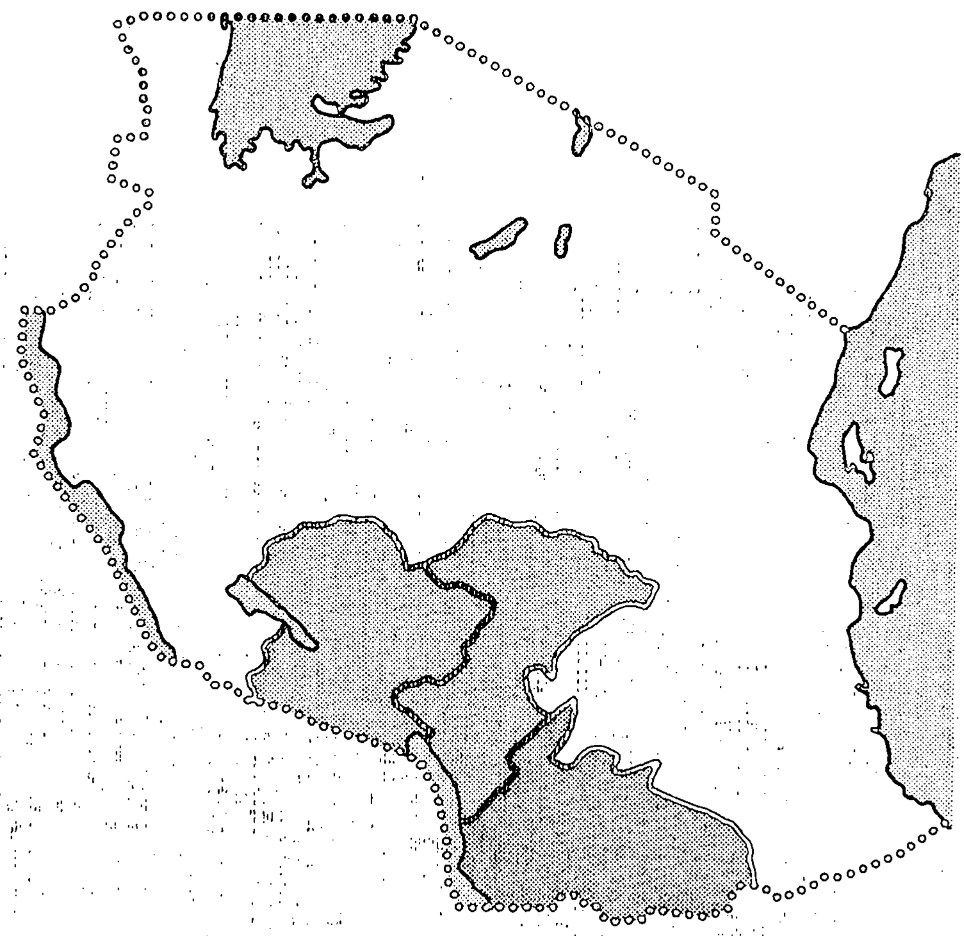
UNITED REPUBLIC OF TANZANIA

DANISH INTERNATIONAL DEVELOPMENT AGENCY ◦ DANIDA

WATER MASTER PLANS FOR IRINGA, RUVUMA AND MBEYA REGIONS

HYDROGEOLOGIC DATA.TREATMENT, METHODS AND GEOPHYSICS

VOLUME 10A



CARL BRO ◦ COWICONSULT ◦ KAMPSAX - KRÜGER ◦

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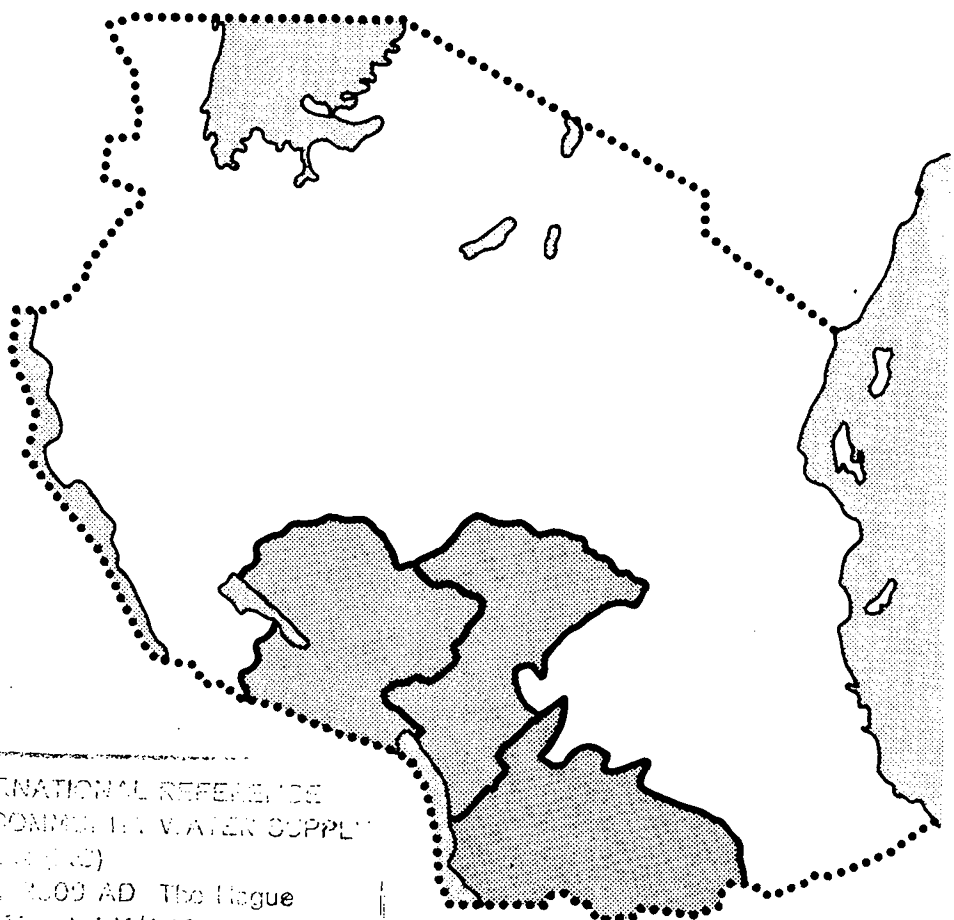

CARL BRO • COWICONSULT • KAMPSAX - KRÜGER • CCKK 1982

GUIDE TO WATER MASTER PLANS FOR IRINGA,RUVUMA AND MBEYA

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THE REFERENCE CODE 5A/6 MEANS, VOLUME 5A, CHAPTER 6.

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CONTENTS - HYDROGEOLOGIC DATA, METHODS, TREATMENT AND GEOPHYSICS

CONTENTS - HYDROGEOLOGIC DATA, METHODS, TREATMENT AND GEOPHYSICS

1. INTRODUCTION

This volume describes the methods that have been used to collect, treat, and analyse data. The geophysical methods are only very briefly described, as these are standard methods well described in the literature.

The principles and philosophy behind the construction of geological and especially hydrogeological maps are elaborated upon in some detail. The hydrogeological maps accompanying this Report in many aspects differ from what has usually been done. This is partly because the hydrogeology of the Iringa, Ruvuma, and Mbeya Regions is influenced by Neogene rift faulting to such an extent that it cannot be overlooked.

Therefore, it has been the prime objective of the Consultants to let the description of groundwater conditions be controlled by a framework defined by the geomorphological and geological set-up of the regions.

Appendix 1

Methods.

2. WELL RECORD SYSTEM

2.1 Introduction

A well record system has been set up for the boreholes drilled in the regions, existing as well as the ones drilled by the Consultants. This system enables any user to easily retrieve any existing information pertaining to boreholes within the regions. The basic idea is that the record should contain observed data without any degree of interpretation.

The well record system adopted here is a modification of a system that has been widely used by the Consultants all over the world. It has been revised and changed according to Tanzanian practice. For each borehole two forms are made, a Borehole Completion Record and a Borehole Location Record.

2.2 Borehole Completion Record

A Borehole Completion Record is shown in Figure 2.1. It is divided into four sections, one describing the borehole location and the drilling organisation, one describing the borehole construction with details on drilled and completed depth, casing, and screening, one describing data pertaining to water such as water struck, standing water level, and hydraulic parameters, and finally one section giving a description of penetrated strata. All numerical data are given in the metric system.

The record sheet contains all the information usually recorded by the drillers in Tanzania, plus some additional information. The sheet is chiefly self-explanatory but some remarks are given below.

Location - Recorded as 'Region, District, Village/Estate'.

Coordinates - If topographical or geological maps are available the exact coordinates are noted.

Test yield - If the pumping test is carried out by means of the air-lift method the maximum (initial) discharge should be given, and the test should be long enough to establish the steady yield, preferably longer (cf. Subsection 6.4.10). If a borehole pump yielding a constant discharge is used only the steady yield is filled in.

T and r_w^2S	-	The hydraulic properties are recorded if the test has been analysed.
Method of pumping	-	It is important to know what type of pumping device has been used.
Suction/ Air outlet	-	Is filled in so that it is possible to check that the water level has not been lowered to the pump suction level or close to the air outlet.
Apparent quality	-	Driller's estimate based on tasting.
Water analysis	-	P: physical analysis available, C: chemical analysis available, B: bacteriological analysis available.
Symbol	-	The symbol adopted representing the rock type. Used by geologist or hydrogeologist in producing maps.
BH No.	-	MAJI's Borehole number.
CCKK No.	-	The Consultants' consecutive borehole number. Symbols used are: ID, Iringa (Region) Deep (borehole) IS, Iringa (Region) Shallow (borehole) RD, Ruvuma (Region) Deep (borehole) RS, Ruvuma (Region) Shallow (borehole) MD, Mbeya (Region) Deep (borehole) MS, Mbeya (Region) Shallow (borehole) The deep boreholes are drilled by Rig 45, the shallow boreholes by Rig 53.

The Borehole Completion Records from boreholes in the study regions are presented in Volume 10B, Appendix 1.

2.3 Borehole Location Record

The purpose of the Borehole Location Record is to make it easy to locate the borehole at a later stage. Once the village/estate is

BOREHOLE COMPLETION RECORD		
LOCATION:		BH NO. CCKK NO.
COORDINATES:	ELEVATION: m.asl	MAP NO.
COMPLETION DATE:	DRILL. METHOD:	
DRILLER/ORGANIZATION:	DRILL UNIT NO.	
CLIENT:		

FORMATION DESCRIPTION BY DATE	
SYM-BOL	
DEPTH M	
AQUIFER	
REMARKS	

CONSTRUCTION DETAILS			
DRILLED DEPTH M	COMPL. DEPTH M		
DRILLED DIAM. MM	FROM	TO	
DETAILS OF CASING LEFT IN BOREHOLE			
INTERNAL DIAM. MM CLASS	PLAN FROM	TO	PERFORATED FROM TO
SCREENING			
INTERNAL DIAM. MM TYPE	SLOT SIZE	FROM	TO
GRAVEL PACK MM	FROM M	TO M	
WATER			
WATER STRUCK			MBG
STANDING WATER LEVEL			MBG
TEST YIELD M^3/HR	MAX	STEADY	
MAXIMUM DRAWD. M	DURATION TEST		MIN
T(M^2/SEC)	$r^2{}_wS(M^2)$		
METHOD OF PUMPING			
SUCTION/AIR OUTLET SET AT			MBG
APPARENT QUALITY OF WATER			
WATER ANALYSIS	P	C	B
WATER TEMPERATURE °C	DATE, WRITTEN BY		

Figure 2.1 Borehole Completion Record

found, the well site sketch is sufficient to find the borehole. A Borehole Location Record is shown in Figure 2.2.

The record is divided into two main groups, one containing data obtained from the Borehole Completion Record, and one containing data and sketches from the site.

Most of the information is similar to the information discussed in the previous section, so only a few points need explanation.

M.A.S.L.	-	Metres above sea level.
M.$\frac{a}{b}$.G.	-	Metres above/below ground level.
M.B.G.	-	Metres below ground level. If the water level is above ground level the figure is negative.
M.P.	-	Measuring point.

The Borehole Location Records from the boreholes in the study regions are presented in Volume 10B, Appendix 2.

BOREHOLE LOCATION RECORD			
LOCATION:		BH NO.	
		CCKK NO.	

DATA COLLECTED	FROM WELL LOG	ON SITE	
COMPLETION DATE		GROUND ELEV. MASL	
CASING DIA. MM		MEASUR.POINT M$\frac{a}{b}$G	
TYPE OF SCREEN DIAMETER, MM		MP ELEVATION,MASL	
		WATER LEVEL, MBG	
DRILLED DEPTH, M		WATER LEVEL, MASL	
STAND.WATER LEVEL,MBG		SKETCH OF WELL TOP/MP	
WATER STRUCK, MBG			
STEADY YIELD, M^3/HR			
DRAWDOWN, M			
METHOD OF PUMPING			
WATER ANALYSIS	P. C. B.		

REMARKS

SKETCH OF WELL SITE	WELL POINT
	MAP NO.: SCALE: DISTANCE FROM EDGE OF MAP (MM)
	LOCATED DATE:
	BY:

Figure 2.2 Borehole Location Record

3. GEOPHYSICAL INVESTIGATIONS

3.1 Introduction

Geophysical investigations in connection with groundwater studies are essentially the interpretation of the variations in measured response at the surface or in boreholes to certain forces either naturally or artificially generated within the crust of the earth. Such variations result from differences in physical characteristics like density, elasticity, magnetism, radioactivity, and electrical resistivity of the underlying materials.

Geophysical investigations made in combination with reconnaissance, surface geologic investigations, and exploratory drilling may provide a fast and relatively low-cost evaluation of the subsurface geology and the general groundwater conditions of an area.

To assure reliable interpretation the geophysical surveys should be correlated with the geologic conditions. Such correlations permit projection of geologic conditions to distant areas through analysis of the geophysical measurements.

The accuracy and reliability of data obtained from a geophysical survey depend in large parts on the control available with sources sending disturbing signals to the measuring equipment (background noise) as well as the geologic complexity of the area under investigation.

In many textbooks on geophysical prospecting full accounts of the geophysical methods applied here are given, so this description only gives a few of the main principles of application.

3.2 Geoelectrical Survey

Of all surface geophysical methods the electrical resistivity method has been applied most widely for groundwater investigations. The basis of the method is that when a current is introduced into the ground through electrodes any subsurface variation in conductivity alters the current flow within the earth, and this in turn affects the distribution of electric potential. The degree to which the potential at the surface is affected depends upon the thickness, location, shape, and conductivity of the material within the ground. It is, therefore, possible to obtain information about the subsurface distribution of this material from measurements of the electric potential made at the surface. In the electrical resistivity method an electrical current is introduced into the earth by means of two current electrodes located at the surface, and the electrical potential difference is measured between two other electrodes. From the value of the potential difference, the current applied, and also the electrode separation a quantity termed "the apparent resistivity" can be calculated. In a homogeneous ground this is the true ground resistivity but usually it represents a weighted average of the resistivities of all the formations through which the current passes. It is the variation of this apparent resistivity with change in electrode spacing and position that gives information about the variation in the subsurface layering.

3.2.1 Field Technique and Procedure

Two different procedures have been used to determine the resistivity variation with depth and with lateral extent.

Geoelectrical soundings are used to determine the variation of the resistivity with depth at a fixed point at the surface. The Schlumberger electrode configuration has been used for this type of measurement. Constant separation traverses have been used to measure the variation of the resistivity along a line on the surface. The Wenner electrode configuration has been used for this type of measurement.

In the Schlumberger configuration two current electrodes and two potential electrodes are arranged in a straight line on the surface, and the distance between the current electrodes is large compared with the distance between the potential electrodes. For this survey the electrodes have been placed symmetrically about the centre of the spread.

In performing the geoelectrical sounding the potential electrodes remain fixed while the current electrode spacing is expanded symmetrically about the centre of the configuration. For large values of the current electrode spacing (2 L) it becomes necessary to increase the potential electrode spacing (2 l) to maintain a measurable potential. The following electrode separations were used:

l = 0.5 m, L = 1.5, 2.1, 3.0, 4.4, 6.3, 9.1, 13.2, 19.0, 27.5, 40.0 m
l = 5.0 m, L = 13.2, 19.0, 27.5, 40.0, 58.0, 83.0, 120.0, 175.0 m
l = 25.0 m, L = 58.0, 83.0, 120.0, 175.0, 250.0 m.

The constant separation traverses are performed by placing two current and two potential electrodes at equal distances from each other along a straight line and move the whole configuration along this line. The actual electrode separation depends on the information on the subsurface that is required. The larger the electrode separation, the deeper the penetration.

3.2.2 Interpretation Technique

The field data for each geoelectrical sounding are represented in logarithmic graphs in which the half length of the current electrode separation L is plotted on the abscissa and the corresponding apparent resistivity is plotted on the ordinate.

The object of the interpretation of the geoelectrical sounding curves is to determine the thicknesses and the true resistivities of the individual layers in the ground.

The interpretation was carried out by means of master curves. These curves are theoretical resistivity curves constructed for different combinations of homogeneous isotropic layers with different thicknesses and resistivities. The master curves are drawn to the same logarithmic scale as the field curves.

The main interpretation problem is that it is often possible to match field curves with more than one master curve. Two slightly different curves can correspond to very different resistivity distributions. For instance it is difficult if not impossible to distinguish between two layers of different thicknesses and resistivities if the products of the thickness and resistivity are the same. This is called the principle of equivalence.

Another aspect of the lack of uniqueness is referred to as the principle of suppression. This relates to those layers whose resistivities are intermediate between the resistivities of the enclosing layers. Such layers as long as they do not have sufficient thickness have practically no influence on the resistivity curve.

Finally, anisotropic ground will lead to errors in the interpretation, as will the effect of rugged topography.

To avoid interpretation problems, a geoelectrical sounding in the immediate vicinity of most of the existing boreholes has been carried out, and by comparison with the geological logs the soundings have been calibrated.

Constant Separation Traverses

The field data for each constant separation traverse is represented in graphs in which the positions of the centre of the electrode configuration at each measurement are plotted along the abcissa in a linear scale while the corresponding value of the apparent resistivity is plotted on the ordinate in a linear scale as well.

The horizontal resistivity profiles have only been interpreted qualitatively. The geoelectrical trenchings were used to find where the bedrock was deepest or where the weathering profile was deepest, and this is expected to be where the horizontal resistivity profiles have their minimum points.

A total of 212 geoelectrical soundings and 12 constant separation traverses have been carried out.

The final interpretation results, the geoelectrical sounding curves, and constant separation traverses are represented in Volume 10 A, Appendix 3.

3.2.3 The Measuring Equipment

The measuring equipment consisted of two sets ABEM Terrameter SAS-300 Master Units and two sets ABEM Terrameter SAS-2000 Booster Units. The terrameter reads the ratio between the voltage drop and the current (the resistivity) directly.

Maximum performance of the instruments:

Terrameter SAS-300 alone:
20 mA at 150 V maximum current electrode potential.

Terrameter SAS-300 connected with Terrameter SAS-2000 Booster:
500 mA at 500 V maximum current electrode potential.

3.3 Seismic Survey

The physical basis of the seismic exploration methods is the fact that differences occur between the velocity of seismic waves in different geologic formations.

There are three different types of seismic waves, compressional (sound waves), shear and surface waves (Rayleigh waves). Only the compressional waves have been used in this survey.

Exploration seismology is an offspring of earthquake seismology and involves basically the same type of measurements. However, the energy sources are controlled and movable, and the distance between the source and the recording points is relatively small.

The basic technique of seismic exploration consists of generating seismic waves and measuring the time required for the waves to travel from the source to a series of sensitive wave detectors, geophones, usually placed along a straight line directed towards the source. From a knowledge of travel times to various geophones and the velocity of the waves it is possible to construct the paths of the seismic waves.

3.3.1 Field Technique and Procedure

All the seismic surveys were performed as in-line refraction profiling with 24 geophones placed along a straight line at equal distances from each other and shot points at each end of the geophone spread.

In order to record both the direct wave through the top layer and the refracted waves from all the other layers, the length of the geophone spread needs to be at least 2-3 times as long as the depth to bedrock. The geophone separation was, therefore, chosen in every case according to the expected depth to bedrock. A geophone spacing varying from 3 to 10 m was used.

As energy source for generating seismic waves explosives were used. The shots were fired in 0.5 to 0.7 m deep hand-drilled holes. The amount of explosives for each shot ranged from 100 to 500 grammes of dynamite.

To initiate the explosion electric blasting caps were used. Special instant-fire seismic caps are required if the shot instant is to be taken directly from the firing circuit, but these could not be provided during the investigation period. To record the shot instant one of the geophones was then used as "start geophone" and the shot hole was placed near to this.

The seismic waves are in the geophones transformed to small electric currents which are transmitted to an amplifier and from there to a recorder and printed on direct print-on paper (the seismogram). From the seismogram the arrival times of the seismic waves at the individual geophones are read from their traces, from the deflection that the first impulse produces, the shot instant being zero time.

3.3.2 Interpretation Technique

Based on the seismograms, travel time graphs for the first arrivals are constructed with the distance from the shot point plotted along the abscissa and the corresponding first arrival travel time plotted along the ordinate at a linear scale.

The objective of the interpretation of the travel time graphs is to determine the thicknesses and the seismic velocities of the individual layers in the ground and especially the depth to bedrock using standard formulas.

These formulas are based on certain assumptions which the actual conditions do not always fulfil, several complicating factors can exist. These originate in the seismic source, in the subsurface geology, and in the seismic recording process itself.

If the seismic pulses generated by the seismic source have flat shapes it may be difficult to read the timebreaks exactly on the seismograms. This problem has been met by using explosives as source which generate very steep pulses in comparison with other energy sources, and by making the contact between the explosives and the ground as good as possible. However, by travelling through the ground the seismic waves will gradually lose its higher frequencies, becoming smoother and more prolonged in time, and the timebreaks will become less and less distinct as the distance to the source is increased.

If there was uncertainty in reading the timebreak, the condition of reciprocity was used to draw the straight lines through the arrival time points on the travel time graphs. The condition of reciprocity states that the total travel time is the same for shots from both ends of the same geophone spread. One of the two travel time graphs will usually be better defined by the data points than will the other. The better defined lines are drawn first and the other lines are then drawn as well as possible through the data points to satisfy reciprocity.

Irregular surface and interface topography may also result in a scattering of the data points on the travel time graphs.

Problems sometimes result from a hidden zone, a layer whose velocity is higher than those of the overlying beds but which never produces first arrivals because the layer is too thin and/or its velocity is not sufficiently greater than those of the overlying beds.

If the increase of velocity in the layers with depth is inversed and a lower layer has a velocity less than that of the layer above it, then critical refraction does not take place and there are no refracted arrivals through the layer. Such a layer is undetectable by the refraction methods.

The total of 50 seismic profiles have been carried out. The final interpretation results and the travel time graphs are presented in Volume 10 A, Appendix 3.

3.3.3 The Measuring Equipment

The measuring equipment consisted of two sets ABEM Trio SX-24 portable seismic refraction systems with 25 recording channels, 24 seismic traces and 1 shot instant trace.

3.4 Down-the-Hole Logging

Down-the-Hole logging includes all techniques of lowering sensing devices into a borehole and recording some physical properties of the formation penetrated by the borehole. The logs are in most cases used in a qualitative sense for identification of lithology, borehole construction and conditions, and for stratigraphic correlation.

The equipment used during the study was capable of doing the following logs: resistivity log, self-potential log, fluid resistivity log, radiation log, temperature log and caliper log.

3.4.1 Resistivity Logs

The principles of resistivity logging are similar to those used in surface resistivity surveys. This type of logs can only be made where the borehole has not been cased.

Current and potential electrodes are lowered into a borehole to measure electrical resistvities of the surrounding media and to obtain a trace of their variation with depth. The result is a resistivity log.

Several electrode configurations have been developed but they are all affected by the fluid within the borehole, by changes in the diameter of the borehole, and by the character of the surrounding strata.

In the normal electrode configuration two current electrodes and two potential electrodes are used. One current and one potential electrode on the logging probe are closely spaced downhole and the other two are fixed at the top of the hole. Three different electrode separations have been used: 0.25' (0.08 m), 2.5' (0.76 m), and 10' (3.05 m).

The apparent resistivity gives useful qualitative information regarding the type of formations penetrated by the borehole and the depths of the formation boundaries. The definition and sharpness of the normal logs decrease with an increasing hole diameter and with a decreasing mud resistivity. The effects of adjacent beds and the invasion of porous zones by drilling mud are also significant.

With small electrode separations the measured apparent resistivity is strongly influenced by the mud and invasion zones, but formation boundaries are indicated rather distinctly. As the electrode separation is increased the influence of mud etc. decreases, and the apparent resistivity will better approximate the true formation resistivities, but the boundary indication will not be so distinct.

The effective penetration into the formation is about twice the electrode spacing and varies inversely with the hole diameter.

In the lateral electrode configuration two current electrodes and two potential electrodes are used as well. Three electrodes, two potential and one current electrode, on the logging probe are spaced downhole and the last current electrode is fixed at the top of the hole. The following electrode separations have been used: 10' (3.05) with potential electrode separation 0.25' (0.08 m) and 2.5' (0.76 m).

The prime objective of the lateral log is to measure the formation resistivity by use of an electrode spacing large enough to ensure that the mud invasion zone has little or no effect on the measurements.

The effective penetration is approximately equal to the electrode spacing.

In the "single-point" electrode configuration only one electrode is lowered in the borehole, and this has the combined function of current and potential electrode. The apparent resistivity measured is considerable different from the true value because it is built up by cable resistance, formation resistance, contact resistance between the grounded electrodes at the top of the borehole and the soil, and contact resistance between electrode in the borehole and the fluid within the borehole.

The method gives only qualitative information regarding resistivity changes caused by variation in lithology or the salinity of the pore water.

The effective penetration into the formation is small, from five to ten times the electrode diameter.

3.4.2 Self-potential Log

Self-potential logs are records of the natural potentials developed between mineralogically different formations and salinity differences between formation liquids and drilling mud.

This type of logs can only be made where the borehole has not been cased.

Only one electrode is lowered into the borehole and one is fixed at the top of the borehole. The natural potentials are measured in millivolts.

The self-potential logs give qualitative information on the formations penetrated by the borehole. It is possible to indicate thin clay lenses which cannot be observed clearly in the resistivity logs, and it can be used within salt water zones where the resistivity logs no longer make differentiation possible between sand and clay beds.

The effective penetration into the formation is highly variable.

3.4.3 Fluid Resistivity Logs

Fluid resistivity logs are continuous records of the conductivity of the fluid in a borehole which may be related to the conductivity of fluids in the adjacent formations.

Fluid resistivity logs are used to determine water quality in wells, in particular to locate salt water and to help in the interpretation of formation resistivity logs.

The fluid resistivity probe used consists of a non-conductive tube that contains four electrodes, two current electrodes, and two potential electrodes.

3.4.4 Radiation Logs

Radiation logs are continuous records of the radioactive radiation from the formations penetrated by the borehole. Radiation logs may be applied in either cased or uncased boreholes that are filled with any type of fluid.

Some atomic nuclei emit natural radiation in the form of alpha, beta, and gamma rays or neutrons. The most commonly used type of logs and the type used in this survey is logs of the natural gamma radiation.

Gamma radiation is an electromagnetic radiation and is not electrically charged. During nuclear disintegrations gamma rays are emitted.

Natural gamma radiation in the ground results from the presence of small amounts of radioactive isotopes which mainly are potassium -40 (K^{40}), uranium -238 (U^{238}), thorium -232 (Th^{232}), and daughter products of the uranium and thorium decay series.

The amount of radioactive isotopes is roughly lowest in basic igneous rocks, intermediate in metamorphic rocks, and highest in some sediments.

In general, the natural gamma activity of clay-bearing sediments is much higher than that of quartz, sands, and carbonates. It is, therefore, possible to get useful qualitative information regarding the lithology and stratification from a gamma log.

The gamma probe used consists of a detector and an amplifier. The detector is a scintillation counter in which the incident gamma pulses in an activated transparent crystal are transformed into light flashes. These flashes cause electron emission from a photocathode, and the corresponding current is amplified by means of electron multiplication by secondary emission from a number of electrodes. The total current amplification is appr. 10^6. The current is further amplified in the probe and then transmitted to the surface recording equipment.

The radius of investigation of a gamma probe depends on the borehole fluid, the borehole diameter, size of casing, density of the rocks, etc., but roughly 90% of the measured radiation originate within approx. 30 cm of the borehole wall.

3.4.5 Temperature Log

Measurement of temperature in boreholes is the oldest logging technique. The temperature logs can be used to detect fluid movements in uncased boreholes or through screens or casing leaks. Further, they can provide some qualitative information concerning the lithology.

Ordinarily temperatures will increase with depth in accordance with the geothermal gradient amounting to approx. $3^{\circ}C$ for each 100 m depth. Departures from this normal gradient may provide information on fluid circulation or geologic conditions. In general, the geothermal gradient is larger in rocks with low permeability than in rocks with high permeability, possibly because of groundwater flow. This fact makes it possible to determine the relative magnitude of permeability of the formations from a temperature log. The temperature probe used contains a temperature sensitive element, a thermistor, whose internal electrical resistance changes in response to temperature changes. A small electric current is sent through the thermistor to measure changes in resistance.

Temperature logs should be run with downward moving probe to avoid temperature disturbance caused by fluid displacement in the borehole.

3.4.6 Caliper Log

Variations of the diameter in a borehole is measured by a caliper probe. Changes in hole size are caused by a combination of drilling techniques and lithology,e.g. change of drilling bits, circulation of drilling mud, degree of cementation, compaction and porosity of the formations, and size, spacing and orientation of fractures.

Caliper logs are utilised as a guide to well construction, to correct the interpretation of other logs for hole diameter effects, for lithology identification, and for location of fractures in hard rocks.

The caliper probe used is provided with three feeler arms the movements of which are recorded by an electric circuit and then transmitted to the surface recording equipment.

Caliper logs should be run with upward moving probe to prevent the probe to stick in the borehole. The probe is lowered with the feeler arms closed into the borehole. At the desired depth an upward movement of the probe releases the feeler arms to contact with the borehole wall.

3.4.7 The Measuring Equipment

The measuring equipment consisted of a Johnson-Keck Borehole Geophysical Logging System Model SR-3000.

The equipment was provided with six logging modules:

- Two resistivity log modules
- One self-potential log module
- One temperature log module
- One gamma log module
- One caliper log module

and two strip-card recorders.

Two types of logs can be run simultaneously.

The following probes were used:

1. Resistivity/self-potential probe.
   The probe can be used for normal resistivity, lateral resistivity, single-point and self-potential measurements.

2. Fluid resistivity probe.

3. Temperature probe.
4. Gamma/single-point/self-potential probe.
   The probe can be used for natural gamma radiation, single-point and self-potential measurements.
5. Caliper probe.

4. PREPARATION OF DRAWINGS

4.1 Geology (Drawing II-8)

The construction of the geological map and the accompanying description has been based on the following available information:

- Available literature, bulletins, and publications.
- Existing geological maps, mainly Quarter Degree Sheets 1:125,000. These maps are available in three editions, preliminary and first editions surveyed during the 1940's to the mid 1950's, and a corrected edition mapped during the 1960's.

Most of the regions as a whole is mapped to that scale except for the northern part of Mbeya and Iringa Regions, and the eastern part of Ruvuma Region. In these areas the geologic interpretation has been based on:

- The general Geological Map of Tanganyika, 1:2,000,000.
- Satellite imageries comprising 1:500,000 colour composite, 1:500,000 Bands 4 and 5, and 1:250,000 Band 7. Full coverage at the 1:500,000 scale and partial coverage at the 1:250,000 scale was obtained.
- Airborne magnetic survey maps.
- The borehole files of MAJI, Dodoma, and the regional headquarters.
- Results of the present geological, geomorphological, geophysical, and hydrogeological field surveys.

The geological map has been prepared in two editions, a detailed map giving as much details on the rocks as deemed necessary for the purpose of the hydrogeological study, and a general geological map delineating the main rock groups. This map is used as an overlay for the hydrogeological maps for easy cross reference.

It should be observed that the satellite imageries used have not been geographically corrected, so slight inaccuracies are present on all maps where satellite imageries have been employed to construct the map. However, since the study regions are situated so close to the equator the errors are small and cause no problems in using and interpreting the maps.

4.2 Geomorphology (Drawing II-9)

The construction of the geomorphological map has been based on the following information:

- Available literature, bulletins, and publications.
- Existing geological maps and the geological map prepared by the Consultants.
- Satellite imageries as above.
- Field surveys.
- Topographical maps of various scales.

The actual delineation of the geomorphological units is based predominantly on the satellite imageries, but the decision on which plateaus belong to which erosion surface is made after an extensive field survey supported by the explanation given on the Geological Quarter Degree Sheets which in some cases comment on the erosion features of the areas covered by the individual sheets.

King (1962) published a preliminary geomorphological map of Africa and this map was used as a starting point. The final result of this study in many areas differs considerably from Kings' suggestions. The classical literature on the geomorphology of East and Central Africa has been widely used as it mentions some specific areas within the study regions.

The geomorphological map was constructed stepwise. First the characteristic African erosion surface was delineated because it is easily identified in the field. Then the aggradational surfaces were delineated. What was left could be only Gondwana or post-Gondwana erosion surfaces (plateaus more elevated than the African Plateaus), or post-African, or Coastal/Congo (plateaus situated at lower levels).

Once the basic information was assembled, necessary corrections were made currently in order to more accurately locate the boundaries between the erosion surfaces.

The geomorphological map has been prepared to meet the requirements of the hydrogeological study. The situation is much more complex than shown on the map. The Gondwana land surface for instance is much more dissected by valleys belonging to the post-Gondwana erosion cycle than indicated, and along the edges of the African land surface a detailed study may reveal many minor erosion features caused by the post-African erosion cycle.

Nevertheless the geomorphological map is believed to represent the actual erosion features to a degree that is satisfactory for its purpose.

4.3 Dambos, Springs and Main Faults (Drawing II-12)

The main structures are drawn on basis of the geological map prepared by the Consultants, and the same sources have been used. The main structures in Ruvuma Region have been based mainly on the aeromagnetic maps as far as the eastern Karroo basin is concerned, since there is no available detailed geological mapping there.

General structural maps of Tanzania have been used to correlate the structures with the overall structural pattern since it is believed that the main structures in the regions form part of an overall pattern in East Africa and, thus, cannot be treated separately. The wellknown rift faulting is of course the major structural feature, but the main structures in the eastern Karroo basin have been found to be a continuation of the fault lines in the northern Tanzania which apparently has not hitherto been recognised.

The dambos are outlined using air photos, photo mosaics, satellite imageries, 1:250,000 topographical maps and geological maps. The dambos are most easily recognised on the air photos and transferred from these to the base map, which was at the 250,000 scale. Since the regions were not fully covered by air photos geological maps have been widely used, and on some 250,000 topographical maps dambos are shown as swampy areas.

In the eastern Karroo basin dambos have not been mapped. The geology and erosion of the Karroo is quite different from the Basement Complex, and it is far from certain that the low-lying areas in the river valleys can be regarded as dambos or they are more akin to classical alluvial tracts.

The majority of the springs shown is recorded in the village inventories.

On some of the geological map sheets springs are mapped. Most of the juvenile springs shown have been obtained from this source. Many more spring than those shown on the map are believed to exist. No distinction is made between perennial and intermittent springs since this was not possible as only spot gaugings have been available.

4.4 Cyclogram Map (Drawing II-10)

The cyclogram mapping technique was developed at the Geological Survey of Denmark (Andersen, 1975) and is a very useful method of visualising borehole data and spatial distribution of layers. In its original form the cyclogram map provides a three-dimensional view of the distribution of subsurface strata, together with all technical data from the boreholes.

However, this presumes an area of low topographical relief so that boreholes show strata from more or less the same levels. This makes it impossible to produce a cyclogram map in its original form covering the whole study area because the differences in altitudes over short distances result in boreholes drilled into completely different formations, and correlation in the usual sense becomes meaningless.

The cyclogram map presented here is consequently a modified version of the original one but yet preserving the two most important features, the borehole data and the stratigraphy.

The cyclograms are oriented in such a way that the ground level is placed at 9 o'clock in the first ring (cf. legend, Drawing II-10). The depth of the borehole increases clockwise and each ring embraces 100 m of penetration. The first ring embraces layers from ground level to 100 m below ground level. The second ring embraces layers from 100 m.b.g.l. to 200 m.b.g.l. and so on. Across the Basement Complex which is of main interest, the first section of the first ring, therefore, usually represents the saprolite, and correlation of saprolite thicknesses from borehole to borehole becomes immediately possible. This is very important since the saprolite is the most interesting layer from a groundwater point of view.

senting the borehole site is divided into four sections indicating what type of data is available: chemical analysis, water level data, location record, or strata log.

In this way the cyclogram is a graphical and numerical representation or reference to all available data pertaining to groundwater, and it can be used without having to consult the original data records. For a complete identification of the groundwater conditions as given by available data only the chemical map has to be consulted.

4.5 Groundwater Chemistry (Drawing II-11)

Data on the chemical quality are based on chemical analyses from existing wells and analyses from wells drilled by the Consultants. Data from existing wells in most cases consist of partial analyses, or even less than that. In some cases only the total dissolved solids (TDS) are given.

The existing analyses have been collected from the borehole files of MAJI, Dodoma, and Ubungo, and from the regional headquarters. Water samples from the wells drilled by the Consultants have been analysed by means of Hach Kits, and by using standard laboratory procedures at MAJI, Ubungo. Some samples were sent to Denmark for full analyses.

Selected chemical analyses are represented by a circular diagram (Pie-diagram) on the Chemical Map.

The calculation and plotting of the diagrams were performed by the Geological Survey of Denmark using EDP techniques.

4.5.1 Data Treatment

The concentration of the respective ions was converted from ppm (mg/l) to meq/l (milliequivalents per litre). When the ion concentrations are expressed as meq/l the total number of meq/l anions is equal to the total number of meq/l cations. It is thus possible to depict the percentagewise concentration of each cation on the upper semicircle and of each anion on the lower semicircle.

The conversion from ppm (mg/l) to meq/l is performed according to the following formula:

$$meq/l = \frac{ppm}{\text{equivalent weight of ion}}$$

The equivalent weights of the respective ions are given in Table 4.1.

The analyses to be illustrated were selected from an evaluation of the reliability of each individual analysis and the balance of anions and cations.

Anion	Equivalent Weight	Cation	Equivalent Weight
CO_3^{--}	30.01	Ca^{++}	20.04
HCO_3^{-}	61.02	Mg^{++}	12.16
SO_4^{--}	48.03	Fe^{++}	27.92
Cl^{-}	35.46	Mn^{++}	27.47
NO_3^{-}	62.01	NH_4^{+}	18.04
NO_2^{-}	46.01	Na^{+}	22.99
		K^{+}	39.10

Table 4.1 Equivalent weights of anions and cations.

4.5.2 Graphical Representation of Analyses

The selected analyses are represented by pie-diagrams in which the distribution of the major ions (Ca^{++}, Mg^{++}, Na^{+}, K^{+}, HCO_3^{-}, SO_4^{--}, Cl^{-} etc.) is shown by circle sectors.

In the upper semicircle the cations (pos. charge) are depicted, in the lower semicircle the anions (neg. charge).

The smallest circle sector which can be illustrated in a normal pie-diagram is appr. 5^{o}, and consequently ion concentrations below 3% of the total anion or cation concentration (corresponding to an angle of 5.4^{o}) have not been plotted.

The area of the circle is proportional to the total ion concentration in the water sample.

The following dissolved components and elements which are of particular interest from a water treatment point of view are given by figures stating concentrations in ppm (mg/l) where applicable: pH, NH_4^+, NO_3^-, Cl^-, Fe^{++}, Mn^{++}, aggressive CO_2, $NaHCO_3$, temporary and total hardness and conductivity.

For identification purposes the borehole number is given together with the date of sampling where the latter is known.

In Volume 10 B, Appendix 3, the chemical data are given for each borehole.

4.6 Groundwater Development Potential (Drawing II-13)

The map showing the groundwater development potential is based on the other maps produced and on the findings of the hydrogeology study. The basic sources of information are, therefore, those already mentioned.

The base for drawing the map has been the 1:500,000 satellite imageries which not having been corrected causes slight deviations to occur between the actual geographical position of major topographical features and those depicted on the map. The deviations are small and have no influence on the general use of the map.

As the main purpose of the study has been to evaluate the potential in relation to village water supply, the groundwater abstraction potential has been based on a handpump solution, and this means that the influence of the walking distance has also been taken into consideration.

The depth to the water level is of paramount importance for the yield of a hand pump, and the depth is largely depending on the local topography. Therefore, the topography has had to be taken into consideration too. The expected yields of wells are shown in the graphs on the map as specific capacities. For a given drawdown the expected yield is the specific capacity times the drawdown.

The general geological map is shown as an overlay. This makes it possible for the user to determine the geology of the saprolite parent rock at a proposed site, and from that differentiate the expected yields over an area.

The classes shown are based on the geomorphological units, and differentiations within the units are based on the topography. Within the Basement Complex groundwater is generally occurring, and the yields of wells are statistically uniform. However, as the topography becomes more and more undulating it becomes more and more difficult to place boreholes in the villages or their immediate vicinity.

The class with the best groundwater potential in this sense covers areas of low topographical relief, and siting of wells suitable to meet requirements of walking distances can be generally done in such areas.

5. DESCRIPTION OF HYDROGEOLOGICAL TERMS

5.1 Objective

To avoid unnecessary repetition of the explanation of hydrogeological terms the terms commonly used in this Report are described here. The description will be general but does in some aspects pertain to African conditions.

5.2 Types of Aquifers

5.2.1 Perched Aquifers

The first aquifer encountered in many areas is often a perched aquifer (Figure 5.1). This aquifer is of phreatic type (see below) and is controlled by structure or strathigraphy. Perched aquifers are usually of limited areal extent and thickness and are, therefore, not suitable for any large scale groundwater development.

If the perched aquifer is controlled by, say, a clay layer that outcrops a spring might develop. Because of the comparatively small storage capacity of the aquifer such springs are usually seasonal and discharge small volumes of water only, and often shortly after heavy rainfall.

5.2.2 Phreatic Aquifers

Aquifers being in direct contact with the atmosphere through open spaces in permeable overburden are phreatic or water table aquifers. The water table is defined as the surface at which the water pressure equals the atmospheric pressure, and the zone above is unsaturated.

A water table aquifer may in principle be found at any depth depending on the local strathigraphy, usually the water table will be rather shallow.

5.2.3 Artesian Aquifers

Artesian or confined aquifers are commonly deep-seated, and if water table aquifers are existing in the area the artesian aquifer is situated below these. In the artesian aquifer, water is under pressure, and the water level in a well drilled to the aquifer will rise to a level above the confining layer. This level is the piezometric surface.

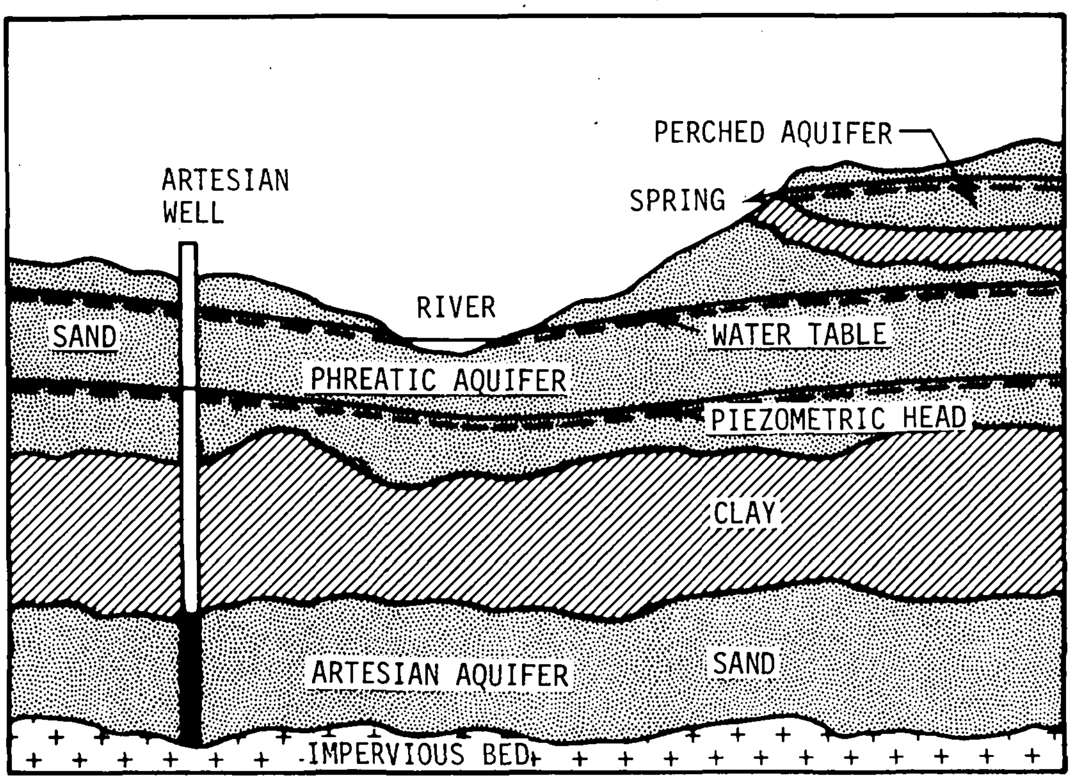


Figure 5.1 Schematic cross section through aquifers.

Artesian aquifers are divided into two groups, nonleaky and leaky aquifers.

Nonleaky Artesian Aquifers

A nonleaky artesian aquifer is an aquifer to which there is no flow of water through the confining beds, and no flow will be induced when pumping takes place from the aquifer.

This type of aquifer is physically not very realistic because there is no explanation to its existence except some sudden geological event that has trapped and sealed off water between impermeable beds, or in cases where the aquifer is partly exposed at the land surface allowing for direct infiltration by rainfall.

However, from a mathematical point of view the nonleaky artesian aquifer is very important because it provides the physical background for the basic solution of the problem of groundwater flow around a well being pumped at a constant rate (the Theis solution, cf. Section 6.4).

Leaky Artesian Aquifers

The most common artesian aquifer is the leaky one. It occurs where the confining beds are semi-permeable allowing flow of water to the aquifer from surrounding water bearing strata having higher pressure. The flow of water to the aquifer depends on the permeability of confining beds and the pressure difference, and consequently obeys Darcy's law.

When a leaky artesian aquifer is pumped the pressure difference is increased and the leakage becomes larger. During the initial stage of pumping the aquifer behaves nonleaky. After some time (tens of minutes to a few days) leakage flow starts to dominate, and a pseudo-steady state may develop during which the volume of water extracted from the aquifer is balanced by leakage flow. Unless the source bed has got an extremely large storage capacity (e.g. a lake) drawdowns will occur in the source bed. The leakage flow, therefore, can no longer balance the volume pumped (after days to months) and the drawdown will increase in the pumped aquifer. This state which describes the long-term behaviour of the aquifer may continue for years until some independent source of recharge is reached to yield the final steady state condition.

5.3 Hydraulic Properties of Aquifers

The hydraulic properties of aquifers are influenced by large-scale parameters like the thickness, width, and dip of the aquifer, and by small-scale parameters like porosity, grain size, uniformity, etc. The main properties, however, are best described by the following parameters: transmissivity, storage coefficient, and leakage coefficient since these reflect the influence of various other parameters some of which are mentioned above.

5.3.1 Transmissivity

The transmissivity T is a parameter which describes the gross hydraulic conductivity of an aquifer. According to Darcy's law the discharge from an aquifer with height h, width b, permeability or hydraulic conductivity p, and hydraulic gradient I, is $Q = p \times h \times b \times I$. The transmissivity is defined as the product of the permeability and thickness of the aquifers, i.e. T = p x h. Physically, therefore, the transmissivity is the discharge through a cross section of unit width and gradient extending through the full height of the aquifer (Figure 5.2). Similarly the permeability or hydraulic conductivity is defined as the discharge through a cross section of unit area having unit gradient.

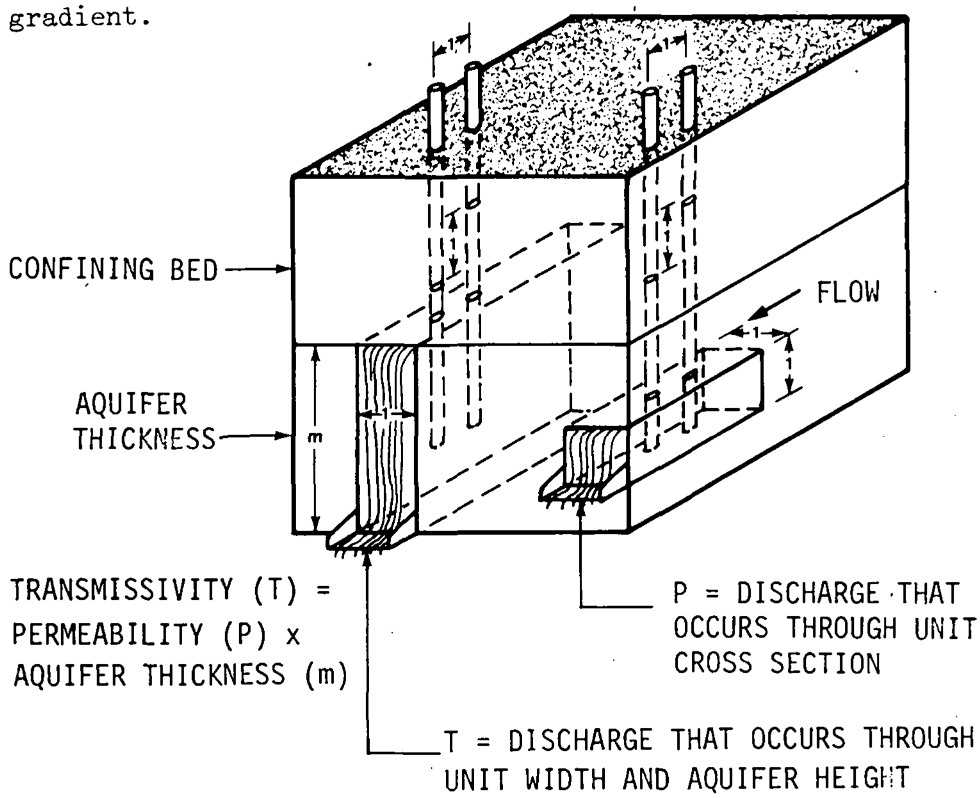


Figure 5.2 Graphical concepts of the coefficients of permeability and transmissivity. (After Johnson, 1966)

5.3.2 Storage Coefficient

The storage coefficient S is a quantity which describes the ability of an aquifer to store or release water. It is defined as the volume of water released per volume of a column through the aquifer with unit cross-sectional area and per unit decline of head.

There is a sharp distinction between the storage coefficient or specific yield S_y of a phreatic and that of an artesian aquifer. In a phreatic aquifer the storage coefficient equals the effective porosity which is approximately the volume of water released per unit volume of the aquifer during gravity drainage. Therefore, the storage coefficient is of the order of magnitude 0.01-0.2. The flow of water in a phreatic aquifer is controlled by gravity, and accordingly the area of influence due to pumping will be small compared to the area of influence in a similar artesian aquifer.

In an artesian aquifer the water is released due to the elastic compression of the intergranular skeleton, and the storage coefficient accordingly is small, usually in the range 0.00001-0.001.

In an artesian aquifer the flow of water is controlled by the pressure gradient. As the volume of water released per volume of aquifer is very small the area of influence due to pumping rapidly becomes very large. To obtain the same amount of information on an aquifer the duration of test in an artesian aquifer will be considerably shorter than in a phreatic aquifer. The difference between the storage coefficients of phreatic and artesian aquifers is illustrated in Figure 5.3.

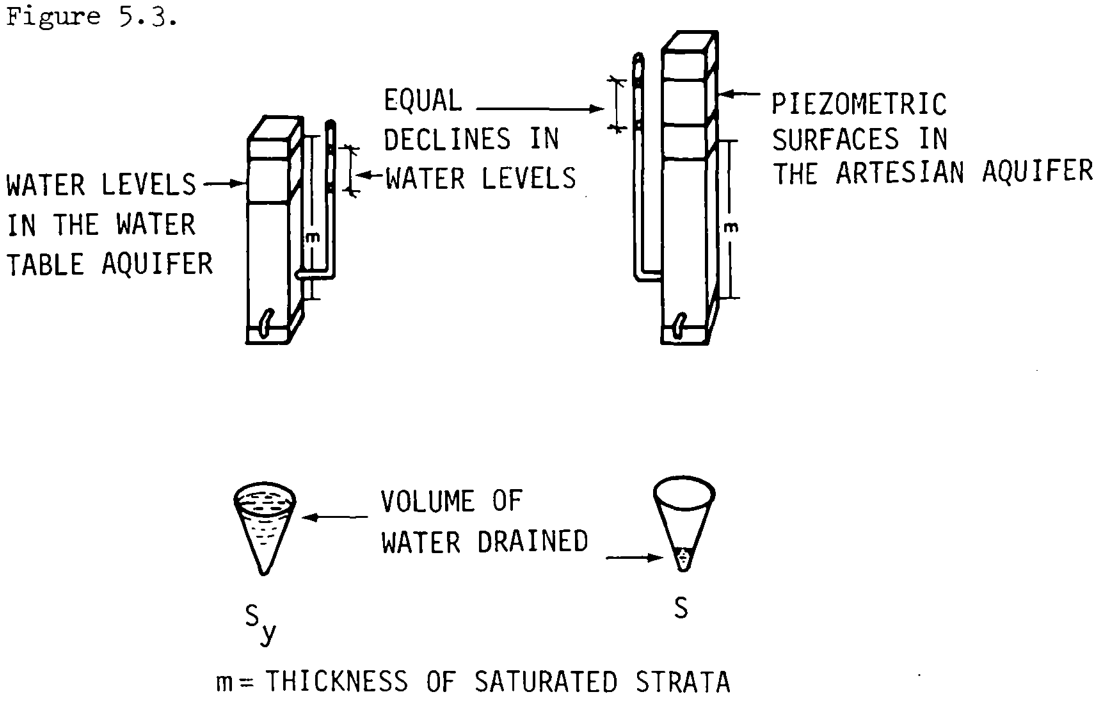


Figure 5.3 Unit prisms of water table and artesian aquifers, illustrating differences in storage coefficients. (After Heath and Trainer, 1968)

5.3.3 Leakage Coefficient

The leakage coefficient P'/m' is associated with leaky artesian aquifers only and is simply the ratio of the permeability and the thickness of the confining layer through which leakage occurs.

The leakage is contolled by pressure differences between the aquifer and the confining layer and may, therefore, originate from layers above or below the aquifer, depending on pressure. The leakage coefficient is a parameter derived from mathematical considerations and plays an important role in the interpretation of pumping test results from leaky artesian aquifers. Once determined it can be applied to calculate recharge to artesian aquifers when the hydrogeological set-up is known.

5.4 Recharge to Aquifers

Because of the different physical background recharge to aquifers is naturally divided into recharge to phreatic and recharge to artesian aquifers.

5.4.1 Recharge to Phreatic Aquifers

Recharge to phreatic aquifers is established by the rather simple mechanism of direct infiltration through the soil above the water table. The net infiltration available for recharge is the rainfall reduced by evaporation, evapo-transpiration, overland flow, and interflow, all of which vary considerably according to local climatic, hydrogeological, and geographical conditions.

Phreatic aquifers are very sensitive to longer periods of drought during which they may discharge their water content completely to nearby rivers or lakes. Unless the saturated zone of a phreatic aquifer is very thick and thus contains a large volume of water, it cannot usually form the base for a large-scale development of groundwater, especially in areas with typical seasonal rainfall. Wells in such aquifers of relatively small storage capacity may run dry during dry periods and may be operational again shortly after the rainy season has started.

5.4.2 Recharge to Artesian Aquifers

Nonleaky artesian aquifers can be recharged only in cases where the aquifer is exposed at the surface, and the recharge mechanism is direct infiltration. Leaky artesian aquifers are recharged by the mechanism of leakage flow from adjacent layers having a higher pressure head, as described previously.

Artesian aquifers are much less sensitive to draught periods than phreatic aquifers because they are always fully saturated with water. Groundwater abstraction by wells can continue from artesian aquifers through long periods of no recharge, and artesian wells are not liable to run dry easily. This only happens as a result of mining of groundwater during long periods in which case the well must be shut down for a period of a year or more, depending on the recharge conditions, before it is operational again.

5.5 Drainage

In the following a short description will be given of the types of drainage pattern commonly found in the study regions. For further details reference is given to Monkhouse and Small (1978) which has been consulted in preparing the descriptions below.

Dendritic drainage - a tree-like pattern where tributaries resemble branches converging upon the main stream. Mostly found where there is no structural control and where rocks are similar over the drainage basin. Very common across the African erosion surface where not tectonically disturbed.

Parallel drainage - streams and tributaries are almost parallel to one another. Common in alluvial fans and below escarpments.

Rectilinear drainage - tributary junctions are generally at right angles. Sections between junctions are of approximately the same length. Usually connected to a similar joint pattern. Often seen above escarpments.

Radial drainage - streams flowing down the slopes of dome or cone-shaped uplands. Commonly seen around the craters in the Rungwe Volcanic Province.

Trellis drainage - a rectilinear drainage pattern mostly in scarplands where adjustment to structures has occurred.

Dambo - a river valley with a wide flat grass-covered floor resulting from sheet wash. Stream channels are usually poorly defined. May or may not be flooded during the rainy season. Dambos reflect the surface as well as the subsurface drainage pattern which is commonly dendritic in tectonically undisturbed plains. Common across the African land surface.

Mbuga - a seasonally flooded depression in a plain often situated within drainage lines.

6. PUMPING TESTS

6.1 Objective

Pumping tests are carried out on water wells to determine the hydraulic properties of the formation tapped. With known values of aquifer characteristics it is possible to determine the optimal yield that can be obtained from the well, taking into consideration the life time of the well. If the discharge is too great so that the water level is lowered below the top of screen or inflow face, the water is oxidised with a possible deterioration of the chemical quality as a consequence.

Furthermore, an assessment of the aquifer potential for withdrawal of water cannot be carried out without a proper knowledge of aquifer transmissivity or permeability. The analysis of pumping test data to determine aquifer hydraulic properties, therefore, is essential to the planning of future aquifer development.

6.2 Types of Tests

There are numerous ways of testing wells, depending on the objective of the test and the equipment available for testing. The tests to be mentioned in the following are those most commonly used, because they usually provide the most reliable results.

6.2.1 Specific Capacity Test

This test is the most simple to perform. The well is pumped for a certain period of time, preferably at a constant rate, and the drawdown is measured immediately before pumping stop. The ratio of the discharge rate Q and the drawdown in the well s_w, Q/s_w is the specific capacity which expresses the performance of the well. The larger Q/s_w, the better the well is. The specific capacity can be further used to obtain an estimate of the aquifer transmissivity.

6.2.2 Constant Discharge Test

The constant discharge test is the test most commonly used to determine aquifer hydraulic properties and boundary conditions. To obtain the best results, several observation wells are required.

The test is carried out by discharging the pumping well at a constant rate and measure the drawdown in the well and in the observation wells frequently to obtain time-drawdown relationships.

The duration of the test depends on the purpose of the test. If transmissivity and storage coefficient only are to be determined, 2-3 hours will usually do. If boundary conditions are to be clarified, the duration may be a week or longer in a confined aquifer, and often several weeks in an unconfined aquifer.

6.2.3 Variable Discharge Test

If the discharge varies about some mean value, this value can be used as the discharge, and the methods used to analyse constant discharge tests may be applied.

If the discharge rate decreases monotonously, the constant discharge assumptions cannot be met, and different techniques must be applied. Decreasing discharge tests are most commonly encountered when pumping takes place by means of the air-lift method.

Initially there is a larger column of water above the air outlet, and since the initial discharge is proportional to the length of this column, the discharge rate decreases with increasing drawdown and becomes eventually steady when the drawdown rate is small.

The time required to obtain a steady discharge depends, as will be shown later, on the aquifer properties, and this time may vary from a few minutes to a day. In the latter case, data from the most important part of the test is heavily influenced by the change in discharge, and special methods are developed here (Section 6.4) to analyse such data.

6.3 Effects Influencing Pumping Test Data

In deriving analytical formulas for the drawdown around a pumping well, it is assumed that the borehole can be considered a mathematical sink, i.e. a well with infinitesimal radius and no borehole storage.

Since this is never the case in practice, early data from the pumping well will be influenced by the effects of skin effect and borehole storage.

6.3.1 Borehole Damage and Skin Effect

Due to the method of drilling, the formation adjacent to the well bore is always more or less disturbed or damaged during drilling. This goes for both down-the-hole hammer drilling in hard rocks and mud drilling in soft formations.

Small particles will fill in the fissures of rocks, and mud will penetrate into the formation. Therefore, before the well is tested, it should be cleaned or jetted. As the cleaning of the well can seldom be carried out completely, the pumping test results are influenced by the restricted entry into the well bore, exhibiting a well loss due to the reduced area of the inflow face.

The drawdown in the well, therefore, will be greater than the drawdown that would be observed, had the skin effect not been present. This is shown in Figure 6.1 where the Theis curve represents the time-drawdown relationship that would be observed under ideal circumstances (Section 6.4).

During pumping, the well may develop and the skin effect become small and be negligible for all practical purposes compared to the theoretical drawdown, especially if the discharge rate is small.

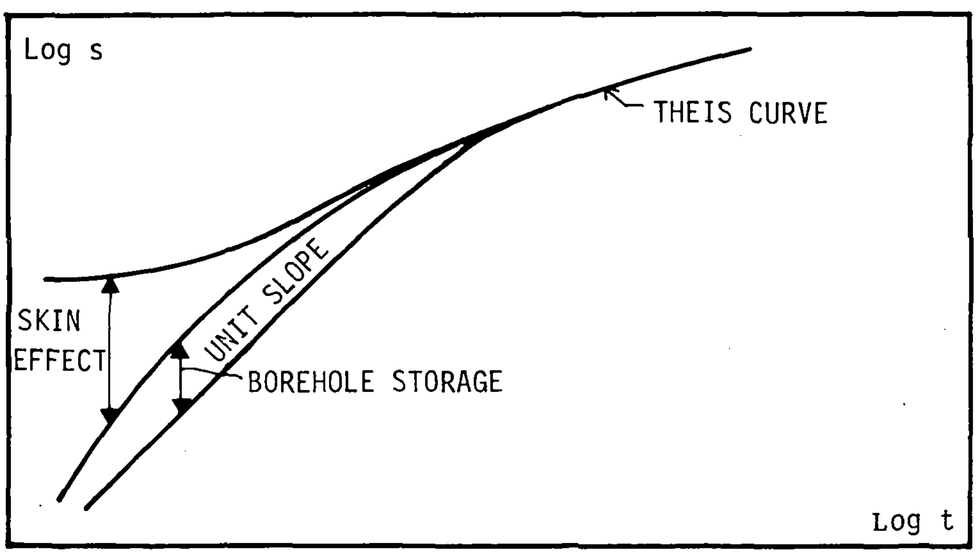


Fig. 6.1 The effect of skin and borehole storage
s = drawdown; t = time

In the skin effect is included well loss in the usual sense, i.e. a loss which is proportional to the square of the discharge. This loss is constant (if the discharge is constant) and is usually small compared to the drawdown when the discharge or the transmissivity is small.

6.3.2 Borehole Storage

Before water starts to flow from the formation into the well, a certain pressure drop must be established. If the volume of water stored in the well is large it may take some time before enough water has been pumped out to establish the pressure drop. During this period, which may last from a few seconds to some tens of minutes depending on the discharge rate, the drawdown in the well behaves as if a pipe is being emptied at at constant rate. Therefore, early data points will form a straight line with unit slope, as shown on Figure 6.1, when plotted on a logarithmic scale. When the drawdown in the well is large enough, water starts to flow into the well. The effect of borehole storage then vanishes and the drawdown will follow a Theis curve onwards.

6.3.3 Decrease of Saturated Aquifer Thickness

Groundwater development in phreatic aquifers results in a decrease of the saturated thickness of the aquifer. If the drawdown becomes comparable to the initial saturated thickness of the aquifer, the transmissivity can no longer be considered a constant, and corrections must be applied in order to be able to interpret drawdown data by means of standard methods.

Usually it is necessary to apply correction only to data from the pumping well where the drawdown is much larger than in observation wells.

If the drawdown is small compared to the initial saturated thickness of the aquifer, drawdown data can be analysed as if the aquifer were confined. Although this is not strictly correct, the errors introduced by doing this will be negligible.

6.4 Analysis and Interpretation of Pumping Test Data

6.4.1 Flow in Porous Media

A porous medium is characterised by a large storage capacity and a small hydraulic conductivity. The differential equation governing the flow of water in a porous medium is equivalent to the heat conduction equation, and in fact, many solutions of groundwater flow problems can be found in text books describing the flow of heat in solids.

Solutions to the most common flow problems connected to aquifer and well testing are described in the literature, and in the following sections solutions pertaining to the present study are presented and discussed. The solutions of the groundwater flow around a well discharging at a decreasing rate will be discussed in more detail as these solutions are not presented in the literature.

6.4.2 Constant Discharge Test

Nonleaky Aquifers

The most commonly used method of interpretation is that of Theis. The Theis solution describes the drawdown as a function of time and distance around a well producing at a constant rate. This solutions is expressed in the following way:

$$s = \frac{Q}{4\pi T} W(u), \text{ where}$$

$$W(u) = \int_u^\infty \exp(-x)dx/x \text{ (the well function)}$$

$$u = r^2 S/4Tt$$

s = drawdown

Q = discharge

T = transmissivity

S = storage coefficient

r = distance to observation point

t = time

The graph of the well function is shown graphically in Figure 6.2. The Theis solution is derived assuming a fully penetrating well, a homogeneous aquifer of infinite areal extent, and that water is released instantaneously from storage due to aquifer elasticity.

Although these rather strict assumptions could be expected to restrict the applicability of Theis' solution, practice has shown that this is not so. Even in nonhomogeneous aquifers, Theis curves are produced during pumping. Because of the nonhomogeneity, different curves are observed at different places in the aquifer, but these differences, if properly interpreted, can be used to explain the nature and degree of inhomogeneity.

The Theis solution is used to determine T and S. Normally these aquifer properties are determined by using drawdown curves from observation wells. If only a pumping well is available usually only T is determined, because the determination of S is too uncertain, due to the fact that the effective radius of the well is not known.

Very close to the pumping well or for large times ($u<0.05$) the Theis solution simplifies to the Jacob solution:

$$s = \frac{0.183Q}{T} \quad \log \frac{135Tt}{r^2S}$$

Data points should form a straight line when plotted on semi-logarithmic paper. The transmissivity is determined from the slope of the line. Again, the coefficient of storage should be determined from observation well data, but if the transmissivity is very small (u large) a value of r_w^2S can be estimated from pumping well data, r_w being the effective radius of the well.

Usually, recovery data after pumping has stopped is recorded. These data can be advantageously used if the discharge rate has been irregular within limits. Recovery data is analysed in the same way as drawdown data, and may prove to be a valuable help in determining aquifer parameters.

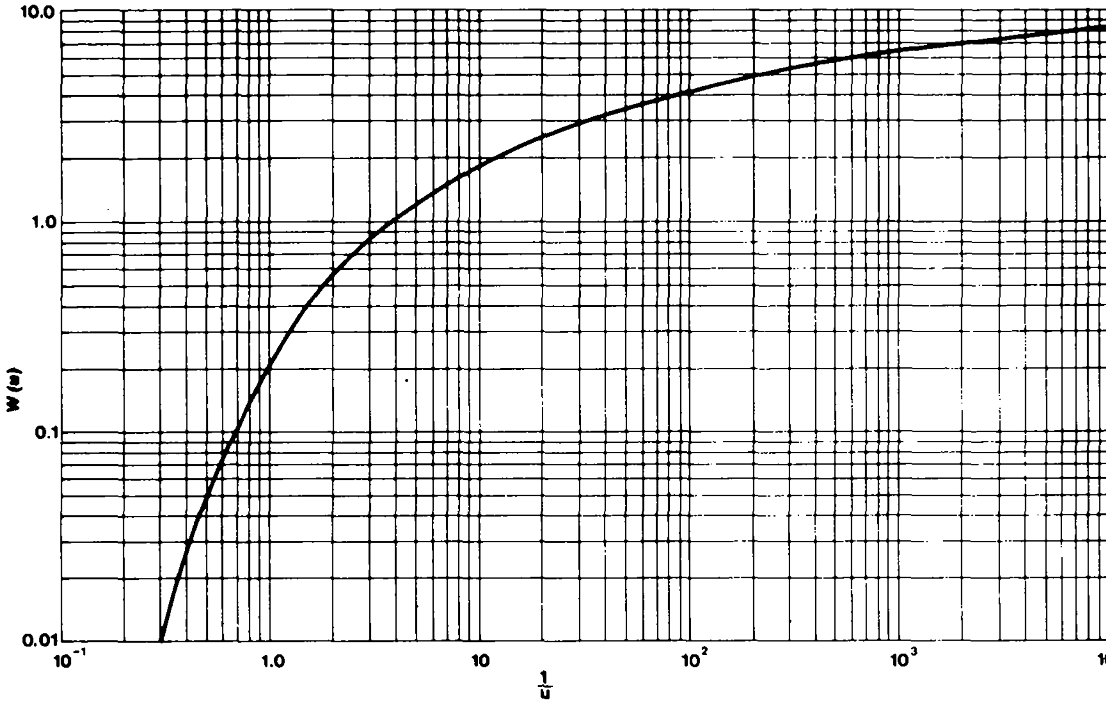


Figure 6.2 Non-leaky artesian type curve (Theis curve).

Leaky Aquifers

During some pumping tests it is observed that the drawdown becomes constant after a certain period which may vary from a few hours to several days. This is caused by leakage from adjacent layers. Assuming linear leakage, i.e. proportional to the drawdown, the drawdown around the pumping well is described as a function of time and space through the Jacob-Hantush formula:

$$s = \frac{Q}{4\pi T} \quad W(u,r/B)$$

$$W(u,r/B) = \int_u^\infty \exp\left(-x - \frac{(r/B)^2}{4x}\right) \frac{dx}{x}$$

$$B = (Tm'/P')^{\frac{1}{2}}$$

m' = thickness of confining layer through which leakage occurs

P' = permeability of confining layer through which leakage occurs

Other symbols are as previously defined. The graph of W(u,r/B) is shown in Figure 6.3. Using type curves, the transmissivity, storage coefficient and the leakage coefficient P'/m' may be determined from observation well data. If the transmissivity is very small sometimes pumping well data can be used to obtain T and approximate values of r_w^2S and r_w^2P'/m'.

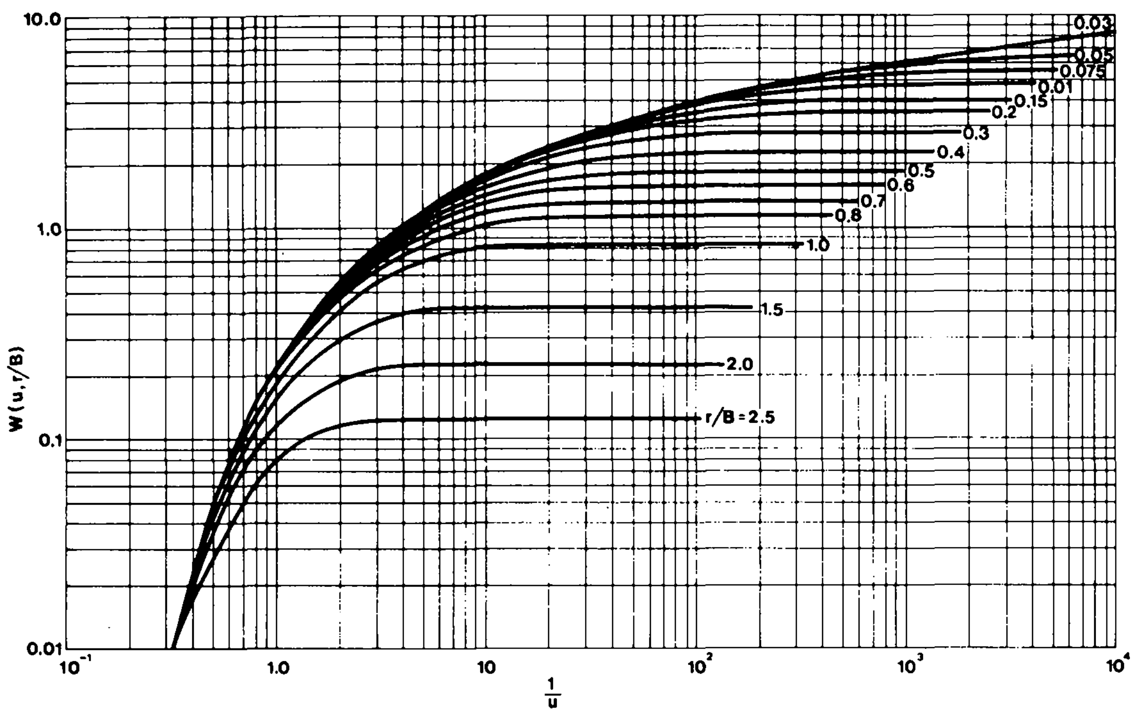


Figure 6.3 Leaky artesian type curves.

6.4.3 Variable Discharge Test

It is obvious that the drawdown formulas derived assuming a constant discharge rate do not apply if the variation in discharge is considerable.

Very little is written in the literature about wells with decreasing discharge. Hantush (1964) has developed an approximate method of analysis for different cases of discharge decay, and Abu-Zied and Scott (1963) developed a method of analysing distance-drawdown data around a well, discharging at an exponentially decreasing rate. However, since only pumping wells are available for this study, neither of these methods are very useful, and it is, therefore, necessary to develop methods of interpretation of pumping well data.

6.4.4 Theory

To find a solution to a given flow problem, one has to solve the differential equation governing the flow, and use this solution to satisfy the boundary conditions. This can be done rigorously using standard methods. But it can also be done by writing down the step response function, which is the aquifer response to a sudden stepwise change in the flow conditions.

A time ($t = 0$) a well starts to discharge at the rate $Q = Q_o f(t)$ where $f(t)$ is a function of time alone. The change in discharge is in the form of a sudden step and then maintained as the discharge function $f(t)$ prescribes. Using the Theis' assumption, the solution for the drawdown in the aquifer is the step response function:

$$s = \frac{Q_o}{4\pi T} \int_o^t f(t')\exp(-r^2S/4T(t-t'))\frac{dt'}{t-t'} \qquad (1)$$

In the case of a constant discharge, $f(t) = 1$ and using the substitution $x = r^2S/4T(t-t')$, the integral reduces to:

$$s = \frac{Q_o}{4\pi T} \int_{\frac{r^2S}{4Tt}}^{\infty} e^{-x}dx/x \qquad (2)$$

which is the Theis solution.

To obtain an analytical solution of the step response function $f(t)$ must be so that the integral can be evaluated. If not, numerical methods must be applied.

6.4.5 Well with Exponentially Descreasing Discharge in a Non-leaky Artesian Aquifer

The discharge function in this case decreases exponentially from an initial value Q_1 to an asymptotic value Q_2 (Figure 6.4) according to:

$$f(t) = Q_2(1+(\alpha d-1)e^{-kt}), \ \alpha = Q_1/Q_2$$

and k is the time scale of the discharge function.

The step response function now reads:

$$s = \frac{Q_2}{4\pi T} \int_o^t (1+(\alpha-1)e^{-kt'})\exp(-r^2S/4T(t-t'))\frac{dt'}{t-t'}$$

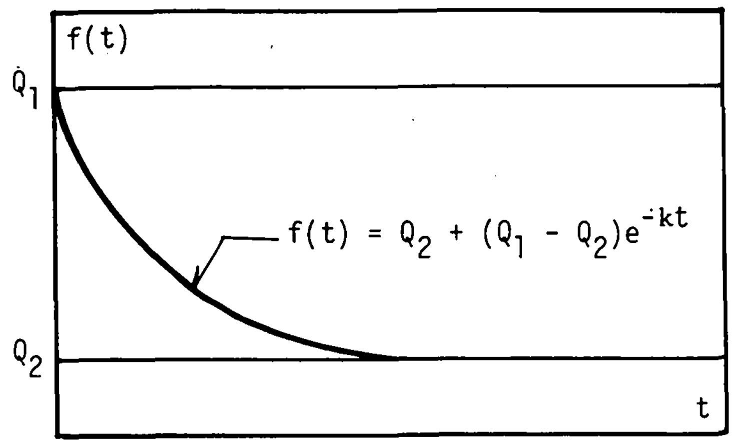


Figure 6.4 Exponentially decreasing discharge function.

