Hydrogeology of the Buttala Campus Premises Besed on Geo-electrical Resistivity Investigations

By

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DECLARATION

I carried out the work described in this thesis at the Faculty of Applied Sciences under the supervision of Dr. H.A. Dharmagunawardhna Department of geology, University of Peradeniya and Dr. R.L.R. Chandrajith Department of Natural Resources, Sabaragamuwa University. This report or any part of this has not been submitted to any other University for any another degree.

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AFFECTIONATELY DEDICATED

TO

MY PARENTS, BROTHER AND SISTERS

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ABSTRACT

Deep water-supply boreholes are a common drinking water source in Buttala area. The geoelectrical resistivity method has been used by the relevant organization to locate sites for these deep boreholes and to understand the aquifer properties of the geological formations.

In the present study, geo-electrical resistivity sounding and profiling were carried-out within the Buttala campus premises of Sabaragamuwa University. This study describes the horizontal and vertical variation of the physical properties, and occurrences of hydro-geologically favorable and unfavorable zones and some recommendation for future ground water development within the campus premises.

Hydrologically important tectonic lineaments and /or deeply weathered zones could be identified as comparatively low resistivity zones in the resistivity profiles and they could be further conformed by sounding. Present investigation showed that about 60% of the study area is suitable for dug well construction. About one third of this zone also suitable for constructing tube wells. The remaining 40 present of the area is suitable for tube wells but not for dug wells mainly because of shallow overburden conditions or because the fracture horizons are situated very deep in the hard rock in those zones.

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CHAPTER-1

1.0 INTRODUCTION

Detailed and comprehensive study of groundwater and conditions in which it occurs can only be done by subsurface investigations. The information needed to concern an aquifer (its location, thickness, composition, permeability, and yield of groundwater, its, movement, and the quality), quantitative data can be obtained from subsurface examination. It should be emphasized that all work classed as subsurface investigations is conducted entirely by personnel on the surface who operate equipment extending underground.

Geophysical surveys made in conjunction with reconnaissance surface geologic investigations and exploratory drilling may permit a rapid and relatively low-cost evaluation of the sub surface geology and possibly the general groundwater condition of an area. Such survey may materially reduce drilling requirements and resultant overall costs of a groundwater investigation.

Geophysical surveys are essentially the interpretation of the variation in measured response at the surface to certain forces, either natural or artificially generated within the Earth's crust. Such variation result from differences in physical characteristic such as density, elasticity, magnetism, and electrical resistivity of underlying materials. Measurements are usually made at predetermined distances or locations along a traverse or on a grid.

Geophysical surveys can be correlated with geologic conditions of each area to assure reliable interpretation; therefore, a survey is usually started near an outcrop or drill hole where subsurface conditions are known or can be readily interpreted. Such correlation permits projection of geologic conditions to distant area through analysis of the geophysical measurements. The accuracy and reliability of data obtained from a geophysical survey depend in large part on the amount of subsurface control availability, as well as the geologic complexity of an area. The number of holes to be drilled, therefore, varies with the complexity and size of the area under study and the degree of accuracy and detail desired.

Seismic, electrical resistivity, gravimetric, and magnetic measurements. During the present study, electrical resistivity method was used.

Electrical resistivity is a characteristic which makes possible the differentiation between types of earth materials. A resistivity survey are made by sending a direct or low-frequency alternating current through the ground between two metal stakes and measuring both the current and its chemical characteristics. For example, dry gravel and sand have higher resistivity than saturated gravel and sand, Clay and shale also have very low resistivity values.

1.1 BACKGROUND OF THE STUDY

Electrical prospecting makes use of a variety of techniques, of which the electrical resistivity method is commonly employed in groundwater investigation. The contact between certain lithological units, between water saturated and dry formation, and zones with different salanities can be identified from the constants in electrical resistivities. Geo-electrical resistivity investigation method is one of the most commonly used technique for surveying of hydrogeological condition in areas where underlying by crystalline rocks. This method has been applied in many areas in Sri Lanka, especially siting tube wells. Based on this method, it is possible to estimate thickness of weathered overburden, depth to the groundwater level and the presence of water bearing horizons within hard rocks.

Using the resistivity method, an assessment of the horizontal variation of hydrogeological properties can be made with horizontal profiling whereas vertical variation of hydrogeological properties can be estimated by vertical resistivity sounding.

The present study was carried out at the Buttala Campus Premises, which is approximately 120 acres in size. In this study, special attention were given to interpret the hydrological properties of the area.

1.2 OBJECTIVES

The main objectives of the present study were:

(a) To study the horizontal and vertical variation of physical properties of the geological formations within the campus premises based on resistivity profiling and sounding.

(b) To assess the hydrogeological properties of the formation and to demarcate hydrogeologically favorable and unfavorable areas within the campus premises.

(c) To recommend a methodology for future groundwater development within the campus premises

1.3 Study area

The study area in which covers the Buttala Campus Premises, located in the Uva Province of the Monaragala District. The area is approximately 125 acres in size, and is situated about 1.5 kilometers from Buttala town along the Wellawaya-Monaragala road. The study area is located in a valley between two picturesque hillocks that are covered with thick forest. A small seasonal stream that originates from these hills flows its way across the premises of the campus.

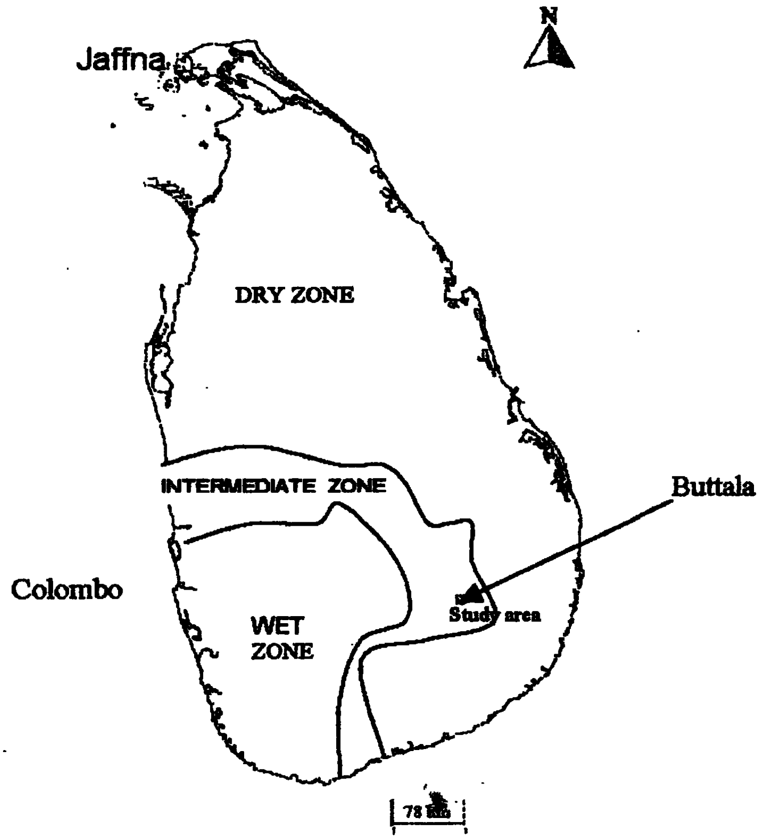


Figure 1.1 Index map showing the location of study area.

1.3 1 Climate of the area

The study area is located in the intermediate zone of Sri Lanka and is basically determined by the seasonal spell of rains, resulting in two rainy seasons namely Maha (main) season and Yala (minor). The two rainy seasons extend from early October to late January and form late March to late May respectively. Corresponding to these long and short rainy seasons there is also a long and short dry seasons (June-September and February-March).

Total rainfall in this area ranges 1328-1821mm (50-72in) per year. Over 84 present of rain is received during October to January and March to May. For any given year the rainfall pattern is erratic and hard to forecast. The area of high rainfall enjoys best of both northeast and southwest monsoonal rains. Maha season corresponds to northeast monsoon period while yala falls within southwest monsoon period.

Mean daily temperature variation of the area is little over the year as the altitude within the vast low country of the district does not exceed 91m (300ft). The temperature varies only from 26°C in January to 29°C in June. However there is a high average annual, diurnal temperature range of 8 °C.

The mean annual relative humidity in the area varies from 60 (day) to 86 (night) present. (According to the closet readings of the campus, 2001)

1.3.2 Soil of the area

The soil of the area varies from place to place. There are two major soil types that can be identified in the area namely Redish Brown earths and Low humic clay soil and Redish Brown earths and immature brown loms.(Agro-ecological map,1996)

CHAPTER-2

2.0 GEOLOGICAL BACKGROUND

2.1 GEOLOGY

2.1.1 Outline of Geology of Sri Lanka

The greater part of Sri Lanka is made up of highly crystalline, non-fossiliferous rocks of Precambrian age belonging to one of the most ancient and stable parts of the earth's crust. The main occurrence of sedimentary rocks is along the northwest coast of the island, which is built up of limestones of the Miocene age.

Several dolerite dykes, small granitic bodies, and a series of pegmatites have intruded in to the Precambrian rocks. Two small occurrences of Gondwana sediments (Jurassic) are located in the northwest of the country at Tabbowa and Andigama. The lower-miocene sedimentary beds are noted at minihagalkanda in the SE of the country

On the basis of the lithology, structure, and age, the Precambrian rocks have been subdivided in to 4 major groups (Cooray 1984),

(a) Highland Complex (HC)
(b) Vijayan Complex (VC)
(c) Wanni Complex (WC)
(d) kadugannawa complex (KC)

The Highland complex (HC)

The central belt extending in NE-SW direction and consists of granulite grade metasediments, migmatites and granitiod gneiss (Cooray, 1978; Vitanage, 1985) and is presently called as HC (Kroner et al., 1991, Cooray, 1994). The metasediments include quartzites, forsterite marble, scapolite-wollastonite granulites and gneisses, garnet-sillimanite-graphite gneisses, cordierite-bearing gneisses and garnet-quartz-feldspar, granulite. Interlayered with these metasediments and forming over 50 percent of the HC are rocks of granitoid origin (Kroner. et al. 1991,). These rocks are quartzo-feldspathic banded gneisses and charnockitic (hypersthene-bearing) gneisses.

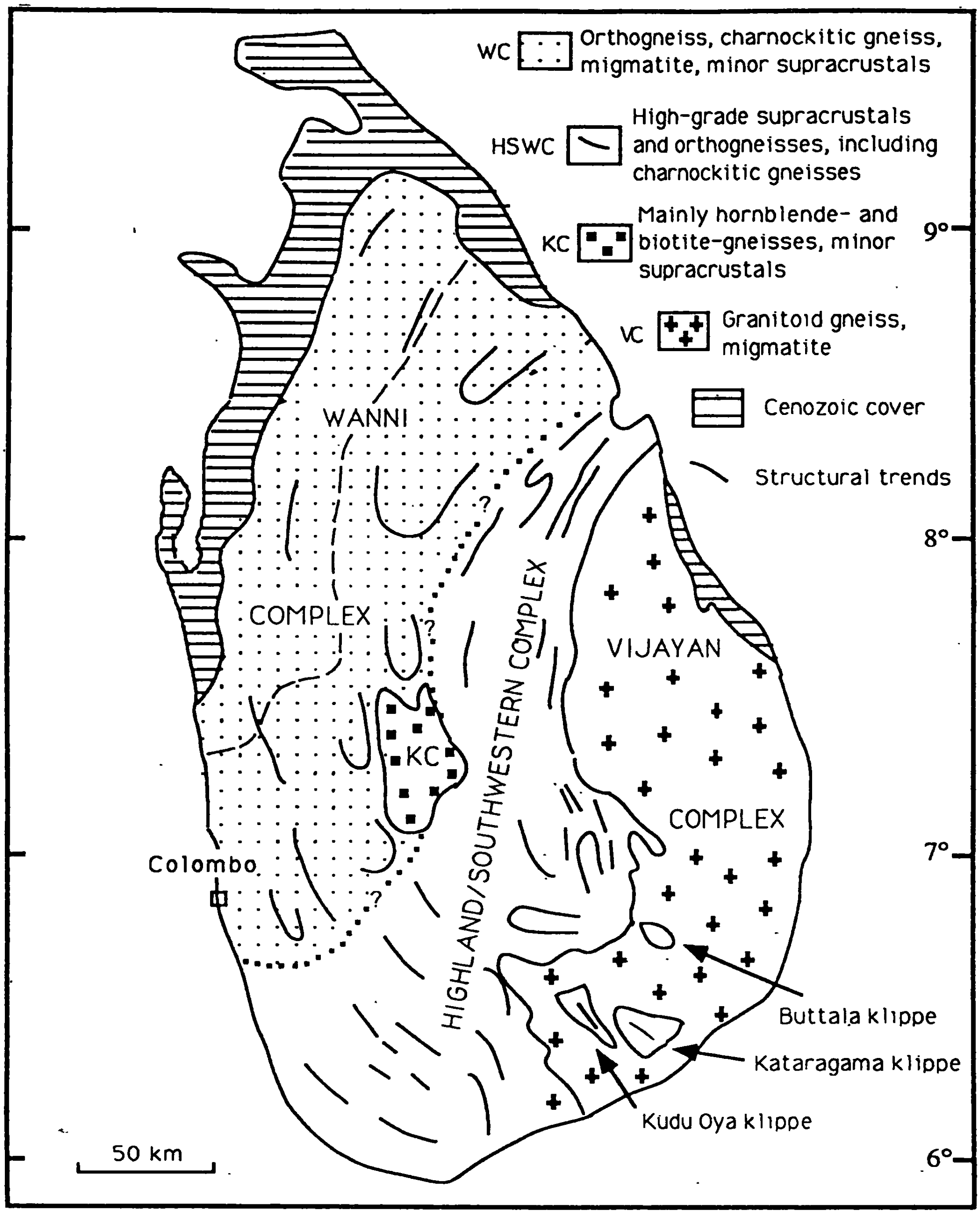


Fig.2.1 Sketch map of Sri Lanka showing the nomenclature and extent of the main precambrian lithotectonic unit of the island (Kroner 1991)

The banded nature of the gneisses is due to original compositional differences, dike intrusion and metamorphic differentiation.

The main structural elements in the HC are a well-developed gneissic foliation and a strong mineral and stretching lineation. The HC has evidently suffered a Polyphase deformation.

The first and second phases of deformation of Highland Complex with isoclinal folding D1 and D2 are coeval with granulite grade metamorphism. These folds show intense flattening and N-S directed stretching with prominent L-S fabrics. The major deformation of D3 folding designated as 'Taprobanian folds' (Almond, 1992) are upright, open structures which have given rise to an elongate dome and basin structured pattern known as arenas. An additional phase of deformation, D4, which includes small scale ductile and brittle shears and some minor folds associated with granitic veins and in situprograde chanockitization, has recently been recognized. Several regional scale faults, shear zones and some kilometer scale folds are also included within the D4 phase of deformation.

The Wanni Complex (WC)

On the west boundary of this central belt occurs the Wanni Complex (WC) consists of orthogneisses and migmatites of amphibolite facies rocks and late- tectonic granites. The large extent of chanockitic terrain is present in the north of WC (Kroner et al. 1991). The metamorphic grade of WC is lower than that of Highland Complex with a distinct gradient in to the latter. There is no clear structural breack between there two units.

The regional granulite fancies metamorphism of HC and WC including KC took place between 610-559 Ma (Kroner, 1991). The P-T condition of this metamorphism of WC are 3.5-7.5 kb of pressure and 600 °C -900 °C of temperature while for HC the pressure varies from 7 kb to 10 kb and temperature ranges between 710 °C and 900 °C .

The Vijayan Complex (VC)

Vijayan Complex lies on the eastern side of the HC and consists of a variety of gneisses and granitoids ranging in composition from tonalite to leucogranite (Milisenda and Hofman, 1991). It also contains minor xenolithic inclusions of metaquartzites and cala silicate rocks (Dahanayake and Jayasena, 1982). The original granitoids are strongly migmatized in many localities and display well-defined compositional layering. Much of the structural history of the VC is comparable to that of the HC, but the two units are of completely different origins, brought together by thrusting (Cooray, 1994).

The Kadugannawa Complex (?)

Kadugannawa Complex occupies distinct, well-defined, elongate, upright, doubly plunging synformal basins (arenas) around Kandy within the Highland complex. They consist many of biotite-hornblende and biotite gneisses together with concordant amphibolite, miner quartzo-feldspathic and pelitic gneisses and metaquartzites. Early recumbent F1 folds were overfolded by asymmetric reclined F2 folds; large upright F3 structueres with variable axial plunges gave rise to the present basin-and-dome pattern. There is still no agreement to the origin of these rocks. It is thought that all the rocks in the arenas once experienced granulite facies metamorphism (Cooray, 1994).

2.1.2 Geology of the study area

Geologically the study area lies within the Vijayan Complex accoding to the geological map of Sri Lanka (Cooray, 1984), the major rock type in the study area is hornblend-biotite gneiss.

CHAPTER-3

3.0 PRINCIPLES OF RESISTIVITY SURVEY

Electrical resistivity survey method is used to determine the sub surface geological condition, by passing an artificially generated electric current through the ground.
An electric current is passed through the ground across a pair of the electrodes A and B (that are metal posts driven in to the ground).(fig 3.1) The potential difference between two intermediate points in the line of the electrodes is measured through another two electrodes M and N.

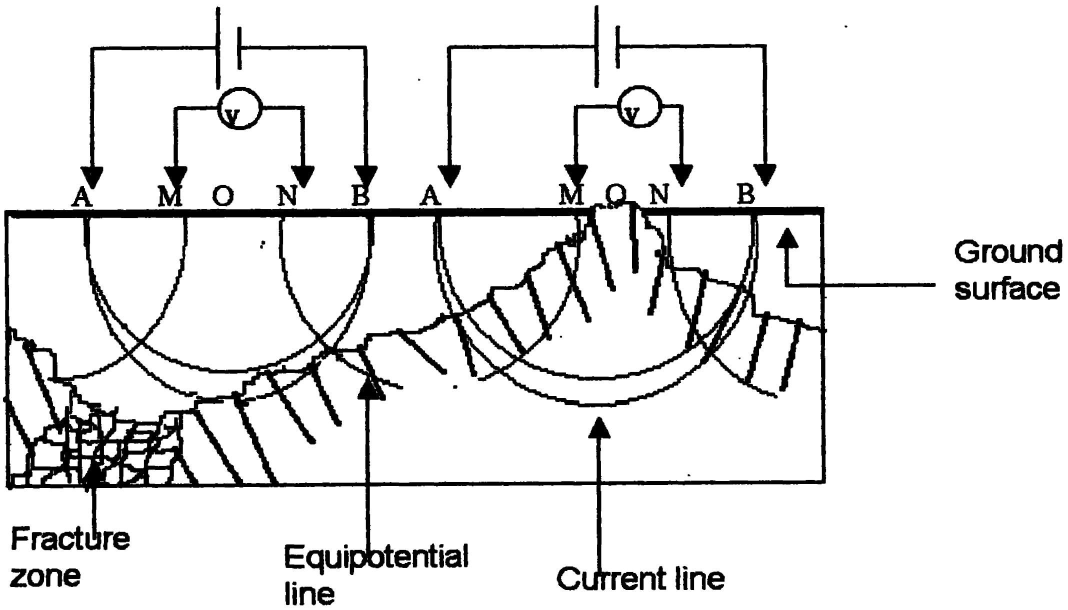


fig.3.1 electrode arrangement of resistivity profiles

sing the potential difference, electrode separation and the applied current, ground resistance can be calculated. The apparent resistivity, which is the key parameter to determine the subsurface condition, can be calculated using the value of the resistance and the electrode spacing. The thickness and resistivities of the subsurface layers can be calculated by measuring the variation of apparent resistivity with respect to the positions of electrodes, which indicate the depth of penetration of the current.

