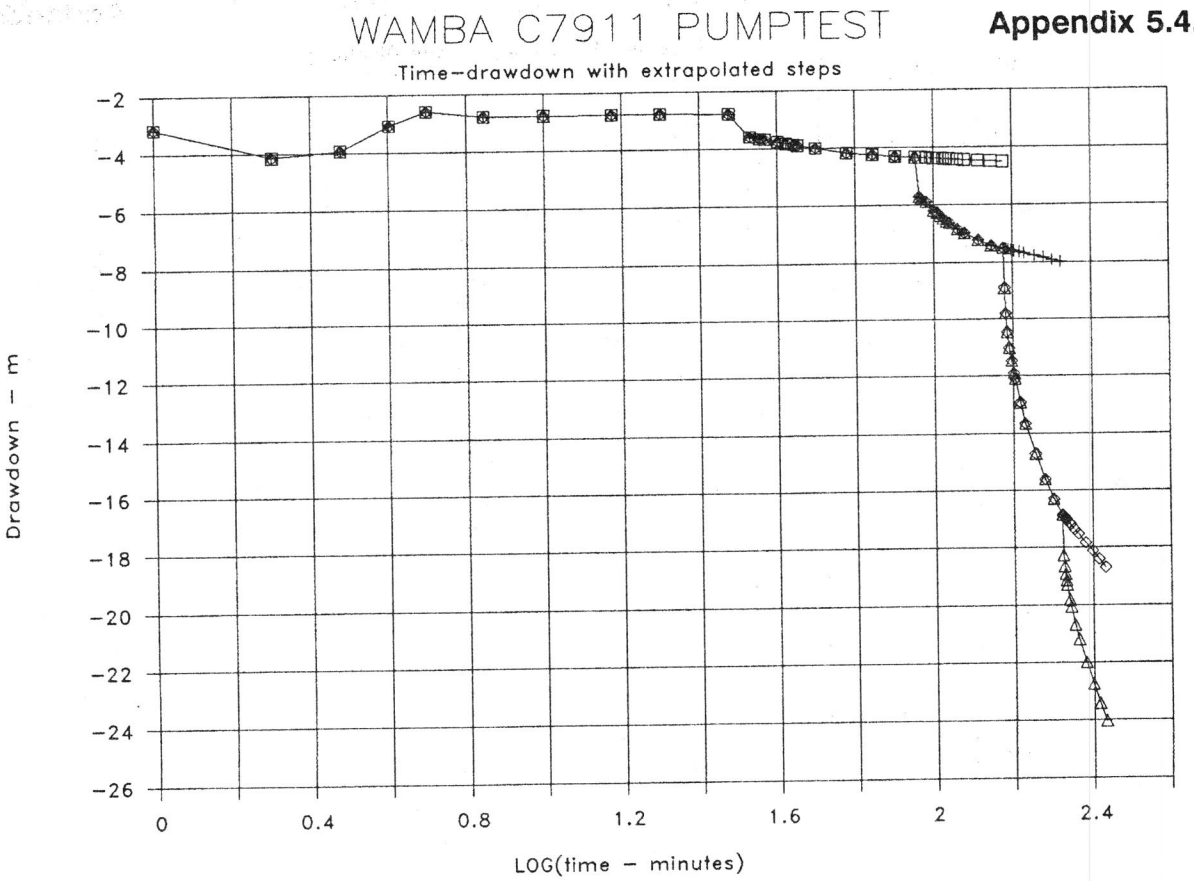


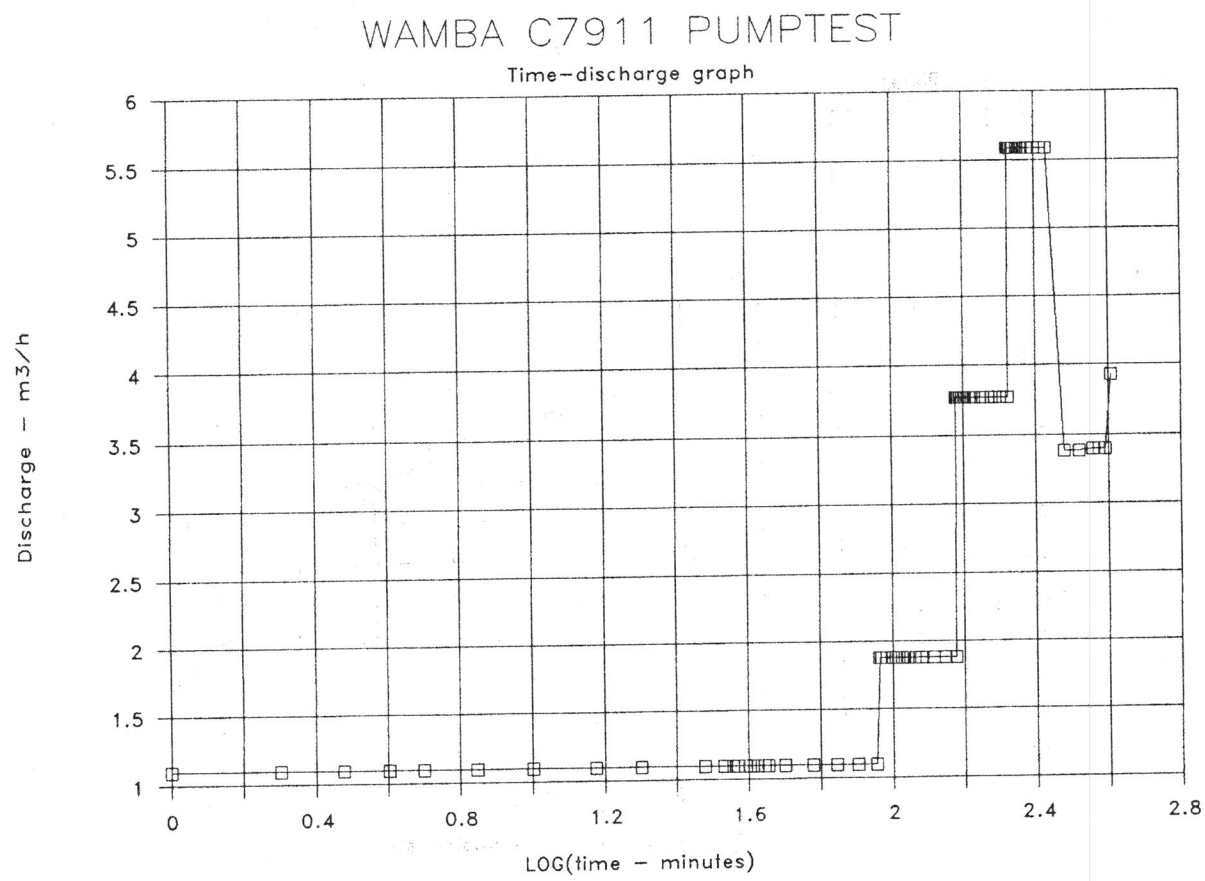

# WAMBA C7911 PUMPTEST

Recovery



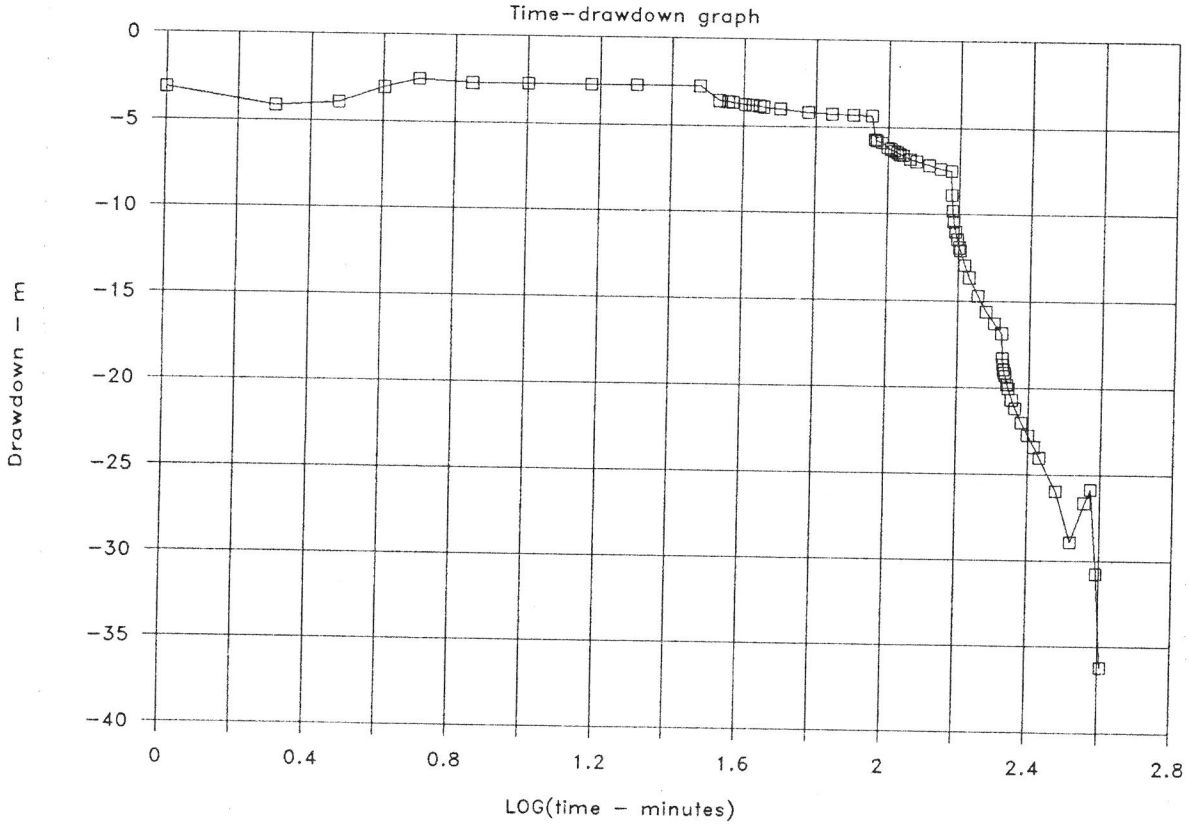
**Appendix 5.4.3**



# WAMBA C7911 PUMPTEST

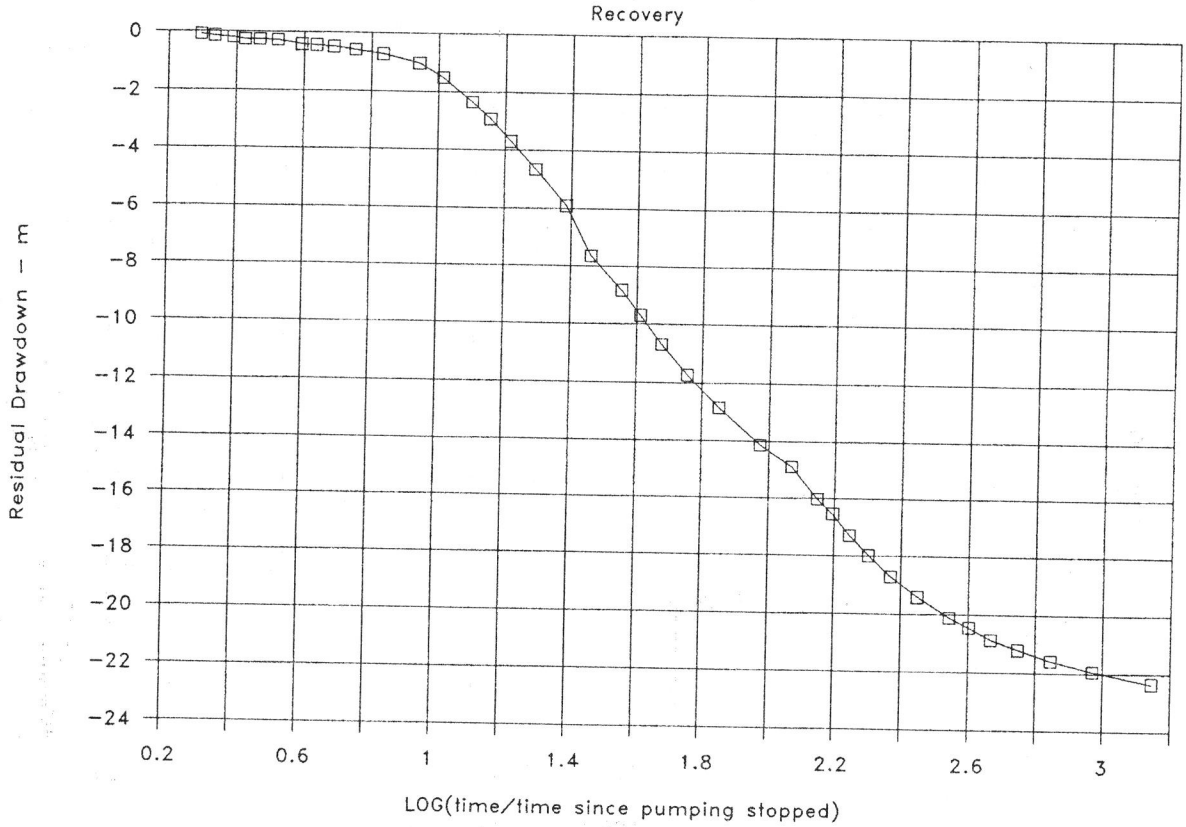
**Appendix 5.4.3**



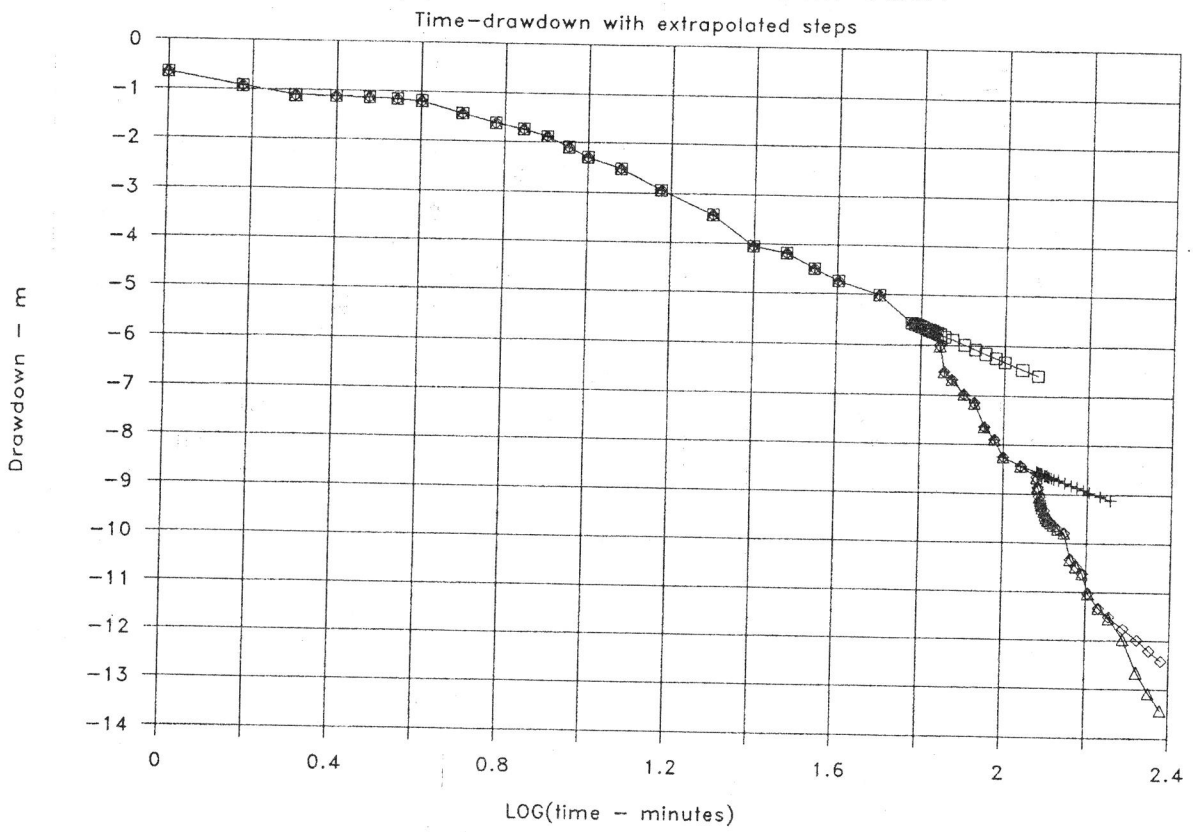
### 5.4.4 Lengusaka, C7914

# LENGUSAKA C7914 PUMPTEST

**Appendix 5.4.4**



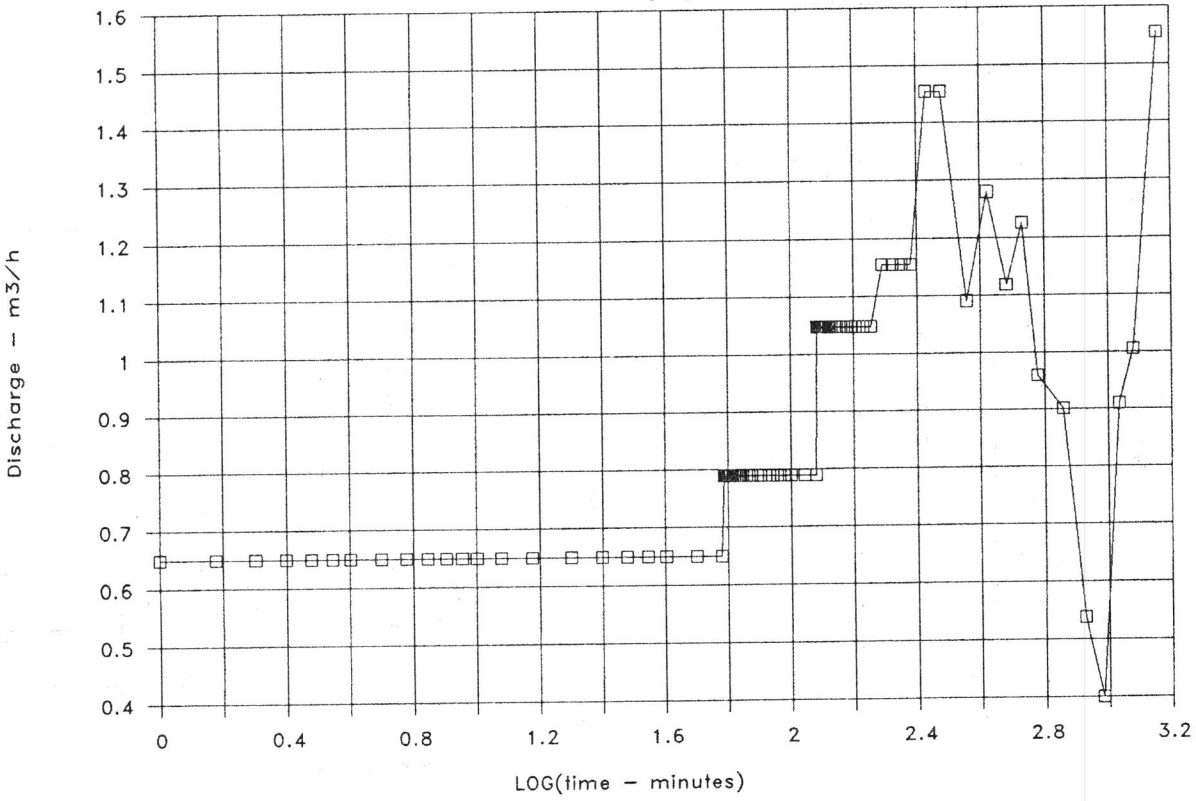

# LENGUSAKA C7914 PUMPTEST



**Appendix 5.4.4**

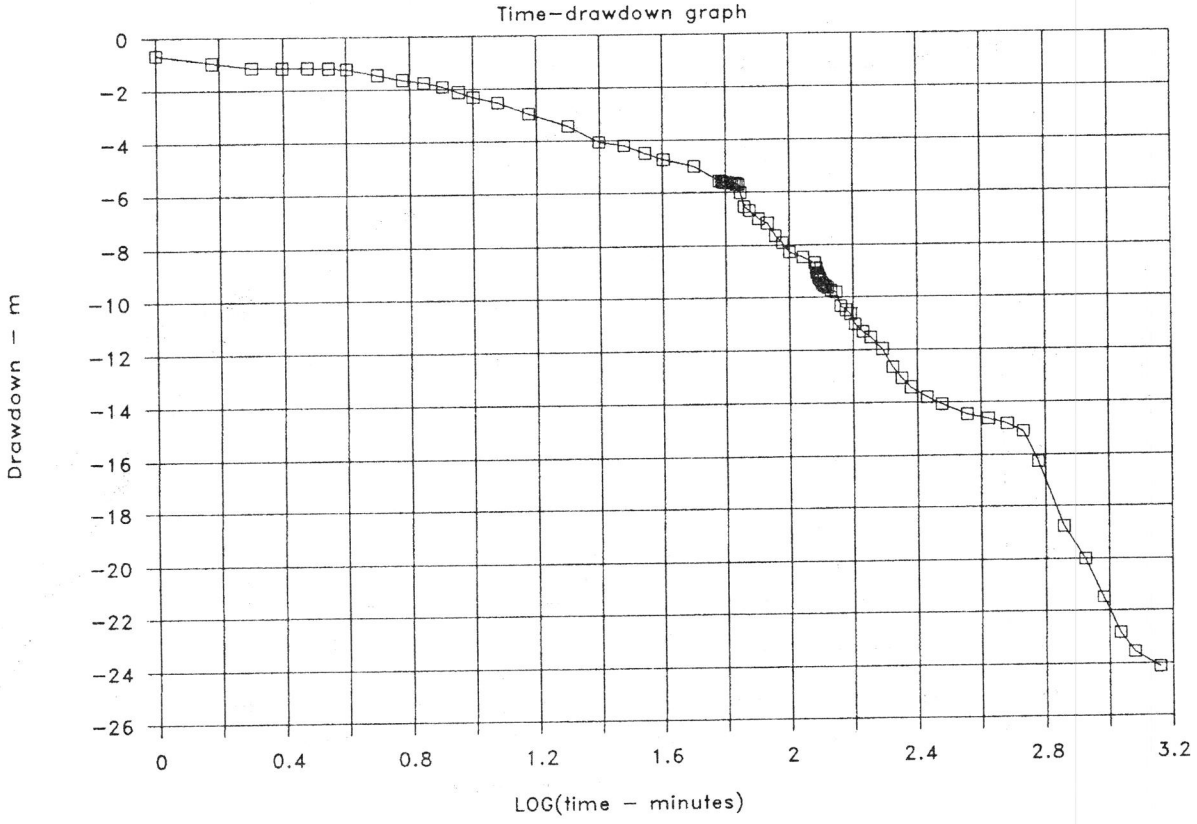
# LENGUSAKA C7914 PUMPTEST

Time–discharge graph

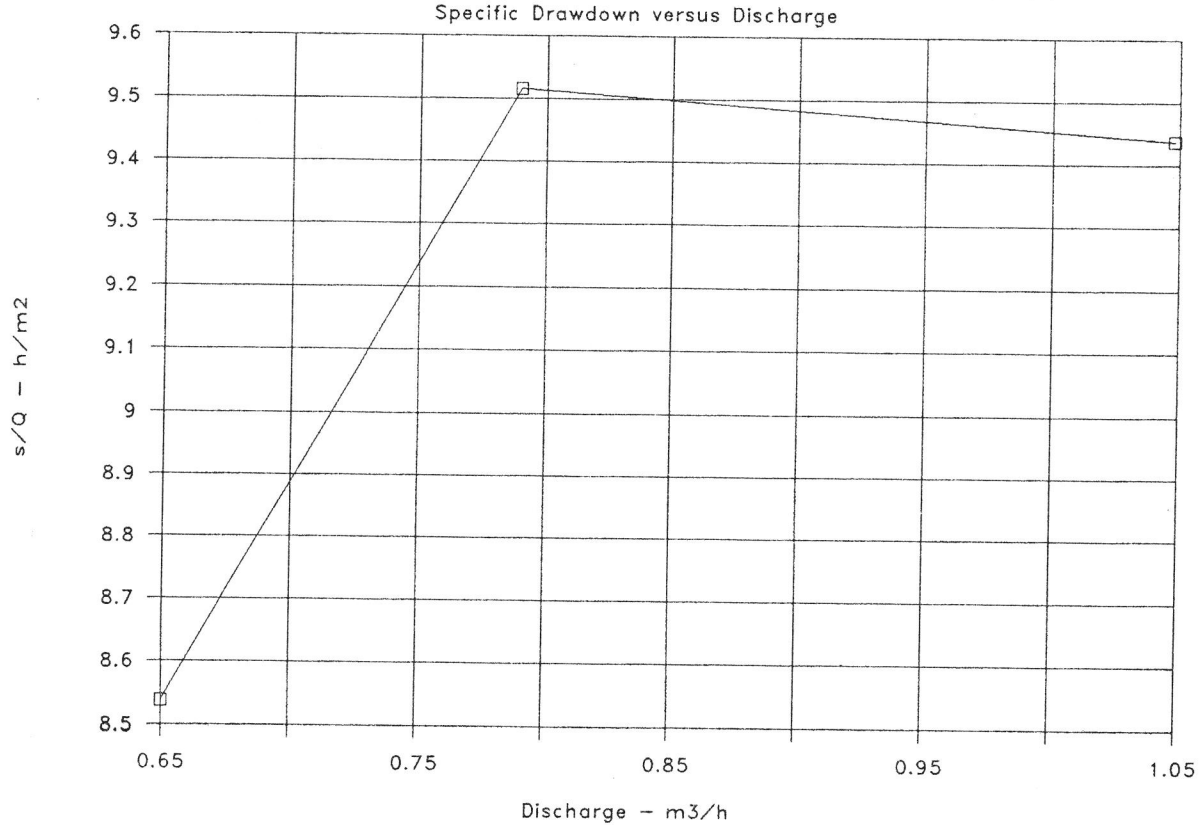