Substituting again $x = r^2S/4T(t-t')$, the integral is reduced to:

$$s = \frac{Q_2}{4\pi T} \left\{ \int_{\frac{r^2S}{4Tt}}^{\infty} (\exp{-x})dx/x + (\alpha-1)e^{-kt} \int_{\frac{r^2S}{4Tt}}^{\infty} \exp(-x-kr^2S/4x)dx/x \right\}$$

or in symbolic form:

$$s = \frac{Q_2}{4\pi T} (W(u) + (\alpha-1)e^{-\beta^2/4u}W(u\beta)) \qquad (3)$$

where $u = r^2S/4Tt$ and $\beta^2 = r^2kS/T$.

The solution is composed of two parts, the Theis formula and a second term which tends to zero as time increases. After sufficiently long time the drawdown will follow a Theis curve corresponding to the final steady yield Q_2, as if there had been no initial decrease of discharge.

During the very initial period, the drawdown follows a Theis curve corresponding to the initial discharge Q_1. During the intermediate period which is the most important period of the test there is a transition from one Theis curve to the other.

The solution is shown graphically in Figure 6.5, for $\alpha = 5$ and different values of β. These curves are called type curves.

β is the dimensionless time scale of the step response function which depends on the time scale of the discharge function as well as the aquifer hydraulic properties. The smaller the aquifer diffusivity T/S, the faster the steady discharge is reached.

In some cases the duration of the test is not long enough to define the steady discharge rate, in which case the discharge function is $f(t) = Q_1 e^{-kt}$. The solution to the problem is found from Eq.(3) to be

$$s = \frac{Q_1}{4\pi T} e^{-\beta/4u} W(u,\beta) \tag{4}$$

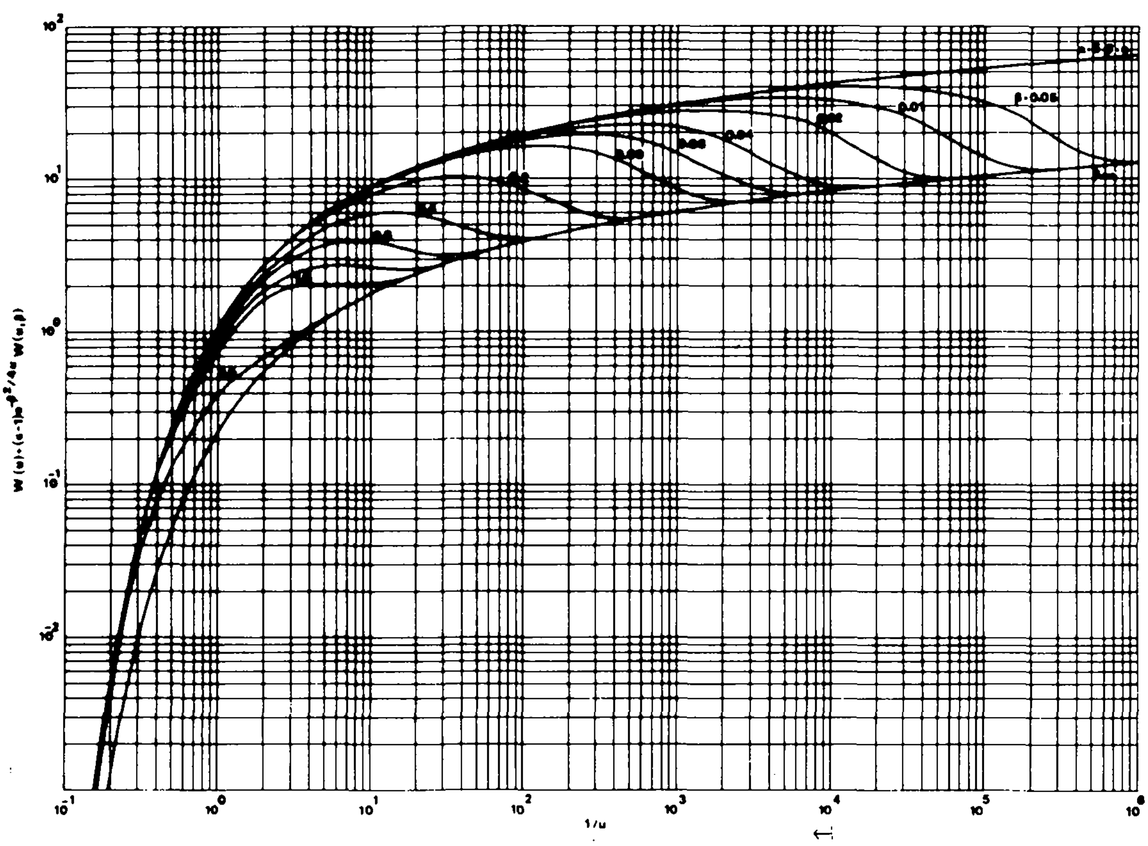


Figure 6.5 Type curves, exponentially decreasing discharge in a non-leaky aquifer; $\alpha = 5$.

The corresponding type curves are shown in Figure 6.6. The drawdown follows a Theis curve in the beginning of pumping and then rapidly recovers.

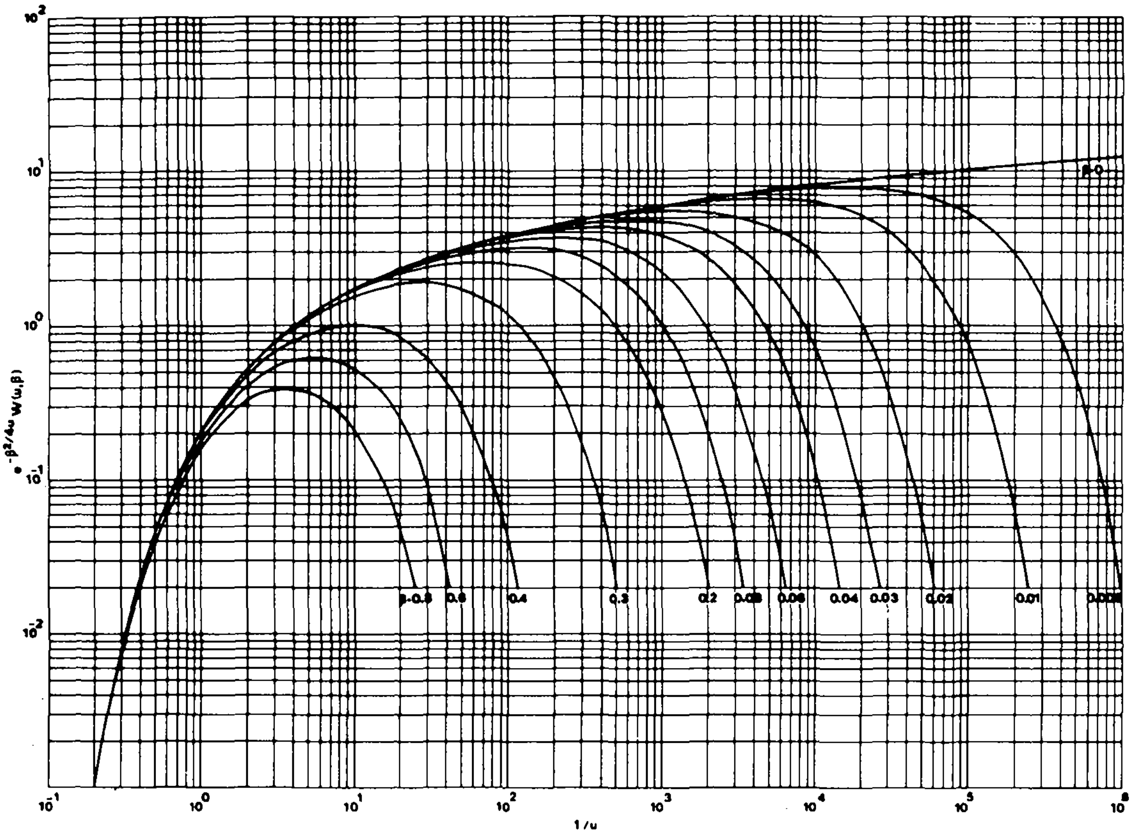


Figure 6.6 Type curves, exponentially decreasing discharge in a non-leaky aquifer. No steady discharge.

To illustrate the effect of α, Eq.(3) is shown in Figure 6.7 for different values of α with β = 0.2.

The effect of increasing α is simply a larger deviation from the late Theis curve. The larger the value of α, the larger the deviation.

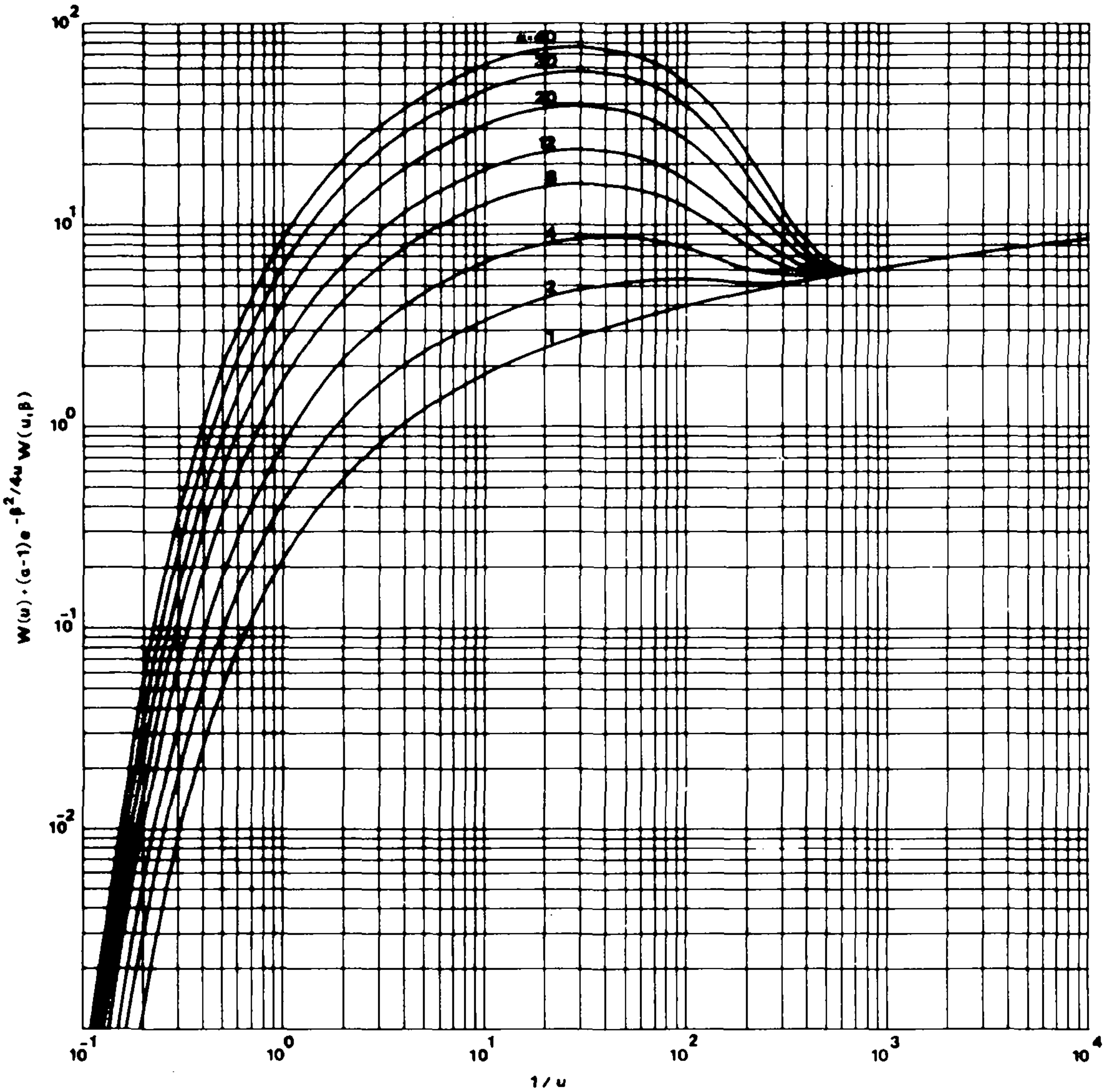


Figure 6.7 Type curves, exponentially decreasing discharge in a non-leaky aquifer; $\beta = 0.2$.

6.4.6 Well with Hyperbolically Decreasing Discharge in a Non-leaky Artesian Aquifer

The discharge function in this case is:

$$f(t) = Q_2\left(1+ \frac{\alpha-1}{kt+1}\right), \quad \alpha = Q_1/Q_2$$

as shown in Figure 6.8 next page.

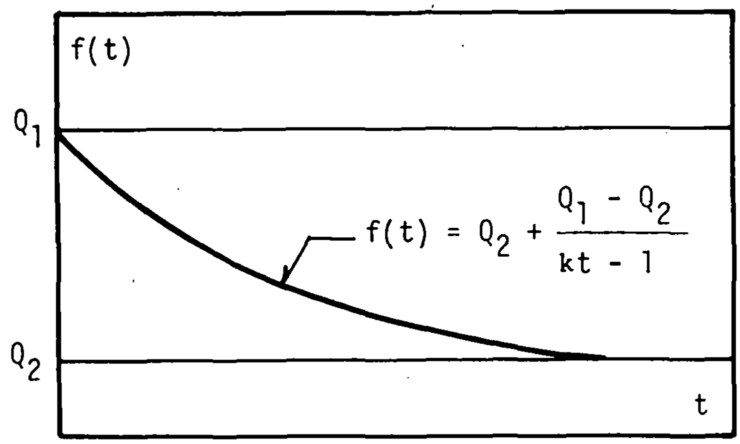


Figure 6.8 Hyperbolically decreasing discharge function.

The step response function reads:

$$s = \frac{Q_2}{4\pi T} \int_o^t \left(1 + \frac{\alpha-1}{kt'+1}\right) \exp(-r^2S/4T(t-t')) \frac{dt'}{t-t'}$$

Using the same substitution as before and evaluating the integral yields after some reduction:

$$s = \frac{Q_2}{4\pi T} \left(W(u) + \frac{(\alpha-1)\exp(-1/(1/u + 4/\beta^2))}{1 + \beta^2/4u} W(u-1/(1/u + 4/\beta^2))\right) \quad (5)$$

Eq.(5) is shown graphically in Figure 6.9, with $\alpha = 5$, and for different values of β.

It is noted that this family of curves has a close resemblance to the curves of Figure 6.5, and the same comments as before could be applied as the discharge function is qualitatively the same.

If the test is too short to reveal the steady discharge rate Q_2, then as before Eq.(5) is reduced, and the result is:

$$s = \frac{Q_1 \exp(-1/(1/u + 4/\beta^2)) W(u-1(1/u + 4/\beta^2))}{4\pi T(1 + \beta^2/4u)} \quad (6)$$

The graph of Eq.(6) is shown in Figure 6.10 for different values of β.

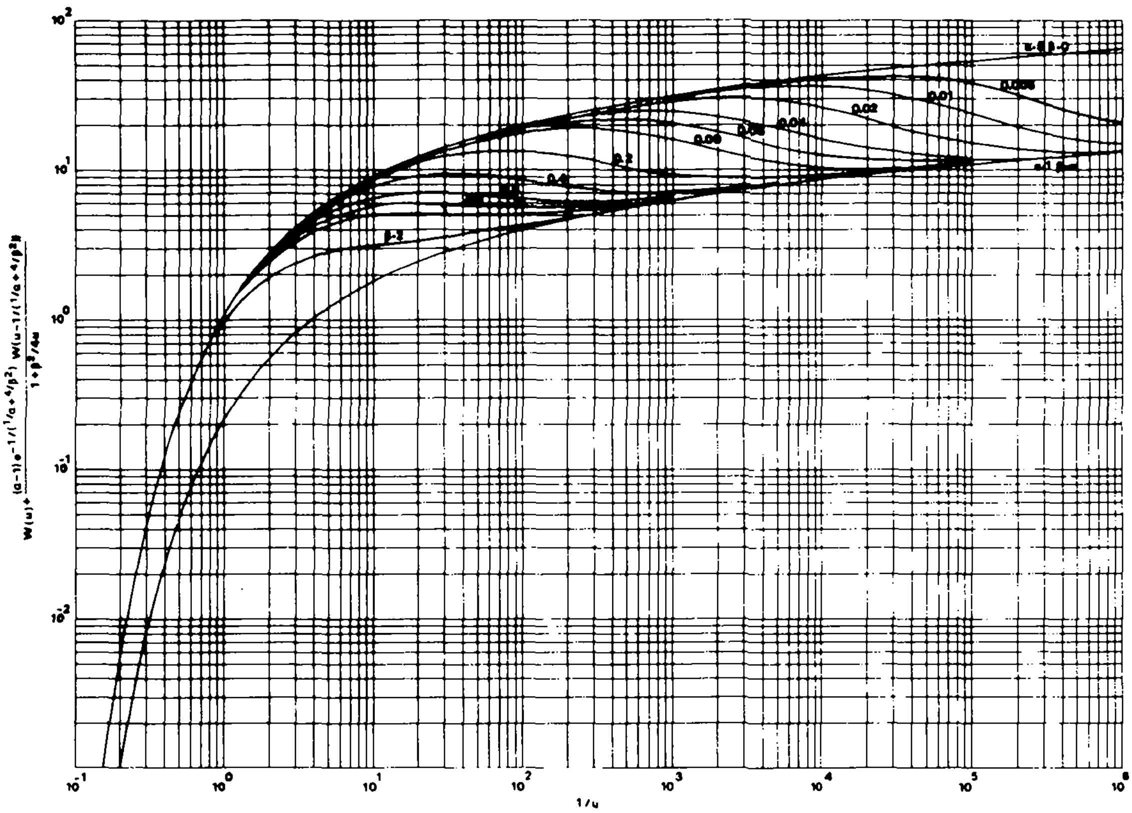


Figure 6.9 Type curves, hyperbolically decreasing discharge in a non-leaky aquifer; $\alpha = 5$.

6.4.7 Well with Linearly Decreasing Discharge in a Non-leaky Artesian Aquifer

The discharge function is taken to be $f(t) = Q_1\ (1-kt)$ and is shown in Figure 6.11.

The step response function is:

$$s = \frac{Q_1}{4\pi T} \int_o^t (1-kt')\exp(-r^2S/4T(t-t'))\ \frac{dt'}{t-t'}$$

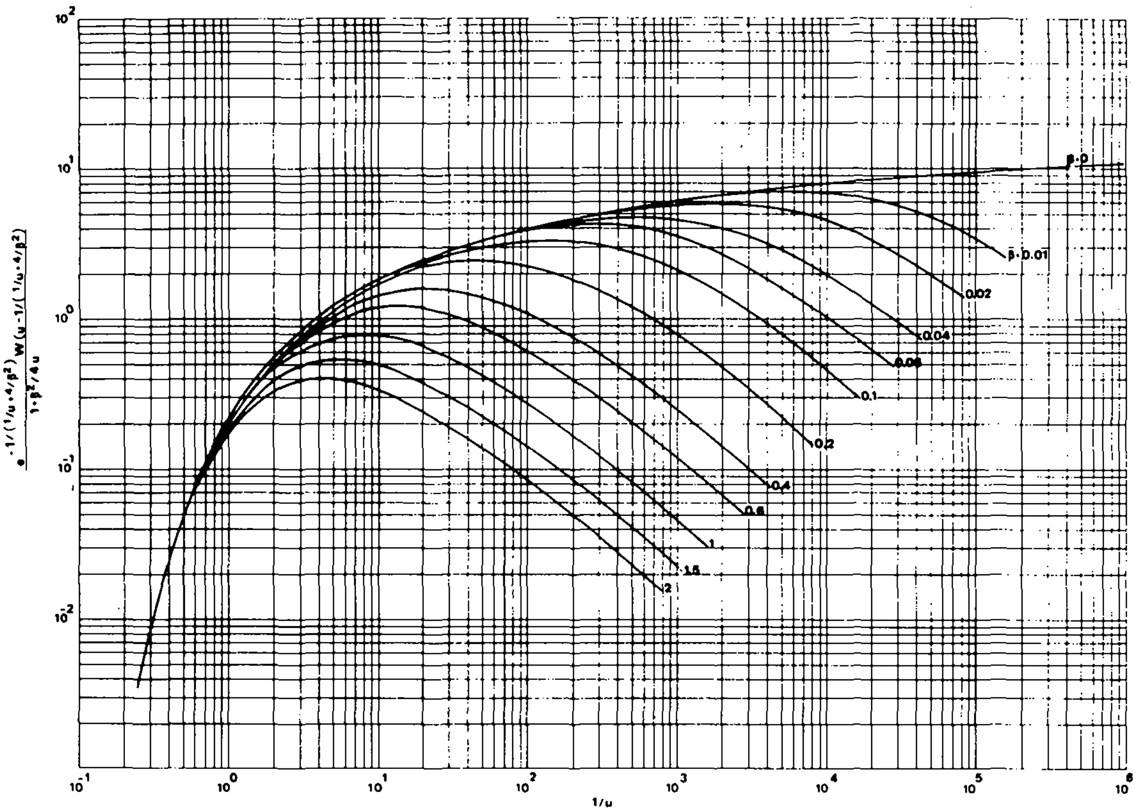


Figure 6.10 Type curves, hyperbolically decreasing discharge in a non-leaky aquifer. No steady discharge.

Proceeding in the usual way, the result is:

$$s = \frac{Q_1}{4\pi T}\,(W(u)(1-\beta^2/4(1/u + 1)) + e^{-u}/u) \qquad (7)$$

The graph of Eq.(7) is shown in Figure 6.12.

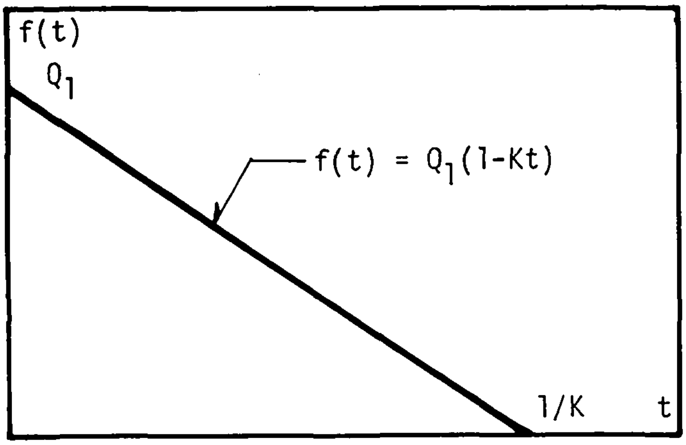


Figure 6.11 Linearly decreasing discharge function.

6.4.8 Well with Exponentially Decreasing Discharge in a Leaky Artesian Aquifer

The discharge function is the same as the one used in a non-leaky aquifer, i.e. $f(t) = Q_2\ (1 + (\alpha-1)e^{-kt})$ (Figure 6.2).

The step response function in this case is:

$$s = \frac{Q_2}{4\pi T} \int_0^t (1 + (\alpha-1)e^{-kt'}) \exp(-r^2 S/4T(t-t') - \beta^2 T(t-t')/r^2 S)\ \frac{dt'}{t-t'}$$

Proceeding in the usual way the integral can be reduced to:

$$s = \frac{Q_2}{4\pi T}\ (W(u,\delta) + (\alpha-1)e^{-\beta^2/4u}\ W(u,\ (\delta^2+\beta^2)^{\frac{1}{2}})) \qquad (8)$$

where $\delta = r/B$. All other symbols have been previously defined.

The graph of Eq.(8) is shown in Figure 6.13. The type curves behave qualitatively in the same manner as those shown in Figure 6.5, except that the final state is not a Theis curve, but the family of Jacob-Hantush curves.

6.4.9 Interpretation Procedure

Interpretation of pumping test data by means of type curves is carried out by the Match Point procedure, the explanation of which is given in many text books on hydrogeology.

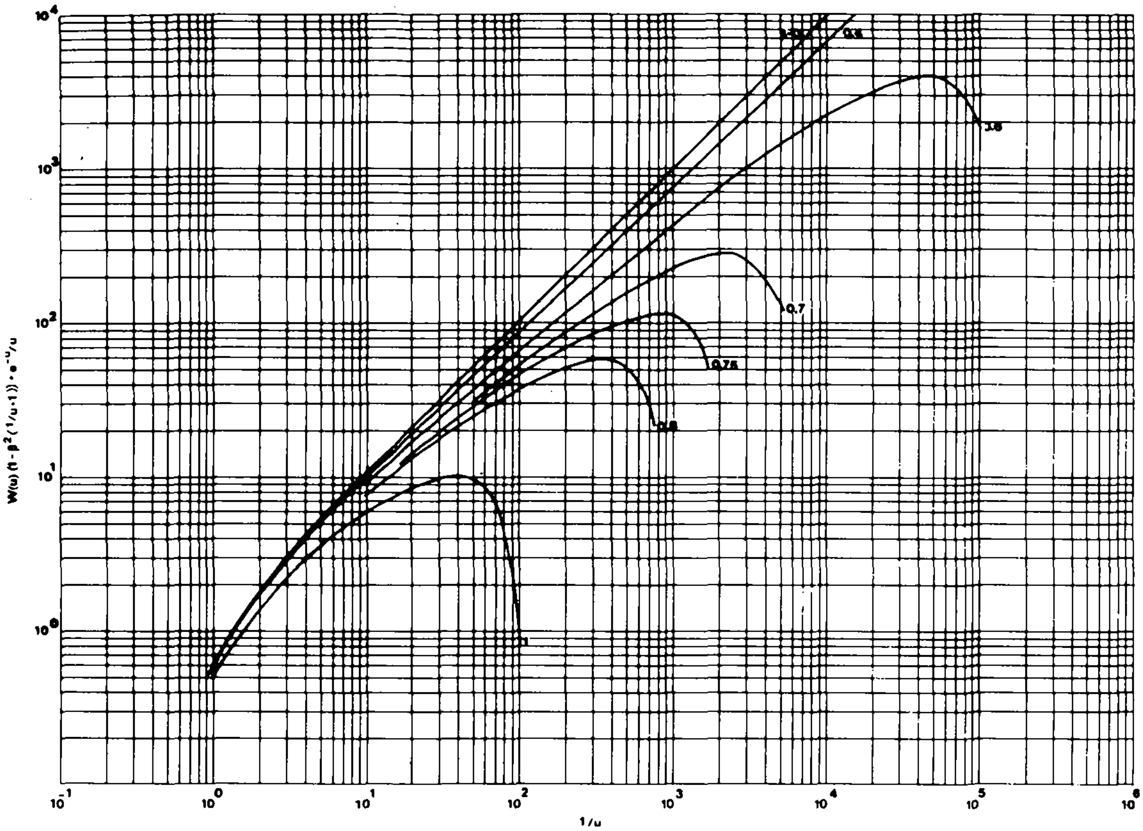


Figure 6.12 Type curves, linearly decreasing discharge in a non-leaky aquifer.

The procedure shortly is that drawdown data is plotted on logarithmic paper and the type curve(s) are plotted also on logarithmic paper having the same scale.

The type curve for the particular case fitting the data curve best is selected, and a point common to both plots is selected. This point is the Match Point. For convenience the type curve sheet coordinates are taken (F(u), u) = (1,1) in which u is the abcissa and F(u) the ordinate. The corresponding coordinates on the data sheet are (s,t).

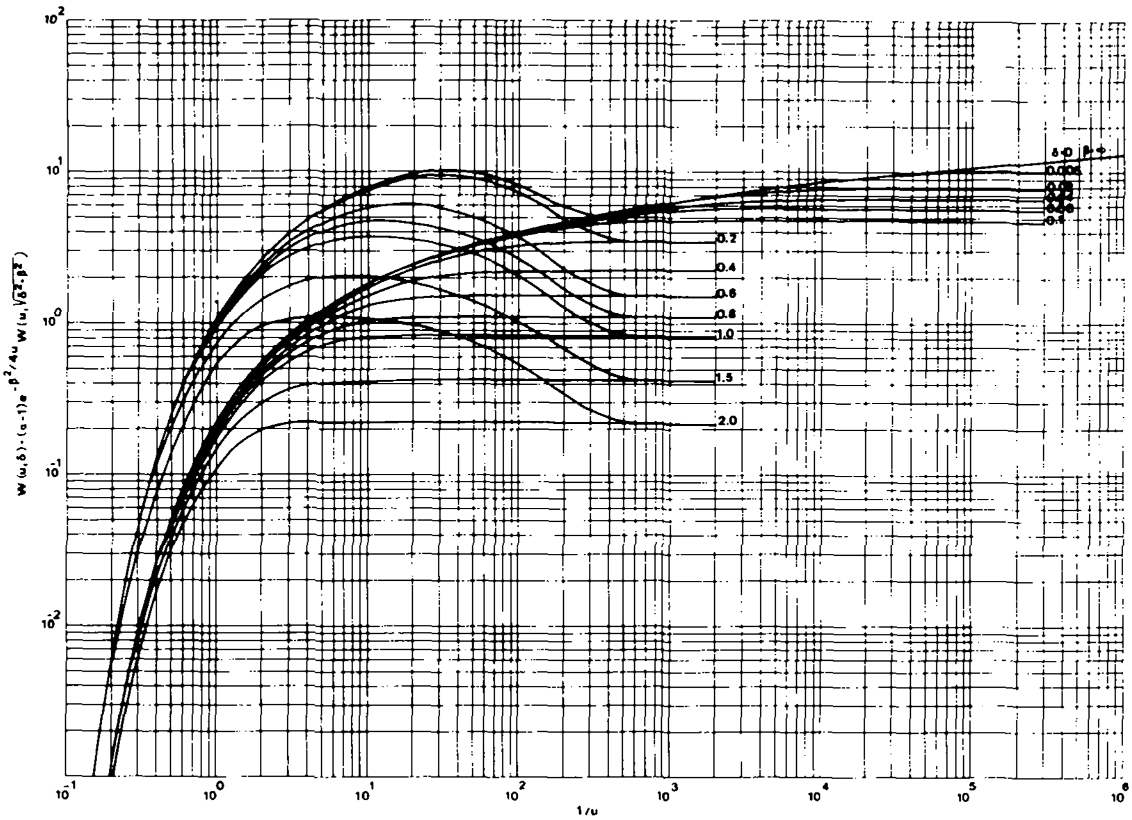


Figure 6.13 Type curves, exponentially decreasing discharge in a leaky aquifer. $\alpha = 5$, $\beta = 0.2$.

From this the transmissivity, storage coefficient and other parameters can be determined.

For each type of aquifer and test method the formulas are listed below.

Non-leaky Aquifer

Any type of discharge:

$$T = \frac{Q}{4\pi s}$$

$$S = 4Tt/r^2$$

If the discharge is decreasing, the time scale k is determined from discharge data. When T and S (or $r_w^2 S$) are determined, β can be calculated and checked with the actual value used from the type curve selected. Any deviation requires an explanation. This actually offers a built-in test on the results of the interpretation.

Leaky Aquifers

Constant discharge and exponentially decreasing discharge:

$$T = \frac{Q}{4\pi s}$$

$$S = 4Tt/r^2$$

$$P'/m' = \frac{(r/B)^2 T}{r^2} \quad \text{where:}$$

r/B is obtained from the type curve selected. In the case of an exponentially decreasing discharge there are two parameters to choose, β and δ, which makes the number of possible type curves very large, and it may prove very difficult to find a correct type curve. β can be used in the same way as before to check the interpretation results, but this assumes that the chosen value of δ is correct.

6.4.10 Discussion of Interpretation Procedure

The Match Point method as discussed so far is strictly only for observation well data. If u is very large, which happens for small T-values, pumping wells will produce a distinctive and well defined drawdown curve which can be matched to a type curve.

However, the method has one disadvantage which may make the matching difficult, namely that the effects of well loss and well storage are included in the drawdown. Well losses result in a greater drawdown in the well than theoretically prescribed, and well storage effects result in smaller drawdowns. Therefore, when applying type curves to pumping well data, care must be taken to identify these effects and adjust the interpretation procedure accordingly.

If the test is long enough to define the resulting Theis curve after the discharge has become steady, transmissivity and storage coefficient should be well determined, but if the test is terminated during the transient period, which has very often been the case, some uncertainty is involved.

In Figure 6.14 discharge and drawdown curves are shown together for a particular set of parameters, in the case of a non-leaky aquifer and exponentially decreasing discharge. It appears from the figure that the drawdown starts to follow the Theis curve a little sooner than the instant the discharge becomes steady. For instance, if $\beta = 0.2$, then the discharge rate is constant after 300 minutes, and the Theis curve is reached practically around 200 minutes. To define the Theis curve properly, at least one decade should be obtained, i.e. the test should continue up to approximately 3500 minutes of pumping.

Another disadvantage connected to pumping wells is that the effective radius of the well is not known. Depending on the degree of weathering and jointing the effective radius may vary considerably. Therefore, a proper distance r cannot be used in the formulas, and instead of calculating the storage and leakage coefficients themselves, the quantities $r_w^2 S$ and $r_w^2 P'/m'$ shall be given, as these are also measures of the storage capacity and leakage.

6.4.11 Flow in Fractured Rock

Fractures are characterised by a large flow capacity and a small storage capacity. In some cases flow occurs both in the fractures and in the blocks if these are porous (sandstone). Such a flow system forms a double porosity system with two modes of flow: a large flow and small storage capacity system (fractures) and a small flow and a large storage capacity system (porous blocks).

Flow in fractured rocks have been relatively recently investigated, and the result of this research can be summarised as follows:

For large times, when the radius of the cone of depression has become large compared to a characteristic length of the fracture system (e.g. the distance between fractures) the overall flow pattern becomes similar to that of a porous medium which means that the Theis method of analysis may be applied.

For small times, however, it may be possible to distinguish clearly between porous medium and fracture flow. Fracture storage, although small, may dominate the flow pattern during the first few minutes of the pumping test, which can be identified by the fact that data points should form a straight line with half unit slope when plotted on logarithmic paper. This period, however, may coincide with the period during which the well storage effect is present, which may render the fracture storage period indistinguishable.

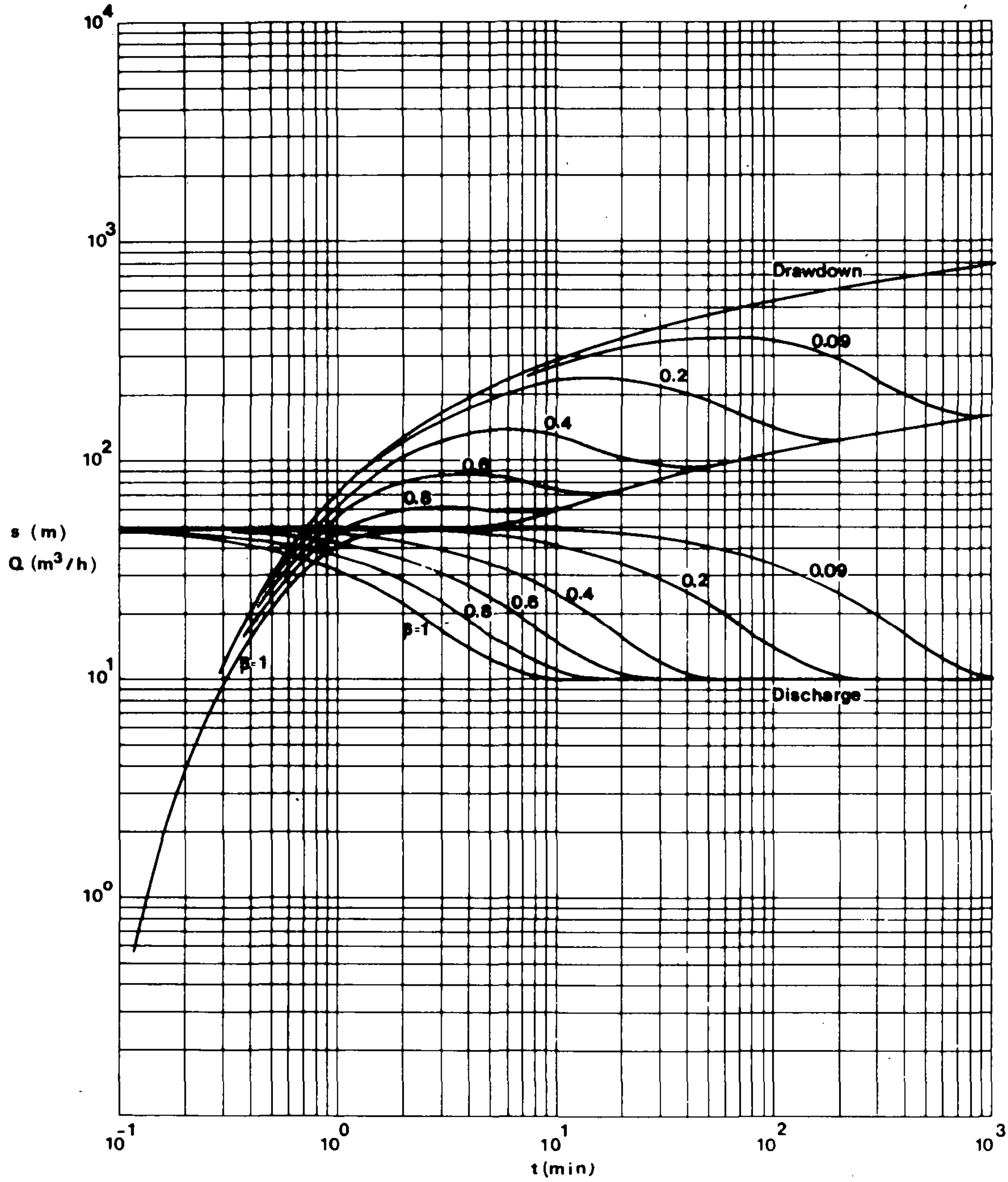


Figure 6.14 Comparison of discharge and drawdown decay. Exponentially decreasing discharge in a non-leaky aquifer.
$T = 10^{-5}\ m^2/s,\ r^2S = 10^{-3}\ m^2,\ \alpha = 5.$

After some time, the reduced pressure in the fractures may introduce a flux of water from the blocks into the fractures. This causes a transition period to occur, at the end of which data points start following a Theis curve.

It is now obvious that when testing wells in fractures or slightly weathered rocks, the first say ten minutes of pumping are extremely important because the analysis of only the early period data can clearly reveal the true nature of the aquifer tapped.

If the system of fractures degenerates into one single fracture, special methods of analysis must be applied, but this subject is beyond the scope of this discussion.

So far the discussion on fracture flow has assumed a constant discharge rate. If the discharge decreases the mathematics involved in producing type curves will be extremely complicated and can be solved only by using large digital computers. This is again beyond the scope of this study.

It is obvious that the terms transmissivity and storage coefficient have different physical meanings for fracture flow and porous media flow. For engineering purposes these terms will be used in connection with fractured aquifers, but it should be understood that they are actually only equivalent aquifer parameters describing the long term flow pattern.

6.5 Statistical Analysis of Pumping Test Results

Statistical analysis of pumping test results are carried out in order to obtain a picture of the behaviour of wells within certain groundwater domains where a certain uniformity is expected to exist.

It is a for a long time established fact that the specific capacities of wells in aquifers of the same geohydraulic nature follow a logarithmic probability distribution. Values of specific capacities plotted against the percentage of wells on logarithmic probability paper will form a straight line in such aquifers. These plots have been made for wells across the African and post-African land surfaces and across alluvial deposits. Further, wells from the study regions and from other regions as well have been analysed this way to obtain a statistical background to determine expected yields from the Basement Complex.

An other important statistical method is the analysis of yields of wells as a function of drilling depth. These plots are made for wells drilled into the Basement Complex and give a clear indication of where the productive aquifer horizons are situated depthwise.

The graphs mentioned are all shown in Volume 9, Chapter 7, together with graphs showing distribution of water levels, drilling depths, and saprolite thicknesses.

These graphs have proven their importance for the assessment of the groundwater conditions across the Basement Complex, the Karoo basins, and the Neogene alluvial deposits.

6.6 Organisation of Pumping Tests

6.6.1 Equipment

Pumping tests were scheduled to be performed with a pumping test unit provided by MAJI. This unit, however, turned out to be inoperational, and all attempts to find spare parts for its generator were unsuccessful.

It was then decided to purchase a new complete pumping test unit. This unit comprised the following main components:

4 - GRUNDFOS SP4-6 submersible pumps
1 - GRUNDFOS SP4-16 submersible pump
1 - GRUNDFOS SP4-19 submersible pump
2 - HONDA generators ES 4500

The equipment turned out to be well-suited for the purpose. The discharge and head range of the pumps covered all testing requirements, and the generators gave no operation problems.

6.6.2 Field Work

Field work was performed with a MAJI crew of seven pump test technicians and the counterpart hydrogeologists under supervision by the Consultant. The MAJI crew were trained in pump installation procedures as well as general maintenance of the equipment.

The counterparts were trained in all pumping test procedures.

Pumps were installed with a hydraulic crane mounted on a 10 ton truck used for transport of the testing unit. Several pumping tests were performed on some boreholes in order to find the discharge rate best suited for the borehole yield.

Water level measurements were recorded with electrical water level instruments. Discharge rates were recorded with a stop watch and a container with a volume of 27.6 litres.

7. GROUNDWATER CHEMISTRY

7.1 Introduction

The results of the analyses performed on water samples are given on data sheets in Volume 10 B, Appendix 3. Selected analyses are presented on Drawing II-11, Groundwater Chemistry.

The explanation of the groundwater chemistry is done by means of Piper-diagrams. This method immediately classifies the groundwater in main types and explains its origin. In the following the principles of the trilinear Piper-diagrams are explained. The description is based on Walton (1970).

7.2 The Trilinear Piper-Diagram

The trilinear Piper-Diagram developed by Piper (1953) is an effective tool in segregating analysis data for critical study with respect to sources of the dissolved constituents in groundwaters. It is also useful in defining the modifications in the character as groundwater passes through an area. (Walton, 1970).

The groundwater is treated substantially as though it contained three cation constituents (Mg, Na, Ca) and three anion constituents (Cl, SO_4, HCO_3). Less abundant constituents than these major cations and anions are summed with the major constituents. The common and minor constituents of groundwater are shown in Table 7.1.

Cations	Anions
Alkaline earths	Weak acids
Calcium (Ca^{++})	Bicarbonate (HCO_3^-)
Barium (Ba^{++})	Carbonate (CO_3^{--})
Strontium (Sr^{++})	Tetraborate ($B_4O_7^{--}$)
Magnesium (Mg^{++})	Orthophospate (PO_4^{3-})
Alkalies	Strong acids
Sodium (Na^+)	Sulphate (SO_4^{--})
Potassium (K^+)	Chloride (Cl^-)
Rubidium (Rb^+)	Bromide (Br^-)
Lithium (Li^+)	Fluoride (F^-)
Ammonium (NH_4^+)	Nitrate (NO_3^-)

Table 7.1 Common and minor constituents of groundwater (After Walton, 1970)

The Piper trilinear diagram (Figure 7.1) combines three distinct fields for plotting, two triangular fields at the lower left, and lower right, respectively, and an intervening diamond shaped field. In the triangular field at the lower left, the percentage reacting values of the three cation groups (Ca, Mg, Na) are plotted as a single point according to conventional trilinear coordinates. The three anion groups (HCO_3, SO_4, Cl) are plotted likewise in the triangular field at the lower right. (Walton, 1970).

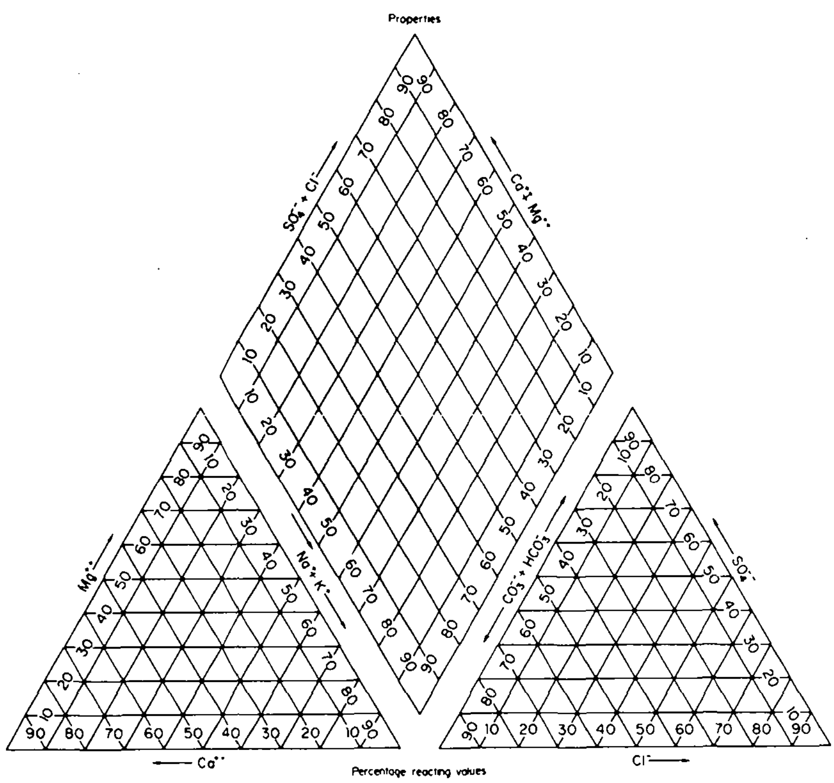


Figure 7.1 Piper trilinear diagram

The central diamond shaped field is used to show the overall chemical character of the groundwater by a third single point plotting, which is at the intersection of rays projected from the plottings of cations and anions. Because the conductivity commonly is decisive in many problems of interpretation, it is convenient to indicate the plotting in the central field by a circle whose area is larger, the larger the conductivity of the water.

8. DRILLING PROGRAMME

8.1 Introduction

An account of the objectives and results of the drilling programme is given in Volume 9, Chapter 11. Here the methodology and more practical aspects of the drilling are described.

8.2 Organisation

8.2.1 Staff

The project drilling engineer arrived in October 1981 and the mechanical advisor in March 1981. A drilling foreman was employed in October and November 1981 to assist with the completion of the Ruvuma Programme.

The drilling crews provided by Maji, which were originally too many for efficient operation of the rigs and placed a severe logistical load on the programme, were reduced to achieve an optimum performance.

8.2.2 Transport

Maji supplied one 7 ton support truck for Rig 53 and Danida provided two 7 ton and two 10 ton trucks. 5 Land Rovers were used for the Consultants' and MAJI's Drilling Staff.

8.2.3 Communications

These were maintained by fixed and mobile radios.

8.2.4 Fuel

The Consultants made a supply agreement with a local oil company in May 1981 and this worked satisfactorily. Prior to May some 27 days were lost waiting for fuel. The Consultants also had 5 fuel storage tanks built in Dar-es-Salaam.

8.2.5 Planning

In planning the actual drill sites, consideration had to be given to access for Rig 45 which weighed some 28 tons. Access therefore was limited to major roads in the Regions. Rig 45 for example could not be used to drill in the area south of Tunduru due to bridge loading limits. A similar situation occurred with Rig 53 on the Usangu Flats, Mbeya Region.

8.3 Equipment

8.3.1 Deep Boreholes - Schramm Rig 45

The MAJI T64 Schramm Rig 45 was overhauled and re-equipped to use 4 main drilling methods. These were in increasing order of technical and logistical complexity:

- Straight rotary drilling with tricone roller or fishtail rock bits using air or foam as a circulating (flushing) agent.
- Down-the-hole air hammer drilling using straight air or foam for circulation.
- The Atlas Copco ODEX down the hole hammer and continuous reaming system using welded casing and foam circulation.
- Mud rotary drilling using tricone or fishtail rock bits and a bentonite or "revert-type" based drilling mud as a circulating agent.

In practice air hammer and mud drilling proved suitable for all the drilling conditions encountered. The Rig 45 mud pump drive system, however, broke down during the Ruvuma drilling.

To supplement the Schramm piston compressor mounted on Rig 45, the Consultants imported an Atlas Copco XRH 350 Compressor for the deep drilling. This compressor was mounted on a 7 ton truck. The rig compressor was found to be producing nowhere near the specified capacity of 4.25 cfm at 250 psi (200 l/s at 18 bar). The Atlas Copco XRH 350 performance is 750 cfm at 275 psi (350 l/s at 20 bar).

8.3.2 Shallow Boreholes - CME Rig 53

This rig was equipped solely to drill using 6 5/8" flight-augers. While originally the CME rig was equipped for diamond core and rotary drilling, MAJI did not wish to have the rig re-equipped. Drilling operations with this rig were, therefore, limited to auger drilled holes until solid formation was encountered or to a maximum depth of 36 metres.

8.3.3 Operation and Maintenance of the Rigs

Both the Schramm Rig 45 and the CME Rig 53 have been used for six or seven years prior to the Consultants overhauling them.

Both rigs were, therefore, of uncertain mechanical condition and numerous minor breakdowns and equipment failures occurred to both rigs.

Regarding the major breakdowns to the back axle of the Schramm Rig 45, MAJI have had some 20 Schramm Rigs of which 14 were mounted on Volvo chassis - this includes Rig 45. Of the 14 Volvo mounted rigs no fewer than eight have had major back axle and drive train breakdowns. The Consultants' problems with the Rig Volvo included 2 broken half shafts, a completely smashed differential, a completely sheared off back axle (this was welded back on in the field), and a rear suspension failure which nearly resulted in overturning the rig.

Altogether some 126 days were lost due to major breakdowns to Rig 45. A similar loss of time occurred because of breakdowns to Rig 53.

8.4 Drilling Methods and Well Construction

The general policy was to drill the deep holes as efficiently as possible using the simplest method. In practice only 3 holes, Nos 3/81, 5/81 and 276/81 were drilled with mud. Down-the-hole air hammers were used to drill the rest of the holes. Experience gained of the geology at 4 sites in Tunduru District (Nos 257, 259, 260 and 261/81) showed that mud drilling would be preferred for the first 50 to 60 metres of drilling when constructing production boreholes.

Drilling with Rig 53 was limited to straight flight augering. This limited the use of the rig to areas of unconsolidated to semi-consolidated formations. Conditions in the Karroo in Ruvuma where very clayey horizons blocked both the screening and the borehole walls, showed up the deficiencies of this method of drilling. Elsewhere in outwash and alluvial material the augered holes could be easily cleaned using the Atlas Copco Air Compressor. High pressure water flushing with a surging action would have been needed in Ruvuma.

The boreholes drilled by both rigs were completed in one of four ways.

- Using plain surface steel casing and open hole - i.e. holes Nos 4/81 and 76/81. This proved satisfactory for boreholes drilled in the less weathered lower saprolite zone. Experience showed, however, that a close geological control was required if the hole is drilled for production purposes, otherwise too many fines and clay enter the borehole if the plain casing is not set deep enough.
- Using six inch UPVC plain and slotted plastic pipes. Most of the early Auger Rig holes at Kyela were satisfactorily completed in this manner.
- Using four inch UPVC plain pipes and purpose made screening. This construction method was the most widely used and produced wells suitable for production purposes.
- At the beginning of the deep drilling programme one well (BH 2/81) was completed using 6" wire-wound screening.

One aspect of the auger well drilling was the difficulty of cleaning the hole and setting the casing. An auger rig would need some kind of high pressure jetting and surging equipment available to clean production boreholes satisfactorily.

Appendix 2

Pumping Test Data

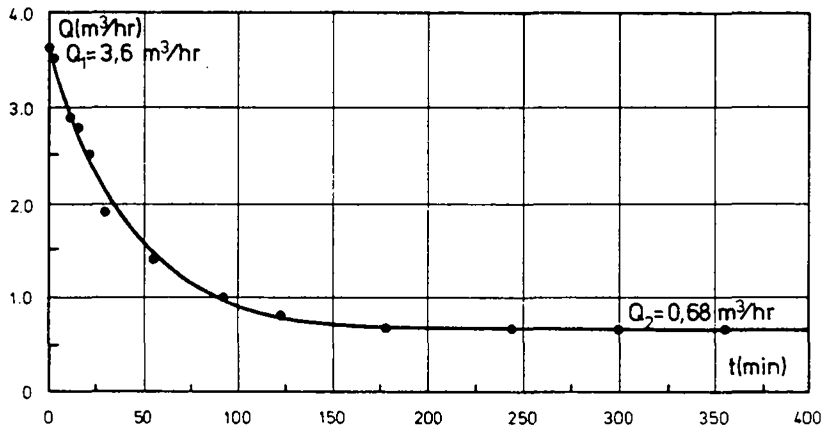
IRINGA

THE UNITED REPUBLIC OF TANZANIA

REGION: IRINGA	DISTRICT: IRINGA	VILLAGE: CHAMDINDI	B.H. No. 13/76 CCKK No.

DISCHARGE DATA

$Q = 0.68 + 2.92 \exp(-0.025t), m^3/hr$



α = 5,3

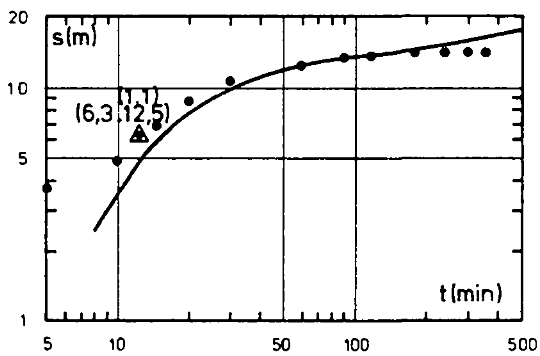
k = 0,025 min^{-1}

Type of decay: Exponential

Test performed: 1976.2.4.

DRAWDOWN DATA

Type curves for a non leaky aquifer are used.



$k_{cal} < k_{obs}$ indicating well losses.

T = 2,4 x 10^{-6} m^2/sec.

r_w^2S = 0,0073 m^2

$r_w^2P^1/m^1$ = m^2/sec.

ε = 0,9

k_{obs} = 0,025 min^{-1}

k_{cal} = 0,016 min^{-1}

Q/S_w = 0,05 m^3/hr/m

T = 4 x 10^{-6} m^2/sec.

RECOVERY DATA

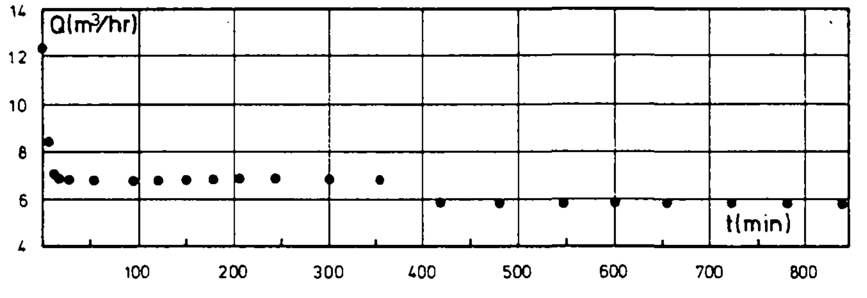
T = m^2/sec.

r_w^2S = m^2

THE UNITED REPUBLIC OF TANZANIA

REGION: IRINGA	DISTRICT: IRINGA	VILLAGE: IKENGEZA	B.H. No. 14/76 CCKK No.

DISCHARGE DATA



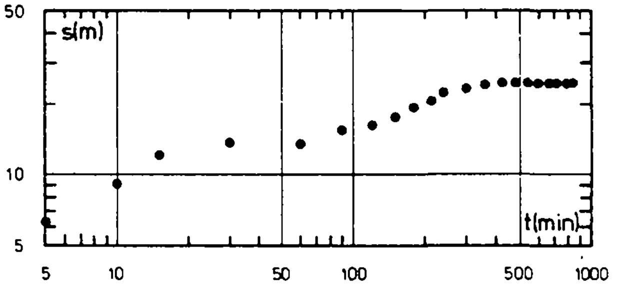
α = 2,1

k = min^{-1}

Type of decay:

Test performed:
1976.2.18

DRAWDOWN DATA



With the given variation in discharge, data cannot be matched with a type curve probably due to excessive well losses.

T = m^2/sec.

$r_w{}^2S$ = m^2

$r_w{}^2P^1/m^1$ = m^2/sec.

ε =

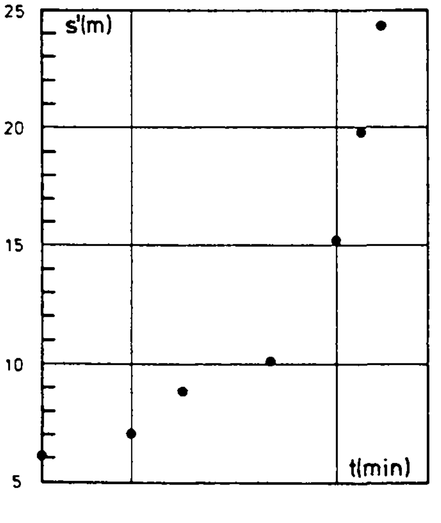
k_{obs} = min^{-1}

k_{cal} = min^{-1}

Q/S_w = 0,24 m^3/hr/m

T = 3 x 10^{-5} m^2/sec.

RECOVERY DATA



No interpretation attempted. Drawdown and recovery data are very dissimilar.

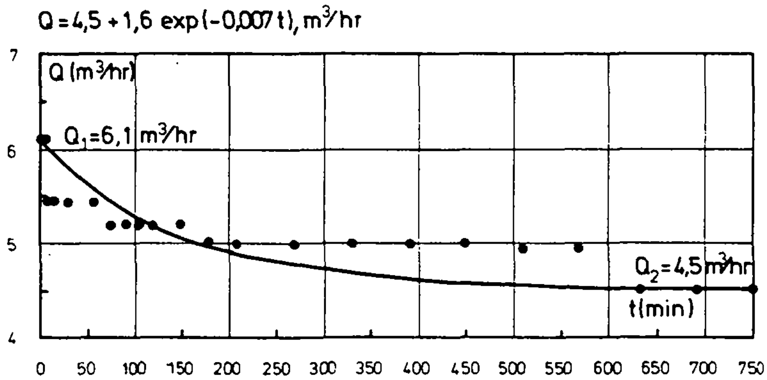
T = m^2/sec.

$r_w{}^2S$ = m^2

THE UNITED REPUBLIC OF TANZANIA

REGION: IRINGA	DISTRICT: IRINGA	VILLAGE: CHAMDINDI	B.H. No. 29/76 CCKK No.

DISCHARGE DATA



α = 1,36

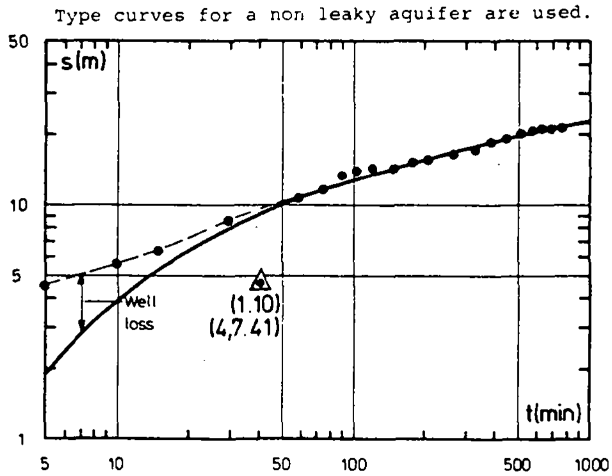
k = 0,007 min^{-1}

Type of decay: Exponential

Test performed: 1976.2.10

DRAWDOWN DATA

Type curves for a non leaky aquifer are used.



$k_{cal} > k_{obs}$ indicating well storage in stead of well loss. Interpretation doubtful.

T = 2,1 x $10^{-5} m^2$/sec.

$r_w^2 S$ = 0,021 m^2

$r_w^2 P^1/m^1$ = m^2/sec.

ξ = 0,6

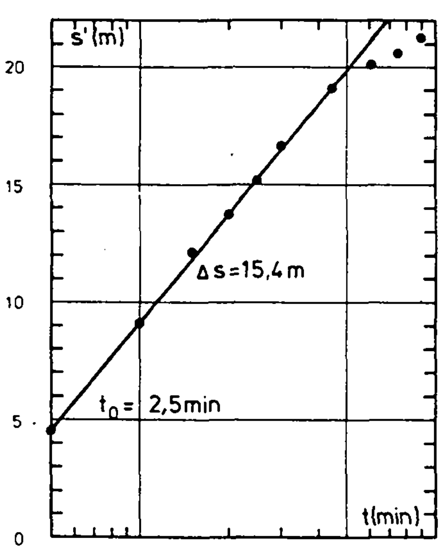
k_{obs} = 0,007 min^{-1}

k_{cal} = 0,022 min^{-1}

Q/S_w = 0,21 m^3/hr/m

T = 3 x 10^{-5} m^2/sec.

RECOVERY DATA



T = 1,5 x $10^{-5} m^2$/sec.

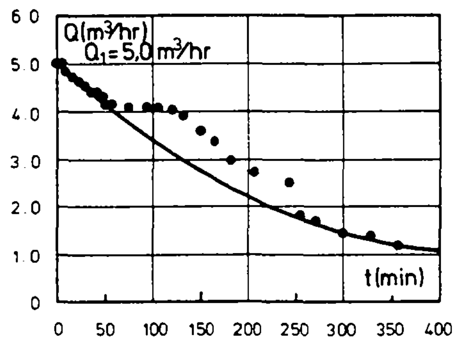
$r_w^2 S$ = 0,005 m^2

THE UNITED REPUBLIC OF TANZANIA

REGION: IRINGA	DISTRICT: NJOMBE	VILLAGE: UFAMBOLI	B.H. No. 54/76 CCKK No.

DISCHARGE DATA

Q = 5 exp(-0,004t)



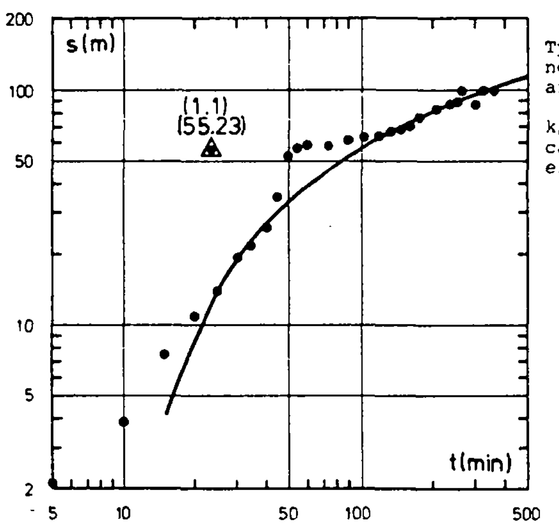
a =

k = 0,004 min^{-1}

Type of decay: Exponential

Test performed: 1976.6.25

DRAWDOWN DATA



Type curves for a non leaky aquifer are used.

$k_{cal} < k_{obs}$, indicating well loss effects.

$T = 2,0 \times 10^{-6}$ $m^2/sec.$

r_w^2S = 0,011 m^2

$r_w^2p^1/m^1$ = $m^2/sec.$

ε =

k_{obs} = 0,004 min^{-1}

k_{cal} = 0,001 min^{-1}

$Q/S_w \approx$ 0,012 $m^3/hr/m$

$T \approx 2 \times 10^{-6}$ $m^2/sec.$

RECOVERY DATA

T = $m^2/sec.$

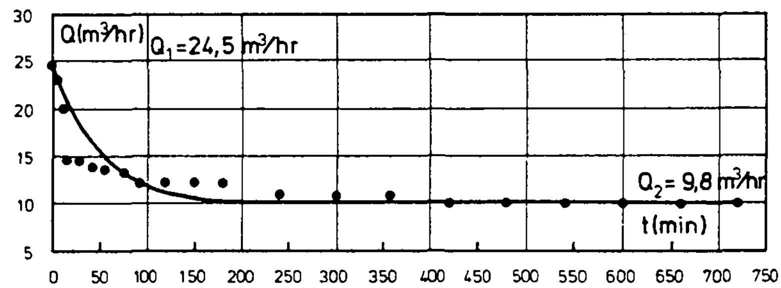
r_w^2S = m^2

THE UNITED REPUBLIC OF TANZANIA

REGION: IRINGA	DISTRICT: NJOMBE	VILLAGE: IYAI	B.H. No. 55/76
			CCKK No.

DISCHARGE DATA

$Q = 9{,}8 + 14{,}7 \exp(-0{,}02\,t)$, m^3/hr



$\alpha = 2{,}5$

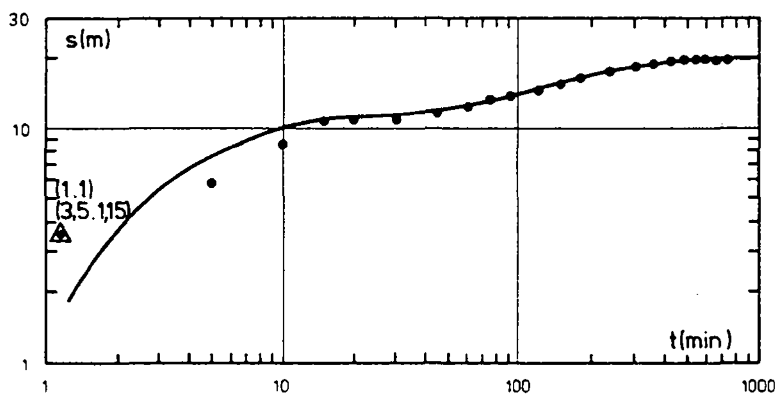
$k = 0{,}02\ min^{-1}$

Type of decay: Exponential

Test performed: 1976.3.12

DRAWDOWN DATA

Type curves for a non leaky aquifer are used .



$k_{cal} > k_{obs}$ indicating well storage effects .

$T = 6{,}2 \times 10^{-5}\ m^2/sec.$

$r_w^2 S = 0{,}017\ m^2$

$r_w^2 P^1/m^1 = \quad m^2/sec.$

$\varepsilon = 0{,}5$

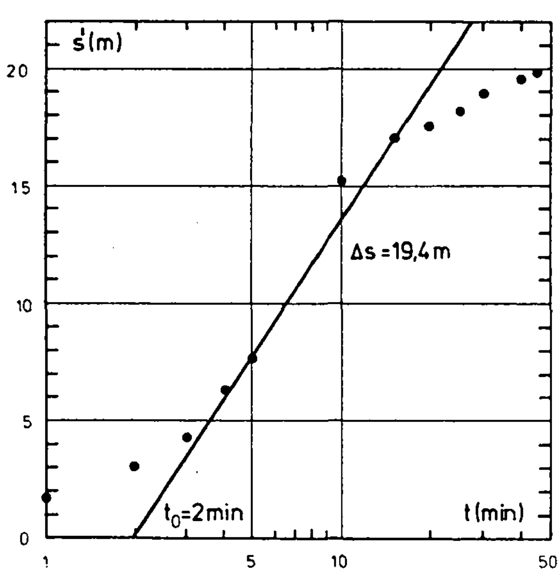
$k_{obs} = 0{,}02\ min^{-1}$

$k_{cal} = 0{,}054\ min^{-1}$

$Q/S_w = 0{,}5\ m^3/hr/m$

$T \approx 5 \times 10^{-5}\ m^2/sec.$

RECOVERY DATA



$T = 2{,}6 \times 10^{-5}\ m^2/sec.$

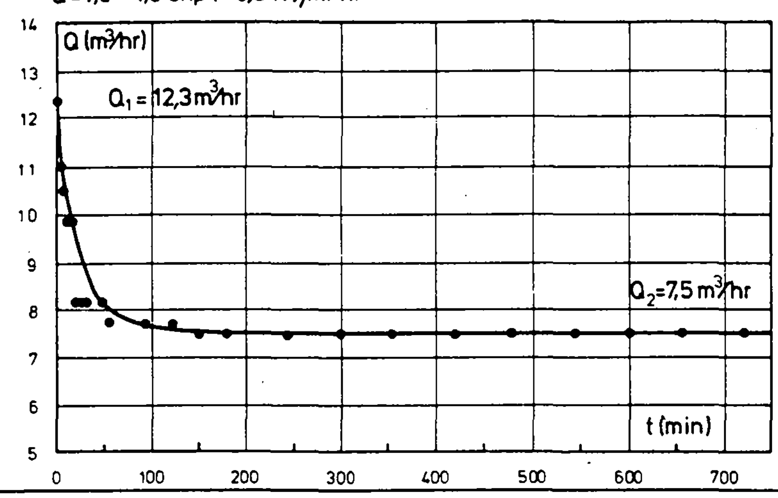
$r_w^2 S = 0{,}0069\ m^2$

THE UNITED REPUBLIC OF TANZANIA

REGION: IRINGA	DISTRICT: NJOMBE	VILLAGE: IKINGULA	B.H. No. 70/76 CCKK No.

DISCHARGE DATA

$Q = 7{,}5 + 4{,}8\exp(-0{,}04t), m^3/hr$



$a = 1{,}64$

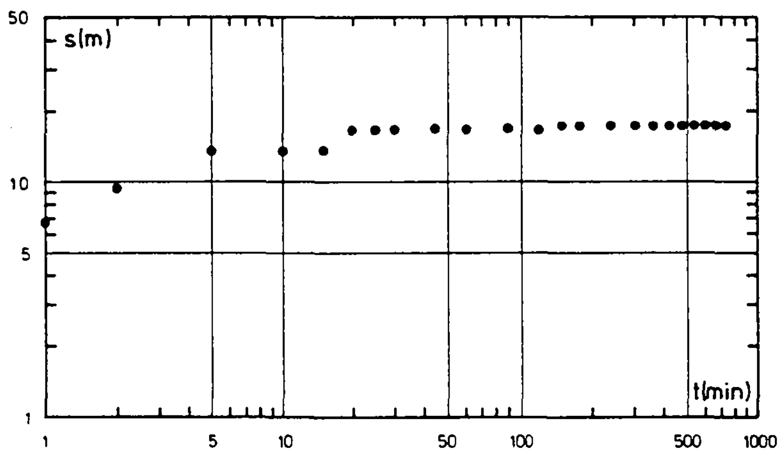
$k = 0{,}032\ min^{-1}$

Type of decay: Exponential

Test performed: 1976.5.22

DRAWDOWN DATA

Well losses to excessive to allow for interpretation by type curve method.



$T =$ $m^2/sec.$

$r_w^2 S =$ m^2

$r_w^2 P^1/m^1 =$ $m^2/sec.$

$\varepsilon =$

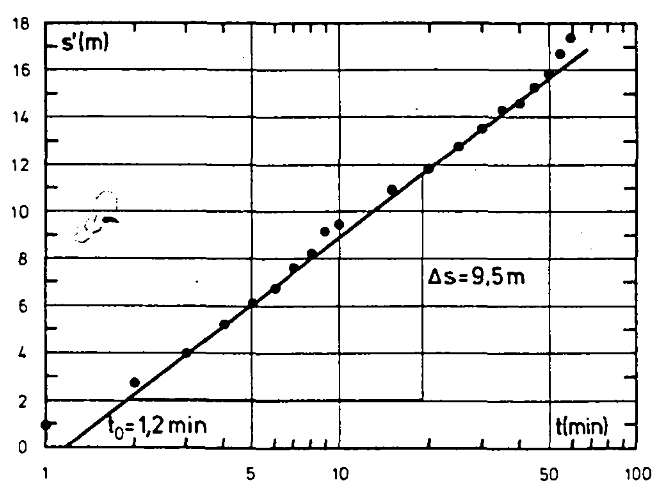
$k_{obs} =$ min^{-1}

$k_{cal} =$ min^{-1}

$Q/S_w = 0{,}43\ m^3/hr/m$

$T = 6 \times 10^{-5}\ m^2/sec.$

RECOVERY DATA



$T = 4{,}0 \times 10^{-5}\ m^2/sec.$

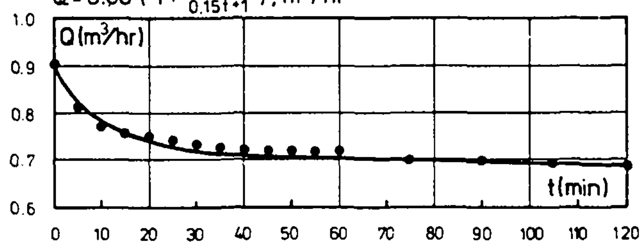
$r_w^2 S = 0{,}0065\ m^2$

THE UNITED REPUBLIC OF TANZANIA

REGION: IRINGA	DISTRICT: NJOMBE	VILLAGE: UTAJA	B.H. No. 71/76 CCKK No.

DISCHARGE DATA

$Q = 0.68\left(1 + \frac{0.34}{0.15t+1}\right), m^3/hr$



α = 1,33

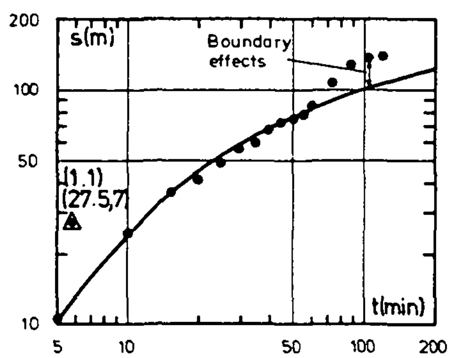
k = 0,15 min^{-1}

Type of decay: Hyperbolic

Test performed: 1976.4.17

DRAWDOWN DATA

Type curves for a non leaky aquifer are used.



T = 5,6 x $10^{-7} m^2/sec.$

$r_w^2 S$ = 0,00077 m^2

$r_w^2 P^1/m^1$ = $m^2/sec.$

β = 2,0

k_{obs} = 0,15 min^{-1}

k_{cal} = 0,17 min^{-1}

Q/S_w = 0,0076 $m^3/hr/m$

T ≈ 4 x 10^{-7} $m^2/sec.$

RECOVERY DATA

T = $m^2/sec.$

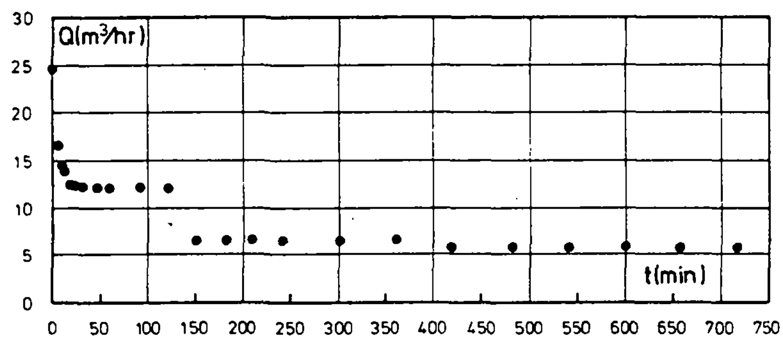
$r_w^2 S$ = m^2

THE UNITED REPUBLIC OF TANZANIA

REGION: IRINGA	DISTRICT: NJOMBE	VILLAGE: HZLALI	B.H. No. 67/76 CCKK No.

DISCHARGE DATA

Discharge data too irregular to allow for interpretation



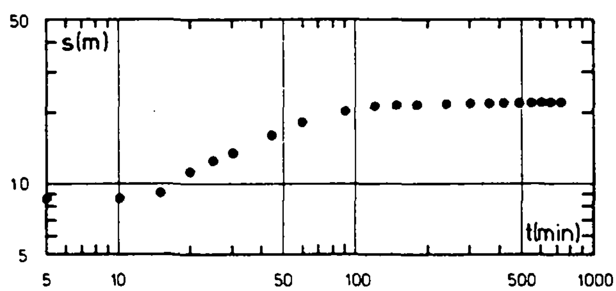
α = 4,02

k = min^{-1}

Type of decay:

Test performed:
1976.3.20

DRAWDOWN DATA



The discharge is constant after 150 minutes, but since there is no variation in drawdown, type curve method cannot be applied.

T = m^2/sec.

$r_w{}^2S$ = m^2

$r_w{}^2P^1/m^1$ = m^2/sec.

ε =

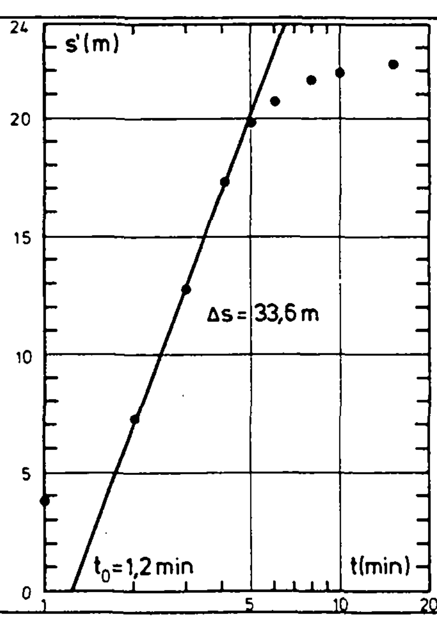
k_{obs} = min^{-1}

k_{cal} = min^{-1}

Q/S_w = 0,27 m^3/hr/m

T ≈ 10^{-5} m^2/sec.