The basic equations used in Resistivity determination is given by the oms's low

$$\Delta V = IR \quad (1)$$

Where

ΔV-Potential difference between electrodes M and N (volt)

I-Current passed through the ground (Ampere)

R-Resistance between the potential electrodes (ohms)

Resistivity is defined as the resistance in ohms between opposite faces of a meter cube of a material, and is measured in ohm-m/m, or simply ohm-m. The resistivity ρ is given by,

$$\rho = RA/L \quad (2)$$

Where

ρ- Resistivity (Ohm meter)

R- Resistance between the potential electrodes (ohm)

A-Cross section of area through which the current flows

L-Length (m)

The resistivity **ρ** is calculated using the equation

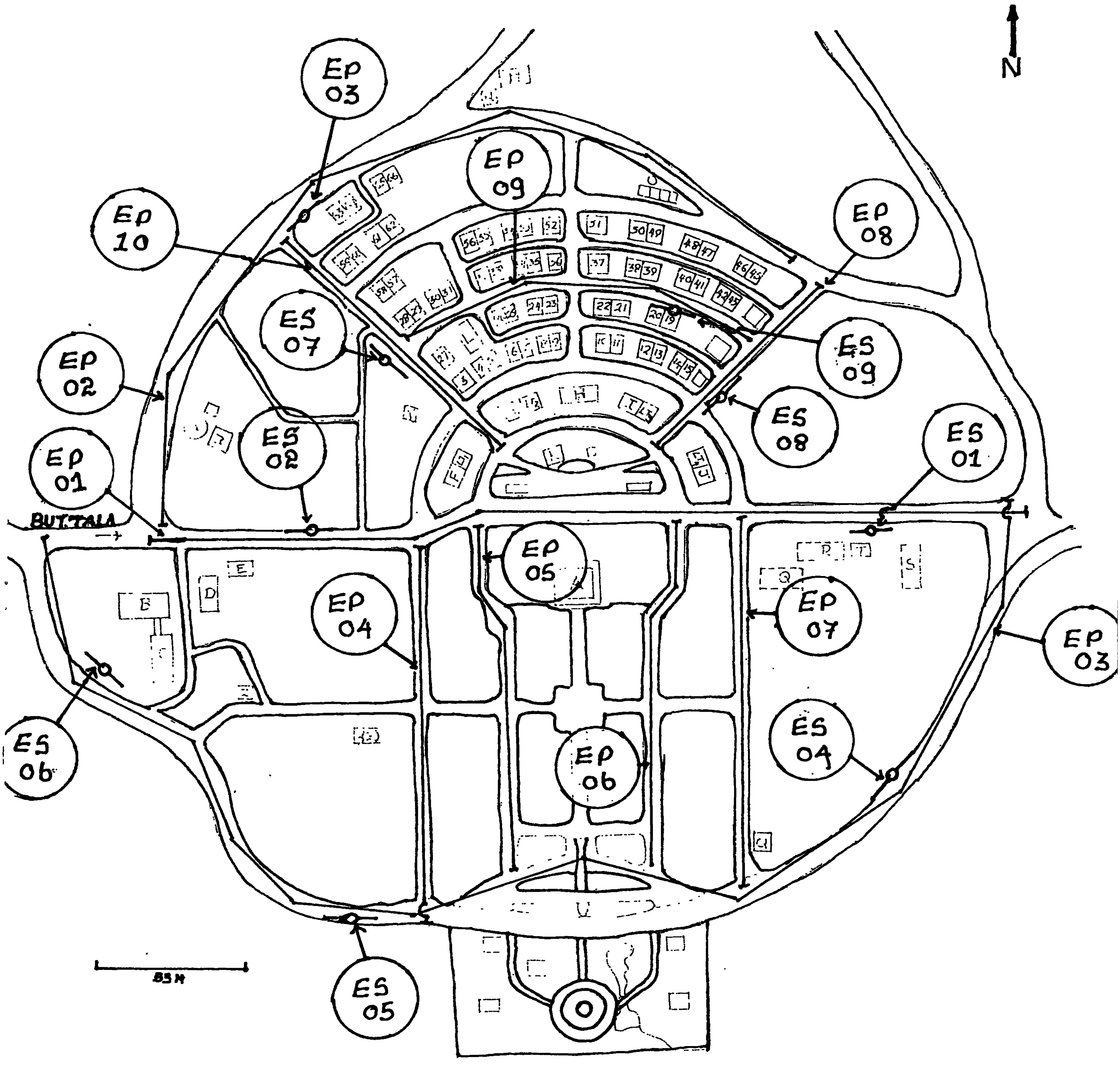
$$\rho = 2\pi kR \quad (3)$$

Where

ρ-Resistivity (Ohm meter)

k-Constant (meter)(vary with the type of electrode arrangement)

Resistivity surveys include Resistivity profiling and Resistivity sounding which is described in chapter 4



Geo-electrical resistivity profile

Geo-electrical resistivity sounding with number

Fig.3.2 Map showing the locations of geo-electrical sounding and profiling

CHAPTER-4

MATERIALS AND METHODS

4.1 FIELD TECHNIQUES

During this study, geoelectrical resistivity profiling and sounding were carried-out using resistivity meter, model SAS 300 terameter.

4.1.1 Resistivity profiling (EP)

Resistivity profiling is used to determine the variation of physical properties along the horizontal distance by measuring the variation of apparent resistivity along the same direction. In this method electrodes are kept at a constant distance and the whole set of electrodes are moved toward the required direction along the survey line. For each position of the electrode, apparent resistivity is obtained and apparent resistivity value is plotted against the distance along the profile.

This is useful to take an idea about the overburden thickness of the area. The high resistivities indicate that the bed rock is very close to the ground surface. The low resistivity indicates a deep weathering, weathering profiling or highly fractured, water saturated bed rock.

The Wenner (a=10) configuration was used in profiling for comparing the hydrologically potential for zones/water along profiles. Readings were taken at every 30m intervals along each traverse. In this method, electrodes are separated by a constant distance (a=10) as shown in fig 4.2, 10 profiles were performed during this study.

The apparent resistivity in this configuration is given by equation no 3,

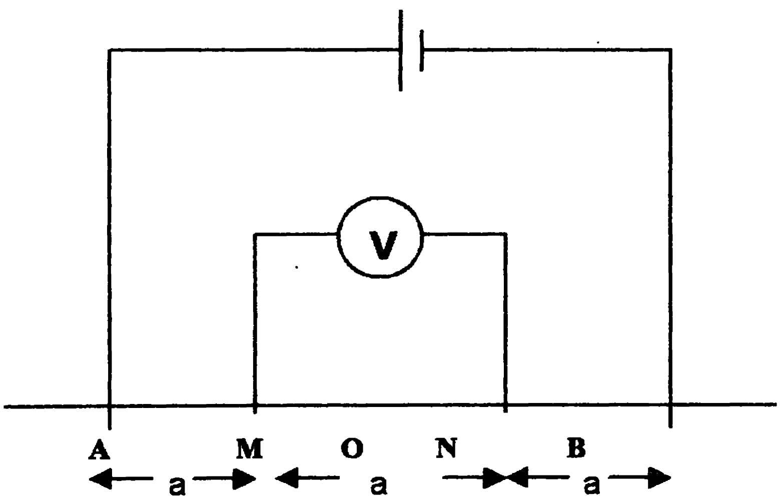
4.1.2 Resistivity sounding (ES)

Resistivities sounding were carried out using Schlumberger electrode configuration to determine the apparent resistivity of the subsurface layers. Suitable position for electrical sounding was selected based on the results of resistivity profiling. The position with very high and low resistivities on profiles were selected for resistivity sounding.

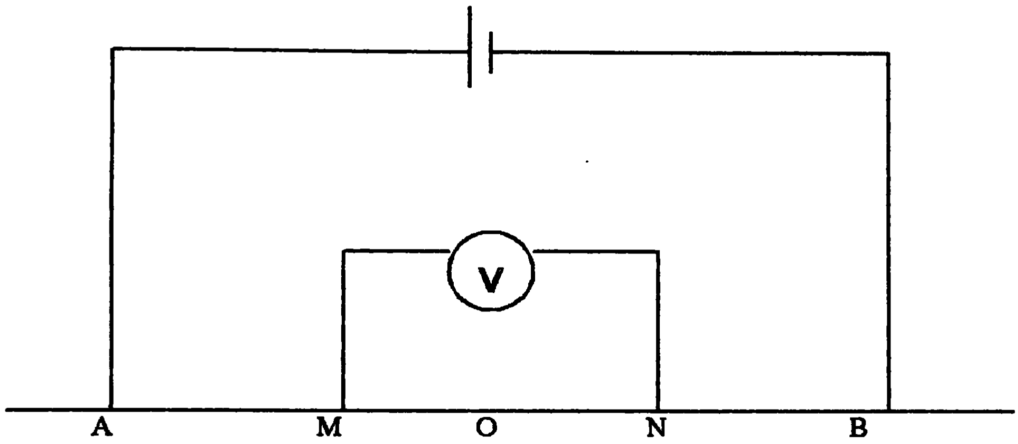
MN/2, 0.5 to 5 m and AB/2, 1.5 to 83 m was used as the electrode separation in the present study. Table 4.1 shows the current and potential electrode separation used in each sounding. Majorities of the sounding were performed with a maximum current electrode separation (AB) of 240m. Narrower or wide separation were also used, depending on the terrain, accessibility and measuring condition during this study resistivity sounding, 9 sounding were conducted at various locations on the profiles.

The apparent resistivity is calculated by the equation,

$$\lambda = \Pi \frac{\left[\left(\frac{AB}{2} \right)^2 - \left(\frac{MN}{2} \right)^2 \right] R}{MN} \quad (4)$$



Wenner configuration



Schlumberger configuration

Fig..4.2 Electrode arrangement in Wenner and Schlumberger configuration

Table 4.1 Electrode separation in the Schlumberger configuration.

	MN/2 (m)	
	0.5	5
AB/2 (m)	1.5	-
	2.1	-
	3	-
	4.4	-
	6.3	-
	9.1	-
	13.2	13.2
	19	19
	27.5	27.5
	40	40
	58	58
	83	83

By measuring the current electrode spacing step by step, the resistance of the subsurface can be taken. The values of the resistance vary with the type of subsurface layer.

4.3 INTERPRETATION OF PROFILING DATA

Interpretation of profiling data was done by plotting the apparent resistivity values (ρa) against the distance along the profile (L). Variation of the resistivity along the profile was determined using the data plots of the profiles. Location for resistivity sounding was selected considering low and high resistivity on profiles. The apparent resistivity values were plotted in a map of the study area to prepare the resistivity contour map.

4.4 INTERPRETATION OF SOUNDING DATA

Resistivity sounding curves were drawn by plotting apparent resistivity value (ρa) against the half of the current electrode separation (AB/2) in a logarithmic paper.

Those sounding curves, which reflects the vertical distribution of the formation resistivities of the subsurface layers were analyzed by an auxiliary point curve matching method and also using a computer program (G68). The formation resistivities of subsurface layers and corresponding thickness were then calculated.

Depth profile data are obtained at a site by taking a series of resistance readings at different electrode spacing. The apparent resistivity is then plotted against electrode spacing on a log-log paper and the resulting field curve is interpreted for its geologic and hydrologic indication.

The interpretation of field data is done in two stages. In the first stage, the interpretation is theoretical for known earth models, and in the second stage the results are translated in geological parameters on the basis of subsurface geological information obtained from test drillings. Theoretical interpretation can be achieved by partial curve matching with the help of 2, 3 and 4 layer master curves for various ratios of resistivities.

CHAPTER 5

RESALTS AND DISCUSSION

4.1 RESISTIVITY PROFILING

10 resistivity profiles were done and apparent resistivity values were plotted against the distance along the profiles. The result of resistivity profile are presented in figures 5.1.1 to 5.1.10 in which the position of the mid point of the electrode configuration at each measurement is set out along the abscissa while the corresponding value of the apparent resistivity is plotted on the ordinate. Peaks and high resistivity section of those plots indicate presence of high resistivity formations, which is close to the ground surface. Low resistivity zone on the profile is the indicator for weathered rock, thick overburden, joint, or fracture zone of the geological formation. These zones are the ones that are impotent for construction of dug wells or shallow wells.

EP-01

EP1 runs along the central road of the campus premises between two main gates and in the East-West direction. On the profile EP1 the resistivity varies between 50ohm m and 550ohm m. EP1 profile diagram (fig..5.1.1) Shows the variation of the apparent resistivity along the distance. At the beginning until 60m distance the resistivity is comparatively high. Then it decreases along the distance up to about 120m. After that it again increases until 330m. It decreases again up to about 520m point. Then the resistivity increases with the distance though there is a decrease at 570m point.

There are two low resistivity zones on the EP1 profile between 50m-150m(average apparent resistivity is 150ohm) and 450m-575 m (average apparent resistivity is 50ohm).

EP-02

EP2 runs along circular road around the campus premises and shown in the fig 5.1.1 On this profile, resistivity varies between 92ohm m and 1644ohm m. EP2 profile diagram shows the variation of the apparent resistivity with the distance (fig..5.1.2). At the beginning resistivity is comparatively low and it increases along the distance up to about

90 m. after that it decreases until 330 m and it increases again up to about 570 m point. But there low resistivity were reported at the 450 m and 480m points. Then the resistivity decreases with the distance.

According to the diagram their high resistivity zones on the EP2 profile. Generally all resistivity valves are higher than those of EP1

EP-03

EP3 profile runs along circular road around the campus premises between two main gates and south of the central road. On this profile, resistivity varies between 32ohm m and 1011ohm m. The EP3 profile diagram shows the variation of the apparent resistivity with the distance (fig..5.1.3). At the beginning resistivity values are comparatively high and it decreases till about 60m. Then it increases until 720 m Point on the decreases again.

According to fig 5.1.3 there is a low resistivity zone between 60 m and 570-m point (average resistivity value 75-ohm m). Rest of the profiles shows high resistivity values.

EP-04

EP4 profile runs South-North direction between station 19 of the EP3 and station 14 of the EP1 profile. On the EP4, resistivity values varies between 69ohm m and 449 ohm m (fig..5.1.4). At the beginning resistivity is comparatively high. Then it had shown a low value at 30m. After that it increases until 180m.Then it decreases again up to about 210m point. The last segment shows high resistivity values.

There is one low resistivity zone on the EP4 profile between 30 m and 120 m (average apparent resistivity is 50 ohm m).

EP-05

EP5 runs North-South direction between station 12 of the EP1 and station 17 of the EP3 on the campus premises. On the profile, resistivity varies between 62ohm m and 395 ohm m fig..5.1.5 show the apparent resistivity variation of the EP5 profile. At the beginning resistivity is comparatively high. A low value is seen at 30m. After that it increases until 90m and decreases again up to about 120 m. Then the resistivity increases until 150m after that decrease up to about 180 m and increases at the last section.

There is a low resistivity zone on the EP5 profile between 110 m and 225 m (average apparent resistivity is 100 ohm m) and rest of the profile shows high resistivity values.

EP-06

EP profile runs south-north direction between station 13 of the EP3 and station 8 of the EP1. On this profile, resistivity values vary between 98 ohm m and 229 ohm m. EP4 profile diagram shows the variation of the apparent resistivity with distance (fig 5.1.6). The resistivity is comparatively low in the beginning and slight increases toward the end.

The EP6 profile shows a low resistivity zone along its entire length.

EP-07

EP7 runs along the North-South direction between station 6 of the EP1 and station 11 of the EP3. On the profile resistivity varies between 11 ohm m and 1126 ohm m. EP7 profile diagram (fig..5.1.7) Shows the variation of the apparent resistivity. At the beginning resistivity is comparatively high. Then it decreases along the distance up to about 125-m. after that it increases until 140 m.

There is a one low resistivity zone on the EP7 profile between 50 m and 210 m (average apparent resistivity is 100ohm m). This profile shows a very high and low resistivity value.

EP-08

EP8 runs NE-SW direction between station 19 of the EP2 and canteen. On the profile resistivity varies between 408 ohm m and 926 ohm m. Fig..5.1.8 shows the variation of the apparent resistivity with the distance. At the beginning resistivity is comparatively high. Then it increases along the distance up to about 60 m . Then it decreases until 90 m and again increases up to about 120 m. This profile indicates a high resistivity zone in the study area.

EP-09

EP9 runs along circular road between station 2 of the EP8 and station 3 of the EP10. On their profile, resistivity values vary between 517 ohm m and 2066 ohm m (fig.5.1.9). At the beginning resistivity is comparatively high and at 30m there is a low resistivity point. After that it increases until 180m. There is a low resistivity point at 120. It again decreases up to about 240m point. Then the resistivity increases with the distance.

According to profile diagram, there are no low resistivity zones observed on the EP9 profile.

EP10

EP10 runs along NE-SW direction between station 7 of the EP2 and the canteen. On this profile resistivity values varies between 395 ohm m and 1613 ohm m. Fig..5.1.10 shows the variation of the apparent resistivity along with the distance on EP10. At the beginning resistivity is comparatively low. Then it increases along the distance up to about 90m. But there are low resistivities at 60-m point and it decreases until 180 m. through out the profile apparent resistivity is generally high.