# LENGUSAKA C7914 PUMPTEST

Time–drawdown graph



# LENGUSAKA C7914 PUMPTEST **Appendix 5.4.4**

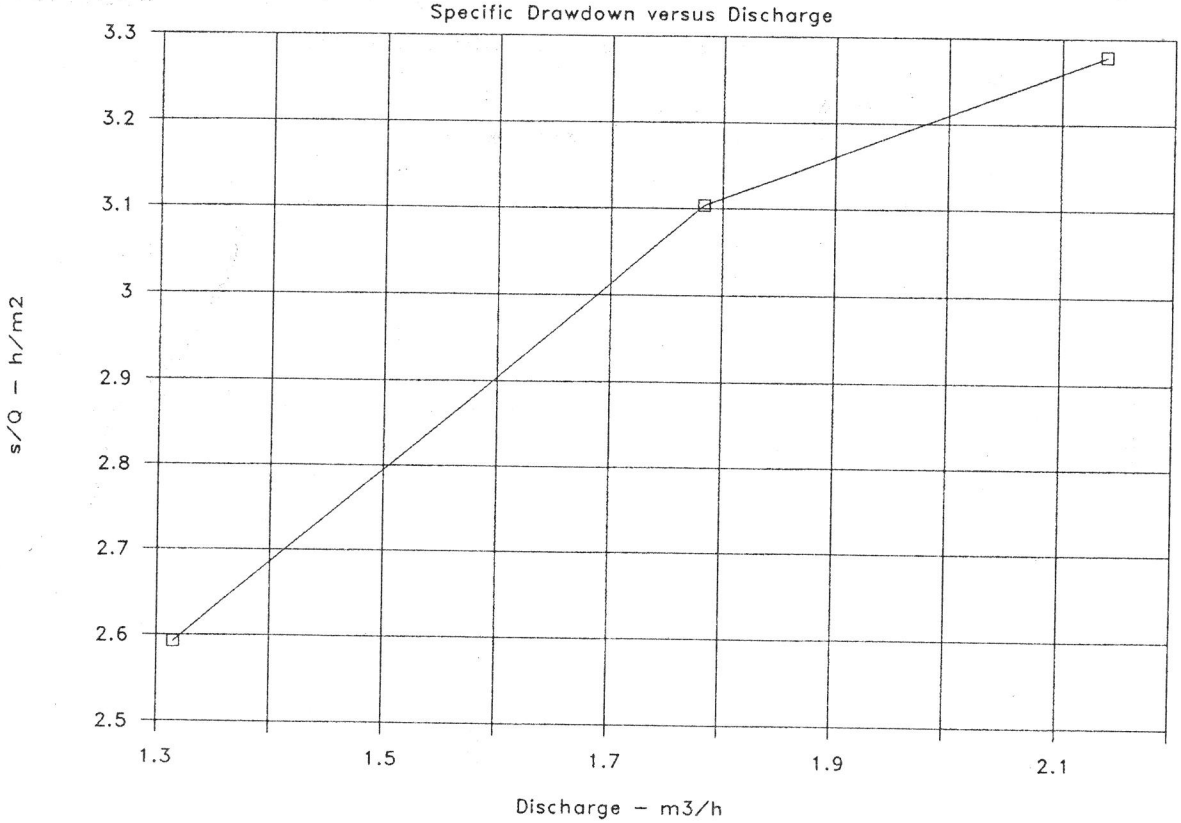


### 5.4.5 Lengei C7915

**Appendix 5.4.5**

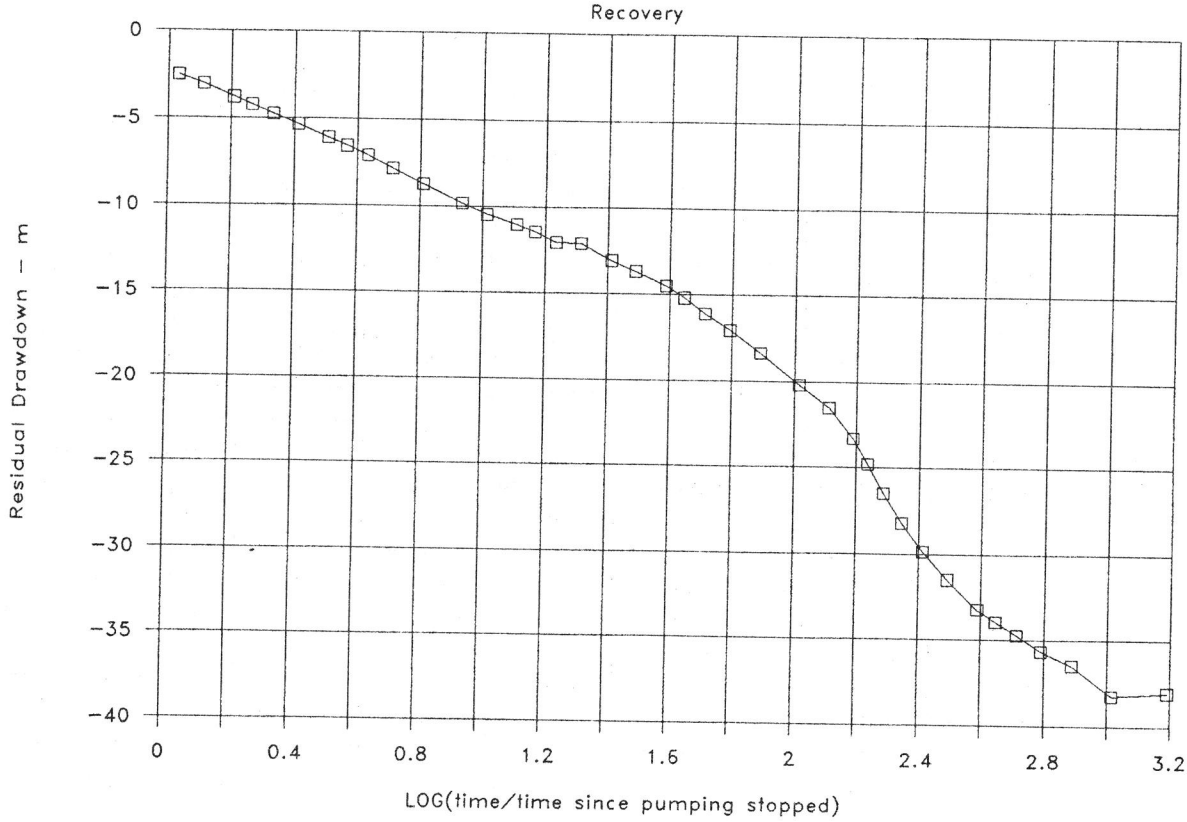
# LENGEI C7915 PUMPTEST

Specific Drawdown versus Discharge




# LENGEI C7915 PUMPTEST

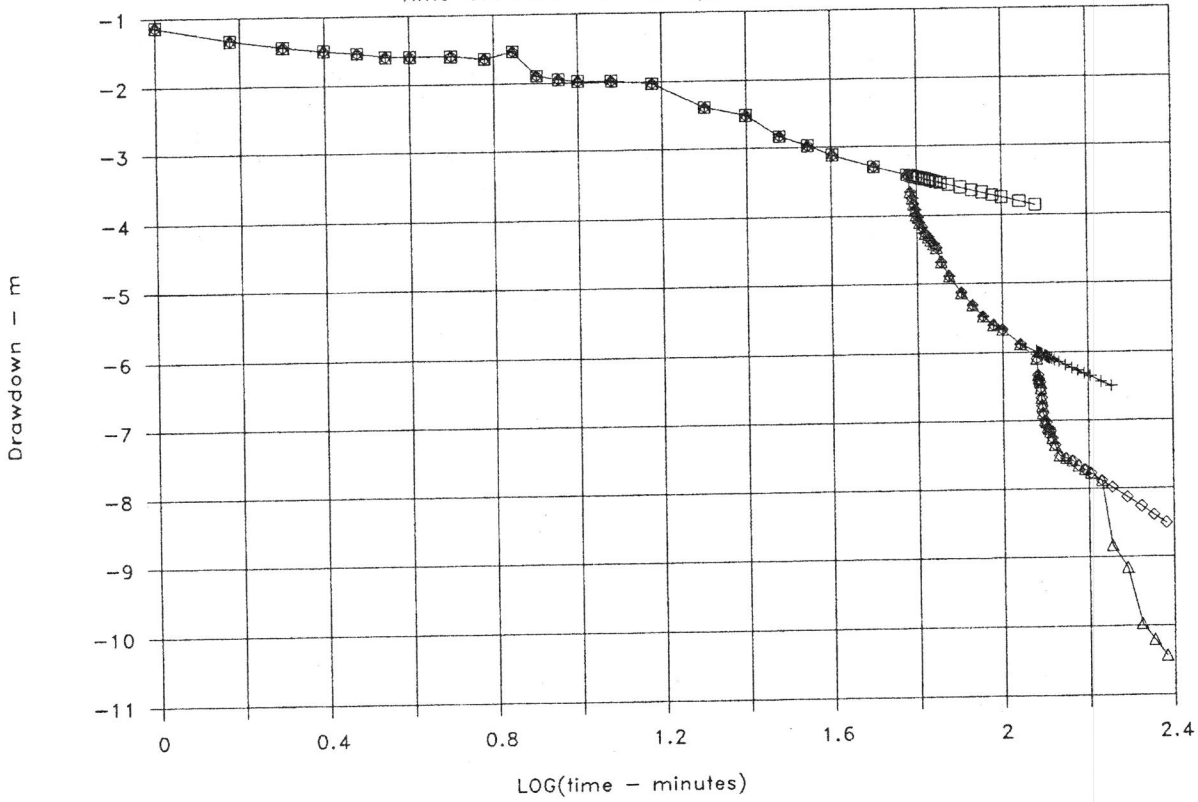
Recovery



**Appendix 5.4.5**

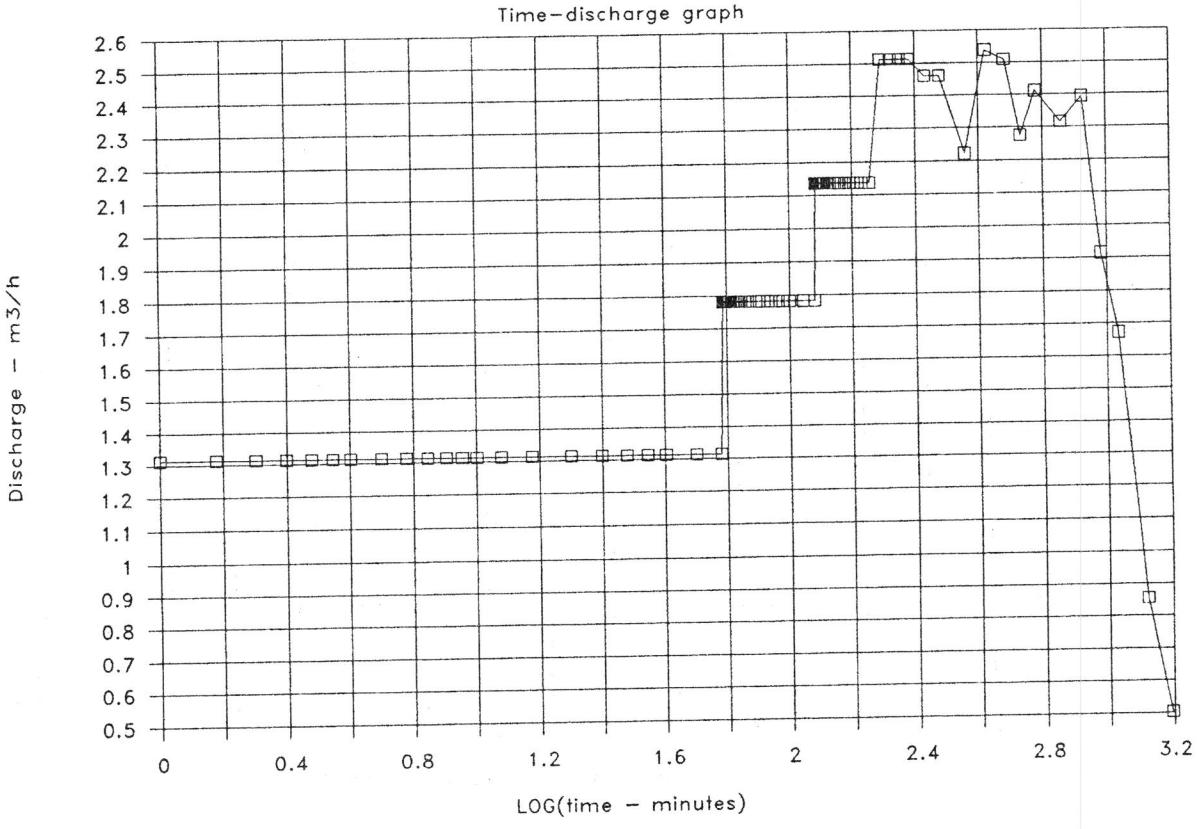
# LENGEI C7915 PUMPTEST

Time–drawdown with extrapolated steps



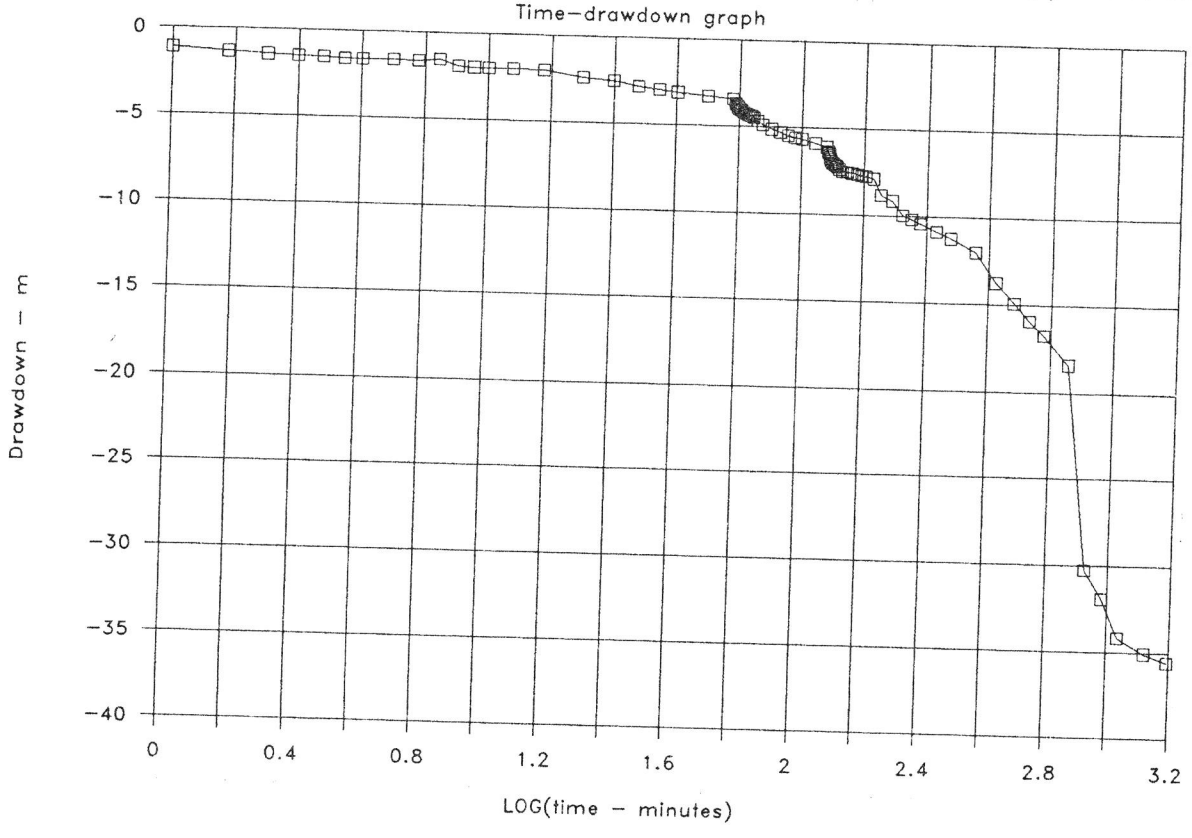

# LENGEI C7915 PUMPTEST

Time–discharge graph



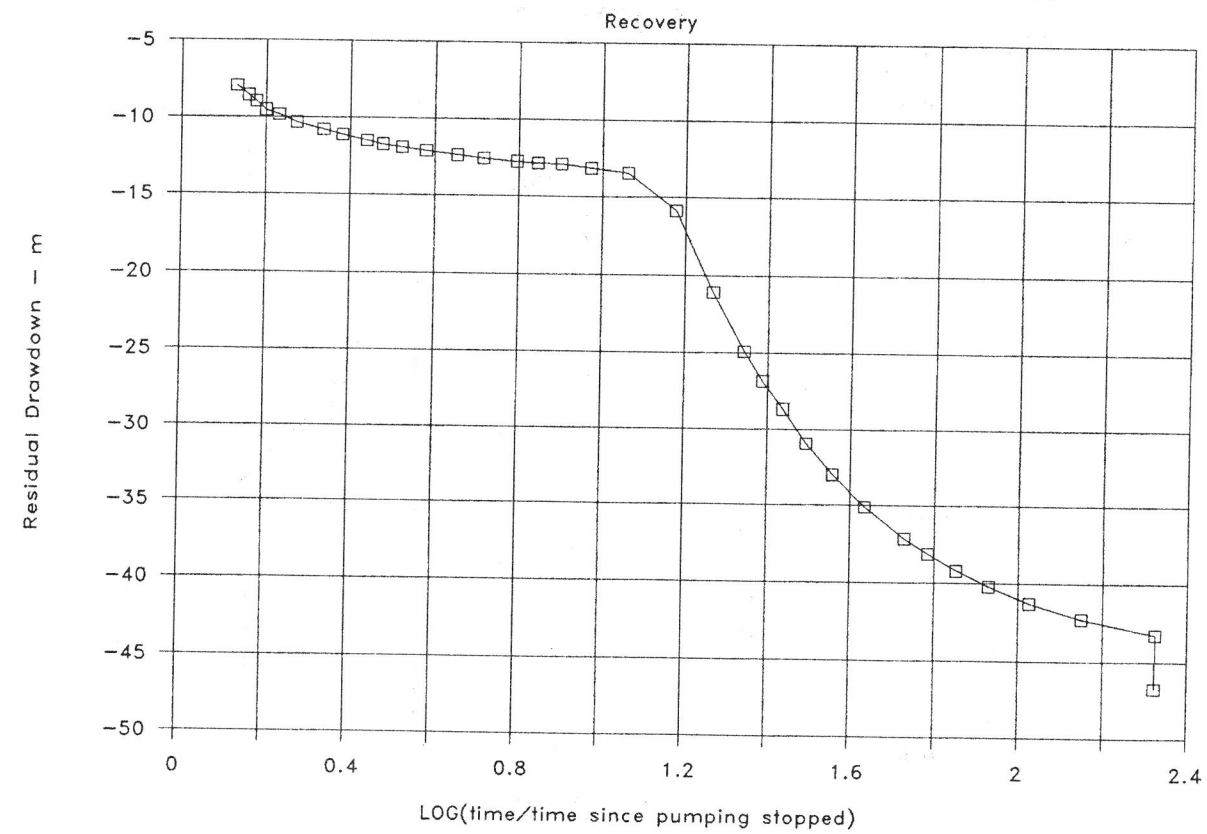