RECOVERY DATA



T = 9,2 x 10^{-6} m^2/sec.

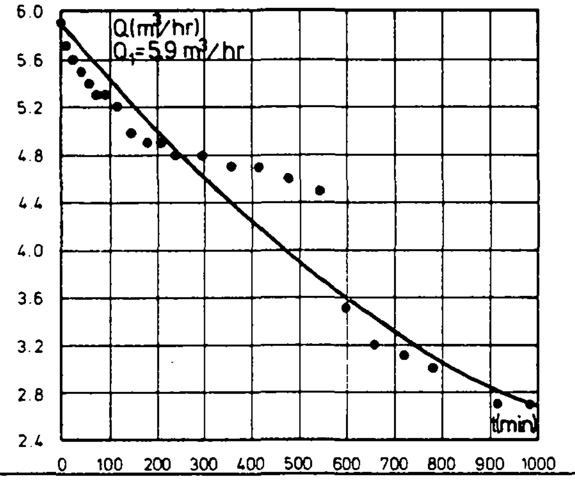
$r_w{}^2S$ = 0,0015 m^2

THE UNITED REPUBLIC OF TANZANIA

REGION: IRINGA	DISTRICT: MUFINDI	VILLAGE: MALANGALI	B.H. No. 216/76 CCKK No.

DISCHARGE DATA

$Q = 5{,}9 \exp(-0{,}00082\,t)\ m^3/hr$



$\alpha =$

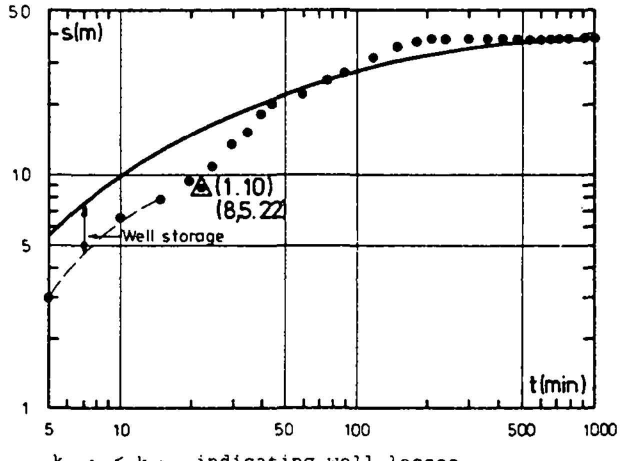
$k = 0{,}00082\ min^{-1}$

Type of decay: Exponential

Test performed: 1976.10.22

DRAWDOWN DATA

Type curves for a non leaky aquifer are used.



$k_{cal} < k_{obs}$ indicating well losses.
Interpretation doubtful.

$T = 1{,}5 \times 10^{-5}\ m^2/sec.$

$r_w^2 S = 0{,}0076\ m^2$

$r_w^2 P^1/m^1 =$ $m^2/sec.$

$\beta = 0{,}04$

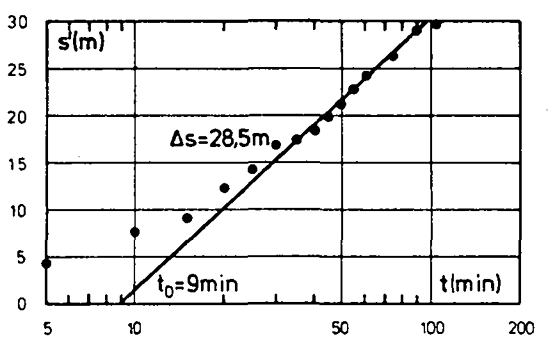
$k_{obs} = 0{,}00082\ min^{-1}$

$k_{cal} = 0{,}00019\ min^{-1}$

$Q/S_w \sim 0{,}07\ m^3/hr/m$

$T \approx 6 \times 10^{-6}\ m^2/sec.$

RECOVERY DATA



Since the discharge did not become steady, tye figures are approximate.

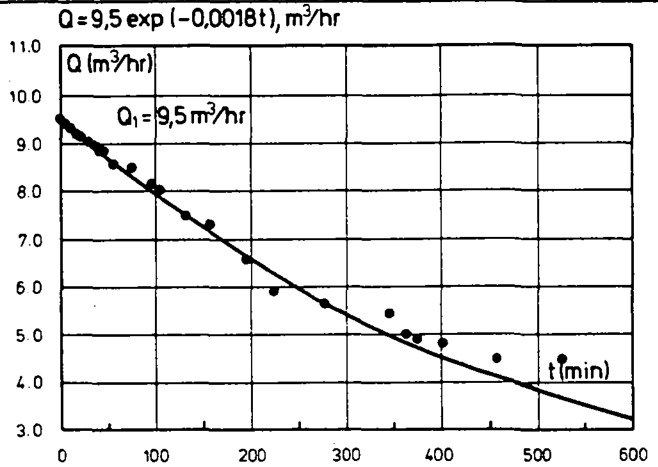
$T = 4{,}8 \times 10^{-6}\ m^2/sec.$

$r_w^2 S = 0{,}0059\ m^2$

THE UNITED REPUBLIC OF TANZANIA

REGION: IRINGA	DISTRICT: MUFINDI	VILLAGE: MALANGALI	B.H. No. 217/76 CCKK No.

DISCHARGE DATA



The fitted curve is valid up to approx. 400 minutes.

α =

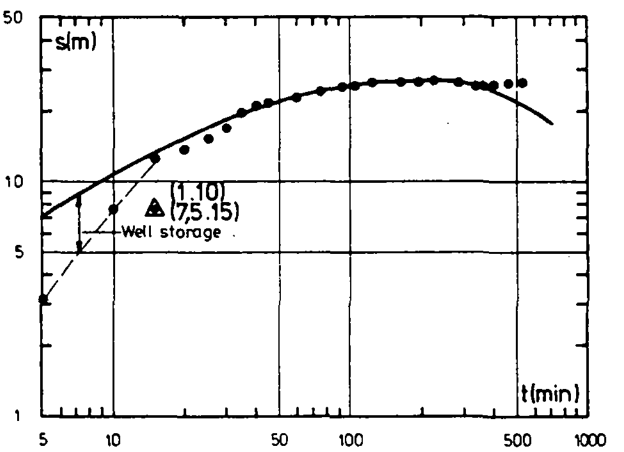
$k = 0,0018\ min^{-1}$

Type of decay: Exponential

Test performed:

DRAWDOWN DATA

Type curves for a non leaky aquifer are used.



$T = 2,8 \times 10^{-5} m^2/sec.$

$r_w{}^2 S = 0,01\ m^2$

$r_w{}^2 P^1/m^1 =\ \ m^2/sec.$

$\beta = 0,08$

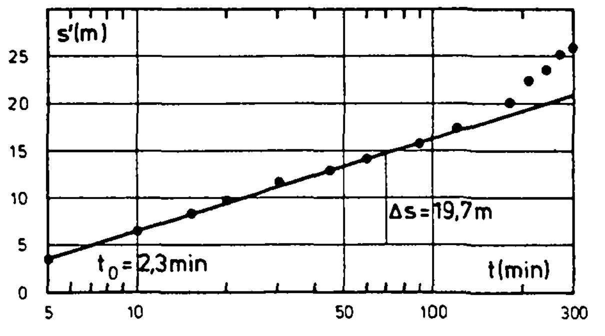
$k_{obs} = 0,0018\ min^{-1}$

$k_{cal} = 0,0018\ min^{-1}$

$Q/S_w \sim 0,17\ m^3/hr/m$

$T \simeq 2 \times 10^{-5}\ m^2/sec.$

RECOVERY DATA



$T = 1,2 \times 10^{-5} m^2/sec.$

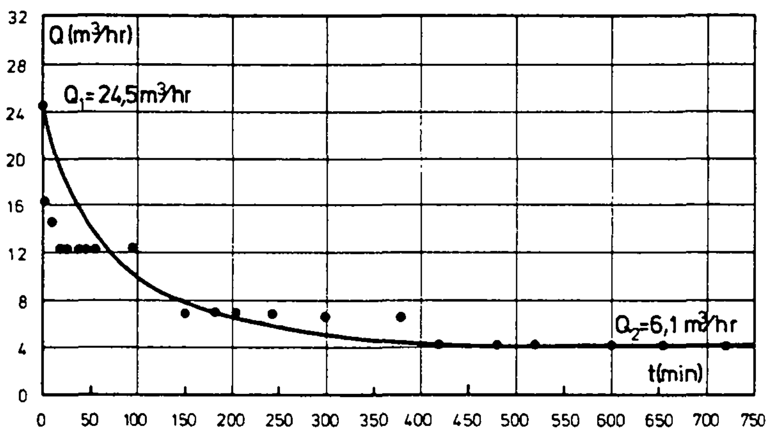
$r_w{}^2 S = 0,0036\ m^2$

THE UNITED REPUBLIC OF TANZANIA

REGION: IRINGA	DISTRICT: NJOMBE	VILLAGE: HALALI	B.H. No. 226/76 CCKK No.

DISCHARGE DATA

$Q = 6{,}1 + 18{,}4\ \exp(-0{,}02t)$



α = 4,02

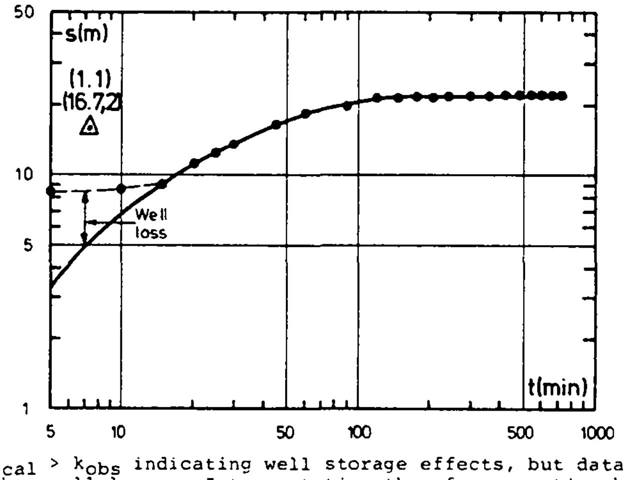
k = 0,02 min^{-1}

Type of decay: Exponential

Test performed: 1976.3.20

DRAWDOWN DATA

Type curves for a leaky artesian aquifer are used, δ = 0,7.



$k_{cal} > k_{obs}$ indicating well storage effects, but data show well losses. Interpretation therefore questionable.

$T = 8{,}4 \times 10^{-6}\ m^2/sec.$

$r_w{}^2S = 0{,}015\ m^2$

$r_w{}^2P^1/m^1 = 4{,}1 \times 10^{-6}\ m^2/sec.$

ε = 2,0

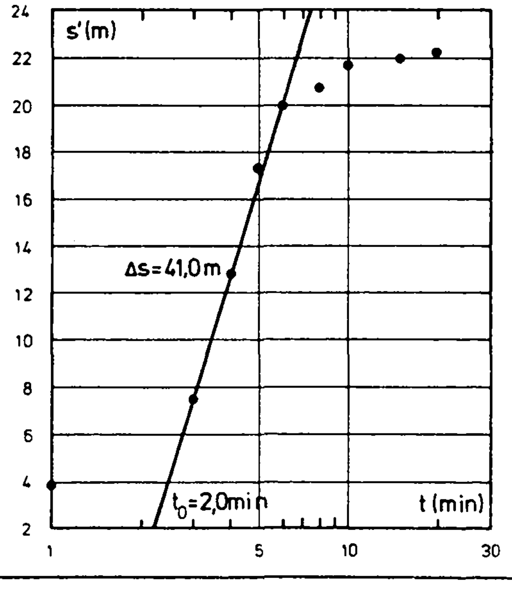
k_{obs} = 0,02 min^{-1}

k_{cal} = 0,13 min^{-1}

Q/S_w = m /hr/m

T = m /sec.

RECOVERY DATA



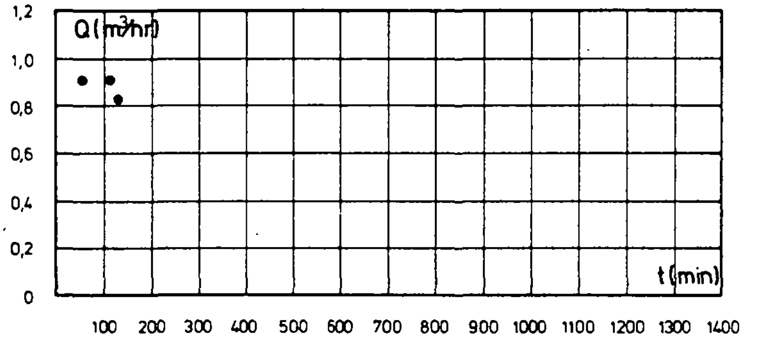
$T = 7{,}6 \times 10^{-6} m^2/sec.$

$r_w{}^2S = 0{,}002\ m^2$

THE UNITED REPUBLIC OF TANZANIA

REGION: IRINGA	DISTRICT: NJOMBE	VILLAGE: USANGE	B.H. No. 230/76 CCKK No.

DISCHARGE DATA



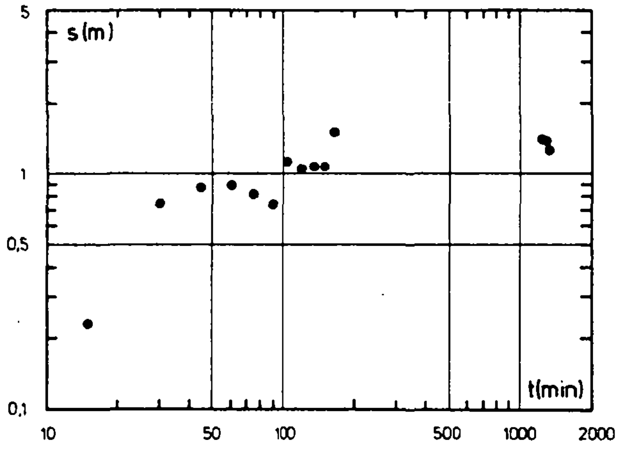
α =

k = min^{-1}

Type of decay:

Test performed:
1976.1.27

DRAWDOWN DATA



Data too scarce and unreliable to allow for interpretation by type curve method.

T = m^2/sec.

$r_w{}^2S$ = m^2

$r_w{}^2P^1/m^1$ = m^2/sec.

β =

k_{obs} = min^{-1}

k_{cal} = min^{-1}

$Q/S_w \sim 0,6$ m^3/hr/m

T = 6×10^{-5} m^2/sec.

RECOVERY DATA

T = m^2/sec.

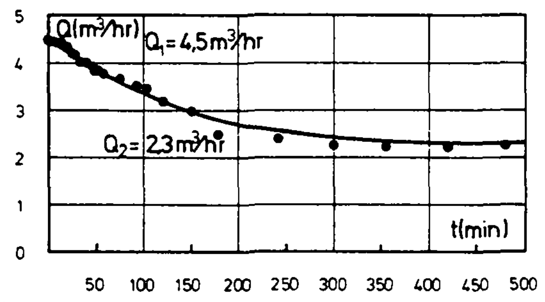
$r_w{}^2S$ = m^2

THE UNITED REPUBLIC OF TANZANIA

REGION: IRINGA	DISTRICT: IRINGA	VILLAGE: KIHESA	B.H. No. 232/76 CCKK No.

DISCHARGE DATA

Q=2,3+2,2 exp(-0,008t),m³/hr



α = 1,96

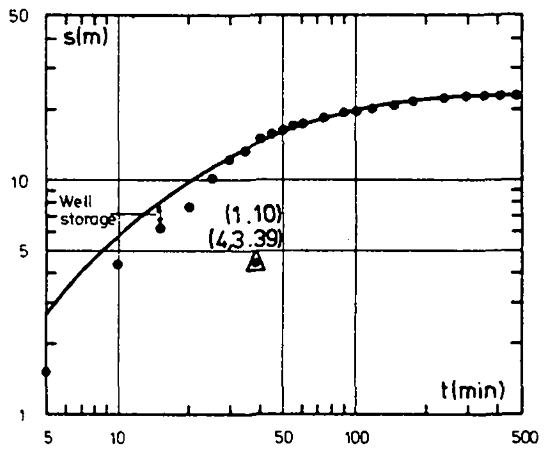
k = 0,008 min^{-1}

Type of decay: Exponential

Test performed: 1976.7.7.

DRAWDOWN DATA

Type curves for a non leaky aquifer are used.



k_{cal} > k_{obs} indicating well storage effects.

T = 1,2 x $10^{-5} m^2$/sec.

$r_w{}^2S$ = 0,011 m^2

$r_w{}^2P^1/m^1$= m^2/sec.

$\hat{\varepsilon}$ = 0,2

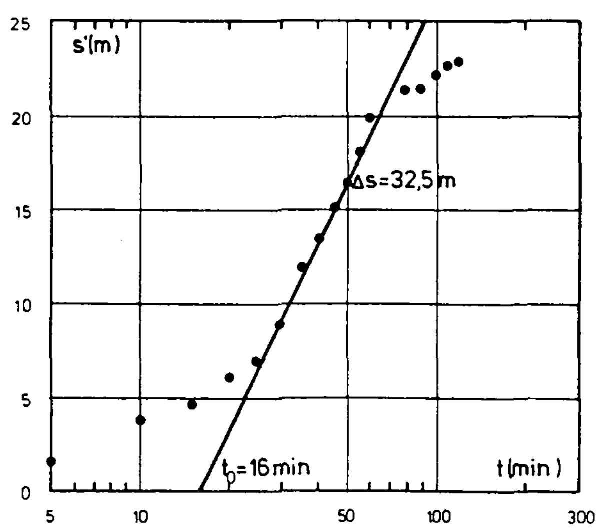
k_{obs} = 0,008 min^{-1}

k_{cal} = 0,026 min^{-1}

Q/S_w = 0,1 m^3/hr/m

T = 10^{-5} m^2/sec.

RECOVERY DATA



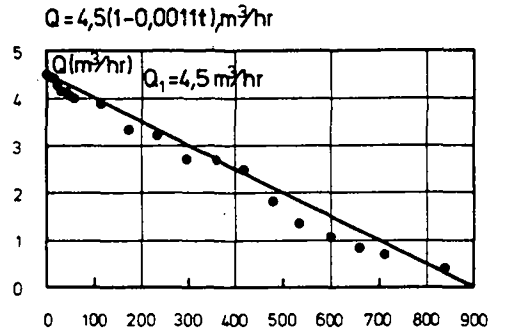
T = 3,6 x $10^{-6} m^2$/sec.

$r_w{}^2S$ = 0,0078 m^2

THE UNITED REPUBLIC OF TANZANIA

REGION: IRINGA	DISTRICT: MUFINDI	VILLAGE: NYANYENDE	B.H. No. 235/76 CCKK No.

DISCHARGE DATA



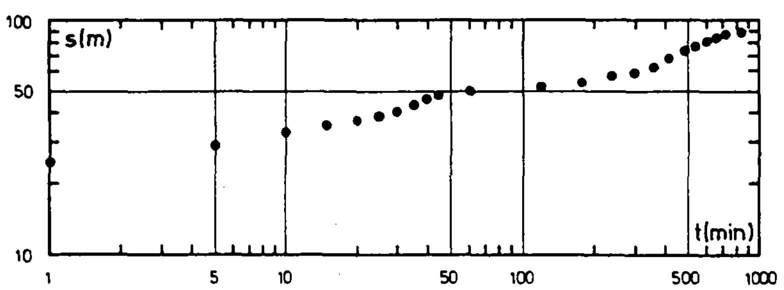
α =

k = 0,0011 min^{-1}

Type of decay:
Linear

Test performed:
1976.11.22

DRAWDOWN DATA



Well losses too excessive to allow a matching with the type curves.

T = m^2/sec.

$r_w^2 S$ = m^2

$r_w^2 P^1/m^1$ = m^2/sec.

β =

k_{obs} = min^{-1}

k_{cal} = min^{-1}

$Q/S_w \sim 0,005$ m^3/hr/m

$T < 10^{-6}$ m^2/sec.

RECOVERY DATA

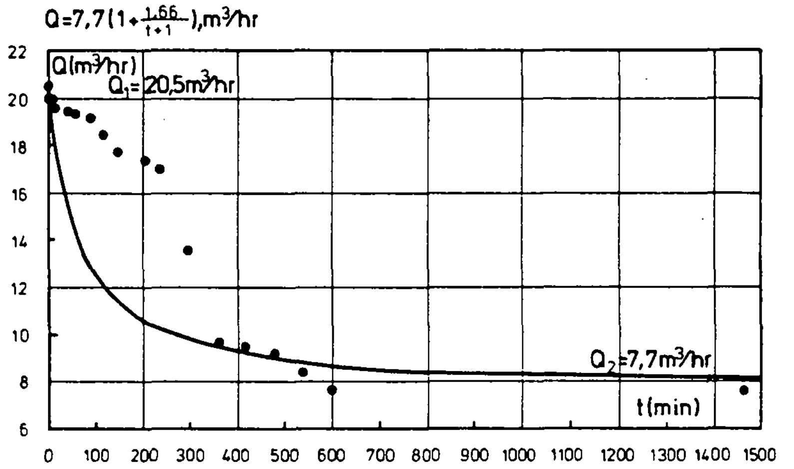
T = m^2/sec.

$r_w^2 S$ = m^2

THE UNITED REPUBLIC OF TANZANIA

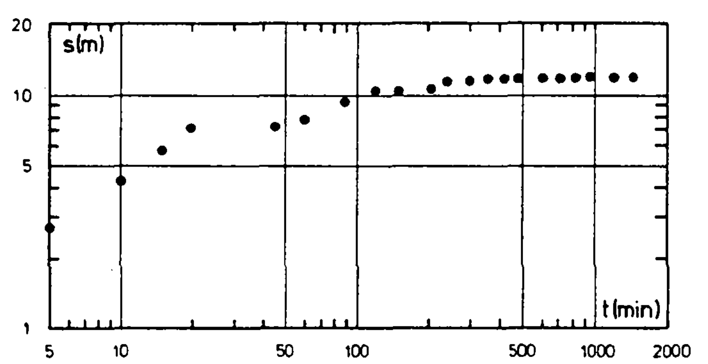
REGION: IRINGA	DISTRICT: NJOMBE	VILLAGE: IDOFI	B.H. No. 247/76 CCKK No.

DISCHARGE DATA



α = 2,66
k = 1,0 min^{-1}
Type of decay: Hyperbolic
Test performed: 1976.11.13.

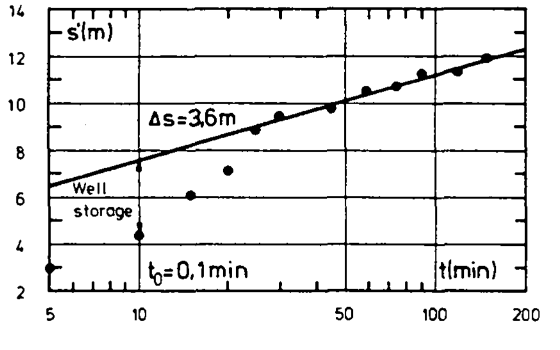
DRAWDOWN DATA



Discharge data too irregular to allow for interpretation.

T = m^2/sec.
$r_w{}^2S$ = m^2
$r_w{}^2P^1/m^1$ = m^2/sec.
ε =
k_{obs} = min^{-1}
k_{cal} = min^{-1}
Q/S_w = 0,66 m^3/hr/m
T ≈ 7 x 10^{-5} m^2/sec.

RECOVERY DATA

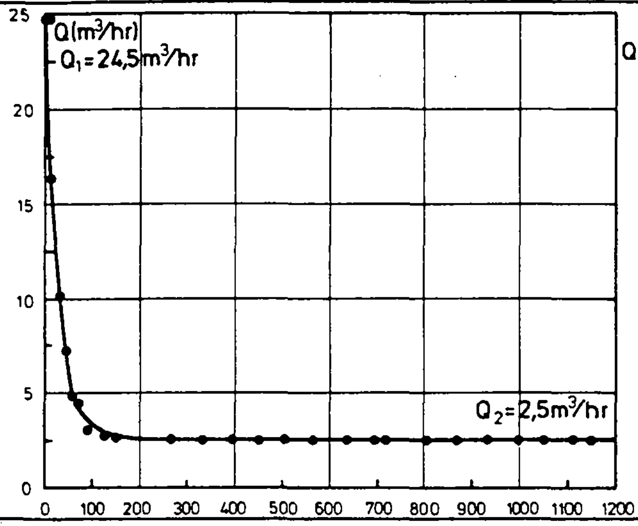


T = 1,1 x 10^{-4} m^2/sec.
$r_w{}^2S$ = 0,0015 m^2

THE UNITED REPUBLIC OF TANZANIA

REGION: IRINGA	DISTRICT: MUFINDI	VILLAGE: SAJA	B.H. No. 265/76 CCKK No.

DISCHARGE DATA



$Q = 2{,}5 + 22 \exp(-0{,}036\,t)$, m^3/hr

α = 9,8

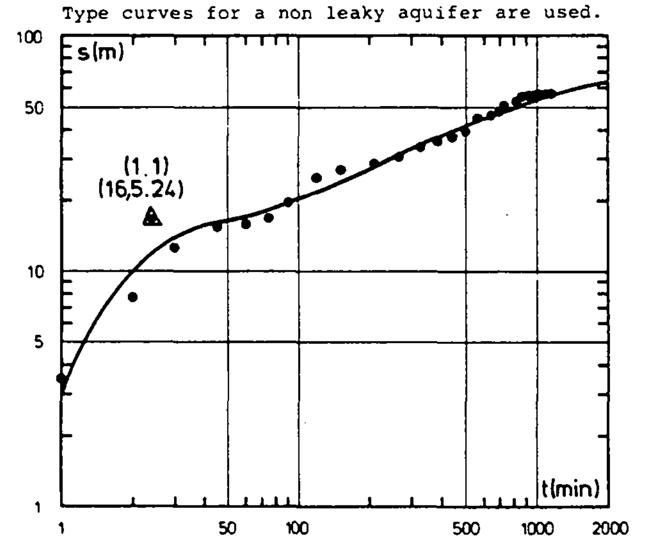
k = 0,036 min^{-1}

Type of decay:
Exponential

Test performed:
1976.12.11.

DRAWDOWN DATA

Type curves for a non leaky aquifer are used.



T = 3,3 x 10^{-6} $m^2/sec.$

r_w^2S = 0,019 m^2

$r_w^2P^1/m^1$ = $m^2/sec.$

β = 1,8

k_{obs} = 0,036 min^{-1}

k_{cal} = 0,033 min^{-1}

Q/S_w = 0,044 $m^3/hr/m$

T = 4 x 10^{-6} $m^2/sec.$

RECOVERY DATA

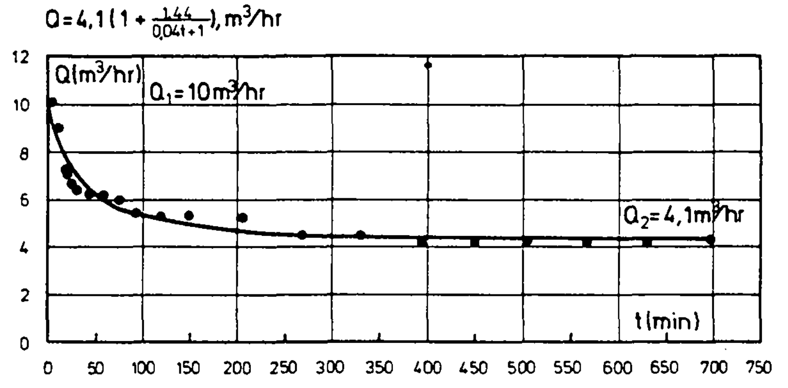
T = $m^2/sec.$

r_w^2S = m^2

THE UNITED REPUBLIC OF TANZANIA

REGION: IRINGA	DISTRICT: NJOMBE	VILLAGE: LYADEBWE	B.H. No. 65/77 CCKK No.

DISCHARGE DATA



α = 2,44

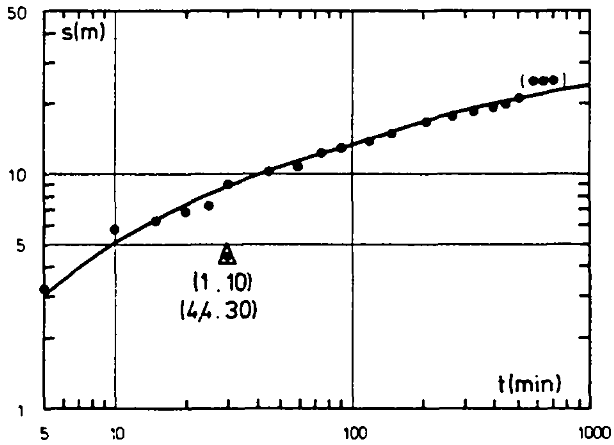
k = 0,04 min^{-1}

Type of decay: Hyperbolic

Test performed: 1977.4.23.

DRAWDOWN DATA

Type curves for a non leaky aquifer are used.



$k_{cal} > k_{obs}$ indicating well storage effects.

T = 2,1 x 10^{-5} m^2/sec.

r_w^2S = 0,015 m^2

$r_w^2p^1/m^1$ = m^2/sec.

£ = 4,0

k_{obs} = 0,04 min^{-1}

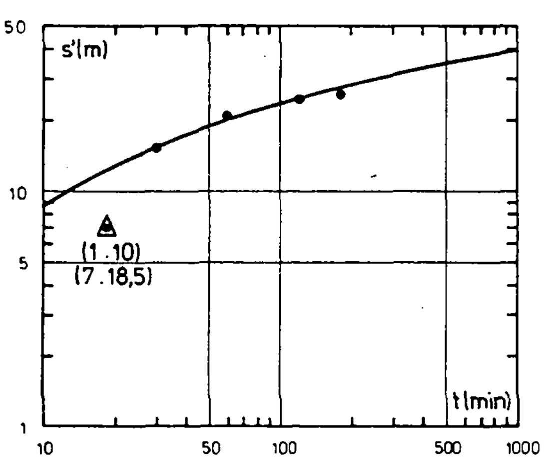
k_{cal} = 0,14 min^{-1}

Q/S_w = 0,16 m^3/hr/m

T = 2 x 10^{-5} m^2/sec.

RECOVERY DATA

The Theis type curve is used.



T = 1,3 x 10^{-5} m^2/sec.

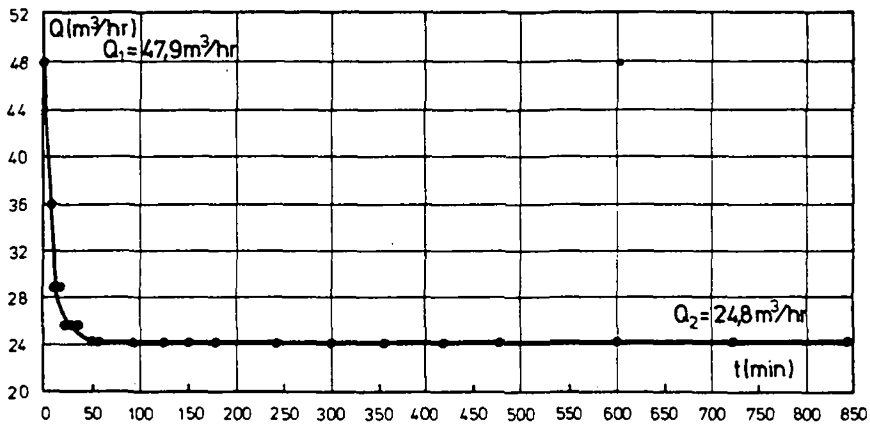
r_w^2S = 0,0057 m^2

THE UNITED REPUBLIC OF TANZANIA

REGION: IRINGA	DISTRICT: IRINGA	VILLAGE: MKULULA	B.H. No. 126/77 CCKK No.

DISCHARGE DATA

$Q = 24{,}8 + 23{,}1 \exp(-0{,}136\,t), m^3/hr$



α = 1,9

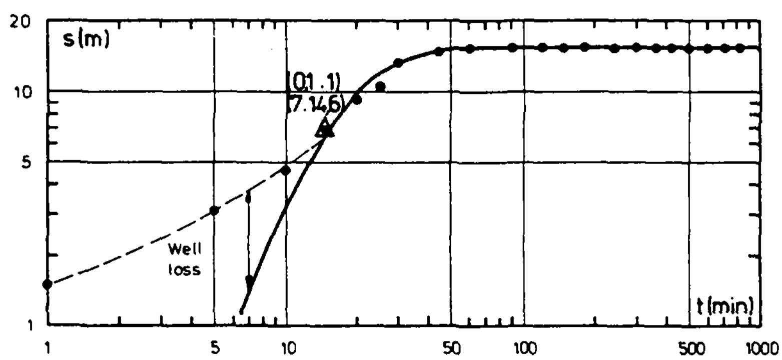
k = 0,136 min^{-1}

Type of decay:
Exponential

Test performed:

DRAWDOWN DATA

Type curves for a leaky aquifer are used, δ = 2,0 is chosen.



$k_{cal} < k_{obs}$ indicating well losses.

T = 8,3 x 10^{-6} m^2/sec.

$r_w^2 S$ = 0,029 m^2

$r_w^2 P^1/m^1$ = 3,3 x 10^{-5} m^2/sec.

δ = 2,0

k_{obs} = 0,136 min^{-1}

k_{cal} = 0,069 min^{-1}

Q/S_w = m^3/hr/m

T = m^2/sec.

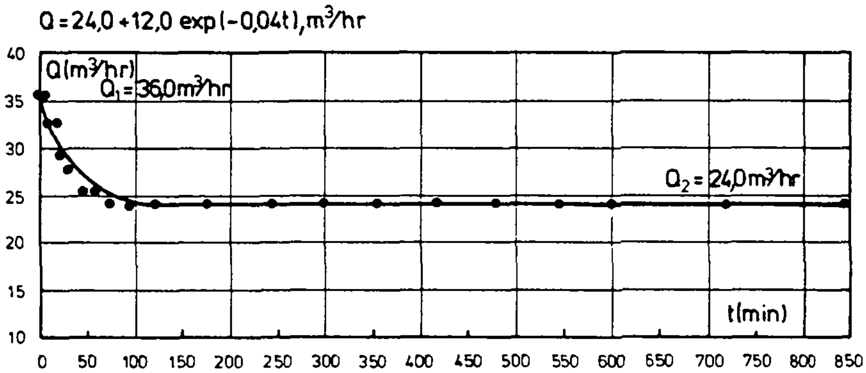
RECOVERY DATA

T = m^2/sec.

$r_w^2 S$ = m^2

THE UNITED REPUBLIC OF TANZANIA			
REGION: IRINGA	DISTRICT: IRINGA	VILLAGE: NYAKANANGALA	B.H. No. 130/77 CCKK No.

DISCHARGE DATA



α = 1,5

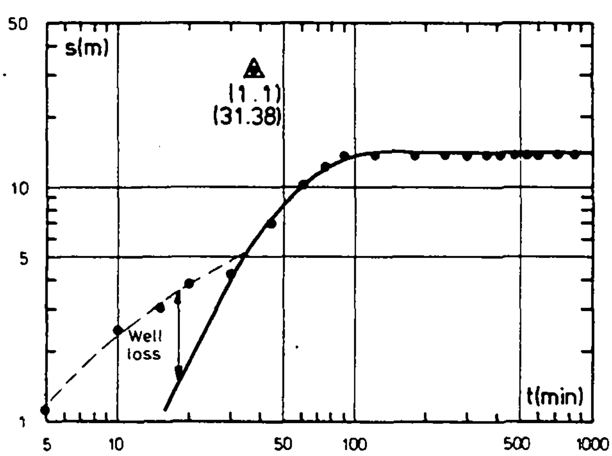
k = 0,04 min^{-1}

Type of decay: Exponential

Test performed:

DRAWDOWN DATA

Type curves for a leaky aquifer are used. δ = 1,5 is chosen.



$k_{cal} < k_{obs}$ indicating well losses.

T = 1,7 x $10^{-5} m^2/sec.$

$r_w^2 S$ = 0,16 m^2

$r_w^2 P^1/m^1$ = 3,8 x 10^{-5} $m^2/sec.$

ρ = 1,0

k_{obs} = 0,04 min^{-1}

k_{cal} = 0,0065 min^{-1}

Q/S_w = $m^3/hr/m$

T = $m^2/sec.$

RECOVERY DATA

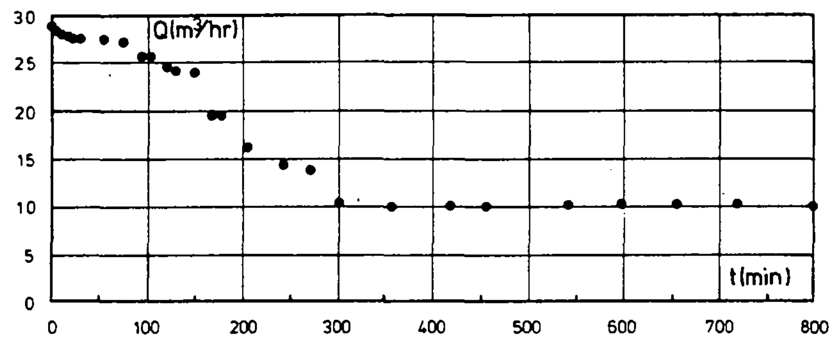
T = $m^2/sec.$

$r_w^2 S$ = m^2

THE UNITED REPUBLIC OF TANZANIA

REGION: IRINGA	DISTRICT: IRINGA	VILLAGE: IROLE	B.H. No. 189/77 CCKK No.

DISCHARGE DATA



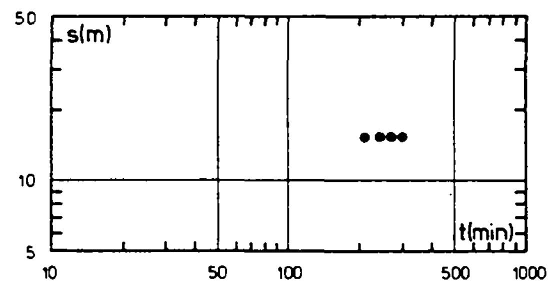
a = 2,8

k = min^{-1}

Type of decay:

Test performed:
1977.10.17.

DRAWDOWN DATA



Data insufficient for interpretation.

T = m^2/sec.

$r_w{}^2S$ = m^2

$r_w{}^2P^1/m^1$ = m^2/sec.

ε =

k_{obs} = min^{-1}

k_{cal} = min^{-1}

$Q/S_w \sim 0,67$ m^3/hr/m

$T \simeq 7 \times 10^{-5}$ m^2/sec.

RECOVERY DATA

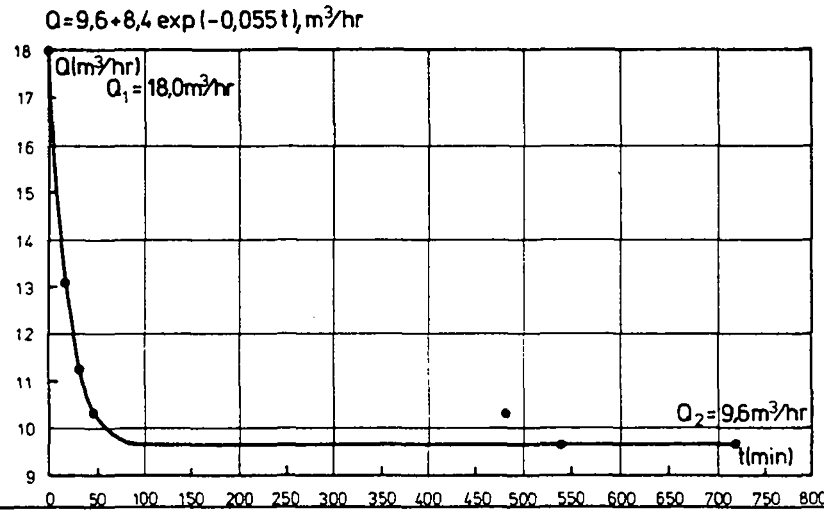
T = m^2/sec.

$r_w{}^2S$ = m^2

THE UNITED REPUBLIC OF TANZANIA

REGION: IRINGA	DISTRICT: IRINGA	VILLAGE: IZAZI	B.H. No. 227/77
			CCKK No.

DISCHARGE DATA



α = 1,9

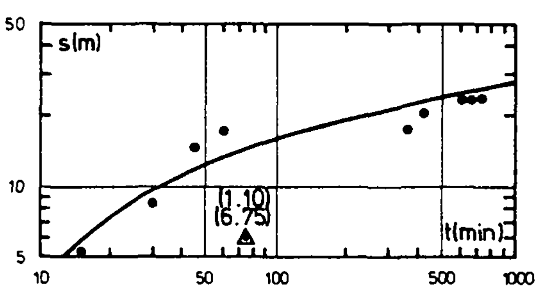
k = 0,055 min^{-1}

Type of decay: Exponential

Test performed: 1977.12.8

DRAWDOWN DATA

Type curves for a non leaky aquifer are used.



k_{cal} < k_{obs} indicating well losses.

T = 3,5 x 10^{-5} m^2/sec.

$r_w{}^2S$ = 0,063 m^2

$r_w{}^2P^1/m^1$ = m^2/sec.

ε = 0,4

k_{obs} = 0,055 min^{-1}

k_{cal} = 0,012 min^{-1}

Q/S_w = 0,4 m^3/hr/m

T = 4 x 10^{-5} m^2/sec.

RECOVERY DATA

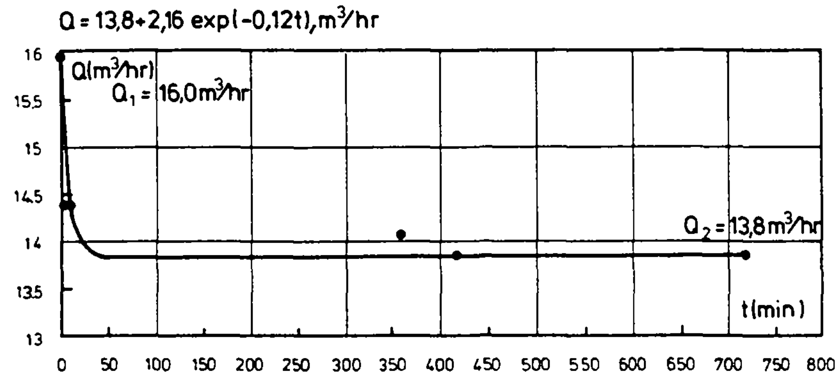
T = m^2/sec.

$r_w{}^2S$ = m^2

THE UNITED REPUBLIC OF TANZANIA

REGION: IRINGA	DISTRICT: IRINGA	VILLAGE: MTERA	B.H. No. 93/79
			CCKK No.

DISCHARGE DATA



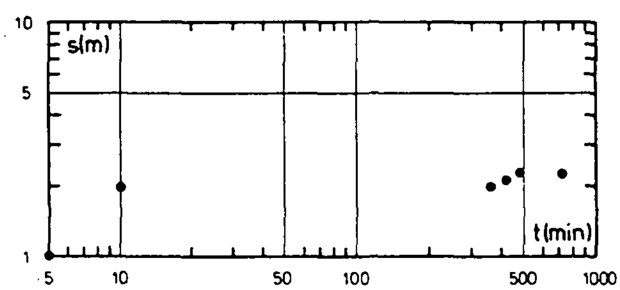
α = 1,16

k = 0,12 min^{-1}

Type of decay: Exponential

Test performed: 1979.12.7.

DRAWDOWN DATA



Water level measurements too scarce to provide means of interpretation by type curve method.

T = m^2/sec.

r_w^2S = m^2

$r_w^2P^1/m^1$= m^2/sec.

δ =

k_{obs} = min^{-1}

k_{cal} = min^{-1}

Q/S_w = 6,1 m^3/hr/m

T = 6 x 10^{-4} m^2/sec.

RECOVERY DATA

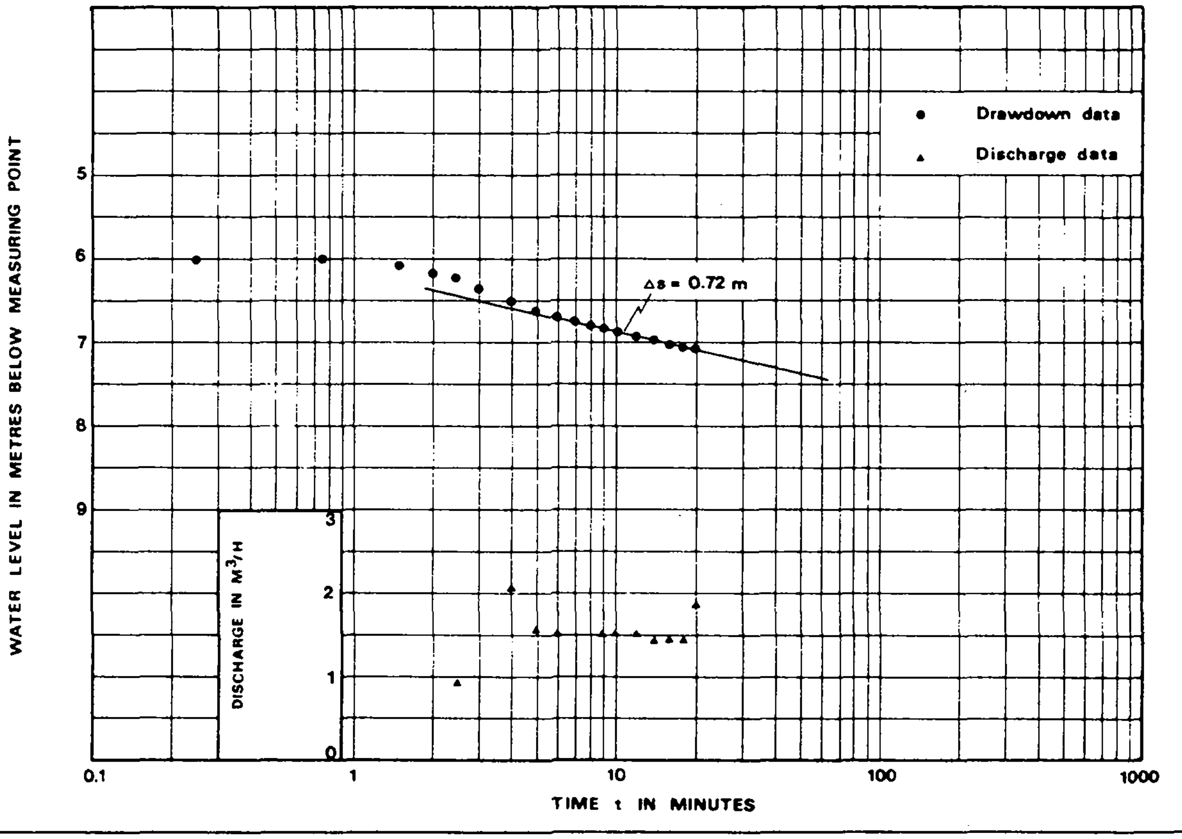
NO DATA.

T = m^2/sec.

r_w^2S = m^2

THE UNITED REPUBLIC OF TANZANIA

REGION: IRINGA	DISTRICT: IRINGA	VILLAGE: NZIHI	BH NO: 2/81 CCKK NO: ID 1



Constant discharge test : October 23, 1981 13^{45} - 14^{05}

Discharge rate : 1.5 m^3/h

Static water level : 5.94 metres below measuring point

Calculation of hydraulic parametres:

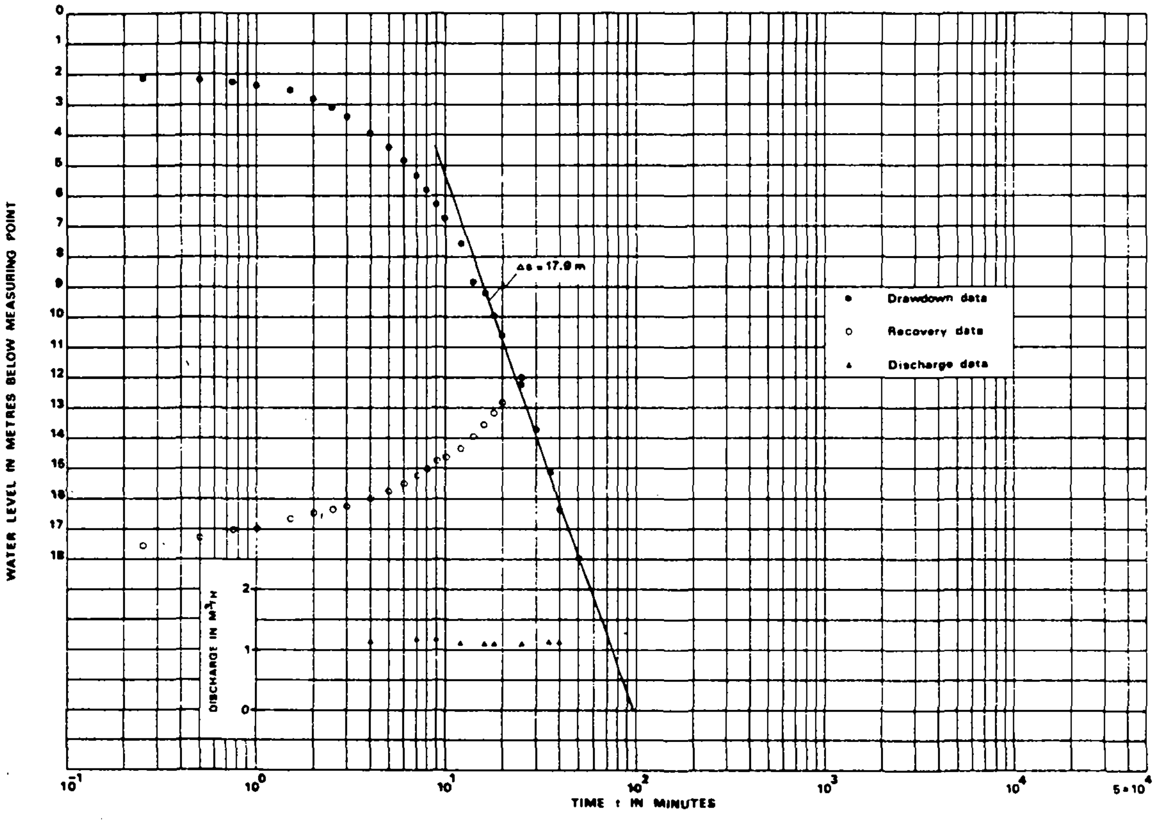
$T = 1.1 \times 10^{-4}\ m^2/sec$

$Q/s_w = 1.35\ m^3/h/m$

The test was stopped because fine material jammed the pump impellers.

THE UNITED REPUBLIC OF TANZANIA

REGION: IRINGA	DISTRICT: IRINGA	VILLAGE: NZIHI	BH NO: 3/81 CCKK NO: ID 2



Constant discharge test : October 23, 1981 15^{00} - 15^{50}

Recovery test : October 23, 1981 15^{50} - 16^{15}

Discharge rate : 1.1 m^3/h

Static water level : 1.77 metres below measuring point

Calculation of hydraulic parametres:

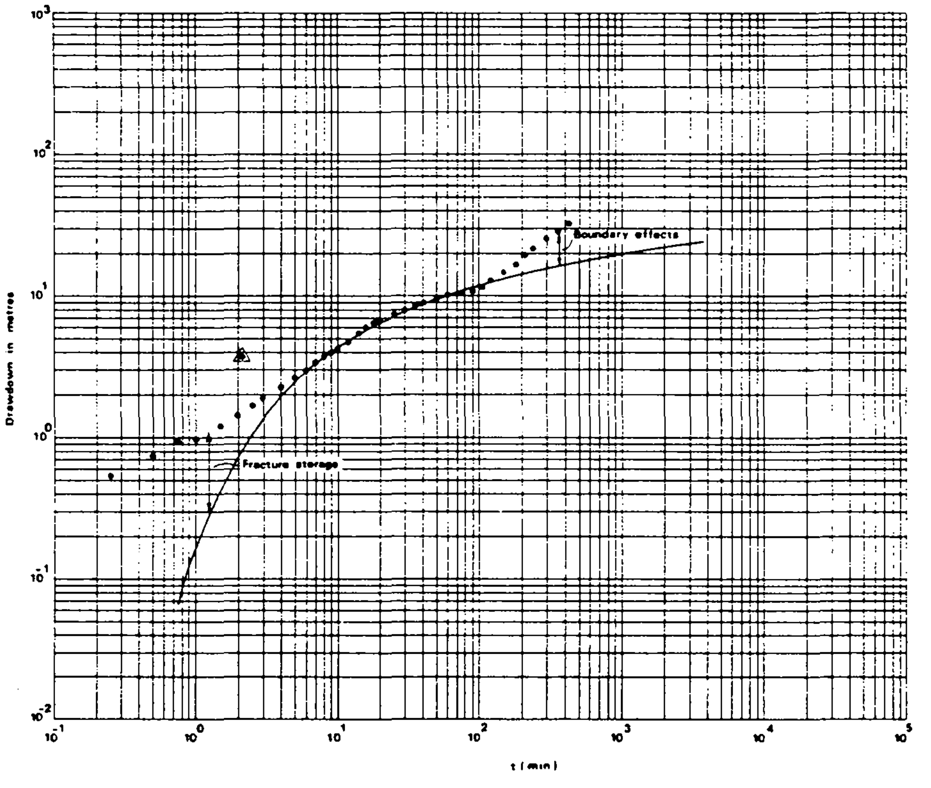
T = 3.2×10^{-6} m^2/sec

$r_w^2 S$ = 2.7×10^{-3} m^2

Q/s_w = 0.068 $m^3/h/m$

THE UNITED REPUBLIC OF TANZANIA

REGION: IRINGA	DISTRICT: IRINGA	VILLAGE: MLOA	BH NO: 4/81
			CCKK NO: ID 3



Constant discharge test : October 22, 1981 16^{10} - October 23, 1981 01^{10}

Discharge rate : 1.2 m^3/h

Static water level : 8.95 metres below measuring point

Calculation of hydraulic parametres:

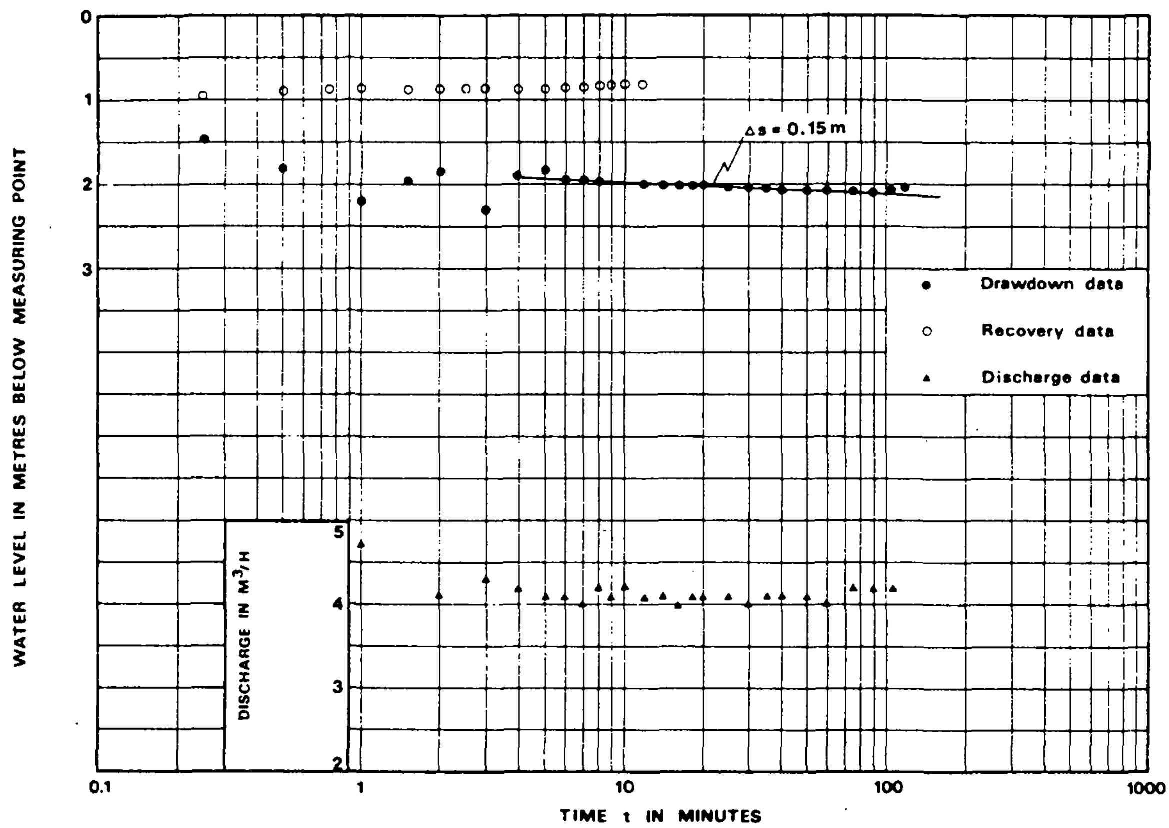
$T = 7.6 \times 10^{-6}\ m^3/sec$

$r_w^2 S = 3.8 \times 10^{-4}\ m^2$

$Q/s_w = 0.027\ m^3/h/m$

THE UNITED REPUBLIC OF TANZANIA

REGION: IRINGA	DISTRICT: MUFINDI	VILLAGE: NDOLEZI	BH NO: 55/81 CCKK NO: IS 1



Constant discharge test : October 27, 1981 11^{30} - 13^{30}

Recovery test : October 27, 1981 13^{30} - 13^{42}

Discharge rate : 4.1 m^3/h

Static water level : 0.72 metres below measuring point

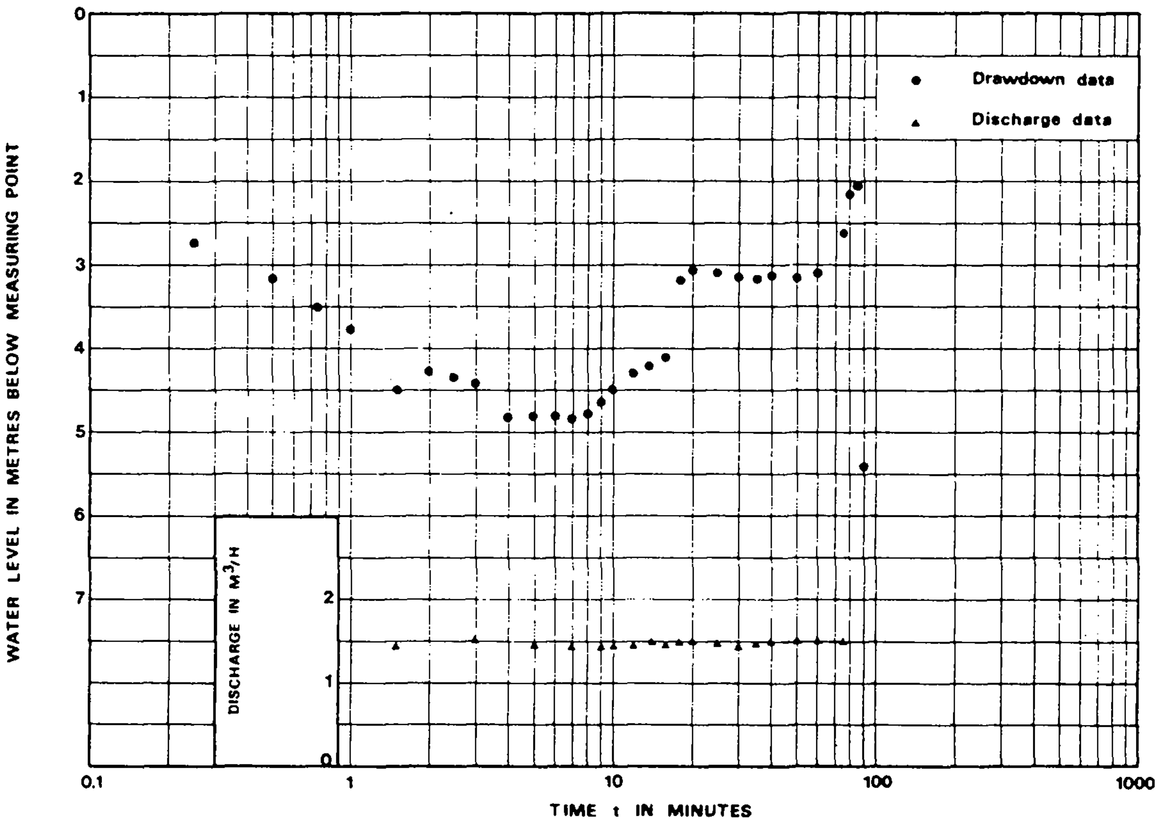
Calculation of hydraulic parametres:

$T = 1.4 \times 10^{-3}\ m^2/sec$

$Q/s_w = 1.44\ m^3/h/m$

THE UNITED REPUBLIC OF TANZANIA

REGION: IRINGA	DISTRICT: MUFINDI	VILLAGE: NDOLEZI	BH NO: 56/81 CCKK NO: IS 2



Constant discharge test : October 28, 1981 9^{55} - 11^{10}

Discharge rate : 1.5 m^3/h

Static water level : 1.98 metres below measuring point

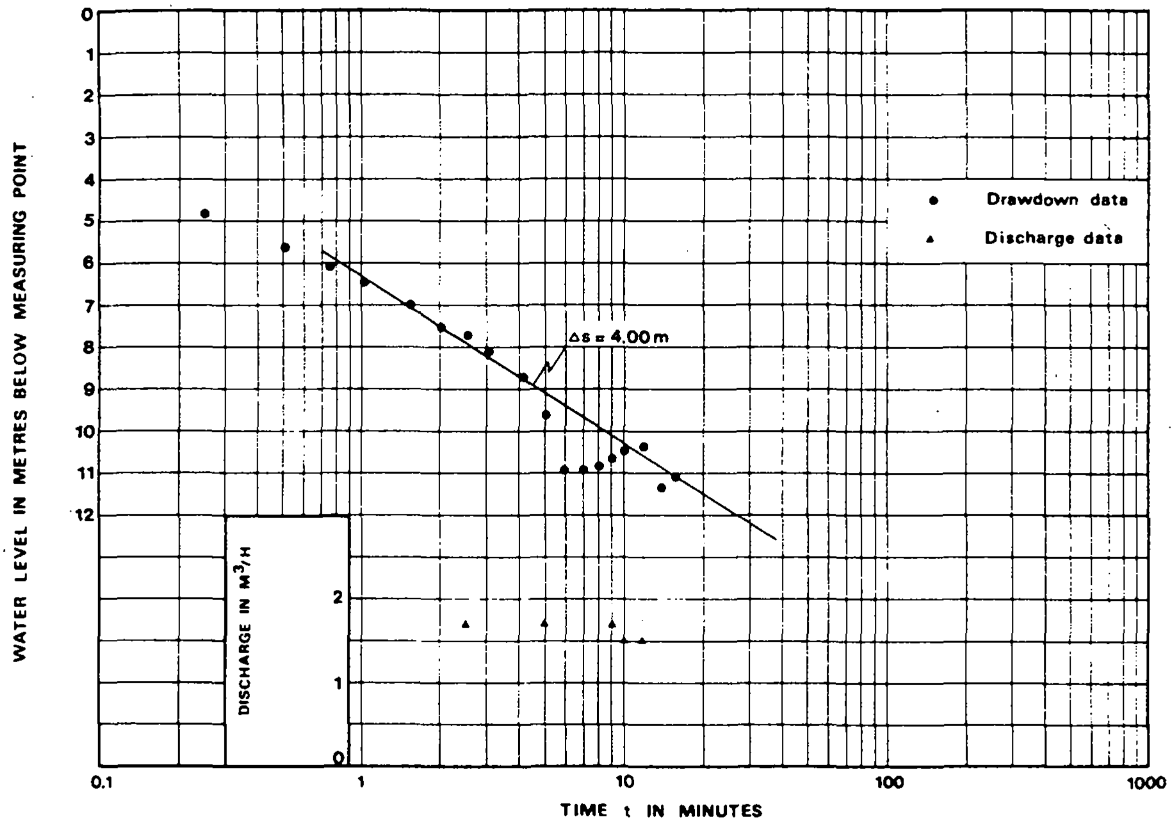
Specific capacity:

Q/s_w = 1.34 $m^3/h/m$

Development was ongoing during pumping. This caused the water level to rise until it after 90 minutes suddenly dropped to pumpintake. The following recovery was completed in 5 minutes, but several repeated tests with same discharge rate all lowered the water level to pumpintake within 2 minutes. Heavy silt/clay deposits were observed in discharge container.

THE UNITED REPUBLIC OF TANZANIA

REGION: IRINGA	DISTRICT: IRINGA	VILLAGE: MLOA	BH NO: 58/81 CCKK NO: IS 4



Constant discharge test : October 22, 1981 16^{40} - 16^{50}

Discharge rate : 1.7 m^3/h

Static water level : 3.31 metres below measuring point

Calculation of hydraulic parametres:

T = 2.2×10^{-5} m^2/sec

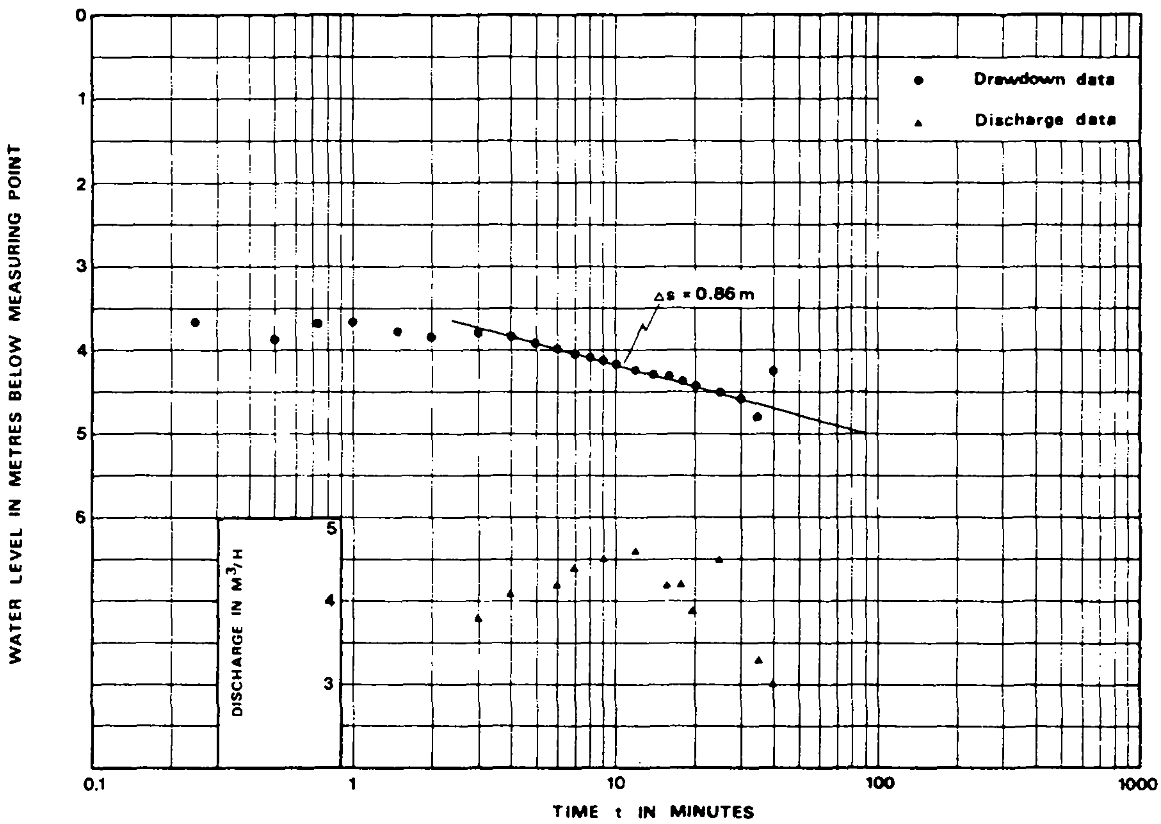
$r_w^2 S$ = 3.6×10^{-2} m^2

Q/s_w = 0.22 $m^3/h/m$

The test was stopped due to jamming of pump impellers by sand.

THE UNITED REPUBLIC OF TANZANIA

REGION: IRINGA	DISTRICT: IRINGA	VILLAGE: IDODI	BH NO: 178/81 CCKK NO: IS 11



Constant discharge test : October 21, 1981 13^{00} - 13^{40}

Discharge rate : 4.2 m^3/h

Static water level : 1.74 metres below measuring point

Calculation of hydraulic parametres:

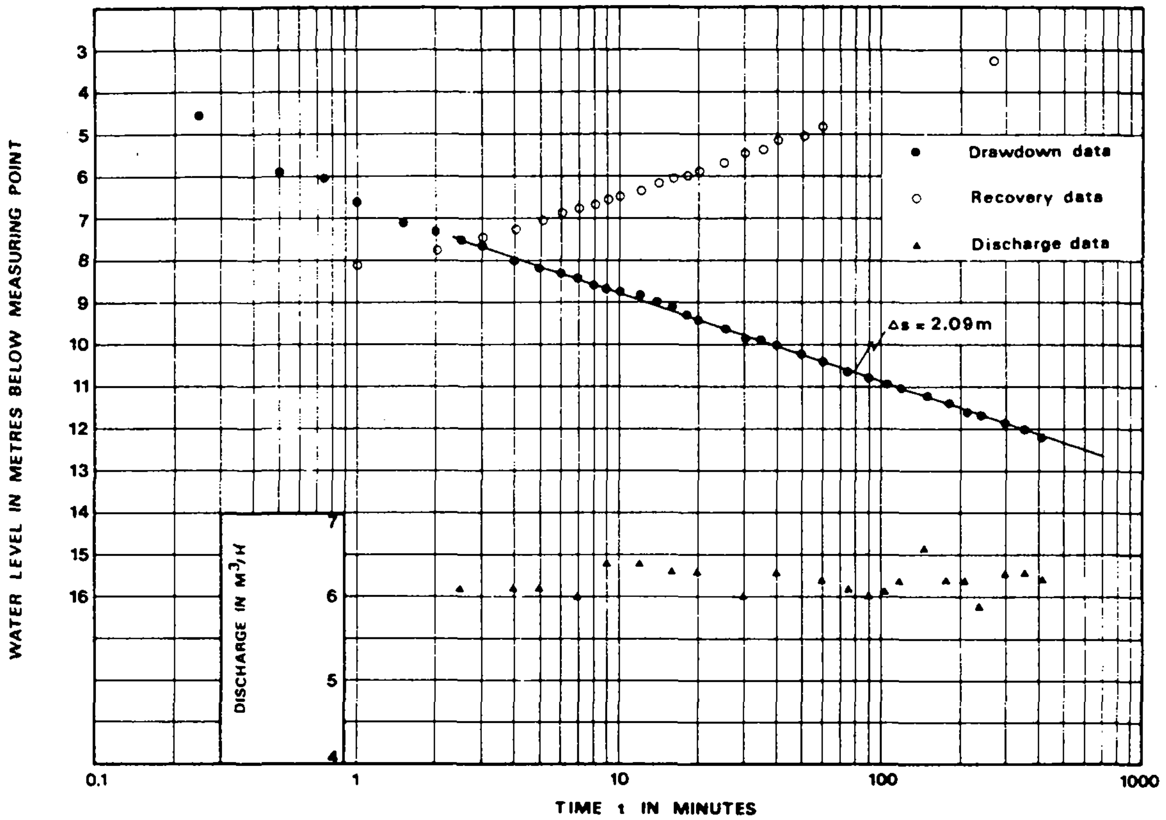
T = 2.5×10^{-4} m^2/sec

Q/s_w = 1.4 $m^3/h/m$

The test was stopped due to heavy sand content in discharged water. The discharge fluctuations were most likely caused by sand deposits in pump impellers.

THE UNITED REPUBLIC OF TANZANIA

REGION: IRINGA	DISTRICT: IRINGA	VILLAGE: MAPOGORO	BH NO: 181/81
			CCKK NO: IS 14



Constant discharge test : October 20, 1981 15^{00} - 22^{00}

Recovery test : October 20, 1981 22^{00} - 23^{00}

Discharge rate : 6.2 m^3/h

Static water level : 3.05 metres below measuring point

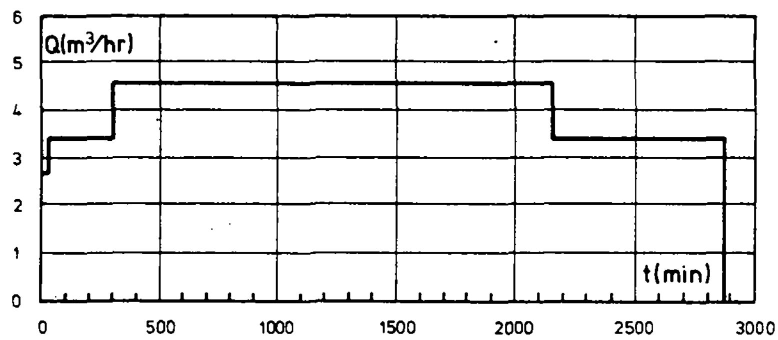
Calculation of hydraulic parametres:

$T = 1.5 \times 10^{-4}\ m^2/sec$

$Q/s_w = 0.68\ m^3/h/m$

THE UNITED REPUBLIC OF TANZANIA			
REGION: RUVUMA	DISTRICT: TUNDURU	VILLAGE: FRELIMO CAMP	B.H. No. 207/73 CCKK No.

DISCHARGE DATA



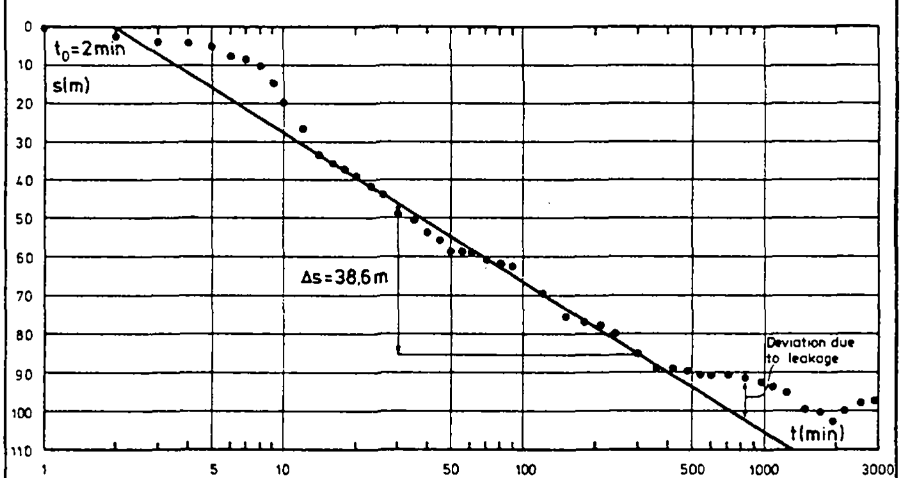
The period 6-300 min has been used for analysis.

α =

k = min^{-1}

Type of decay:
Constant discharge test, Q = 3,41 m^3/hr is used
Test performed:
1973.12.27-29.

DRAWDOWN DATA



T = 4,5 x 10^{-6} m^2/sec.

$r_w{}^2S$ = 0,0012 m^2

$r_w{}^2P^1/m^1$ = m^2/sec.

β =

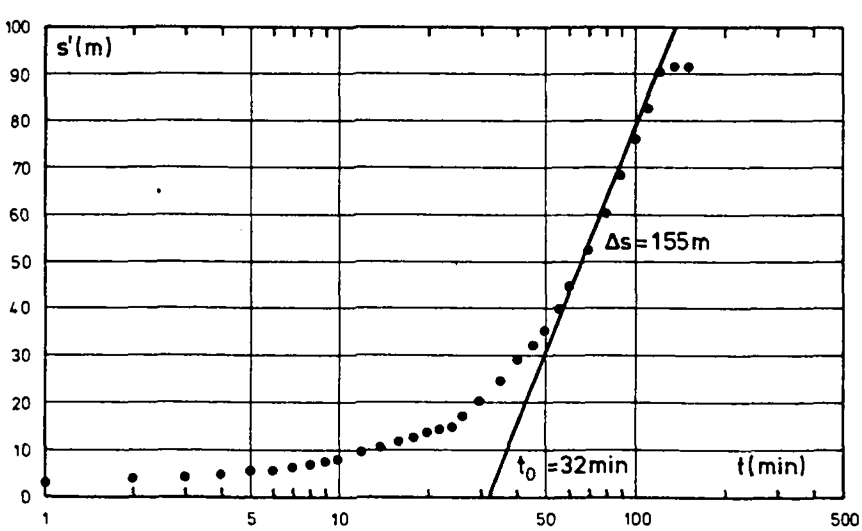
k_{obs} = min^{-1}

k_{cal} = min^{-1}

Q/S_w = m^3/hr/m

T = m^2/sec.