Fig 5:1:1 EP 1 Wenner a = 10m
West to East
Station Interval 30m

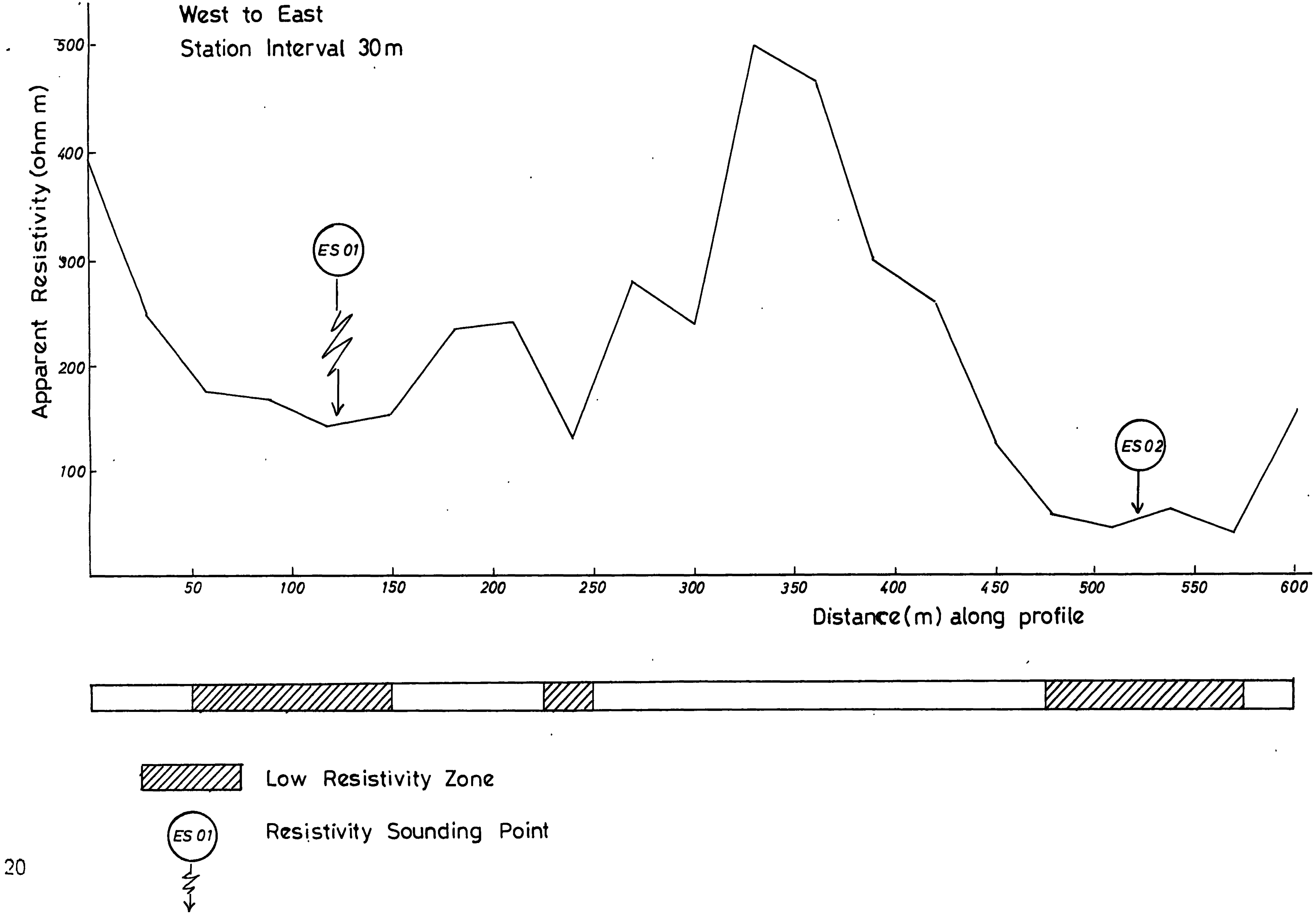


Fig 5:1:2EP 2 Wenner a = 10m

Circular Road

Station Interval 30m

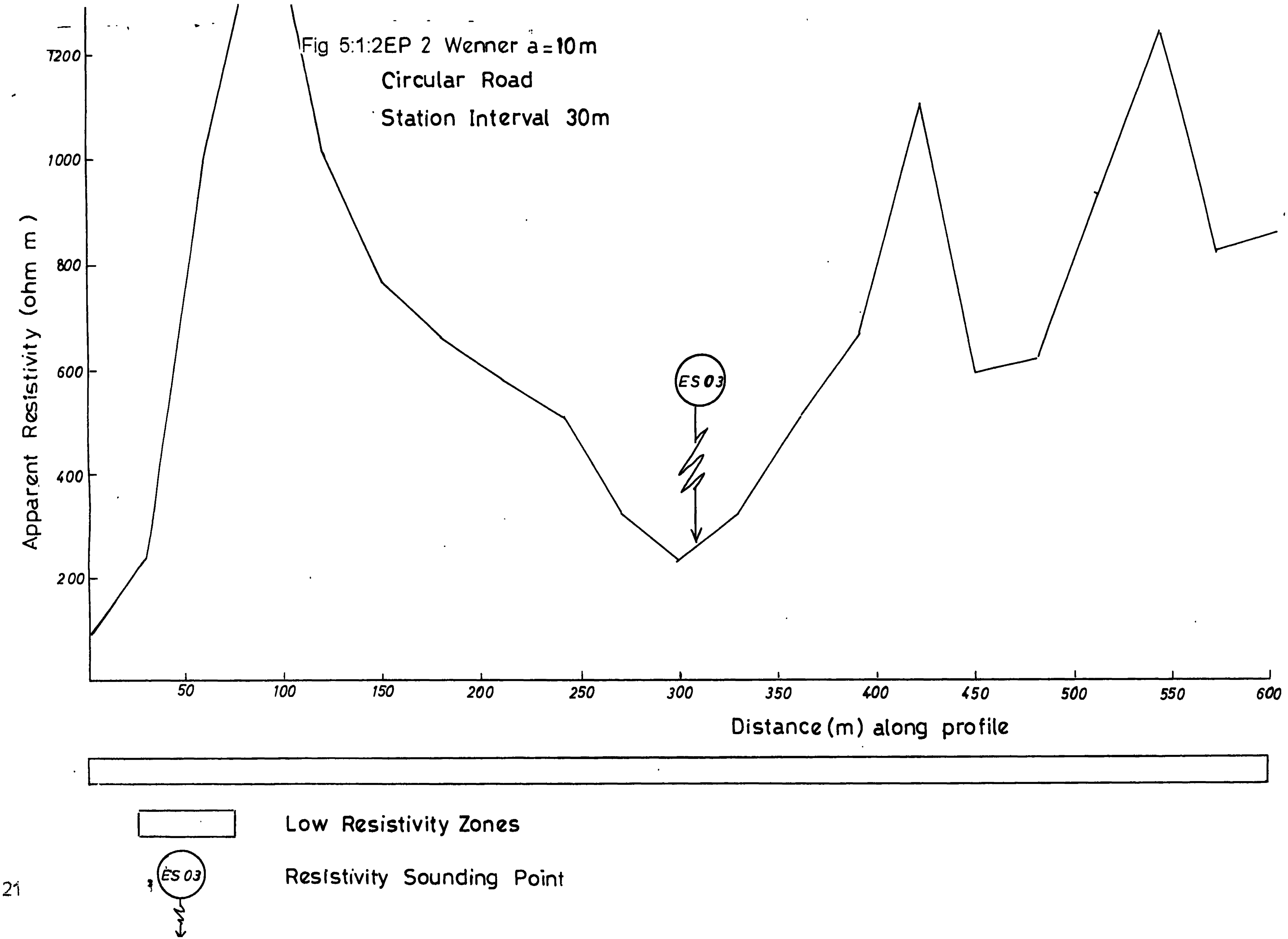
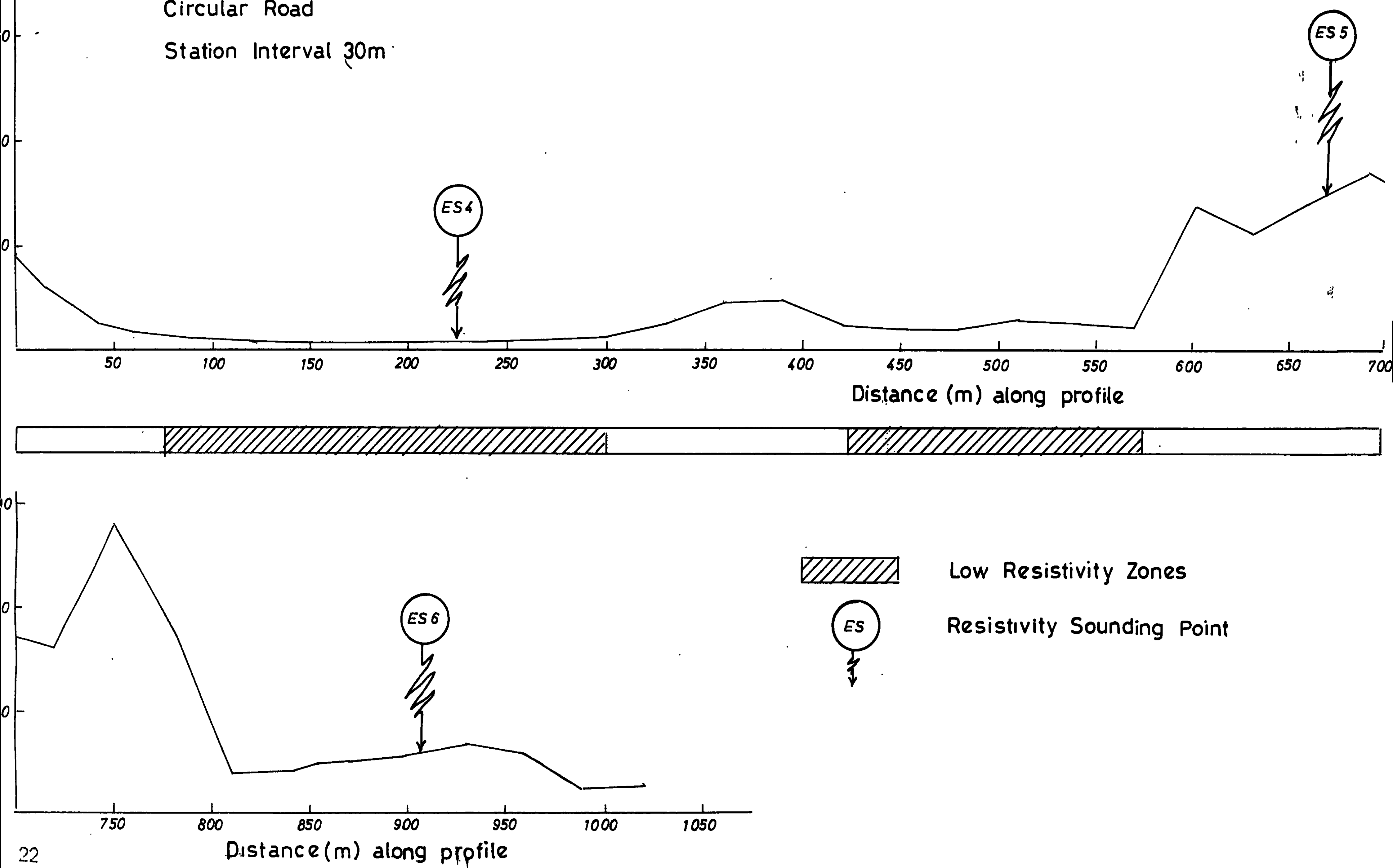


Fig 5:1:3 EP 03 Wenner a = 10m

Circular Road

Station Interval 30m



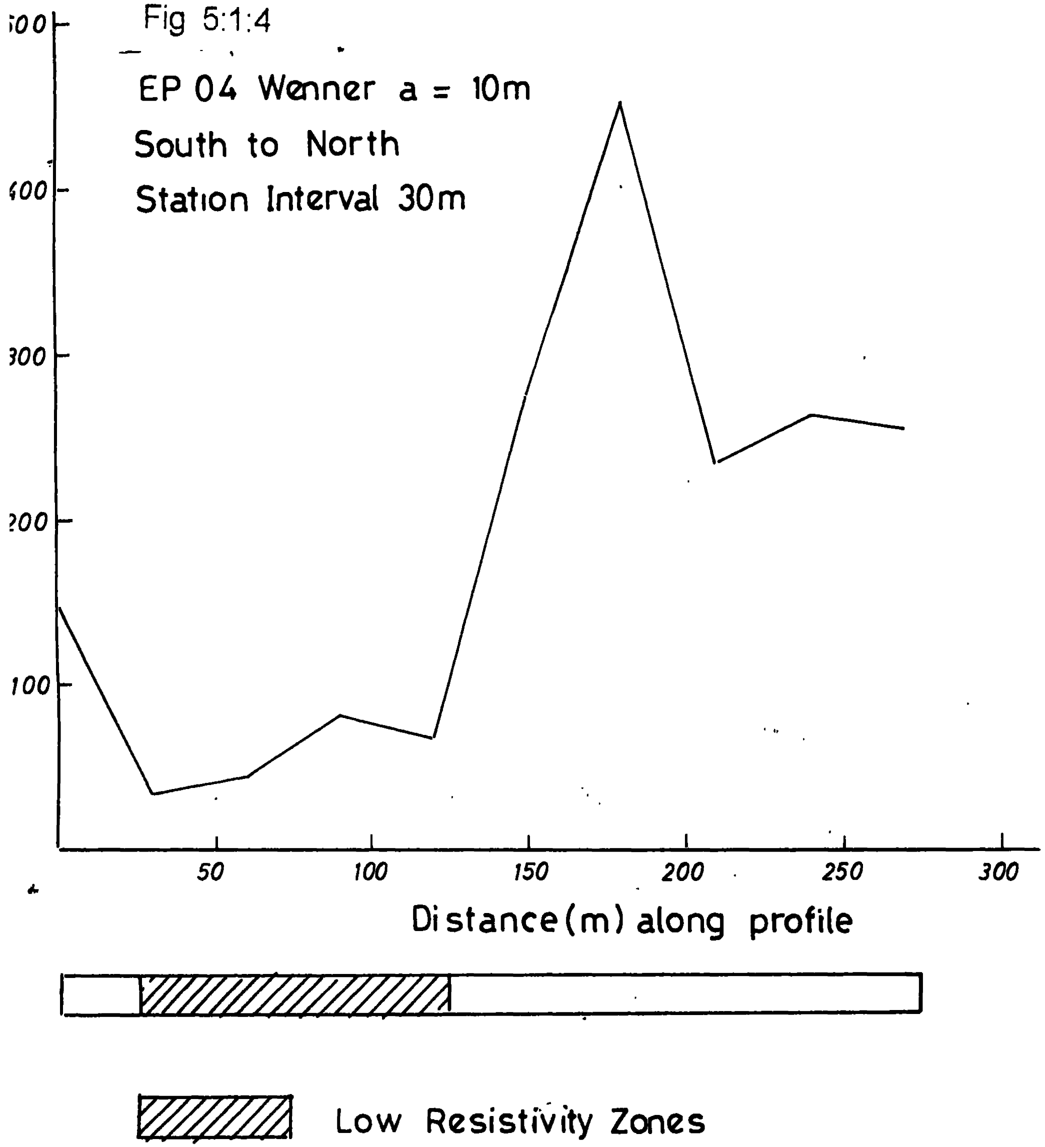


Fig 5:1:4
EP 04 Wenner a = 10m
South to North
Station Interval 30m
500
400
300
200
100
50
100
150
200
250
300
Distance (m) along profile
Low Resistivity Zones

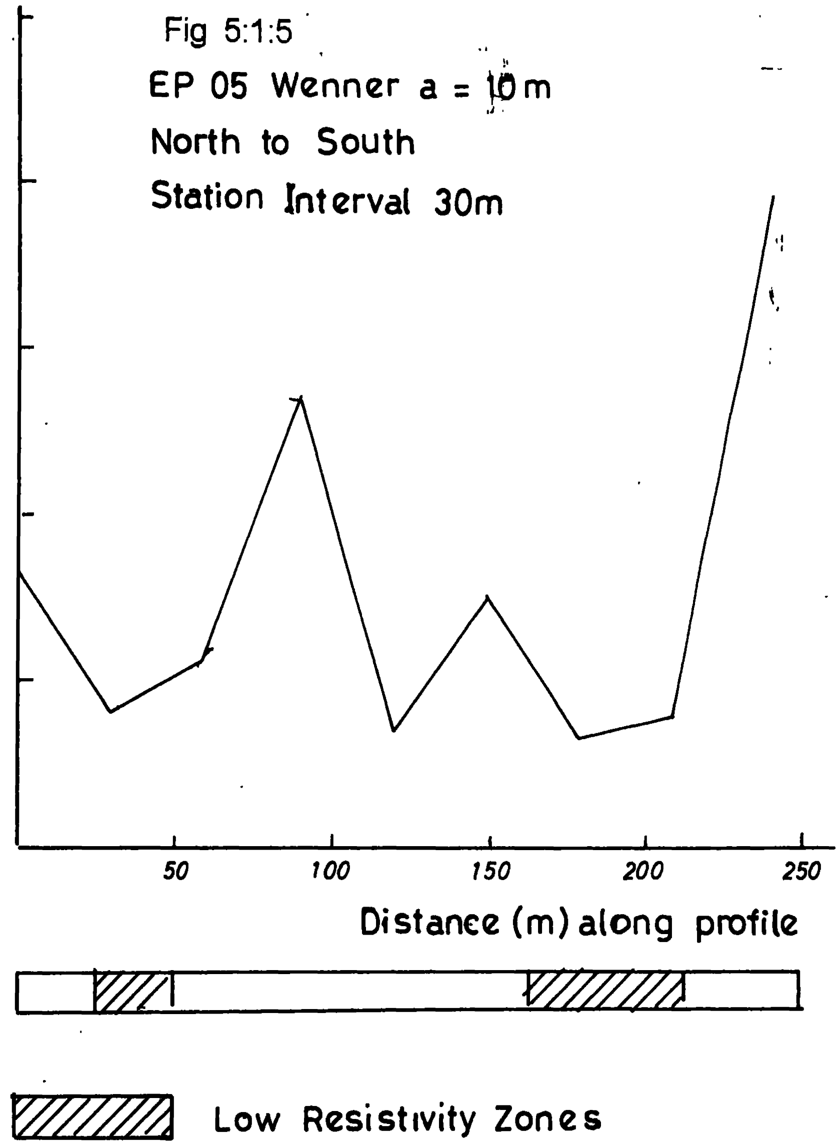


Fig 5:1:5
EP 05 Wenner a = 10m
North to South
Station Interval 30m
50
100
150
200
250
Distance (m) along profile
Low Resistivity Zones

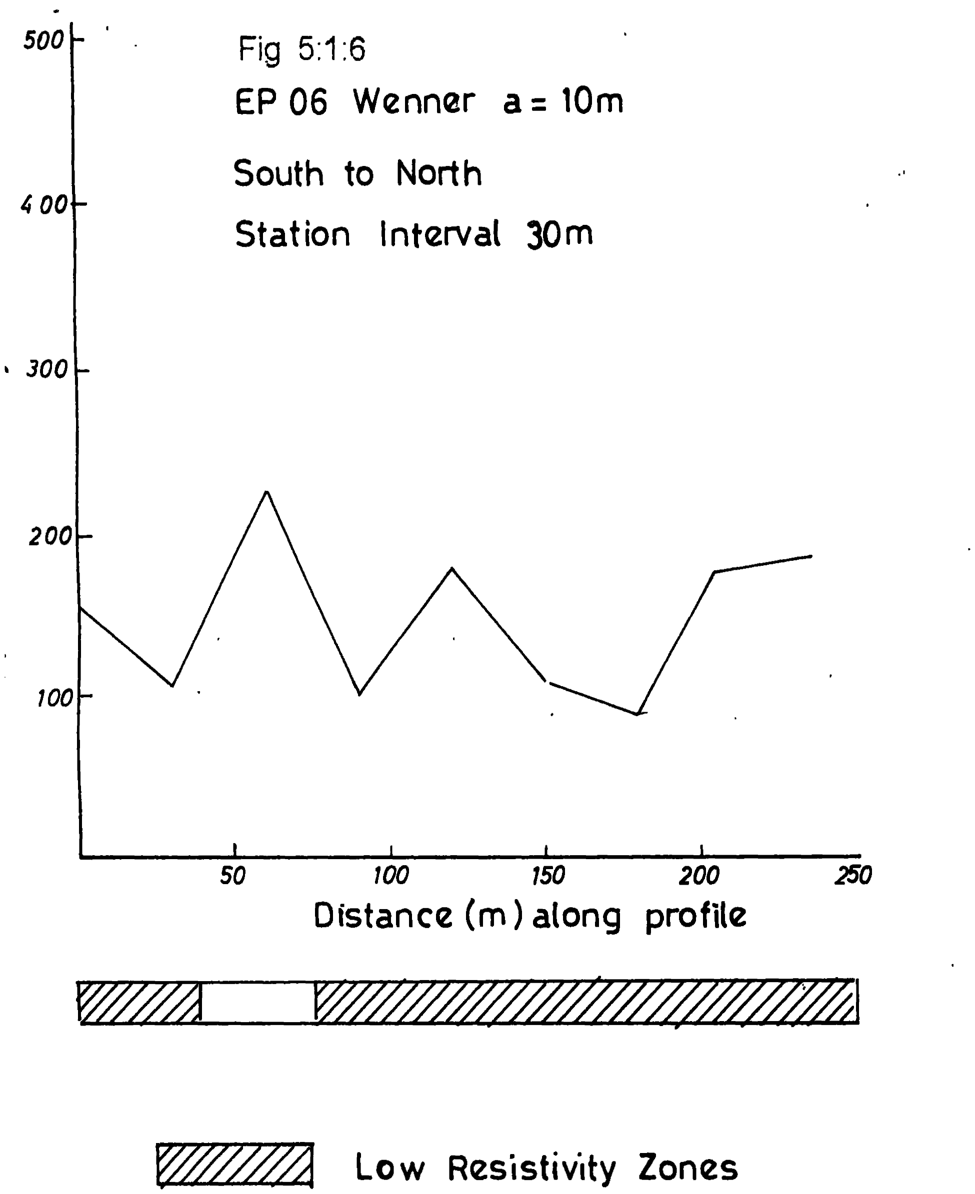


Fig 5:1:6
EP 06 Wenner a = 10m
South to North
Station Interval 30m
500
400
300
200
100
50
100
150
200
250
Distance (m) along profile
Low Resistivity Zones