# LENGEI C7915 PUMPTEST

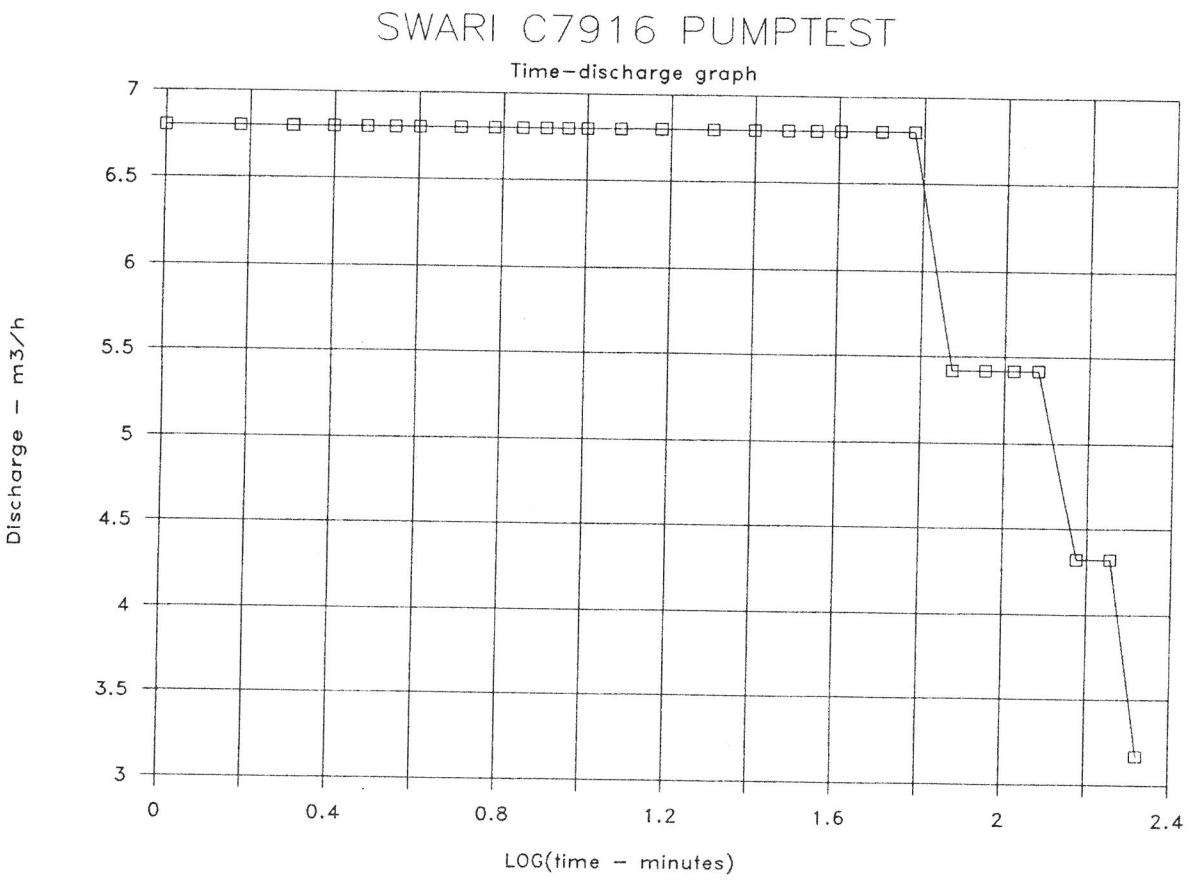
**Appendix 5.4.5**



## 5.4.6a Suari, C7916 First Attempt

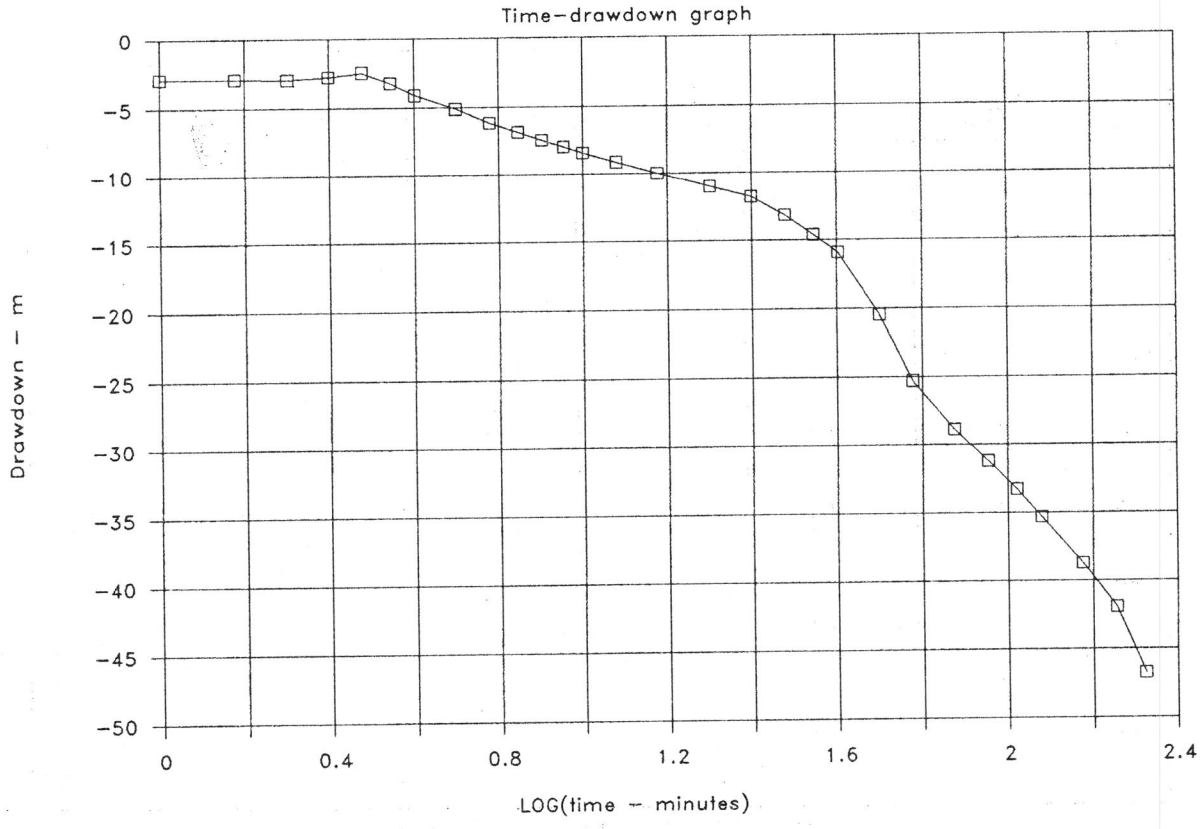
**Appendix 5.4.6a**



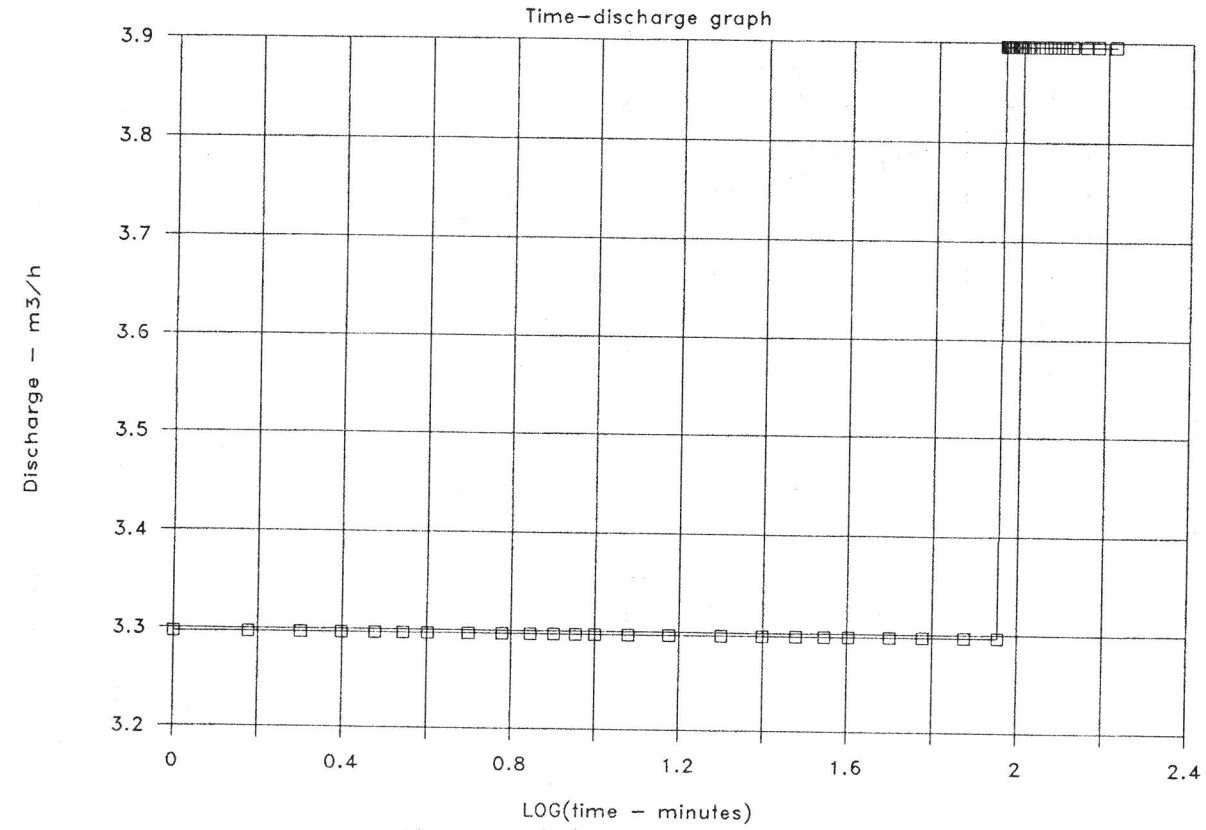
# SWARI C7916 PUMPTEST

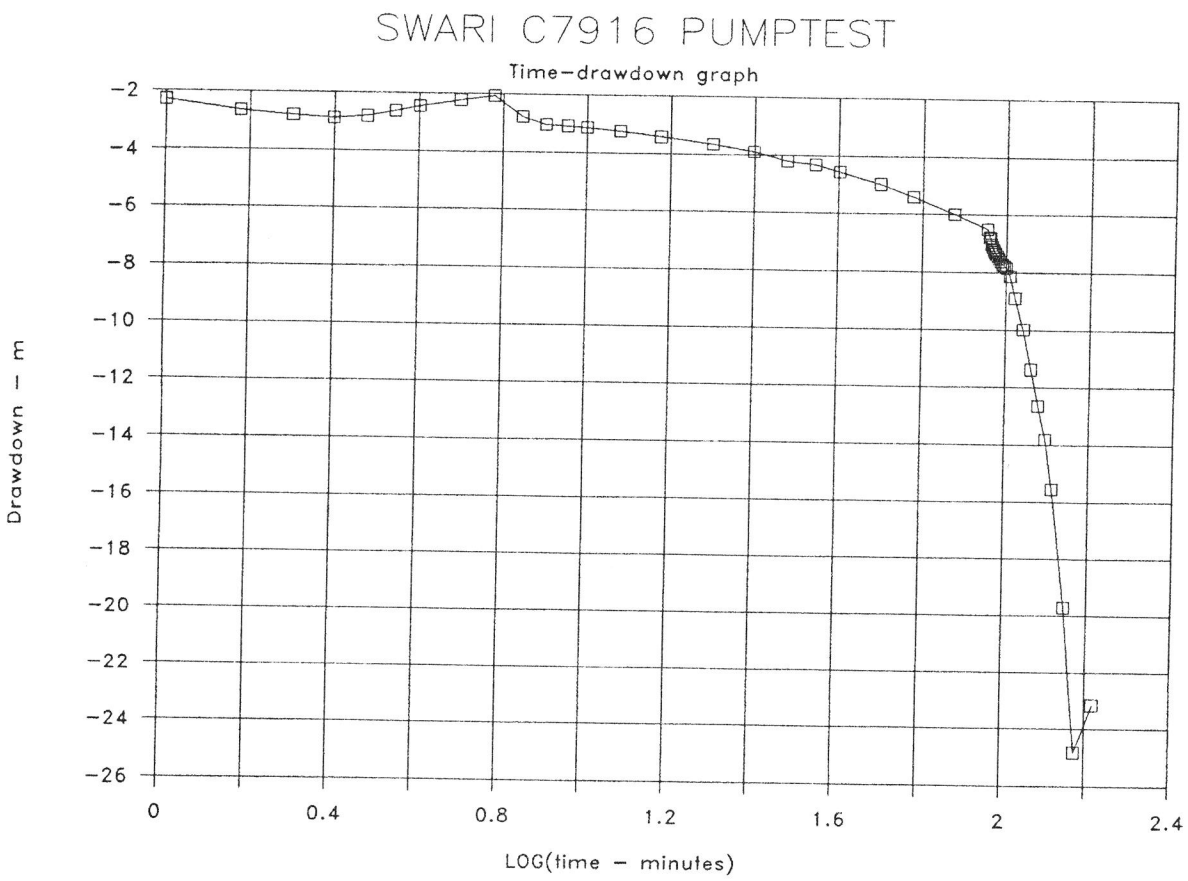
**Appendix 5.4.6a**



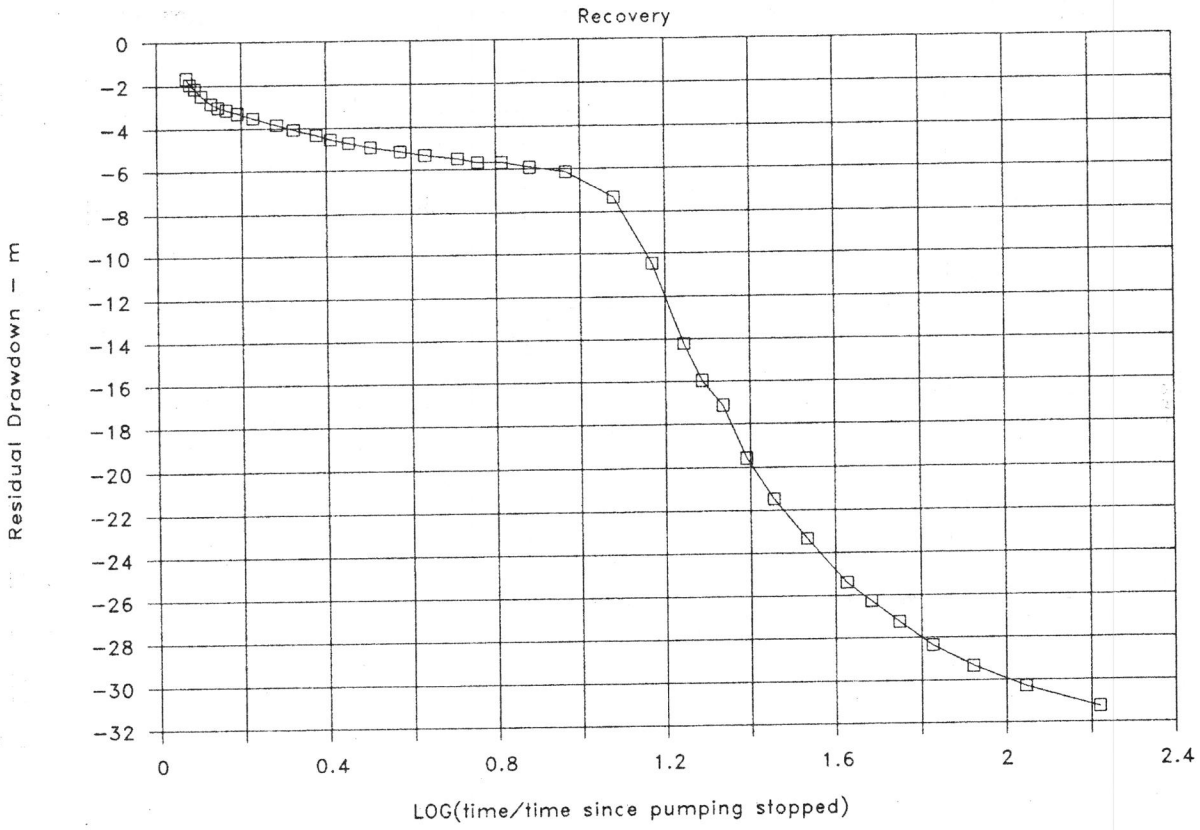
## 5.4.6b Suari, C7916 Second Attempt

**Appendix 5.4.6b**



**Appendix 5.4.6b**

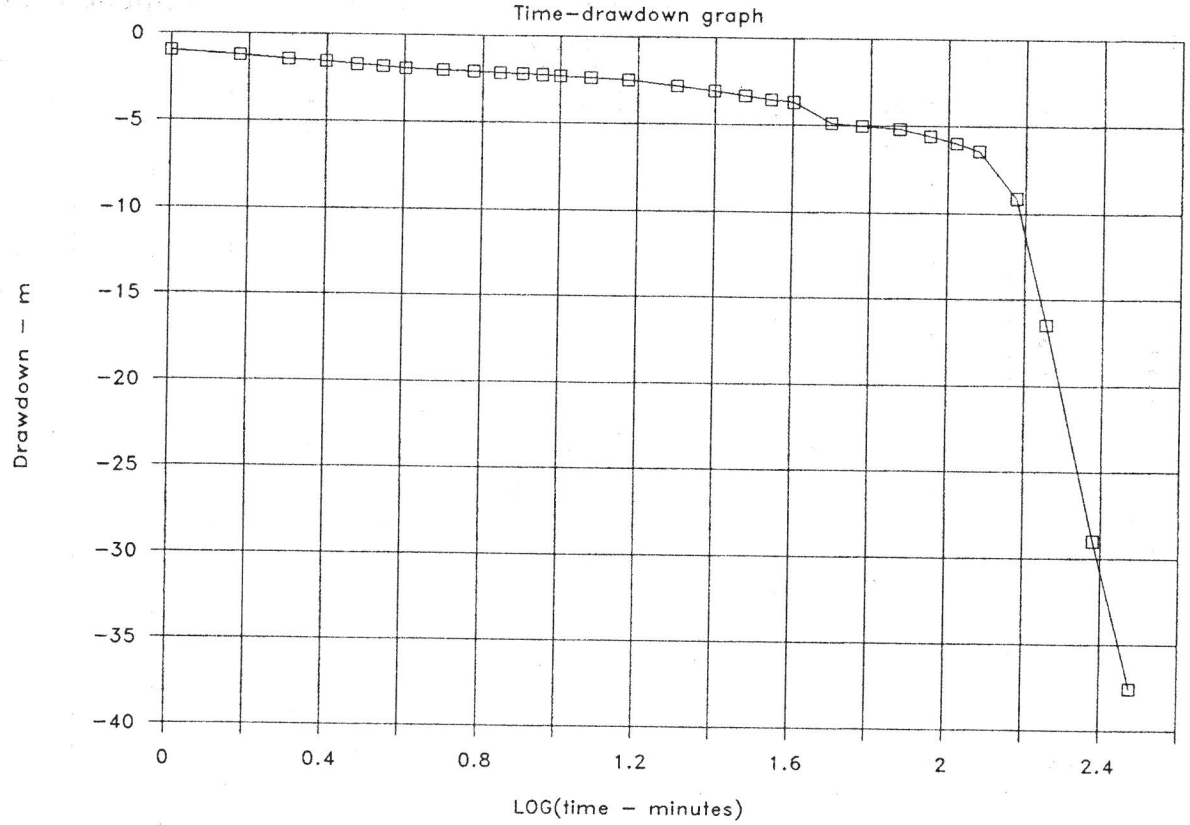


## 5.4.6c Suari, C7916 Third Attempt

**Appendix 5.4.6c**

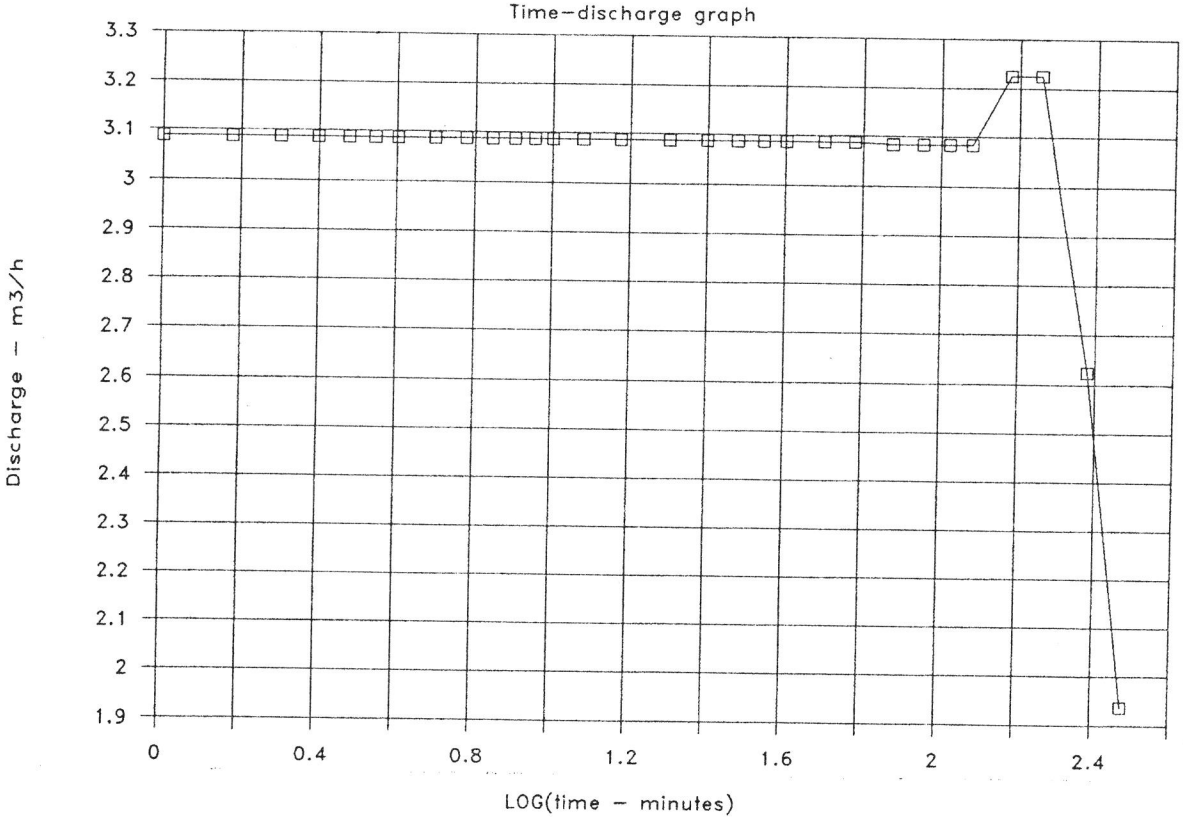
# SWARI C7916 PUMPTEST

Time–drawdown graph