RECOVERY DATA



T = 1,5 x 10^{-6} m^2/sec.

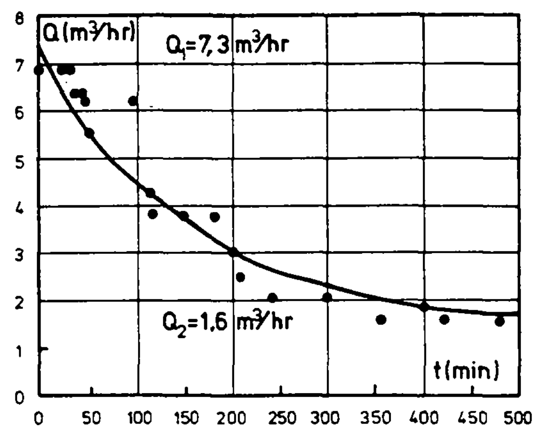
$r_w{}^2S$ = 0,0065 m^2

THE UNITED REPUBLIC OF TANZANIA

REGION: RUVUMA	DISTRICT: TUNDURU	VILLAGE: FRELIMO CAMP	B.H. No. 207/73 CCKK No.

DISCHARGE DATA

$Q = 1,6 + 5.7 \exp(-0,0072t), m^3/hr$



α = 4.3

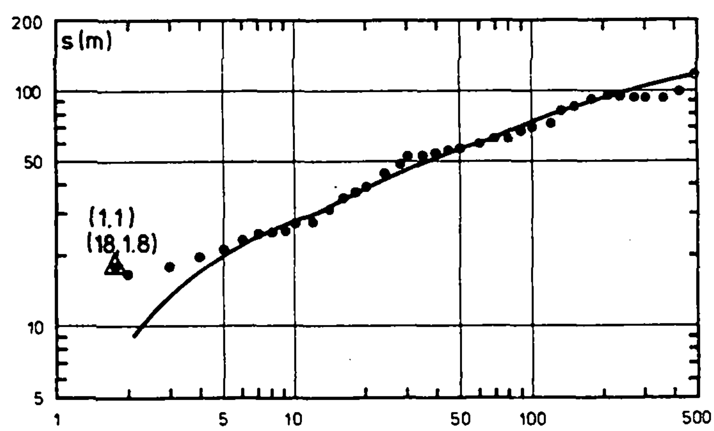
k = 0,0072 min^{-1}

Type of decay: Exponential

Test performed: 1973.10.25

DRAWDOWN DATA

Type curves for a non leaky aquifer are used.



k_{cal} >> k_{obs} indicating very large well storage effect

T = 2,0 x 10^{-6} $m^2/sec.$

$r_w^2 S$ =0,00085 m^2

$r_w^2 P^1/m^1$ = $m^2/sec.$

S = 1,5

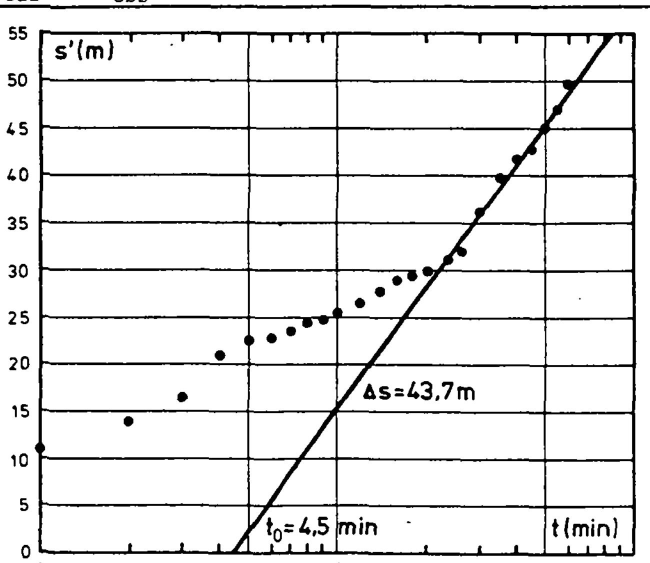
k_{obs} = 0,0072 min^{-1}

k_{cal} = 0,32 min^{-1}

Q/S_w = 0,014 $m^3/hr/m$

T = 10^{-6} $m^2/sec.$

RECOVERY DATA

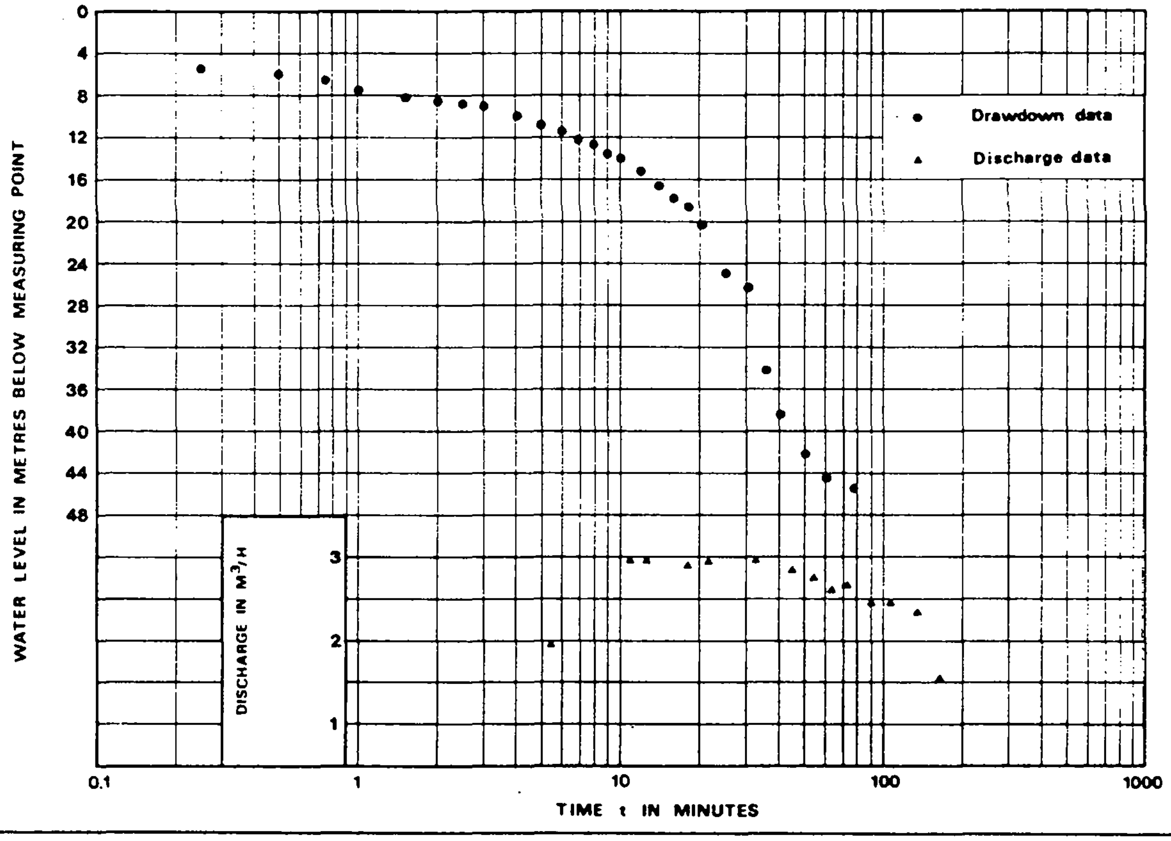


T = 1,9 x 10^{-6} $m^2/sec.$

$r_w^2 S$ = 0,0011 m^2

THE UNITED REPUBLIC OF TANZANIA

REGION: RUVUMA	DISTRICT: SONGEA	VILLAGE: (HANGA RIVER)	BH NO: 253/81
			CCKK NO: RD 1



Constant discharge test : November 6, 1981

Discharge rate : 2.5 m^3/h

Static water level : 4.91 metres below measuring point

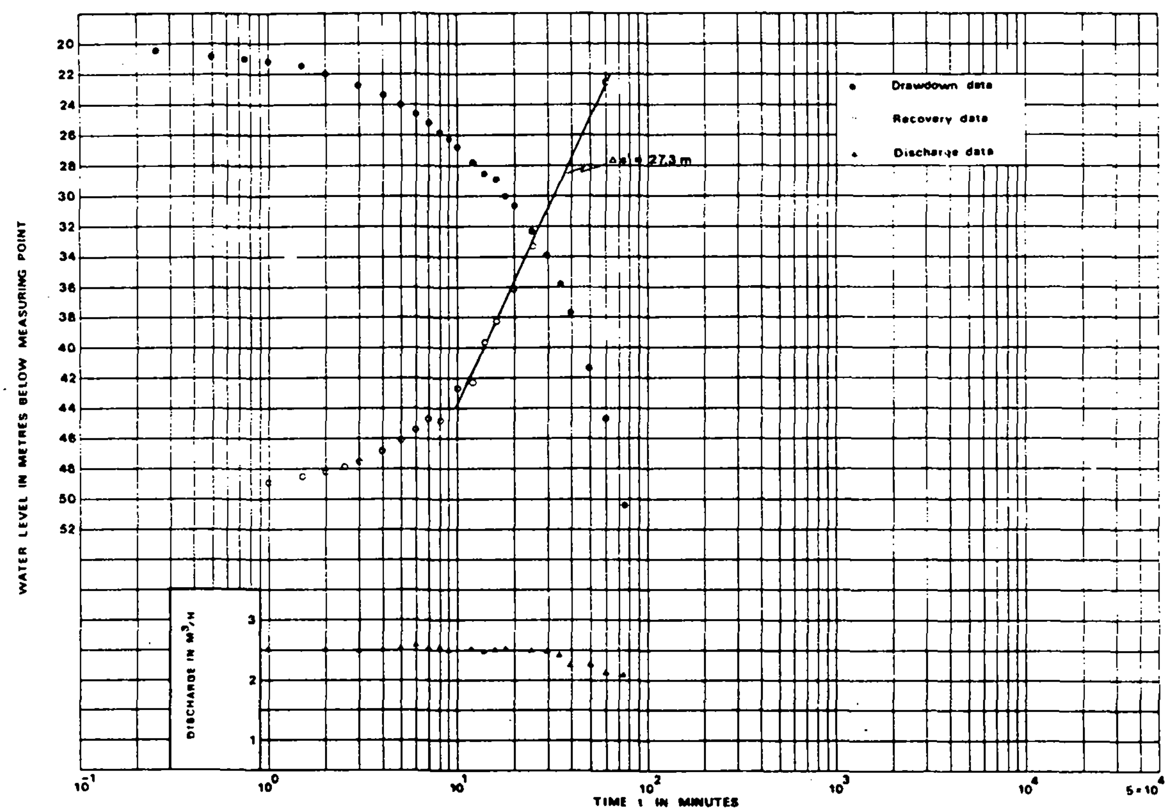
Calculation of hydraulic parametres:

Q/s_w = 0.037 $m^3/h/m$

The increasing decadeslope indicates flow in fractured rocks. Calculation of transmissivity is uncertain and has thus not been attempted.

THE UNITED REPUBLIC OF TANZANIA

REGION: RUVUMA	DISTRICT: SONGEA	VILLAGE: GUMBIRO	BH NO: 254/81 CCKK NO: RD 2



Constant discharge test : November 6, 1981

Recovery test : November 6, 1981

Discharge rate : 2.5 m^3/h

Static water level : 18.72 metres below measuring point

Calculation of hydraulic parametres:

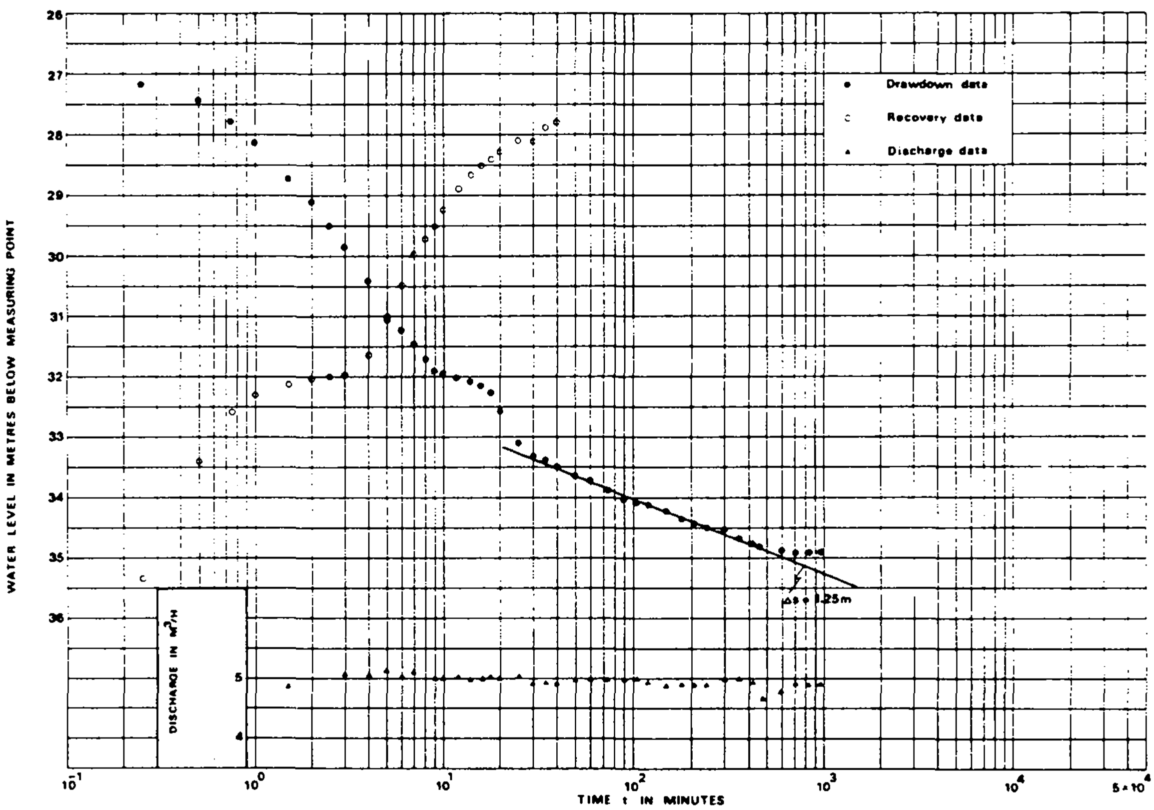
$T = 4.3 \times 10^{-6}\ m^2/sec$

$Q/s_w = 0.066\ m^3/h/m$

Data indicates flow in fractured rocks.

THE UNITED REPUBLIC OF TANZANIA

REGION: RUVUMA	DISTRICT: SONGEA	VILLAGE: MTUKANO	BH NO: 255/81 CCKK NO: RD 3



Constant discharge test : Nov. 7 12^{30} - Nov. 8 4^{30}, 1981

Recovery test : November 8, 1981 4^{30} - 5^{10}

Discharge rate : 5.0 m^3/h

Static water level : 26.81 metres below measuring point

Calculation of hydraulic parametres:

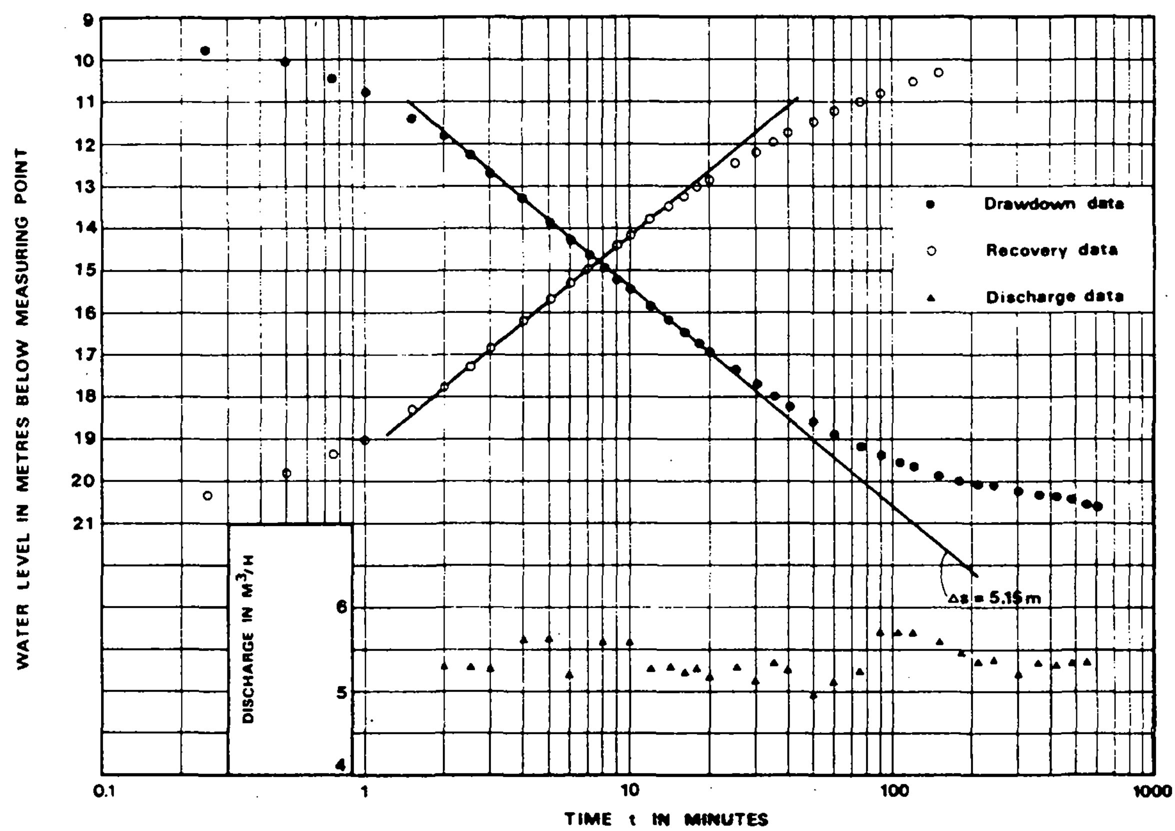
$T = 2.0 \times 10^{-4}\ m^2/sec$

$Q/s_w = 0.60\ m^3/h/m$

The curve deviations after 10 minutes' pumping and the decreasing decadeslope after 30 minutes are most likely caused by development of the well construction.

THE UNITED REPUBLIC OF TANZANIA

REGION: RUVUMA	DISTRICT: TUNDURU	VILLAGE: NDENYENDE	BH NO: 256/81 CCKK NO: RD 4



Constant discharge test : November 12, 1981 9^{30} - 21^{30}

Recovery test : November 12, 1981 21^{30} - 24^{00}

Discharge rate : 5.5 m^3/h

Static water level : 9.47 metres below measuring point

Calculation of hydraulic parametres:

$T = 5.4 \times 10^{-5}\ m^2/sec$

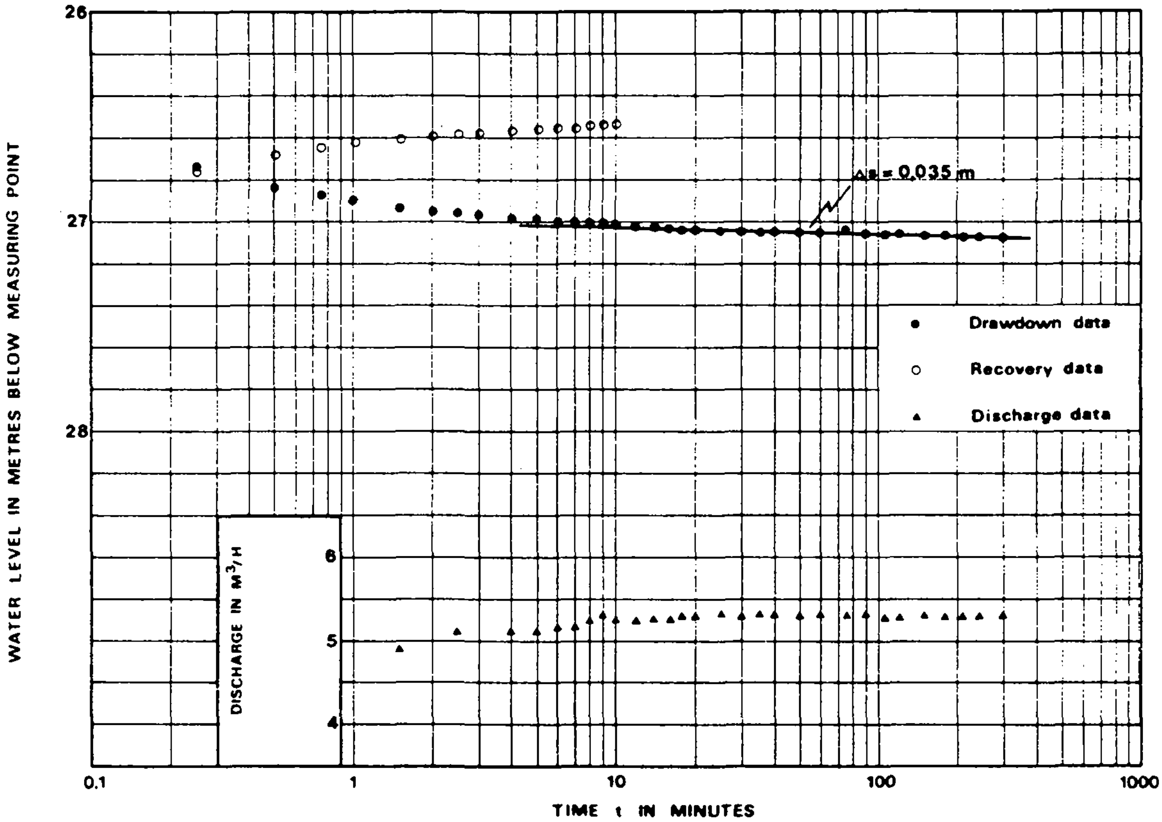
$r_w^2 S = 5.1 \times 10^{-3}\ m^2$

$Q/s_w = 0.48\ m^3/h/m$

The upward deviation from the straight line after 25 minutes is interpreted as caused by leakage from adjacent formations.

THE UNITED REPUBLIC OF TANZANIA

REGION: RUVUMA	DISTRICT: TUNDURU	VILLAGE: NANDEMBO	BH NO: 258/81 CCKK NO: RD 6



Constant discharge test : November 15, 1981 11^{30} - 16^{00}

Recovery test : November 15, 1981 16^{00} - 16^{10}

Discharge rate : 5.3 m^3/h

Static water level : 26.42 metres below measuring point

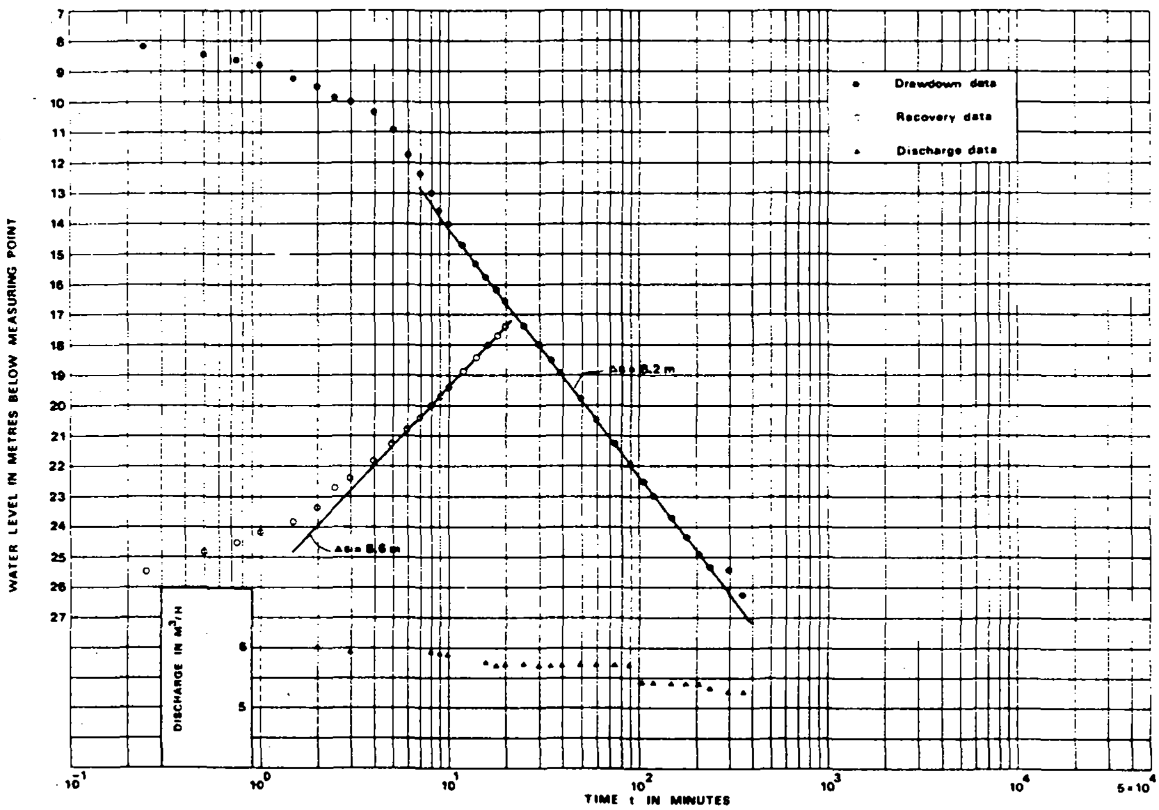
Calculation of hydraulic parametres:

$$T = 7.7 \times 10^{-3}\ m^2/sec$$

$$Q/s_w = 8.03\ m^3/h/m$$

THE UNITED REPUBLIC OF TANZANIA

REGION: RUVUMA	DISTRICT: TUNDURU	VILLAGE: NAMIUNGO	BH NO: 262/81
			CCKK NO: RD 10



Constant discharge test : November 30, 1981 10^{30} - 19^{30}

Recovery test : November 30, 1981 19^{30} - 19^{50}

Discharge rate : 5.5 m^3/h

Static water level : 7.75 metres below measuring point

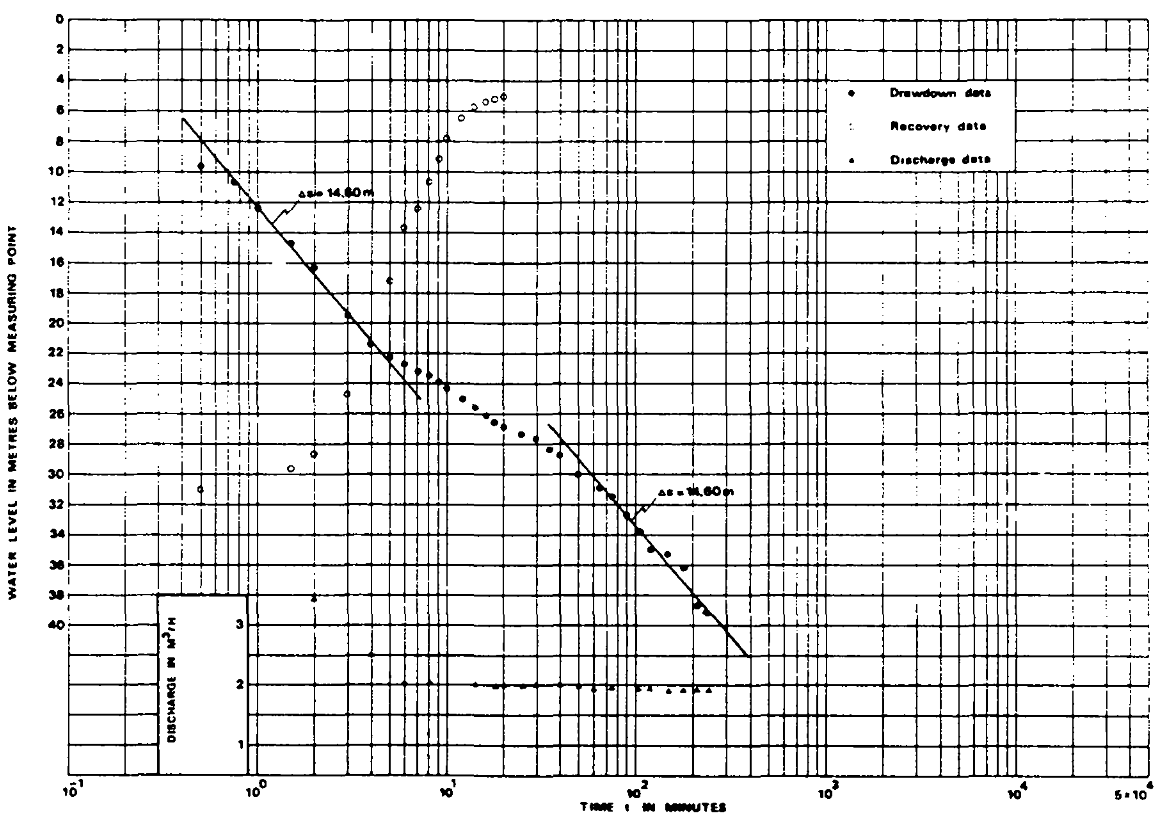
Calculation of hydraulic parametres:

$T =$ 3.4×10^{-5} m^2/sec

$Q/s_w =$ 0.30 $m^3/h/m$

THE UNITED REPUBLIC OF TANZANIA

REGION: RUVUMA	DISTRICT: TUNDURU	VILLAGE: MAJIMAJI	BH NO: 263/81 CCKK NO: RD 11



Constant discharge test : November 21, 1981 11^{10} - 19^{10}

Recovery test : November 21, 1981 19^{10} - 19^{30}

Discharge rate : 1.9 m^3/h

Static water level : 5.00 metres below measuring point

Calculation of hydraulic parametres:

$T = 7.6 \times 10^{-5}\ m^2/sec$

$Q/s_w = 0.056\ m^3/h/m$

The decreased decadeslope from 5 to 60 minutes pumping is interpreted as caused by delayed yield from storage as water table conditions occur.

MBEYA

THE UNITED REPUBLIC OF TANZANIA

REGION: MBEYA	DISTRICT: CHUNYA	VILLAGE: NTUMBI	B.H. No. 6/66 CCKK No.

DISCHARGE DATA

Steady discharge 7,1 m^3/hr with 16,4 metres of drawdown.

α =

k = min^{-1}

Type of decay:

Test performed:

DRAWDOWN DATA

No time-drawdown data.

T = m^2/sec.

r_w^2S = m^2

$r_w^2P^1/m^1$ = m^2/sec.

β =

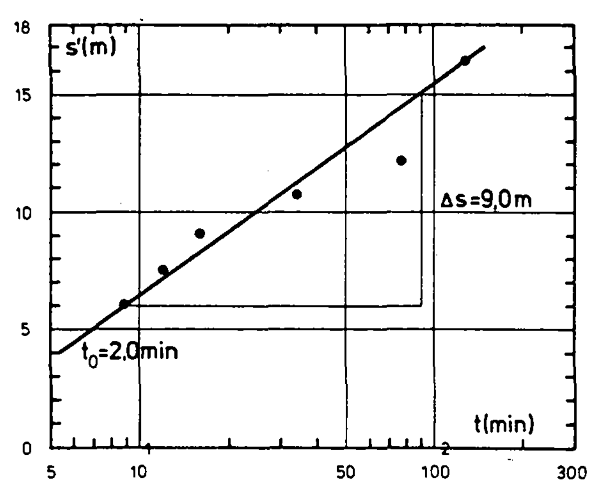
k_{obs} = min^{-1}

k_{cal} = min^{-1}

Q/S_w = 0,43 m^3/hr/m

T ≈ 6 x 10^{-5} m^2/sec.

RECOVERY DATA



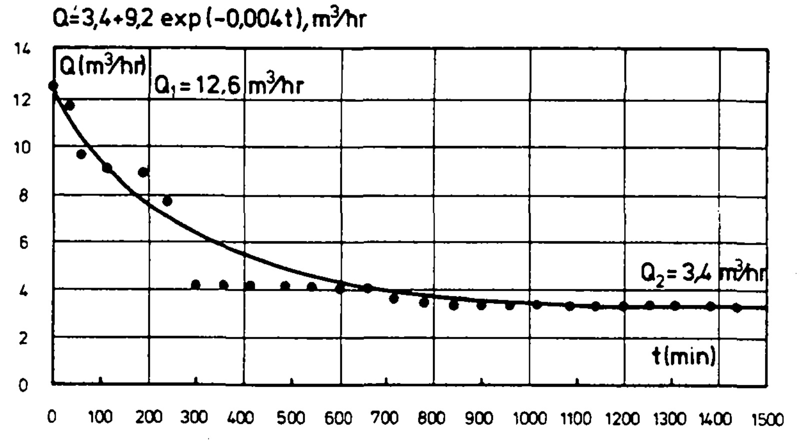
T = 4,0 x 10^{-5} m^2/sec.

r_w^2S = 0,011 m^2

THE UNITED REPUBLIC OF TANZANIA

REGION: MBEYA	DISTRICT: CHUNYA	VILLAGE: MATUNDOSI	B.H. No. 21/71 CCKK No.

DISCHARGE DATA



α = 3,7

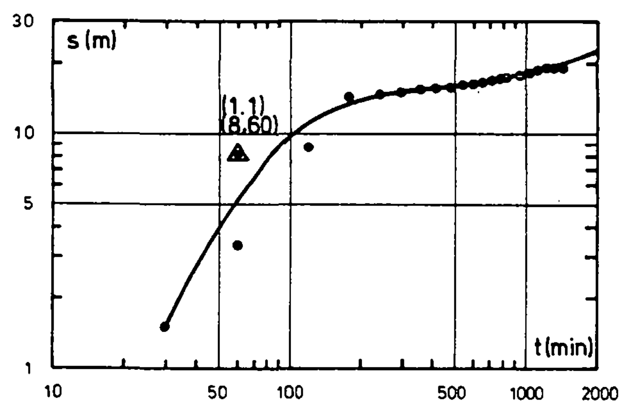
k = 0,004 min^{-1}

Type of decay:
Exponential

Test performed:

DRAWDOWN DATA

Type curves for a non leaky aquifer are used.



T = 9,4 x 10^{-6} m^2/sec.

r_w^2S = 0,14 m^2

$r_w^2P^1/m^1$ = m^2/sec.

β = 1,0

k_{obs} = 0,004 min^{-1}

k_{cal} = 0,004 min^{-1}

Q/S_w = 0,18 m^3/hr/m

T = 2 x 10^{-5} m^2/sec.

RECOVERY DATA

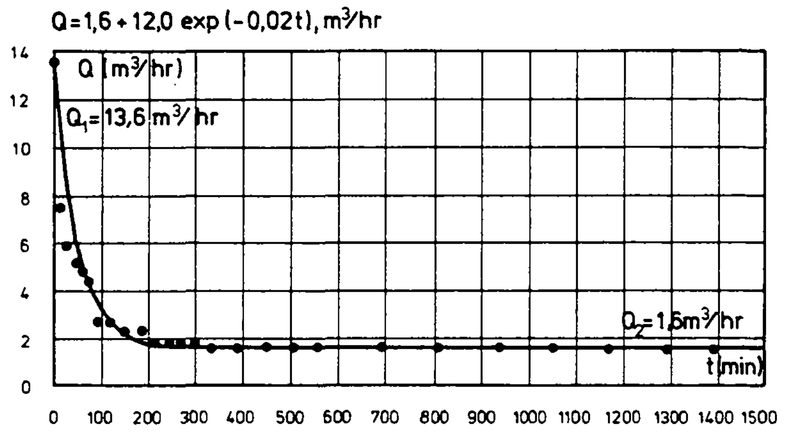
T = m^2/sec.

r_w^2S = m^2

THE UNITED REPUBLIC OF TANZANIA

REGION: MBEYA	DISTRICT: CHUNYA	VILLAGE: KAMBI-KATOTO	B.H. No. 118/71 CCKK No.

DISCHARGE DATA



α = 8,5

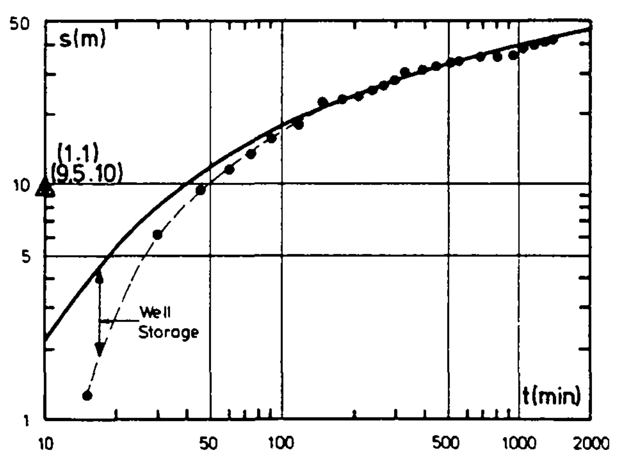
k = 0,02 min^{-1}

Type of decay: Exponential

Test performed: 1972.1.15

DRAWDOWN DATA

A Theis curve is used after 200 minutes.



T = 3,5 x 10^{-6} m^2/sec.

r_w^2S = 0,0084 m^2

$r_w^2P^1/m^1$ = m^2/sec.

β =

k_{obs} = min^{-1}

k_{cal} = min^{-1}

Q/S_w = 0,039 m^3/hr/m

T ≈ 3 x 10^{-6} m^2/sec.

RECOVERY DATA

T = m^2/sec.

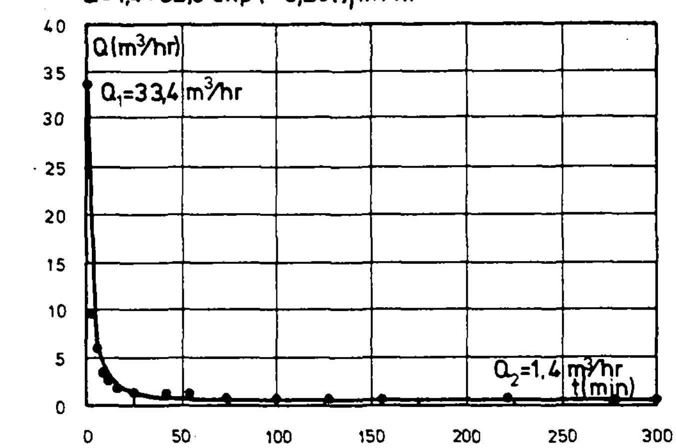
r_w^2S = m^2

THE UNITED REPUBLIC OF TANZANIA

REGION: MBEYA	DISTRICT: CHUNYA	VILLAGE: MAKONGOLOSI	B.H. No. 173/77 CCKK No.

DISCHARGE DATA

$Q = 1{,}4 + 32{,}0 \exp(-0{,}25t), m^3/hr$



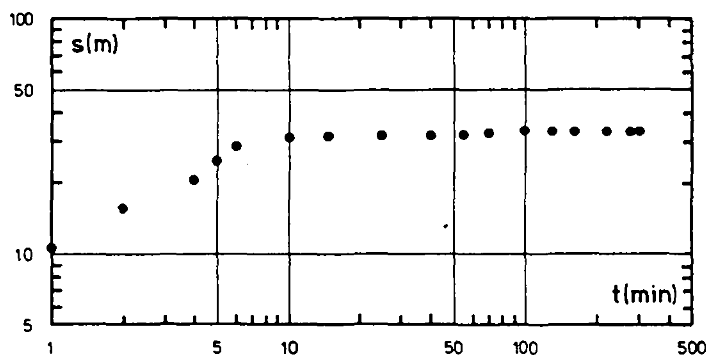
α = 23,9

k = 0,25 min^{-1}

Type of decay:
Exponential

Test performed:
1977.9.17

DRAWDOWN DATA



Type curves cannot be matched to drawdown data,
due to well losses early in the test.

T = m^2/sec.

$r_w^2 S$ = m^2

$r_w^2 P^1/m^1$ = m^2/sec.

β =

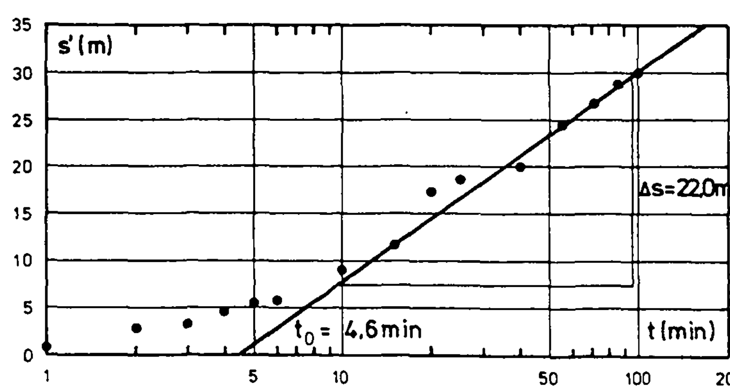
k_{obs} = min^{-1}

k_{cal} = min^{-1}

Q/S_w = m^3/hr/m

T = m^2/sec.

RECOVERY DATA



T = $3{,}2 \times 10^{-6} m^2$/sec.

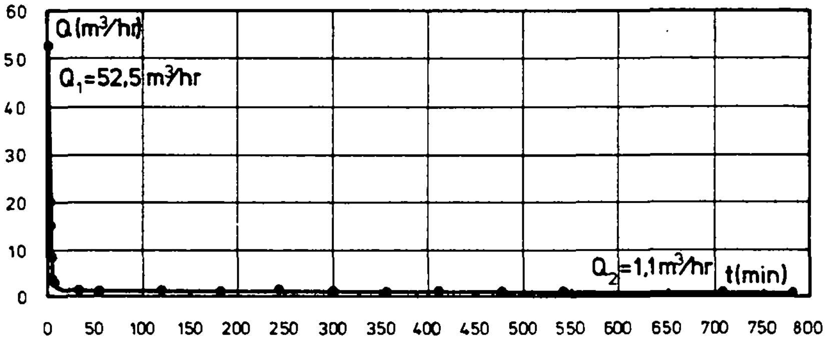
$r_w^2 S$ = 0,002 m^2

THE UNITED REPUBLIC OF TANZANIA

REGION: MBEYA	DISTRICT: CHUNYA	VILLAGE: MAKONGOLOSI	B.H. No. 194/77 CCKK No.

DISCHARGE DATA

$Q = 1{,}1 + 51{,}4 \exp(-0{,}4\,t)$, m^3/hr



α = 47,7

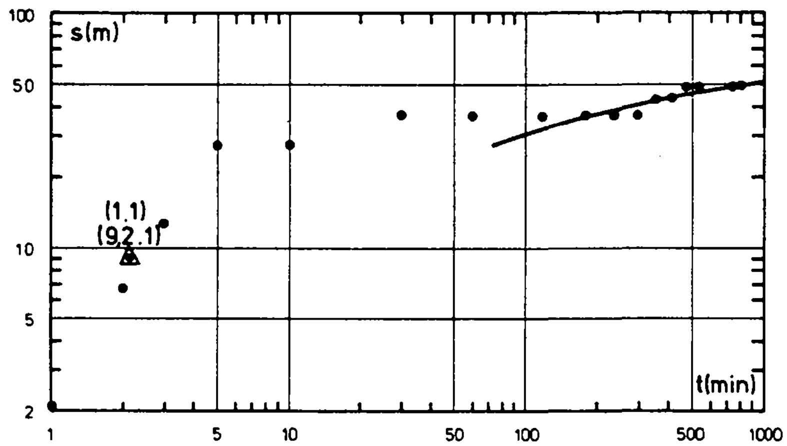
k = 0,4 min^{-1}

Type of decay: Exponential

Test performed:

DRAWDOWN DATA

A Theis curve has been used as an approximation.



$T = 2{,}7 \times 10^{-6}\ m^2/sec.$

$r_w^2 S$ = 0,0014 m^2

$r_w^2 P^1/m^1$ = $m^2/sec.$

β =

k_{obs} = 0,4 min^{-1}

k_{cal} = min^{-1}

Q/S_w = 0,02 $m^3/hr/m$

$T = 4 \times 10^{-6}\ m^2/sec.$

RECOVERY DATA

T = $m^2/sec.$

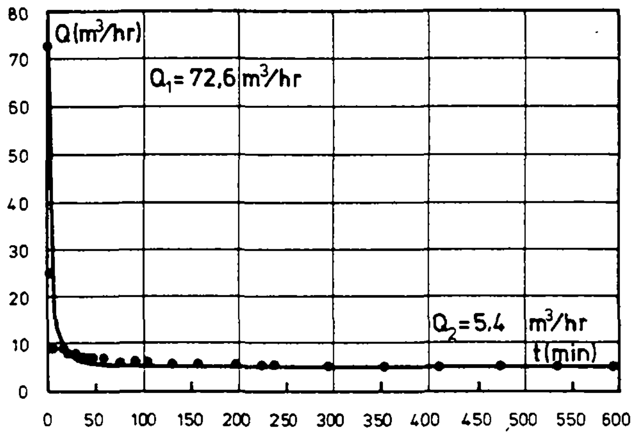
$r_w^2 S$ = m^2

THE UNITED REPUBLIC OF TANZANIA

REGION: MBEYA	DISTRICT: CHUNYA	VILLAGE: MBANGALA	B.H. No. 195/77 CCKK No.

DISCHARGE DATA

$Q = 5{,}4 + 67{,}2 \exp(-0{,}15t), m^3/hr$



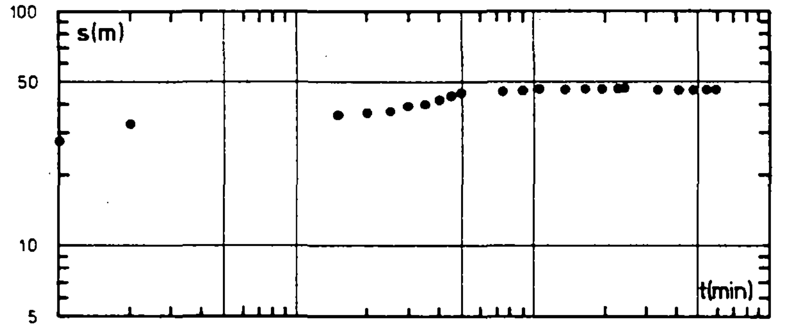
α = 13,3

k = 0,15 min^{-1}

Type of decay:
Exponential

Test performed:
1977.10.25

DRAWDOWN DATA



Well losses to excessive to allow for interpretation by type curve method.

T = m^2/sec.

$r_w{}^2S$ = m^2

$r_w{}^2P^1/m^1$ = m^2/sec.

ε =

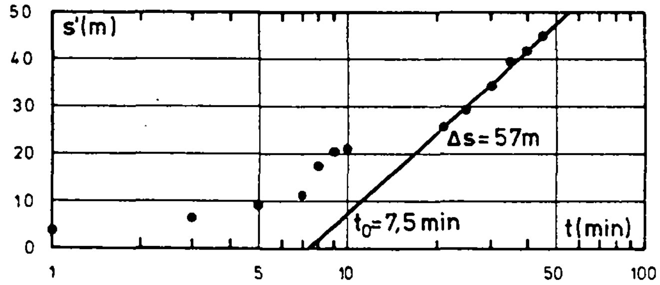
k_{obs} = min^{-1}

k_{cal} = min^{-1}

Q/S_w = m^3/hr/m

T = m^2/sec.

RECOVERY DATA



$T = 4{,}8 \times 10^{-6}\ m^2/sec.$

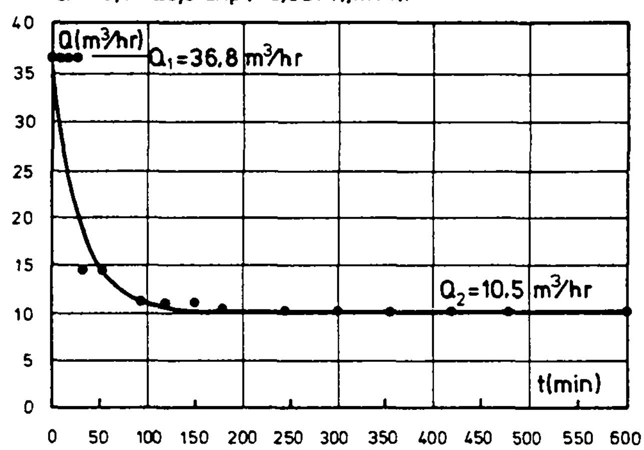
$r_w{}^2S = 0{,}0049\ m^2$

THE UNITED REPUBLIC OF TANZANIA

REGION: MBEYA	DISTRICT: CHUNYA	VILLAGE: MAPOGOLO	B.H. No. 209/77 CCKK No.

DISCHARGE DATA

$Q = 10{,}5 + 26{,}3 \exp(-0{,}037t), m^3/hr$



$\alpha = 3{,}5$

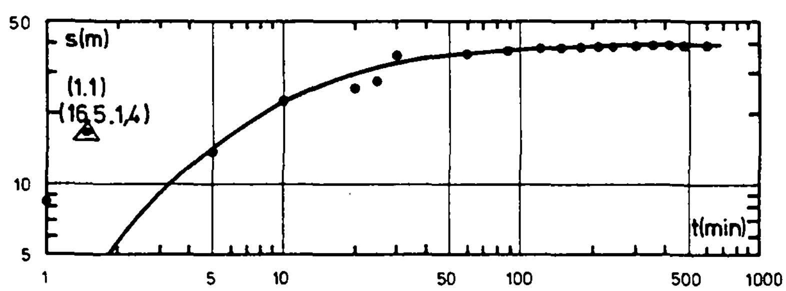
$k = 0{,}037 \ min^{-1}$

Type of decay:
Exponential

Test performed:

DRAWDOWN DATA

Type curves for a leaky artesian aquifer are used, $\delta = 0{,}4$



k_{cal} and k_{obs} deviate too much from each other.
Interpretation doubtful.

$T = 1{,}4 \times 10^{-5} \ m^2/sec.$

$r_w^2 S = 0{,}0049 \ m^2$

$r_w^2 P^1/m^1 = 2{,}2 \times 10^{-6} \ m^2/sec.$

$\beta = 3{,}0$

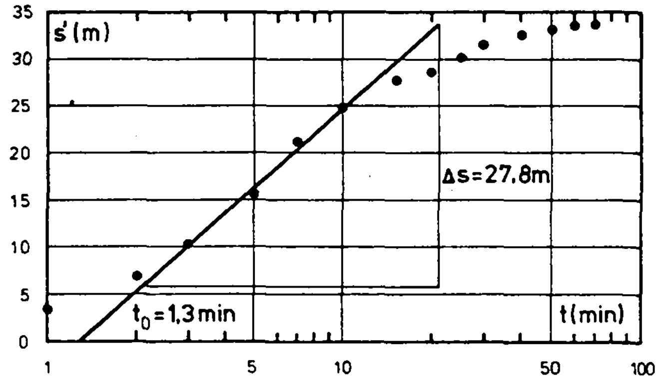
$k_{obs} = 0{,}037 \ min^{-1}$

$k_{cal} = 1{,}54 \ min^{-1}$

$Q/S_w = \qquad m^3/hr/m$

$T = \qquad m^2/sec.$

RECOVERY DATA



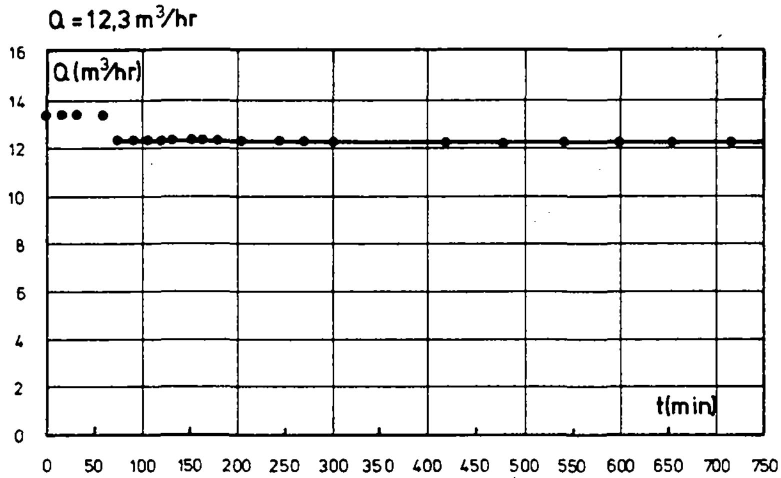
$T = 1{,}9 \times 10^{-5} \ m^2/sec.$

$r_w^2 S = 0{,}0033 \ m^2$

THE UNITED REPUBLIC OF TANZANIA

REGION: MBEYA	DISTRICT: CHUNYA	VILLAGE: CHUNYA	B.H. No. 223/77 CCKK No.

DISCHARGE DATA



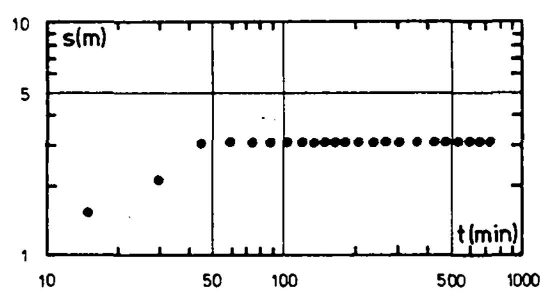
α =

k = min^{-1}

Type of decay:
Approximately constant discharge

Test performed:

DRAWDOWN DATA



Drawdown data not reliable.
Recovery data unused.

T = m^2/sec.

r_w^2S = m^2

$r_w^2P^1/m^1$ = m^2/sec.

β =

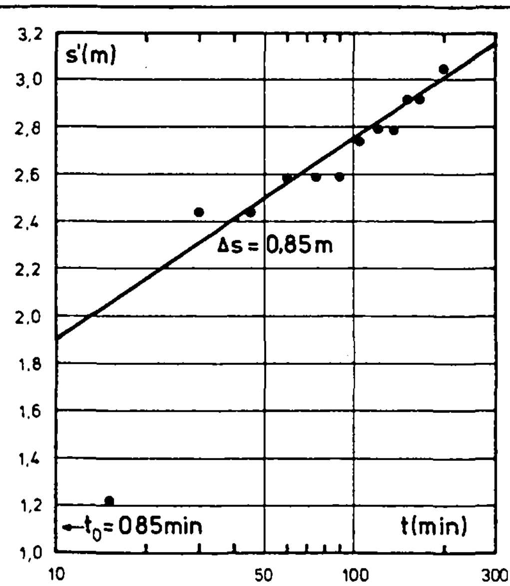
k_{obs} = min^{-1}

k_{cal} = min^{-1}

Q/S_w = m^3/hr/m

T = m^2/sec.

RECOVERY DATA



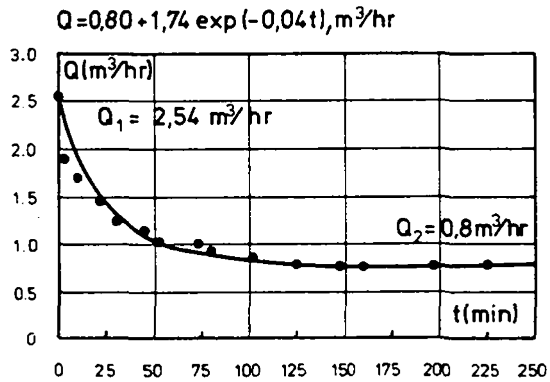
T = 7,4 x 10^{-4} m^2/sec.

r_w^2S = 0,084 m^2

THE UNITED REPUBLIC OF TANZANIA

REGION: MBEYA	DISTRICT: MBOZI	VILLAGE: MKUTANO	B.H. No. 182/78 CCKK No.

DISCHARGE DATA



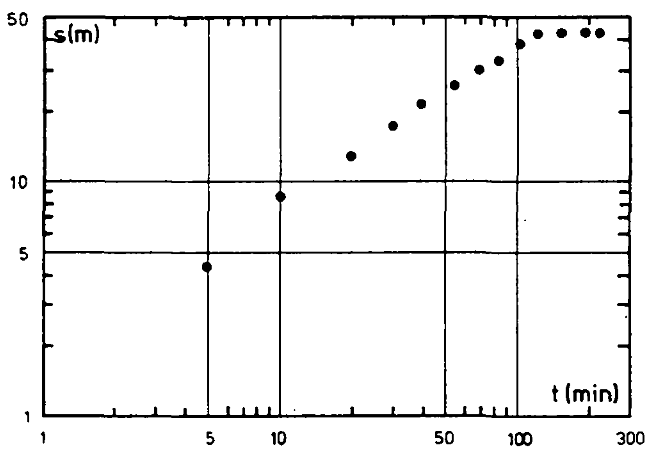
α = 3,2

k = 0,04 min^{-1}

Type of decay:
Exponential

Test performed:

DRAWDOWN DATA



Type curves cannot be filled to data,
due to excessive well storage effects.

T = m^2/sec.

r_w^2S = m^2

$r_w^2P^1/m^1$ = m^2/sec.

β =

k_{obs} = min^{-1}

k_{cal} = min^{-1}

Q/S_w = 0,02 m^3/hr/m

T = 4 x 10^{-6} m^2/sec.

RECOVERY DATA

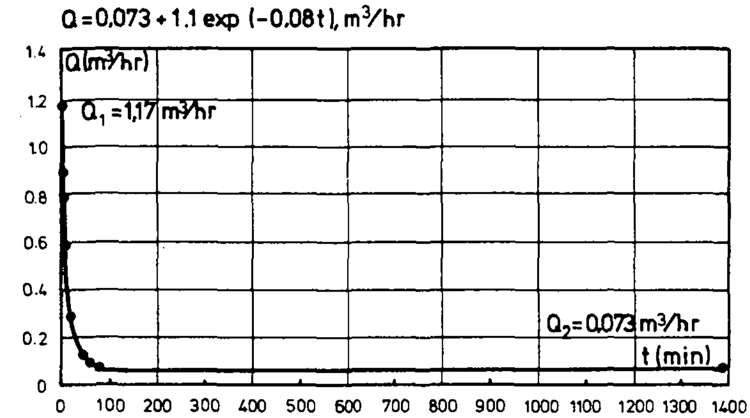
T = m^2/sec.

r_w^2S = m^2

THE UNITED REPUBLIC OF TANZANIA

REGION: MBEYA	DISTRICT: MBOZI	VILLAGE: MBOZI MISSION	B.H. No. 25/81 CCKK No.

DISCHARGE DATA



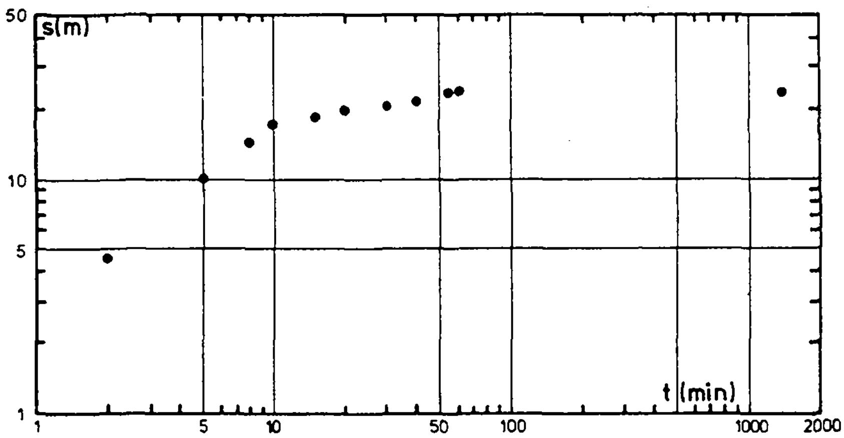
α = 16,0

k = 0,08 min^{-1}

Type of decay: Exponential

Test performed: 1981.4.17

DRAWDOWN DATA



T = m^2/sec.

$r_w{}^2S$ = m^2

$r_w{}^2P^1/m^1$ = m^2/sec.

β =

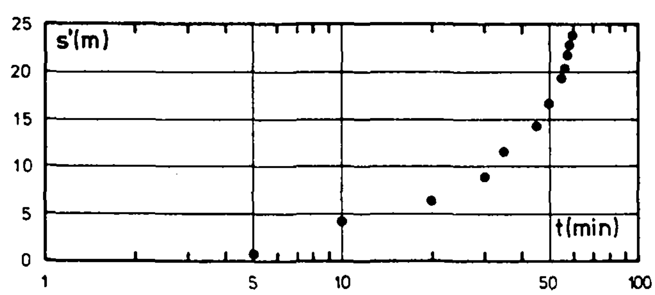
k_{obs} = min^{-1}

k_{cal} = min^{-1}

Q/S_w = 0,0032 m^3/hr/m

T = 2×10^{-7} m^2/sec.

RECOVERY DATA



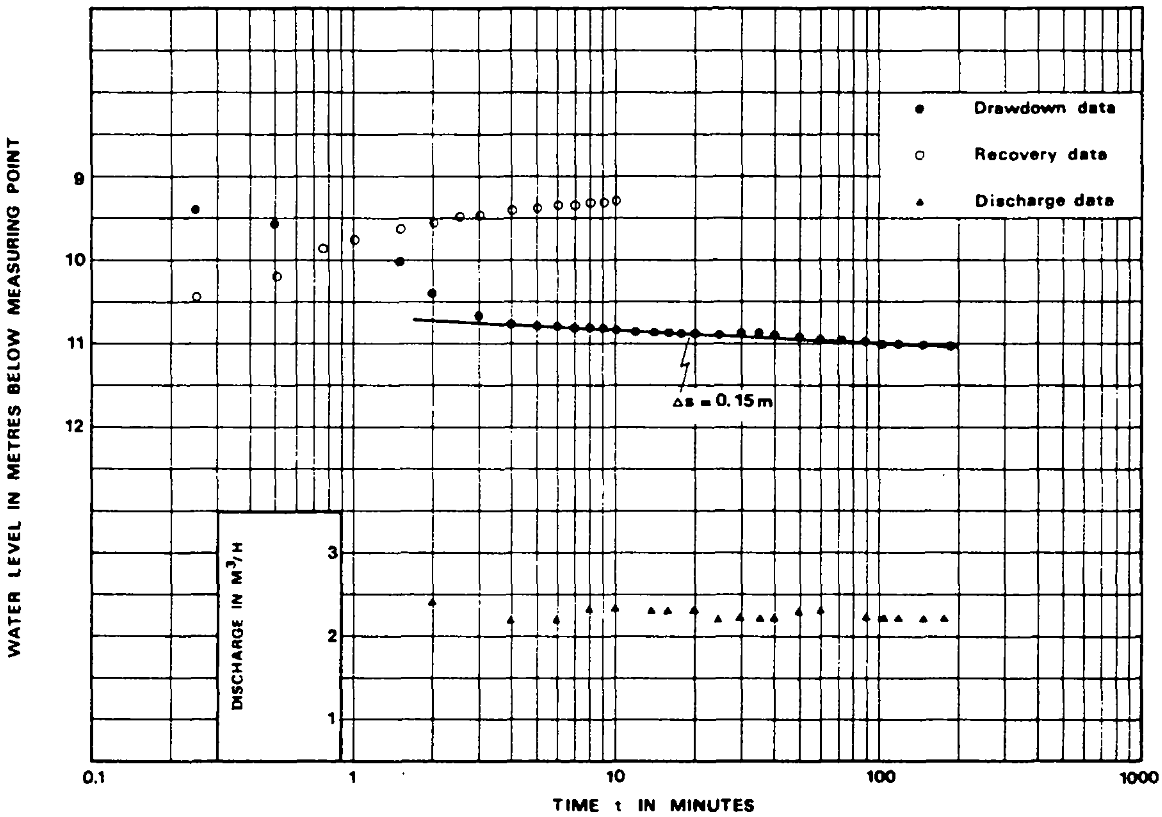
Drawdown and recovery data do not correspond.
No interpretation done. Borehole technically dry.

T = m^2/sec.

$r_w{}^2S$ = m^2

THE UNITED REPUBLIC OF TANZANIA

REGION: MBEYA	DISTRICT: KYELA	VILLAGE: KIKUSYA	BH NO: 19/81 CCKK NO: MS 10



Constant discharge test : October 12, 1981 19^{30} - 22^{00}

Recovery test : October 12, 1981 22^{00} - 22^{10}

Discharge rate : 2.2 m^3/h

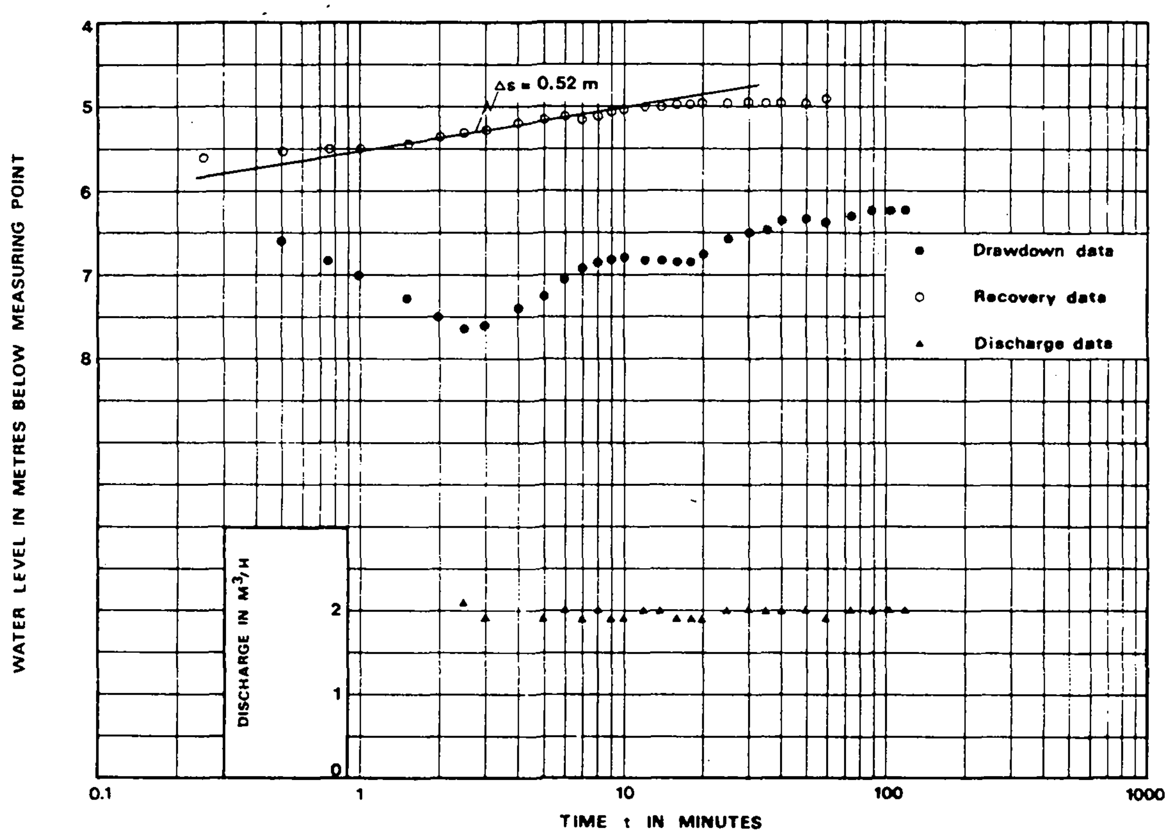
Static water level : 9.34 metres below measuring point

Calculation of hydraulic parametres:

$T =$ 7.5×10^{-4} m^2/sec

$Q/s_w =$ 1.31 $m^3/h/m$

THE UNITED REPUBLIC OF TANZANIA			
REGION: MBEYA	DISTRICT: KYELA	VILLAGE: ITENYA	BH NO: 22/81 CCKK NO: MS 13



Constant discharge test : October 15, 1981 12^{10} - 14^{10}

Recovery test : October 15, 1981 14^{10} - 15^{10}

Discharge rate : 2.0 m^3/h

Static water level : 2.72 metres below measuring point

Calculation of hydraulic parametres:

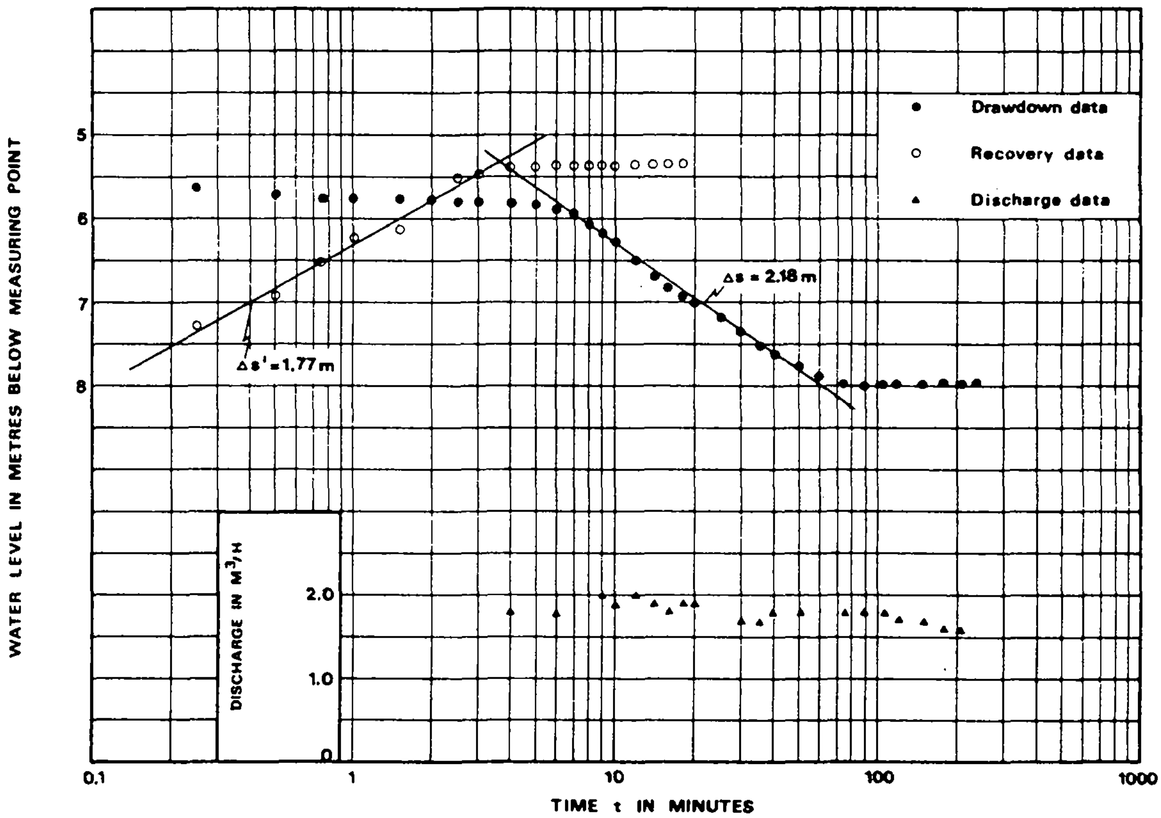
$$T = 2.0 \times 10^{-4}\ m^2/sec$$

$$Q/s_w = 1.48\ m^3/h/m$$

The water level fluctuations were caused by ongoing development during pumping.

THE UNITED REPUBLIC OF TANZANIA

REGION: MBEYA	DISTRICT: KYELA	VILLAGE: KABANGA	BH NO: 24/81 CCKK NO: MS 15



Constant discharge test : October 14, 1981 15^{10} - 19^{10}

Recovery test : October 14, 1981 19^{10} - 19^{28}

Discharge rate : 1.8 m^3/h

Static water level : 5.32 metres below measuring point

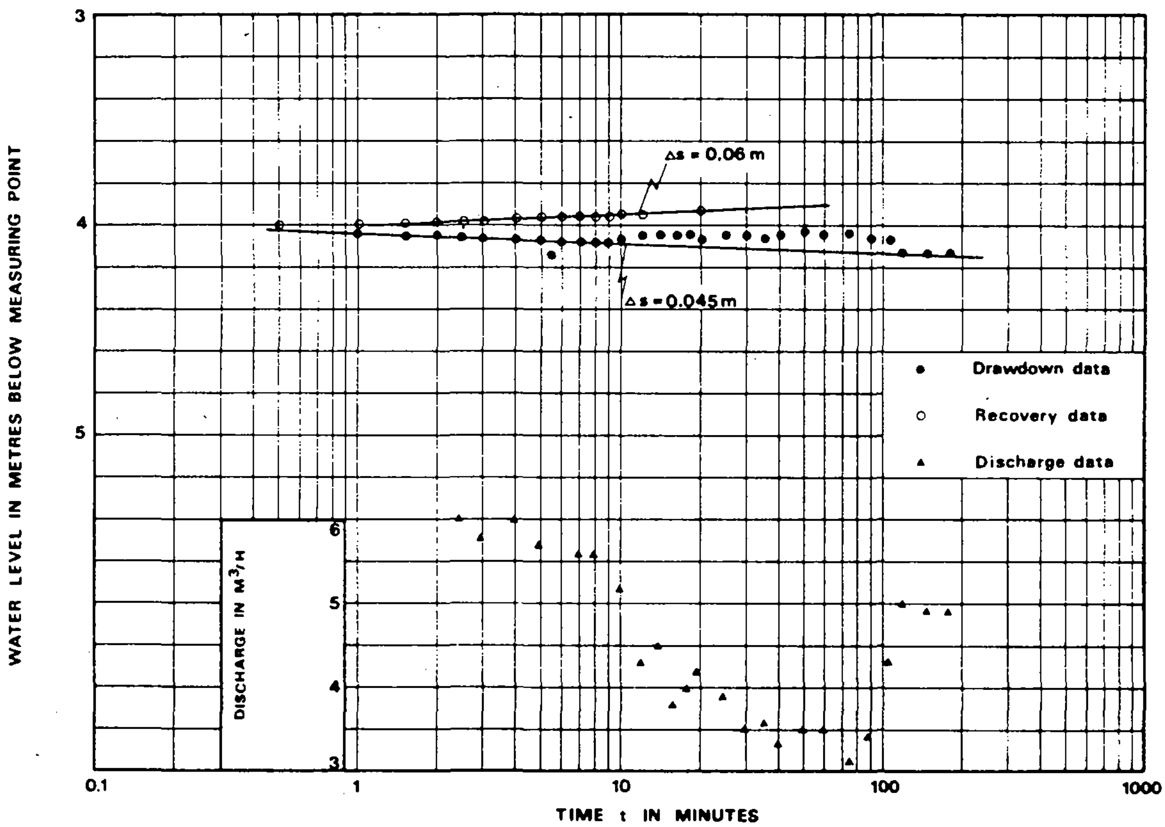
Calculation of hydraulic parametres:

$T = 4.2 \times 10^{-5}\ m^2/sec$

$r_w^2 S = 2.0 \times 10^{-2}\ m^2$

$Q/s_w = 0.69\ m^3/h/m$

THE UNITED REPUBLIC OF TANZANIA			
REGION: MBEYA	DISTRICT: KYELA	VILLAGE: TENENDE	BH NO: 29/81 CCKK NO: MS 16



Constant discharge test : October 13, 1981 10^{00} - 13^{00}

Recovery test : October 13, 1981 13^{00} - 13^{20}

Discharge rate : 3 - 6 m^3/h

Static water level : 3.88 metres below measuring point

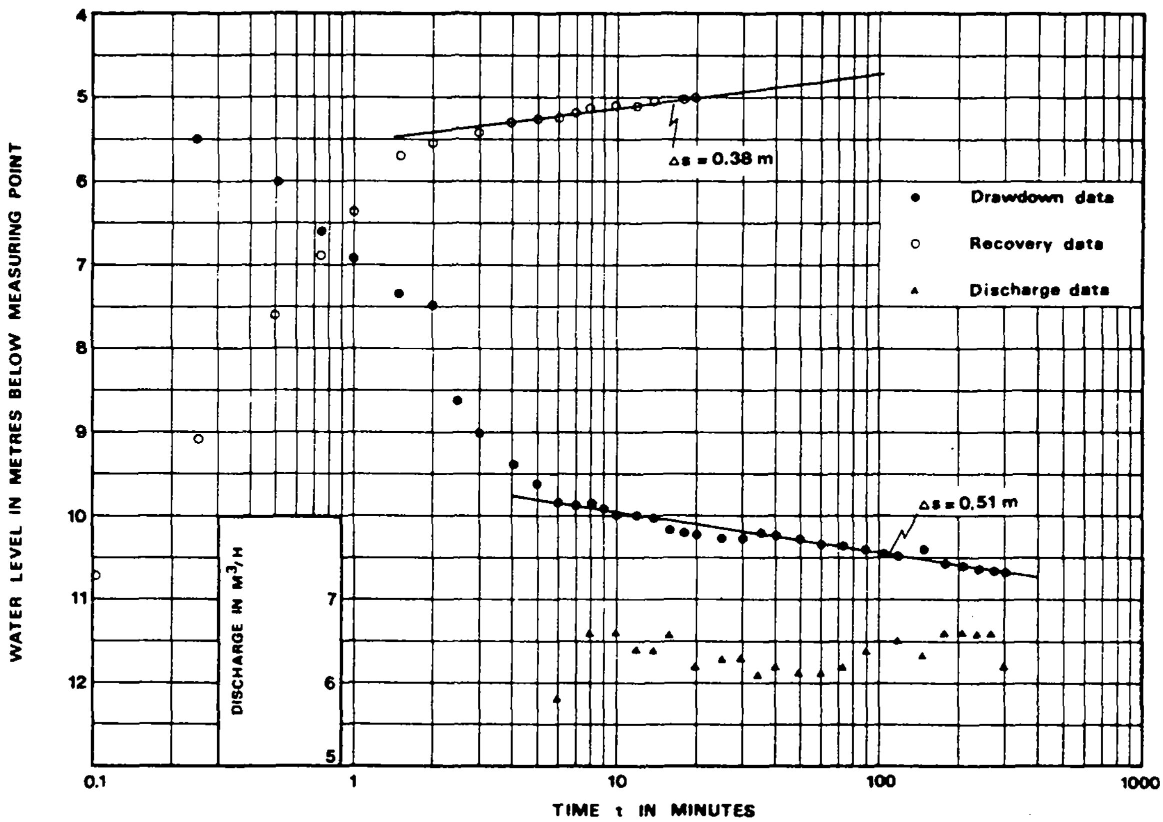
Calculation of hydraulic parametres:

T = 4.2×10^{-3} m^2/sec (recovery data)

Q/s_w = 20.8 $m^3/h/m$

The fluctuating discharge rate may have been caused by temporarily clogging of pump impellers by sand.