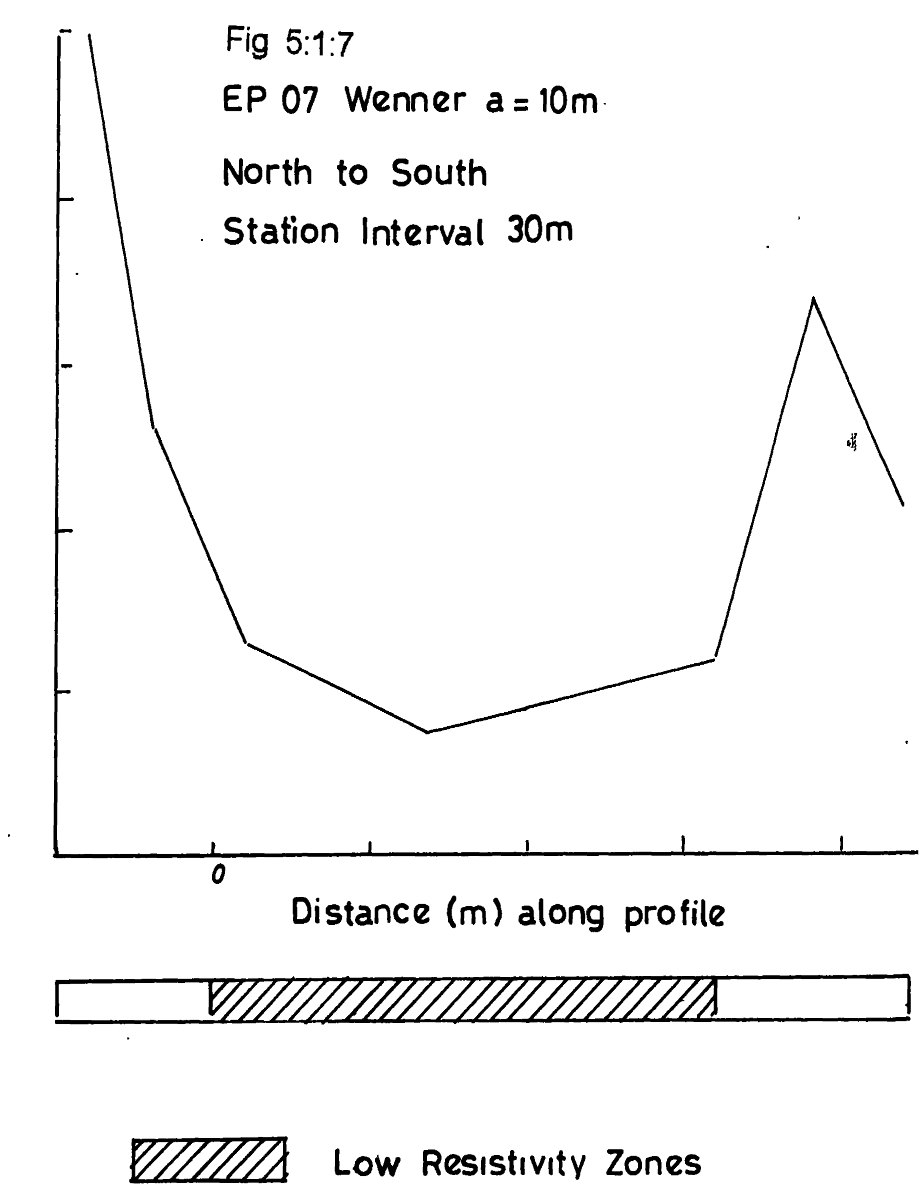


Fig 5:1:7
EP 07 Wenner a = 10m
North to South
Station Interval 30m
0
Distance (m) along profile
Low Resistivity Zones

Fig 5:1:8

EP 08 Wenner a = 10m

NE-SW

Station Intervals 30m

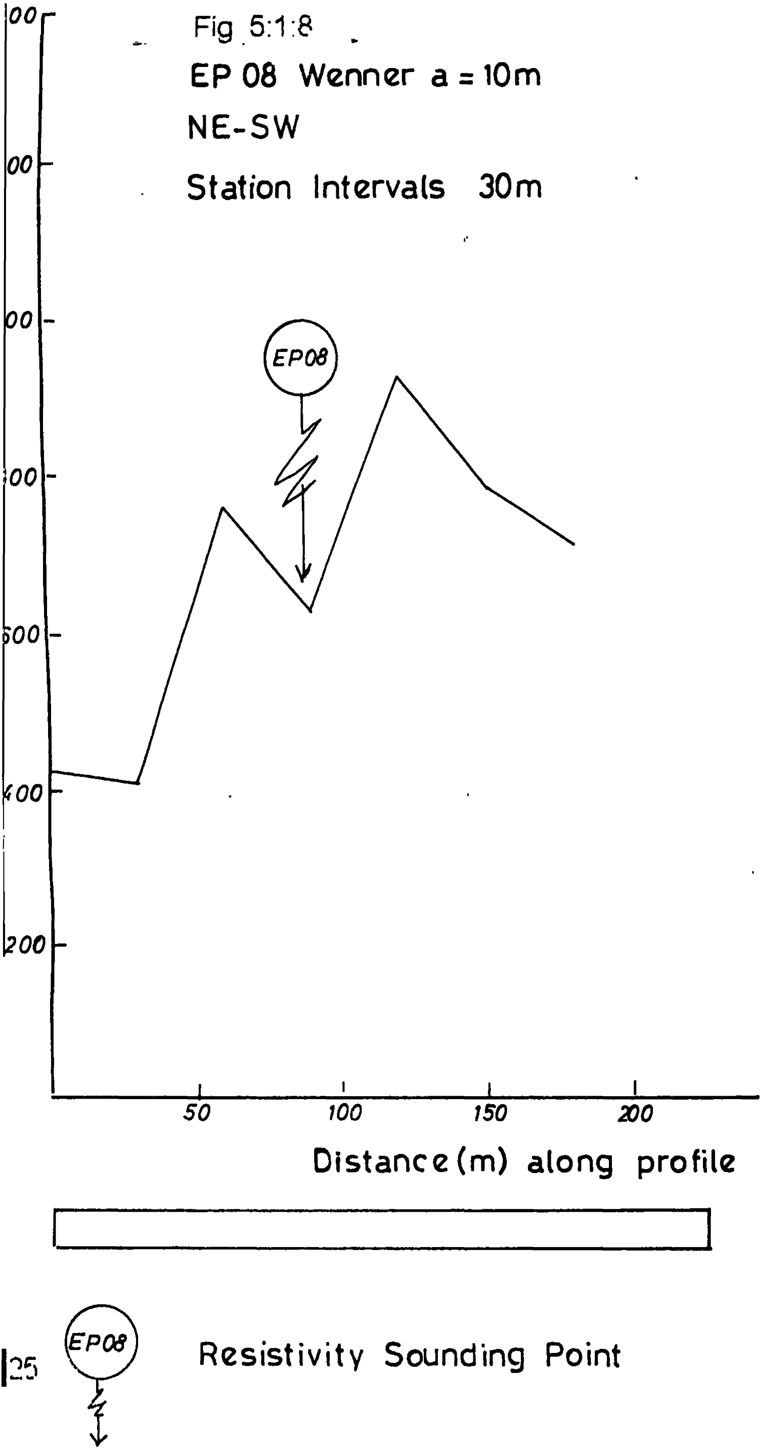


Fig 5:1:9

EP 09 Wenner a = 10m

Circular Road

Station Intervals 30m

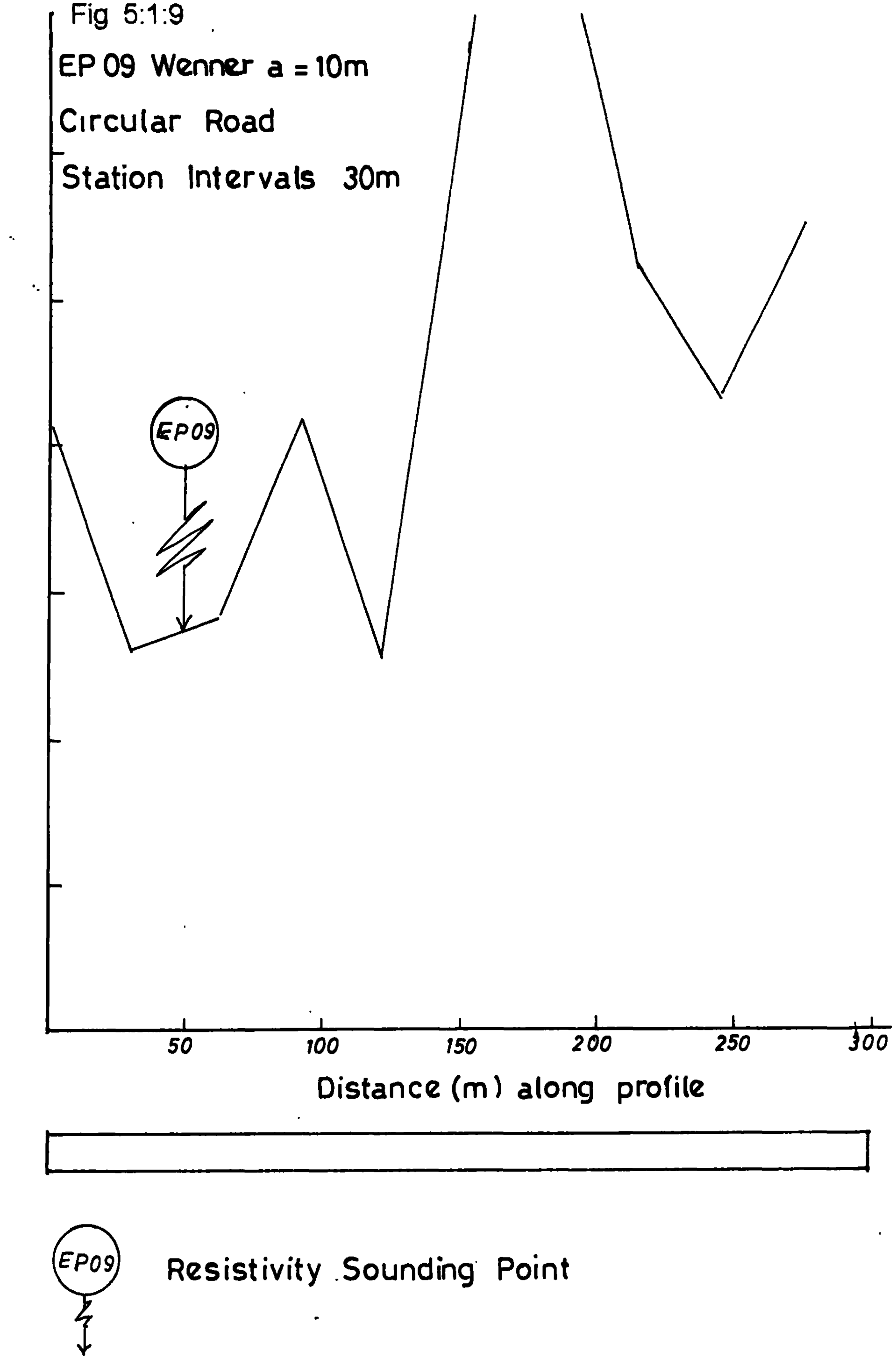
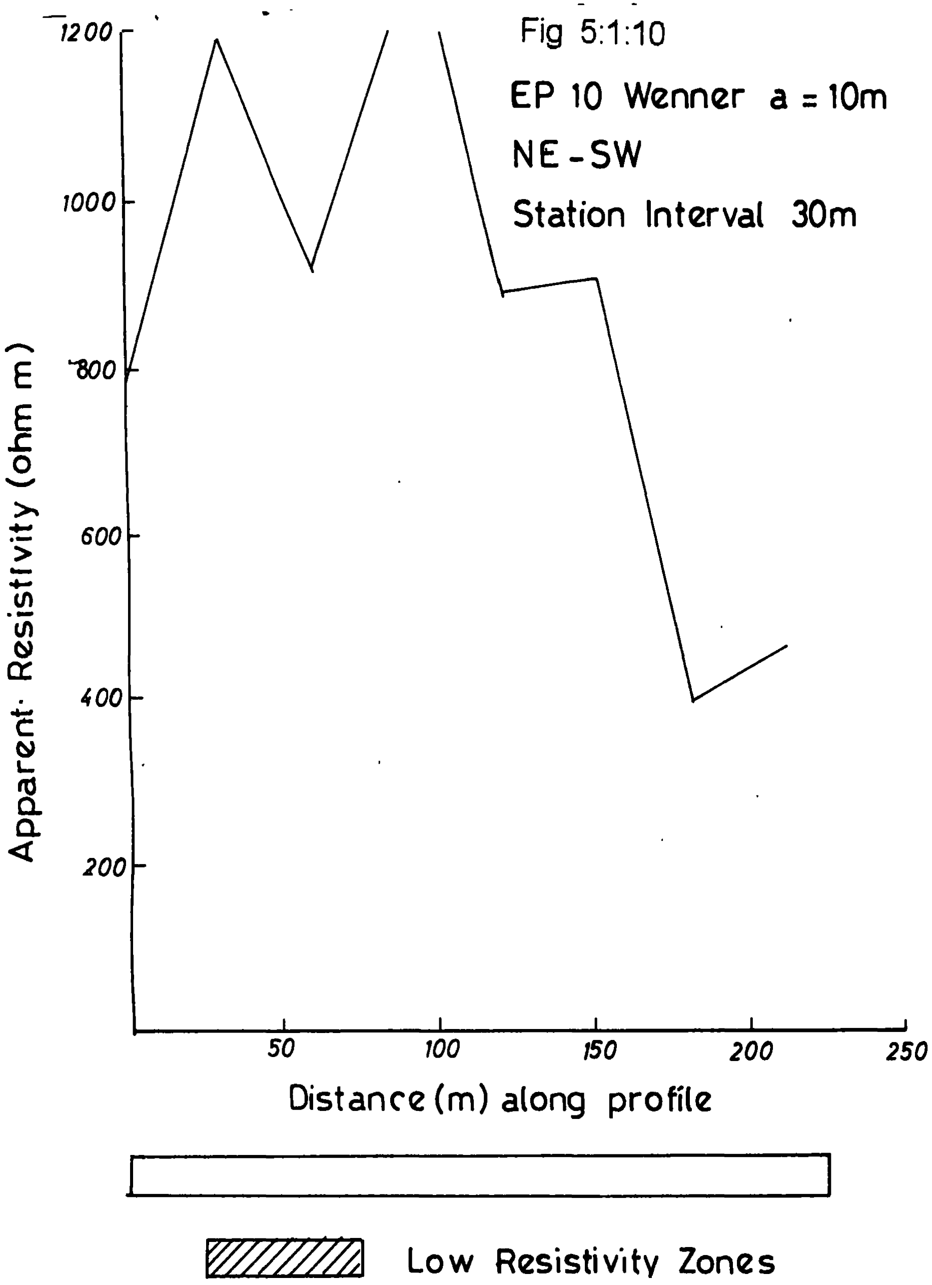


Fig 5:1:10


EP 10 Wenner a = 10m
NE-SW
Station Interval 30m
1200
1000
800
600
400
200
Apparent Resistivity (ohm m)
50
100
150
200
250
Distance (m) along profile
Low Resistivity Zones

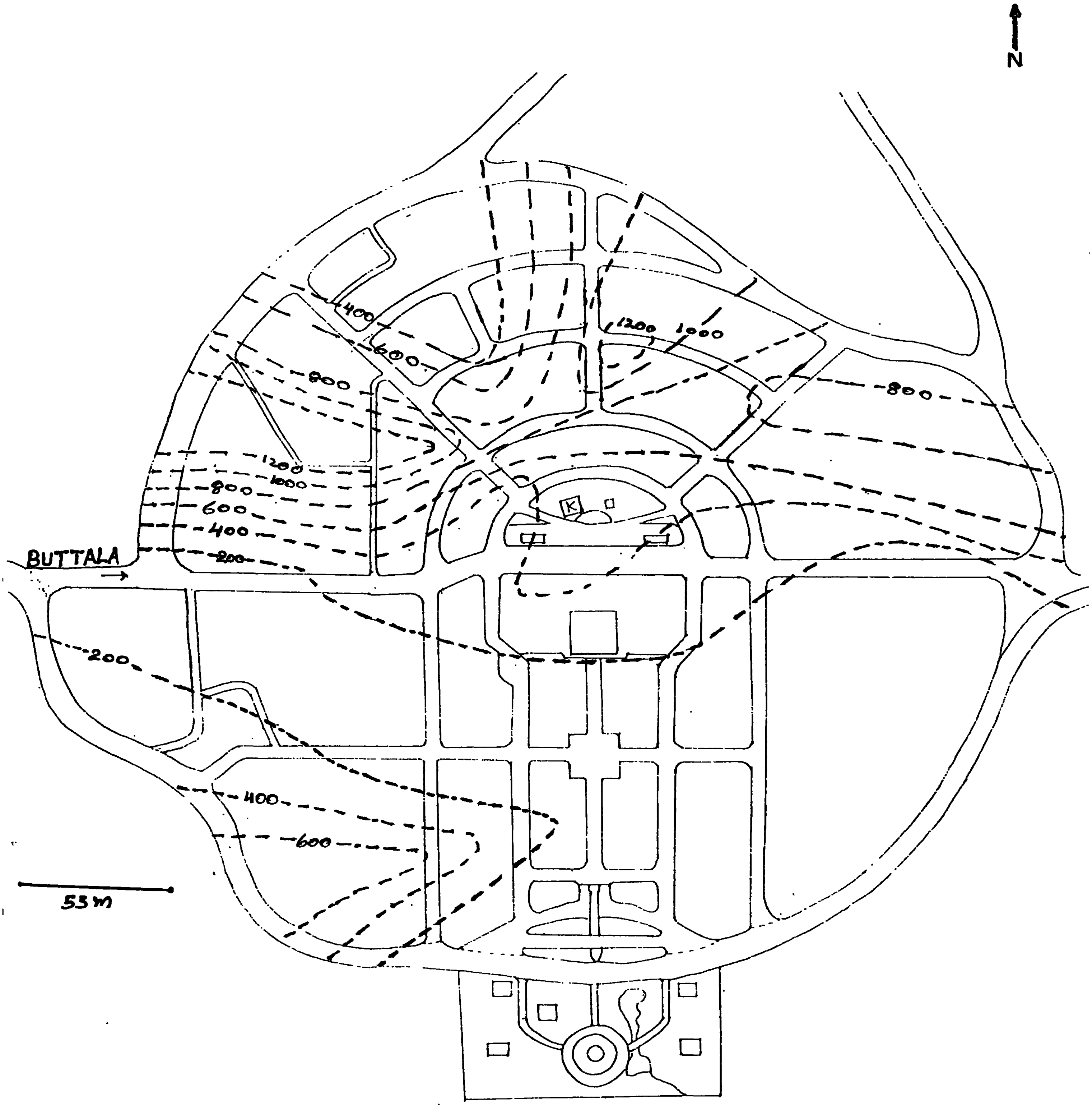


Fig 5.2 Resistivity Contour map of the area

4.2 RESISTIVITY SOUNDING

Figure 5.2.1 to 5.2.9 illustrates the resistivity sounding profiles obtained from the selected location. Table 5.1 summarizes the results obtained from their profiles. In most of locations, three main geological layers are indicated, namely, top soil layer, Highly weathered overburden and the Hard rock, with respect to the resistivity values.