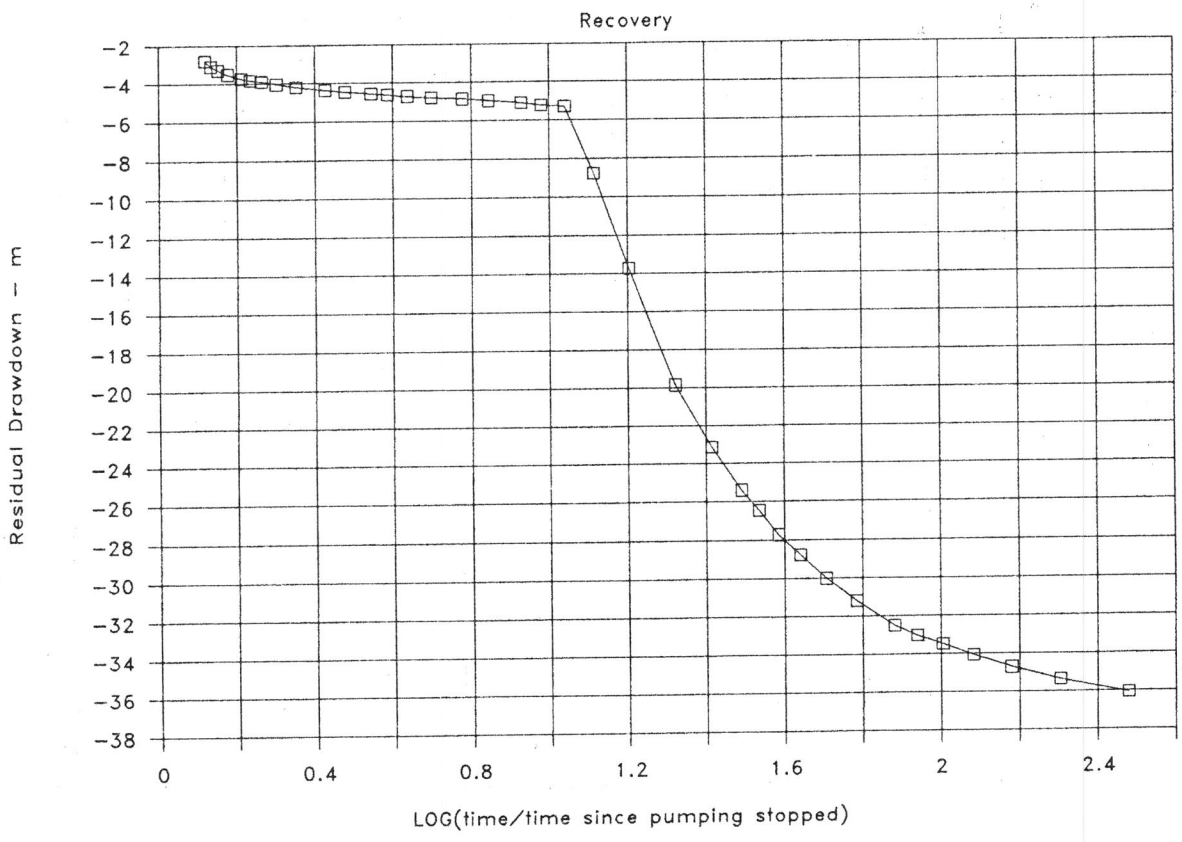

# SWARI C7916 PUMPTEST

Time–discharge graph



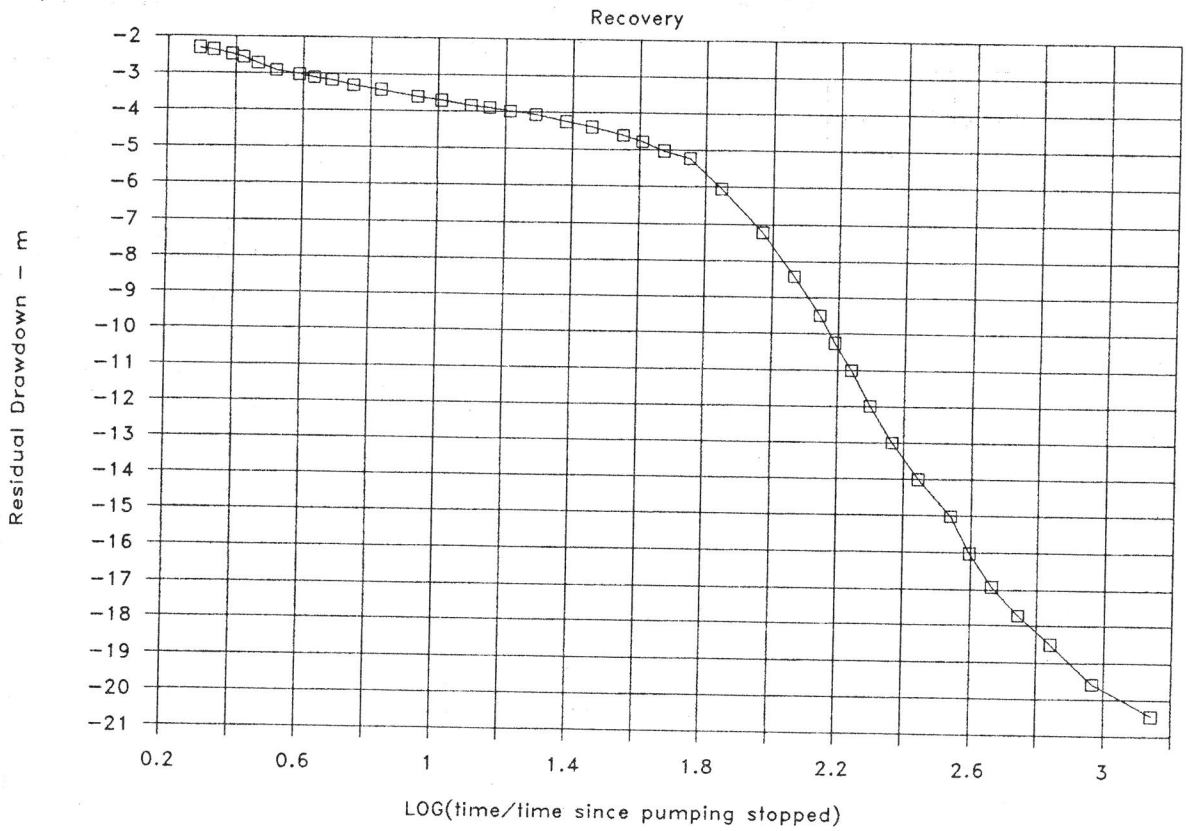
# SWARI C7916 PUMPTEST

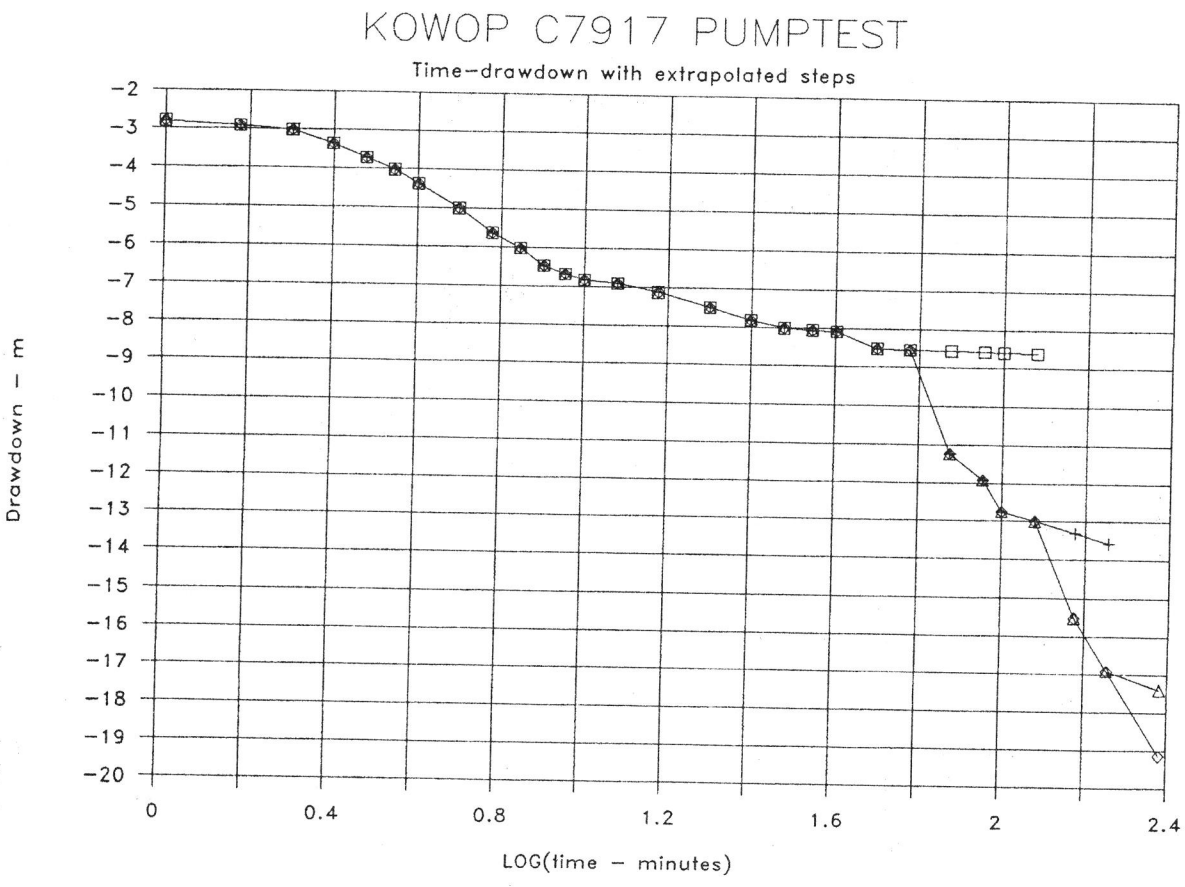
**Appendix 5.4.6c**



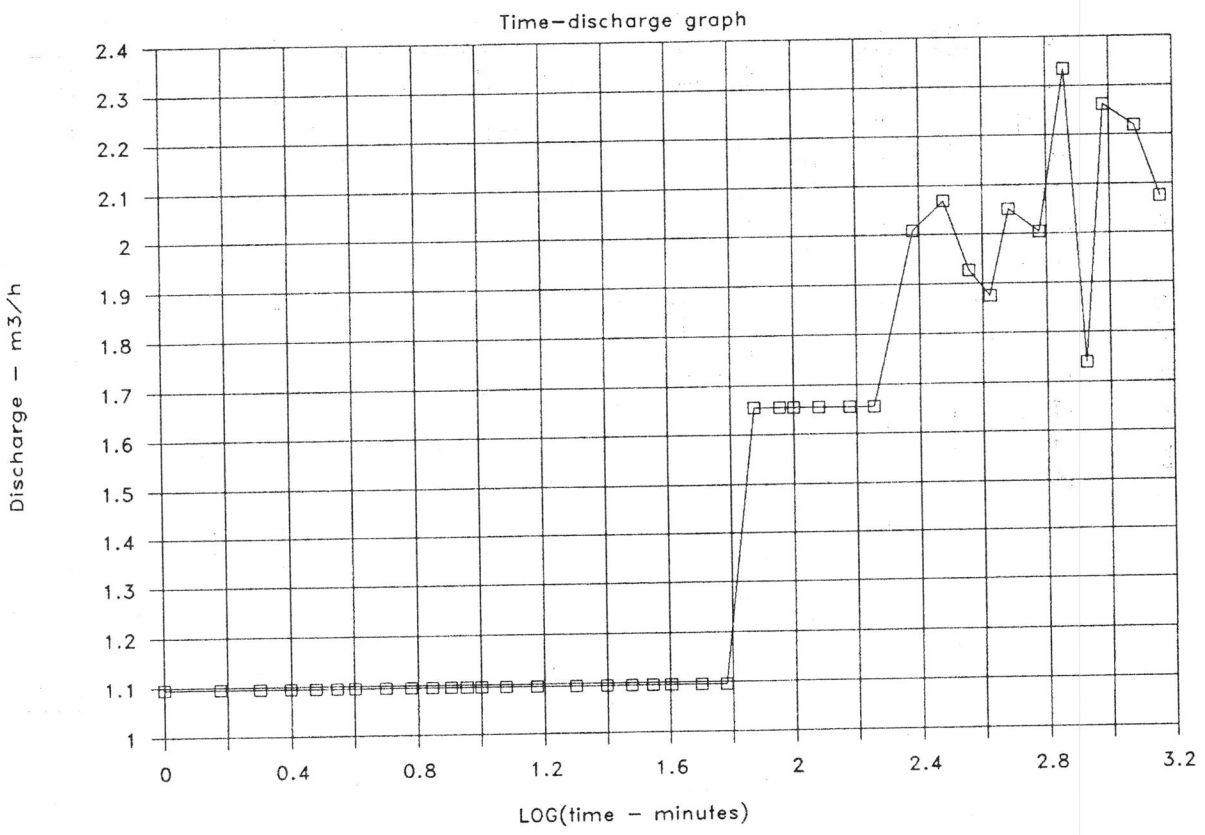
### 5.4.7 Kowop C7917

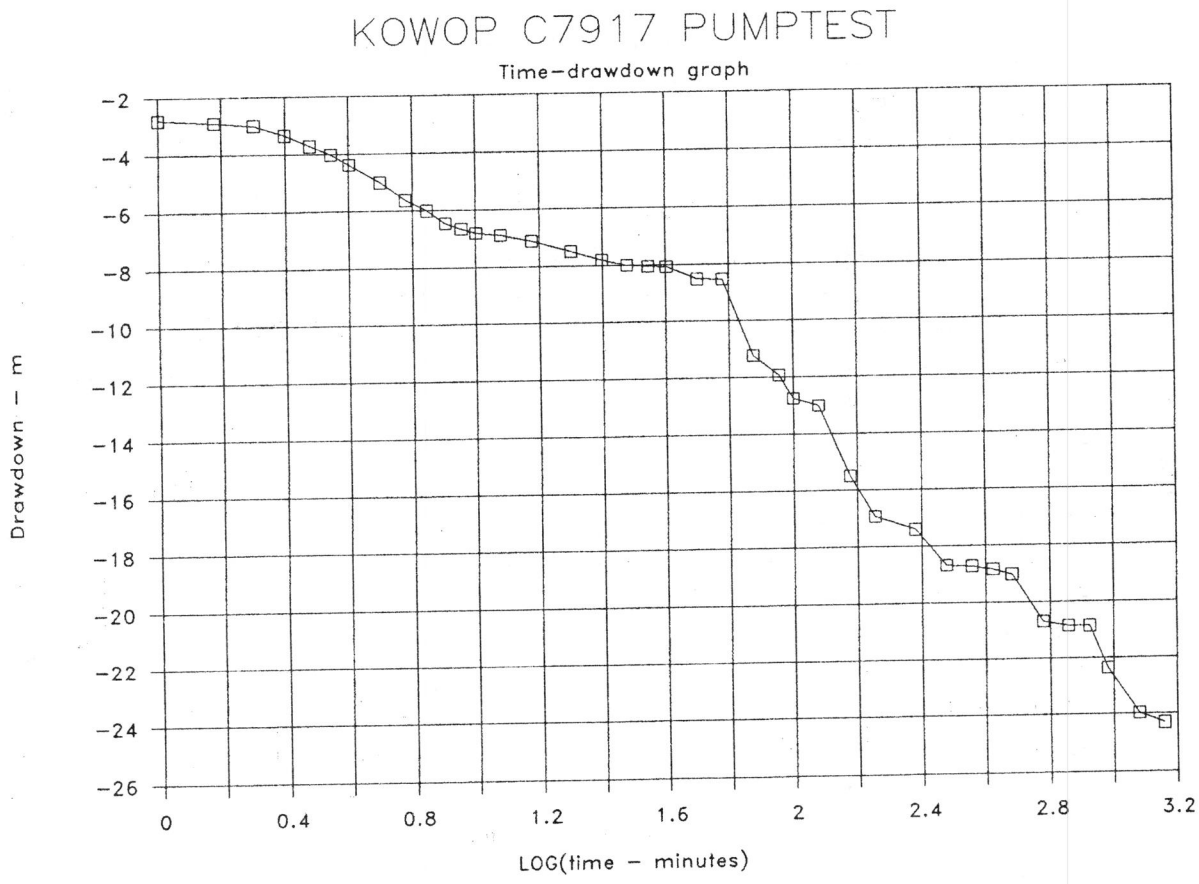
**Appendix 5.4.7**



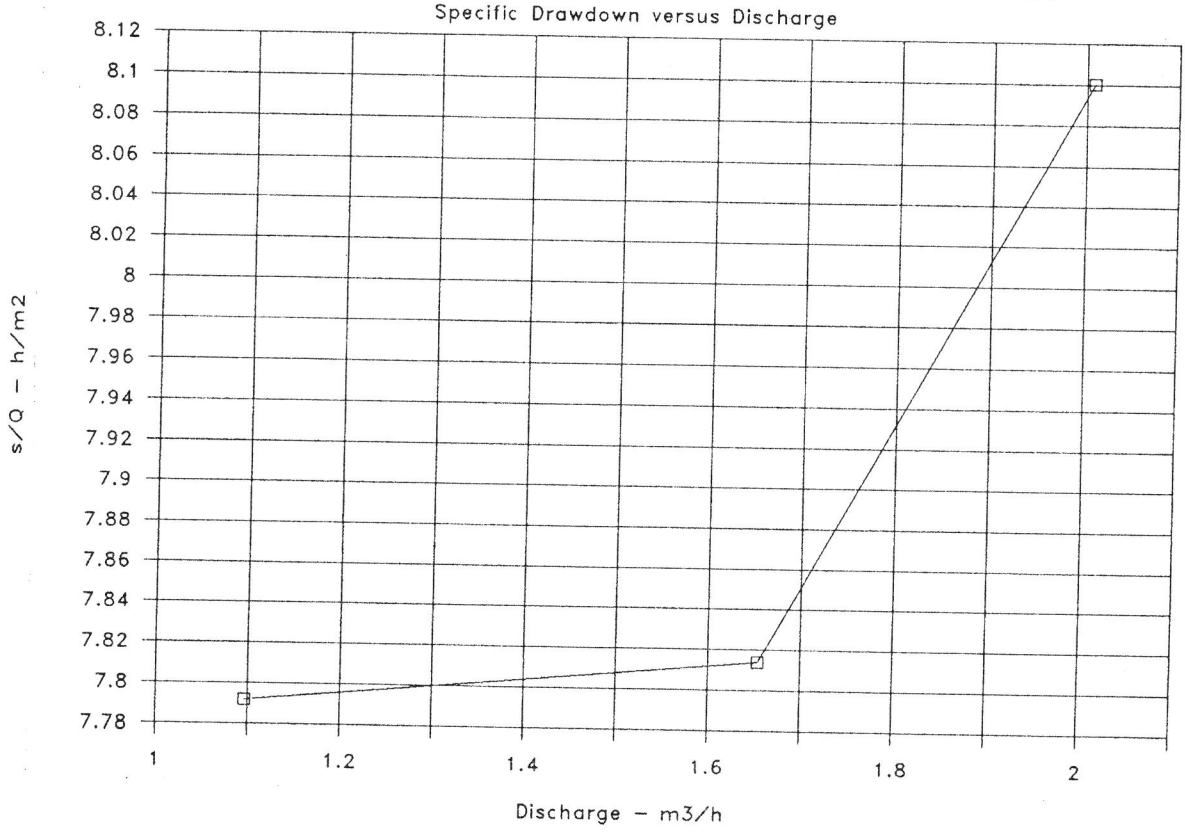
**Appendix 5.4.7**



# KOWOP C7917 PUMPTEST

**Appendix 5.4.7**

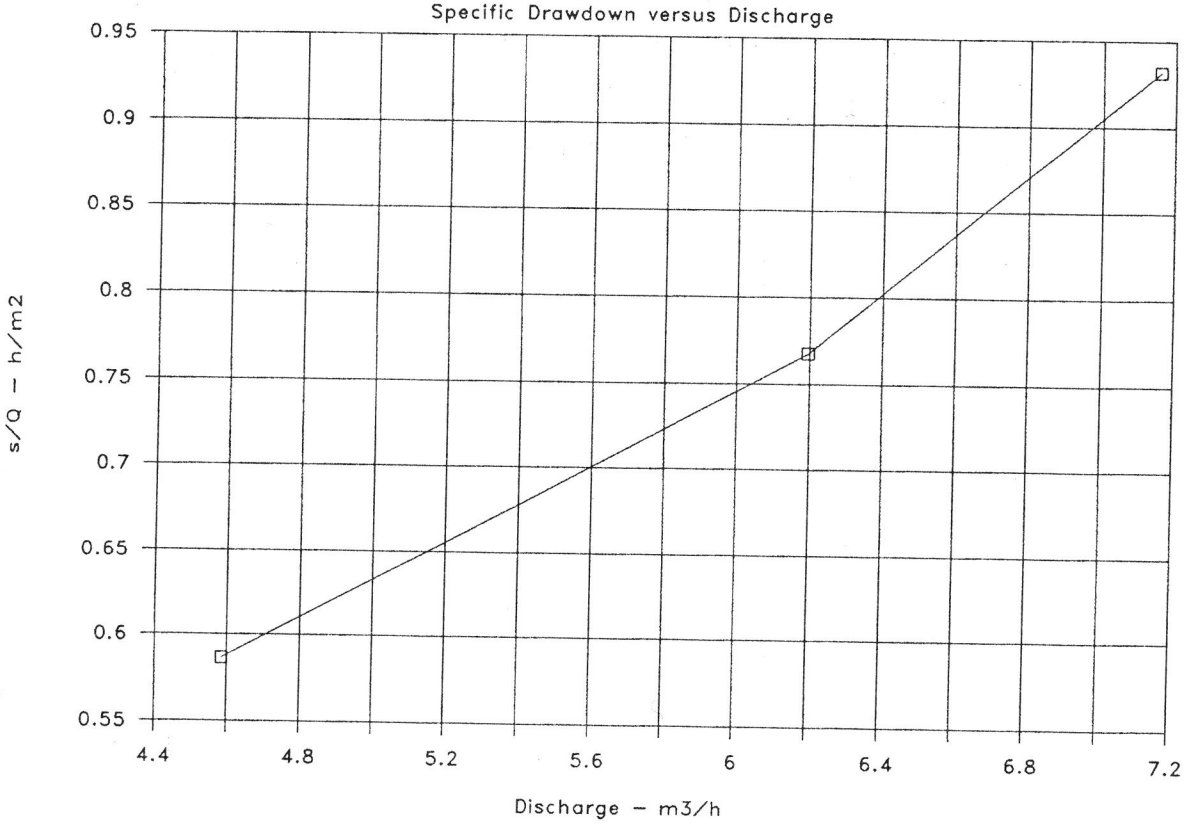


### 5.4.8 Barsaloi C7918

**Appendix 5.4.8**

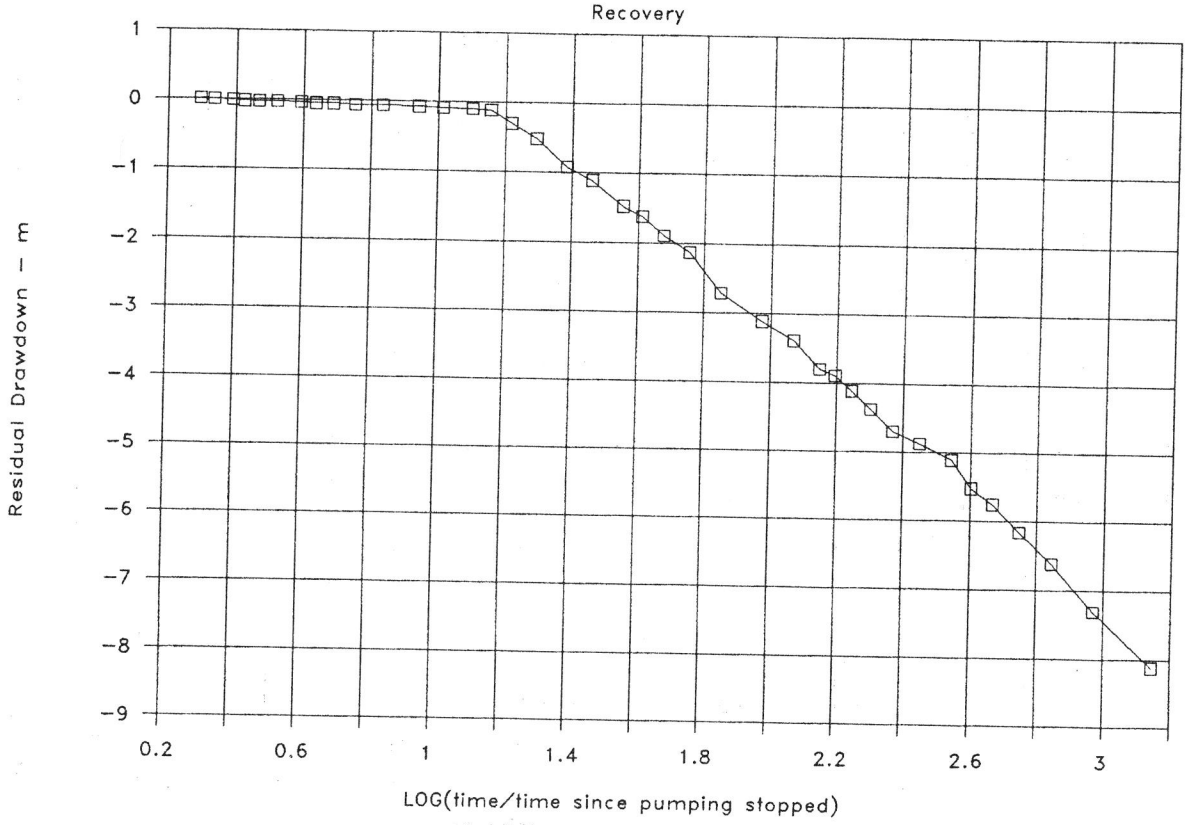
# BARSALOI C7918 PUMPTEST

Specific Drawdown versus Discharge