THE UNITED REPUBLIC OF TANZANIA			
REGION: MBEYA	DISTRICT: KYELA	VILLAGE: IPINDA	BH NO: 30/81 CCKK NO: MS 17



Constant discharge test : October 13, 1981 13^{10} - 17^{10}

Recovery test : October 13, 1981 17^{10} - 17^{30}

Discharge rate : 6.4 m^3/h

Static water level : 4.46 metres below measuring point

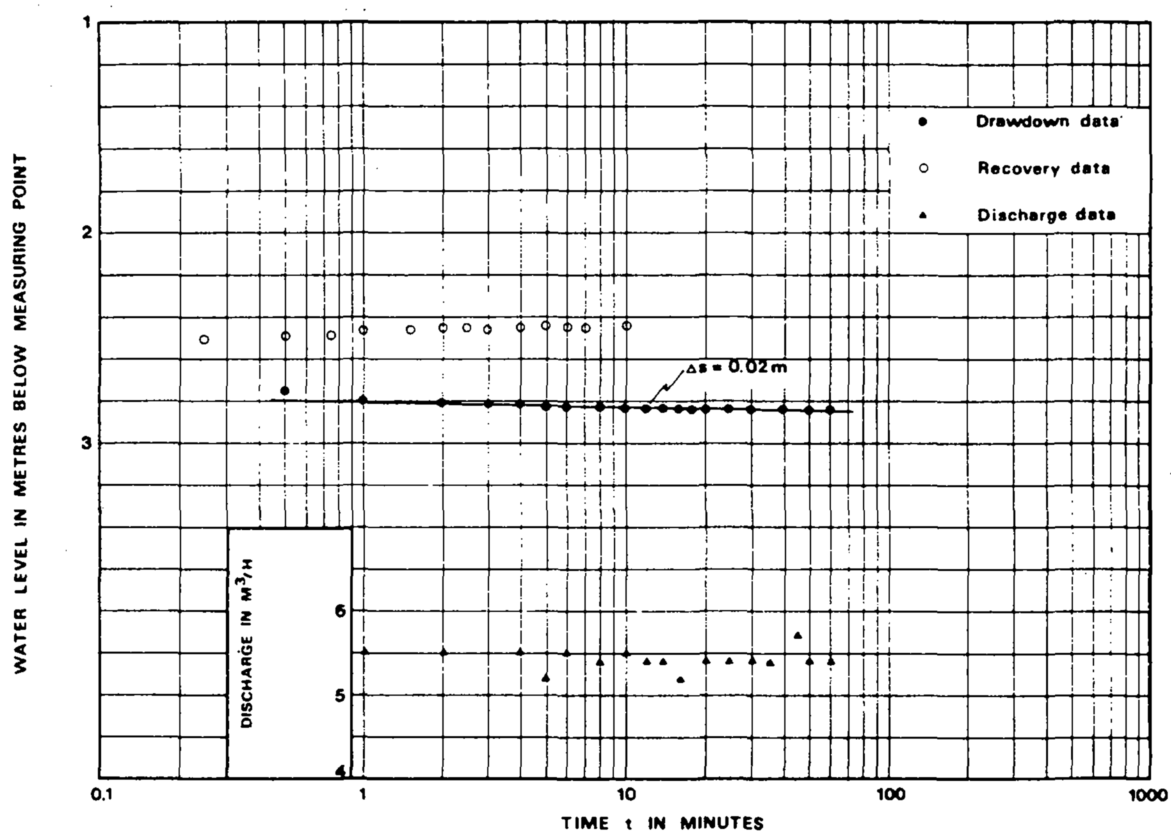
Calculation of hydraulic parametres:

$T =$ 6.4×10^{-4} m^2/sec (drawdown data)

$T =$ 8.6×10^{-4} m^2/sec (recovery data)

$Q/s_w =$ 1.04 $m^3/h/m$

THE UNITED REPUBLIC OF TANZANIA			
REGION: MBEYA	DISTRICT: KYELA	VILLAGE: NDOBE	BH NO: 73/81 CCKK NO: MS 18



Constant discharge test : October 14, 1981 8^{45} - 9^{45}

Recovery test : October 14, 1981 9^{45} - 9^{55}

Discharge rate : 5.4 m^3/h

Static water level : 2.42 metres below measuring point

Calculation of hydraulic parametres:

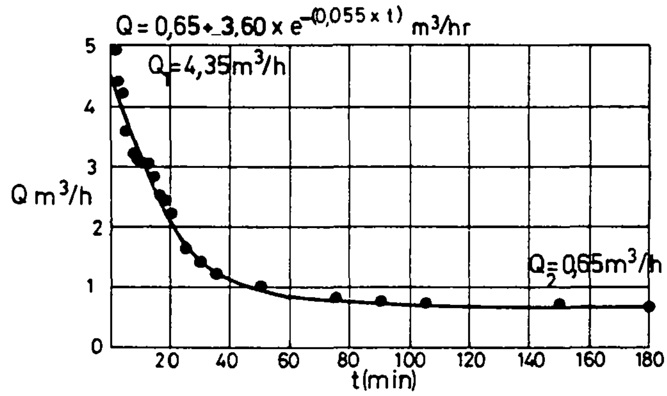
$T = 1.4 \times 10^{-2}\ m^2/sec$

$Q/s_w = 12.86\ m^3/h/m$

THE UNITED REPUBLIC OF TANZANIA

REGION: MBEYA	DISTRICT: MBOZI	VILLAGE: CHIWANDA	B.H. No. 76/81 CCKK No. MD 1

DISCHARGE DATA



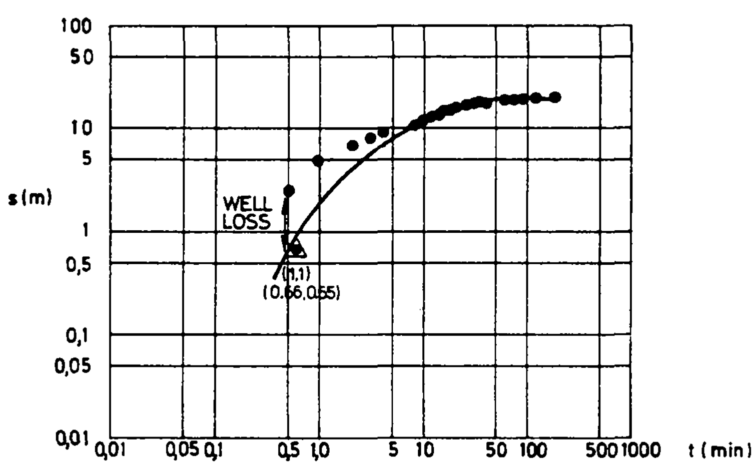
α = 7.7

k = 0.055 min^{-1}

Type of decay:
exponential

Test performed:
81.10.02

DRAWDOWN DATA



$k_{cal} < k_{obs}$ indicating well losses

T = 2.2 x 10^{-5} m^2/sec.

r_w^2S = 3.4x10^{-3} m^2

$r_w^2P^1/m^1$ = m^2/sec.

β = 0.07

k_{obs} = 0.055 min^{-1}

k_{cal} = min^{-1}

Q/S_w = 0.033 m^3/hr/m

T = m^2/sec.

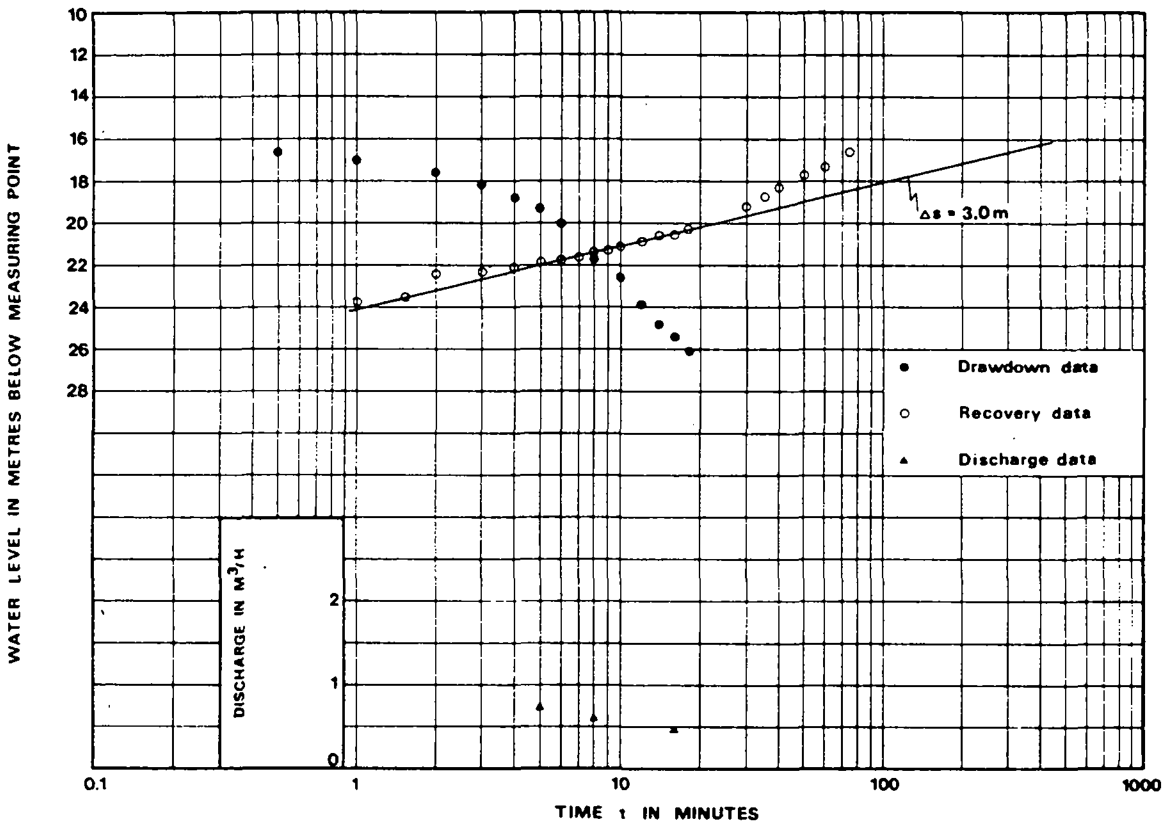
RECOVERY DATA

T = m^2/sec.

r_w^2S = m^2

THE UNITED REPUBLIC OF TANZANIA

REGION: MBEYA	DISTRICT: MBOZI	VILLAGE: MPEMBA	BH NO: 77/81 CCKK NO: MD 2



Constant discharge test	:	October 8, 1981 10^{20} - 10^{38}
Recovery test	:	October 8, 1981 10^{38} - 11^{28}
Discharge rate	:	0.45 m^3/h
Static water level	:	15.03 metres below measuring point

Calculation of hydraulic parametres:

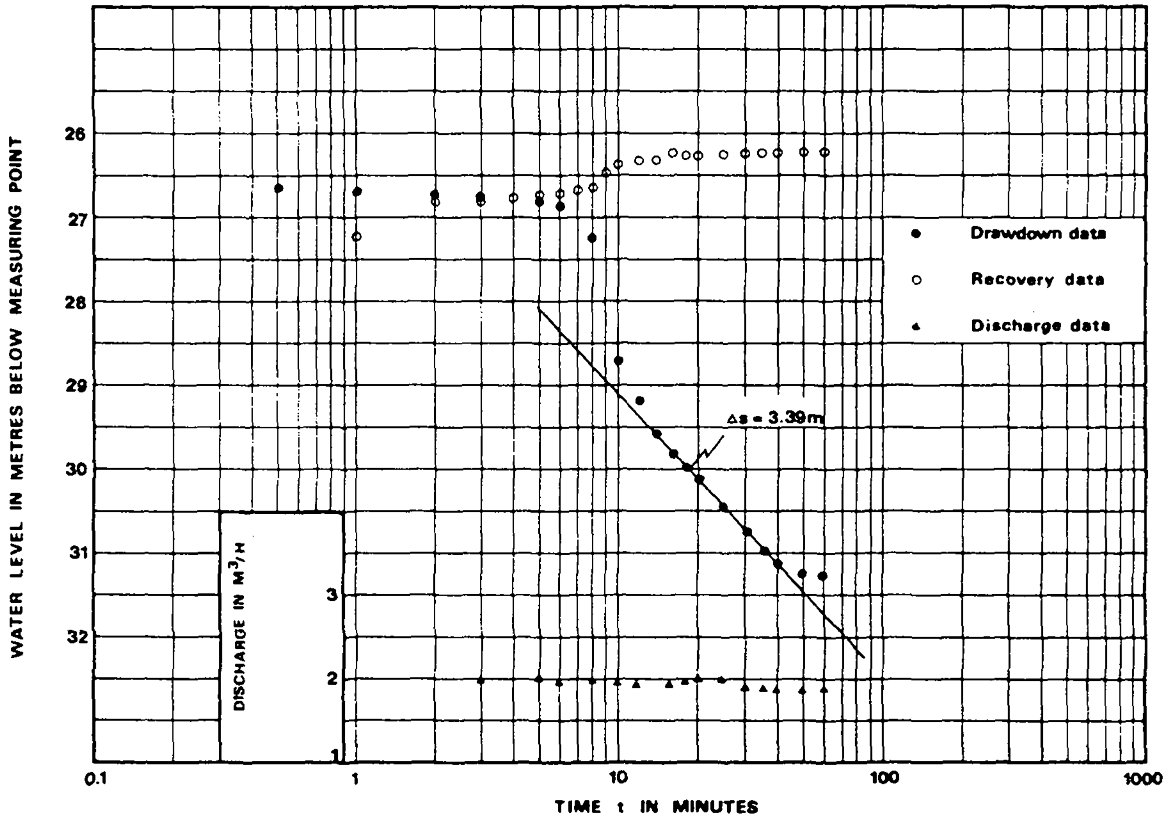
$T =$ $7.6 \times 10^{-6}\ m^2/sec$

$Q/s_w =$ $0.041\ m^3/h/m$

The test was stopped when the water level was lowered to the pump suction.

THE UNITED REPUBLIC OF TANZANIA

REGION: MBEYA	DISTRICT: MBEYA	VILLAGE: IHOWELO	BH NO: 205/81
			CCKK NO: MS 20



Constant discharge test : October 10, 1981 10^{10} - 11^{10}

Recovery test : October 10, 1981 11^{10} - 12^{10}

Discharge rate : 1.9 m^3/h

Static water level : 26.15 metres below measuring point

Calculation of hydraulic parametres:

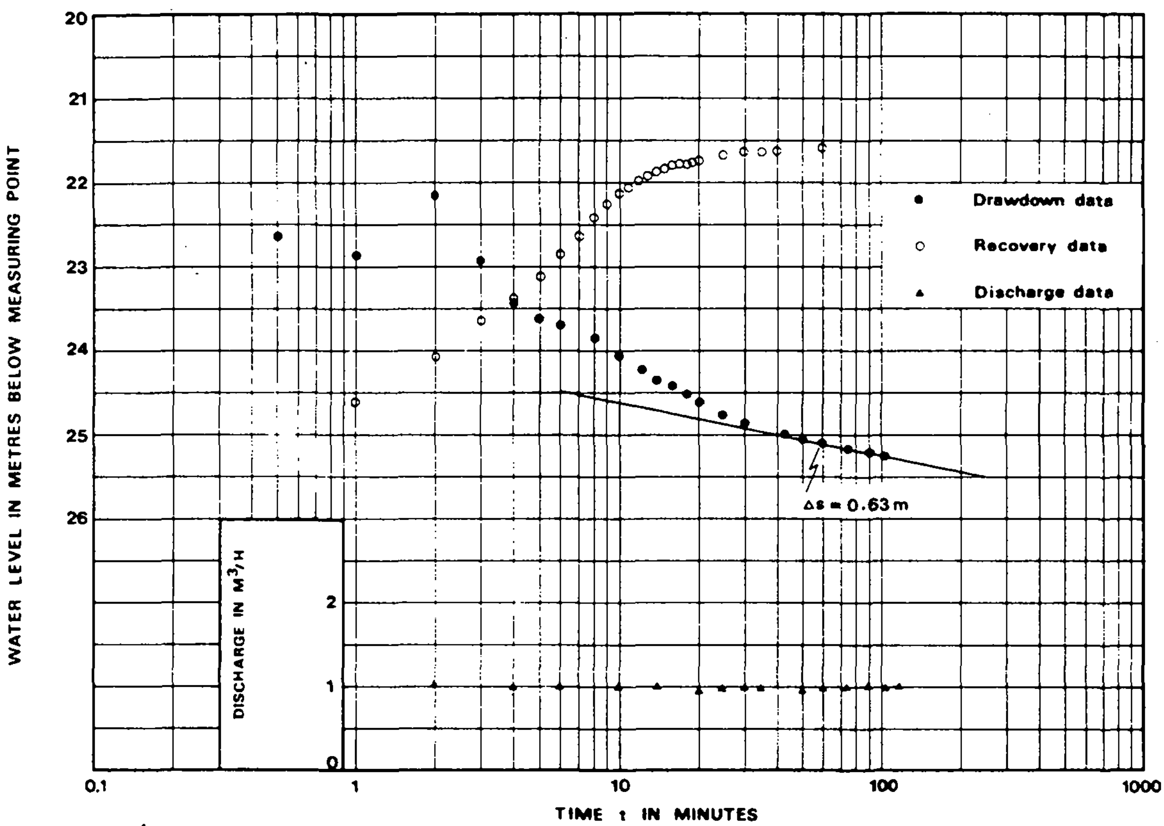
$T = 2.8 \times 10^{-5}\ m^2/sec$

$r_w^2 S = 5.1 \times 10^{-3}\ m^2$

$Q/s_w = 0.32\ m^3/h/m$

The test was stopped when the water level was lowered below top of pump.

THE UNITED REPUBLIC OF TANZANIA			
REGION: MBEYA	DISTRICT: MBEYA	VILLAGE: LUHANGA	BH NO: 208/81 CCKK NO: MS 25



Constant discharge test	:	October 9, 1981 13^{15} - 15^{00}
Recovery test	:	October 9, 1981 15^{00} - 16^{00}
Discharge rate	:	1.0 m^3/h
Static water level	:	21.56 metres below measuring point

Calculation of hydraulic parametres:

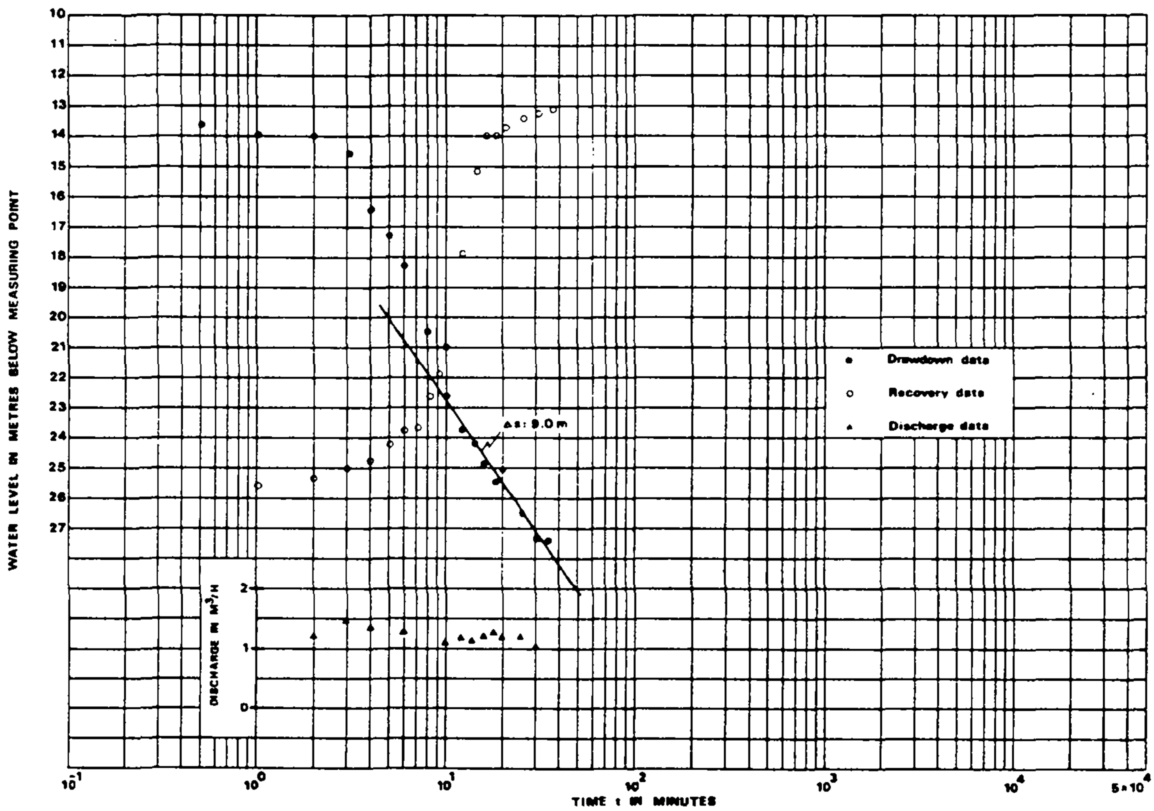
$T = 8.1 \times 10^{-5}\ m^2/sec$

$Q/s_w = 0.25\ m^3/h/m$

The test was stopped when the water level was lowered below top of pump.

THE UNITED REPUBLIC OF TANZANIA

REGION: MBEYA	DISTRICT: MBEYA	VILLAGE: UKWAHERI	BH NO: 209/81 CCKK NO: MS 24



Constant discharge test	:	October 10, 1981 11^{30} - 12^{05}
Recovery test	:	October 10, 1981 12^{05} - 12^{40}
Discharge rate	:	1.15 m^3/h
Static water level	:	13.05 metres below measuring point

Calculation of hydraulic parametres:

$T = 6.5 \times 10^{-6}\ m^2/sec$

$r_w^2 S = 2.0 \times 10^{-3}\ m^2$

$Q/s_w = 0.08\ m^3/h/m$

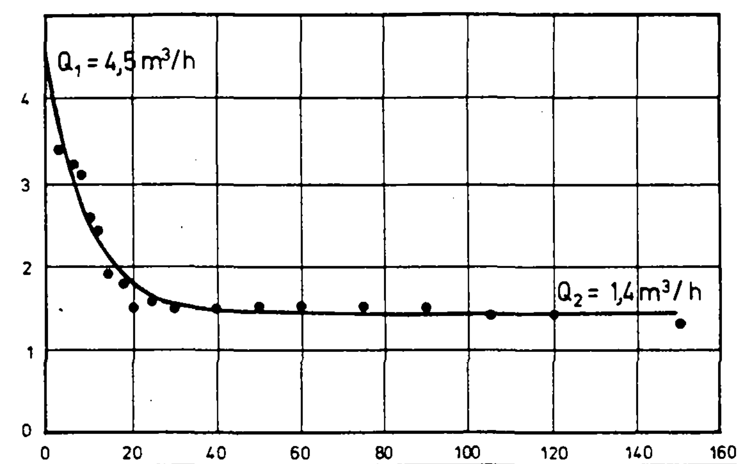
The test was stopped when the water level was lowered to the pump suction.

THE UNITED REPUBLIC OF TANZANIA

REGION: MBEYA	DISTRICT: MBOZI	VILLAGE: VWAWA	B.H. No. 276/81 CCKK No. MD 3

DISCHARGE DATA

$Q = 1{,}4 + 3{,}1 \times e^{-(0{,}1 \times t)}\ m^3/hr$



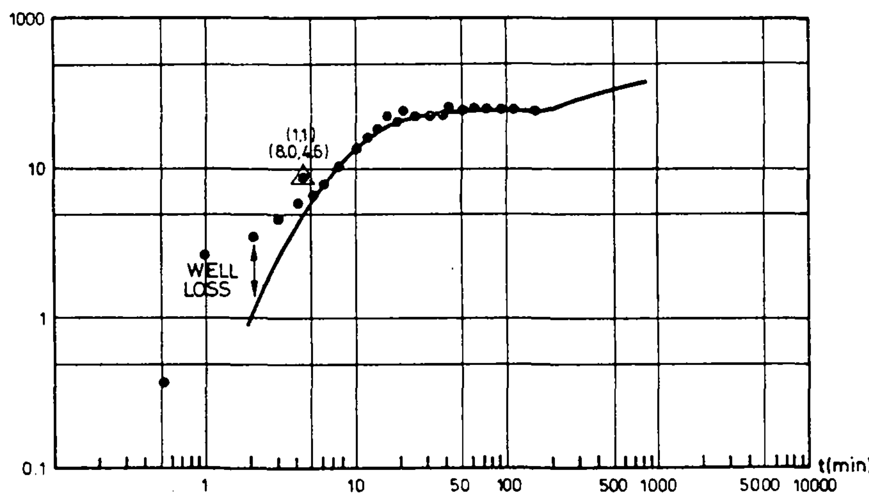
α = 3.21

k = 0.10 min^{-1}

Type of decay:
exponential

Test performed:
81.10.07

DRAWDOWN DATA



T = 3.9 x $10^{-6} m^2$/sec.

$r_w^2 S$ = 4.3 x $10^{-2} m^2$

$r_w^2 P^1/m^1$ = m^2/sec.

β = 0.6

k_{obs} = 0.10 min^{-1}

k_{cal} = 0.02 min^{-1}

Q/S_w = 0.64 m^3/hr/m

T = 6 x 10^{-6} m^2/sec.

RECOVERY DATA

T = m^2/sec.

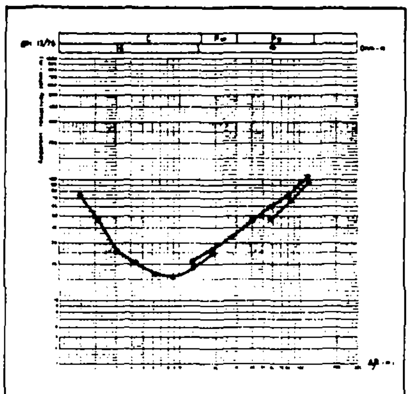
$r_w^2 S$ = m^2

Appendix 3

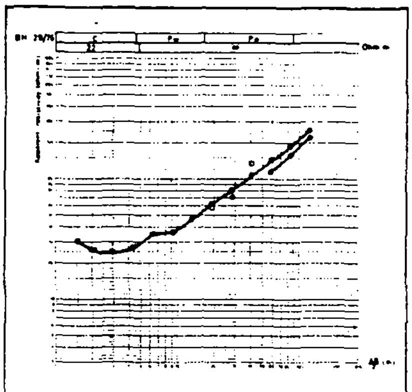
Geophysics.

IRINGA

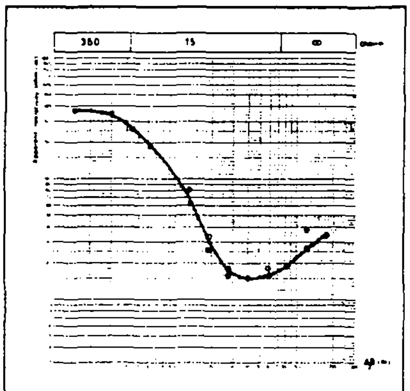
GEOELECTRIC SOUNDINGS	REGION: IRINGA



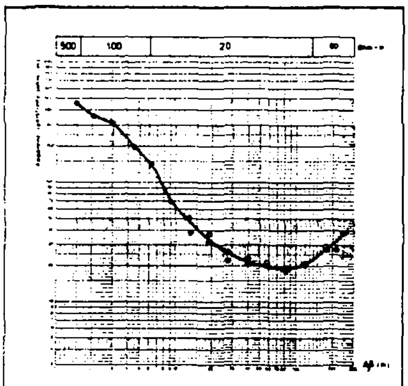
Profile no : 201
Latitude : 7°26.9'
Longitude : 35°43.3'
Village : Chandindi
Date : 14.11.1980



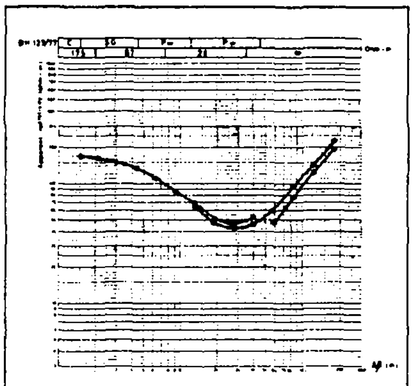
Profile no : 202
Latitude : 7°26.9'
Longitude : 35°44.3'
Village : Chandindi
Date : 14.11.1980



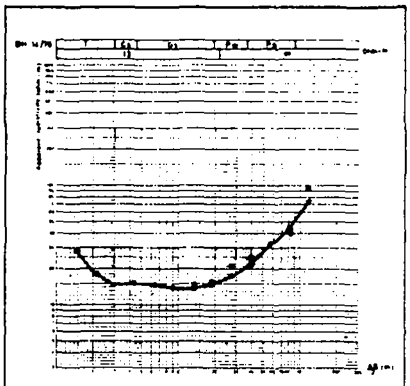
Profile no : 203
Latitude : 7°47.2'
Longitude : 35°11.8'
Village : Chandindi
Date : 13.4.1981



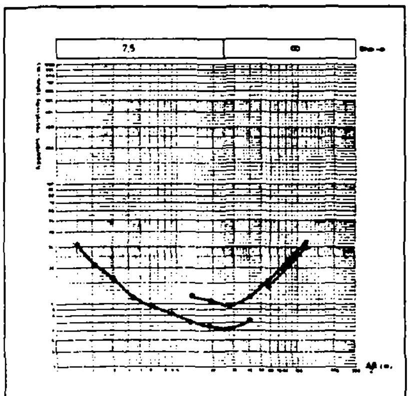
Profile no : 204
Latitude : 7°47.2'
Longitude : 35°11.2'
Village : Idodi
Date : 13.4.1981



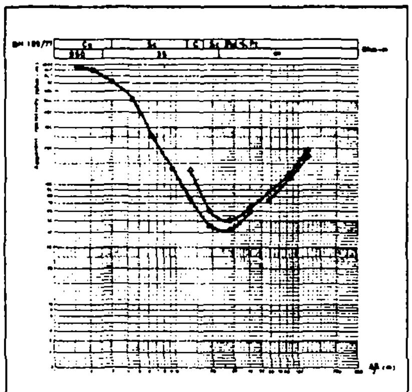
Profile no : 205
Latitude : 7°25.3'
Longitude : 35°52.8'
Village : Iguluba
Date : 18.11.1980



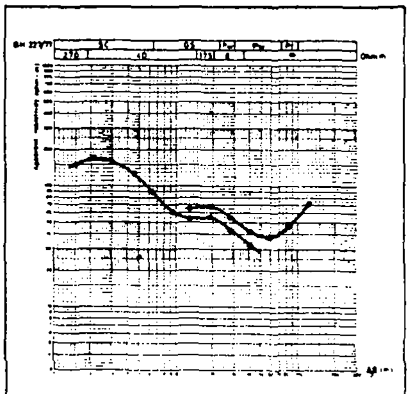
Profile no : 206
Latitude : 7°23.3'
Longitude : 35°42.7'
Village : Ikengeza
Date : 12.11.1980



Profile no : 207
Latitude : 7°28.4'
Longitude : 35°58.9'
Village : Ikuka
Date : 13.11.1980

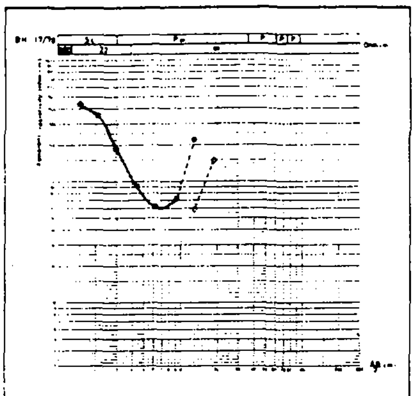


Profile no : 208
Latitude : 7°43.8'
Longitude : 35°51.2'
Village : Irole Mission
Date : 20.11.1980

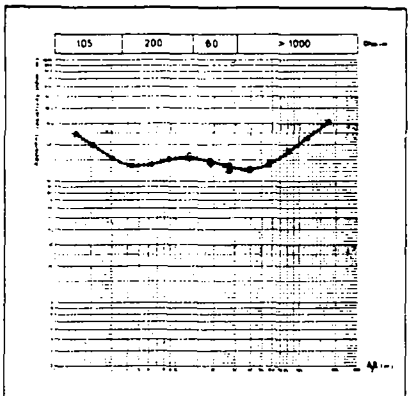


Profile no : 209
Latitude : 7°14.6'
Longitude : 35°43.9'
Village : Izazi
Date : 19.11.1980

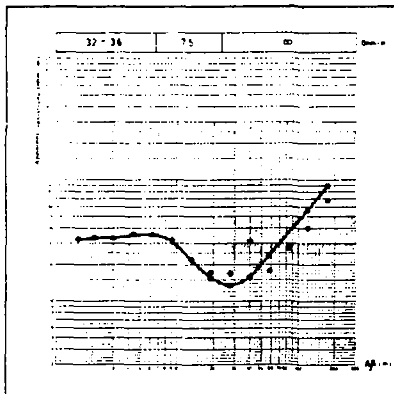
GEOELECTRIC SOUNDINGS	REGION: IRINGA



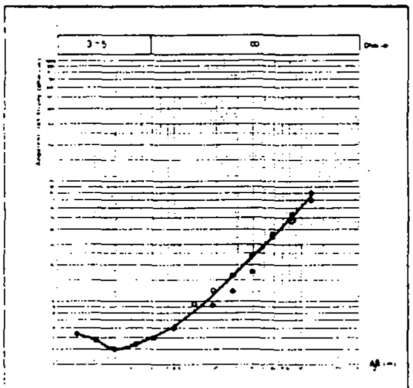
Profile no : 210
Latitude : 7°35'
Longitude : 35°43.3'
Village : Kinywanganga
Date : 12.11.1980



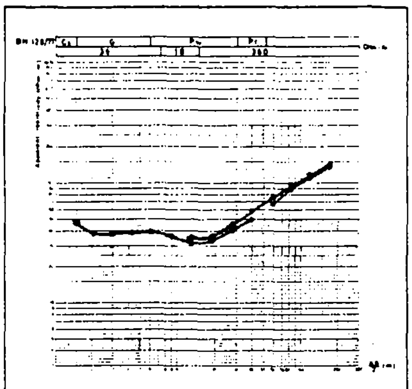
Profile no : 211
Latitude : 7°50.1'
Longitude : 35°09.1'
Village : Kitanewa
Date : 2.4.1981



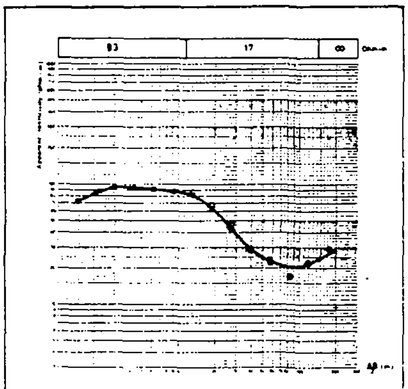
Profile no : 212
Latitude : 7°35.3'
Longitude : 35°22.7'
Village : Mafruto
Date : 29.4.1981



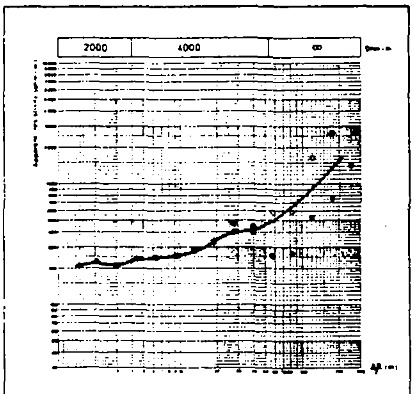
Profile no : 213
Latitude : 7°56.5'
Longitude : 35°04.1'
Village : Mahuninga
Date : 1.4.1981



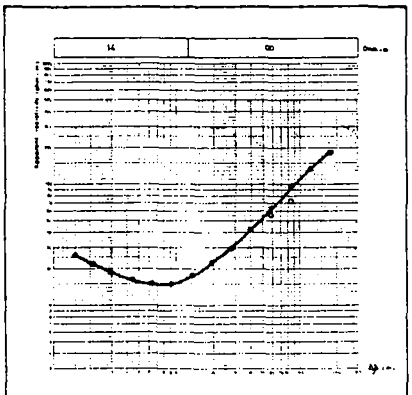
Profile no : 214
Latitude : 7°23.3'
Longitude : 36°00.5'
Village : Makadupa
Date : 18.11.1980



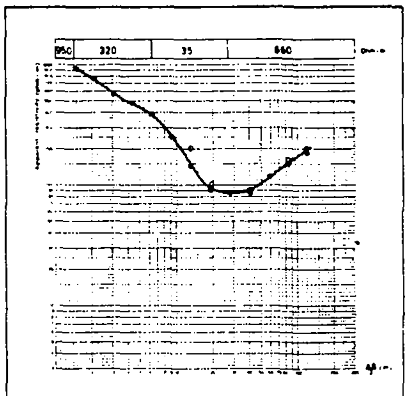
Profile no : 215
Latitude : 7°49'
Longitude : 35°07.8'
Village : Mapogoro
Date : 13.4.1981



Profile no : 216
Latitude : 8°25'
Longitude : 35°05'
Village : Matanana
Date : 7.4.1981



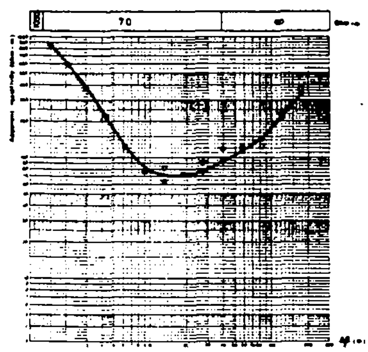
Profile no : 217
Latitude : 7°39.8'
Longitude : 35°23'
Village : Mloa
Date : 27.1.1981



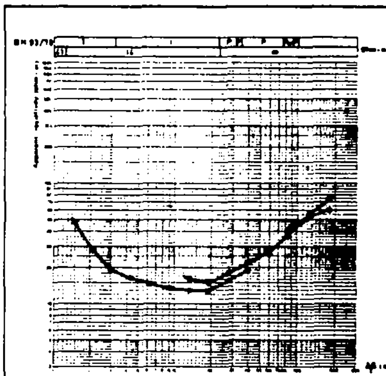
Profile no : 218
Latitude : 7°39.6'
Longitude : 35°22.8'
Village : Mloa
Date : 27.1.1981

GEOELECTRIC SOUNDINGS

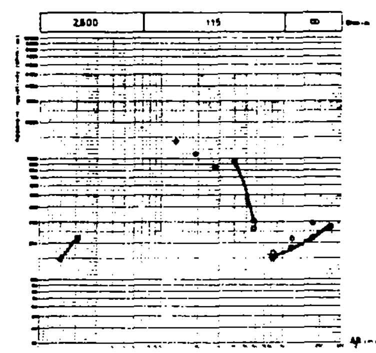
REGION: IRINGA



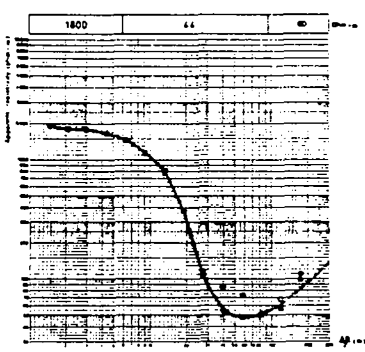
Profile no : 219
Latitude : 7°41.2'
Longitude : 35°22.3'
Village : Mloa
Date : 11.4.1981



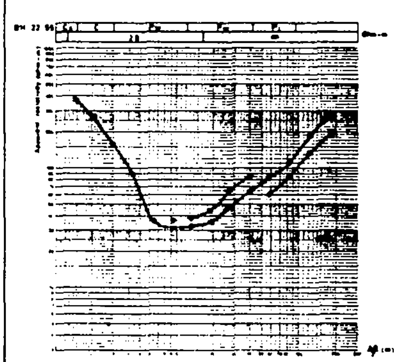
Profile no : 220
Latitude : 7°08.3'
Longitude : 35°48.8'
Village : Mtera
Date : 19.11.1980



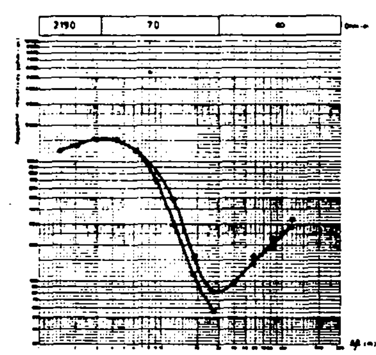
Profile no : 221
Latitude : 7°43.7'
Longitude : 35°17.1'
Village : Musimbe/Mloa
Date : 11.4.1981



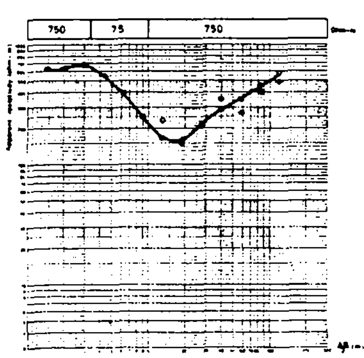
Profile no : 222
Latitude : 7°46.2'
Longitude : 35°12.8'
Village : Musimbe
Date : 11.4.1981



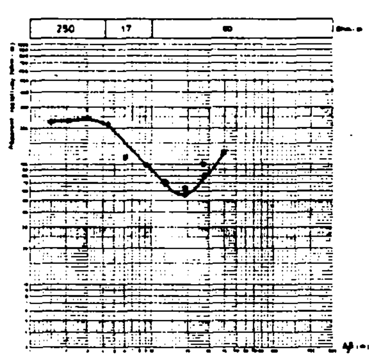
Profile no : 223
Latitude : 7°40.3'
Longitude : 35°45.3'
Village : Nduli Air Field
Date : 12.11.1980



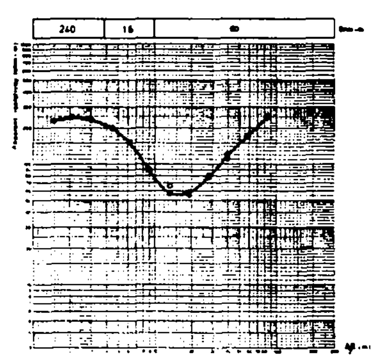
Profile no : 224
Latitude : 7°43'
Longitude : 35°32.1'
Village : Nzihi
Date : 13.1.1980



Profile no : 225
Latitude : 7°43'
Longitude : 35°32.1'
Village : Nzihi
Date : 13.1.1981



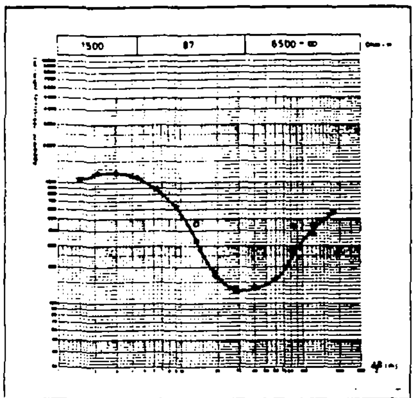
Profile no : 226
Latitude : 7°43.4'
Longitude : 35°32.2'
Village : Nzihi
Date : 14.1.1981



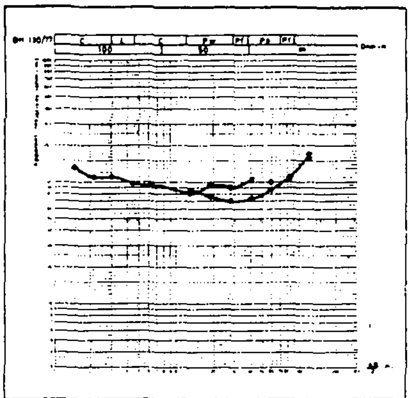
Profile no : 227
Latitude : 7°42.8'
Longitude : 35°32.3'
Village : Nzihi
Date : 14.1.1981

GEOELECTRIC SOUNDINGS

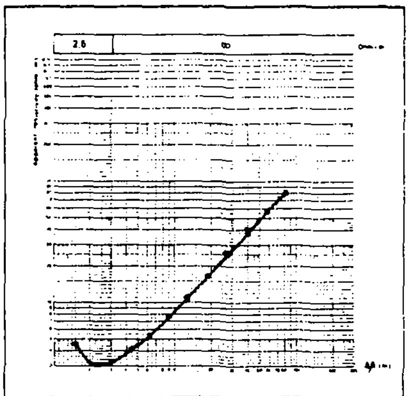
REGION: IRINGA



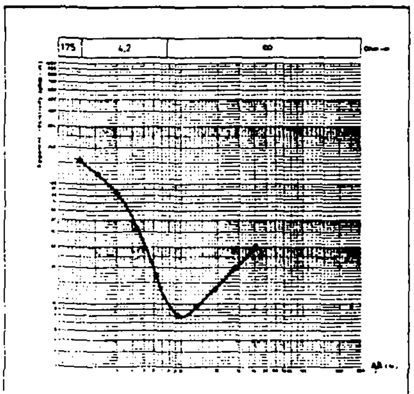
Profile no : 228
Latitude : 7°43.4'
Longitude : 35°31.8'
Village : Nzihi
Date : 15.1.1980



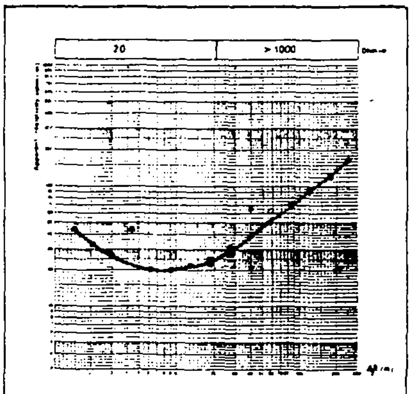
Profile no : 229
Latitude : 7°25.1'
Longitude : 36°04.4'
Village : Nyakawangala
Date : 18.11.1980



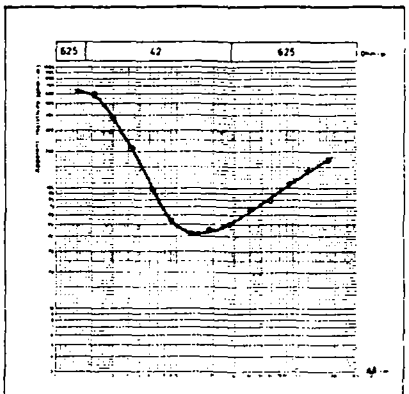
Profile no : 230
Latitude : 7°49'
Longitude : 35°44.4'
Village : Tagamenda
Date : 29.1.1981



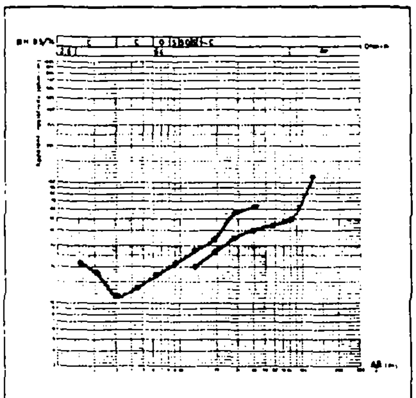
Profile no : 231
Latitude : 7°49'
Longitude : 35°45.4'
Village : Tagamenda
Date : 29.1.1981



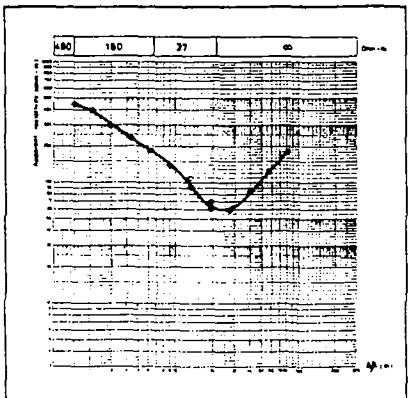
Profile no : 233
Latitude : 7°50'
Longitude : 35°04.2'
Village : Tungamalenga
Date : 2.4.1981



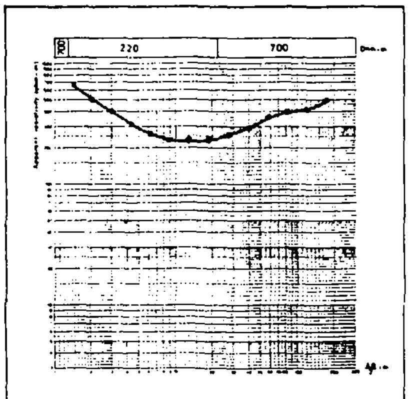
Profile no : 234
Latitude : 7°50.7'
Longitude : 35°05.4'
Village : Tungamalenga
Date : 2.4.1981



Profile no : 235
Latitude : 10°29'
Longitude : 34°42.9'
Village : Ngerenge
Date : 4.12.1980

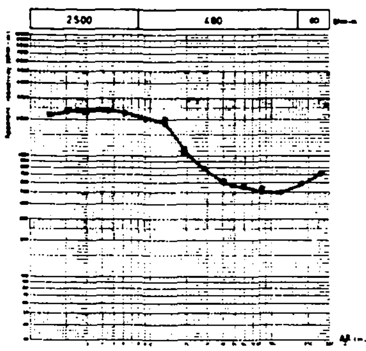


Profile no : 236
Latitude : 8°14.8'
Longitude : 35°15.7'
Village : Ndolezi
Date : 28.1.1981

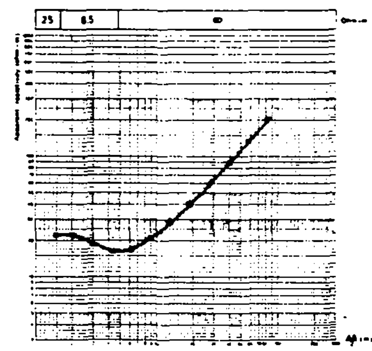


Profile no : 237
Latitude : 8°14.7'
Longitude : 35°15.8'
Village : Ndolezi
Date : 28.1.1981

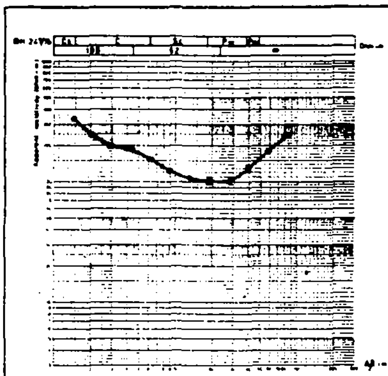
GEOELECTRIC SOUNDINGS	REGION: IRINGA



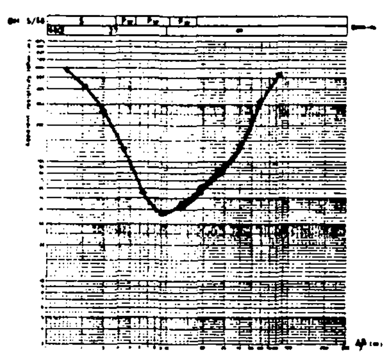
Profile no : 238
Latitude : 8°14.5'
Longitude : 35°15.5'
Village : Ndolezi
Date : 28.1.1981



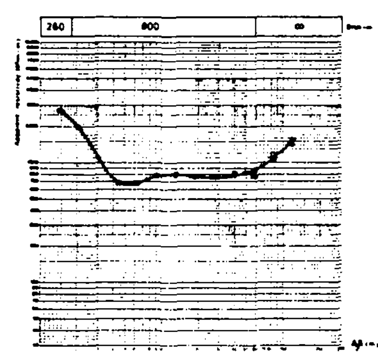
Profile no : 239
Latitude : 8°13.8'
Longitude : 35°00.9'
Village : Sadazi
Date : 28.1.1981



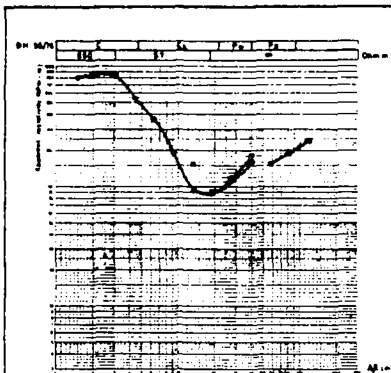
Profile no : 240
Latitude : 8°49.1'
Longitude : 34°50.5'
Village : Idofi
Date : 21.11.1980



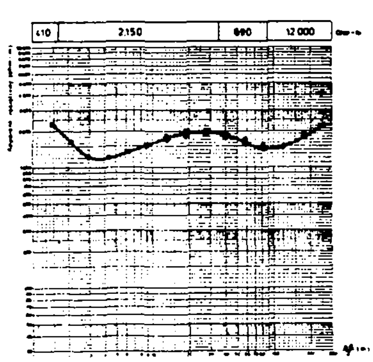
Profile no : 241
Latitude : 8°53.6'
Longitude : 34°34.4'
Village : Jlembula
Date : 2.12.1980



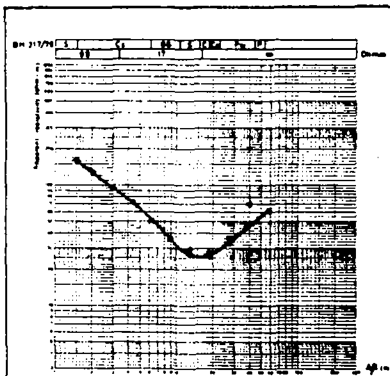
Profile no : 242
Latitude : 9°00.3'
Longitude : 34°50'
Village : Jlunda
Date : 3.6.1981



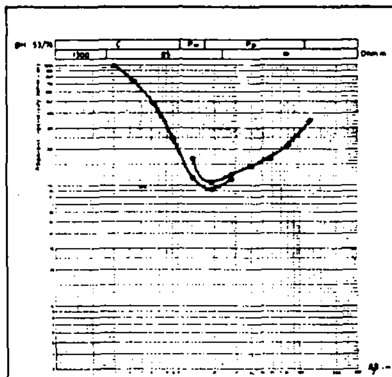
Profile no : 243
Latitude : 8°52.5'
Longitude : 34°32.3'
Village : Jyayi
Date : 3.12.1980



Profile no : 244
Latitude : 9°16.1'
Longitude : 35°00.7'
Village : Kidegembye
Date : 4.6.1981

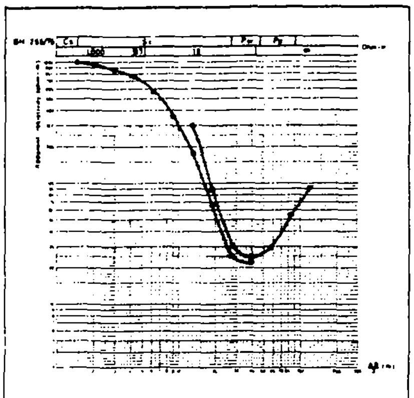


Profile no : 245
Latitude : 8°44.5'
Longitude : 34°47.6'
Village : Kinegembasi
Date : 21.11.1980

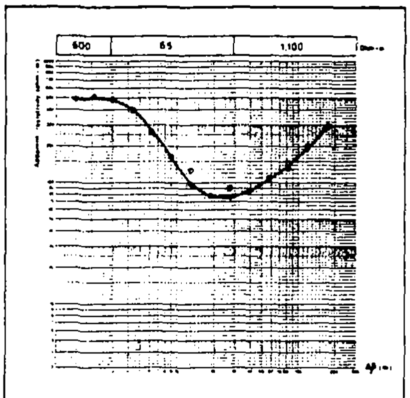


Profile no : 246
Latitude : 8°58.6'
Longitude : 34°35.3'
Village : Palangawano
Date : 17.12.1980

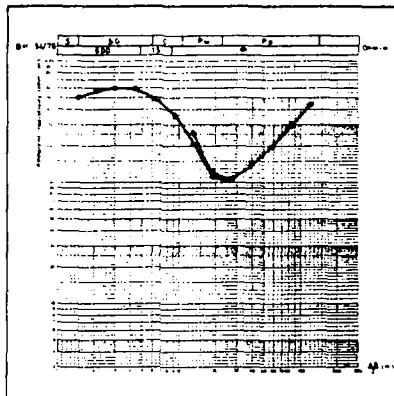
GEOELECTRIC SOUNDINGS	REGION: IRINGA



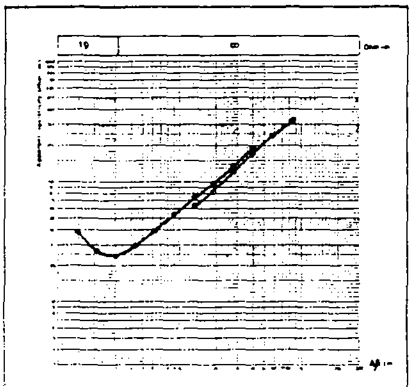
Profile no : 247
Latitude : $8^{\circ}43.9'$
Longitude : $34^{\circ}48.5'$
Village : Saja
Date : 21.11.1980



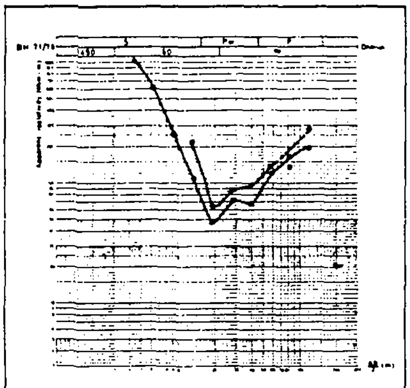
Profile no : 248
Latitude : $8^{\circ}57.6'$
Longitude : $34^{\circ}35.7'$
Village : Udonje
Date : 16.12.1980



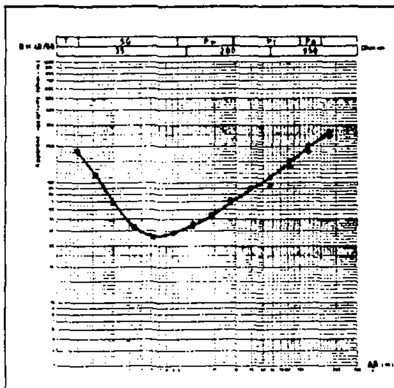
Profile no : 249
Latitude : $8^{\circ}52.9'$
Longitude : $34^{\circ}42.8'$
Village : Uhambule
Date : 3.12.1980



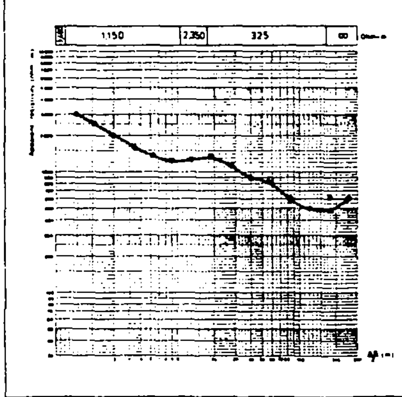
Profile no : 250
Latitude : $8^{\circ}51.7'$
Longitude : $34^{\circ}42.9'$
Village : Ujindile
Date : 3.12.1980



Profile no : 251
Latitude : $8^{\circ}48.9'$
Longitude : $34^{\circ}39.1'$
Village : Utiga
Date : 3.12.1980

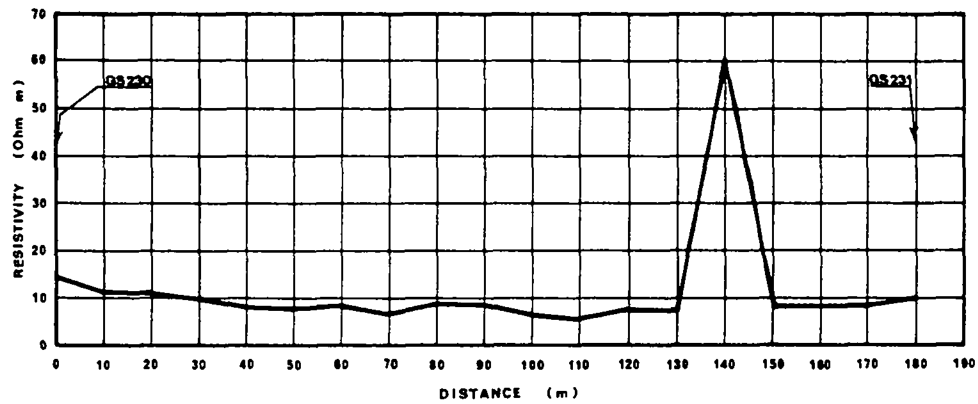


Profile no : 252
Latitude : $8^{\circ}50.7'$
Longitude : $34^{\circ}37.8'$
Village : Wangingambe
Date : 3.12.1980



Profile no : 253
Latitude : $9^{\circ}10'$
Longitude : $34^{\circ}58.2'$
Village : Makombako
Date : 3.6.1981

CONSTANT SEPARATION TRAVERSES	REGION: IRINGA

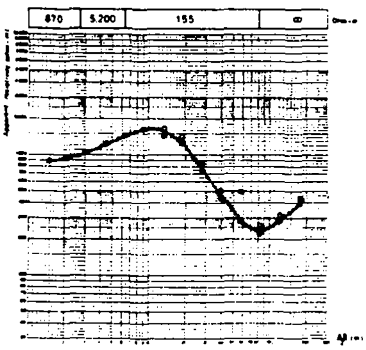


Traverse no	:	232
Latitude	:	7°49'
Longitude	:	35°45.4'
Village	:	Tungamalenga
Date	:	29.1.81

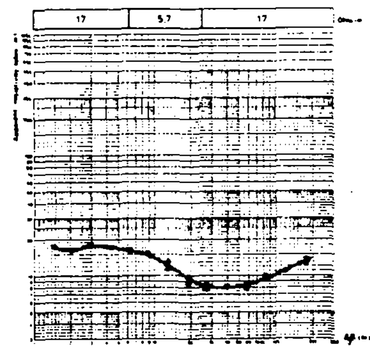
RUVUMA

GEOELECTRIC SOUNDINGS

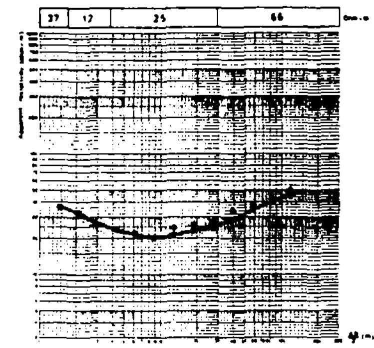
REGION: RUVUMA



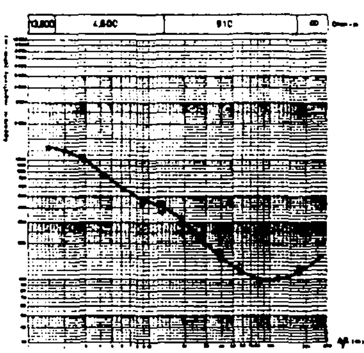
Profile no : 301
Latitude : 10°42.8'
Longitude : 35°11.5'
Village : Kitai
Date : 23.5.1981



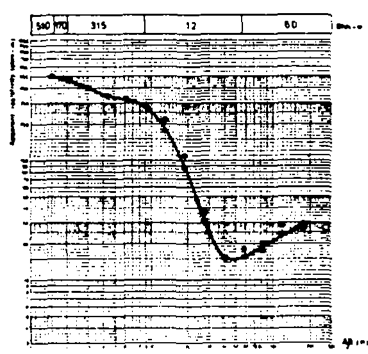
Profile no : 302
Latitude : 10°31.2'
Longitude : 34°45.0'
Village : Lukali
Date : 24.6.1981



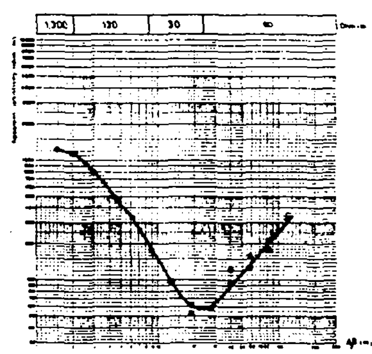
Profile no : 303
Latitude : 10°40.4'
Longitude : 34°39.5'
Village : Mbaha
Date : 24.6.1981



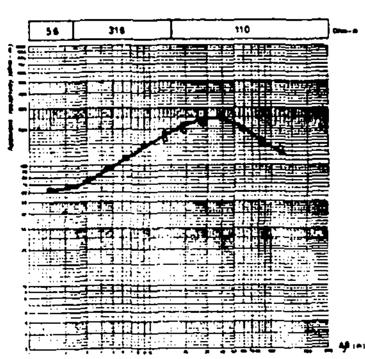
Profile no : 304
Latitude : 11°04'
Longitude : 34°55.7'
Village : Onango
Date : 23.6.1981



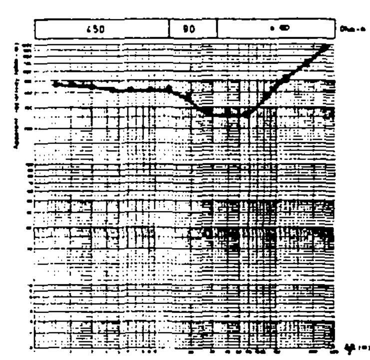
Profile no : 305
Latitude : 10°34.8'
Longitude : 35°02.4'
Village : Lituki
Date : 24.6.1981



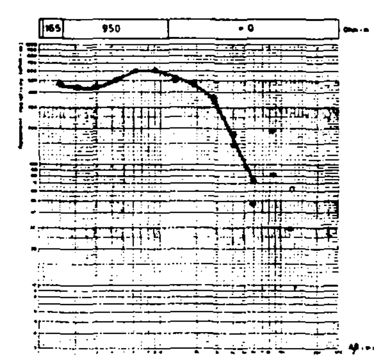
Profile no : 306
Latitude : 10°21.3'
Longitude : 35°39.7'
Village : Songea 40 km
Date : 5.6.1981



Profile no : 307
Latitude : 10°02.3'
Longitude : 35°37.5'
Village : Songea 50 miles
Date : 11.2.1981



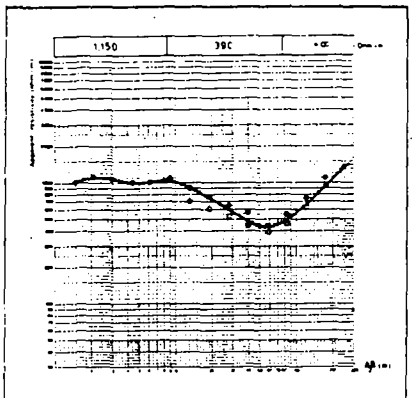
Profile no : 308
Latitude : 10°54.5'
Longitude : 36°05.3'
Village : Ligera
Date : 18.6.1981



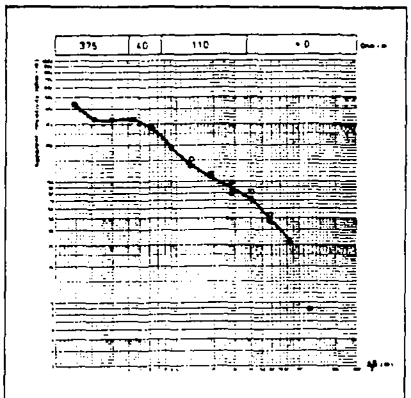
Profile no : 309
Latitude : 11°07'
Longitude : 36°10.8'
Village : Malijoni
Date : 18.6.1981

GEOELECTRIC SOUNDINGS

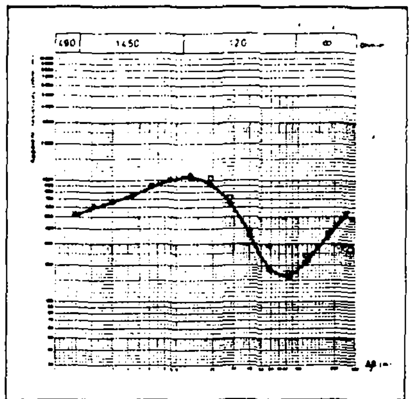
REGION: RUVUMA



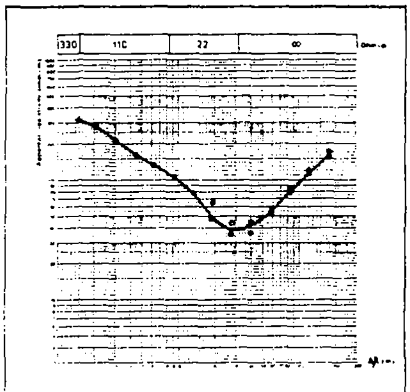
Profile no : 310
Latitude : 10°41.2'
Longitude : 36°03.8'
Village : Mkongo
Date : 18.6.1981



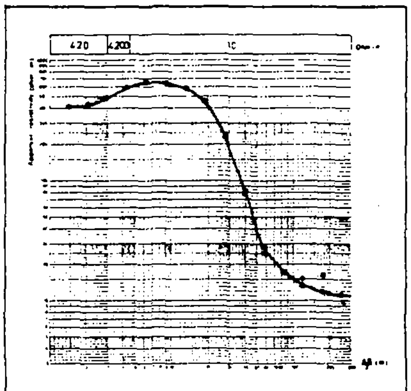
Profile no : 311
Latitude : 10°16.4'
Longitude : 36°20.2'
Village : Mpigamiti
Date : 19.6.1981



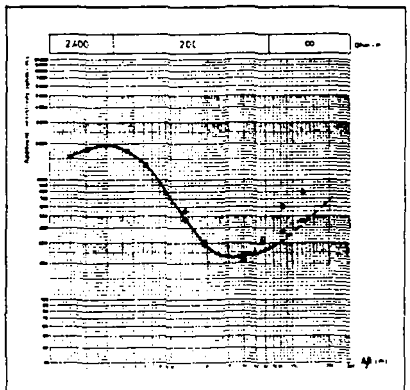
Profile no : 312
Latitude : 10°22.6'
Longitude : 36°09.9'
Village : Mtonya
Date : 19.6.1981



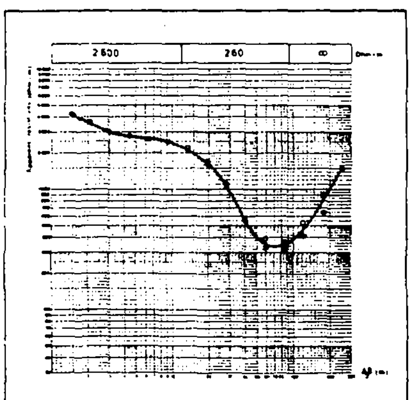
Profile no : 313
Latitude : 11°16'
Longitude : 35°26.8'
Village : Mtua
Date : 22.6.1981



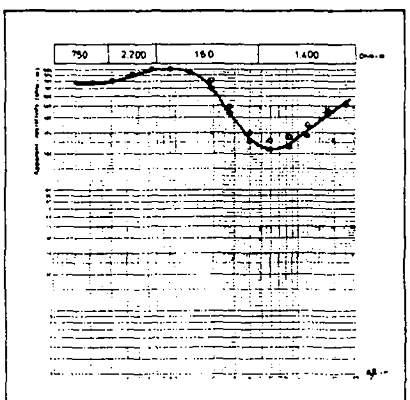
Profile no : 314
Latitude : 11°23.7'
Longitude : 35°24'
Village : Nakawale
Date : 22.6.1981



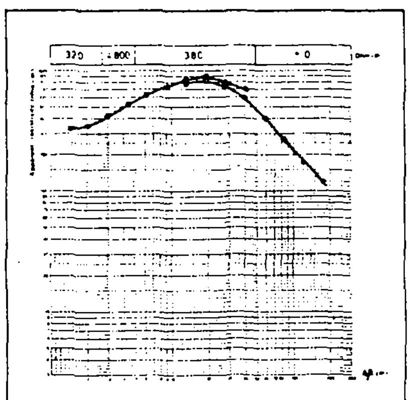
Profile no : 315
Latitude : 10°34'
Longitude : 35°52'
Village : Namabengo
Date : 19.6.1981



Profile no : 316
Latitude : 10°54.9'
Longitude : 35°29.4'
Village : Namatuki
Date : 22.6.1981



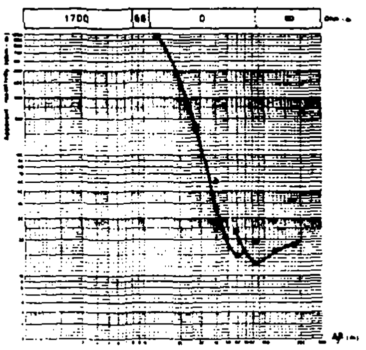
Profile no : 317
Latitude : 10°40.6'
Longitude : 35°35.3'
Village : Songea Airport
Date : 25.6.1981



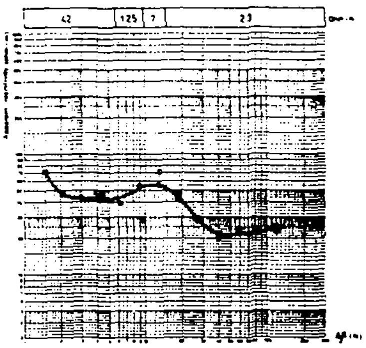
Profile no : 318
Latitude : 9°57'
Longitude : 35°37.6'
Village : Songea 96 km
Date : 12.2.1981

GEOELECTRIC SOUNDINGS

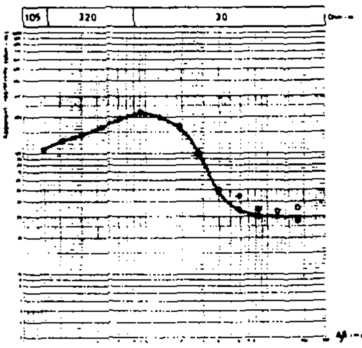
REGION: RUVUMA



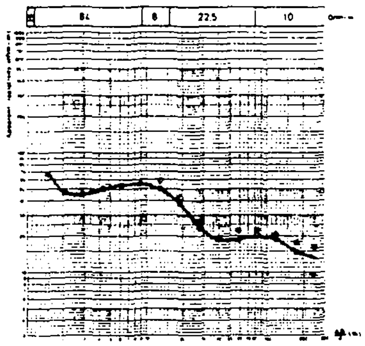
Profile no : 319
Latitude : $10^{\circ}31.6'$
Longitude : $36^{\circ}12.1'$
Village : Sangea 80 km
Date : 10.2.1981



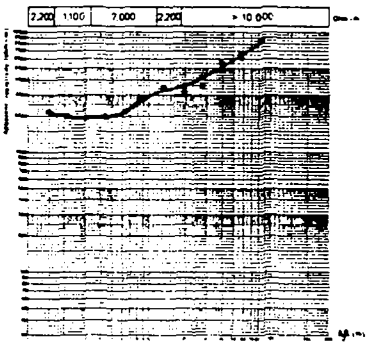
Profile no : 320
Latitude : $10^{\circ}43.6'$
Longitude : $36^{\circ}20.6'$
Village : Sangea 128 km
Date : 16.6.1981



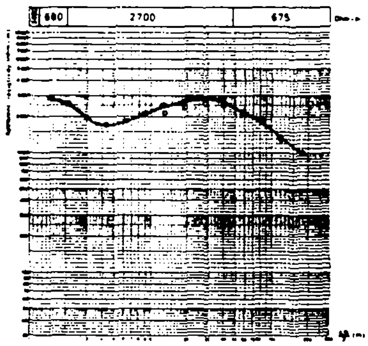
Profile no : 321
Latitude : $10^{\circ}45.6'$
Longitude : $36^{\circ}31.5'$
Village : Sangea 140 km
Date : 16.6.1981