In generally top soil layers and highly weathered zone is indicated by low to moderate resistivity values (5-500 ohm m) depending on the content of moisture. The high resistivity values represent the hard bedrock layers. However when the bedrock is highly fractured or weathered, the resistivity values drops indicating the occurrence of groundwater aquifers.

Table 4.1 Identified Subsurface Layers, their thickness and resistivity.

Profile number	Sounding number	Layer numbers	Apparent resistivity	Depth (m)	Thickness (m)	Possibility	Rehability
EP-01	ES-01	1	174	0.9	0.9	Top soil	
		2	90	8.1	7.2	Highly weathered	Suitable for dug wells
		3	1700	below 8.1		Hard rock	
	ES-02	1	170	1.7	1.7	Top soil	Suitable for dug wells
		2	51	16.2	14.5	Highly weathered	
		3	6800	below16		Hard rock	
EP-02	ES-03	1	230	3	3	Top soil	Suitable for tube wells
		2	1150	24	21	Hard rock	
		3	115	below 24		Fracture zones	
EP-03	ES-04	1	240	2.6	2.6	Top soil	Suitable for dug wells and tube wells
		2	24	15.8	13.2	Highly weathered	
		3	4800	55	44.2	Hard rock	
		4	10	below 55		Fracture zones	

	ES-05	1	250	1.3	1.3	Dry soil	Suitable for tube wells
		2	75	2.5	1.2	Weathered zone	
		3	10000	14.5	11	Hard rock	
		4	92	25	10.5	Fracture zones	
		5	12000	below 25		Hard rock	
	ES-06	1	300	2	2	Top soil	Suitable for dug wells and tube wells
		2	580	5	3	Weathered zone	
		3	116	below 5		Fracture zones	
EP-10	ES-07	1	74	1.5		Wet soil	Suitable for dug wells and tube wells
		2	148	7.5	1.5	Weathered zone	
		3	37	below 7.5	6	Fracture zones	
EP-08	ES-08	1	525	1.9	1.9	Dry soil	Suitable for tube wells
		2	787	40	38.1	Hard rock	
		3	262.5	below 40		Fracture zones	
EP-09	ES-09	1	85	2.1	2.1	Wet soil	Suitable for dug wells
		2	170	13	10.9	Weathered zone	
		3	42.5	27	14	Fracture zones	
		4	1400	below 27		Hard rock	

RESISTIVITY SOUNDING ES-01

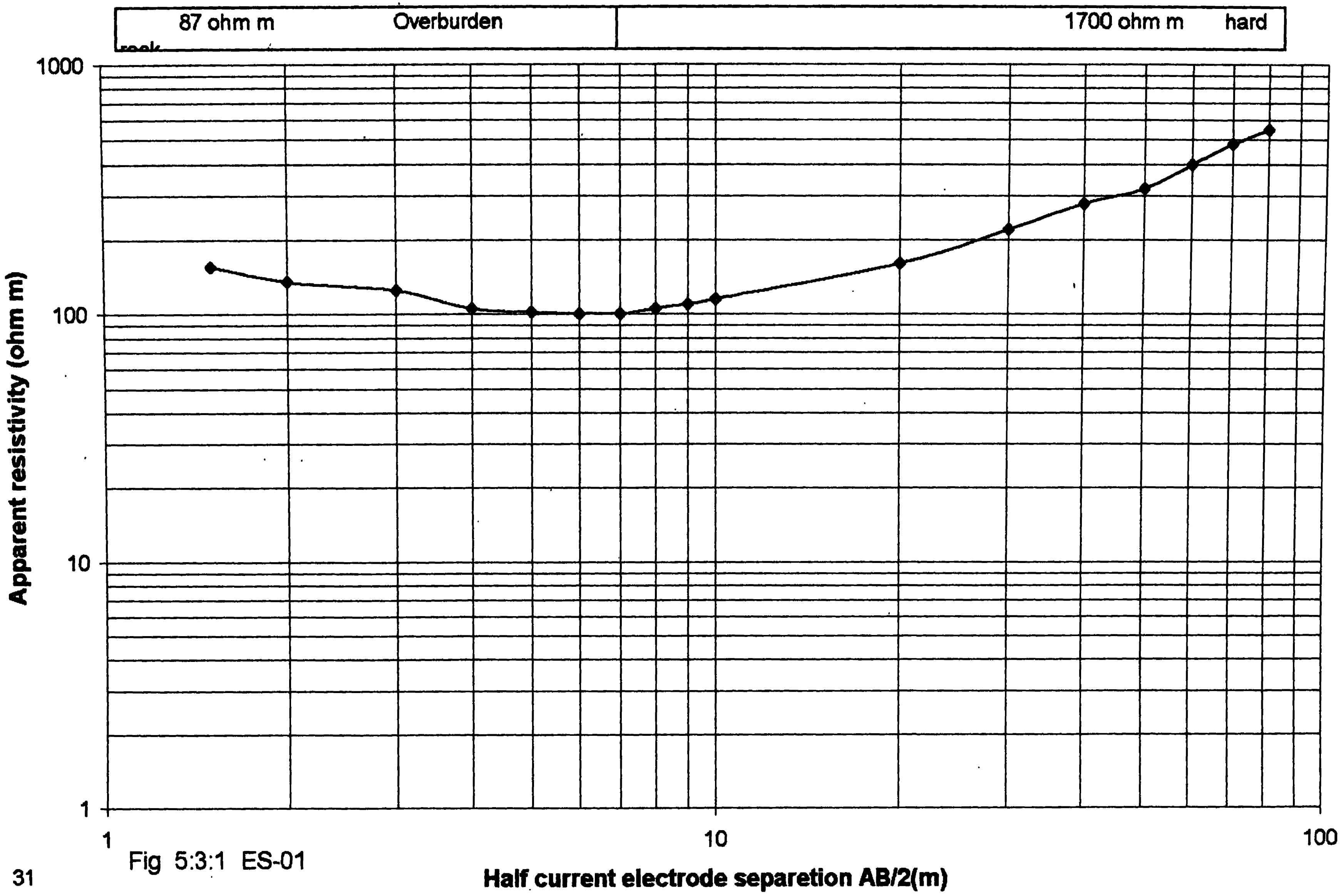


Fig 5:3:1 ES-01

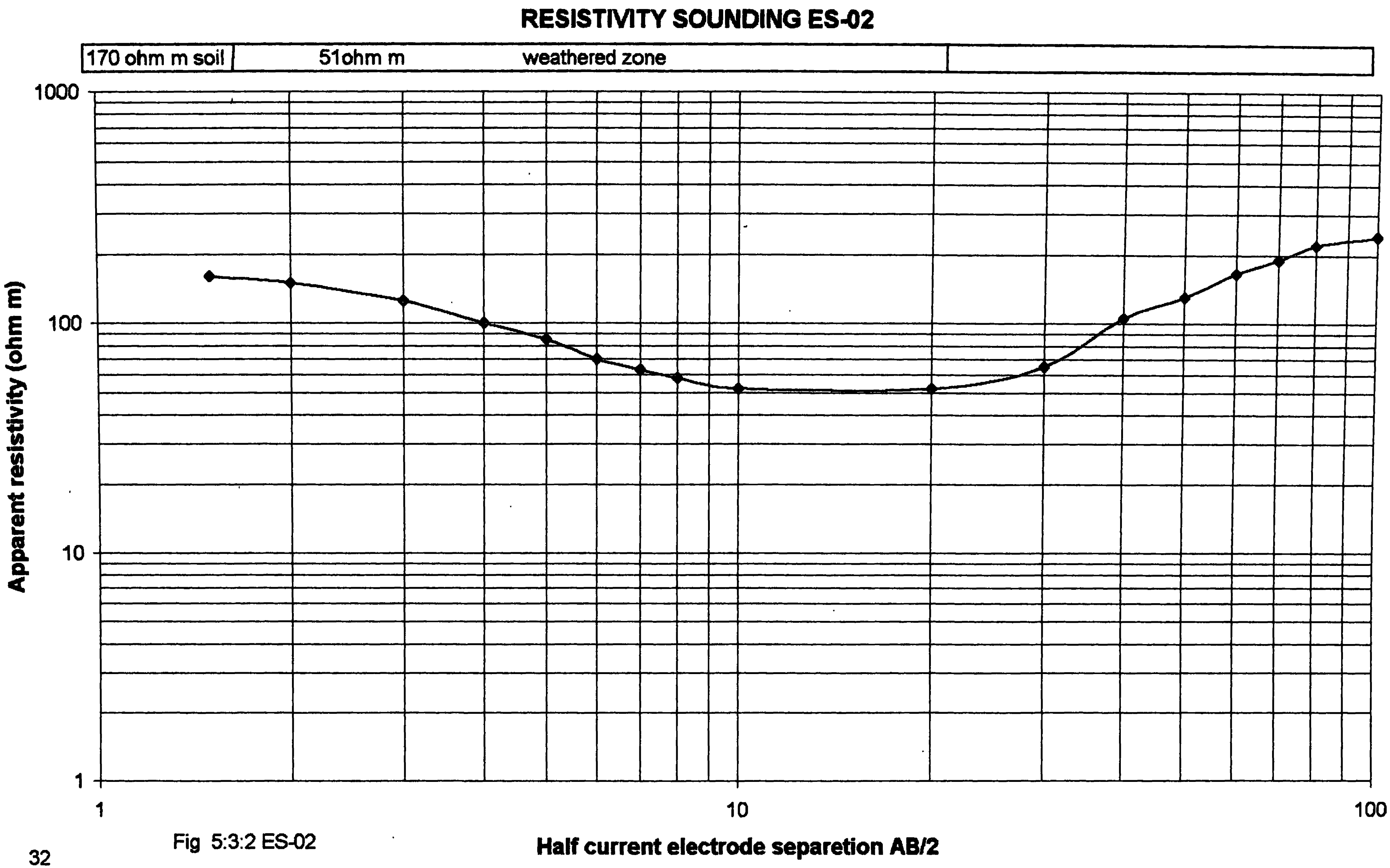
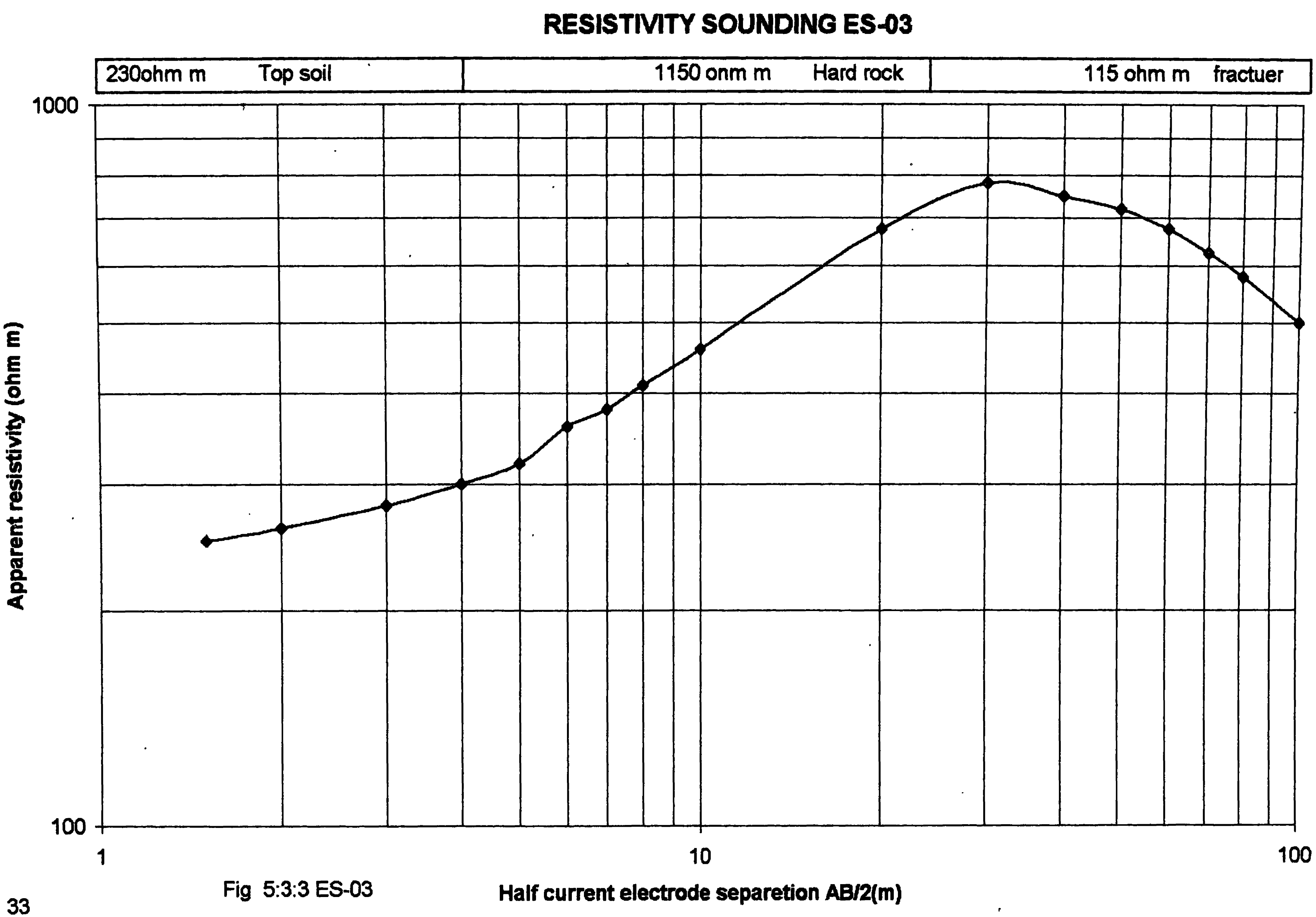

RESISTIVITY SOUNDING ES-02
170 ohm m soil
51ohm m
weathered zone
1000
100
10
1
Apparent resistivity (ohm m)
1
10
100
Half current electrode separetion AB/2

Fig 5:3:2 ES-02



RESISTIVITY SOUNDING ES-03
230ohm m Top soil
1150 onm m Hard rock
115 ohm m fractuer
1000
100
1
10
100
Apparent resistivity (ohm m)
Half current electrode separetion AB/2(m)

Fig 5:3:3 ES-03

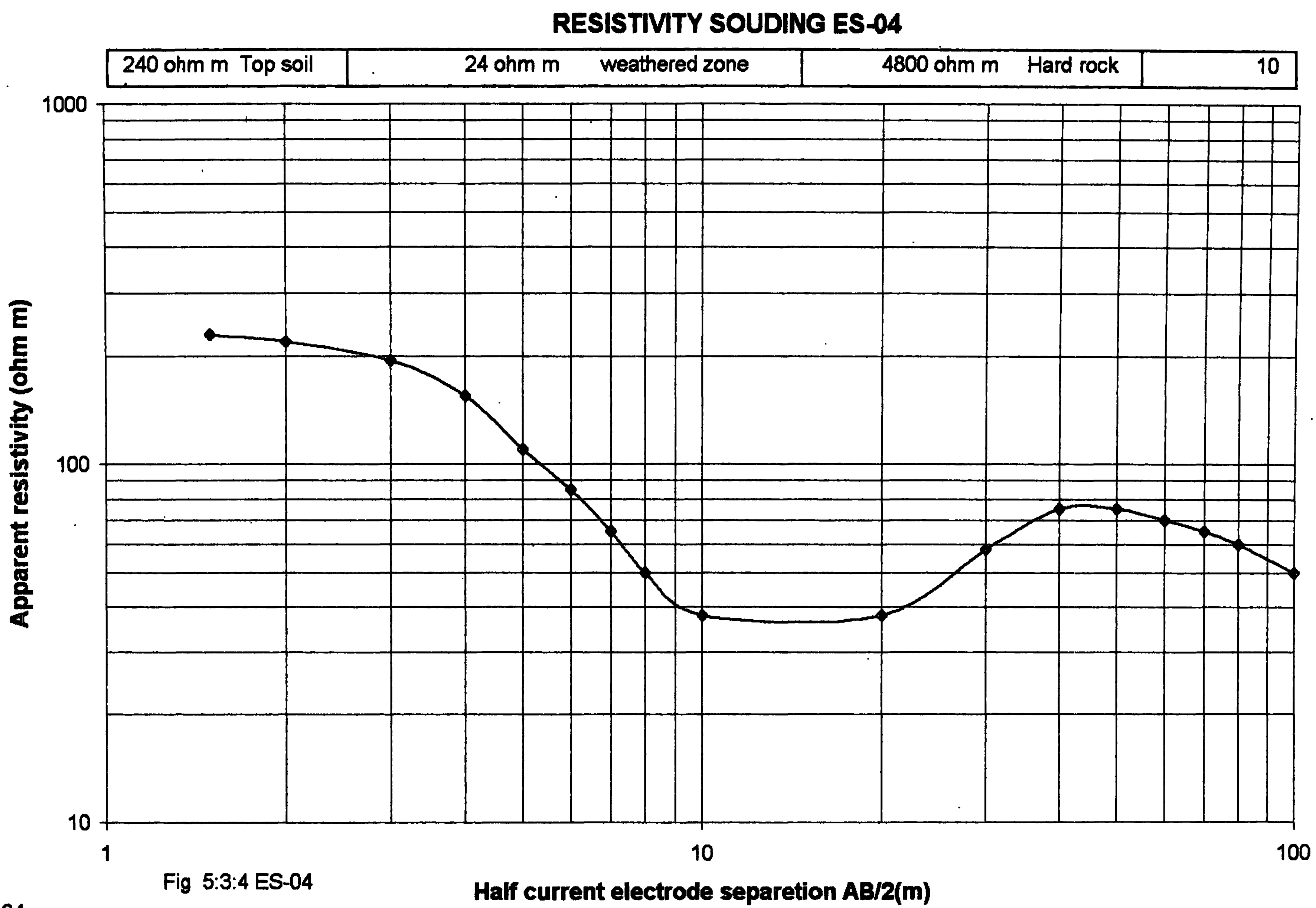

RESISTIVITY SOUDING ES-04
240 ohm m Top soil
24 ohm m weathered zone
4800 ohm m Hard rock
10
1000
100
10
Apparent resistivity (ohm m)
1
10
100
Half current electrode separetion AB/2(m)