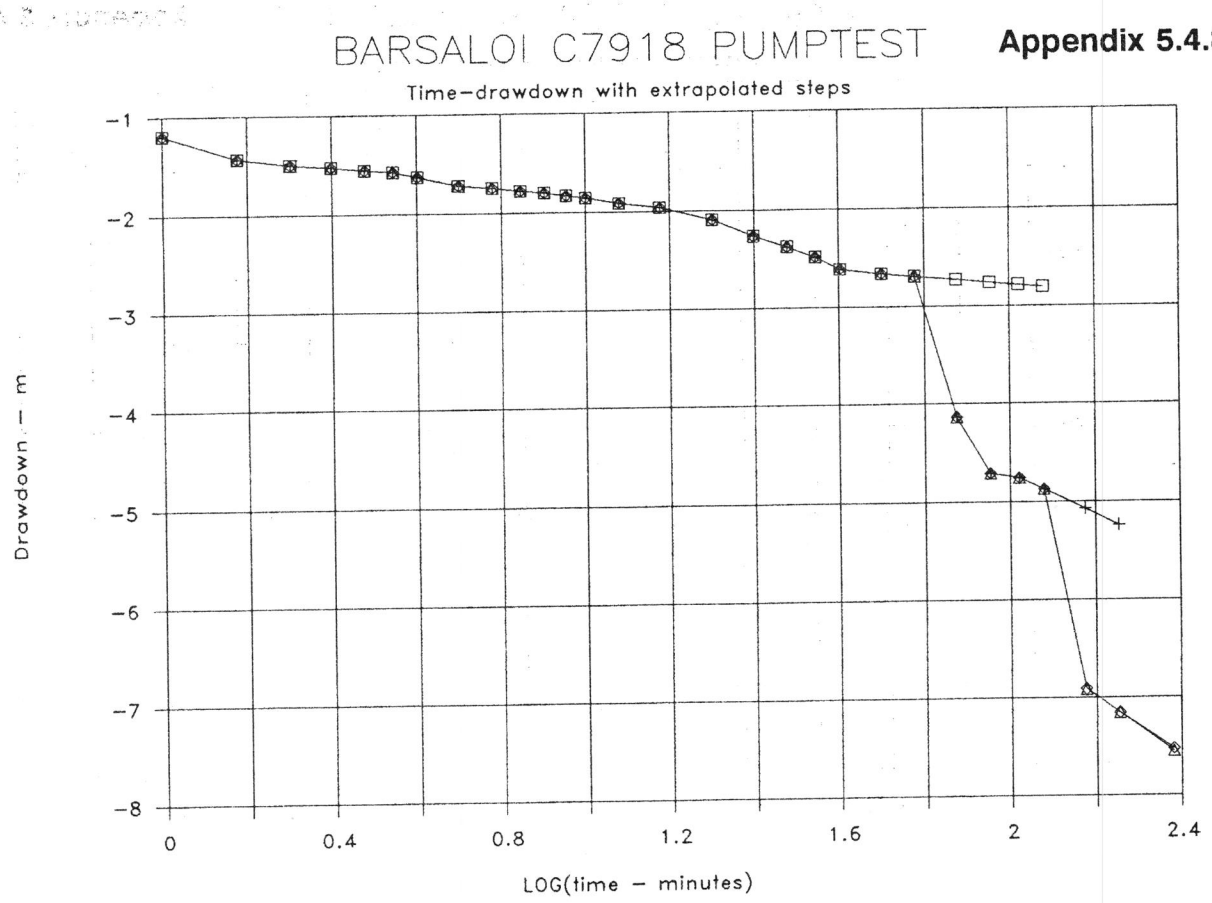


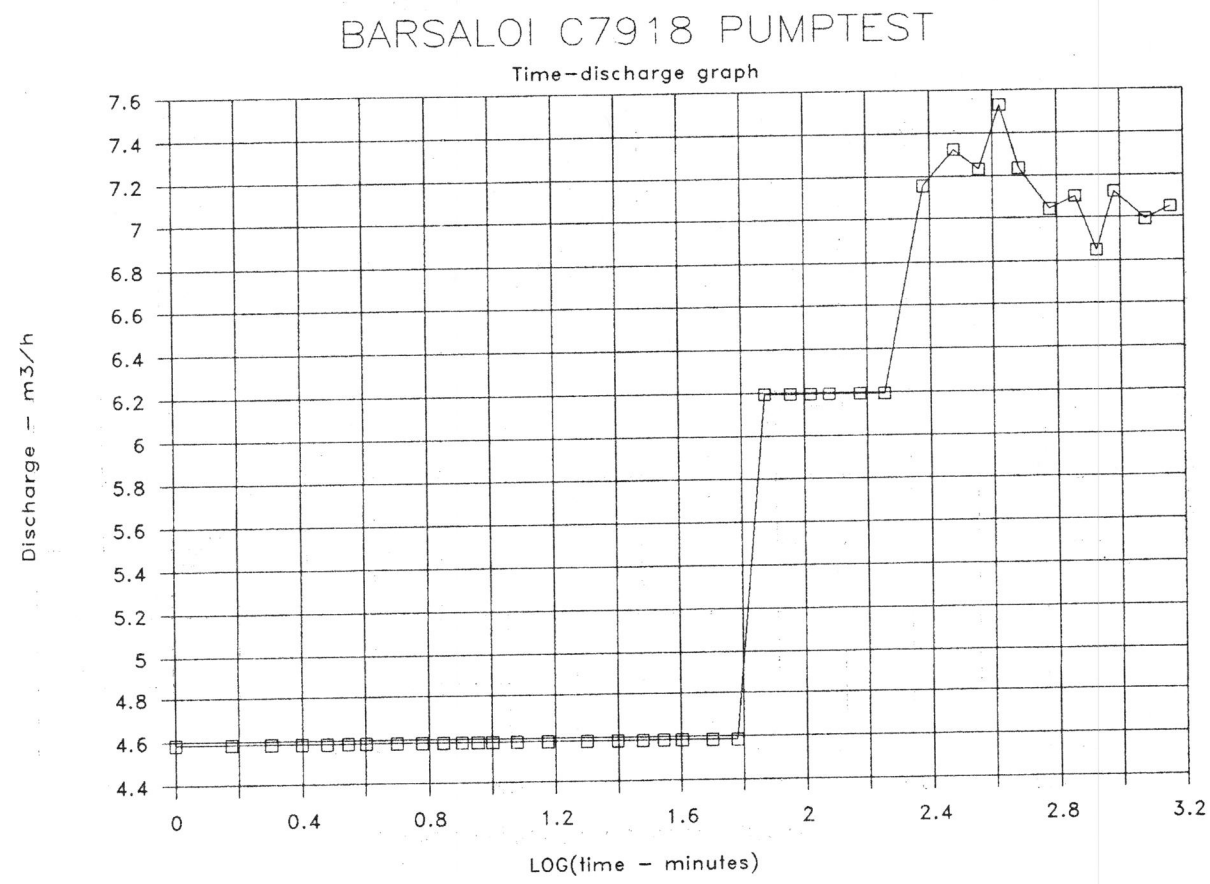

# BARSALOI C7918 PUMPTEST

Recovery



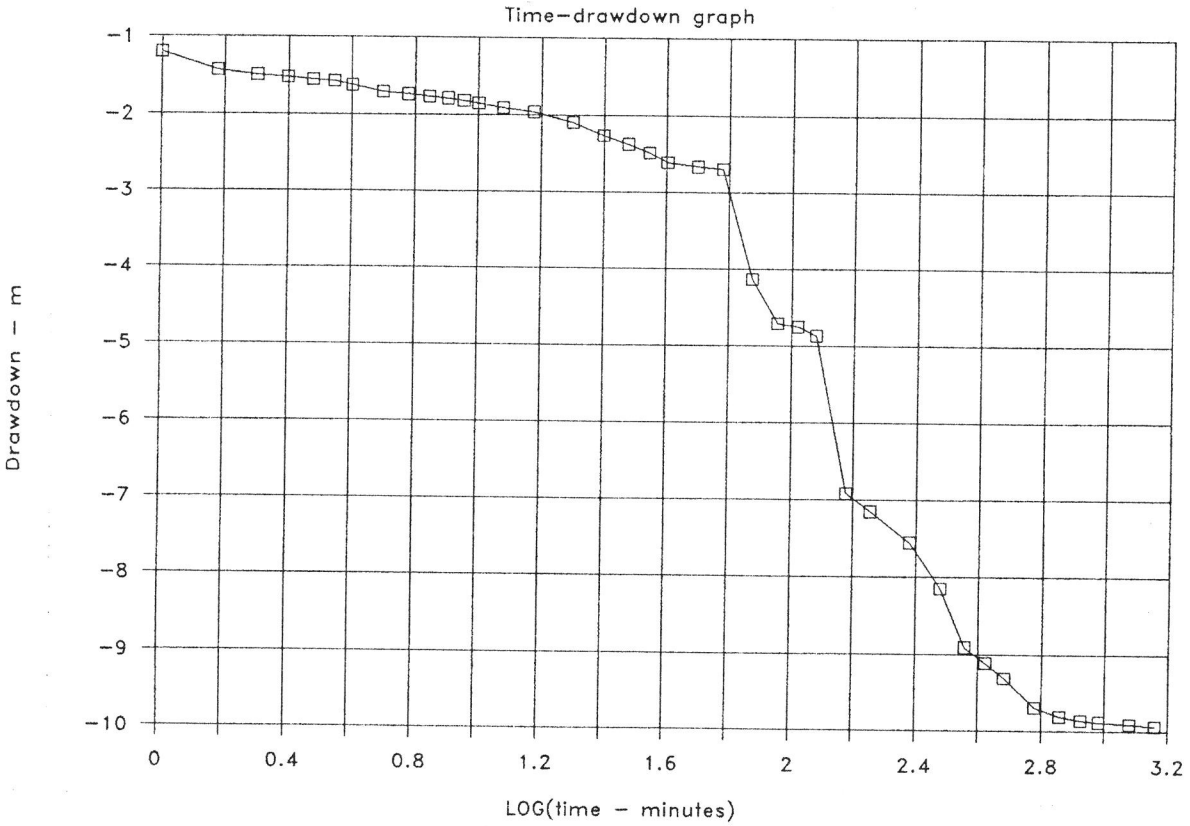
**Appendix 5.4.8**



# BARSALOI C7918 PUMPTEST

**Appendix 5.4.8**

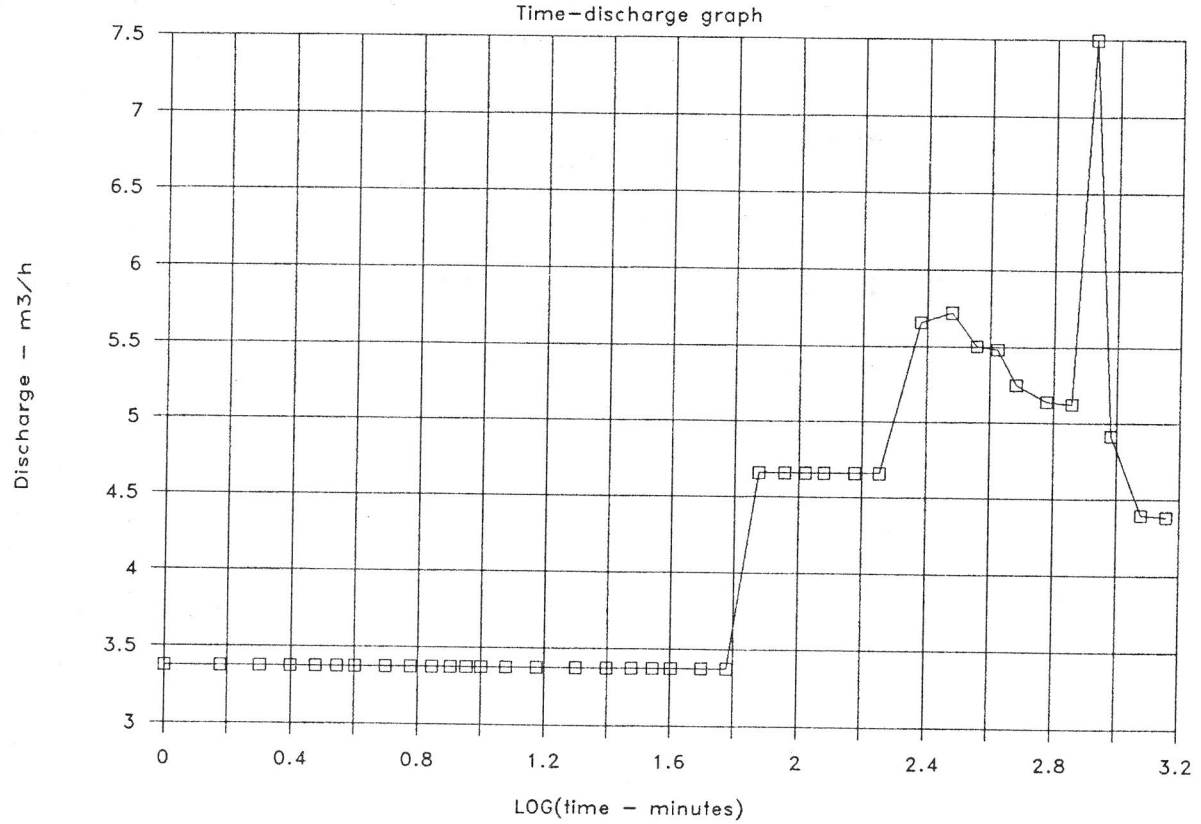


### 5.4.9 Masiketa, C7919

**Appendix 5.4.9**

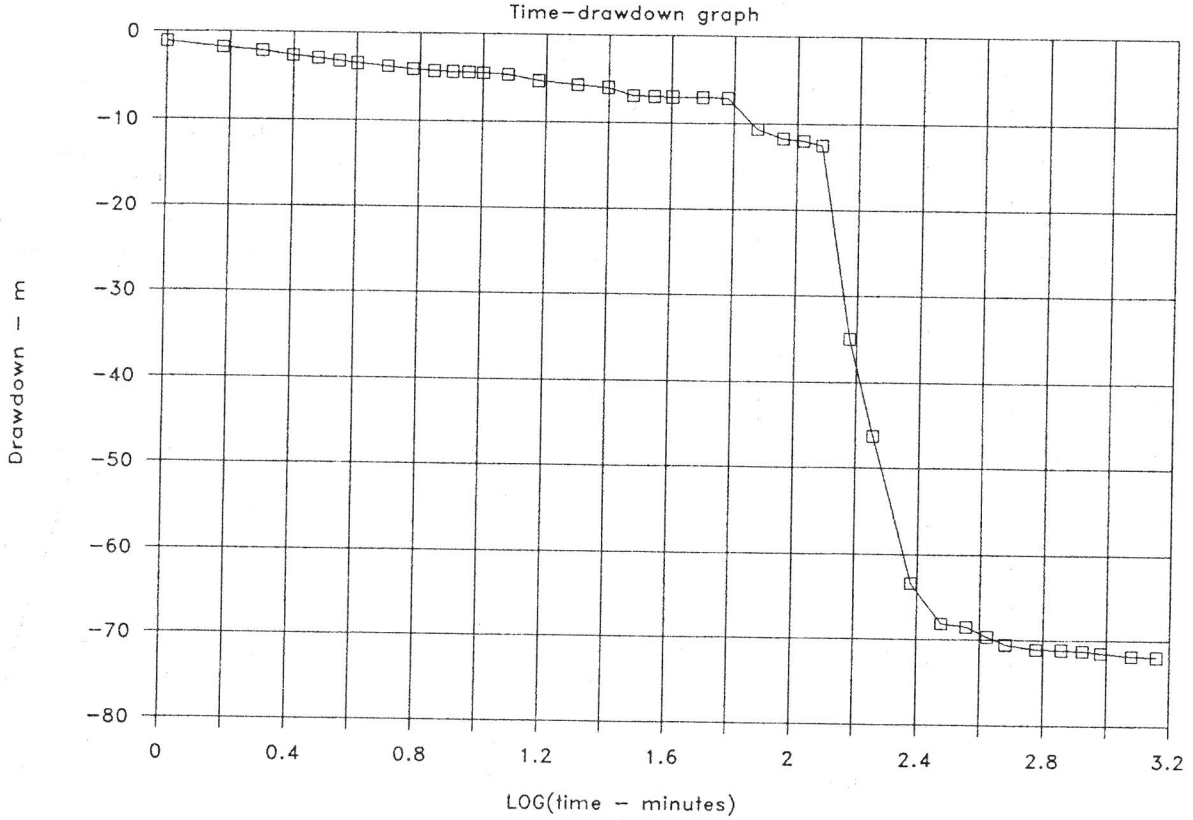
# MASIKITA C7919 PUMPTEST

Time–discharge graph

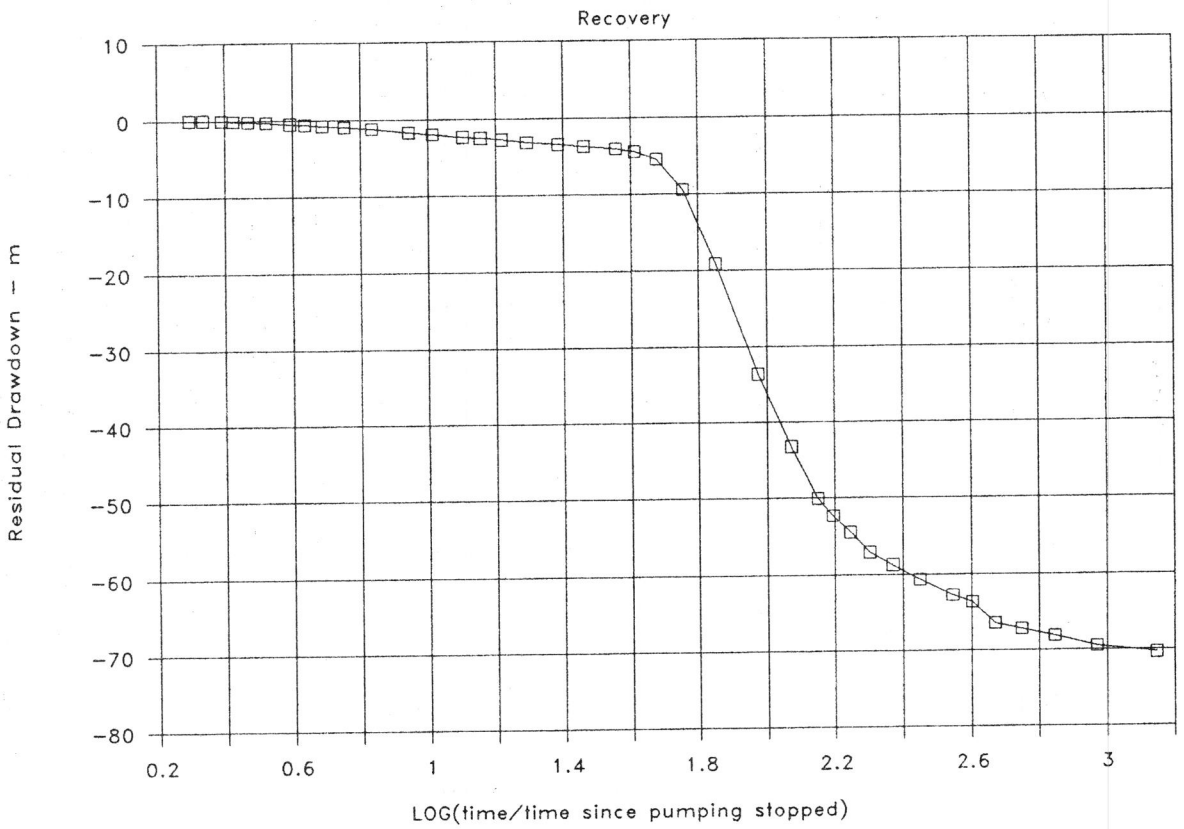


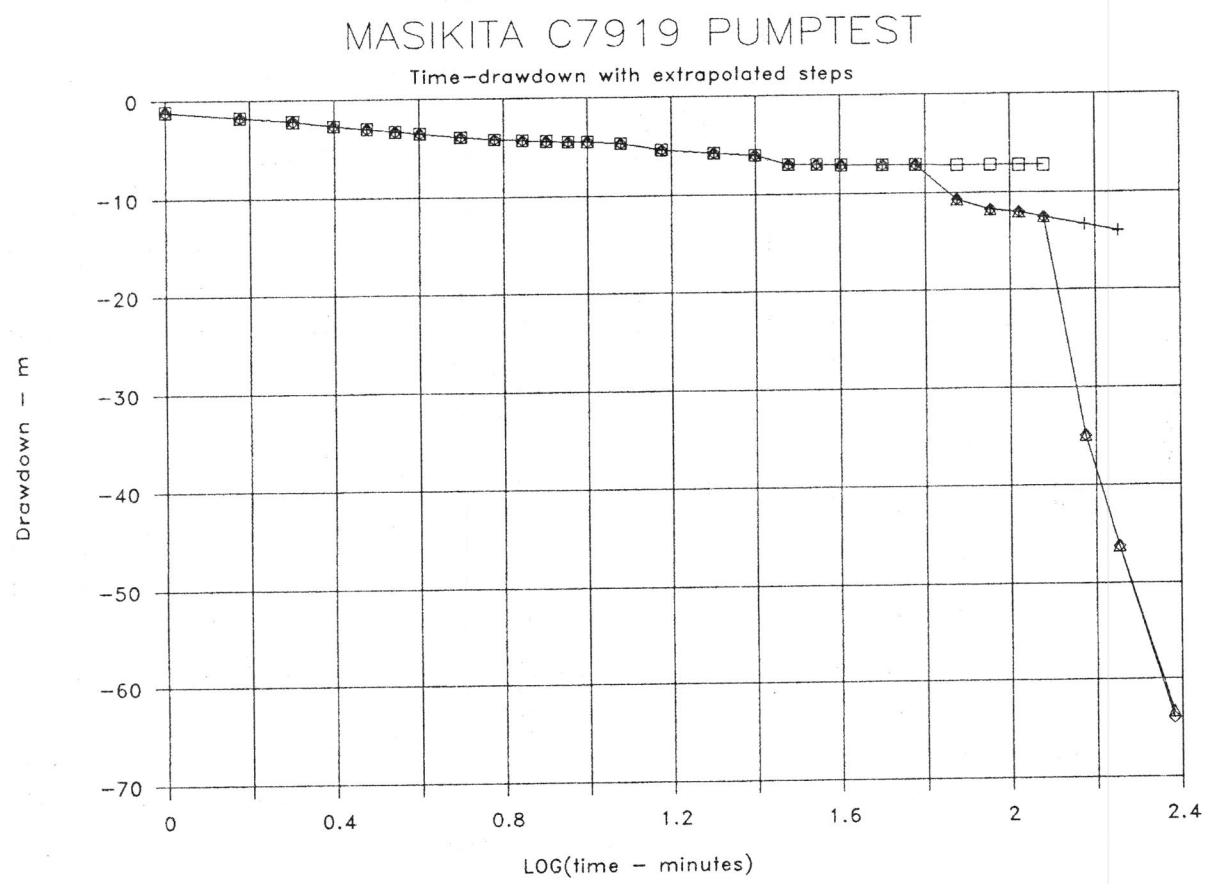

# MASIKITA C7919 PUMPTEST

Time–drawdown graph



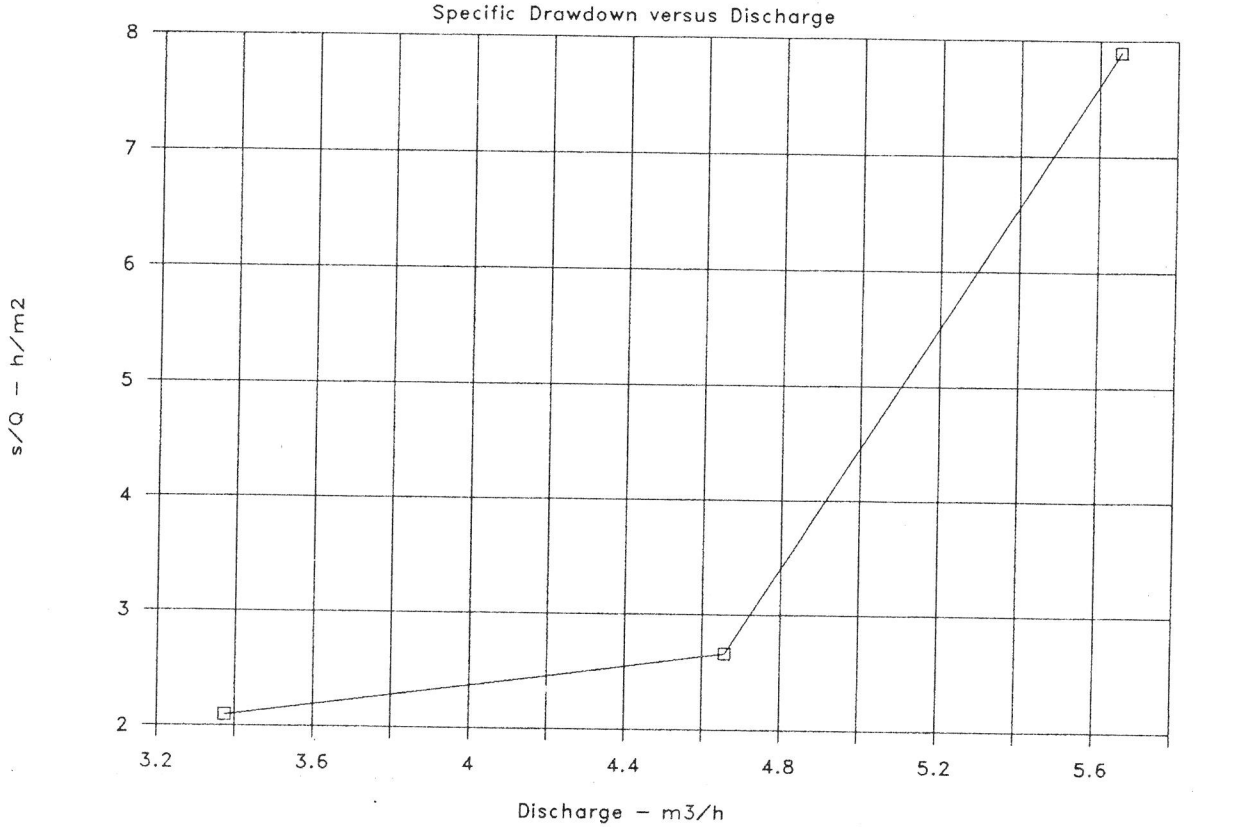