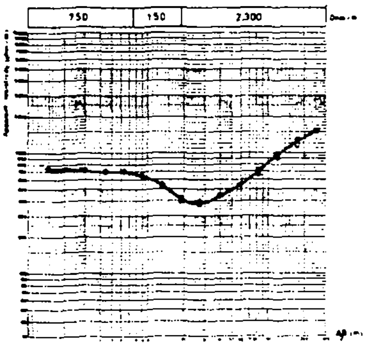
Profile no : 322
Latitude : $10^{\circ}34.6'$
Longitude : $36^{\circ}22.2'$
Village : Tunduru 89 miles
Date : 10.2.1981



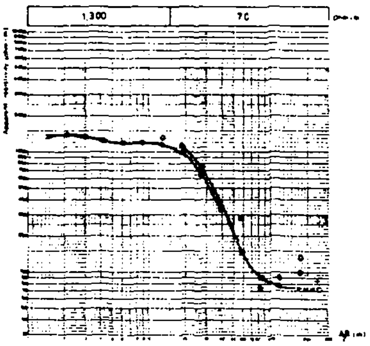
Profile no : 323
Latitude : $11^{\circ}34.7'$
Longitude : $36^{\circ}53.7'$
Village : Chamba
Date : 12.6.1981



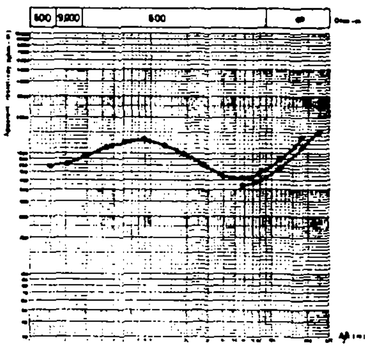
Profile no : 324
Latitude : $11^{\circ}11.1'$
Longitude : $37^{\circ}12.5'$
Village : Chilanga
Date : 9.2.1981



Profile no : 325
Latitude : $10^{\circ}51.4'$
Longitude : $37^{\circ}35.7'$
Village : Katumbi
Date : 8.2.1981



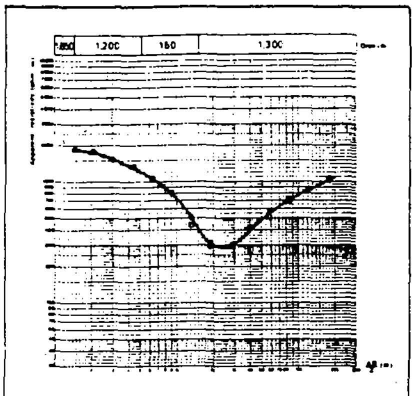
Profile no : 326
Latitude : $11^{\circ}05.5'$
Longitude : $37^{\circ}19.5'$
Village : Kitanda
Date : 9.2.1981



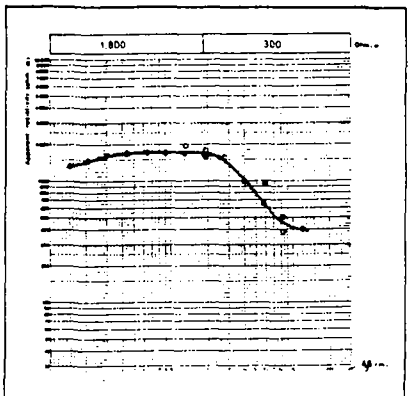
Profile no : 327
Latitude : $10^{\circ}51.4'$
Longitude : $37^{\circ}29.5'$
Village : Kwitanda
Date : 8.2.1981

GEOELECTRIC SOUNDINGS

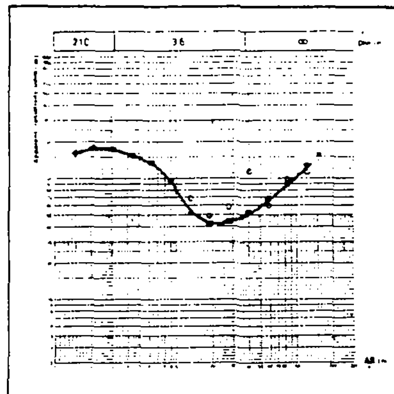
REGION: RUVUMA



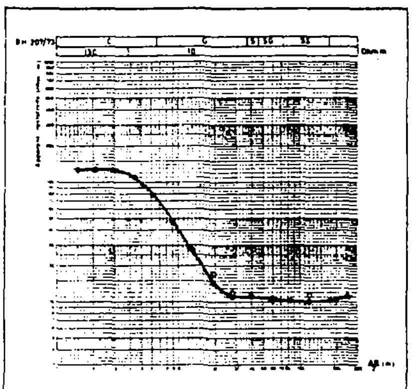
Profile no : 328
Latitude : 11°31.6'
Longitude : 36°56.5'
Village : Likweso
Date : 12.6.1981



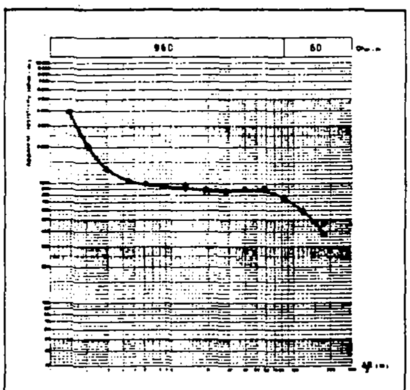
Profile no : 329
Latitude : 11°23.4'
Longitude : 37°01.5'
Village : Lukumbo
Date : 12.6.1981



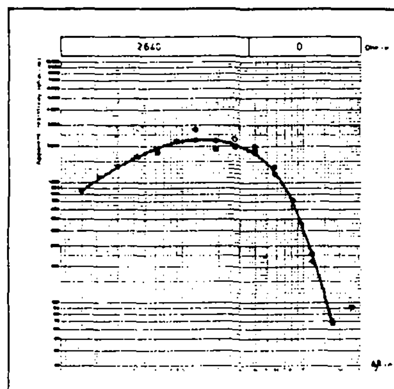
Profile no : 330
Latitude : 11°31.3'
Longitude : 37°21.7'
Village : Lukumbule
Date : 12.6.1981



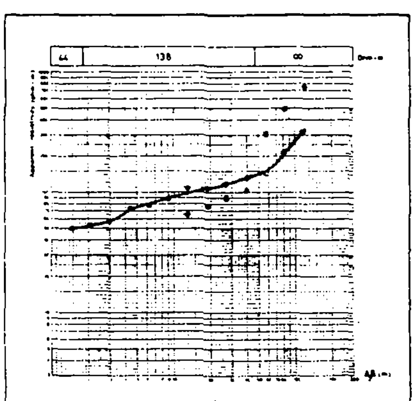
Profile no : 331
Latitude : 10°57.1'
Longitude : 37°19.1'
Village : Masonya
Date : 7.2.1981



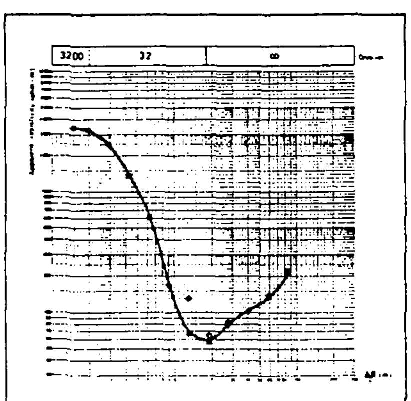
Profile no : 332
Latitude : 11°16.4'
Longitude : 37°08.7'
Village : Nkaudu
Date : 9.2.1981



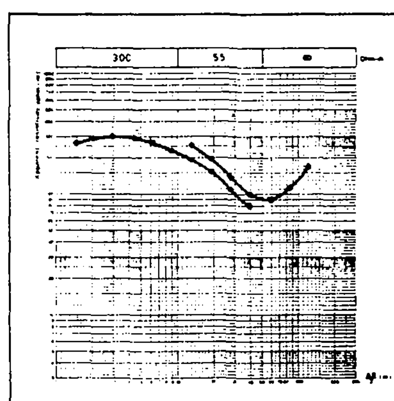
Profile no : 333
Latitude : 11°19.3'
Longitude : 37°05.3'
Village : Mbresa
Date : 9.2.1981



Profile no : 334
Latitude : 10°52.4'
Longitude : 37°43.6'
Village : Mindu
Date : 8.2.1981



Profile no : 335
Latitude : 10°51.8'
Longitude : 37°50.2'
Village : Mindu
Date : 8.2.1981



Profile no : 336
Latitude : 10°50.9'
Longitude : 37°45.7'
Village : Mindu
Date : 8.2.1981

GEOELECTRIC SOUNDINGS

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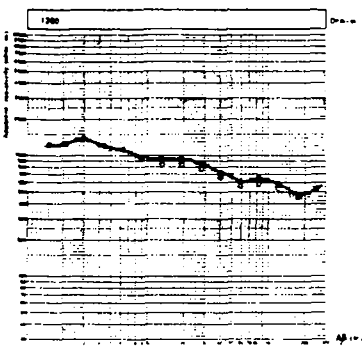
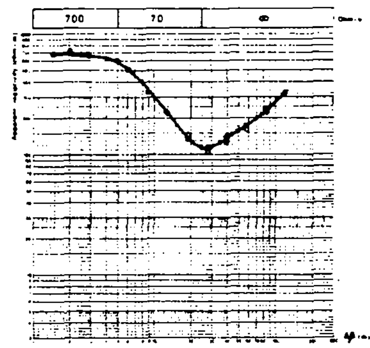
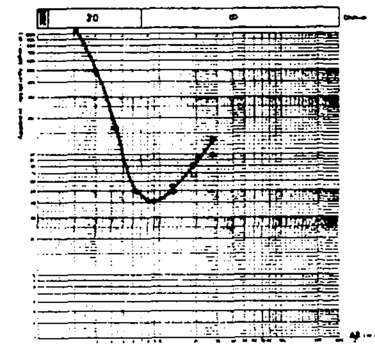


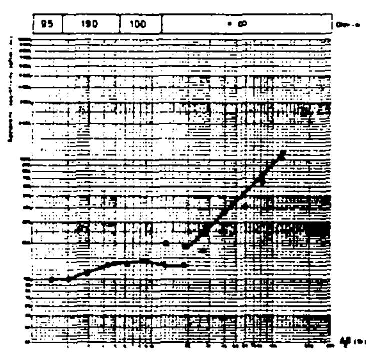
Profile no : 337
Latitude : $10^{\circ}50'$
Longitude : $37^{\circ}46.1'$
Village : Mindu
Date : 8.2.1981



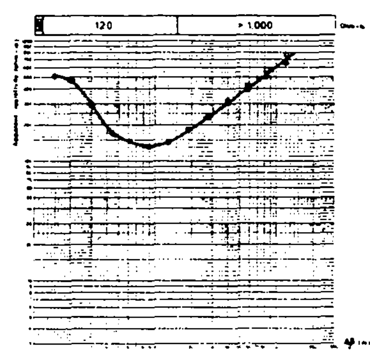
Profile no : 338
Latitude : $10^{\circ}48.4'$
Longitude : $37^{\circ}46.8'$
Village : Mindu
Date : 8.2.1981



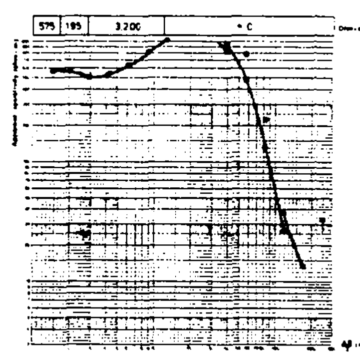
Profile no : 339
Latitude : $10^{\circ}47.3'$
Longitude : $37^{\circ}47.3'$
Village : Mindu
Date : 8.2.1981



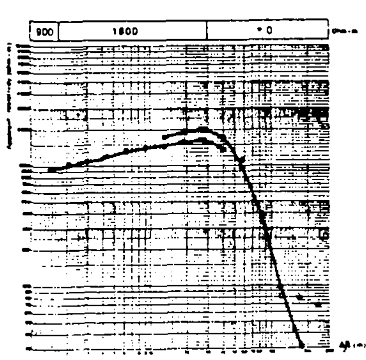
Profile no : 340
Latitude : $10^{\circ}55.2'$
Longitude : $37^{\circ}57.1'$
Village : Mkowela
Date : 11.6.1981



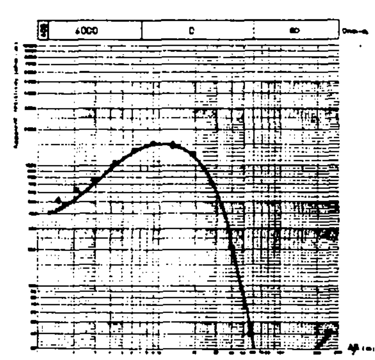
Profile no : 341
Latitude : $10^{\circ}53.2'$
Longitude : $37^{\circ}46.8'$
Village : Mkwajuni
Date : 11.6.1981



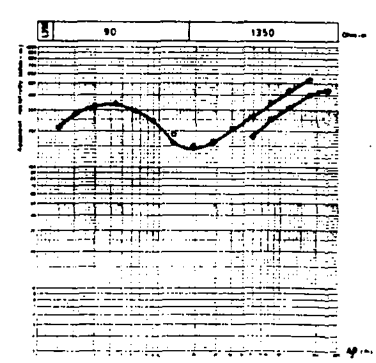
Profile no : 342
Latitude : $11^{\circ}01'$
Longitude : $37^{\circ}18.8'$
Village : Nakayaya
Date : 9.2.1981



Profile no : 343
Latitude : $11^{\circ}13.6'$
Longitude : $37^{\circ}17.5'$
Village : Mpelembe
Date : 9.2.1981



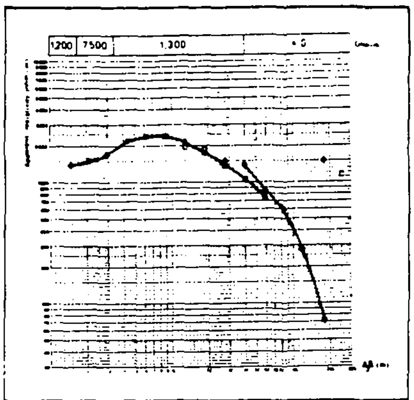
Profile no : 344
Latitude : $10^{\circ}52.8'$
Longitude : $37^{\circ}26.8'$
Village : Msagula
Date : 7.2.1981



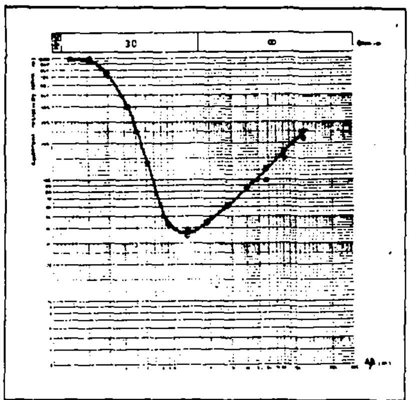
Profile no : 345
Latitude : $10^{\circ}52.8'$
Longitude : $37^{\circ}41'$
Village : Mtetesi River
Date : 8.1.1981

GEOELECTRIC SOUNDINGS

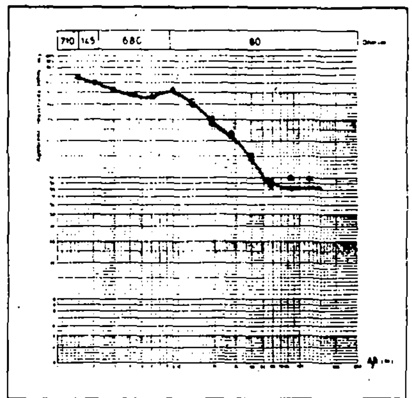
REGION: RUVUMA



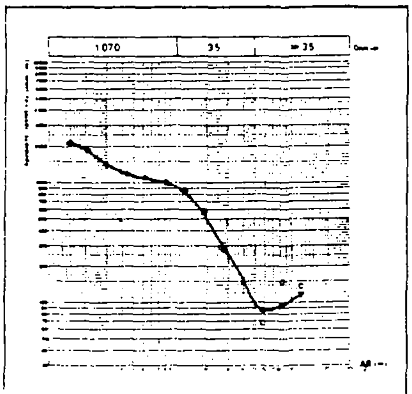
Profile no : 346
Latitude : $11^{\circ}11.4'$
Longitude : $37^{\circ}16'$
Village : 'tola
Date : 9.2.1981



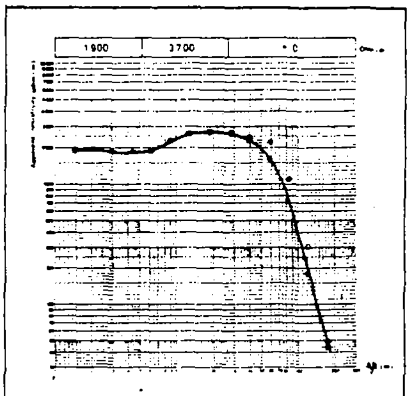
Profile no : 347
Latitude : $10^{\circ}52.5'$
Longitude : $37^{\circ}44.1'$
Village : Mtonya
Date : 10.6.1981



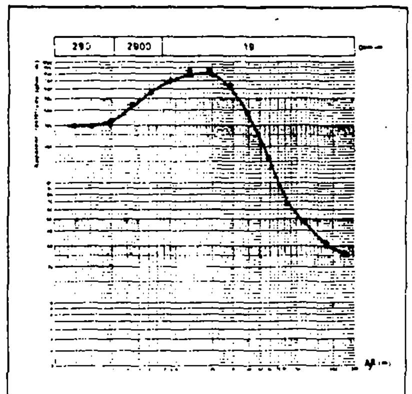
Profile no : 348
Latitude : $11^{\circ}13.1'$
Longitude : $37^{\circ}27.5'$
Village : Mtolela
Date : 13.6.1981



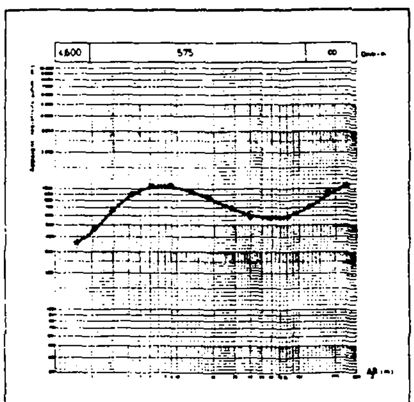
Profile no : 349
Latitude : $11^{\circ}14.8'$
Longitude : $37^{\circ}33.4'$
Village : Mtwaro
Date : 13.6.1981



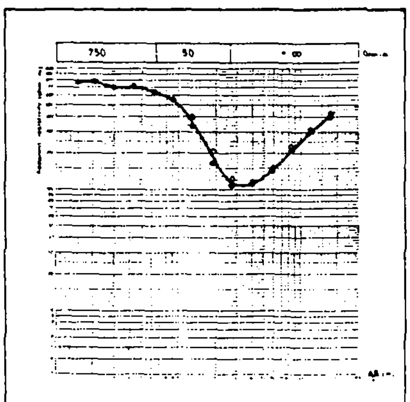
Profile no : 350
Latitude : $11^{\circ}27.9'$
Longitude : $36^{\circ}59'$
Village : Nalasi
Date : 12.6.1981



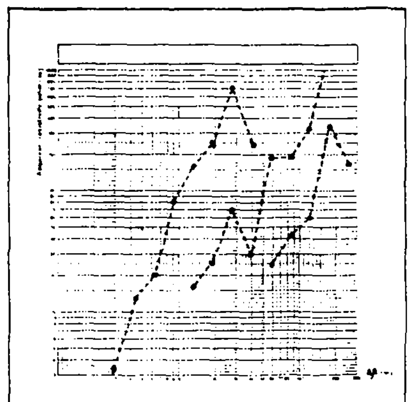
Profile no : 351
Latitude : $10^{\circ}55.4'$
Longitude : $37^{\circ}24.2'$
Village : Nalyawale
Date : 7.2.1981



Profile no : 352
Latitude : $10^{\circ}54.9'$
Longitude : $37^{\circ}51'$
Village : Namakambale
Date : 8.2.1981



Profile no : 353
Latitude : $10^{\circ}54.9'$
Longitude : $37^{\circ}51'$
Village : Namakambale
Date : 11.6.1981



Profile no : 354
Latitude : $10^{\circ}51.3'$
Longitude : $35^{\circ}33.3'$
Village : Namakambale
Date : 8.2.1981

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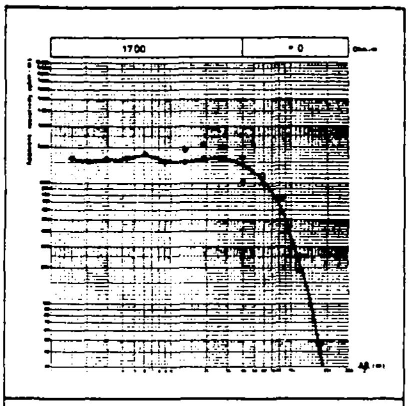
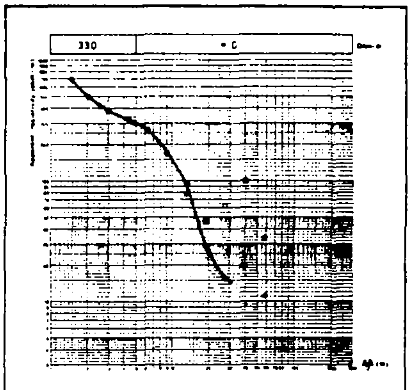
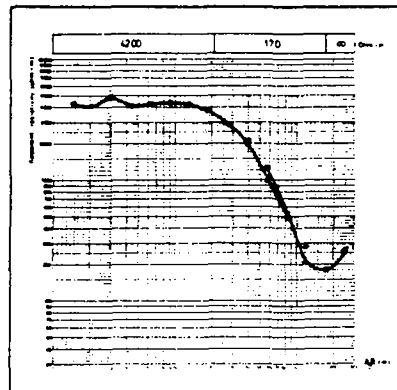


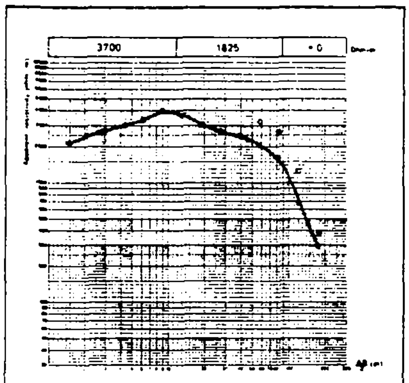
Profile no : 355
Latitude : 10°58.5'
Longitude : 37°23.6'
Village : Namakungwa
Date : 10.6.1981



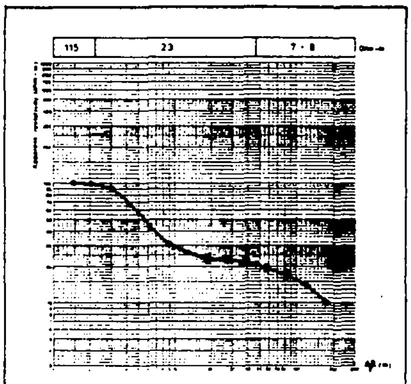
Profile no : 356
Latitude : 10°41.2'
Longitude : 36°53.8'
Village : Namakungwa
Date : 15.6.1981



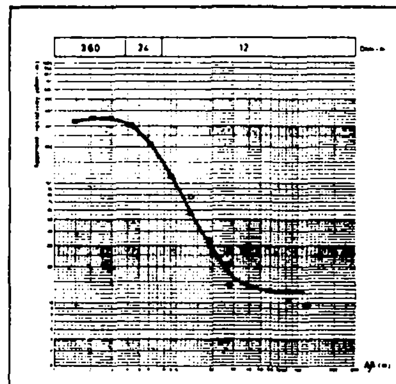
Profile no : 357
Latitude : 10°45.2'
Longitude : 36°57.3'
Village : Namakungwa
Date : 7.2.1981



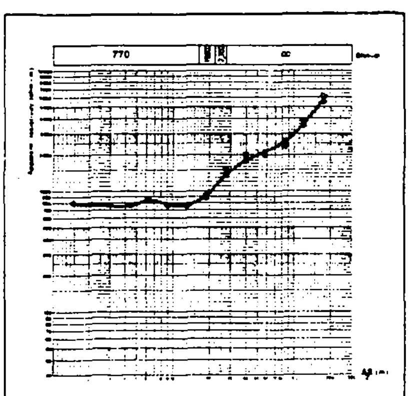
Profile no : 358
Latitude : 11°08.3'
Longitude : 37°27'
Village : Namasakata
Date : 13.6.1981



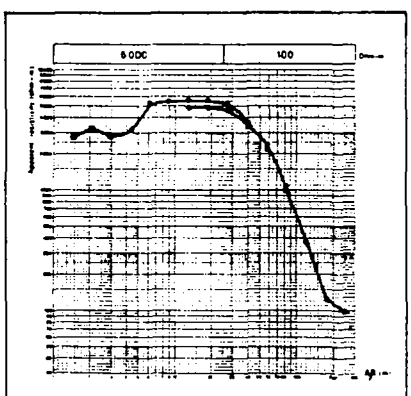
Profile no : 359
Latitude : 10°50.7'
Longitude : 37°10.8'
Village : Nampungu River
Date : 7.2.1981



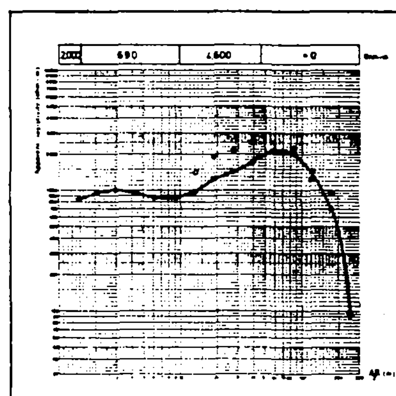
Profile no : 360
Latitude : 10°57.1'
Longitude : 37°14.6'
Village : Nandembo
Date : 15.6.1981



Profile no : 361
Latitude : 11°34.5'
Longitude : 36°54.1'
Village : Ngapunda
Date : 12.6.1981



Profile no : 362
Latitude : 10°48.6'
Longitude : 36°56.7'
Village : Ndeyende Ya Pili
Date : 7.2.1981



Profile no : 363
Latitude : 10°48.1'
Longitude : 36°55.4'
Village : Ndeyende Ya Pili
Date : 15.6.1981

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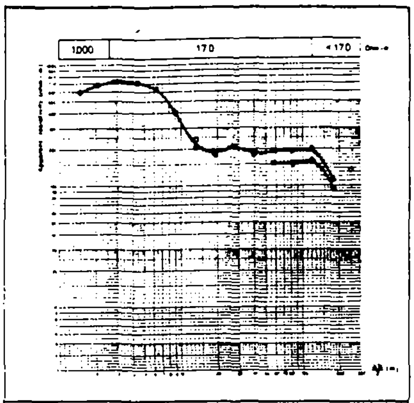
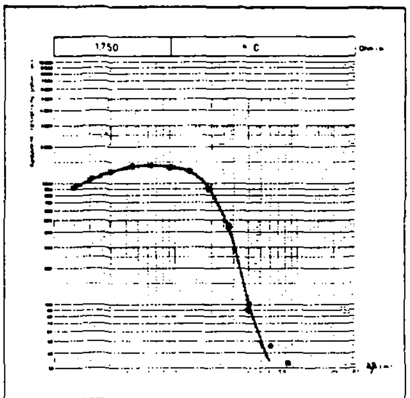
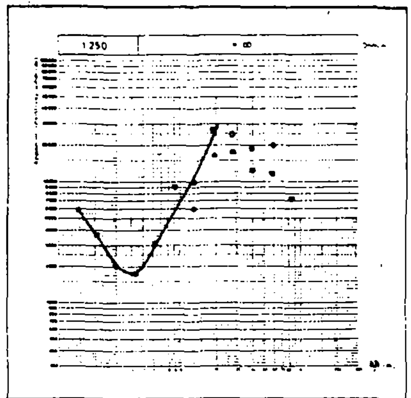


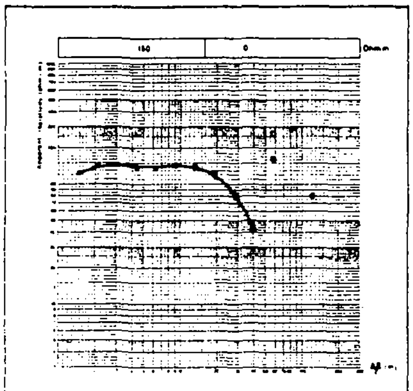
Profile no : 364
Latitude : $10^{\circ}52.2'$
Longitude : $37^{\circ}38.5'$
Village : Pucha Pucha
Date : 8.2.1981



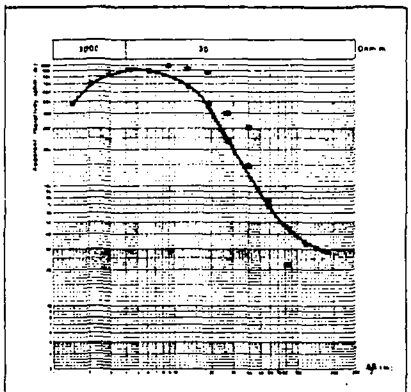
Profile no : 365
Latitude : $10^{\circ}52.7'$
Longitude : $37^{\circ}27'$
Village : Sagula
Date : 10.6.1981



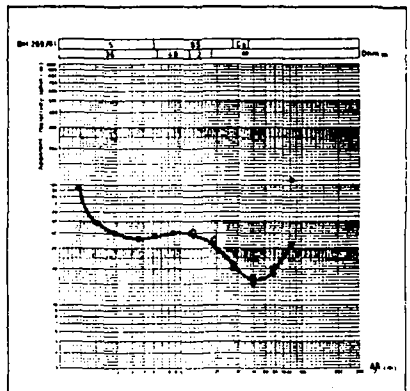
Profile no : 366
Latitude : $10^{\circ}47.8'$
Longitude : $37^{\circ}58'$
Village : Tinginya
Date : 11.6.1981



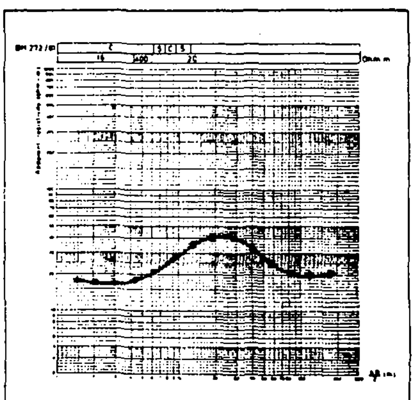
Profile no : 367
Latitude : $11^{\circ}1.6'$
Longitude : $37^{\circ}21.5'$
Village : 3 km, Tunduru
Date : 17.11.1981



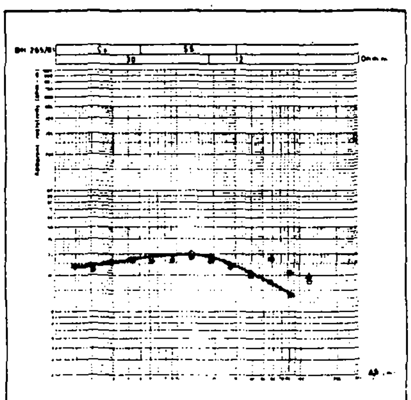
Profile no : 368
Latitude : $10^{\circ}55'$
Longitude : $37^{\circ}24.9'$
Village : Tunduru, Masasi
Date : 17.11.1981



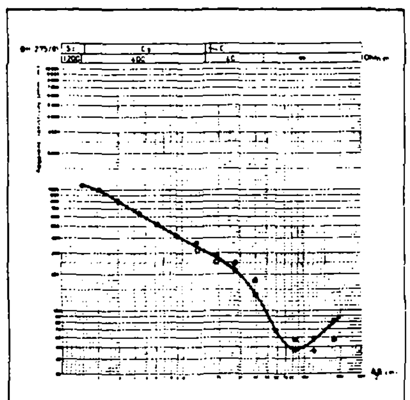
Profile no : 369
Latitude : $10^{\circ}10'$
Longitude : $35^{\circ}39'$
Village : Hanga
Date : 4.11.1981



Profile no : 370
Latitude : $11^{\circ}08'$
Longitude : $37^{\circ}17'$
Village : Azimio
Date : 18.11.1981



Profile no : 371
Latitude : $10^{\circ}10'$
Longitude : $35^{\circ}39.5'$
Village : Hanga
Date : 4.11.1981



Profile no : 372
Latitude : $11^{\circ}10.8'$
Longitude : $37^{\circ}14'$
Village : Azimio
Date : 18.11.1981

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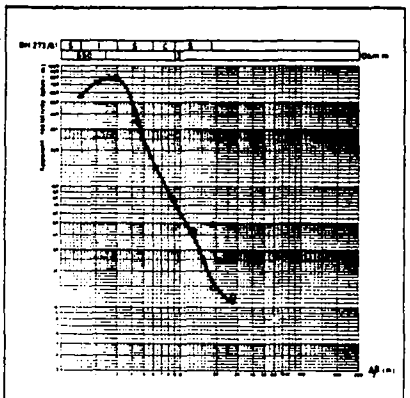
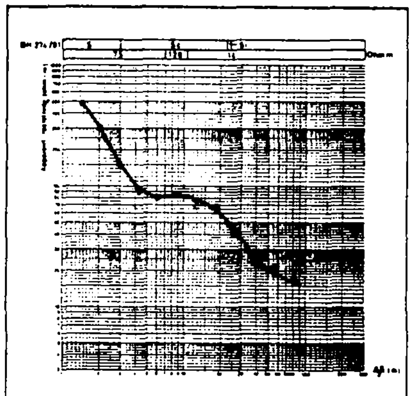
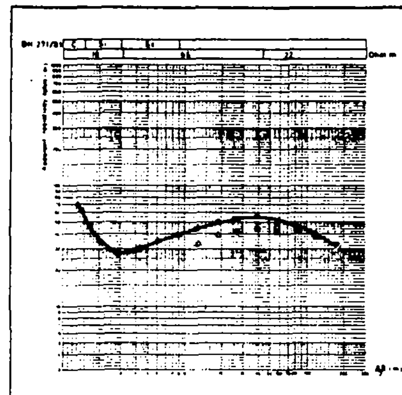


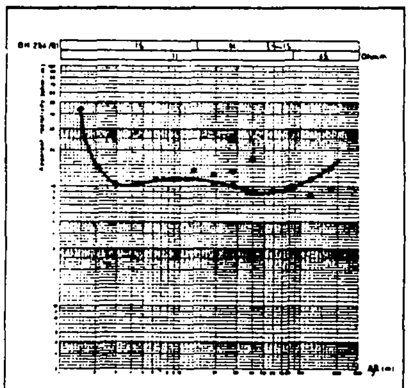
Profile no	:	373
Latitude	:	11°09'
Longitude	:	37°16.5'
Village	:	Azimio
Date	:	18.11.1981



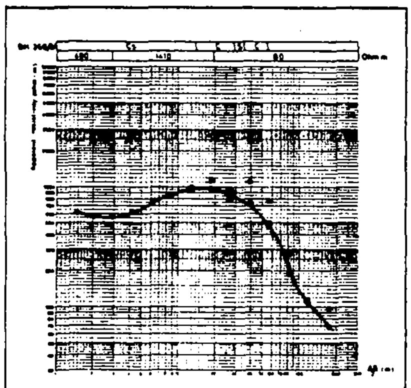
Profile no	:	374
Latitude	:	11°11'
Longitude	:	37°13'
Village	:	Azimio
Date	:	18.11.1981



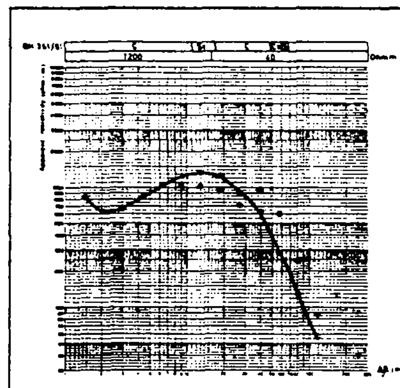
Profile no	:	375
Latitude	:	11°07.5'
Longitude	:	37°17.5'
Village	:	Azimio
Date	:	18.11.1981



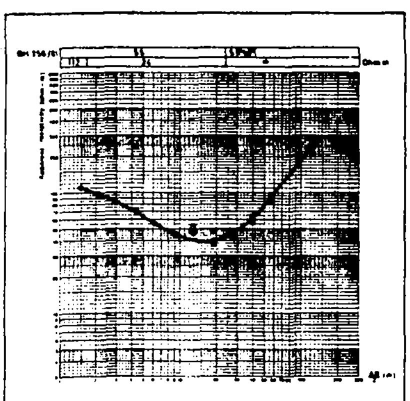
Profile no	:	376
Latitude	:	10°16'
Longitude	:	35°38'
Village	:	Gumbiro
Date	:	4.11.1981



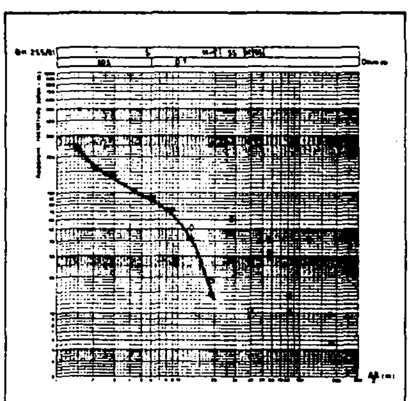
Profile no	:	377
Latitude	:	10°58'
Longitude	:	37°23'
Village	:	Sisikwa, Sisi
Date	:	17.11.1981



Profile no	:	378
Latitude	:	10°59.5'
Longitude	:	37°23'
Village	:	8½ km, Tunduru
Date	:	17.11.1981



Profile no	:	379
Latitude	:	10°46.5'
Longitude	:	36°57.5'
Village	:	Ndenyende
Date	:	11.11.1981

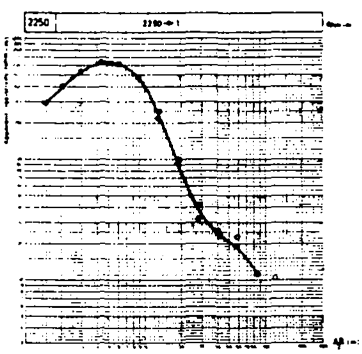


Profile no	:	380
Latitude	:	10°7.8'
Longitude	:	35°40'
Village	:	Mkutano
Date	:	5.11.1981

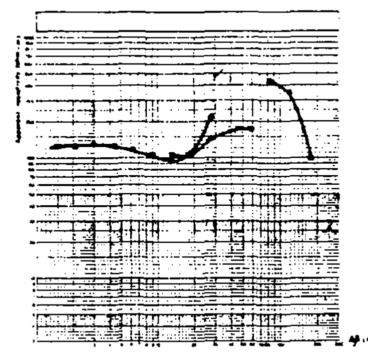
MBEYA

GEOELECTRIC SOUNDINGS

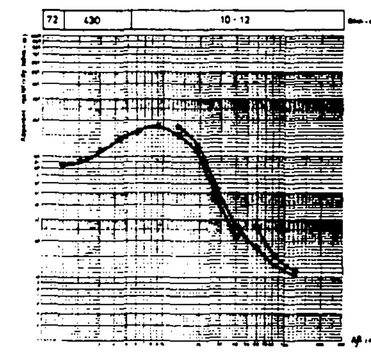
REGION: MBEYA



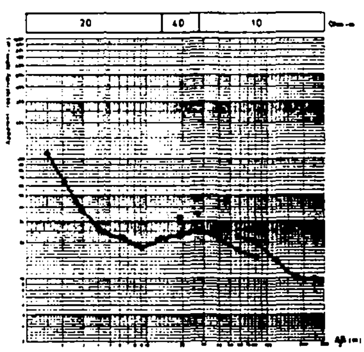
Profile no : 101
Latitude : $8^{\circ}36.8'$
Longitude : $33^{\circ}01.1'$
Village : Galula
Date : 25.9.1980



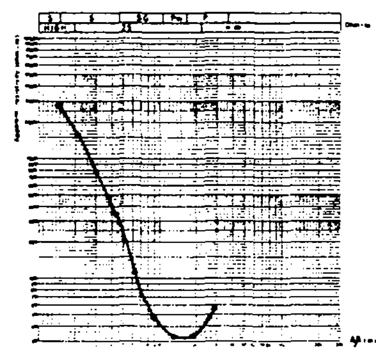
Profile no : 102
Latitude : $8^{\circ}36.8'$
Longitude : $33^{\circ}01.5'$
Village : Galula
Date : 25.9.1980



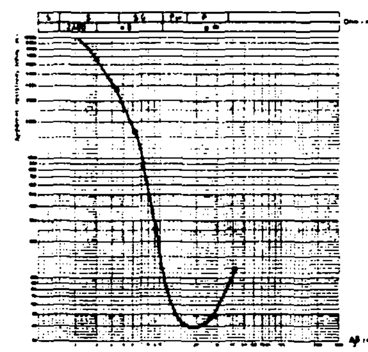
Profile no : 103
Latitude : $8^{\circ}34.4'$
Longitude : $33^{\circ}02.9'$
Village : Ifuko
Date : 25.9.1980



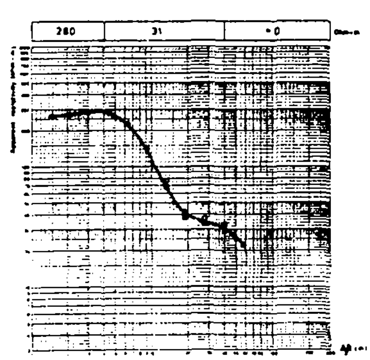
Profile no : 104
Latitude : $8^{\circ}34.4'$
Longitude : $33^{\circ}02.4'$
Village : Ifuko
Date : 25.9.1980



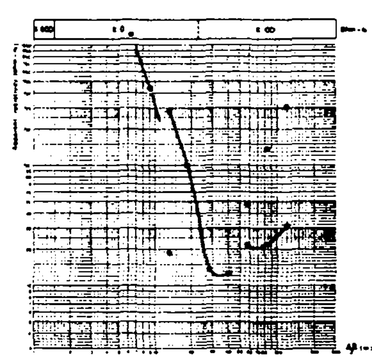
Profile no : 105
Latitude : $7^{\circ}15'$
Longitude : $33^{\circ}31'$
Village : Kambi Katoto
Date : 30.10.1980



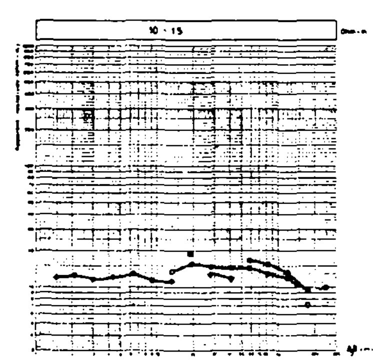
Profile no : 106
Latitude : $7^{\circ}15'$
Longitude : $33^{\circ}31'$
Village : Kambi Katoto
Date : 30.10.1980



Profile no : 107
Latitude : $8^{\circ}34.4'$
Longitude : $33^{\circ}02.1'$
Village : Kanga
Date : 26.9.1980



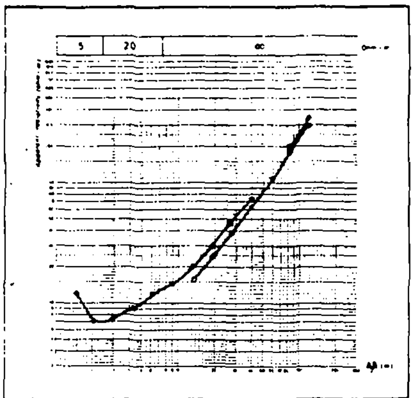
Profile no : 108
Latitude : $8^{\circ}34.4'$
Longitude : $33^{\circ}03.1'$
Village : Kanga
Date : 26.9.1980



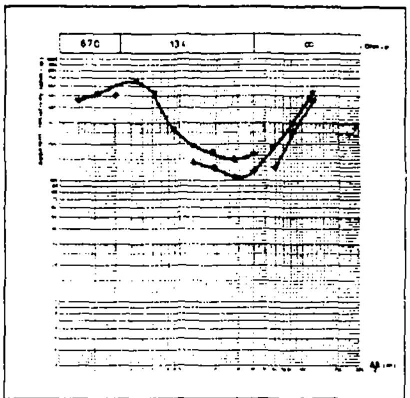
Profile no : 109
Latitude : $8^{\circ}34.4'$
Longitude : $33^{\circ}03.3'$
Village : Kanga
Date : 26.9.1980

G E O E L E C T R I C   S O U N D I N G S

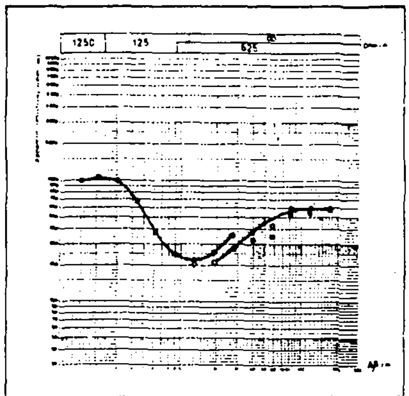
REGION: MBEYA



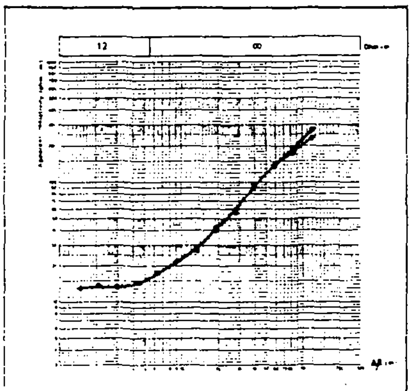
Profile no : 110
Latitude : $8^{\circ}35.1'$
Longitude : $33^{\circ}24.7'$
Village : Kiwanja
Date : 18.9.1980



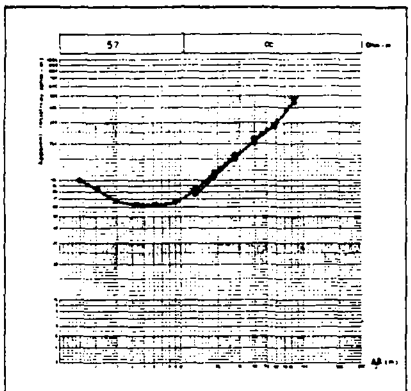
Profile no : 112
Latitude : $8^{\circ}33.3'$
Longitude : $33^{\circ}24.8'$
Village : Kiwanja
Date : 28.4.1981



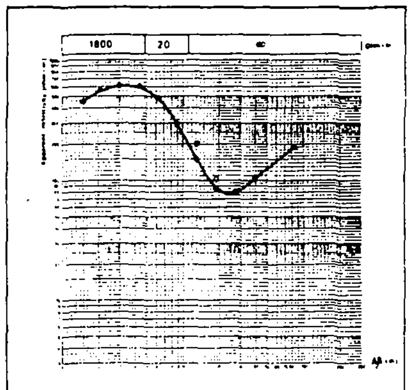
Profile no : 113
Latitude : $8^{\circ}33.5'$
Longitude : $33^{\circ}26'$
Village : Kiwanja
Date : 28.4.1981



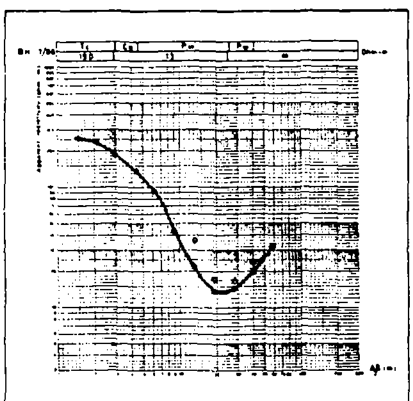
Profile no : 114
Latitude : $8^{\circ}27.6'$
Longitude : $33^{\circ}14.4'$
Village : Kungutas
Date : 30.4.1981



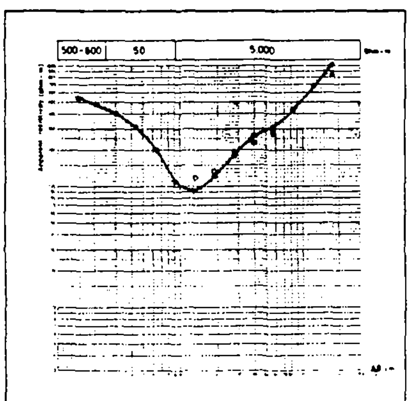
Profile no : 115
Latitude : $8^{\circ}27.5'$
Longitude : $33^{\circ}14.1'$
Village : Kungutas
Date : 30.4.1981



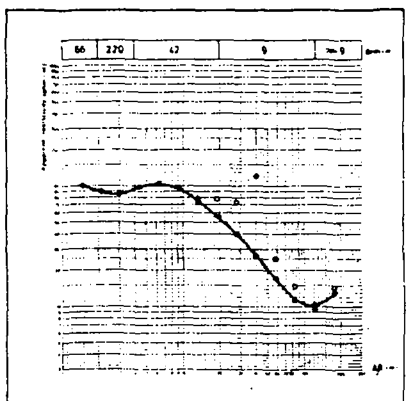
Profile no : 116
Latitude : $8^{\circ}40.7'$
Longitude : $33^{\circ}17.9'$
Village : Lupa Goldfield
Date : 22.10.1980



Profile no : 117
Latitude : $7^{\circ}59.9'$
Longitude : $33^{\circ}16.4'$
Village : Lupa Tingatinga
Date : 30.10.1980



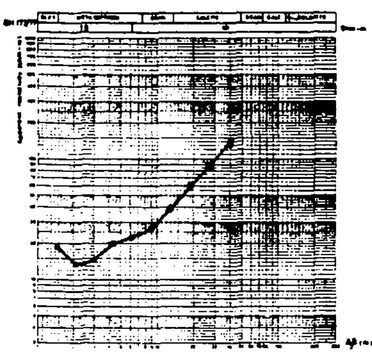
Profile no : 118
Latitude : $7^{\circ}30'$
Longitude : $33^{\circ}26'$
Village : Mafyeko
Date : 30.10.1980



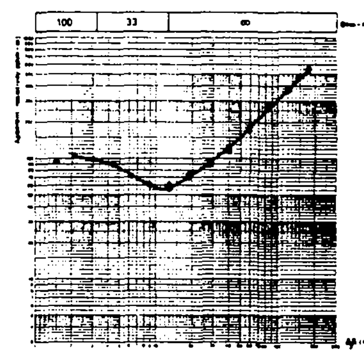
Profile no : 119
Latitude : $8^{\circ}37.5'$
Longitude : $32^{\circ}57'$
Village : Magamba
Date : 2.10.1980

GEOELECTRIC SOUNDINGS

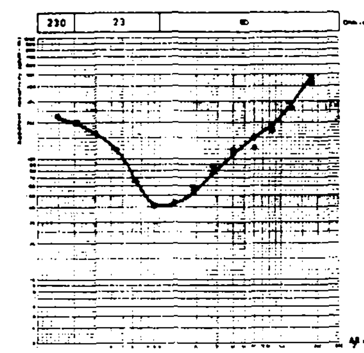
REGION: MBEYA



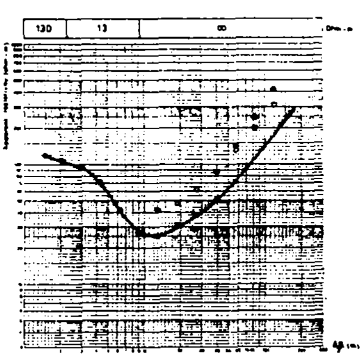
Profile no : 120
Latitude : 8°24.9'
Longitude : 33°10'
Village : Makongolosi
Date : 31.10.1980



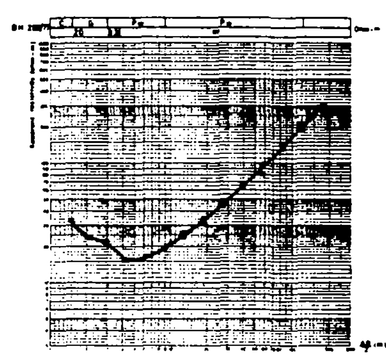
Profile no : 122
Latitude : 8°03.3'
Longitude : 33°16.2'
Village : Mamba
Date : 29.4.1981



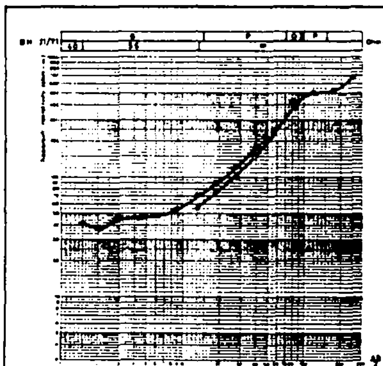
Profile no : 123
Latitude : 8°03.8'
Longitude : 33°15.9'
Village : Mamba
Date : 29.4.1981



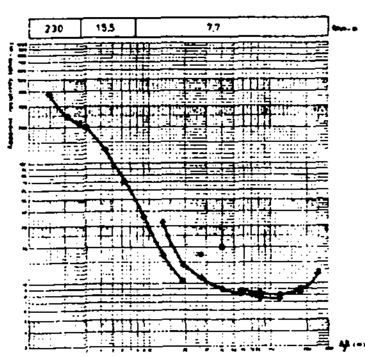
Profile no : 124
Latitude : 8°03.7'
Longitude : 33°16.2'
Village : Mamba
Date : 29.4.1981



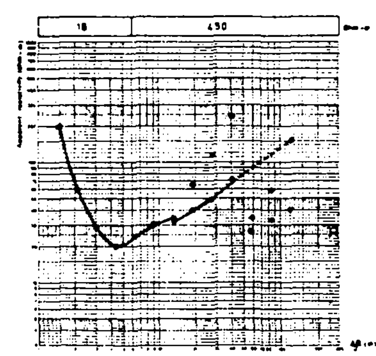
Profile no : 125
Latitude : 8°25.9'
Longitude : 33°31.9'
Village : Mapogolo
Date : 29.10.1980



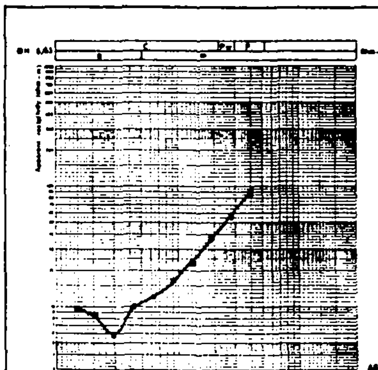
Profile no : 126
Latitude : 8°16.9'
Longitude : 33°16'
Village : Matundasi
Date : 31.10.1980



Profile no : 127
Latitude : 8°31.1'
Longitude : 33°01'
Village : Mbuyuni
Date : 3.10.1980



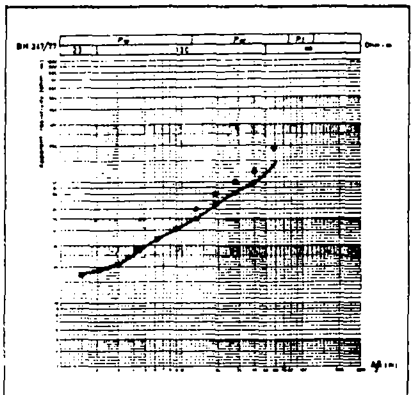
Profile no : 128
Latitude : 8°44.8'
Longitude : 33°09'
Village : Nsangamwelu
Date : 17.10.1980



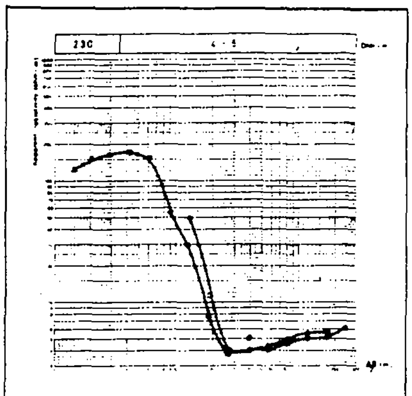
Profile no : 129
Latitude : 8°22.9'
Longitude : 33°18.6'
Village : Ntumbi Mines
Date : 29.10.1980

GEOELECTRIC SOUNDINGS

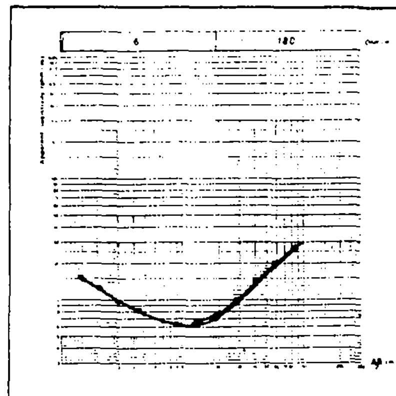
REGION: MBEYA



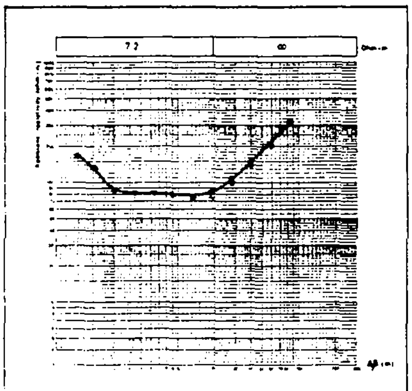
Profile no : 130
Latitude : $8^{o}32'$
Longitude : $33^{o}36.7'$
Village : Sangambi
Date : 22.10.1980



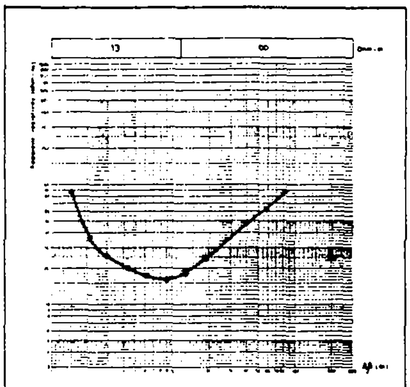
Profile no : 131
Latitude : $8^{o}30'$
Longitude : $32^{o}50.4'$
Village : Totoe/Totowe
Date : 3.10.1980



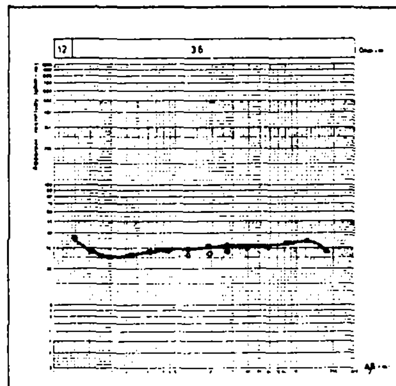
Profile no : 132
Latitude : $9^{o}22.9'$
Longitude : $33^{o}01.9'$
Village : Jkumbilo
Date : 21.11.1980



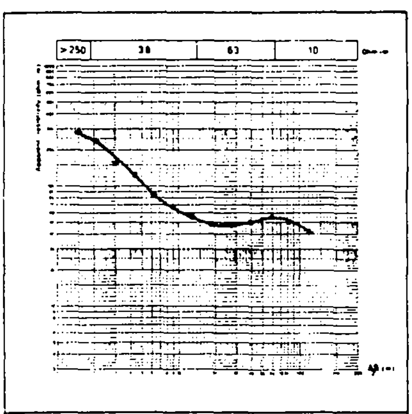
Profile no : 134
Latitude : $9^{o}20.9'$
Longitude : $32^{o}59.1'$
Village : Mbebe
Date : 20.11.1980



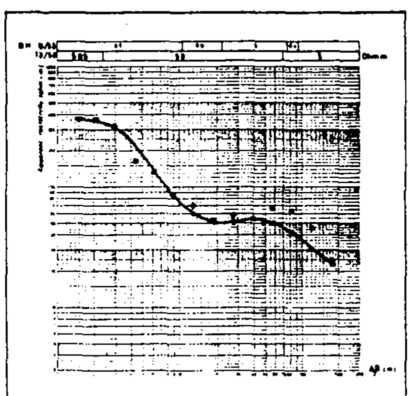
Profile no : 135
Latitude : $9^{o}16.7'$
Longitude : $32^{o}44.1'$
Village : Nandanga
Date : 17.11.1980



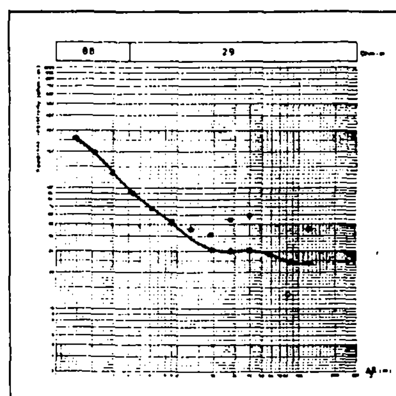
Profile no : 136
Latitude : $9^{o}29.2'$
Longitude : $33^{o}53.2'$
Village : Ipinda
Date : 18.12.1980



Profile no : 137
Latitude : $9^{o}34.6'$
Longitude : $33^{o}51.3'$
Village : Kikusya
Date : 18.12.1980



Profile no : 138
Latitude : $9^{o}36'$
Longitude : $33^{o}51.7'$
Village : Kyela
Date : 16.10.1980



Profile no : 139
Latitude : $9^{o}33.8'$
Longitude : $33^{o}53.2'$
Village : Tenende
Date : 18.12.1980

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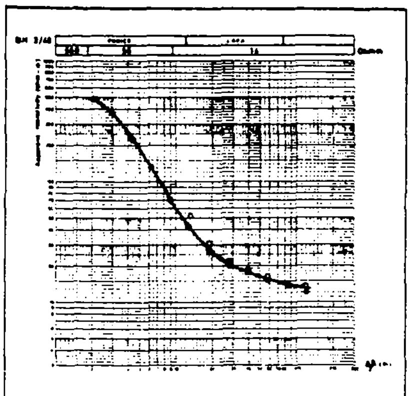
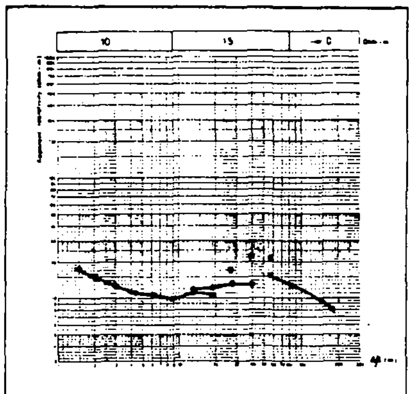
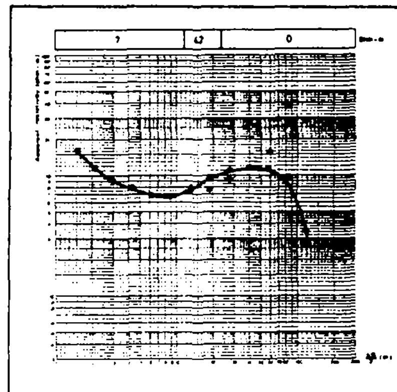
REGION: MBEYA



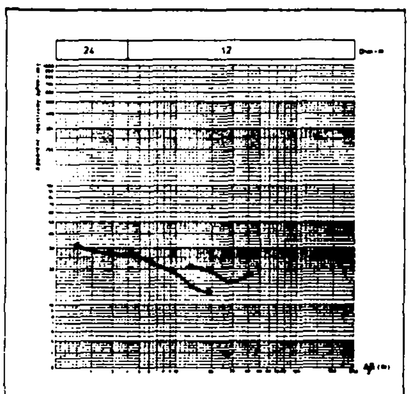
Profile no : 140
Latitude : 8°54.9'
Longitude : 33°27.6'
Village : Mbeya Airport
Date : 8.10.1980



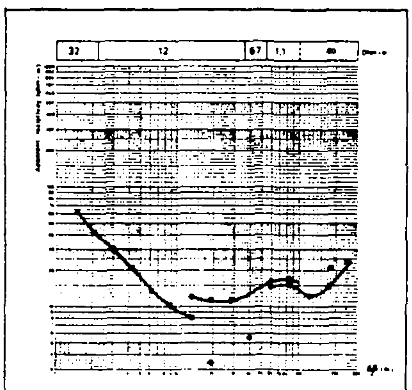
Profile no : 141
Latitude : 8°45.7'
Longitude : 33°38.4'
Village : Ijumbi
Date : 17.9.1980



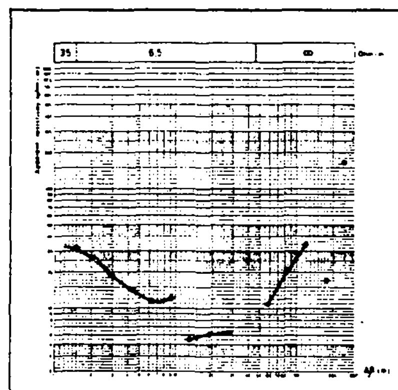
Profile no : 142
Latitude : 8°46.9'
Longitude : 33°43'
Village : Jlongo
Date : 15.9.1980



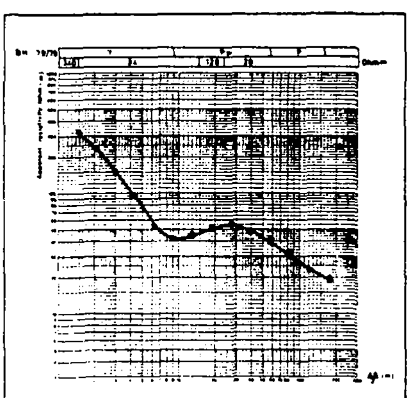
Profile no : 143
Latitude : 8°46.8'
Longitude : 33°43.1'
Village : Jlongo
Date : 10.9.1980



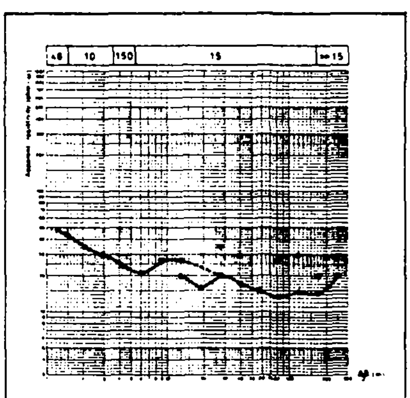
Profile no : 144
Latitude : 8°46.9'
Longitude : 33°43.1'
Village : Jlongo
Date : 15.9.1980



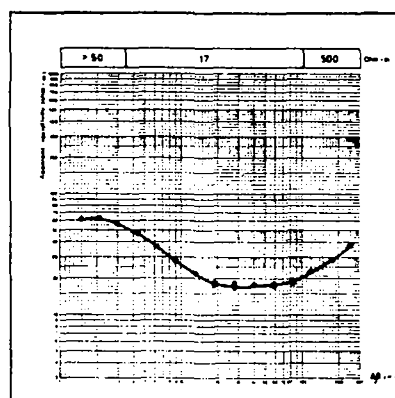
Profile no : 145
Latitude : 8°47.1'
Longitude : 33°43.1'
Village : Jlongo
Date : 15.9.1980



Profile no : 146
Latitude : 8°55.7'
Longitude : 33°23.8'
Village : Iyunga
Date : 8.10.1980



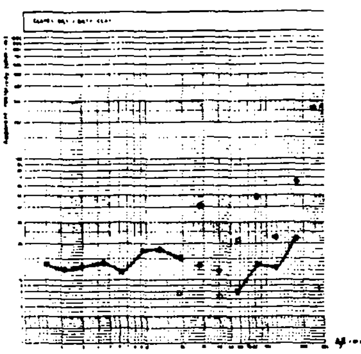
Profile no : 147
Latitude : 8°47'
Longitude : 33°47.6'
Village : Kongolo
Date : 17.9.1980



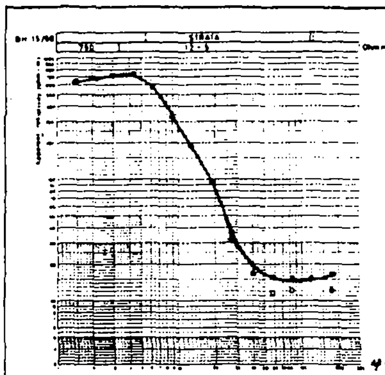
Profile no : 148
Latitude : 8°58.4'
Longitude : 33°13.6'
Village : Magereza
Date : 8.10.1980

GEOELECTRIC SOUNDINGS

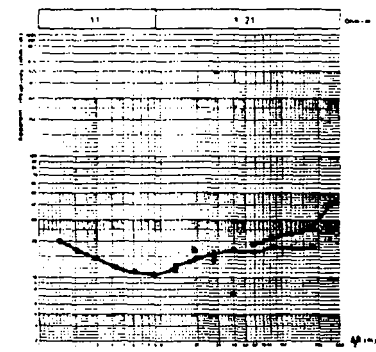
REGION: MBEYA



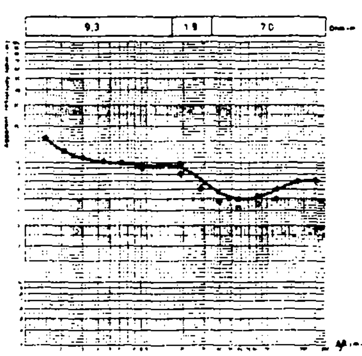
Profile no : 149
Latitude : $8^{o}45.2'$
Longitude : $33^{o}47'$
Village : Mahango
Date : 16.9.1980



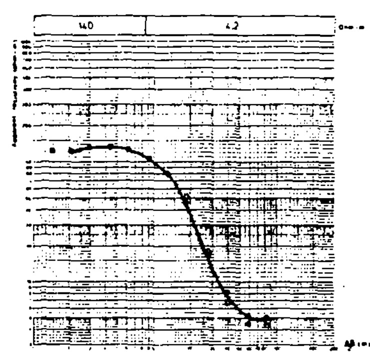
Profile no : 150
Latitude : $8^{o}55.2'$
Longitude : $33^{o}27.3'$
Village : Mbeya
Date : 7.10.1980



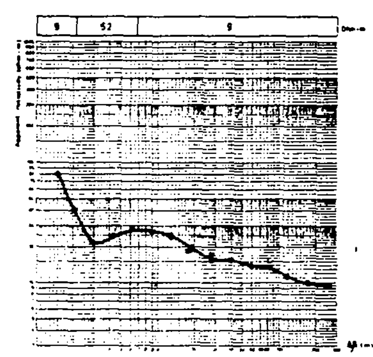
Profile no : 151
Latitude : $8^{o}46.2'$
Longitude : $33^{o}42.3'$
Village : Mlowe
Date : 16.9.1980



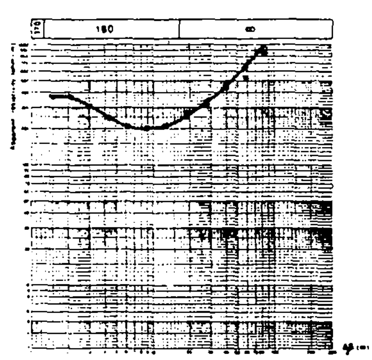
Profile no : 152
Latitude : $8^{o}46'$
Longitude : $33^{o}45.1'$
Village : Nsonyanga
Date : 15.9.1980



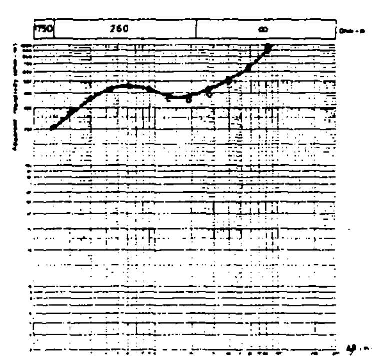
Profile no : 153
Latitude : $8^{o}56.8'$
Longitude : $33^{o}15'$
Village : Songwe
Date : 14.10.1980



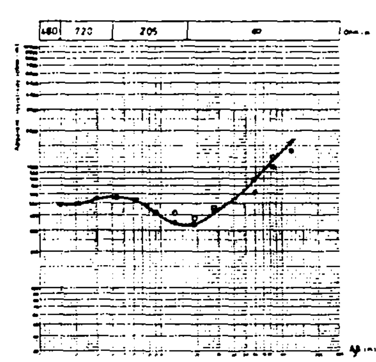
Profile no : 154
Latitude : $8^{o}57'$
Longitude : $33^{o}13.4'$
Village : Songwe
Date : 14.10.1980



Profile no : 156
Latitude : $9^{o}10.8'$
Longitude : $32^{o}33.6'$
Village : Chiwanda
Date : 21.4.1981



Profile no : 157
Latitude : $9^{o}10.4'$
Longitude : $32^{o}33.6'$
Village : Chiwanda
Date : 22.4.1981



Profile no : 158
Latitude : $9^{o}10.2'$
Longitude : $32^{o}33.8'$
Village : Chiwanda
Date : 22.4.1981

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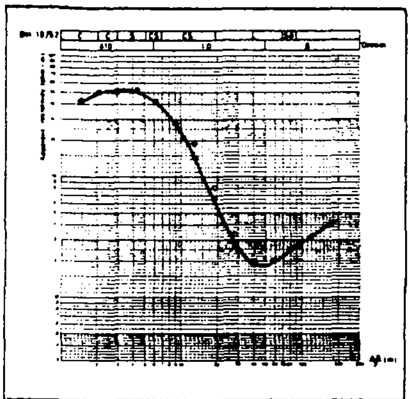
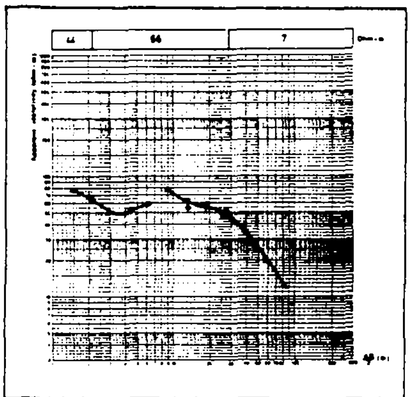
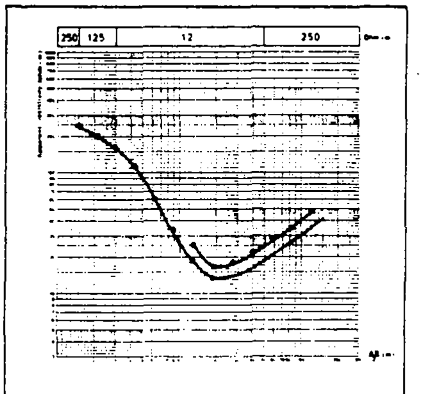


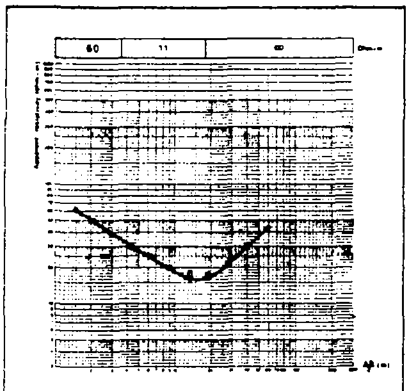
Profile no : 162
Latitude : 8°25.8'
Longitude : 32°28.9'
Village : Ivuna
Date : 27.1.1981



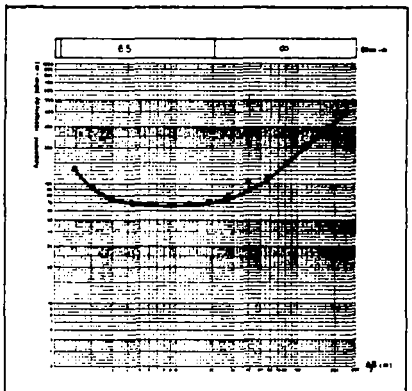
Profile no : 163
Latitude : 8°21.3'
Longitude : 32°17.4'
Village : Kamsamba
Date : 27.1.1981



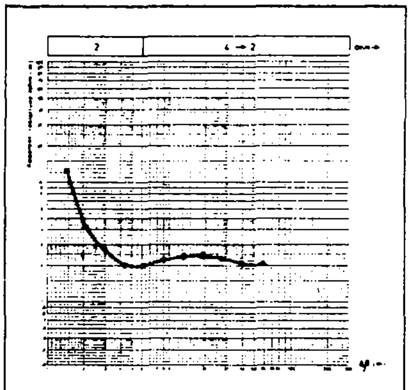
Profile no : 164
Latitude : 8°32.4'
Longitude : 32°27.3'
Village : Mbao
Date : 28.1.1981



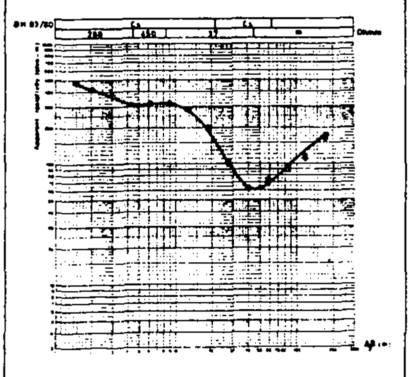
Profile no : 166
Latitude : 9°05.5'
Longitude : 32°57.3'
Village : Mbimba
Date : 28.11.1980