Fig 5:3:4 ES-04

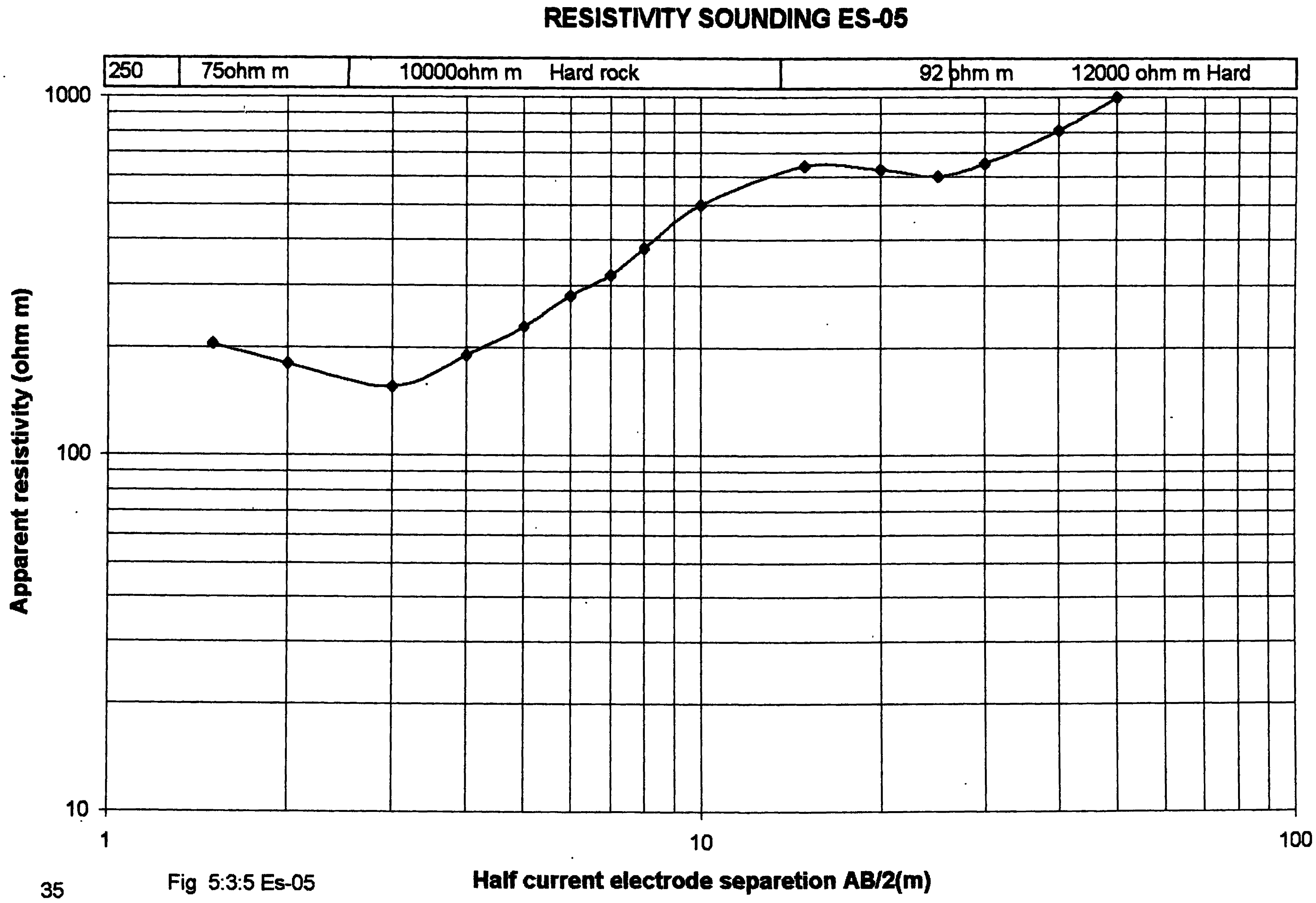

RESISTIVITY SOUNDING ES-05
250
75ohm m
10000ohm m Hard rock
92 ohm m
12000 ohm m Hard
1000
100
10
1
10
100
Apparent resistivity (ohm m)
Half current electrode separetion AB/2(m)

Fig 5:3:5 Es-05

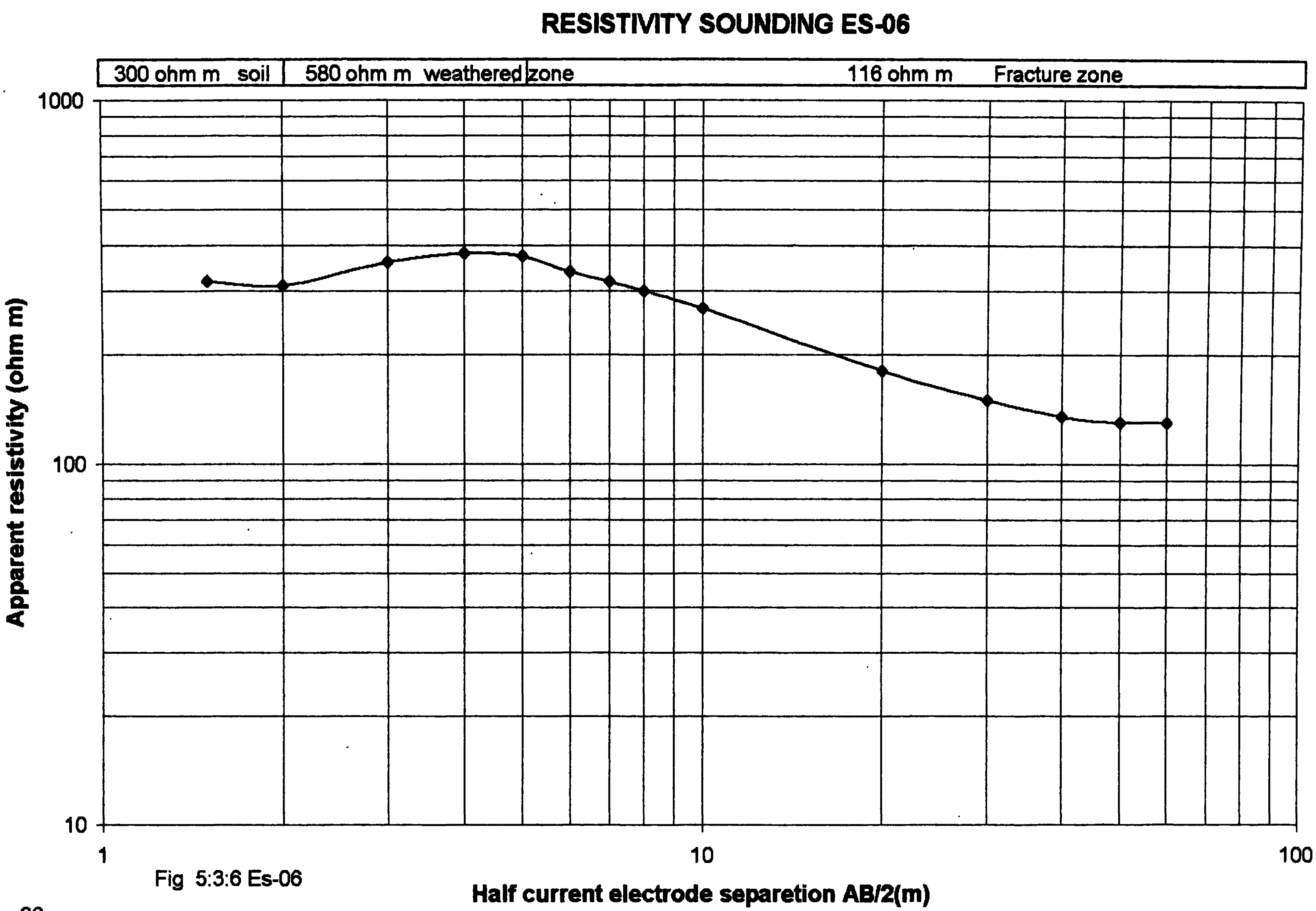
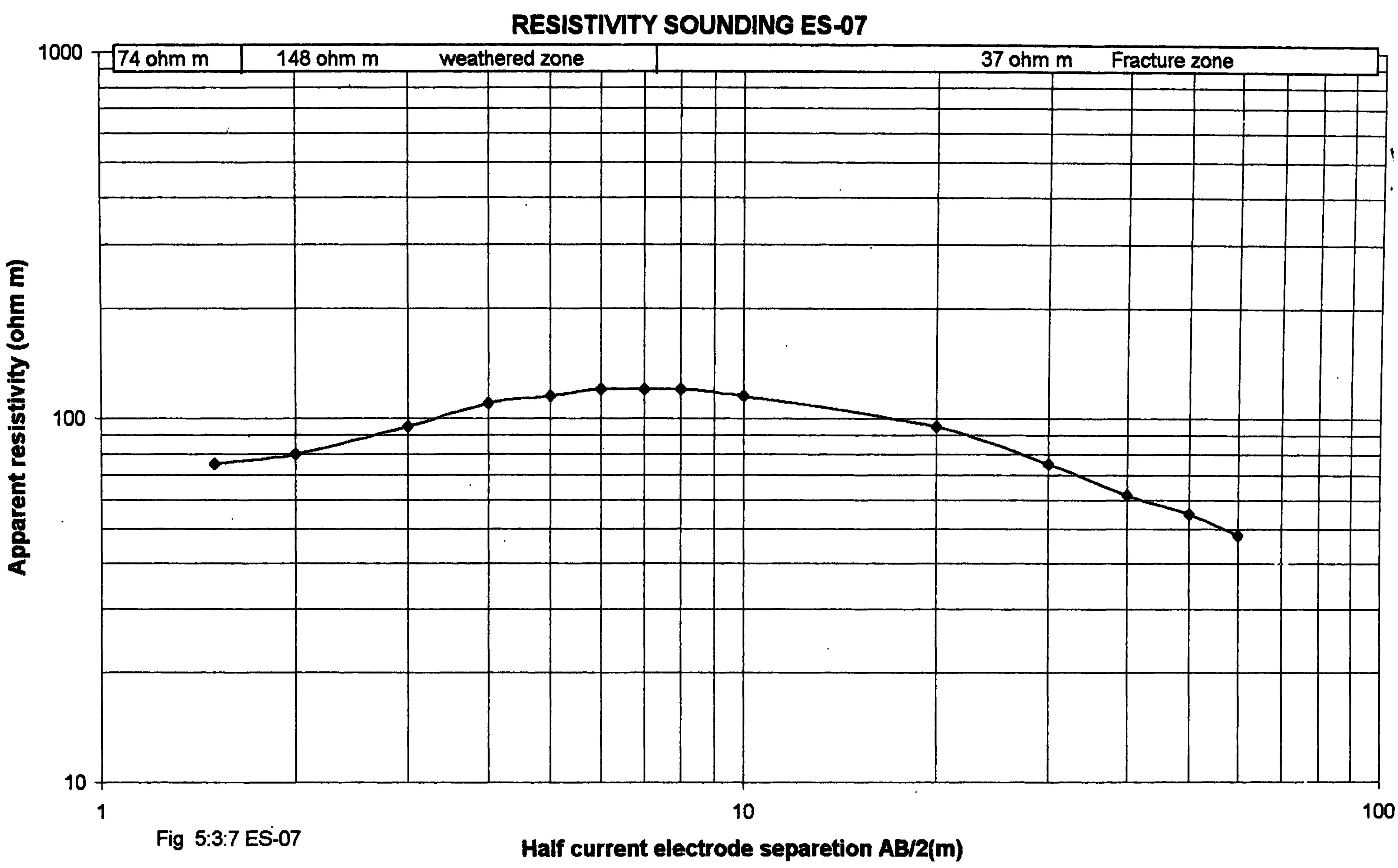

RESISTIVITY SOUNDING ES-06
300 ohm m soil
580 ohm m weathered zone
116 ohm m Fracture zone
Apparent resistivity (ohm m)
1000
100
10
1
10
100
Half current electrode separetion AB/2(m)

Fig 5:3:6 Es-06


RESISTIVITY SOUNDING ES-07
74 ohm m
148 ohm m
weathered zone
37 ohm m
Fracture zone
1000
100
10
Apparent resistivity (ohm m)
1
10
100
Half current electrode separetion AB/2(m)
Fig 5:3:7 ES-07

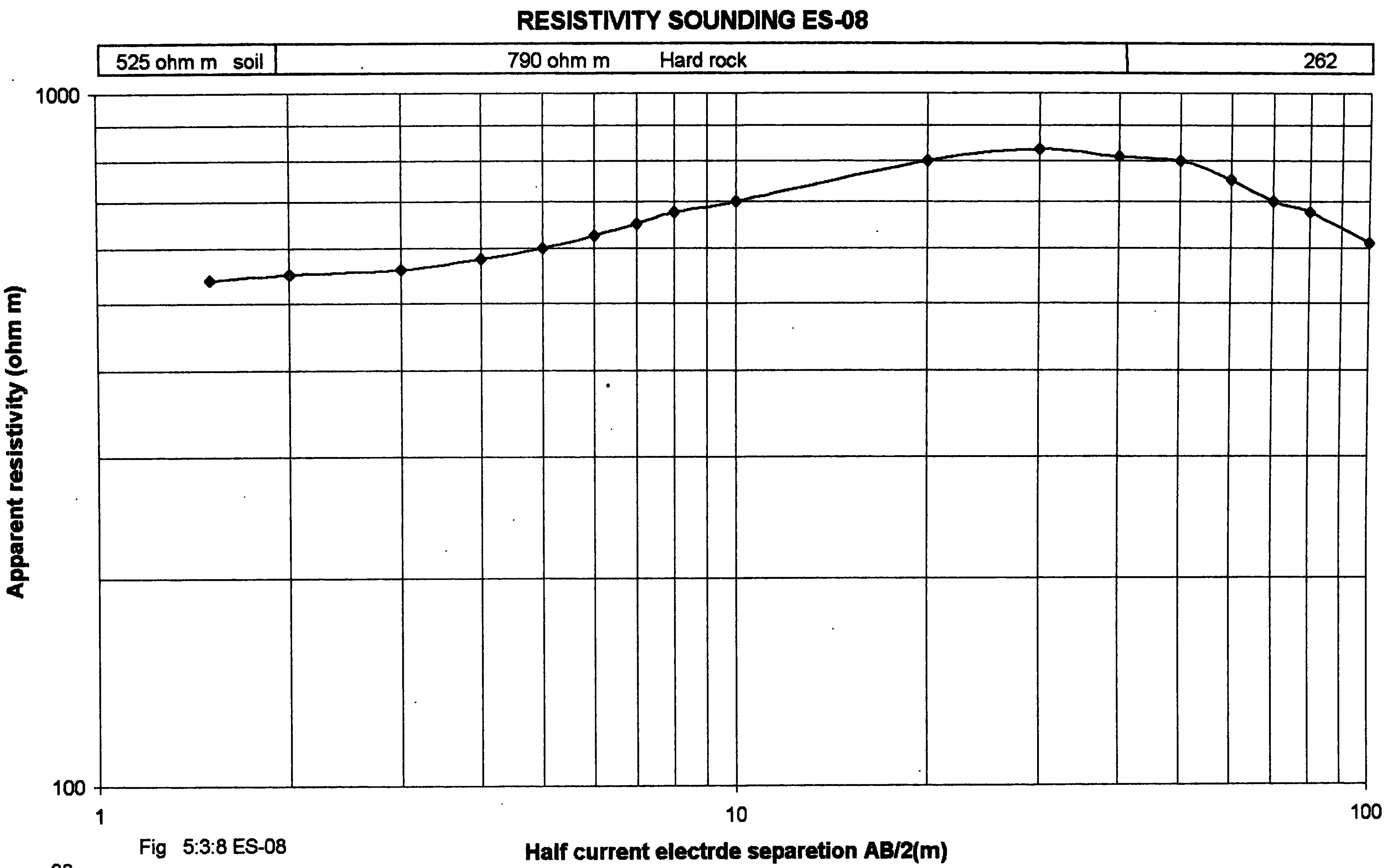

RESISTIVITY SOUNDING ES-08
525 ohm m soil
790 ohm m
Hard rock
262
1000
100
Apparent resistivity (ohm m)
1
10
100
Half current electrde separetion AB/2(m)