**Appendix 5.4.9**



# MASIKITA C7919 PUMPTEST

**Appendix 5.4.9**

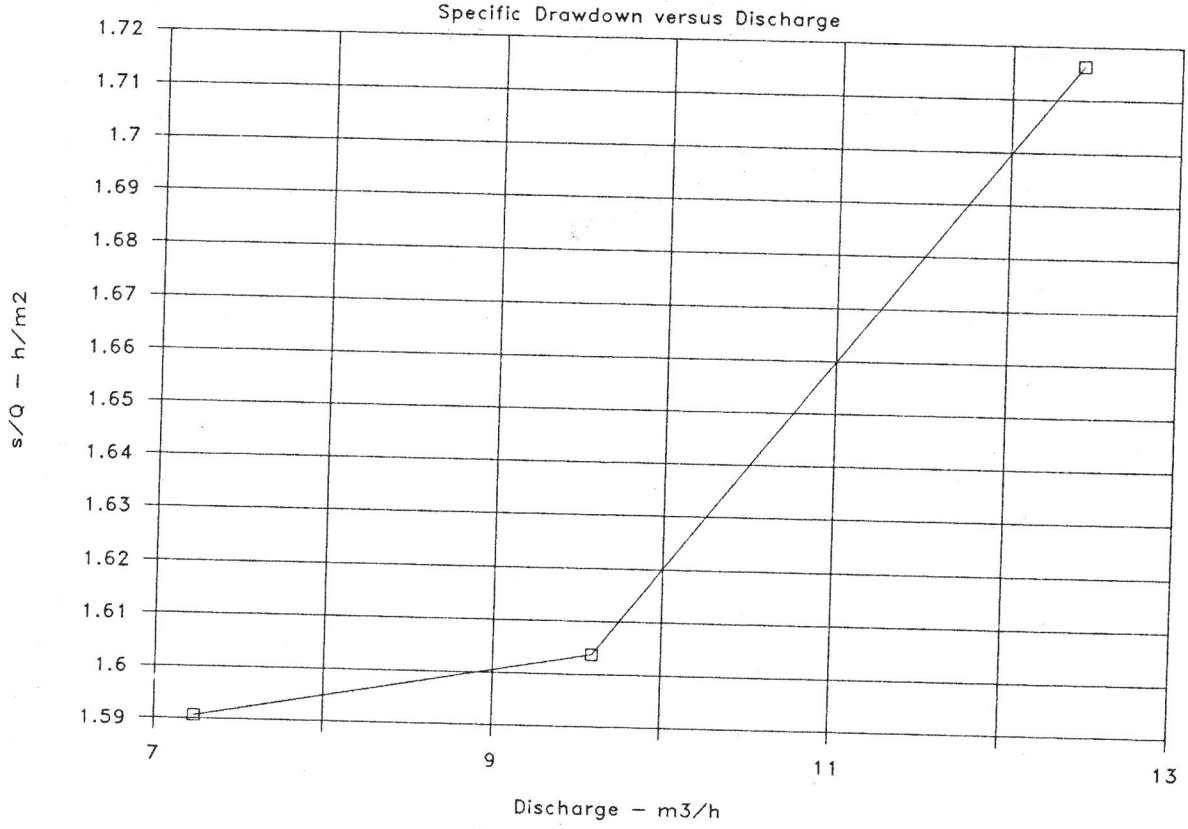


### 5.4.10 Loosuk, C7921

**Appendix 5.4.10**

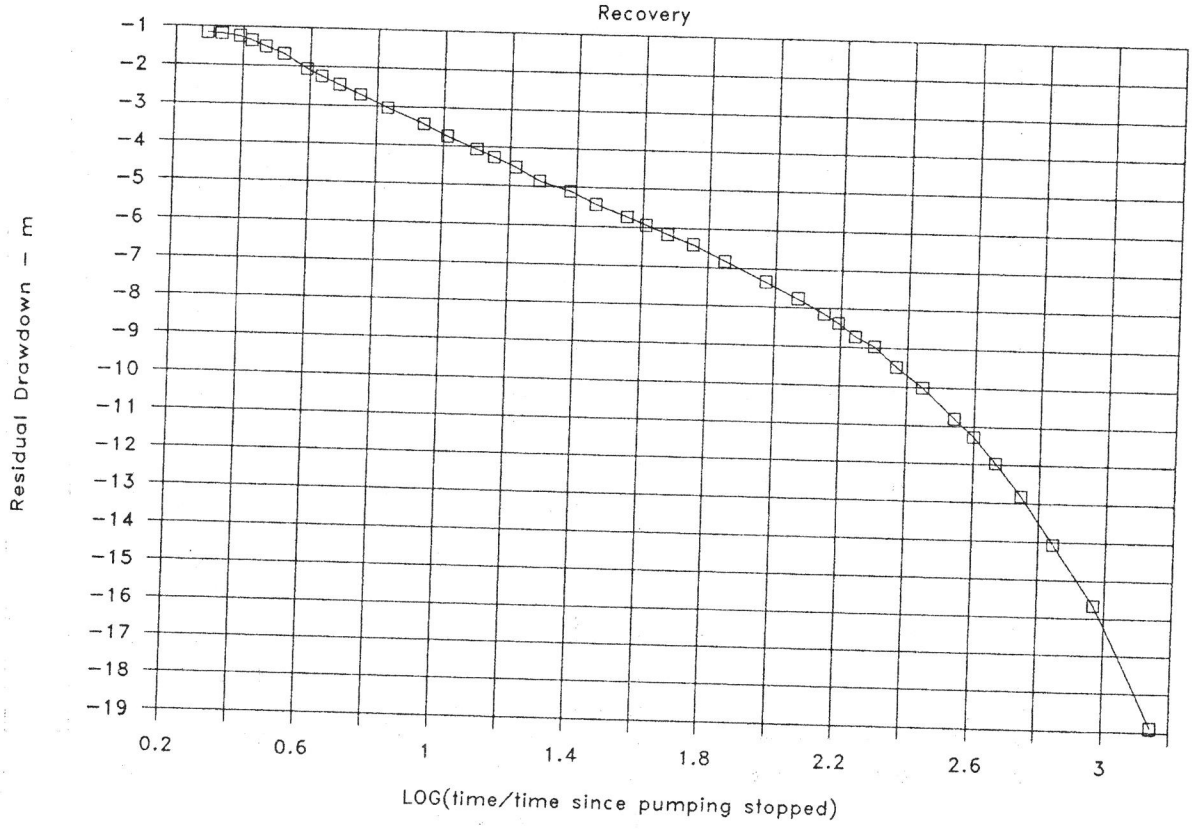
# LOOSUK C7921 PUMPTEST

Specific Drawdown versus Discharge

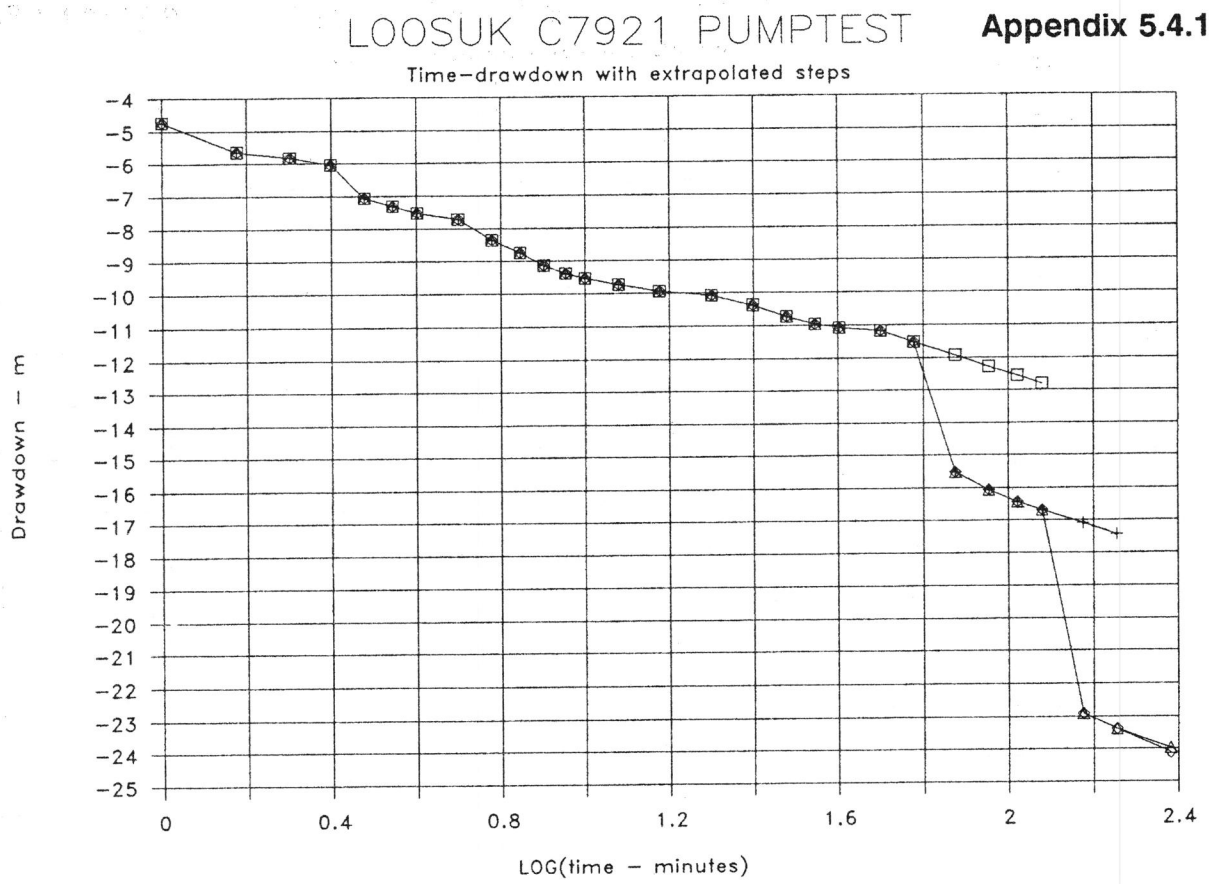


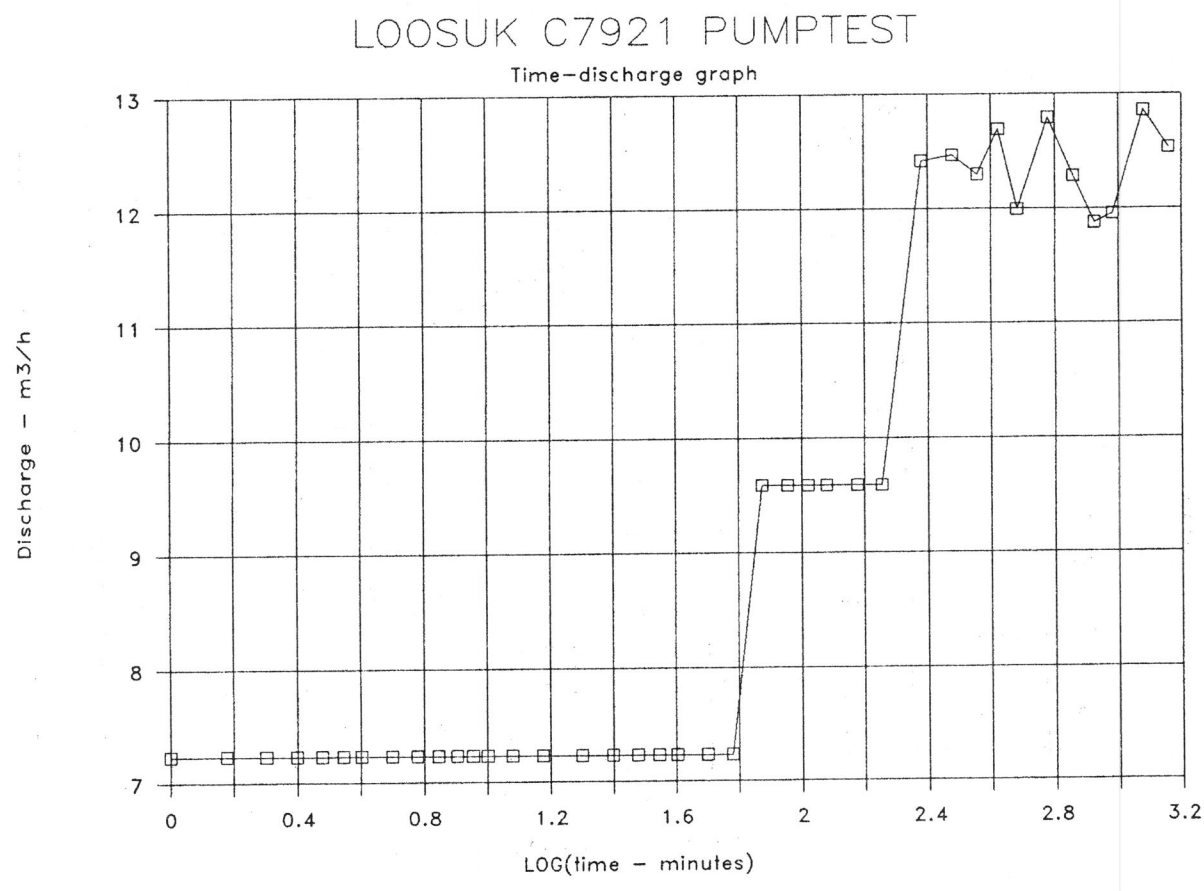

# LOOSUK C7921 PUMPTEST

Recovery



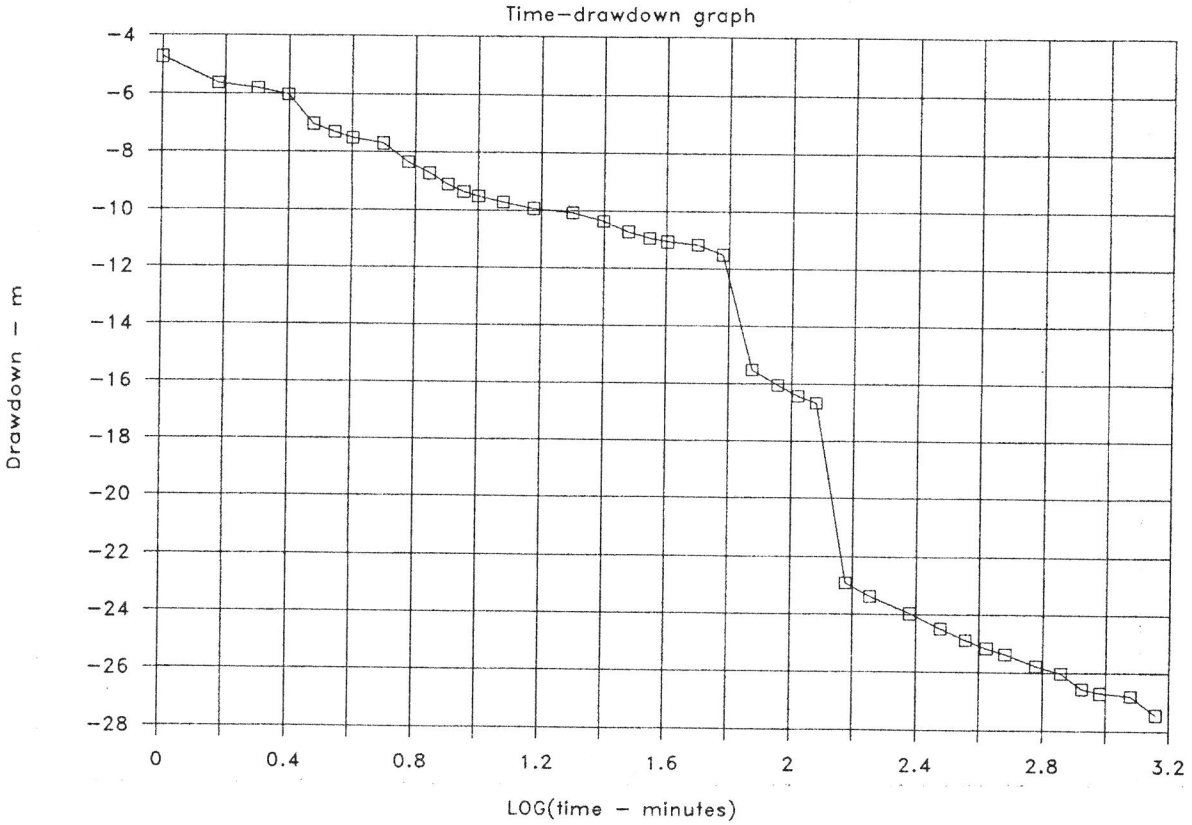
**Appendix 5.4.10**



# LOOSUK C7921 PUMPTEST

**Appendix 5.4.10**

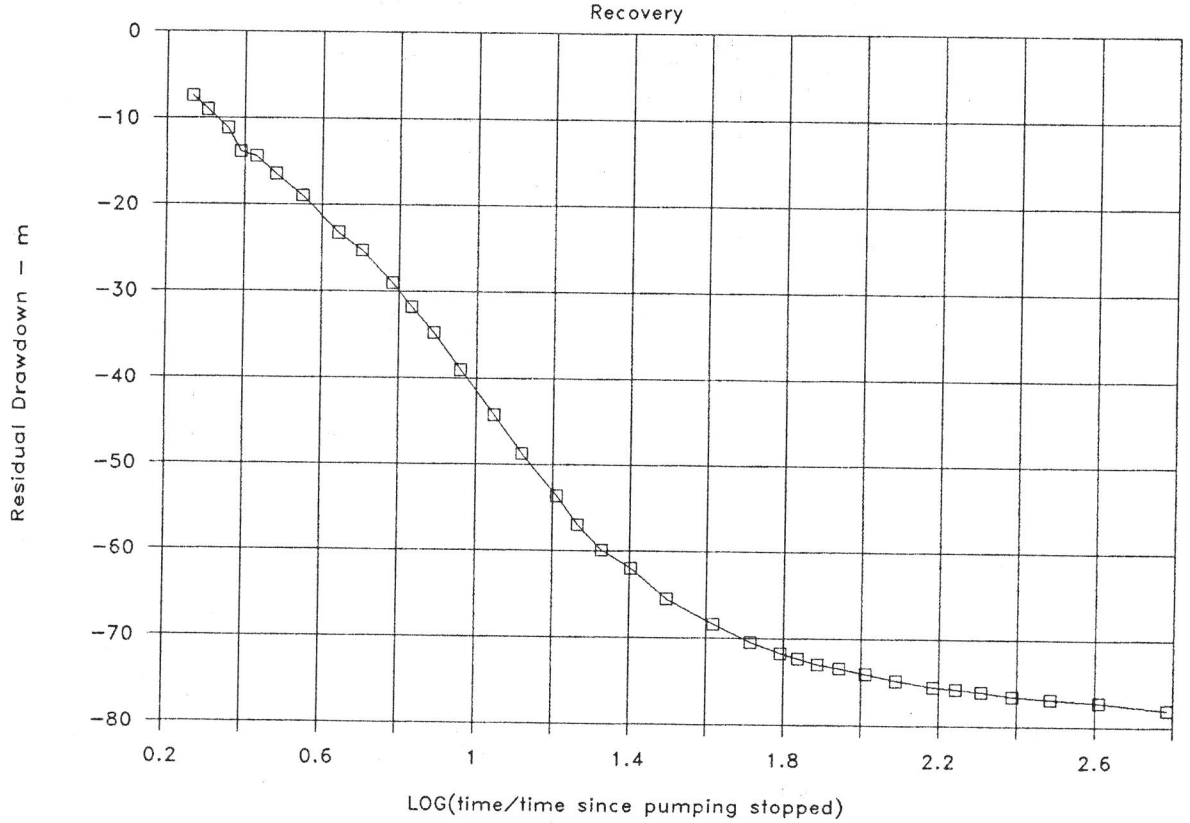


### 5.4.11 Nondoto C7922

**Appendix 5.4.11**

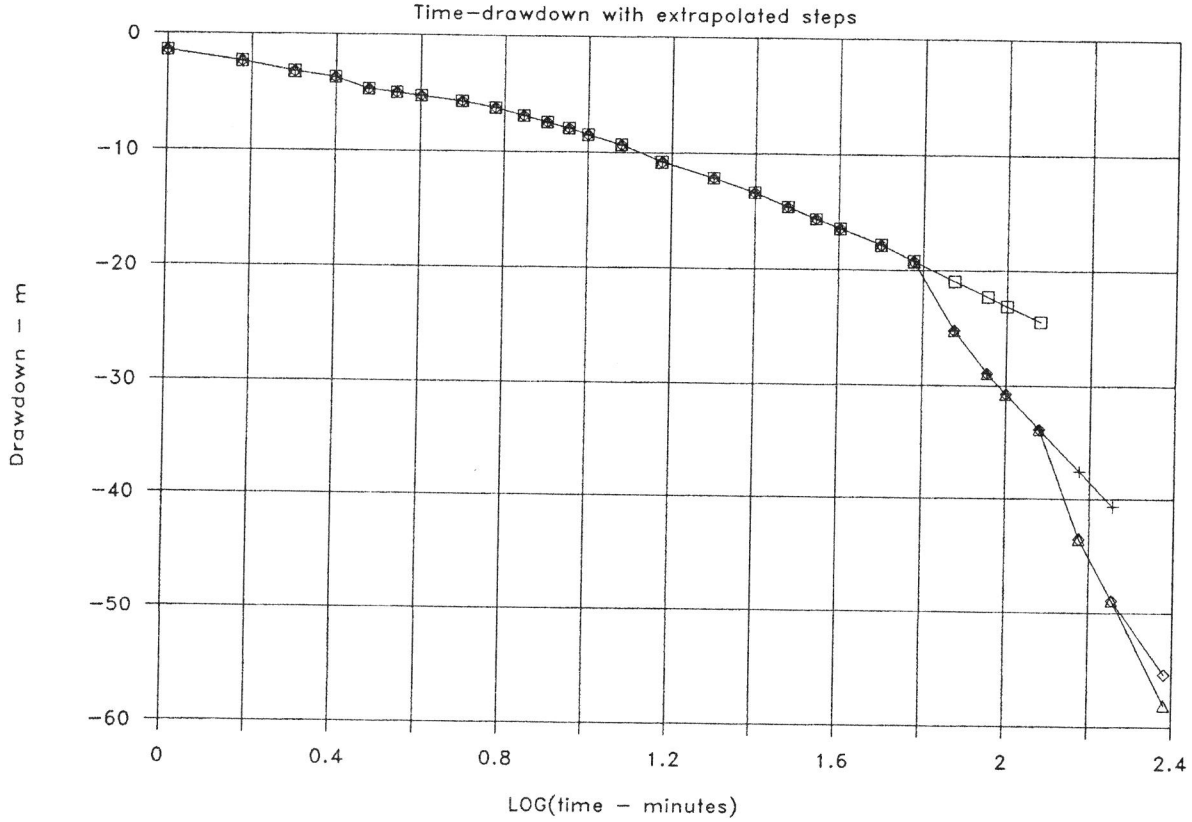