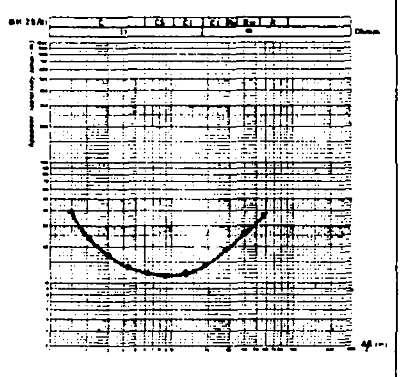
Profile no : 167
Latitude : 9°05.5'
Longitude : 32°57.3'
Village : Mbimba
Date : 9.10.1980



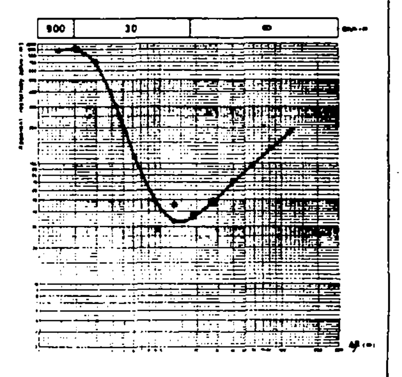
Profile no : 168
Latitude : 8°25.9'
Longitude : 32°31.4'
Village : Kinamwene
Date : 27.1.1981



Profile no : 170
Latitude : 9°01.1'
Longitude : 32°58.7'
Village : Mbozi Mission
Date : 30.9.1980



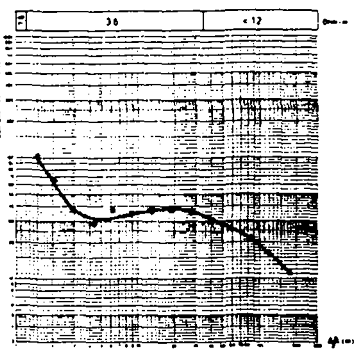
Profile no : 171
Latitude : 9°01.9'
Longitude : 32°55.9'
Village : Mbozi Mission
Date : 8.12.1980



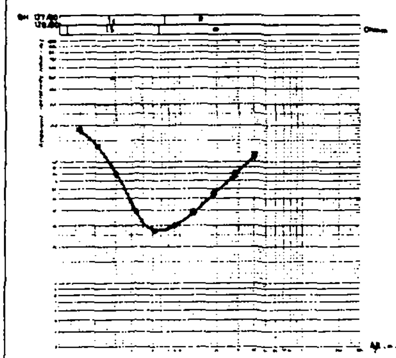
Profile no : 172
Latitude : 8°42.1'
Longitude : 32°10.4'
Village : Mkutano
Date : 13.11.1980

GEOELECTRIC SOUNDINGS

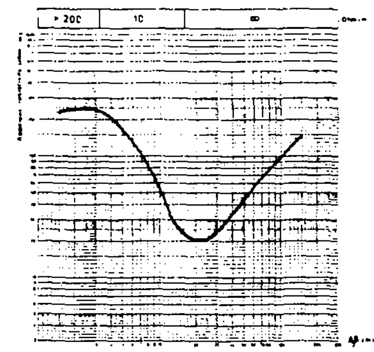
REGION: MBEYA



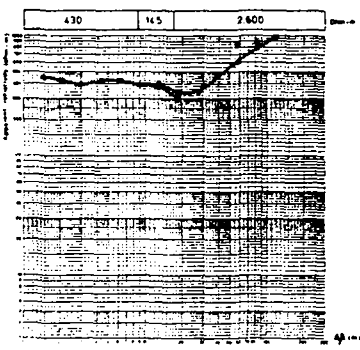
Profile no : 173
Latitude : $8^{\circ}24.3'$
Longitude : $32^{\circ}22.2'$
Village : Mpapa
Date : 28.1.1981



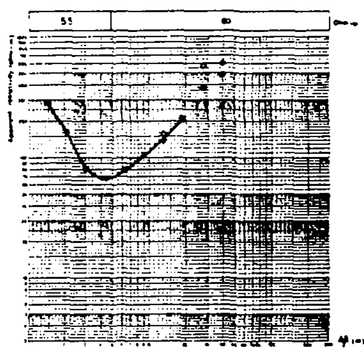
Profile no : 174
Latitude : $9^{\circ}15.7'$
Longitude : $32^{\circ}50.1'$
Village : Mpemba
Date : 11.11.1980



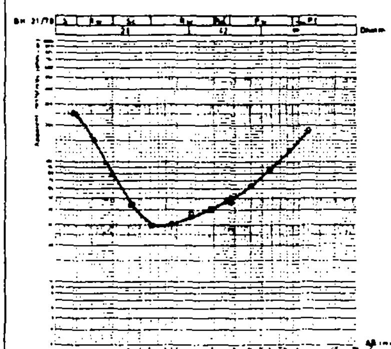
Profile no : 178
Latitude : $9^{\circ}16.2'$
Longitude : $32^{\circ}49.1'$
Village : Mpemba
Date : 14.5.1981



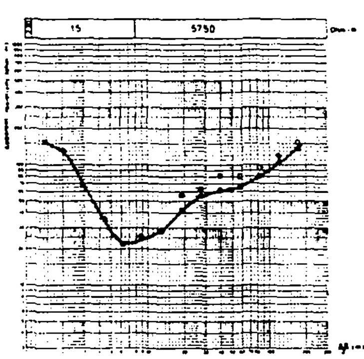
Profile no : 179
Latitude : $9^{\circ}14.6'$
Longitude : $32^{\circ}37.3'$
Village : Nkangamo
Date : 15.11.1980



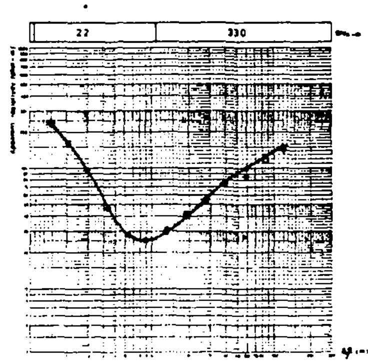
Profile no : 180
Latitude : $9^{\circ}14.5'$
Longitude : $32^{\circ}37.5'$
Village : Nkangamo
Date : 15.10.1980



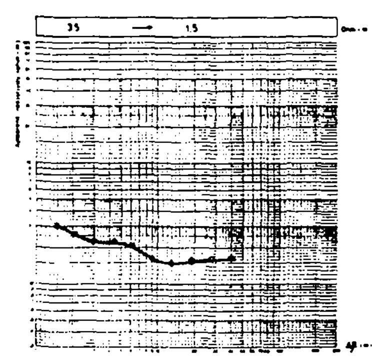
Profile no : 181
Latitude : $8^{\circ}44.1'$
Longitude : $32^{\circ}10.4'$
Village : Nzoka
Date : 13.11.1980



Profile no : 182
Latitude : $8^{\circ}51.7'$
Longitude : $32^{\circ}59.3'$
Village : Rungwa
Date : 30.9.1980



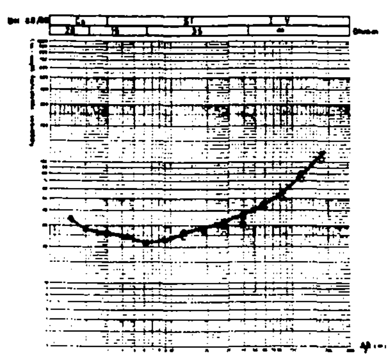
Profile no : 183
Latitude : $8^{\circ}51.8'$
Longitude : $32^{\circ}59.4'$
Village : Rungwa
Date : 30.9.1980



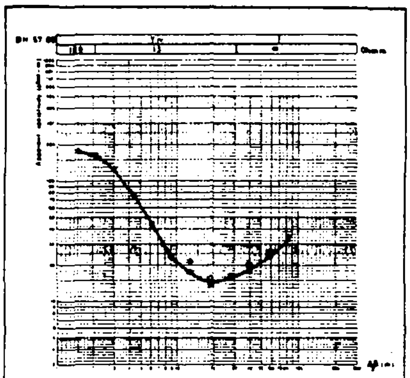
Profile no : 184
Latitude : $8^{\circ}23.4'$
Longitude : $32^{\circ}30.9'$
Village : Sawanyambe
Date : 27.1.1981

GEOELECTRIC SOUNDINGS

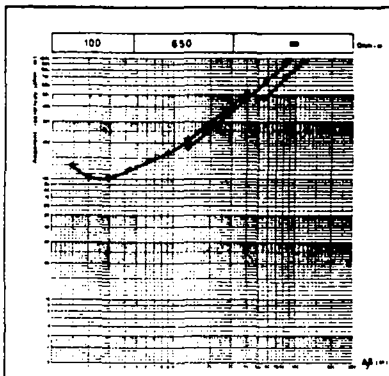
REGION: MBEYA



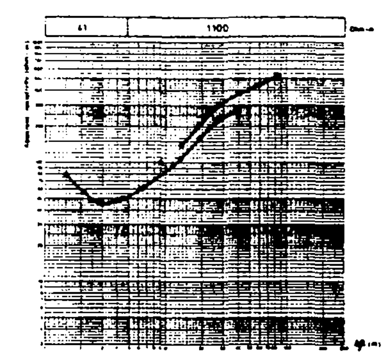
Profile no : 185
Latitude : $8^{\circ}57.1'$
Longitude : $33^{\circ}10.2'$
Village : Senjele
Date : 2.10.1980



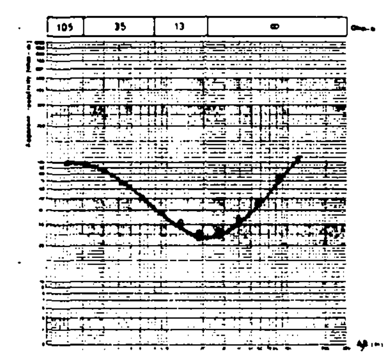
Profile no : 186
Latitude : $8^{\circ}56.8'$
Longitude : $33^{\circ}10.3'$
Village : Senjele
Date : 2.10.1980



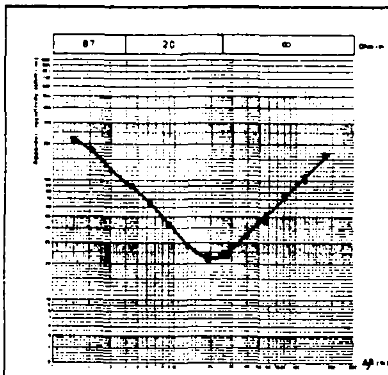
Profile no : 187
Latitude : $9^{\circ}18.8'$
Longitude : $32^{\circ}46.3'$
Village : Tunduma
Date : 8.10.1980



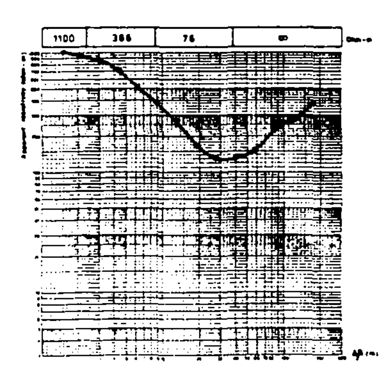
Profile no : 188
Latitude : $9^{\circ}18.6'$
Longitude : $32^{\circ}47.3'$
Village : Tunduma
Date : 9.10.1980



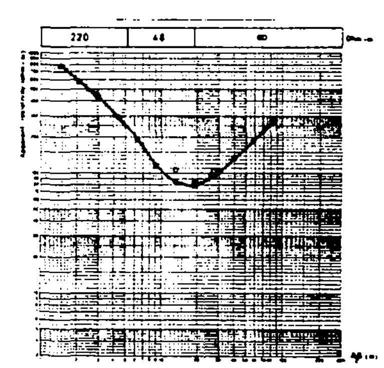
Profile no : 190
Latitude : $9^{\circ}05.2'$
Longitude : $32^{\circ}56.3'$
Village : Vwawa
Date : 10.4.1981



Profile no : 191
Latitude : $9^{\circ}05.2'$
Longitude : $32^{\circ}56.3'$
Village : Vwawa
Date : 9.4.1981



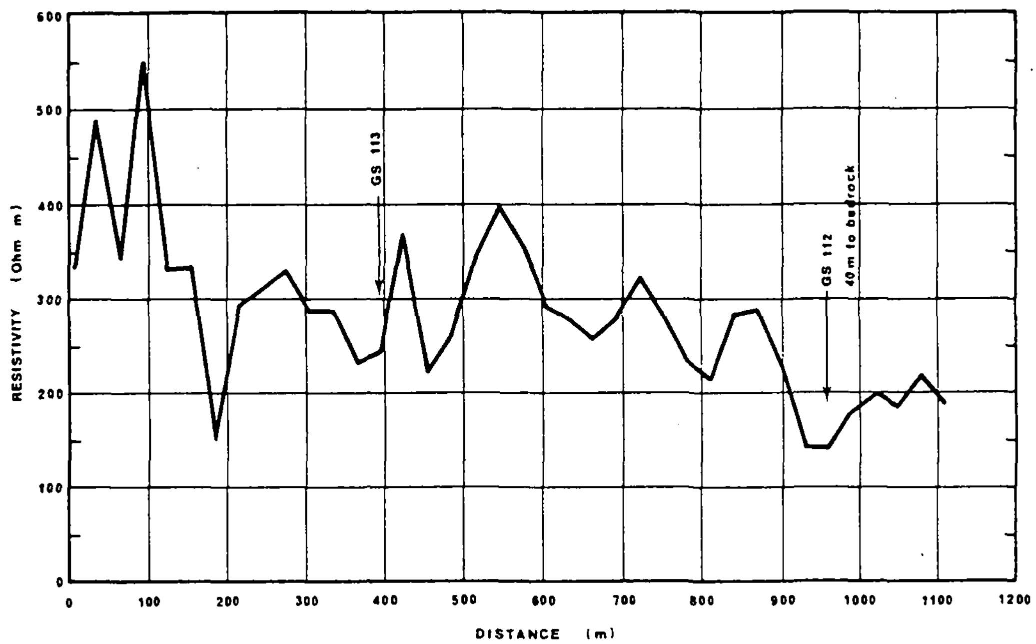
Profile no : 193
Latitude : $9^{\circ}02.4'$
Longitude : $33^{\circ}35.8'$
Village : Idweli
Date : 1.4.1981



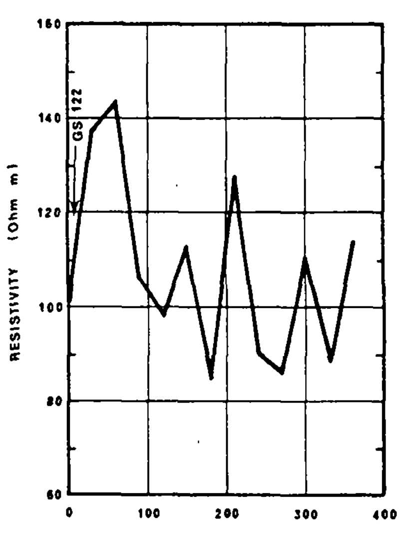
Profile no : 194
Latitude : $9^{\circ}02.8'$
Longitude : $33^{\circ}35.6'$
Village : Idweli
Date : 1.4.1981

CONSTANT SEPARATION TRAVERSES.

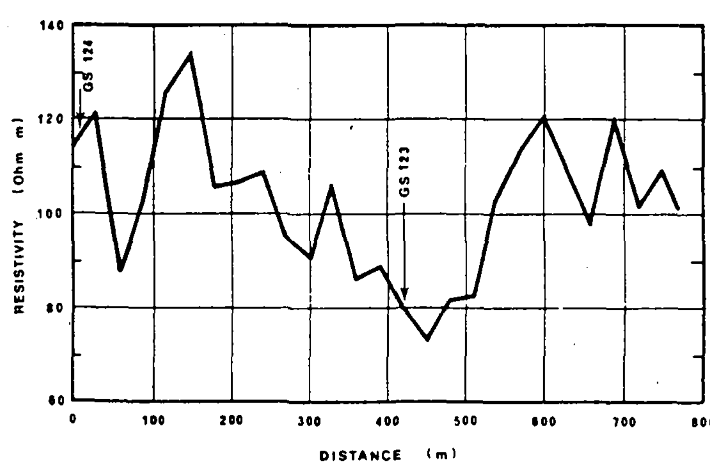
REGION: MBEYA



Traverse no : 101
Latitude : 8°33.4'
Longitude : 33°26'
Village : Kiwanja
Date : 28.4.81

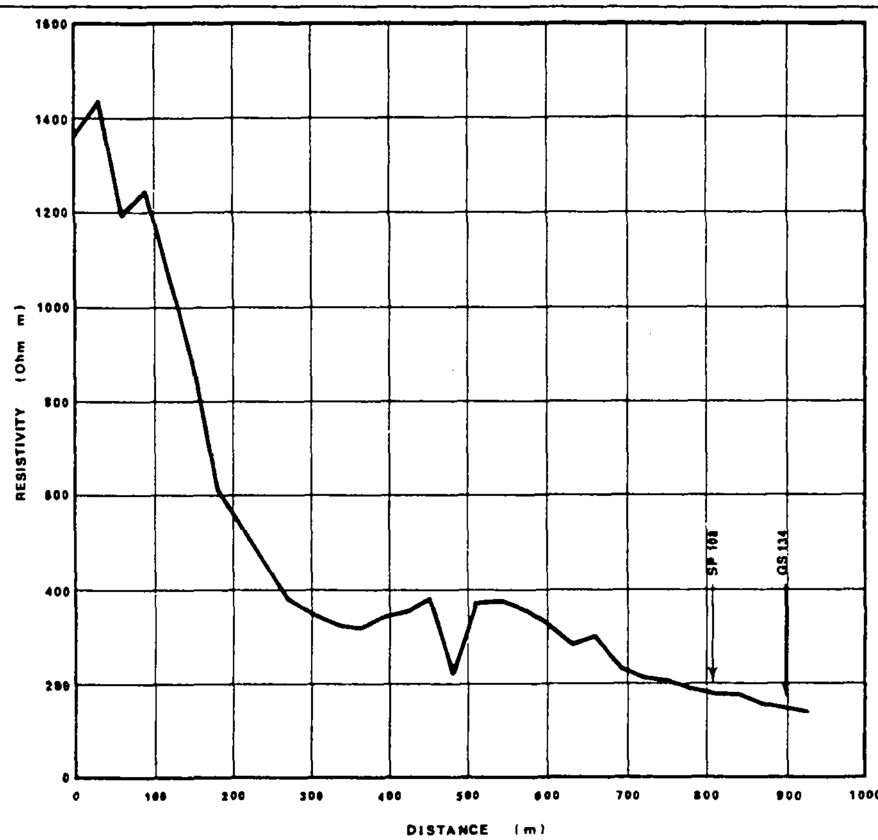


Traverse no : 121 A
Latitude : 8°03.3'
Longitude : 33°16.2'
Village : Mamba
Date : 29.4.81



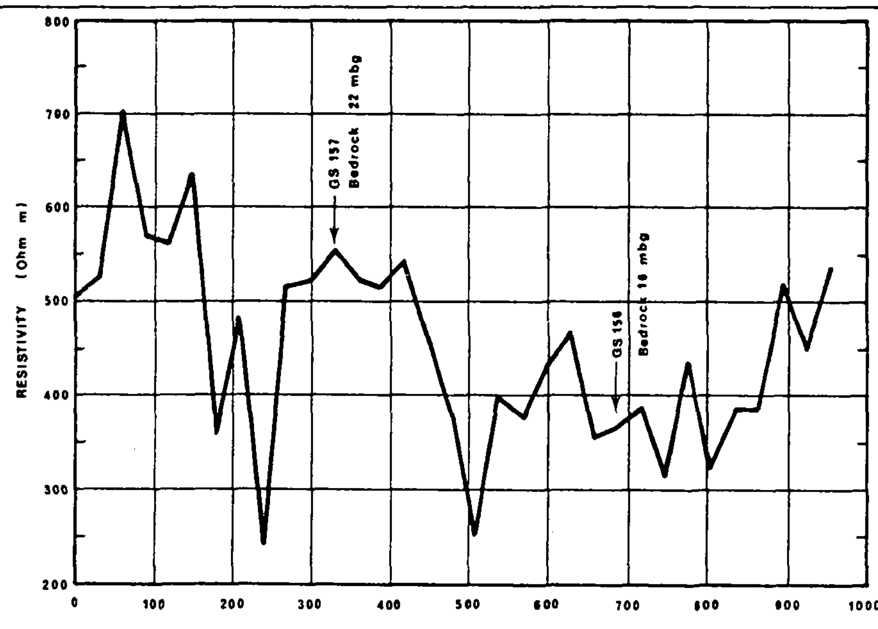
Traverse no : 121 B
Latitude : 8°03.9'
Longitude : 33°15.8'
Village : Mamba
Date : 29.4.81

CONSTANT SEPARATION TRAVERSES	REGION: MBEYA



Traverse no : 133
Latitude : $9^{o}21.1'$
Longitude : $35^{o}58.9'$

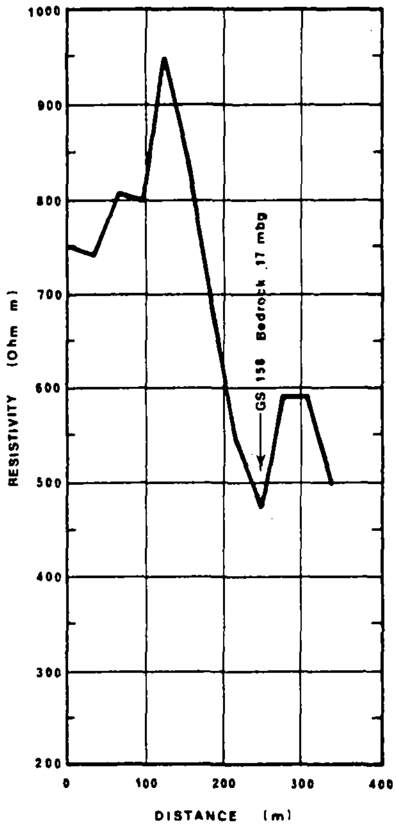
Village : Mbebe
Date : 20.11.80



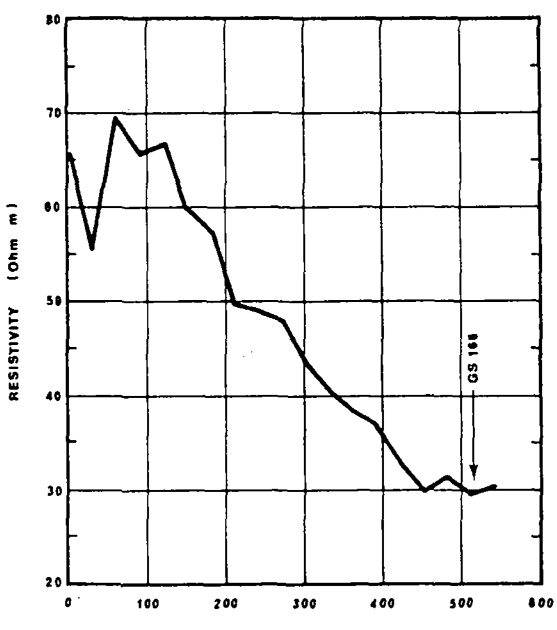
Traverse no : 155 A
Latitude : $9^{o}10.5'$
Longitude : $32^{o}33.6'$

Village : Chiwanda
Date : 22.4.81

CONSTANT SEPARATION TRAVERSES	REGION: MBEYA

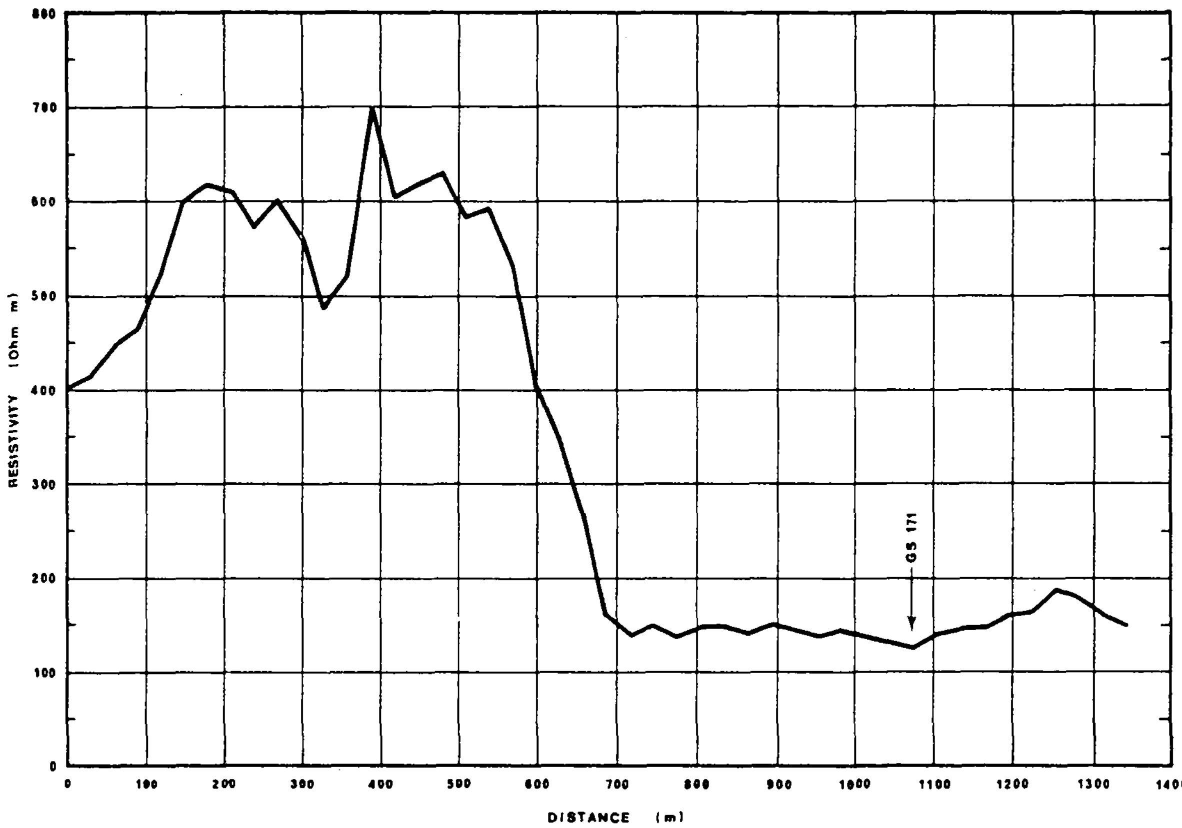


Traverse no : 155 B
Latitude : 9°10.3'
Longitude : 32°33.8'
Village : Chiwanda
Date : 23.4.81

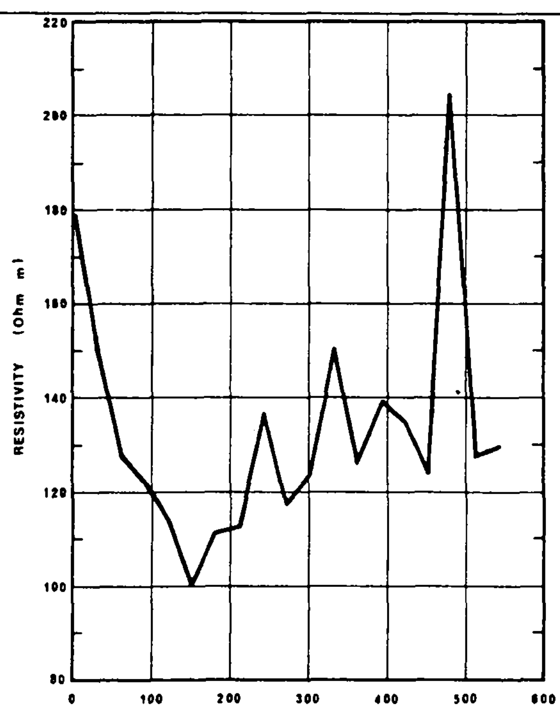


Traverse no : 165
Latitude : 9°05.2'
Longitude : 32°57.4'
Village : Mbimba
Date : 28.11.80

CONSTANT SEPARATION TRAVERSES	REGION: MBEYA

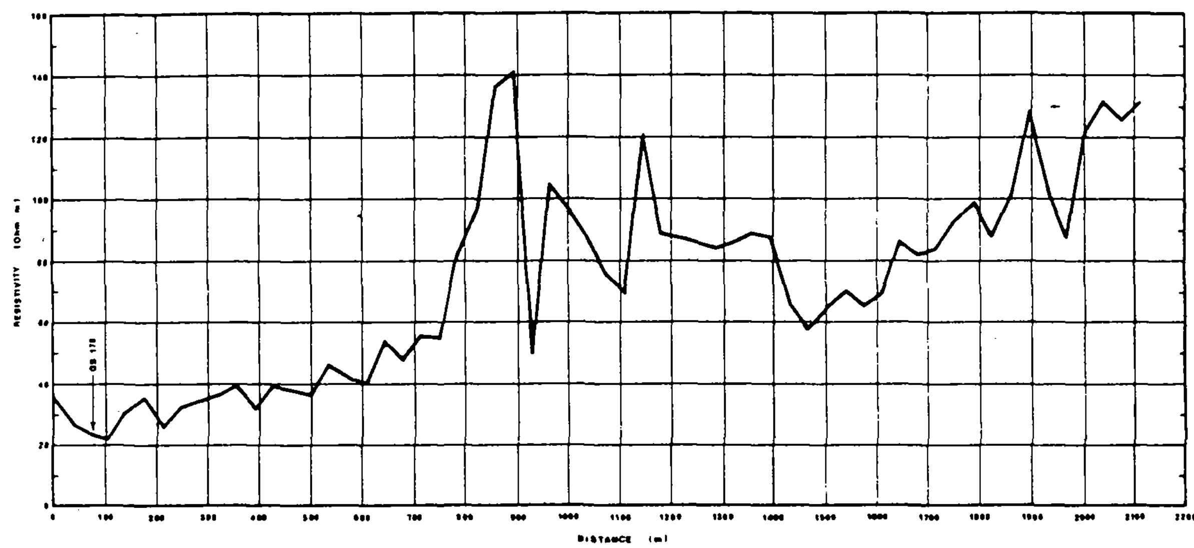


Traverse no : 169
Latitude : $9^{\circ}01.3'$
Longitude : $32^{\circ}58.8'$
Village : Mbozi
Date : 8.12.80

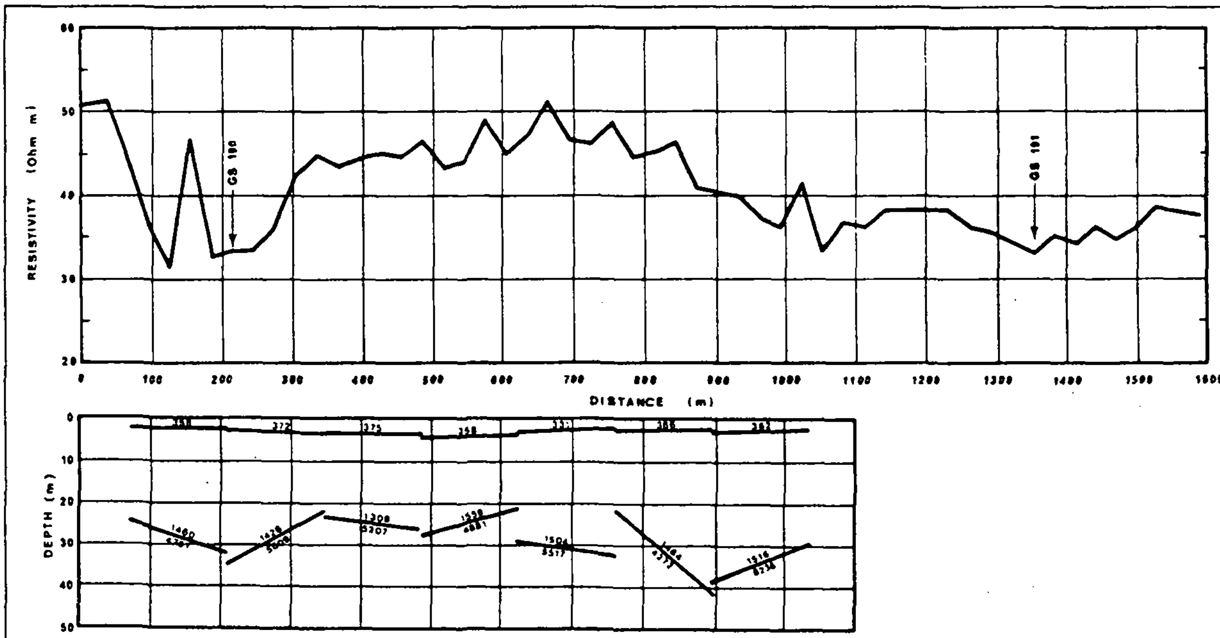


Traverse no : 176
Latitude : $9^{\circ}16.2'$
Longitude : $32^{\circ}49.1'$
Village : Mpemba
Date : 8.4.81

CONSTANT SEPARATION TRAVERSES	REGION: MBEYA



Traverse no : 177
Latitude : 9°15.6'
Longitude : 32°50.2'
Village : Mpemba
Date : 14.5.81

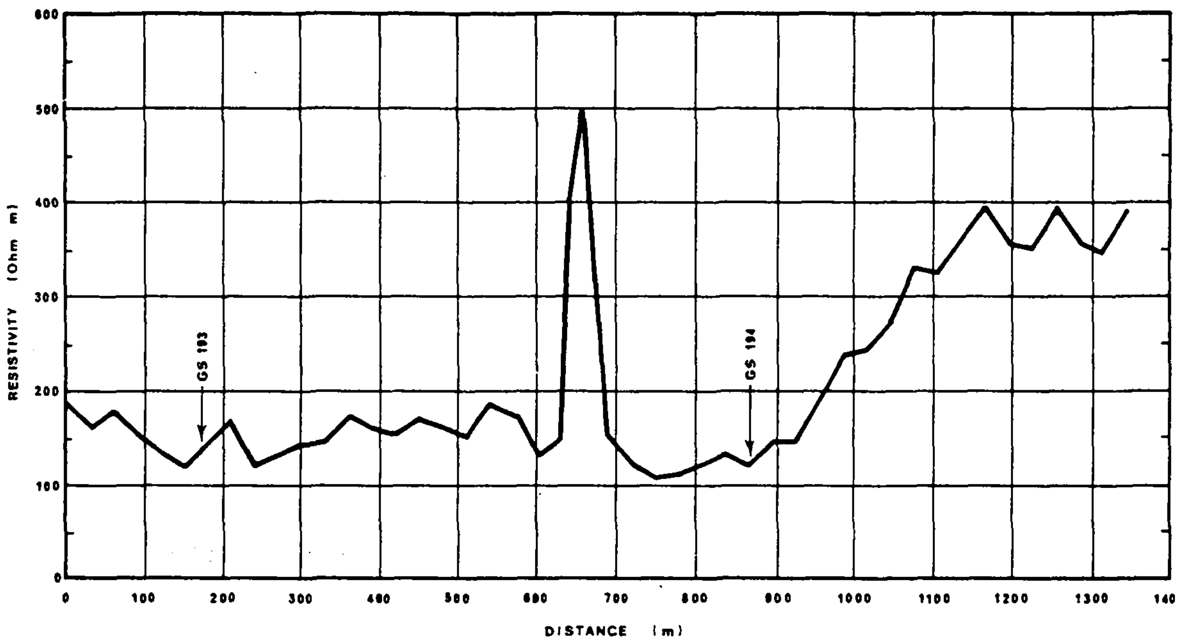


Traverse no : 189
Latitude : 9°03.5'
Longitude : 32°57'
Village : Vwawa
Date : 9.4.81

The lower graph illustrates results from seismic soundings 101-107.

CONSTANT SEPARATION TRAVERSES

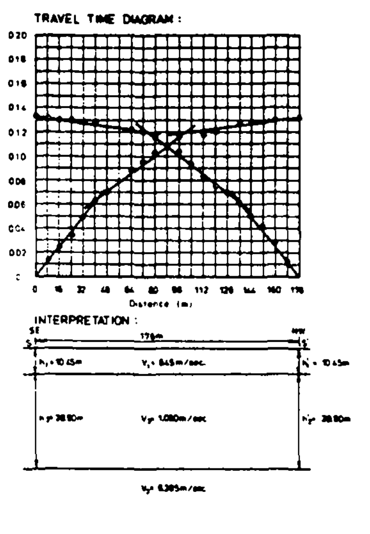
REGION: MBEYA



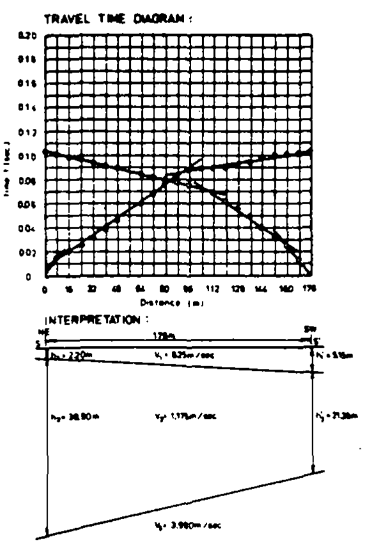
Traverse no	:	192
Latitude	:	9°02.4'
Longitude	:	33°35.6'
Village	:	Idweli
Date	:	6.4.81

IRINGA

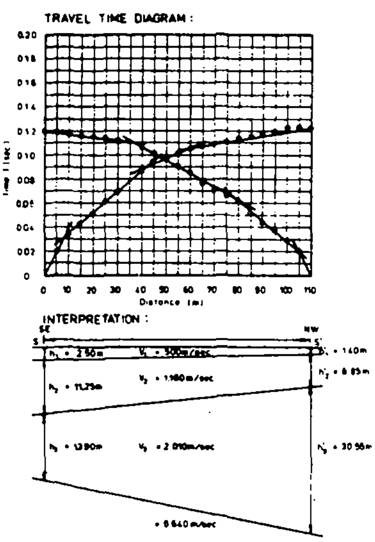
SEISMIC PROFILES	REGION: IRINGA



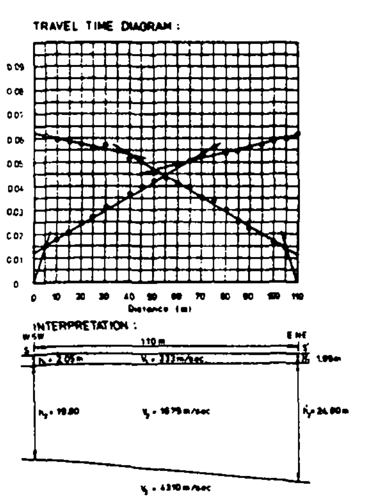
Profile no : 201
Latitude : 7°47.5'
Longitude : 35°10.9'
Village : Idodi
Date : 30.4.1981



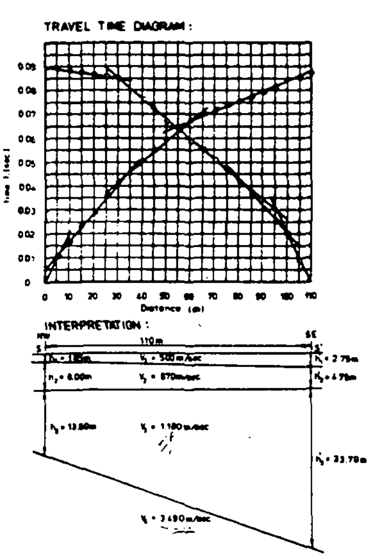
Profile no : 202
Latitude : 7°49.4'
Longitude : 35°06.9'
Village : Mapogoro
Date : 30.4.1981



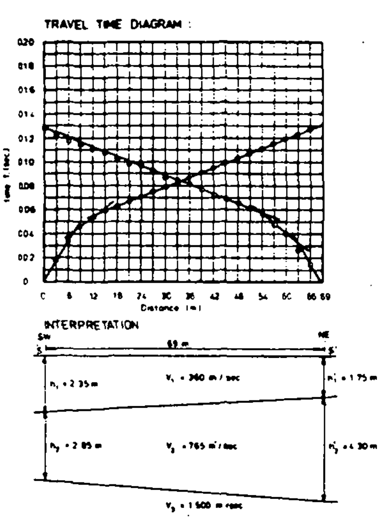
Profile no : 203
Latitude : 7°39.7'
Longitude : 35°22.3'
Village : Mloa
Date : 28.4.1981



Profile no : 204
Latitude : 7°35.7'
Longitude : 35°22.8'
Village : Mafruto
Date : 29.4.1981

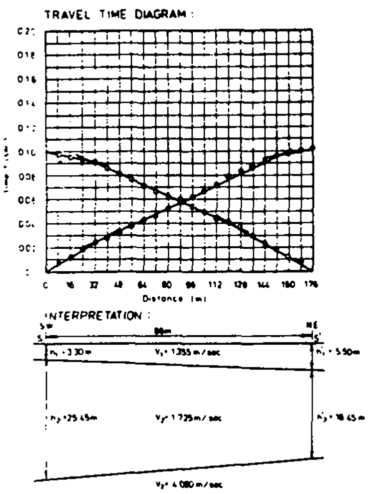


Profile no : 205
Latitude : 7°43.0'
Longitude : 35°32.1'
Village : Nzihi
Date : 28.4.1981



Profile no : 206
Latitude : 10°29.0'
Longitude : 34°42.9'
Village : Ngerenge
Date : 5.12.1980

SEISMIC PROFILES	REGION: IRINGA



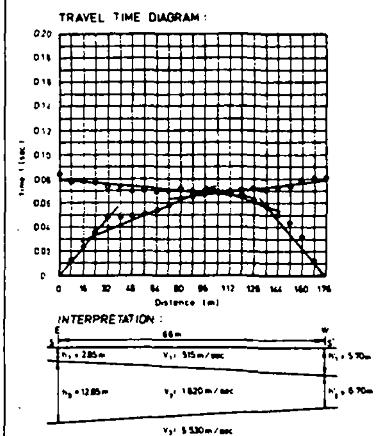
Profile no : 207

Latitude : $8^{\circ}14.8'$

Longitude : $35^{\circ}15.7'$

Village : Ndolezi

Date : 31.3.1981



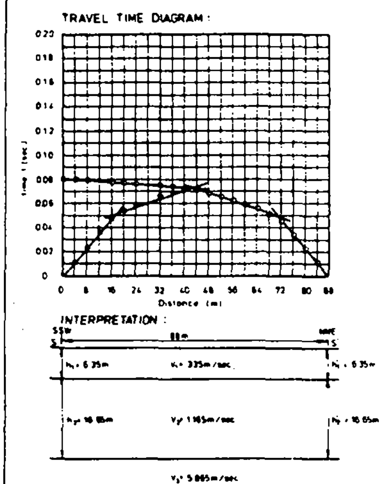
Profile no : 208

Latitude : $8^{\circ}53.6'$

Longitude : $34^{\circ}34.4'$

Village : Ilembula

Date : 17.12.1980



Profile no : 209

Latitude : $9^{\circ}16.3'$

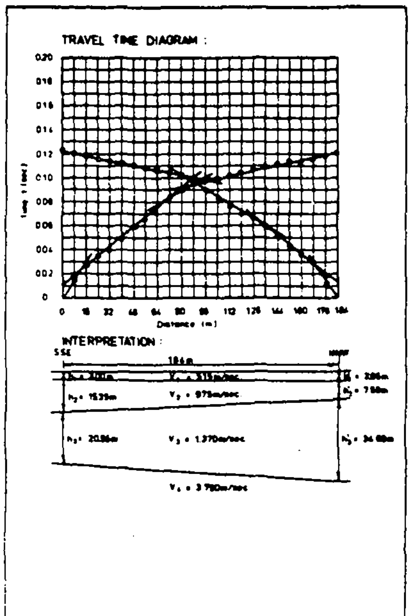
Longitude : $35^{\circ}00.4'$

Village : Kidegembye

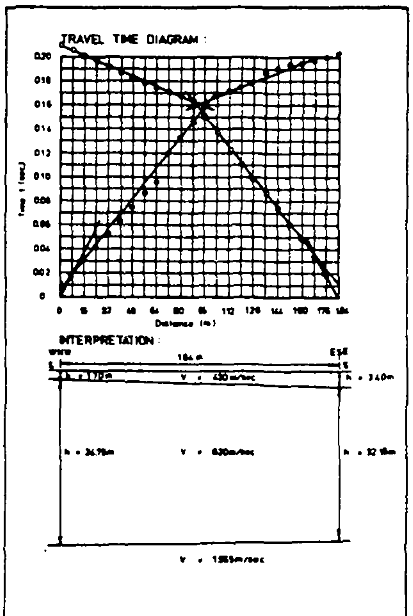
Date : 4.6.1981

RUVUMA

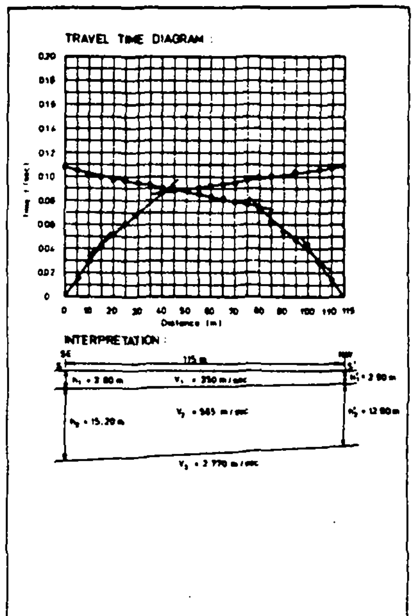
SEISMIC PROFILES	REGION: RUVUMA



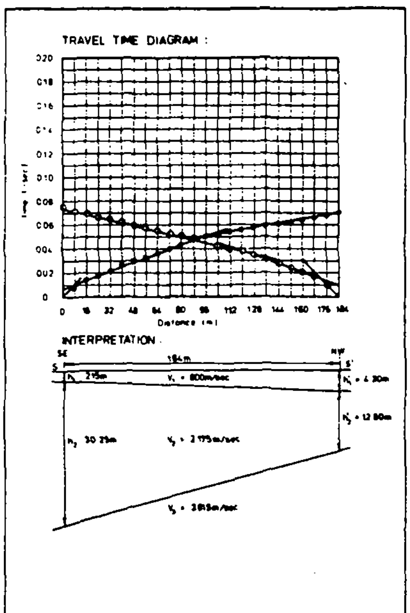
Profile no : 301
Latitude : 10°33.3'
Longitude : 34°37.5'
Village : Lituhi
Date : 24.6.1981



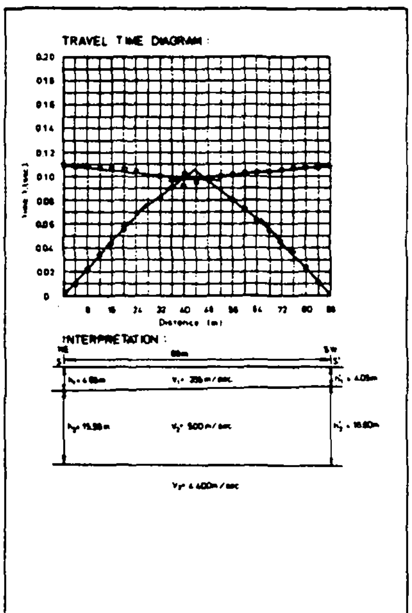
Profile no : 302
Latitude : 11°18.0'
Longitude : 34°50.5'
Village : Mbamba Bay
Date : 23.6.1981



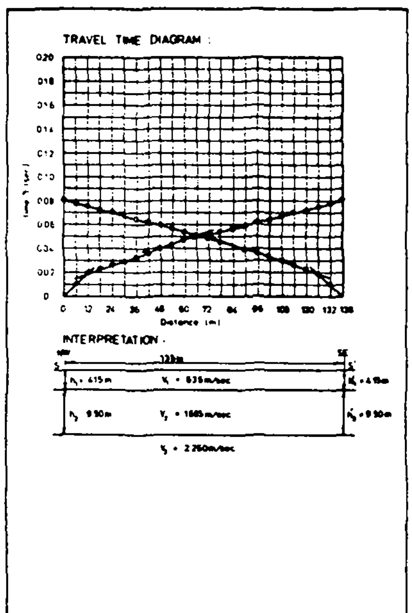
Profile no : 303
Latitude : 10°50.2'
Longitude : 35°00.7'
Village : Mbinga
Date : 23.6.1981



Profile no : 304
Latitude : 10°32.7'
Longitude : 34°57.3'
Village : Rvanda
Date : 24.6.1981



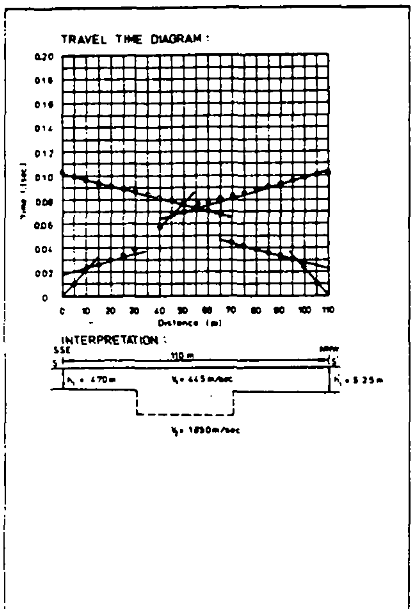
Profile no : 305
Latitude : 10°21.3'
Longitude : 35°39.7'
Village : 40 km from Songea
Date : 5.6.1981



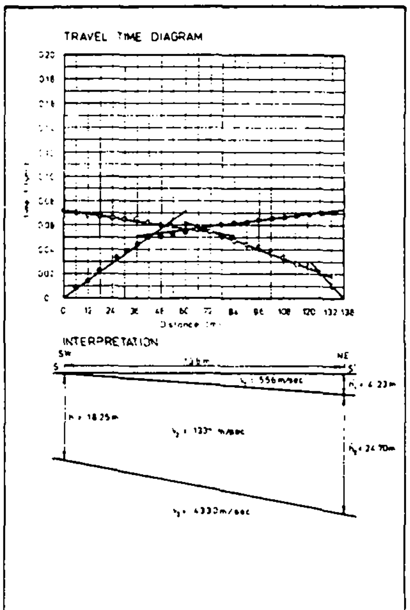
Profile no : 306
Latitude : 10°31.6'
Longitude : 36°12.1'
Village : 80 km from Songea
Date : 16.6.1981

SEISMIC PROFILES

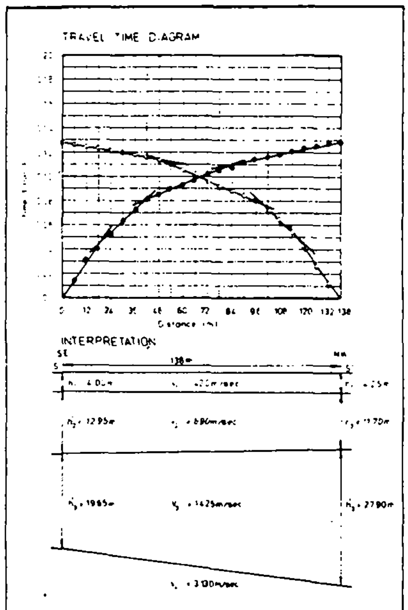
REGION: RUVUMA



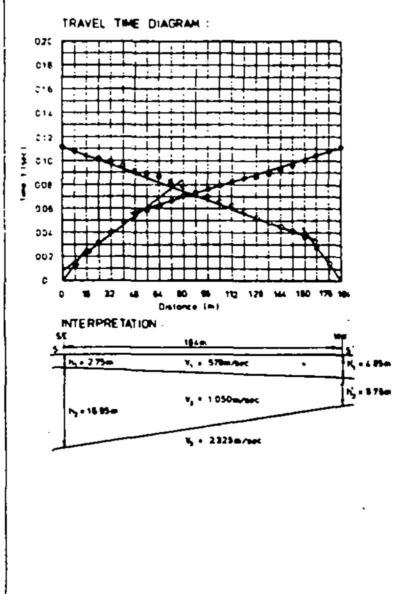
Profile no : 307
Latitude : $9^{\circ}56.5'$
Longitude : $35^{\circ}37.6'$
Village : 95 km from Songea
Date : 5.6.1981



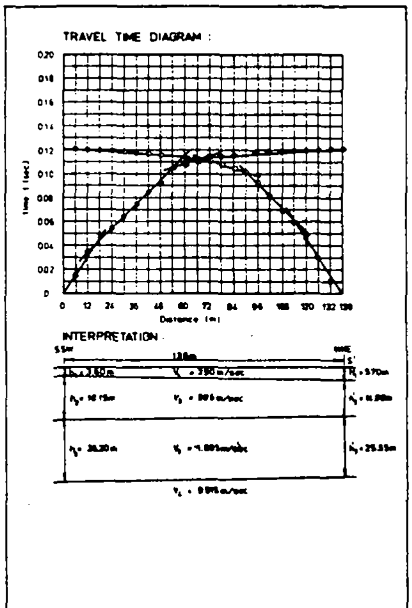
Profile no : 308
Latitude : $10^{\circ}406'$
Longitude : $35^{\circ}35.3'$
Village : Songea Airport
Date : 25.6.1981



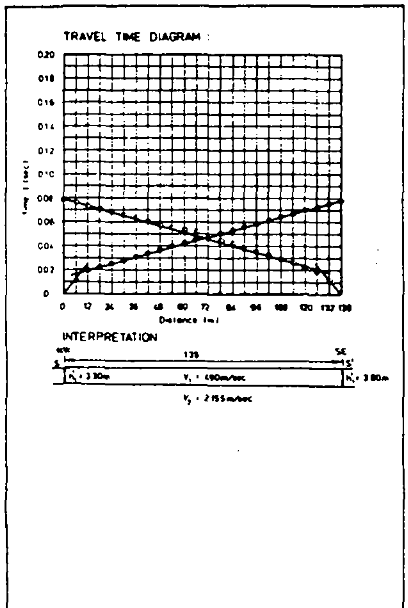
Profile no : 309
Latitude : $10^{\circ}19.0'$
Longitude : $36^{\circ}15.0'$
Village : Likuyu
Date : 19.6.1981



Profile no : 310
Latitude : $11^{\circ}03.8'$
Longitude : $36^{\circ}02.9'$
Village : Lukimwa
Date : 18.6.1981



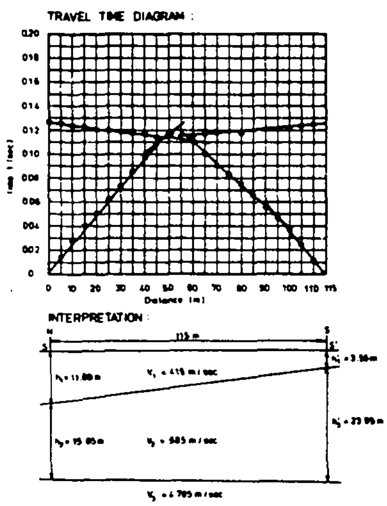
Profile no : 311
Latitude : $10^{\circ}17.8'$
Longitude : $36^{\circ}06.0'$
Village : Mgombasi
Date : 19.6.1981



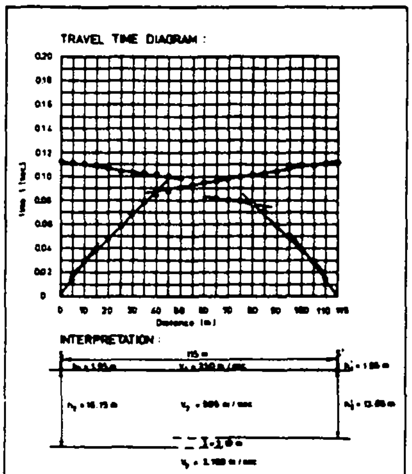
Profile no : 312
Latitude : $11^{\circ}31.8'$
Longitude : $35^{\circ}25.9'$
Village : Mitomoni
Date : 22.6.1981

SEISMIC PROFILES

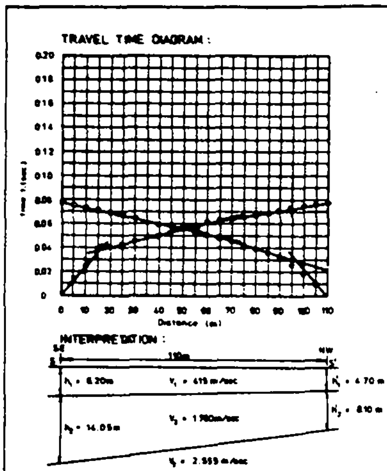
REGION: RUVUMA



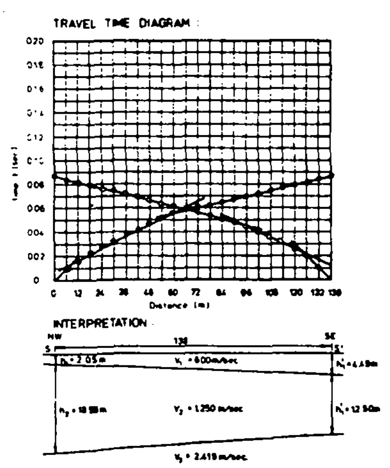
Profile no : 313
Latitude : $11^{\circ}05.7'$
Longitude : $35^{\circ}29.1'$
Village : Mkayukayu
Date : 22.6.1981



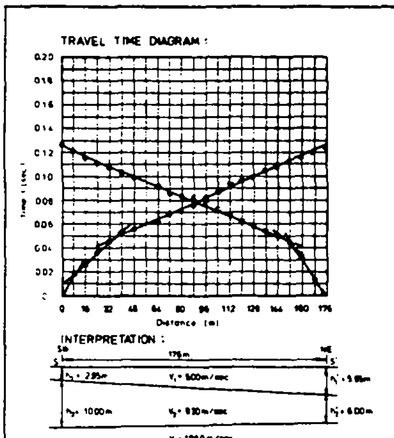
Profile no : 314
Latitude : $10^{\circ}43.0'$
Longitude : $36^{\circ}01.2'$
Village : Mkongo
Date : 18.6.1981



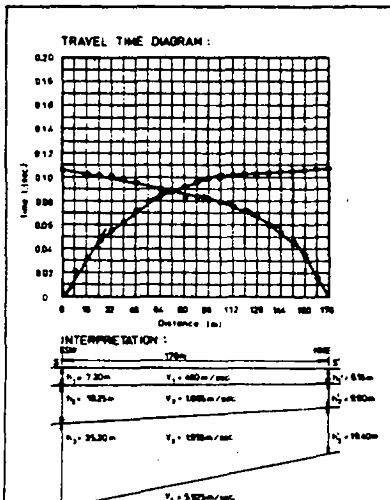
Profile no : 315
Latitude : $9^{\circ}54.4'$
Longitude : $35^{\circ}34.4'$
Village : Rutukira
Date : 5.6.1981



Profile no : 316
Latitude : $10^{\circ}45.2'$
Longitude : $36^{\circ}33.4'$
Village : 144 km from Songea
Date : 16.6.1981



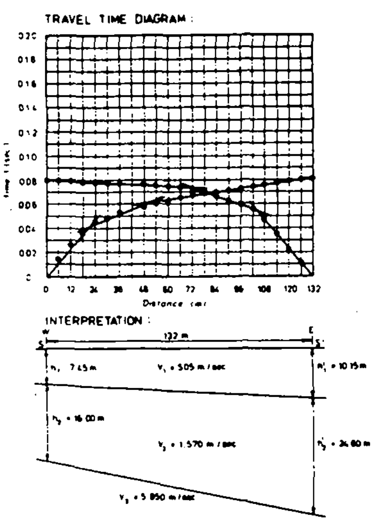
Profile no : 317
Latitude : $11^{\circ}05.9'$
Longitude : $37^{\circ}19.3'$
Village : Kitanda
Date : 12.6.1981



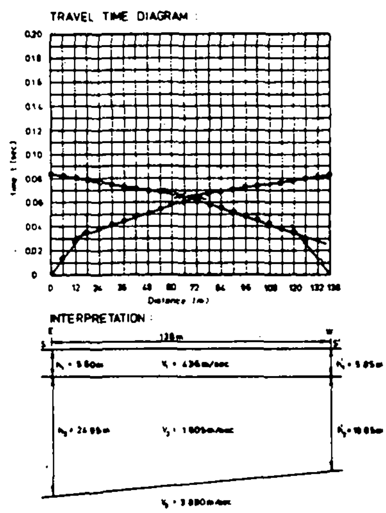
Profile no : 318
Latitude : $10^{\circ}49.8'$
Longitude : $37^{\circ}46.3'$
Village : Mindu
Date : 11.6.1981

SEISMIC PROFILES

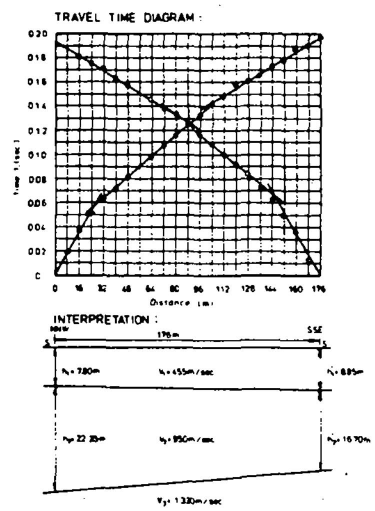
REGION: RUVUMA



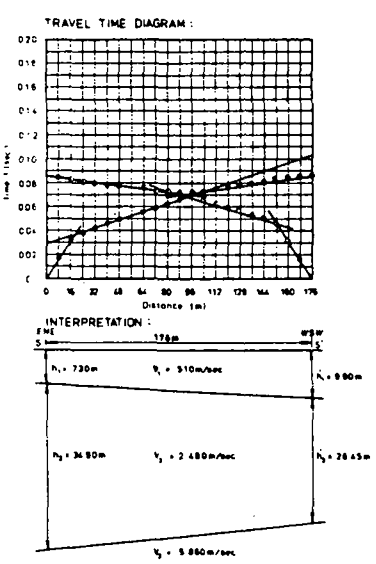
Profile no : 319
Latitude : 10°55.3'
Longitude : 37°56.1'
Village : Mkowela
Date : 11.6.1981



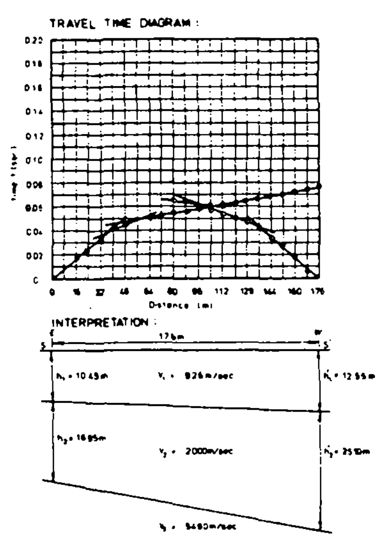
Profile no : 320
Latitude : 11°14.8'
Longitude : 37°33.4'
Village : Mtwaro
Date : 13.6.1981



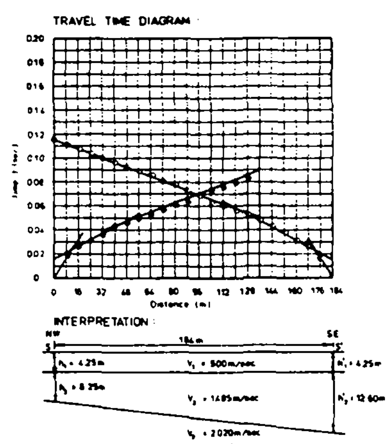
Profile no : 321
Latitude : 11°11.5'
Longitude : 37°16.0'
Village : Mtola
Date : 12.6.1981



Profile no : 322
Latitude : 10°52.4'
Longitude : 37°43.8'
Village : Mtonya/Paheani
Date : 11.6.1981



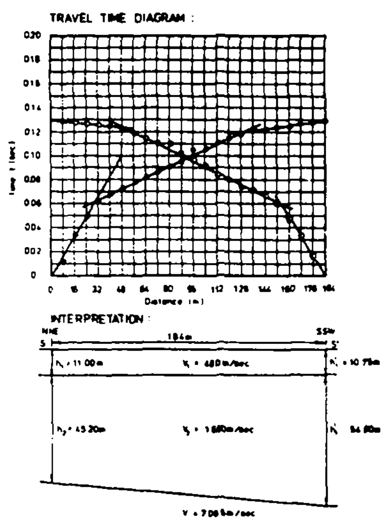
Profile no : 323
Latitude : 10°51.2'
Longitude : 37°31.5'
Village : Namakambale
Date : 10.6.1981



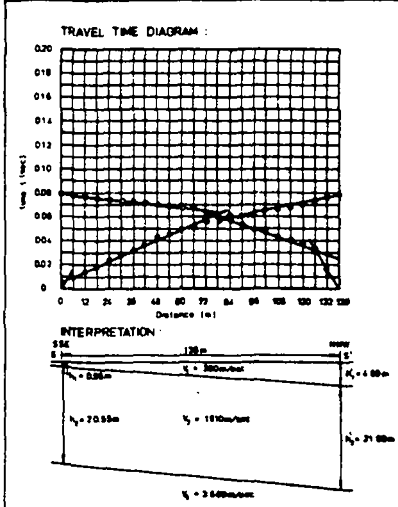
Profile no : 324
Latitude : 10°57.0'
Longitude : 37°14.4'
Village : Nandembo
Date : 15.6.1981

S E I S M I C   P R O F I L E S

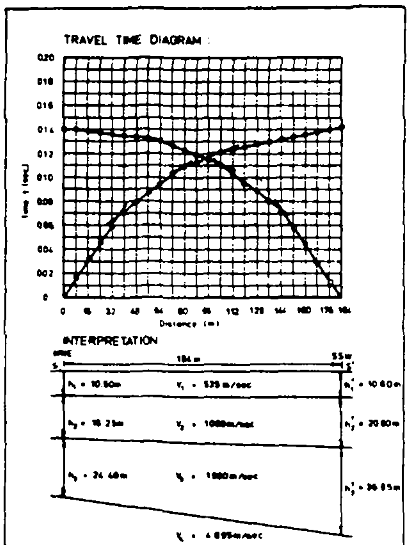
REGION: RUVUMA



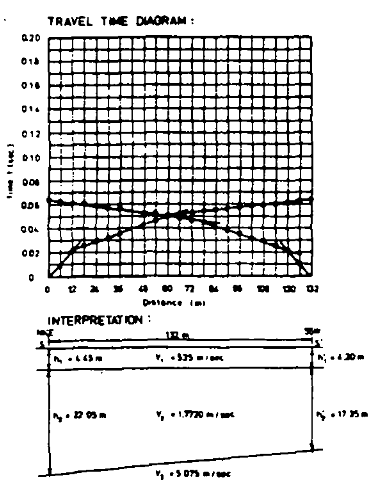
Profile no : 325
Latitude : 10°45.4'
Longitude : 36°57.1'
Village : Matemango
Date : 15.6.1981



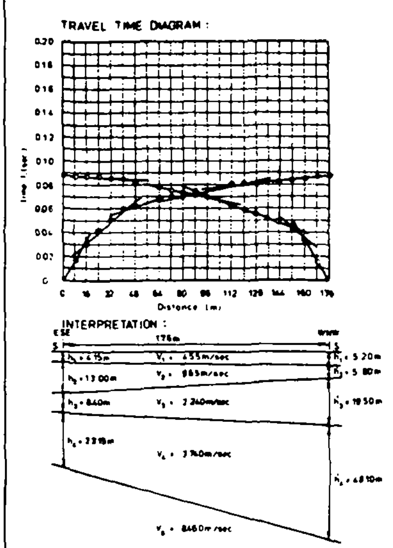
Profile no : 326
Latitude : 10°42.0'
Longitude : 36°54.5'
Village : Namakungwa
Date : 15.6.1981



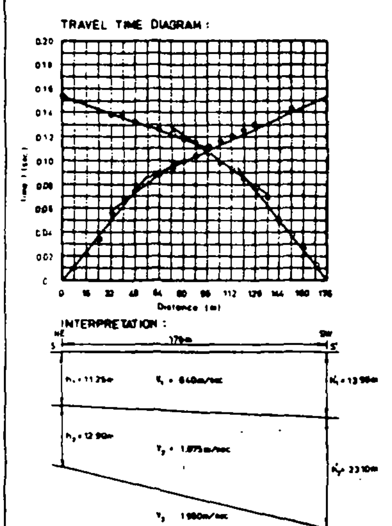
Profile no : 327
Latitude : 11°08.3'
Longitude : 37°27.0'
Village : Namasakata
Date : 13.6.1981



Profile no : 328
Latitude : 10°23.5'
Longitude : 37°21.5'
Village : Ngwanga
Date : 12.6.1981



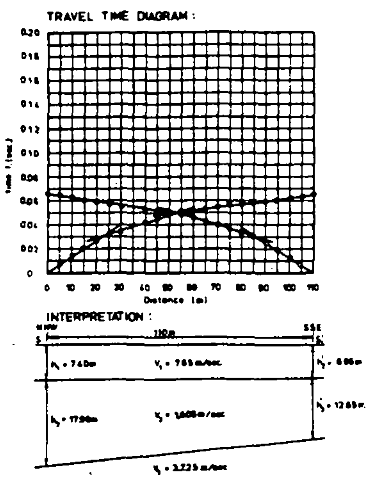
Profile no : 329
Latitude : 10°52.0'
Longitude : 37°38.5'
Village : Puchapucha
Date : 10.6.1981



Profile no : 330
Latitude : 10°55.4'
Longitude : 37°24.2'
Village : Nalywale/Sagula
Date : 10.6.1981

SEISMIC PROFILES

REGION: RUVUMA



Profile no : 331

Latitude : 10°47.4'

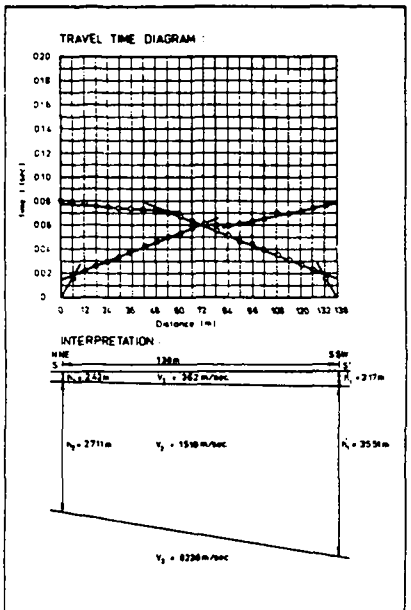
Longitude : 37°58.1'

Village : Tinginya

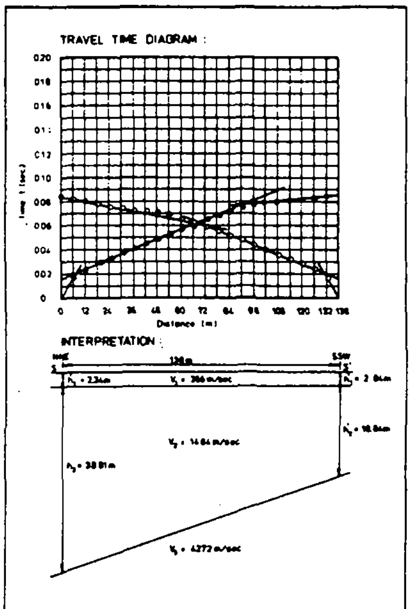
Date : 11.6.1981

MBEYA

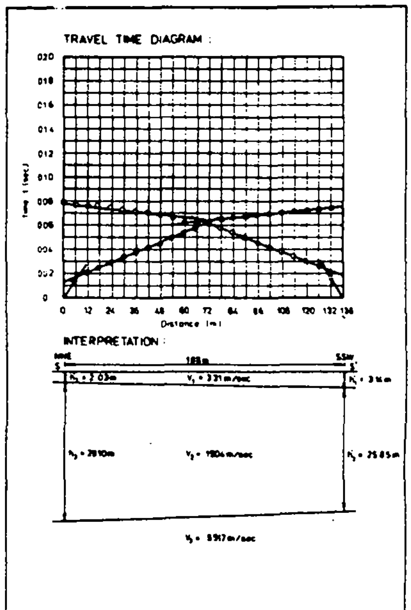
SEISMIC PROFILES	REGION: MBEYA



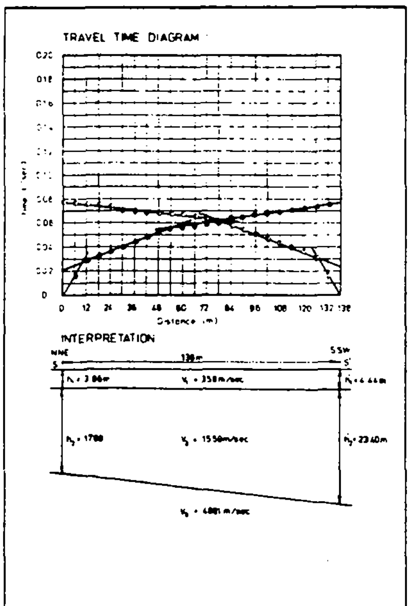
Profile no : 101
Latitude : 9°05.4'
Longitude : 32°56.3'
Village : Vwawa
Date : 24.4.1981



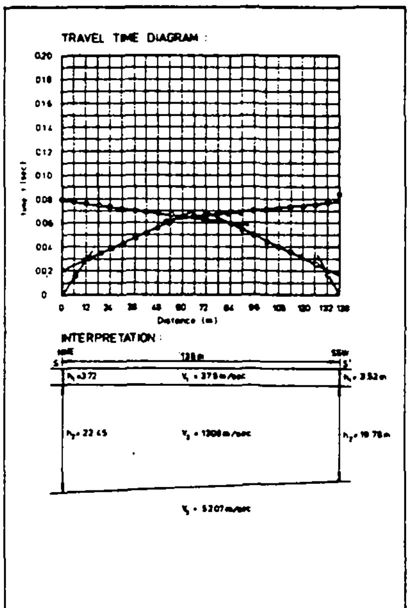
Profile no : 102
Latitude : 9°05.4'
Longitude : 32°56.3'
Village : Vwawa
Date : 24.4.1981



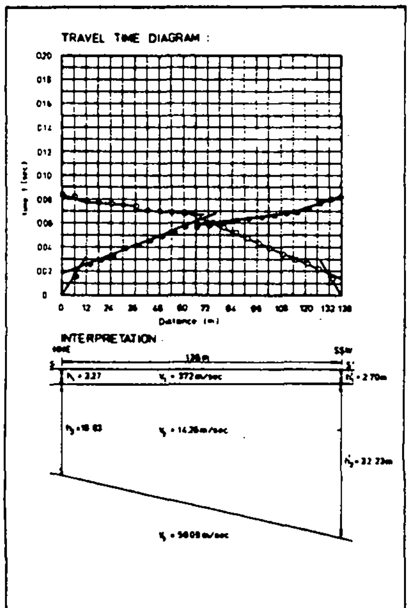
Profile no : 103
Latitude : 9°05.4'
Longitude : 32°56.3'
Village : Vwawa
Date : 24.4.1981



Profile no : 104
Latitude : 9°05.4'
Longitude : 32°56.3'
Village : Vwawa
Date : 24.4.1981



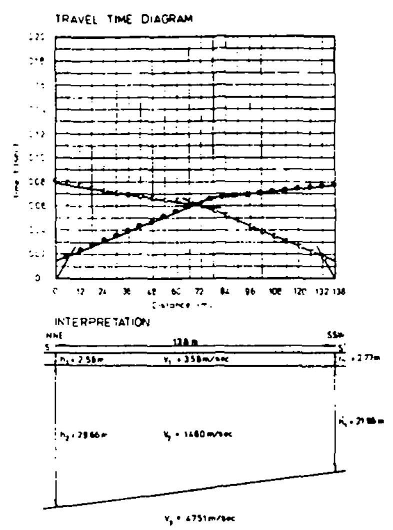
Profile no : 105
Latitude : 9°05.4'
Longitude : 32°56.3'
Village : Vwawa
Date : 24.4.1981



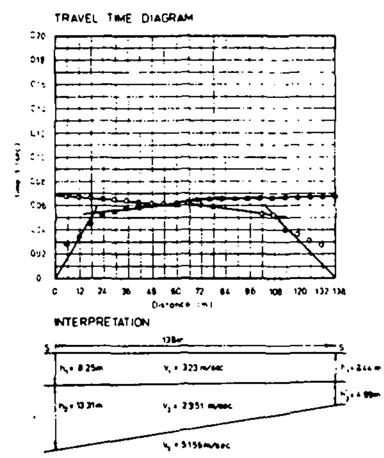
Profile no : 106
Latitude : 9°05.4'
Longitude : 32°56.3'
Village : Vwawa
Date : 23.4.1981