Fig 5:3:8 ES-08

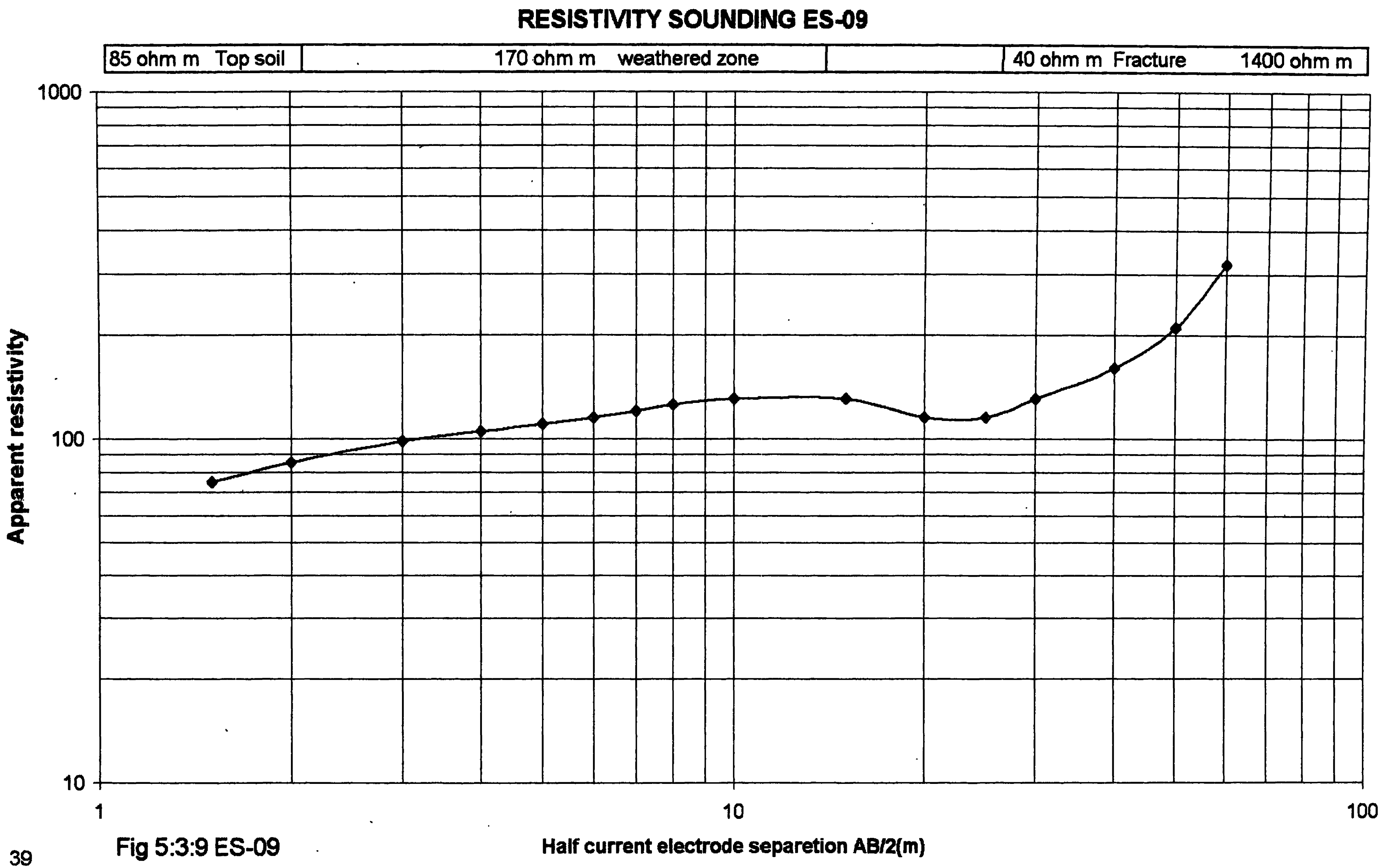
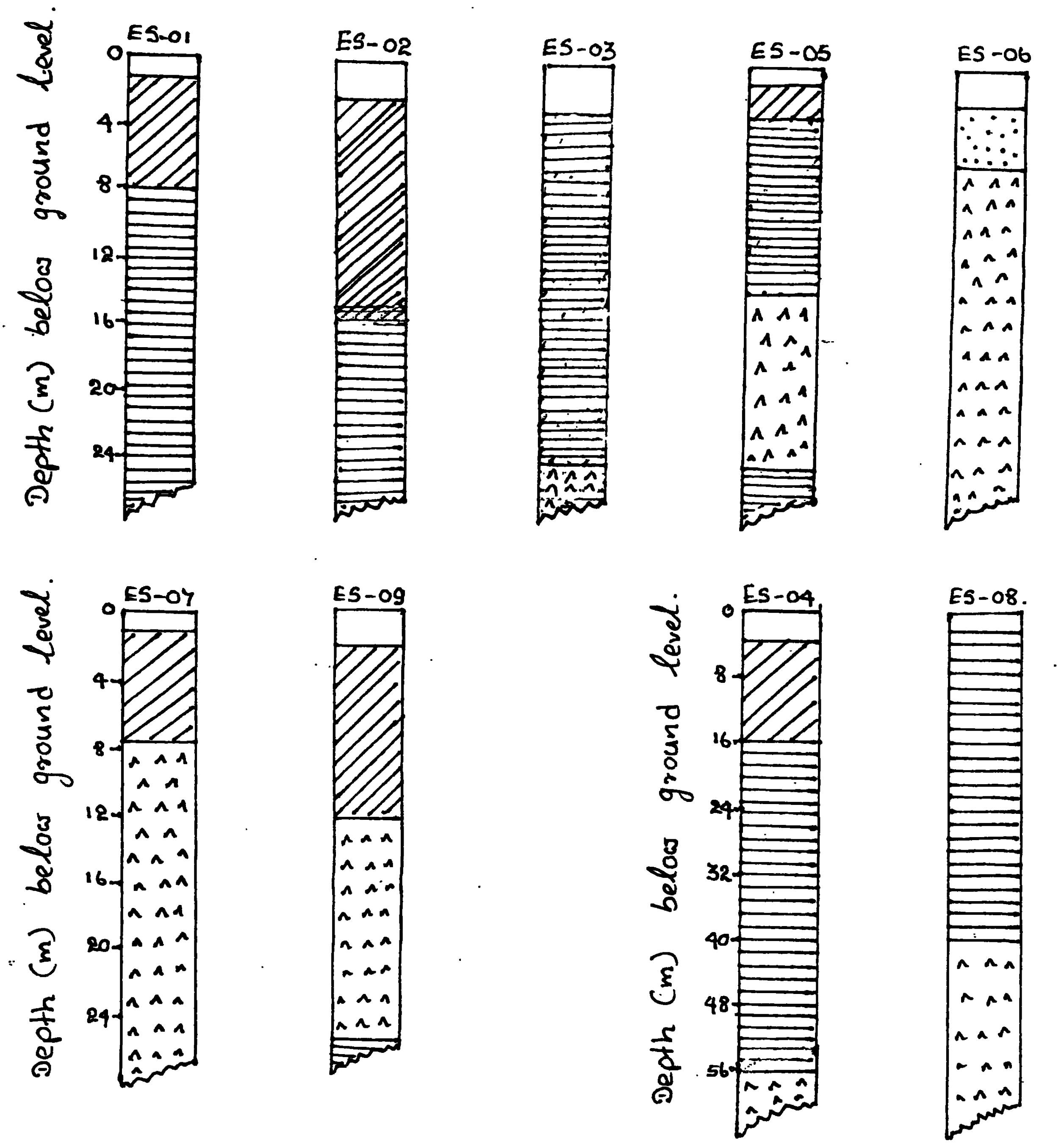

RESISTIVITY SOUNDING ES-09
85 ohm m Top soil
170 ohm m weathered zone
40 ohm m Fracture
1400 ohm m
Apparent resistivity
1000
100
10
1
10
100
Half current electrode separetion AB/2(m)

Fig 5:3:9 ES-09



Legend		Observed resistivity
☐	Top soil or completely weathered rock	5 - 1000 ohm m
▨	Highly/moderately weathered rock	5 – 150 ohm m
⁙	Slightly weathered rock	150 - 300 ohm m
^^^	Fracture, joint or weathered zone	5 – 300 ohm m
☰	Fresh rock	>500 ohm m

Fig. 5 4 vertical geological profiles of sounding location based on sounding data

5.3. Groundwater Potential of the study area

The study area is a flat and slightly undulating land. The ground elevation is high towards North and West. A seasonal stream crosses the study area and it flows in East-West direction parallel to the central road. The central area of the campus premises is low in elevation and elevation increases towards the Northern and Southern parts. Most parts of the area is covered with a soil layer and only few outcrops area present at some locations. Figure 4.3. Illustrates the cross section of the study area. It indicates that thickness of the soil layer vary when moving away from the stream. It also appears that the thickness of the soil layer depends on the ground elevation.

The resistivity values of the soil layer also vary with the distance from the stream. The soils close to the stream contain higher moisture and therefore the resistivity values are low. The soils far from the stream have low moisture content and hence the resistivity values are high. For example ES-08 location has about 500-ohm m of resistivity. According to above observation resistivity method is proven to be very suitable for investigating water-bearing formations.

The vertical geological profiles indicate that weathered zones located below the top soil layers also vary in thickness. When the ground elevation is low, the thickness of the weathered overburden is high. ES-02, 03, and 04 locations have more than 16m thick weathered layer. Locations with high ground elevation, the thickness of the overburden is low. For example ES-05 location has an overburden Of about 1m thick and ES-08 location does not have any weathered rock below soil.

For the contraction of dug wells, condition of the weathered zones is important. If the weathered zone is deep, the location is more favorable for dug wells. In the central part of the study area, close to the stream, thickness of the weathered zones as well as the moisture content of the weathered zone is fairly high. Therefore the area close to the stream can be recommended to constructing dug wells. A dug well, situated in this area has high water yielding capacity through out the year.

Although ES-06 and 07 locations do not show deep weathered zones, there are fractures, joint or weathered zones below the weathered overburden. Therefore, these locations are also suitable for dug wells. This situation can be seen in many parts and therefore more than 60 present of the study area appear to be suitable for constructing dug wells.

According to the vertical sounding cross-section (fig..4.3), depth to bed rock varies with distance from the stream and also depending on the ground elevation. The main reason could be the weatherbility and erosion of the hard rock. There are few outcrops found close to the ES-05 and 08 locations and the sounding also shows that the hard rock is located close to the ground surface.

The ES-04, 05,06,07,08 and 09 locations show presence of fractures joints or weathered zones in the bedrock. These zones do not correlate with stream, ground elevation, or any other surface features.

According to the data about 60 percent of study area is suitable for constructing tube wells too. Some locations are suitable for both dug wells and tube wells because there is low resistivity from surface to depths. The low resistivity zones in the hard rock shows an increasing depth towards the Western part of the area. This could be due to dipping of the fracture, weathered or jointed zones in that direction.

The present study covers only a depth of about 80m below the ground level. Presence of the low resistivity zones below this depth could not be detected with the used electrode configuration.

In general, the present study reveals that the Geological formation in the study area has a succession of top soil, weathered rock in the middle and hard rock at bottom. The deep and wet overburden is present covering about 60 percent of the area (fig..4.4) and is suitable for constructing dug wells. 60% of the area is also suitable for tube well construction inclusive of a considerable part of the area suitable for dug wells (fig..4.3).

The present study further reveals that almost entire study area can be considered as suitable for development of ground water either by dug wells or by tube wells.

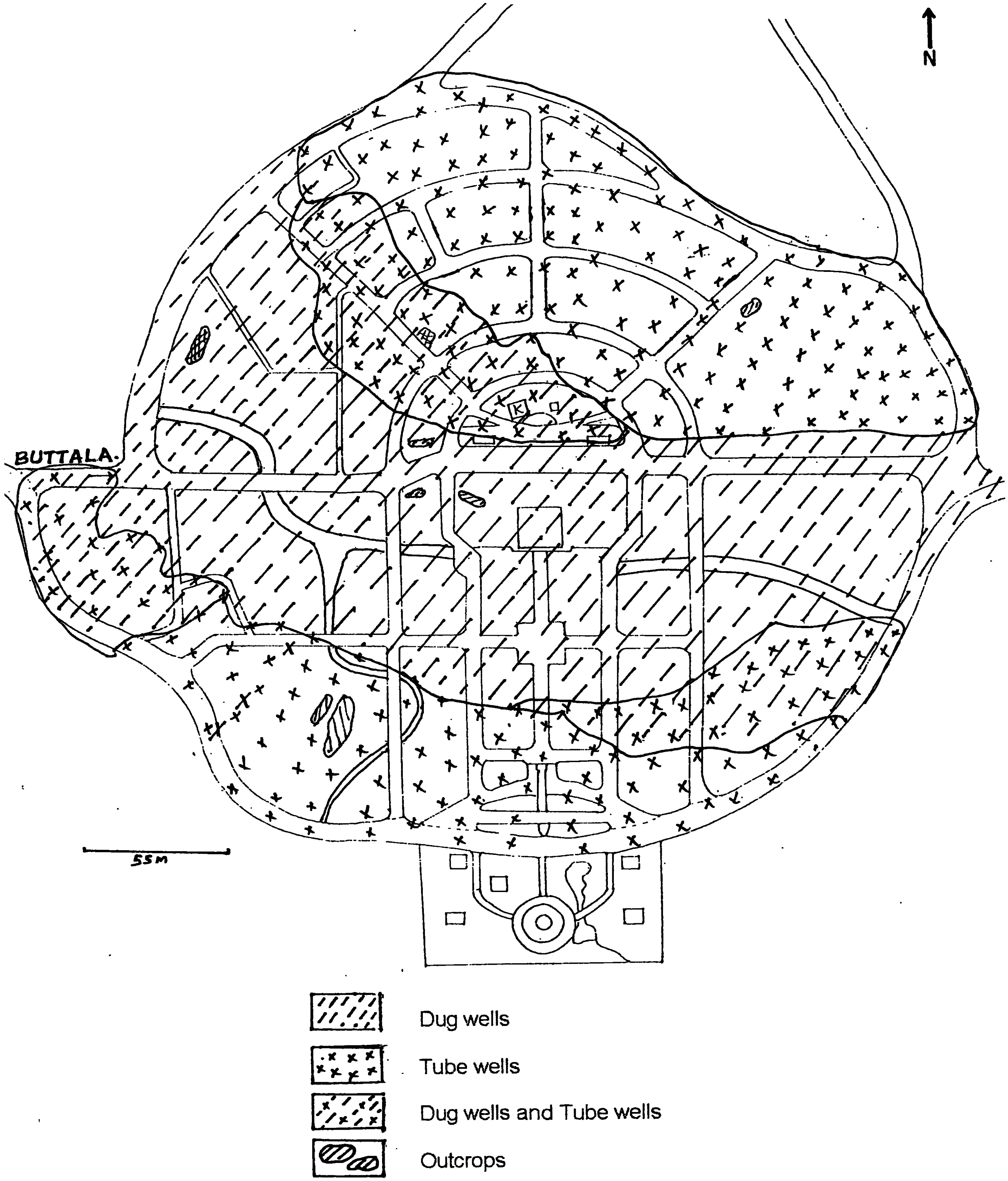


Fig ..5.5 Map showing the location for suitable dug wells and tube wells

CHAPTER 6

CONCLUSIONS

Following conclusion can be drowning based on the finding of the project study.

1. Geo-electrical resistivity profiling provides information about hydrological condition of the study area and this was further confirmed by geo-electrical resistivity sounding.

2. Result of the resistivity profiling data shows remarkable horizontal variation of resistivity with the thickness and soil moisture of top layers and the ground elevation of the study area.

3. Hydrogeologically important tectonic lineaments and /or deeply weathered zones could be identified as comparatively low resistivity zones in the resistivity profiles. Present investigation showed that about 60% of the study area is suitable for dug well construction. About one third of this zones also suitable for constructing tube wells. The remaining 40 present of the area is suitable for tube wells but not for dug wells mainly because of shallow overburden conditions and that the fracture zones are situated deep in the hard rock.

4. A very clear distinction between the overburden and the underlying fresh or slightly weathered bedrock could be made on the basis of the resistivity values.

5. The thickness and character of overburden inferred from resistivity sounding were consistent with that shown in land features.

6. According to the resistivity sounding data and also from filed evidence, there may be a thick soil layer and thick weathered zones close to the stream. However, test drilling may be required to confirm this assumption.

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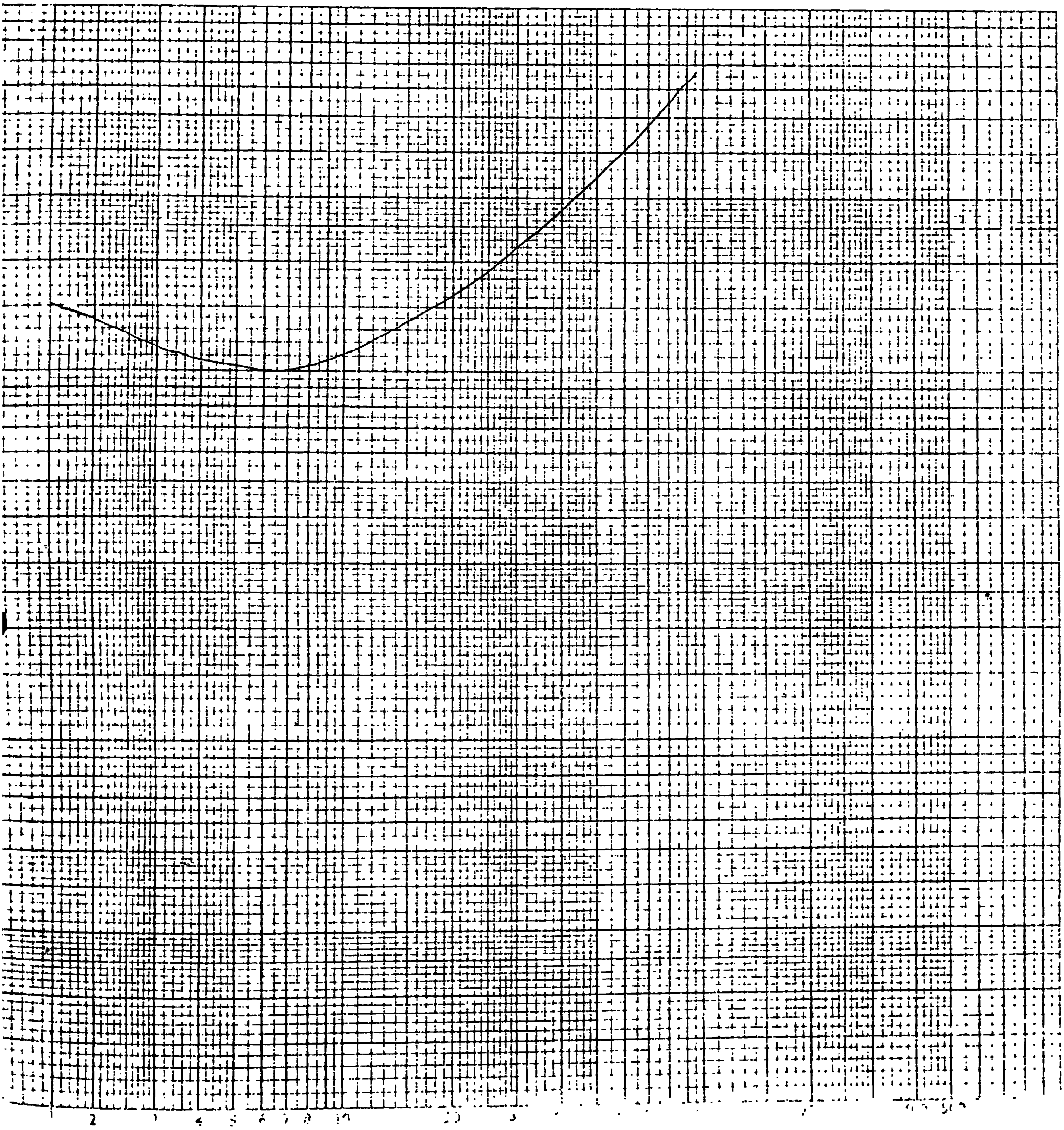
Vitanage, P.W., 1985: Tectonics and mineralization of Sri Lanka. Geol. Soc.

APPENDESES

GEOELECTRICAL SOUNDING

District. Monaragala.	Village: Buttala.
Profile no: ES-01	Date:
Measured by: P:S:K:P:	Ground elevation:
Map: Wallavaya.	Coordinates:
AC ☐ DC ☐ Schlumberger electrode array	

87 Ωm	1700 Ωm.