# NONDOTO C7922 PUMPTEST

Recovery



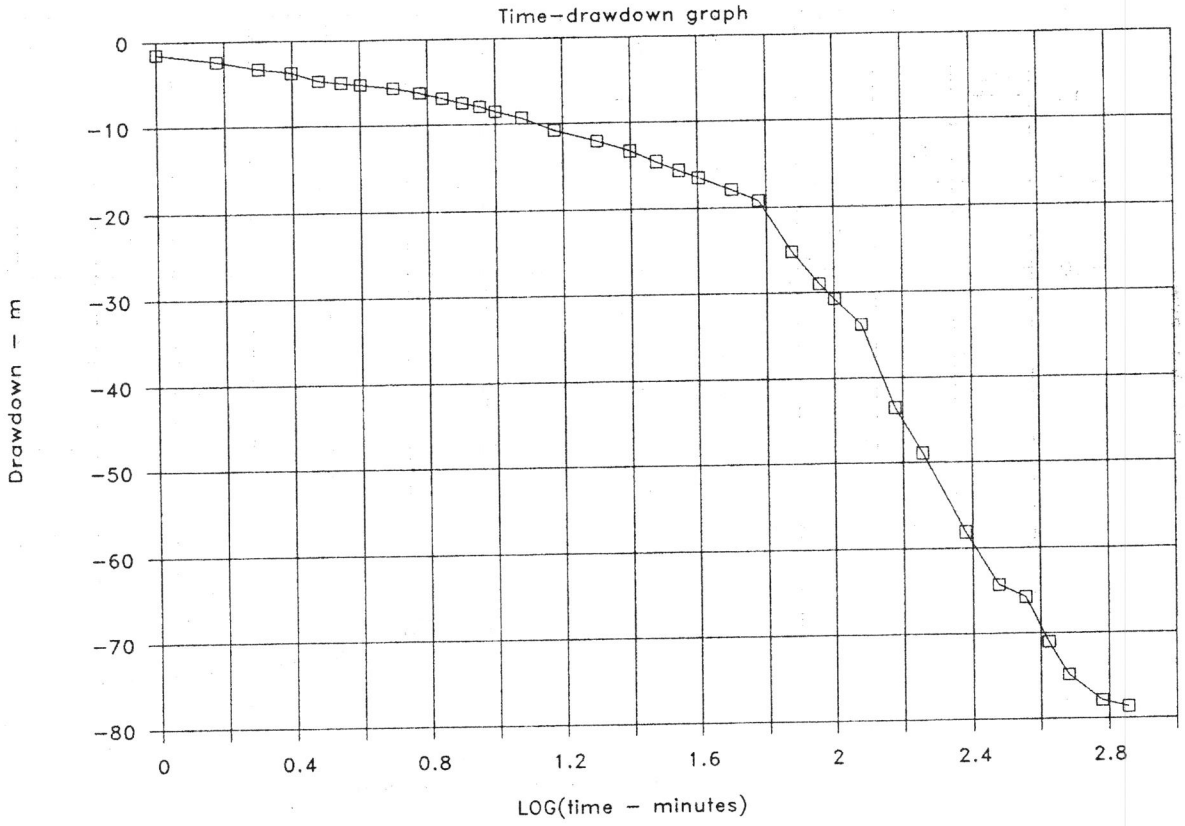

# NONDOTO C7922 PUMPTEST

Time–drawdown with extrapolated steps



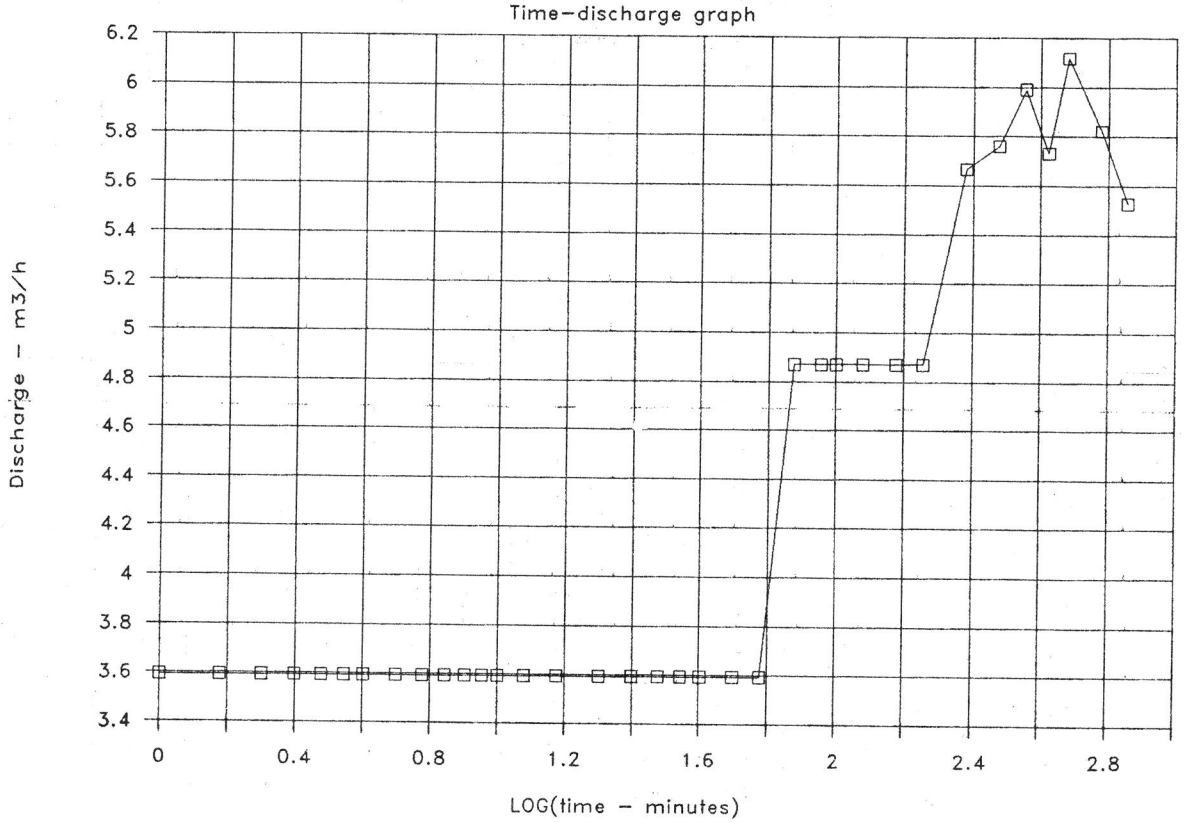
# NONDOTO C7922 PUMPTEST

**Appendix 5.4.11**



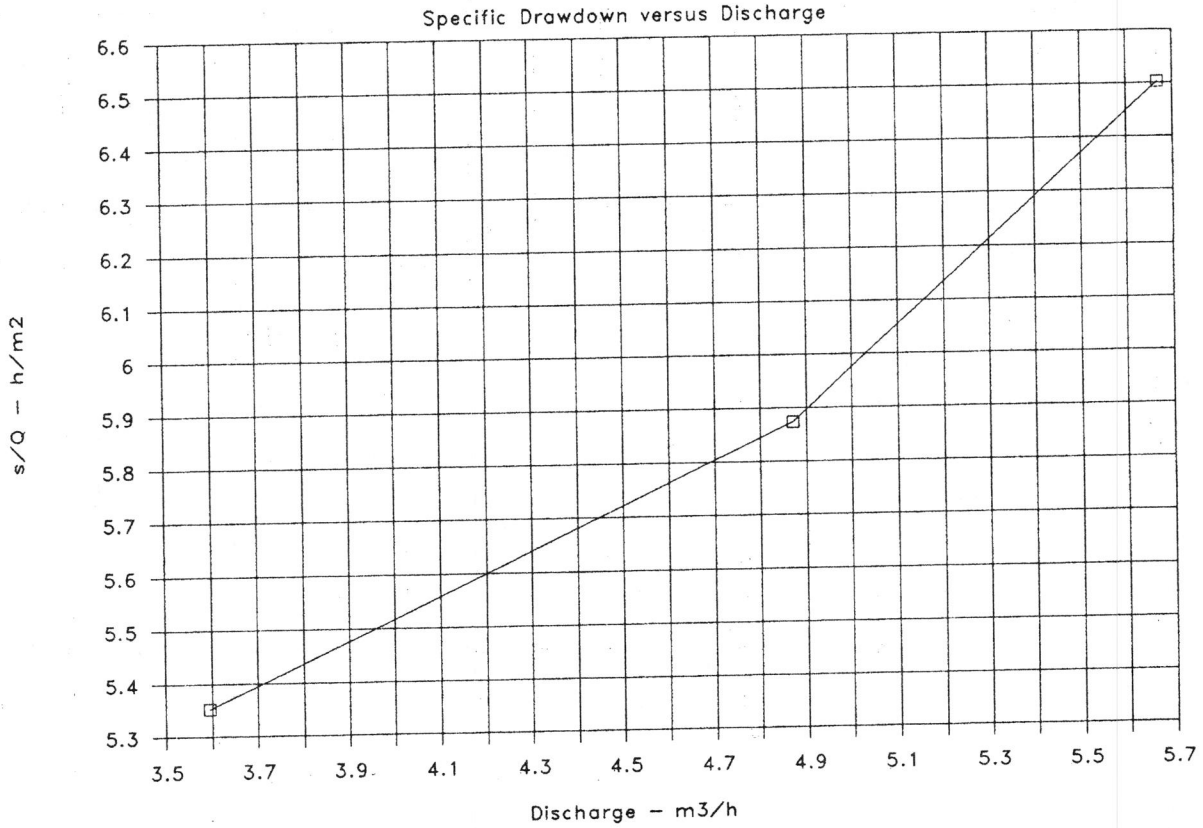
# NONDOTO C7922 PUMPTEST

**Appendix 5.4.11**



# NONDOTO C7922 PUMPTEST

**Appendix 5.4.11**



# Appendix 5.5

## Drinking Water Standards for Kenya

# Appendix 5.5 Drinking Water Standards for Kenya

| Parameter | Unit *mg/l | Acceptable Range | Permissible Range |
|---|---|---|---|
| pH | pH scale | 6.5-8.5 | 6.5-9.2 |
| Colour | mg pt/l | <15 | <50 |
| Turbidity | NTU | <5 | <25 |
| Iron | | <0.3 | <1.0 |
| Manganese | | <0.1 | <0.5 |
| Sodium | | <200 | <200 |
| Aluminium | | <0.2 | <0.2 |
| Total Hardness | mg CaC03/l | <500 | <500 |
| Chloride | | <250 | <600 |
| Fluoride | | <1.5 | <3 |
| Nitrate | | <10 | <10 |
| Sulphate | | <400 | <400 |
| Total Susp. Solids | | None | none |
| TDS | | <1000 | <1500 |
| Copper | | <1.0 | <1.5 |
| Zinc | | <5.0 | <15 |
| **BOD | | | <5 |
| **COD | | | <30 |

After Design Manual for Water Supply in Kenya, MoWD, 1986
* Unless stated otherwise
** Communication with the Head of the Pollution Control Laboratory, MoWD, 1990