SEISMIC PROFILES

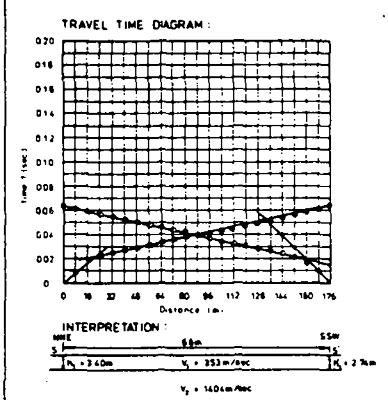
REGION: MBEYA



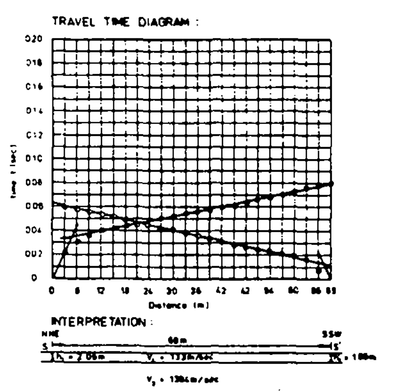
Profile no : 107
Latitude : 9°05.4'
Longitude : 32°56.3'
Village : Vwawa
Date : 16.4.1981



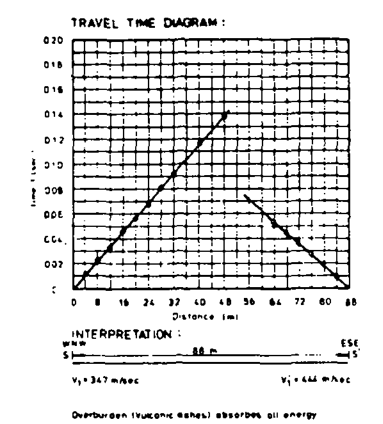
Profile no : 108
Latitude : 9°21.0'
Longitude : 32°59.1'
Village : Mbebe
Date : 19.11.1980



Profile no : 109
Latitude : 9°05.4'
Longitude : 32°56.3'
Village : Vwawa
Date : 10.04.1981

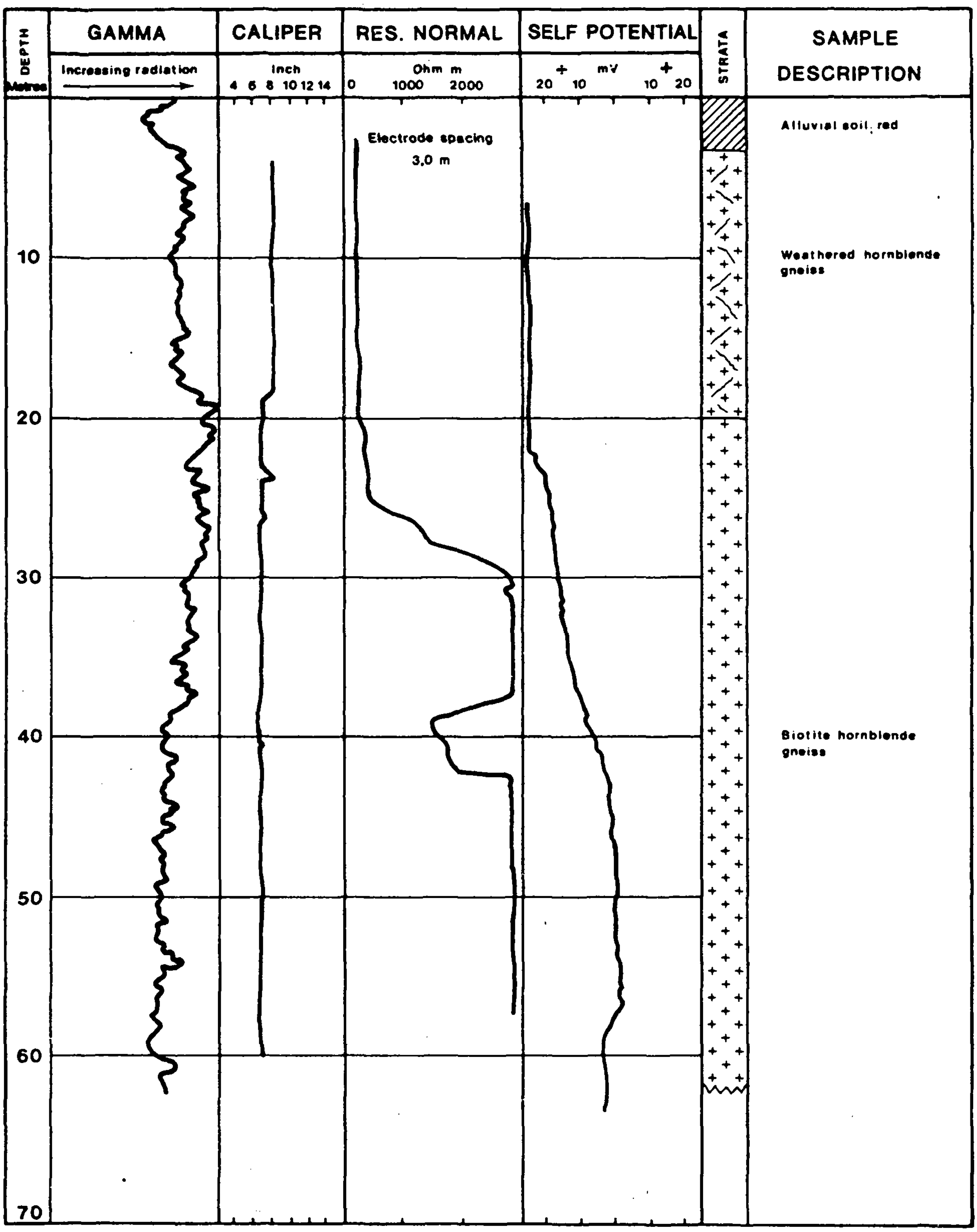


Profile no : 110
Latitude : 9°05.4'
Longitude : 32°56.3'
Village : Vwawa
Date : 10.04.1981

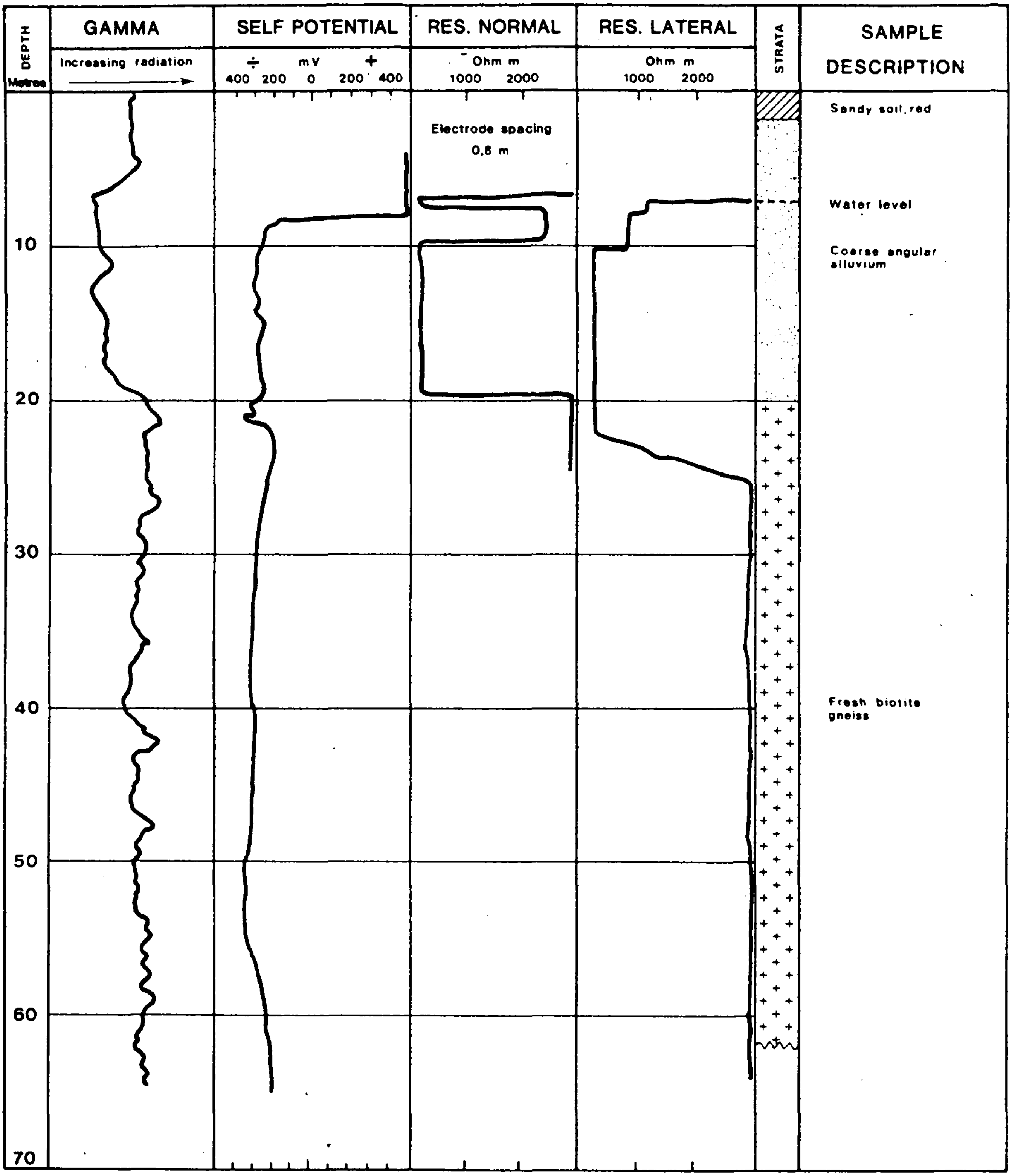


Profile no : 111
Latitude : 9°02.4'
Longitude : 33°36.0'
Village : Idweli
Date : 10.04.1981

IRINGA

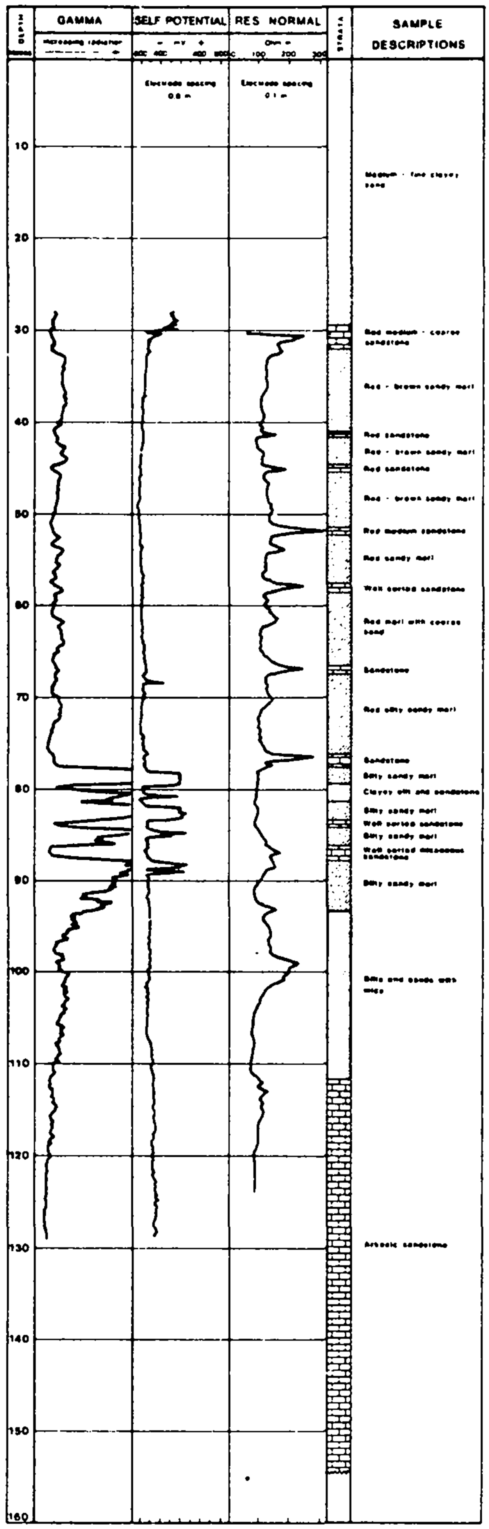


Region : Iringa
District : Iringa
Village : Nzihi
BH NO. : 3/81
CCKK No. : ID 2



Region : Iringa
District : Iringa
Village : Nzihi
BH No. : 4/81
CCKK No. : ID 3

RUVUMA



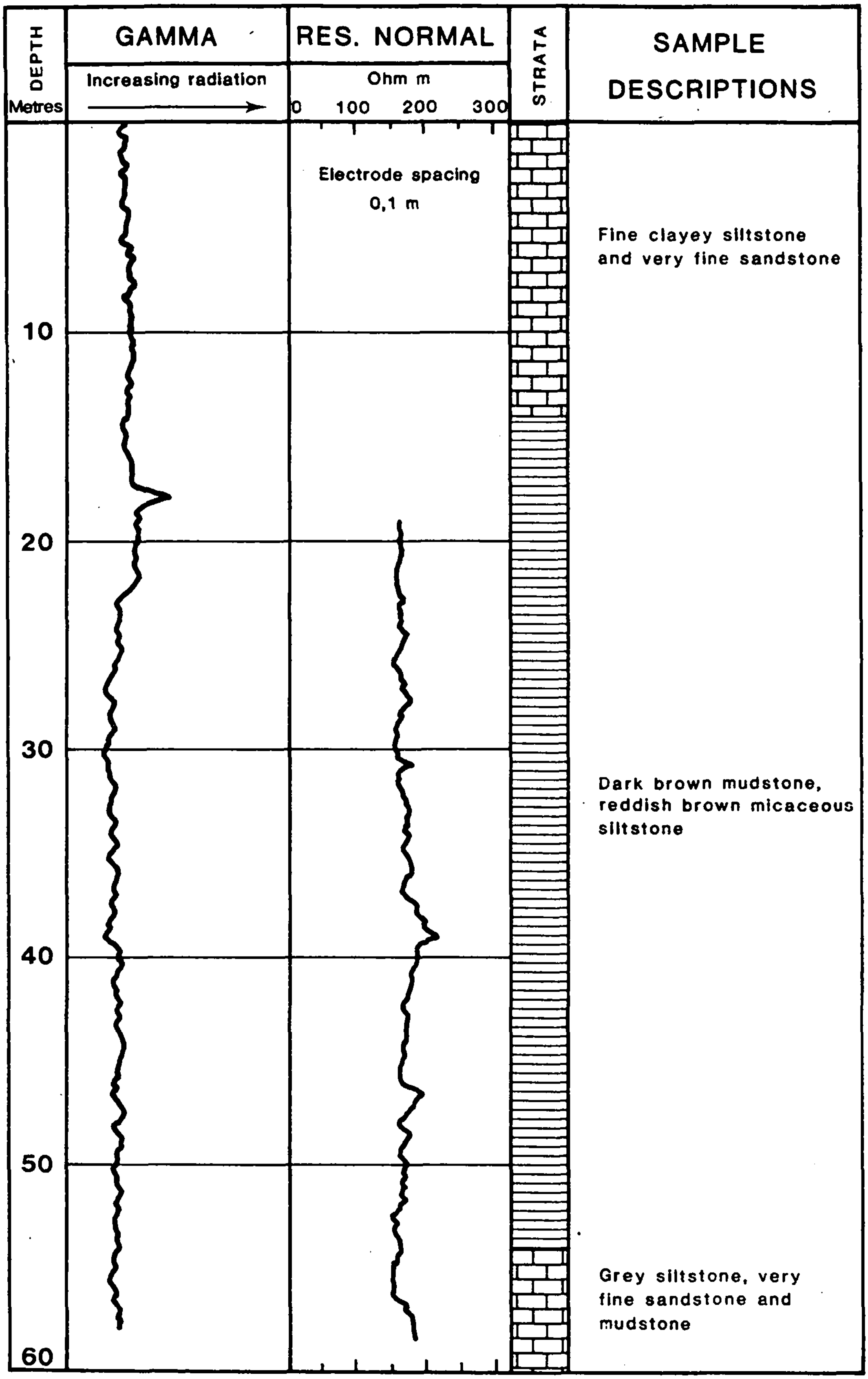
Region : Ruvuma

District : Songea

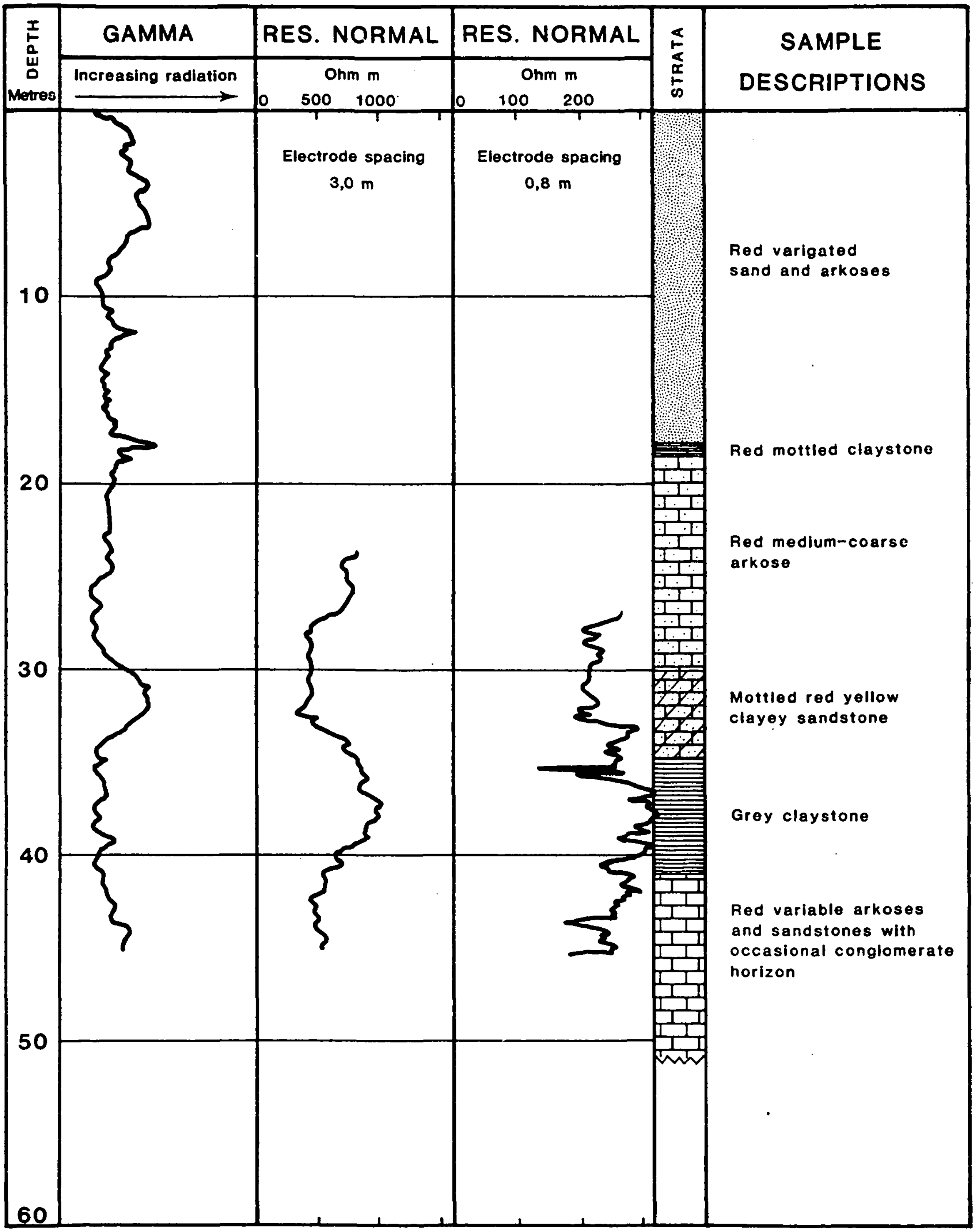
Village : Hanga River

BH No. : 253/81

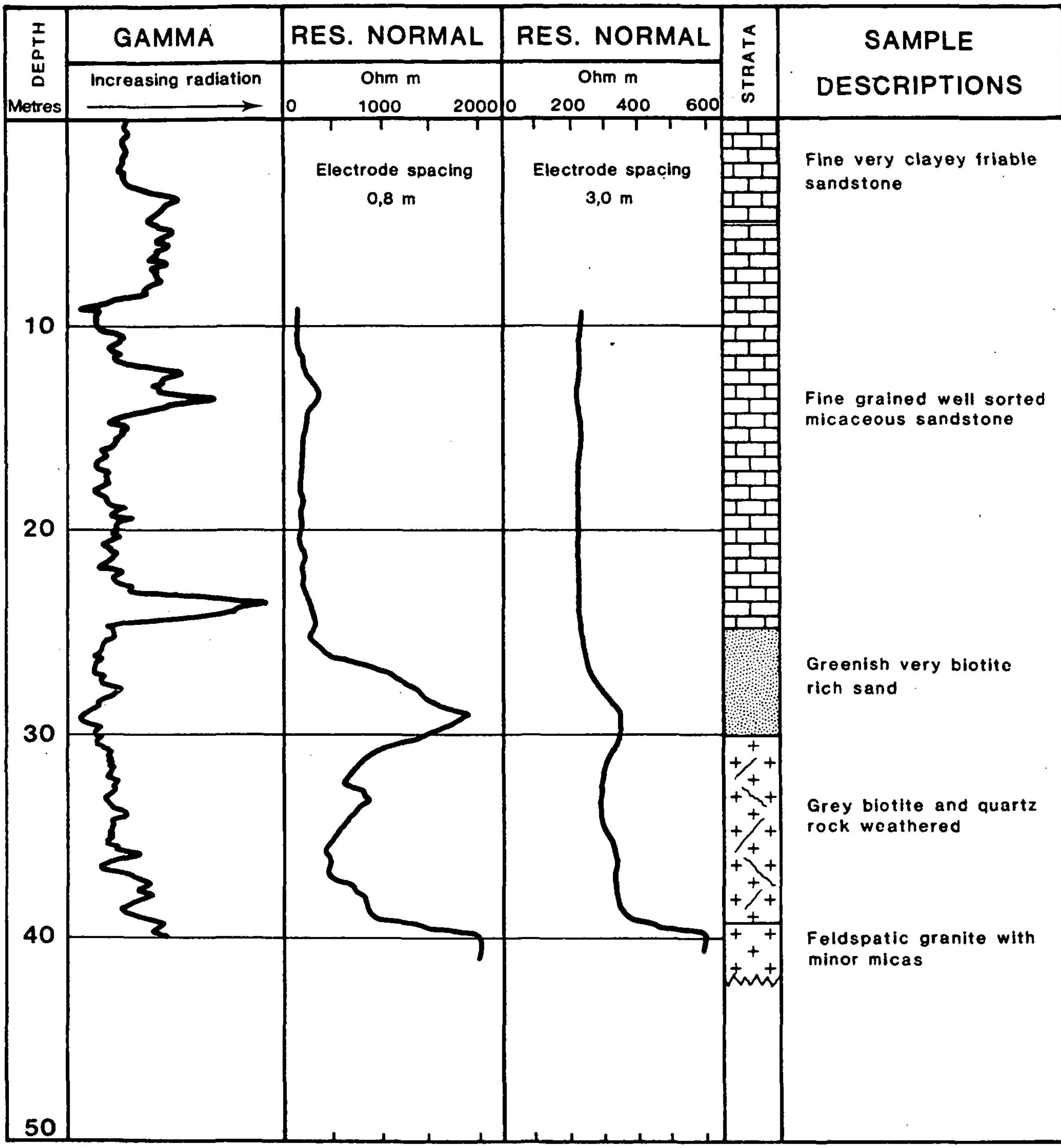
CCKK No. : RD 1



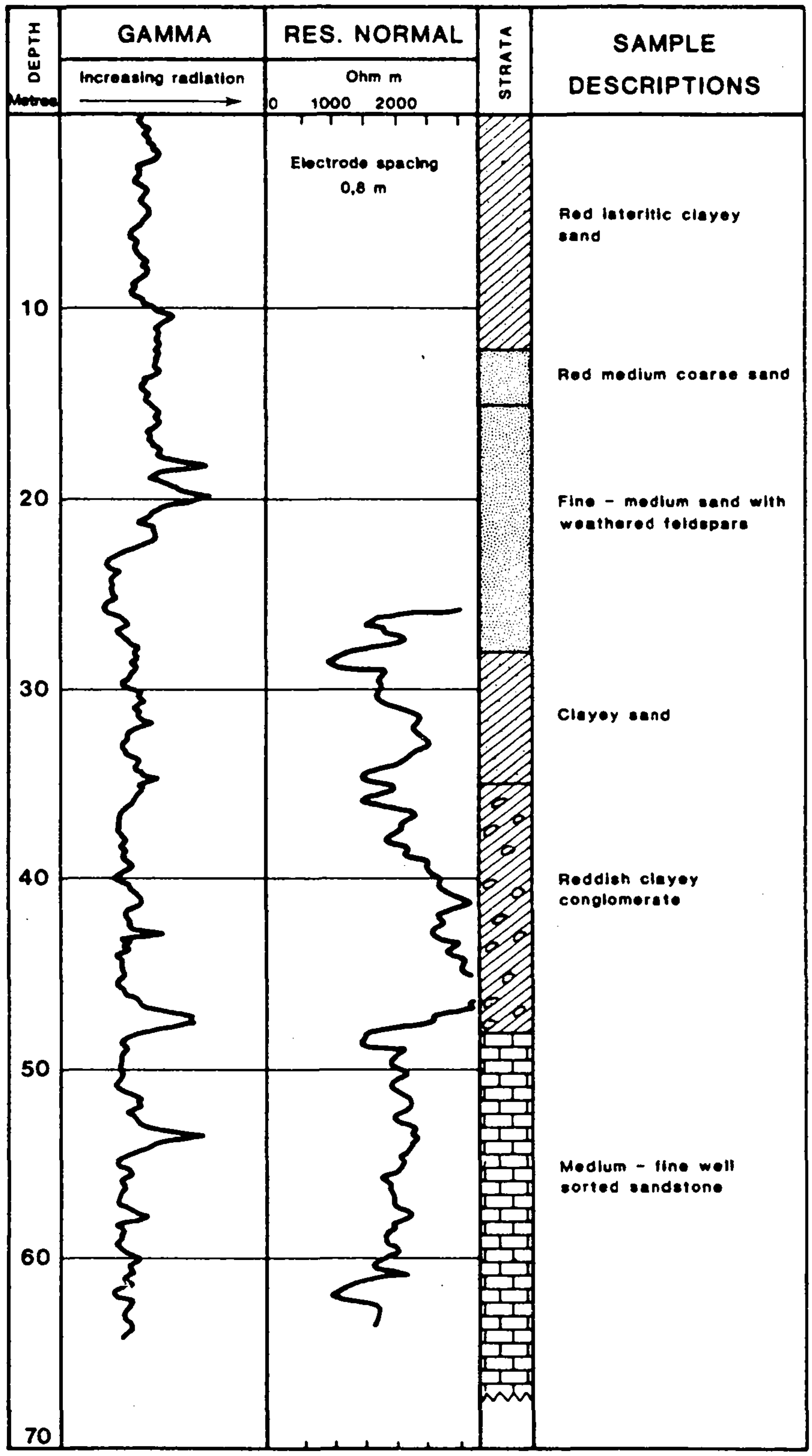
Region	:	Ruvuma
District	:	Songea
Village	:	Gumbiro
BH No.	:	254/81
CCKK No.	:	RD 2



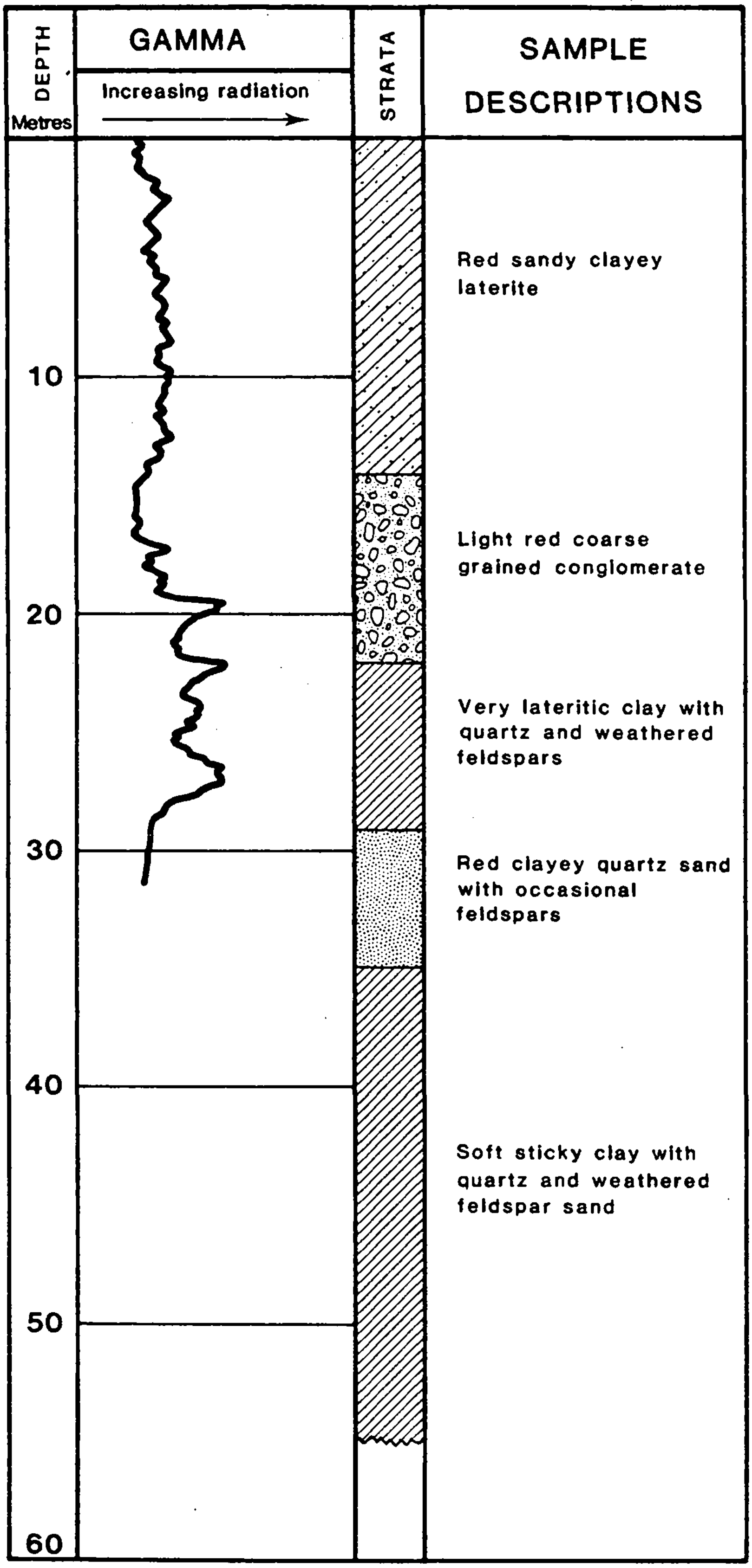
Region	:	Ruvuma
District	:	Songea
Village	:	Mtukano
BH No.	:	255/81
CCKK No.	:	RD 3



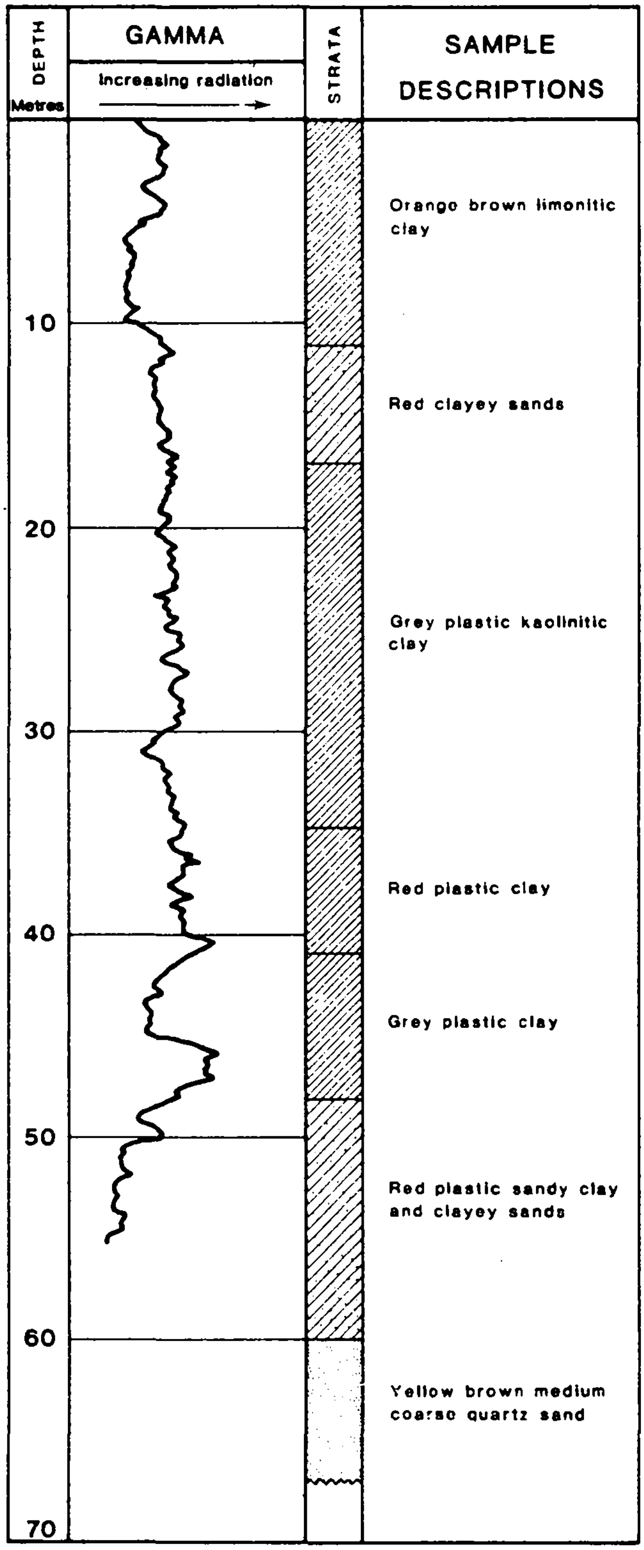
Region	:	Ruvuma
District	:	Tunduru
Village	:	Ndenyende
BH No.	:	256/81
CCKK No.	:	RD 4



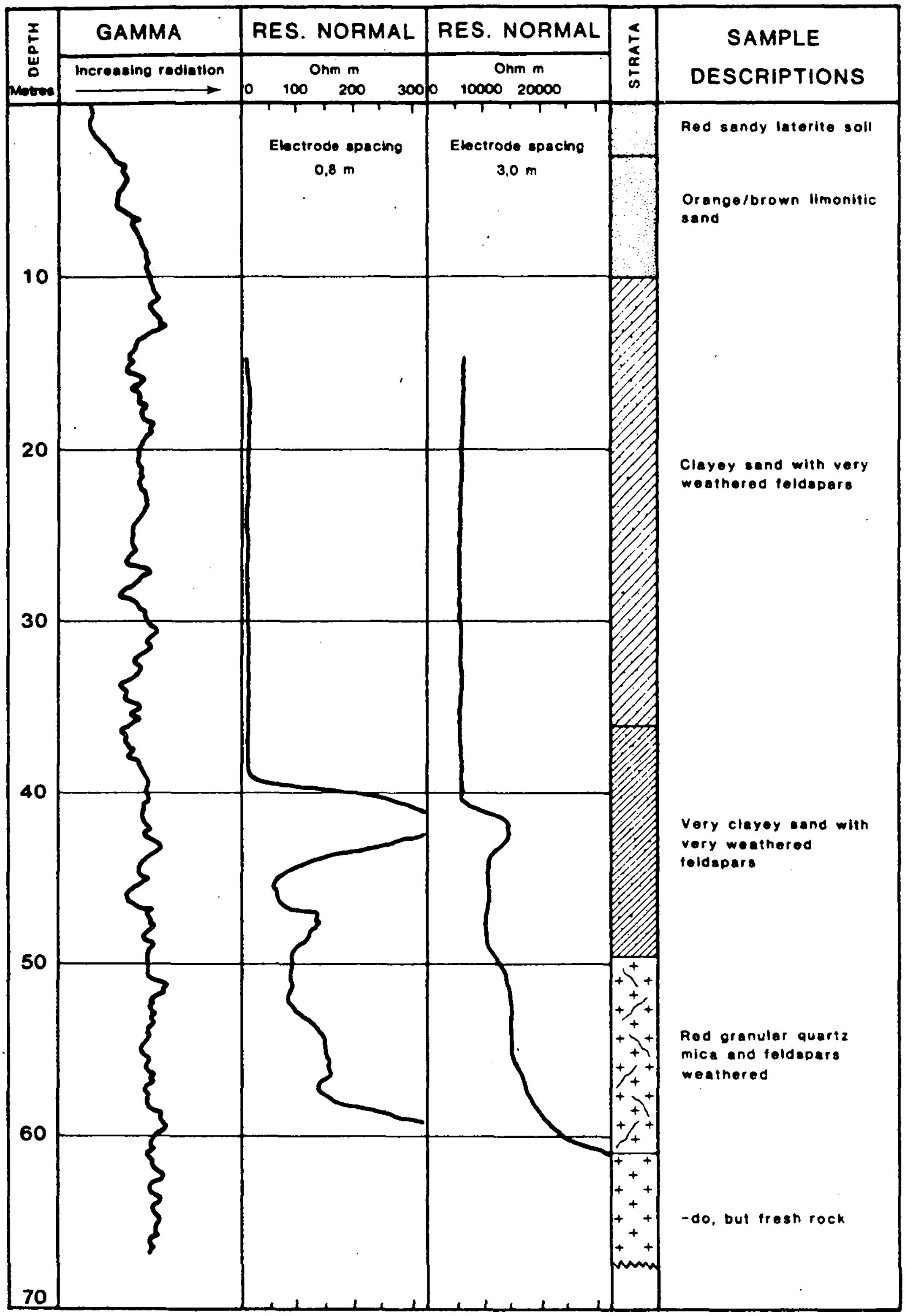
Region	:	Ruvuma
District	:	Tunduru
Village	:	Nandembo
BH No.	:	258/81
CCKK No.	:	RD 6



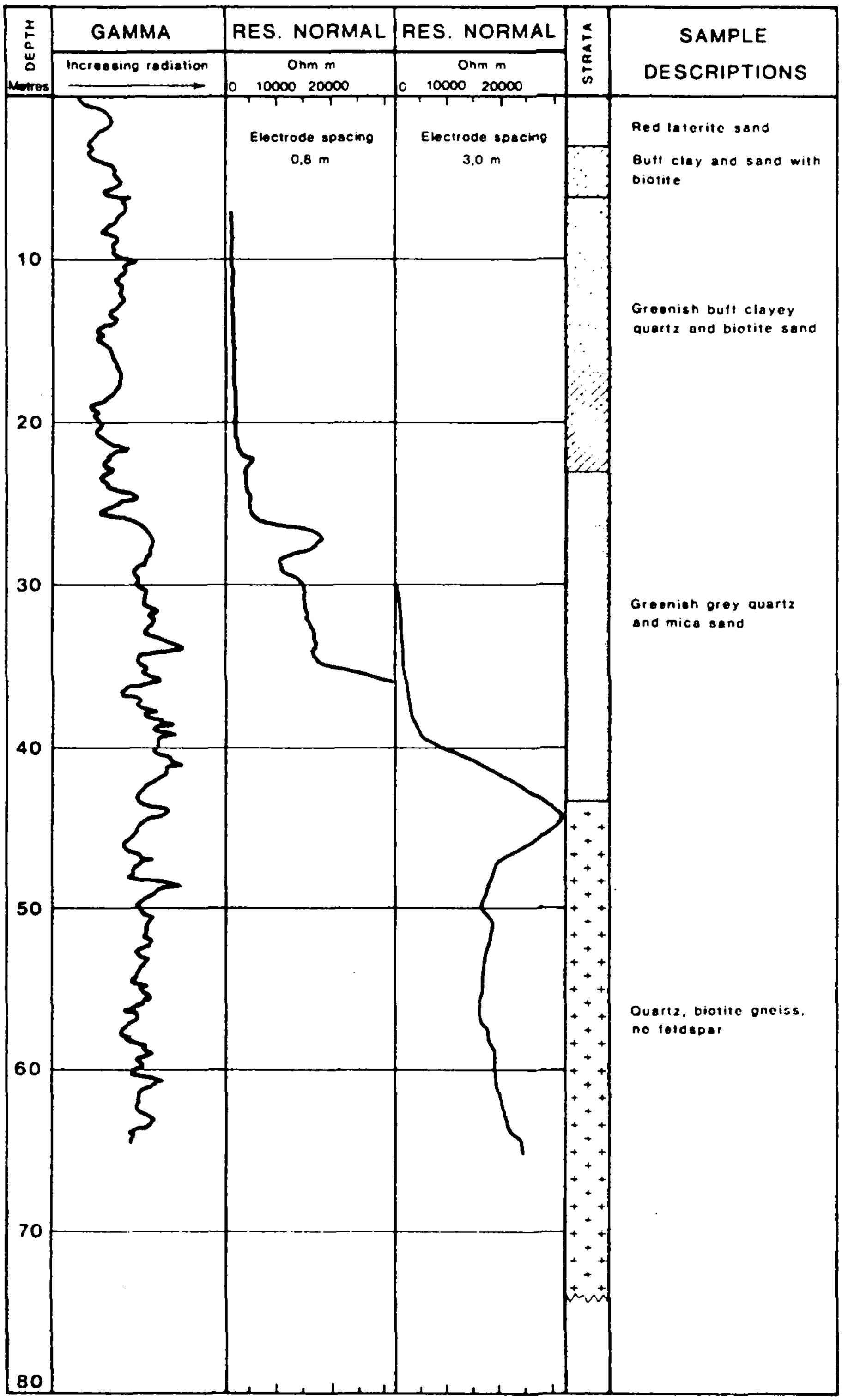
Region	:	Ruvuma
District	:	Tunduru
Village	:	Sisikwasisi
BH No.	:	260/81
CCKK No.	:	RD 8



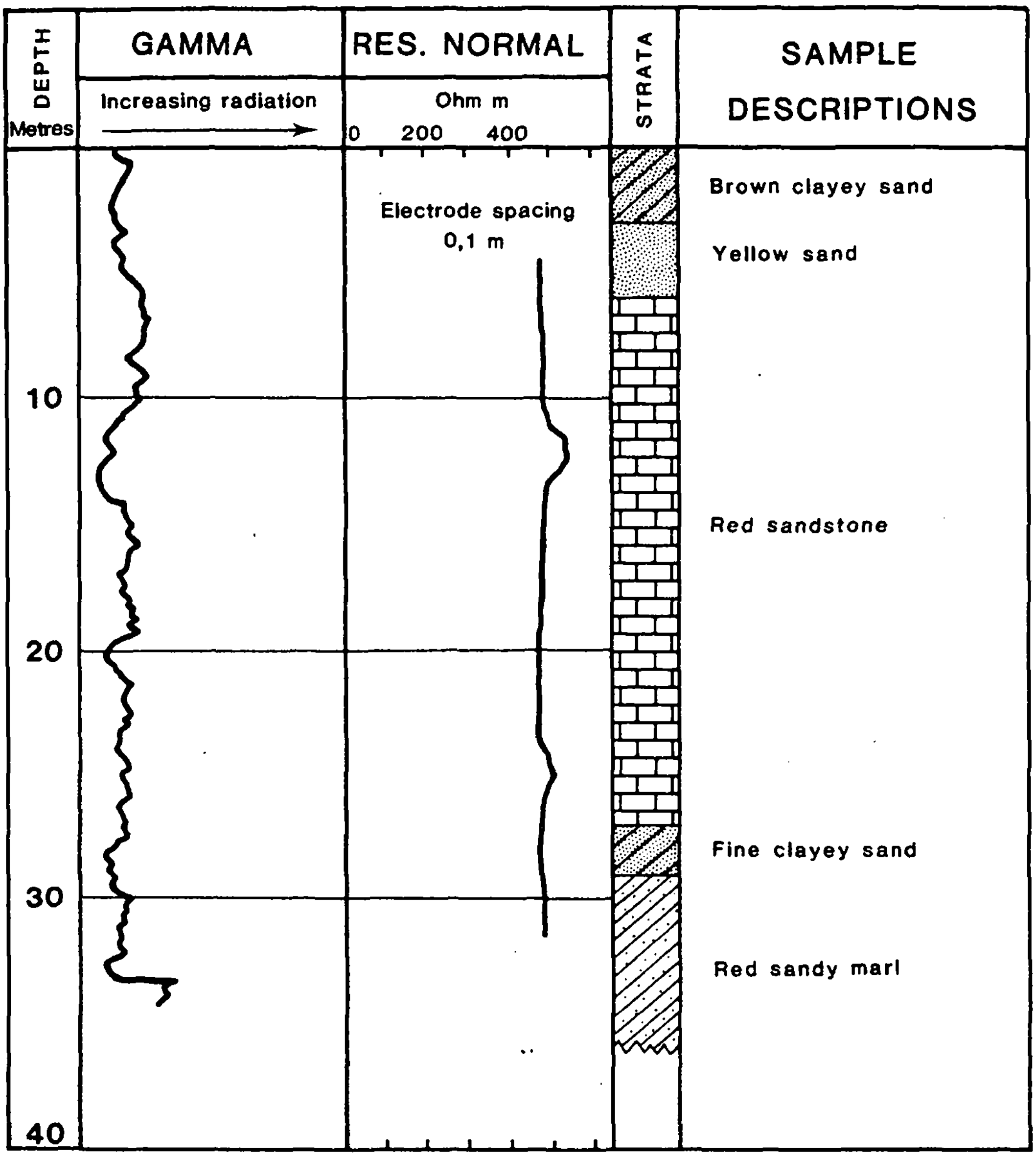
Region	:	Ruvuma
District	:	Tunduru
Village	:	Sisikwasisi
BH No.	:	261/81
CCKK No.	:	RD 9



Region	:	Ruvuma
District	:	Tunduru
Village	:	Namiungo
BH No.	:	262/81
CCKK No.	:	RD 10

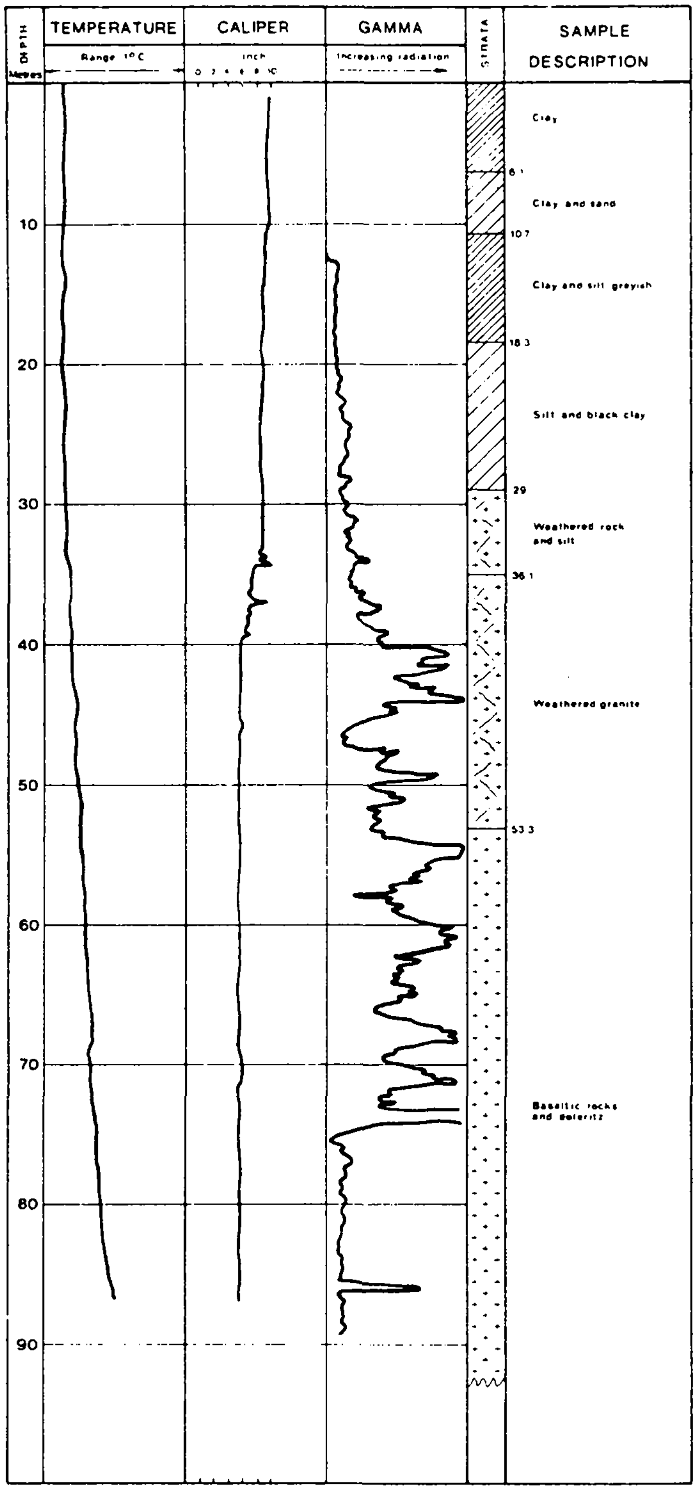


Region : Ruvuma
District : Tunduru
Village : Majimaji
BH No. : 263/81
CCKK No. : RD 4



Region	:	Ruvuma
District	:	Songea
Village	:	Hanga River
BH No.	:	269/81
CCKK No.	:	RS 6

MBEYA



Region : Mbeya

District : Mbozi

Village : Mbozi Mission

BH No. : 25/81

CCKK No. : -

Appendix 4

Springs.

IRINGA

IRINGA REGION

VILLAGE	DISTRICT	REG. NO.	DATE OF VISIT	YIELD (1/s)	COMMENTS
Bulongwa	Makete	495	15.06.81	0.4	
Chamndindi	Iringa	43	07.08.80	0.0	
Ibaga	Iringa	304	23.06.81	NA	
Ibumila	Iringa	527	27.02.81	0.1	
Idegenda	Iringa	222	21.07.80	2.5	
Idende	Makete	595	16.06.81	NA	
Idihani	Njombe	575	06.11.80	0.1	
Idunda	Iringa	203	25.09.80	0.5	
Idundilaga	Njombe	362	04.09.80	0.5	
Igagala	Njombe	54	09.09.80	4.0	
Igeleke	Mufindi	431	15.10.80	0.2	
Igolwa	Makete	196	10.06.81	0.4	
Igoma	Njombe	313	10.09.80	0.5	
Igombavanu	Mufindi	407	12.11.80	2.0	
Igumbilo	Iringa	322	11.06.81	2.0	
Ihalula	Njombe	281	10.09.80	0.3	
Ihanga	Makete	324	09.06.81	1.0	
Ihawaga	Mufindi	406	18.03.81	0.5	
Ihimbo	Iringa	227	30.07.80	1.0	
Ikuna	Njombe	532	09.09.80	0.4	
Ikuvilo	Iringa	260	06.08.80	10.0	
Ikuwo	Makete	334	13.08.81	0.0	
Ilininda	Ludewa	104	17.01.81	0.1	
Image	Njombe	67	26.02.81	0.5	
Imalilo	Njombe	357	24.06.81	0.0	
Imalinyi	Njombe	201	05.10.81	1.0	
Ipalamwa	Iringa	166	30.06.80	1.4	
Ipelele	Makete	198	05.06.81	NA	
Ipepo	Makete	594	10.06.81	1.0	
Ipilimo	Mufindi	122	15.04.81	0.5	
Isupilo	Iringa	23	18.07.80	83.0	
Itambo	Njombe	63	24.02.81	0.2	
Itandula	Njombe	399	03.02.81	0.1	
Itulike	Njombe	190	25.09.80	0.5	
Itundu	Ludewa	83	15.01.81	0.1	
Itunduma	Njombe	377	03.04.81	0.3	

IRINGA REGION

VILLAGE	DISTRICT	REG. NO.	DATE OF VISIT	YIELD (l/s)	COMMENTS
Iwungilo	Njombe	315	04.11.80	0.2	
Iyoka	Makete	312	19.06.81	0.2	
Kidegembye	Njombe	68	08.09.80	0.5	
Kidope	Makete	343	10.06.81	NA	
Kigala	Makete	336	14.08.81	NA	
Kigulu	Makete	570	09.07.81	7.0	
Kihesa/Mgagao	Iringa	180	24.07.80	2.0	4 springs
Kiyombo	Njombe	318	11.06.81	0.1	
Kikombwe	Iringa	29	05.08.80	2.5	
Kikondo	Makete	592	04.06.81	4.0	
Kilanji	Makete	591	18.06.81	0.1	
Kiliminzowo	Mufindi	446	18.03.81	0.1	
Kilolo	Iringa	5	30.07.80	1.0	
Kingole	Ludewa	227	20.11.80	0.1	3 springs
Kitula	Makete	585	18.06.81	0.1	
Kitumbuka	Iringa	485	26.08.80	0.3	
Lima	Njombe	808	26.02.81	0.2	
Limage	Njombe	271	10.09.80	0.5	
Lole	Njombe	588	09.09.80	0.5	
Ludende	Ludewa	91	14.01.81	0.1	
Ludilu	Mufindi	323	12.06.81	40.0	
Lugavo	Makete	556	17.06.81	0.2	
Lugenge	Njombe	367	09.09.80	10.0	2 springs
Lupande	Ludewa	93	04.12.80	0.4	
Lupombwe	Makete	597	12.06.81	0.3	
Lusitu	Njombe	366	06.11.80	5.0	
Luvulunge	Makete	598	11.03.81	0.5	
Madege	Iringa	165	25.07.80	1.0	
Madihani	Makete	310	18.08.81	NA	
Madilu	Ludewa	96	17.01.81	0.1	
Madunda	Njombe	94	04.12.80	0.3	
Mafinga	Njombe	578	23.06.81	0.0	
Magunguli	Mufindi	435	08.04.81	1.0	
Maholongwa	Ludewa	107	14.01.81	0.1	
Mahongole	Njombe	524	16.03.81	0.2	
Mahulu	Makete	311	17.08.81	0.2	

IRINGA REGION

VILLAGE	DISTRICT	REG. NO.	DATE OF VISIT	YIELD (l/s)	COMMENTS
Makangalawe	Makete	300	24.06.81	4.0	
Makewe	Makete	569	05.06.81	0.5	
Makoga	Njombe	52	24.06.81	0.5	
Makwalanga	Makete	560	10.06.81	NA	
Malanduku	Makete	596	11.06.81	NA	
Malembuli	Makete	565	24.06.81	1.0	
Maleutsi	Makete	298	24.06.81	0.1	
Mapanda	Mufindi	463	15.12.80	0.1	
Mapogoro	Iringa	87	15.01.81	0.1	
Masege	Iringa	810	25.07.80	2.0	
Masisiwe	Iringa	325	10.06.81	0.9	
Matenga	Makete	337	14.08.81	NA	
Matinganjola	Njombe	295	08.09.80	0.5	
matola	Njombe	288	23.08.80	0.5	
Mavala	Ludewa	92	15.01.81	0.1	
Mawambala	Iringa	32	25.07.80	NA	2 springs
Mbalatse	Makete	319	12.06.81	0.1	
Mbanga	Makete	559	05.06.81	NA	
Mbega	Njombe	545	06.11.80	0.2	
Mbela	Makete	330	11.08.81	2.5	
Mdasi	Njombe	577	25.06.81	0.0	
Milo	Ludewa	84	14.01.81	0.5	
Misiwa	Makete	345	05.06.81	NA	
Miva	Njombe	363	06.11.80	0.2	
Mjimwema	Njombe	342	05.09.80	NA	
Mlevela	Njombe	533	26.09.80	0.5	
Mlondwe	Makete	329	10.08.81	5.0	
Mlowa	Njombe	521	17.03.81	0.5	
Moronga	Njombe	200	23.06.81	1.0	
Mtulingala	Njombe	520	17.03.81	0.2	
Muwimbi	Iringa	22	21.07.80	2.6	
Mwakauta	Makete	344	09.06.81	NA	
Ndapo	Makete	567	19.06.81	0.0	
Ndulamo	Makete	307	11.03.81	0.5	
Ng'anda	Njombe	403	24.06.81	0.0	
Ng'ang'ange	Iringa	259	10.08.80	167.0	

IRINGA REGION

VILLAGE	DISTRICT	REG. NO.	DATE OF VISIT	YIELD (l/s)	COMMENTS
Ng'ingula	Iringa	14	08.07.80	NA	
Ngoje	Makete	571	20.06.81	0.0	
Nhungu	Makete	326	19.06.81	0.02	
Ninga	Njombe	528	09.09.80	0.5	
Njoomlole	Njombe	498	11.09.80	0.3	
Nkenja	Makete	561	04.06.81	NA	
Nundu	Njombe	479	03.09.80	0.5	
Nyamande	Njombe	478	17.03.81	0.2	
Nyave	Njombe	66	25.02.81	0.2	
Nyigo	Mufindi	131	18.03.81	0.5	
Nyombo	Njombe	474	06.09.80	0.5	
Nzivi	Mufindi	422	29.09.80	10.0	
Peluhanda	Njombe	481	06.09.80	0.5	
Tambalang'ombe	Mufindi	418	12.11.80	0.3	
Ubiluko	Makete	346	10.06.81	15.0	
Udumuka	Iringa	136	14.04.81	0.5	
Ugesa	Mufindi	134	13.10.80	0.1	
Uhekule	Njombe	76	24.06.81	0.0	
Ujindile	Njombe	350	25.06.81	0.0	
Ujuni	Makete	335	04.06.81	1.0	
Ukemele	Mufindi	455	17.03.81	0.5	
Ukwama	Makete	195	09.06.81	0.1	
Ukwega	Iringa	486	01.07.80	0.4	
Ulembwe	Njombe	471	08.09.80	0.3	
Uliwa	Njombe	314	04.11.80	1.0	
Unyang'oro	Makete	568	09.06.81	NA	
Unyangala	Makete	599	17.08.81	1.4	
Usalule	Njombe	555	06.08.80	NA	
Usililo	Makete	494	16.06.81	0.4	
Usungilo	Makete	513	25.06.81	0.2	
Utalingoro	Njombe	554	08.09.80	0.3	
Utanziwa	Makete	586	17.06.81	0.4	
Utelewe	Njombe	475	24.06.81	0.0	
Utengule	Iringa	49	29.07.80	0.3	
Utengule	Njombe	309	18.06.81	0.5	

IRINGA REGION

VILLAGE	DISTRICT	REG. NO.	DATE OF VISIT	YIELD (l/s)	COMMENTS
Utilili	Ludewa	278	16.01.81	0.5	
Utweve	Makete	581	09.06.81	3.0	
Vikula	Mufindi	505	14.10.80	0.2	
Wami/Mbalwe	Mufindi	453	15.10.80	0.2	
Wikichi	Njombe	53	04.09.80	NA	
Winome	Iringa	536	29.07.80	1.5	

RUVUMA

RUVUMA REGION

VILLAGE	DISTRICT	REG. NO.	DATE OF VISIT	YIELD (l/s)	COMMENTS
Buruma	Mbinga	212	10.06.81	0.2	
Changarawe	Tunduru	44	20.06.81	1.0	
Chemuchemu	Tunduru	305	30.05.81	0.1	
Chengena	Songea	98	15.01.81	0.3	
Chikomo	Tunduru	2	06.08.81	2.0	
Chilundundu	Tunduru	9	07.08.81	0.5	
Chinula	Mbinga	165	20.05.81	0.5	
Chiwana	Tunduru	3	06.08.81	3.0	
Fundimbanga	Tunduru	257	19.06.81	0.5	
Gumbiro	Songea	82	31.07.81	0.0	
Hulia	Tunduru	268	23.06.81	0.0	
Ifinga	Songea	285	30.07.81	0.2	
Igawisenga	Songea	90	29.07.81	3.0	
Ilela	Mbinga	216	21.08.81	5.0	
Kagugu	Mbinga	242	13.05.81	0.5	
Kajima	Tunduru	57	22.06.81	1.5	
Kidodoma	Tunduru	37	18.06.81	0.2	
Kigonsera	Mbinga	245	30.07.81	0.2	
Kihagara	Mbinga	174	19.08.81	1.5	
Kihangi/ Makuha	Mbinga	227	26.08.81	5.0	
Kiherekete	Mbinga	210	09.06.81	0.5	
Kihongo	Mbinga	219	12.06.81	0.5	
Kikolo	Mbinga	241	14.05.81	20.0	
Kilagano	Songea	114	27.03.81	1.0	
Kilindi	Mbinga	224	25.08.81	2.0	
Kilosa	Mbinga	279	21.05.81	0.2	
Kingirikiti	Mbinga	213	09.06.81	1.0	
Kipapa	Mbinga	222	11.06.81	0.4	
Kitalo	Tunduru	39	18.06.81	0.5	
Kitanda	Mbinga	16	02.06.81	0.5	
Kitanda	Mbinga	103	14.02.81	0.3	
Kitani	Tunduru	13	10.08.81	8.0	
Langiro	Mbinga	221	11.06.81	0.2	
Legezamwendo	Tunduru	255	17.06.81	0.1	
Libango	Songea	801	30.04.81	0.1	

RUVUMA REGION

VILLAGE	DISTRICT	REG. NO.	DATE OF VISIT	YIELD (l/s)	COMMENTS
Lilambo	Songea	122	13.03.81	1.0	
Lipaya	Songea	139	16.10.80	1.5	
Lipepo	Tunduru	11	07.08.81	0.2	
Lipumba	Mbinga	238	21.02.81	0.3	
Litapwasi	Songea	138	08.01.81	2.0	
Litola	Songea	99	07.04.81	0.5	
Litumba/ Kuhamba	Mbinga	183	29.10.80	0.3	
Litumbandyosi	Mbinga	190	24.10.80	5.0	
Liweta	Songea	283	14.10.80	NA	
Liyangweni	Songea	800	08.01.81	2.0	
Longa	Mbinga	201	15.05.81	0.8	
Luhangarasi	Mbinga	208	09.06.81	0.3	
Lusonga	Songea	132	24.03.81	5.0	
Luwaita	Mbinga	230	19.02.81	0.2	
Lwinga	Songea	108	29.05.81	0.1	
Magazini	Songea	59	06.05.81	2.5	
Maguu	Mbinga	217	10.06.81	0.3	
Mahenge	Mbinga	303	02.12.80	0.2	
Malungu	Mbinga	274	24.10.80	NA	
Mandepwende	Songea	110	29.04.81	1.0	
Mango	Mbinga	172	19.08.81	0.3	
Mapera	Mbinga	218	11.06.81	0.1	
Mapipili	Mbinga	225	27.08.81	3.0	
Maposeni	Songea	123	03.03.81	0.3	
Masuguru	Tunduru	112	29.04.81	0.3	
Matemanga	Tunduru	43	20.06.81	1.0	
Matepwende	Songea	63	05.05.81	0.5	
Matepwende	Songea	72	09.04.81	0.5	
Mateteleka	Songea	91	22.04.81	NA	
Matiri	Mbinga	223	25.08.81	2.0	
Maweso	Songea	92	22.04.81	1.0	
Mbangamao	Mbinga	239	13.05.81	0.5	
Mbati	Tunduru	6	08.08.81	5.0	
Mbuju	Mbinga	198	02.12.80	0.2	
Mbungulaji	Tunduru	42	22.06.81	3.0	

RUVUMA REGION

VILLAGE	DISTRICT	REG. NO.	DATE OF VISIT	YIELD (1/s)	COMMENTS
Mchomoro	Songea	107	29.04.81	0.3	
Mgombasi	Songea	105	28.04.81	0.5	
Mikalanga	Mbinga	214	21.08.81	5.9	
Milonji	Songea	65	06.05.81	0.5	
Minazini	Songea	109	29.04.81	0.1	
Misyaje	Tunduru	254	08.08.81	3.0	
Mkalanga	Mbinga	304	15.05.81	0.5	
Mkali	Mbinga	169	20.08.81	0.2	
Mkasale	Tunduru	310	01.06.81	0.5	
Mkoha	Mbinga	220	11.06.81	3.0	
Mkolola	Tunduru	14	10.08.81	1.0	
Mkongo	Songea	94	14.01.81	3.0	
Mkongotema	Songea	85	23.04.81	0.3	
Mkumbi	Mbinga	200	14.05.81	0.5	
Mlingoti	Tunduru	290	12.08.81	0.1	
Molandi	Tunduru	4	10.08.81	1.0	
Mpandangindo	Songea	149	13.10.81	0.1	
Mpapa	Mbinga	209	09.06.81	0.8	
Mputa	Songea	81	13.02.81	0.5	
Msagula	Tunduru	31	29.05.81	3.0	
Msisima	Songea	62	05.05.81	0.5	
Mtama	Mbinga	236	22.02.81	0.3	
Mtyangimbole	Songea	83	31.07.81	0.2	
Muhuwesi	Tunduru	30	28.05.81	3.0	
Mwanamonga	Songea	128	13.03.81	5.0	
Mwangaza	Songea	229	15.01.81	0.1	
Nahoro	Songea	295	30.03.81	0.5	
Nakawale	Songea	95	14.01.81	1.0	
Nakayaya	Tunduru	293	11.08.81	1.0	
Nalasi	Tunduru	10	08.08.81	0.2	
Naluwale	Tunduru	58	18.06.81	0.5	
Namakungwa	Tunduru	46	23.06.81	4.0	
Nambecha	Songea	104	28.04.81	0.3	
Nampungu	Tunduru	36	18.06.81	0.2	
Namwinyu	Tunduru	45	23.06.81	4.0	
Nang'ombo	Mbinga	162	21.05.81	0.5	

RUVUMA REGION

VILLAGE	DISTRICT	REG. NO.	DATE OF VISIT	YIELD (l/s)	COMMENTS
Nasya	Tunduru	19	02.06.81	2.0	
Ndenyende	Tunduru	34	19.06.81	0.6	
Ndondo	Mbinga	249	23.10.80	0.5	
Ndunduwalo	Songea	119	12.03.81	0.5	
Njalamatata	Songea	97	14.01.81	2.0	
Nyoni	Mbinga	207	09.06.81	0.5	
Parangu	Songea	129	11.03.81	NA	
Raha Leo	Tunduru	41	22.06.81	0.0	
Likuyu/ Sekamanganga	Songea	113	28.04.81	0.1	
Sepukila	Mbinga	243	28.08.81	2.0	
Sisi Kwa Sisi	Tunduru	29	30.05.81	0.3	
Tingi	Mbinga	251	25.10.80	NA	
Tumbi	Mbinga	173	19.08.81	0.5	
Ukata	Mbinga	206	13.05.81	0.1	
Uzena	Mbinga	240	14.05.81	2.0	

MBEYA

MBEYA REGION

VILLAGE	DISTRICT	REG. NO.	DATE OF VISIT	YIELD (1/s)	COMMENTS
Bagamoyo	Rungwe	819	13.02.81	0.0	
Bujesi	Rungwe	329	26.06.80	NA	
Bukinga	Rungwe	818	13.02.81	NA	
Bumbigi	Rungwe	244	13.06.80	0.3	
Bunyakikosi	Rungwe	326	22.10.80	0.0	
Bwenda	Ileje	56	14.09.81	0.	
Bwipa	Ileje	59	19.10.81	NA	
Chembe	Mbeya	47	04.03.81	NA	
Chibila	Ileje	54	14.09.81	0.1	
Chilemba	Ileje	55	05.03.81	0.1	
Chizumbi	Mbozi	833	22.10.80	NA	
Galijembe	Mbeya	145	09.01.81	0.0	
Hamwelo	Mbozi	420	17.09.80	20.0	
Haporoto	Mbeya	158	26.11.80	0.4	
Hatelele	Mbozi	391	30.07.80	2.0	
Hezya	Mbozi	373	24.02.81	NA	
Ibaba	Ileje	40	18.12.80	0.1	
Ibembwa	Mbozi	478	12.08.80	73.0	
Ibula	Rungwe	315	23.09.80	2.5	
Ibumba	Rungwe	320	23.10.80	0.0	4 springs
Ibungu	Rungwe	310	13.12.80	0.1	
Ichesya	Mbozi	505	16.09.80	NA	
Idimi	Mbeya	160	26.11.80	0.3	
Idiwili	Mbozi	384	22.07.80	NA	
Idunda	Mbozi	404	21.07.80	NA	
Igale	Mbozi	376	18.07.80	NA	
Igamba	Mbozi	444	12.08.80	1.4	
Igamba	Rungwe	854	17.02.81	NA	
Iganduka	Mbozi	417	21.08.80	0.3	
Igembe	Rungwe	280	22.07.80	0.2	
Igogwe	Rungwe	817	13.02.81	NA	
Igumbilo	Mbeya	125	22.10.80	0.0	
Ihowa	Mbozi	507	15.07.80	NA	2 springs
Ikama	Rungwe	289	10.06.80	0.6	
Ikhoho	Mbeya	146	22.12.80	0.0	
Ikinga	Ileje	44	20.01.81	0.5	

MBEYA REGION

VILLAGE	DISTRICT	REG. NO.	DATE OF VISIT	YIELD (l/s)	COMMENTS
Ikomelo	Kejela	519	06.02.81	NA	
Ikonya	Mbozi	465	16.09.80	1.5	
Ikubo	Rungwe	276	18.02.81	NA	
Ilembo/Usafwa	Mbeya	831	22.12.80	0.1	
Ilima	Rungwe	350	02.07.80	NA	
Ilinga	Rungwe	290	10.06.80	NA	
Ilolo	Rungwe	317	09.03.81	NA	
Ilomba	Mbozi	462	23.02.81	NA	
Ipapa	Mbozi	433	19.09.81	1.3	2 springs
Iponjola	Rungwe	298	13.06.80	NA	
Ipuguso	Mbozi	272	18.02.81	NA	
Ipunga	Mbozi	398	19.09.80	1.0	2 springs
Ipyana	Mbozi	564	22.07.80	0.8	
Isajilo	Rungwe	351	14.01.81	30.0	
Isaka	Rungwe	303	28.12.81	0.1	
Isalalo	Mbozi	418	19.09.80	1.0	
Isange	Rungwe	242	12.06.80	6.0	2 springs
Isenzanya	Mbozi	393	08.01.81	NA	
Isonso	Mbeya	556	05.03.81	0.0	
Isumba/Kibole	Mbozi	278	22.02.81	NA	
Itaga	Mbeya	170	08.10.80	NA	
Itagata	Rungwe	291	11.06.80	11.2	
Italazya	Mbeya	88	09.02.81	0.2	
Itale	Ileje	27	18.12.80	0.0	
Itepula	Mbozi	458	23.01.81	0.5	
Itete	Rungwe	297	17.06.80	1.5	
Itula	Rungwe	348	01.07.80	NA	
Itumpi	Mbozi	406	27.02.81	NA	
Ivugura	Mbozi	480	16.09.80	NA	
Iwalanje	Mbeya	172	23.12.80	NA	
Iwiji	Mbeya	104	02.07.80	0.6	
Iyendwe	Mbozi	491	28.01.81	NA	
Izumbwe II	Mbeya	97	18.12.80	0.2	
Izuo	Mbeya	108	16.01.81	0.6	
Kafule	Ileje	60	21.01.81	0.1	
Kakozi	Mbozi	382	31.10.80	0.5	

MBEYA REGION

VILLAGE	DISTRICT	REG. NO.	DATE OF VISIT	YIELD (l/s)	COMMENTS
Kalembo	Ileje	45	05.03.81	0.0	
Kapugi	Rungwe	292	14.01.81	0.5	
Kapyu	Rungwe	271	24.09.80	1.5	
Kasyeto	Rungwe	354	14.01.81	NA	
Katundulu	Rungwe	347	01.07.80	NA	
Kifunda	Rungwe	261	17.02.81	NA	
Kilimansanga	Rungwe	557	26.09.80	NA	
Kitali	Rungwe	251	16.02.81	NA	
Kitema	Rungwe	267	25.09.80	NA	
Kiwanja	Chunya	3	21.01.81	NA	
Kyambambembe	Rungwe	357	24.06.80	0.0	
Ludewa	Mbozi	479	22.01.80	0.3	
Lufumbi	Rungwe	330	27.06.80	NA	2 springs
Lugombo	Rungwe	296	13.06.80	0.5	
Lukata	Rungwe	277	22.07.80	NA	
Lulasi	Rungwe	241	06.06.80	20.0	
Lupando	Rungwe	371	26.06.80	NA	
Lupepo	Rungwe	309	11.12.80	NA	
Luswiswi	Ileje	58	14.09.81	0.2	
Lwanjilo	Chunya	167	13.05.80	NA	
Lwifa	Rungwe	372	02.10.80	0.0	
Lyebe	Rungwe	340	11.09.80	28.0	
Lyenje	Rungwe	308	12.12.80	NA	
Mahenje	Mbozi	375	18.09.80	NA	
Majengo	Mbozi	511	06.02.81	NA	
Makongolosi	Chunya	2	13.03.81	0.0	
Malangali	Ileje	51	04.03.81	NA	
Malolo	Mbozi	390	19.09.80	1.4	
Maporomoko	Rungwe	510	06.02.80	NA	
Masebe	Rungwe	325	10.06.80	0.3	
Mashese	Mbeya	527	26.11.80	1.0	
Masoko	Mbeya	87	09.02.81	1.3	
Masukulu	Rungwe	338	27.05.80	4.4	
Matamba	Rungwe	240	18.06.80	6.4	
Matwebe	Rungwe	343	11.09.80	2.0	
Mbagala	Chunya	90	10.02.81	0.8	

MBEYA REGION

VILLAGE	DISTRICT	REG. NO.	DATE OF VISIT	YIELD (l/s)	COMMENTS
Mbawi	Mbeya	567	09.02.81	1.9	
Mbugani	Mbeya	523	16.07.80	0.0	
Mgaya	Ileje	48	19.12.80	0.0	
Mibula	Rungwe	353	14.01.81	4.0	
Mkandami	Mbeya	69	19.11.80	NA	
Mlale	Ileje	30	02.02.81	0.2	
Mpanda	Mbozi	407	24.02.81	NA	
Mpande	Mbeya	112	20.01.81	0.2	
Mpombo	Rungwe	356	24.06.80	11.0	
Mpunguti	Rungwe	273	18.02.81	0.0	
Msangaji	Chunya	154	12.11.80	0.0	
Msanyila	Mbozi	422	31.07.80	2.0	
Msiya	Mbozi	497	02.10.80	0.1	
Mwabowo	Mbeya	571	27.11.80	0.8	2 springs
Mwaka	Mbozi	468	14.05.80	2.8	
Mwala	Mbeya	99	10.02.81	0.7	
Mwasenkwa	Mbeya	547	13.05.80	6.5	
Mwela	Mbeya	525	26.11.80	NA	2 springs
Nambala	Mbozi	385	02.03.81	0.0	
Nambinzo	Mbozi	461	08.01.81	0.3	
Ndandalo	Kyela	213	20.02.81	NA	
Ngulilo	Ileje	57	19.10.81	0.1	
Ngulugulu	Ileje	43	05.03.81	NA	
Njelenje	Mbeya	96	25.09.80	0.5	
Nkangamo	Mbozi	423	14.05.80	0.5	
Nkunga	Ileje	301	20.06.80	NA	
Nsalala	Mbeya	93	06.03.81	0.0	
Ntangano	Mbeya	79	26.12.80	NA	
Old Vwawa	Mbozi	445	06.02.81	2.5	
Pashungu	Mbeya	147	11.02.81	0.0	
Ruanda	Mbeya	110	16.01.81	0.3	
Sakamwela	Mbozi	434	18.09.80	NA	
Sange	Ileje	52	05.03.81	0.1	
Sanje	Mbeya	111	08.12.80	NA	
Sheyo	Ileje	37	18.12.80	3.0	
Shiwinga	Mbozi	386	31.07.80	4.1	

MBEYA REGION

VILLAGE	DISTRICT	REG. NO.	DATE OF VISIT	YIELD (l/s)	COMMENTS
Shizuvi	Mbeya	89	09.02.81	NA	
Simike	Rungwe	299	17.06.80	0.1	
Sumbalwela	Mbozi	463	19.09.80	2.0	
Swaya	Mbeya	155	10.10.80	NA	
Ukwile	Mbozi	483	23.10.80	NA	
Uwambishe	Mbeya	129	28.11.80	0.5	
Wasa		494	03.10.80	3.6	