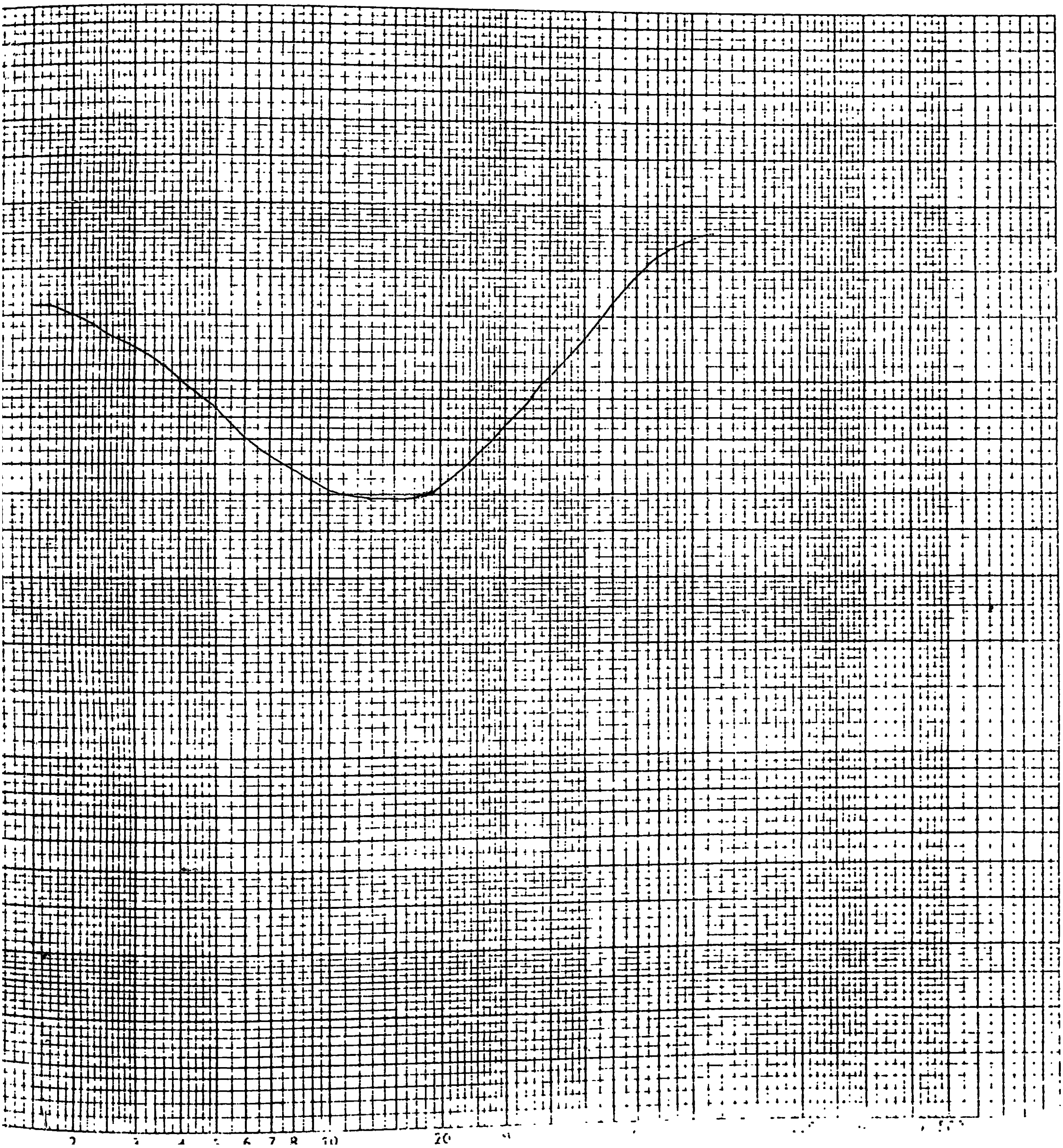


GEOELECTRICAL SOUNDING

District: Monaragala.	Village: Buttala.
Profile no: ES-02	Date:
Measured by: P.S.K.P.	Ground elevation:
Map: Wallavaya.	Coordinates:

AC ☐ DC ☐ Schlumberger electrode array

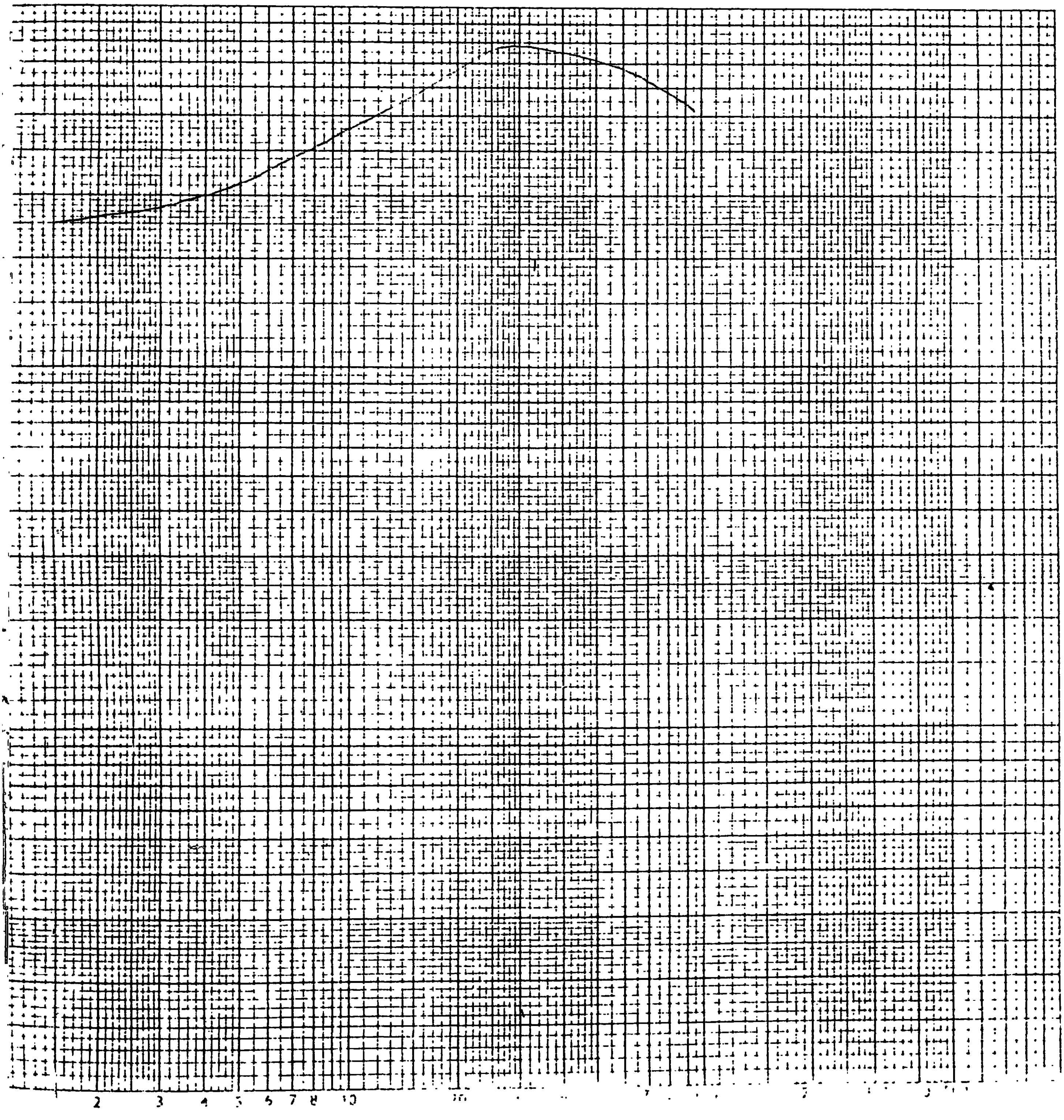
70-Ωm	51 Ωm.	6800 Ωm.



GEOELECTRICAL SOUNDING

District: Monaragala.	Village: Buttala.
Profile no: ES - 03	Date:
Measured by: P. S. K. P.	Ground elevation:
Map: Wallavaya.	Coordinates:
AC ☐ DC ☐ Schlumberger electrode array	

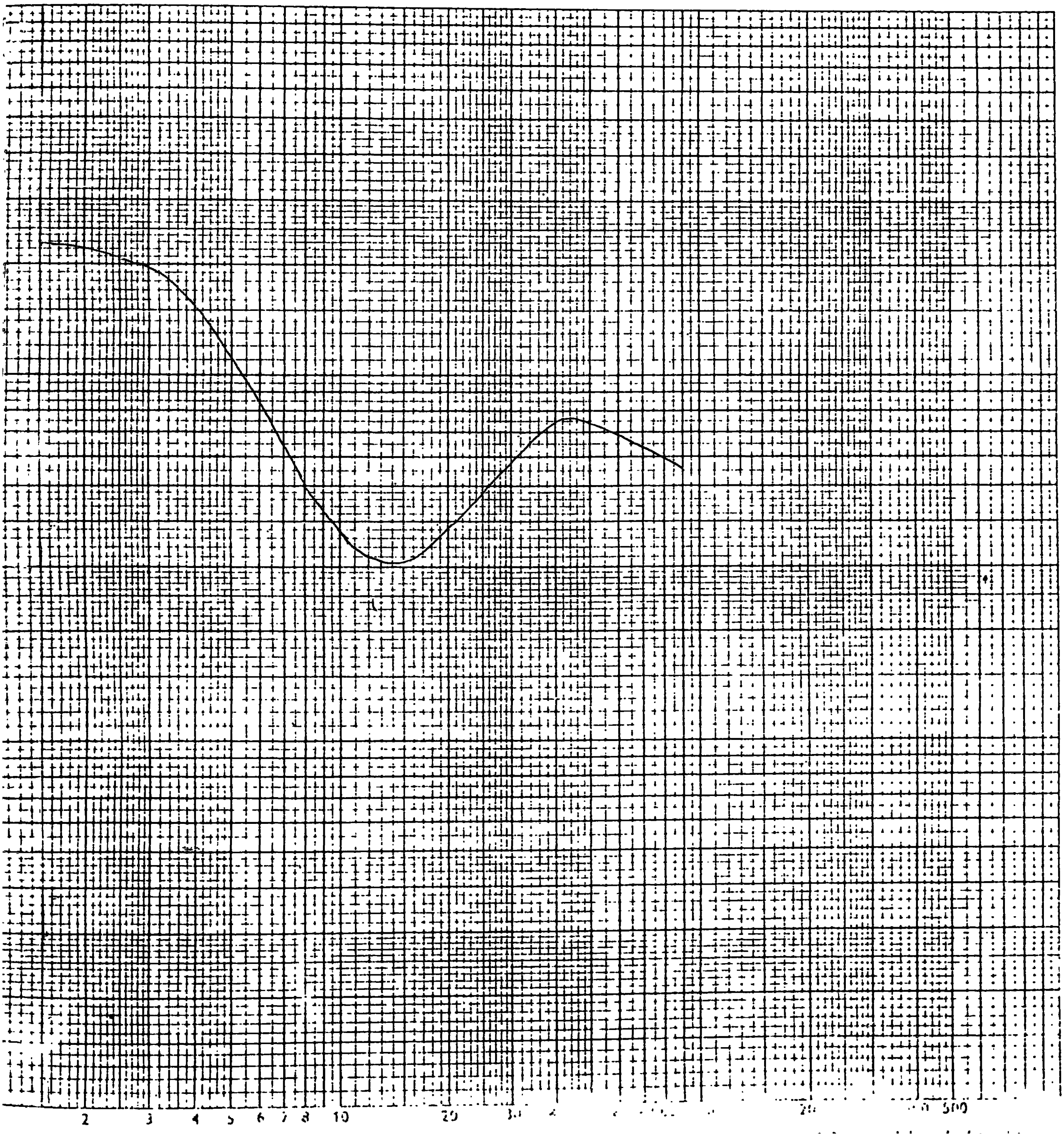
230 Ωm	1150 Ωm	115 Ωm



GEOELECTRICAL SOUNDING

District: Monaragala.	Village: Buttala.
Profile no: ES - 04	Date:
Measured by: P.S.K.P.	Ground elevation:
Map: Wallavaya	Coordinates:
AC ☐ DC ☐ Schlumberger electrode array	

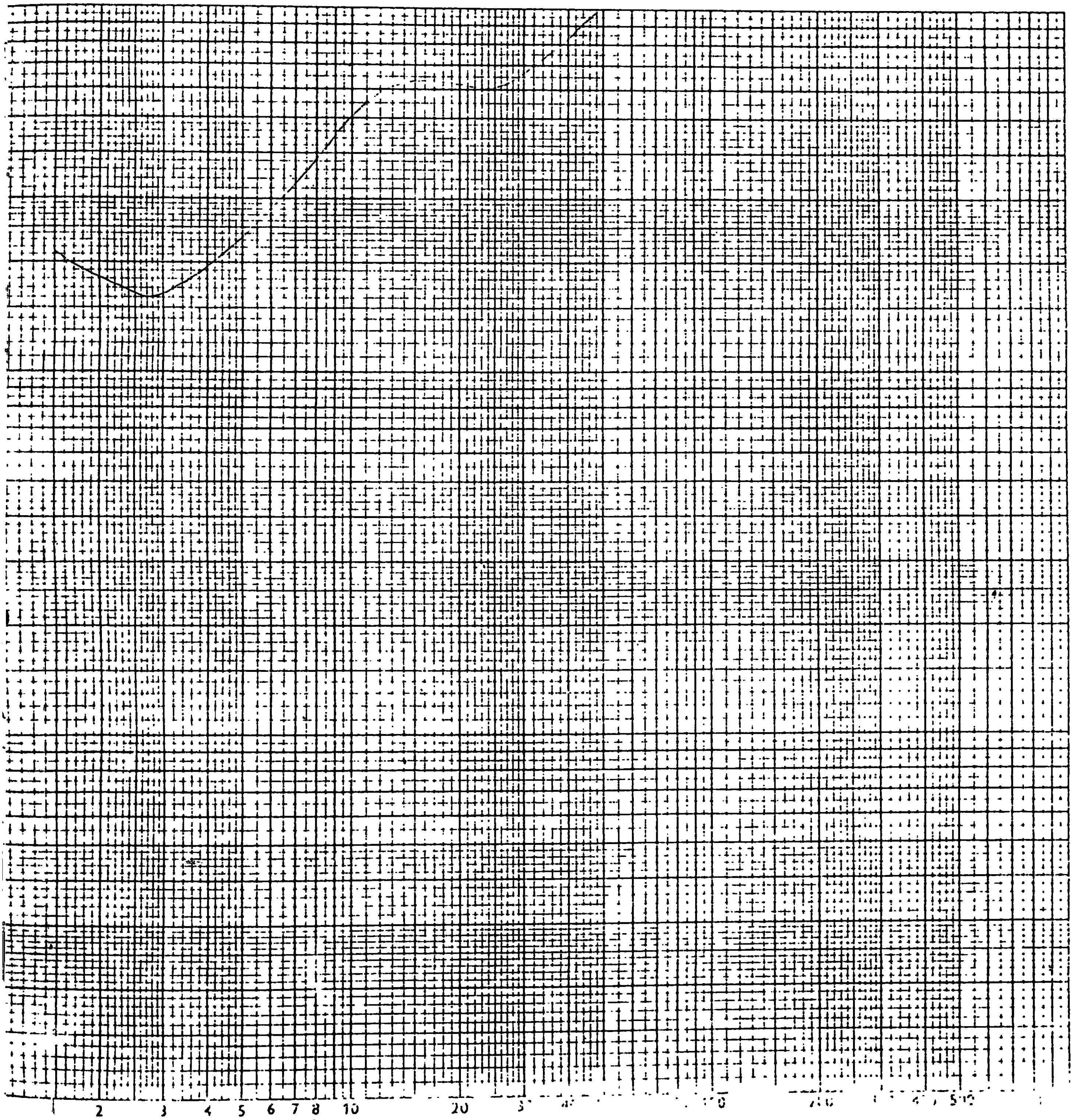
240 Ωm	24 Ωm	4800	10.2



GEOELECTRICAL SOUNDING

District: Monaragala	Village: Buttala.
Profile no: ES-05	Date:
Measured by: P.S.K.P.	Ground elevation:
Map: wallavaya	Coordinates:
AC ☐ DC ☐	Schlumberger electrode array

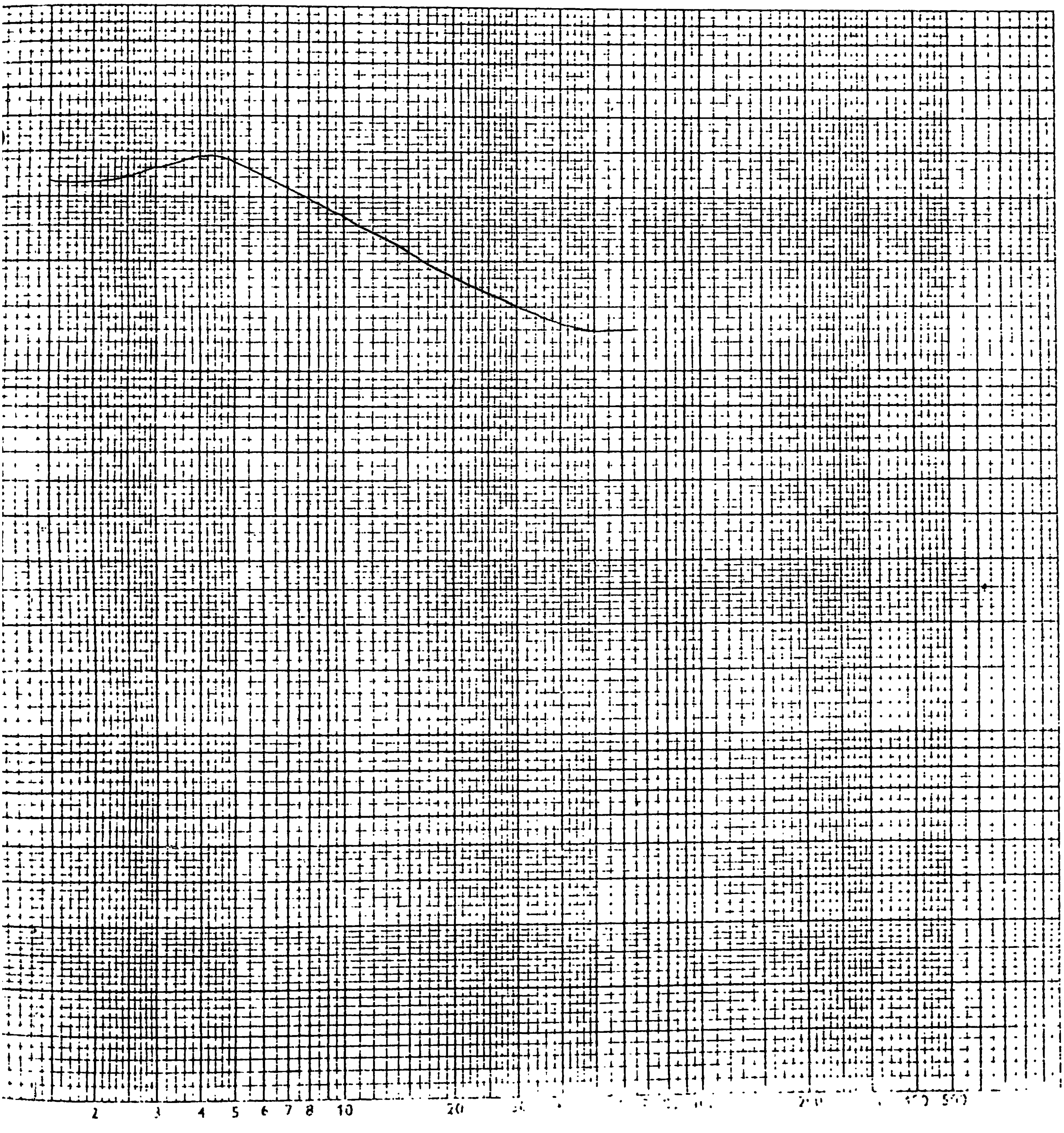
75	10,000 Ωm	92	12000 Ωm



GEOELECTRICAL SOUNDING

District: Monaragala.	Village: Buttala.
Profile no: ES-06.	Date:
Measured by: P.S.K.P.	Ground elevation:
Map: wallavaya.	Coordinates:
AC ☐ DC ☐ Schlumberger electrode array	

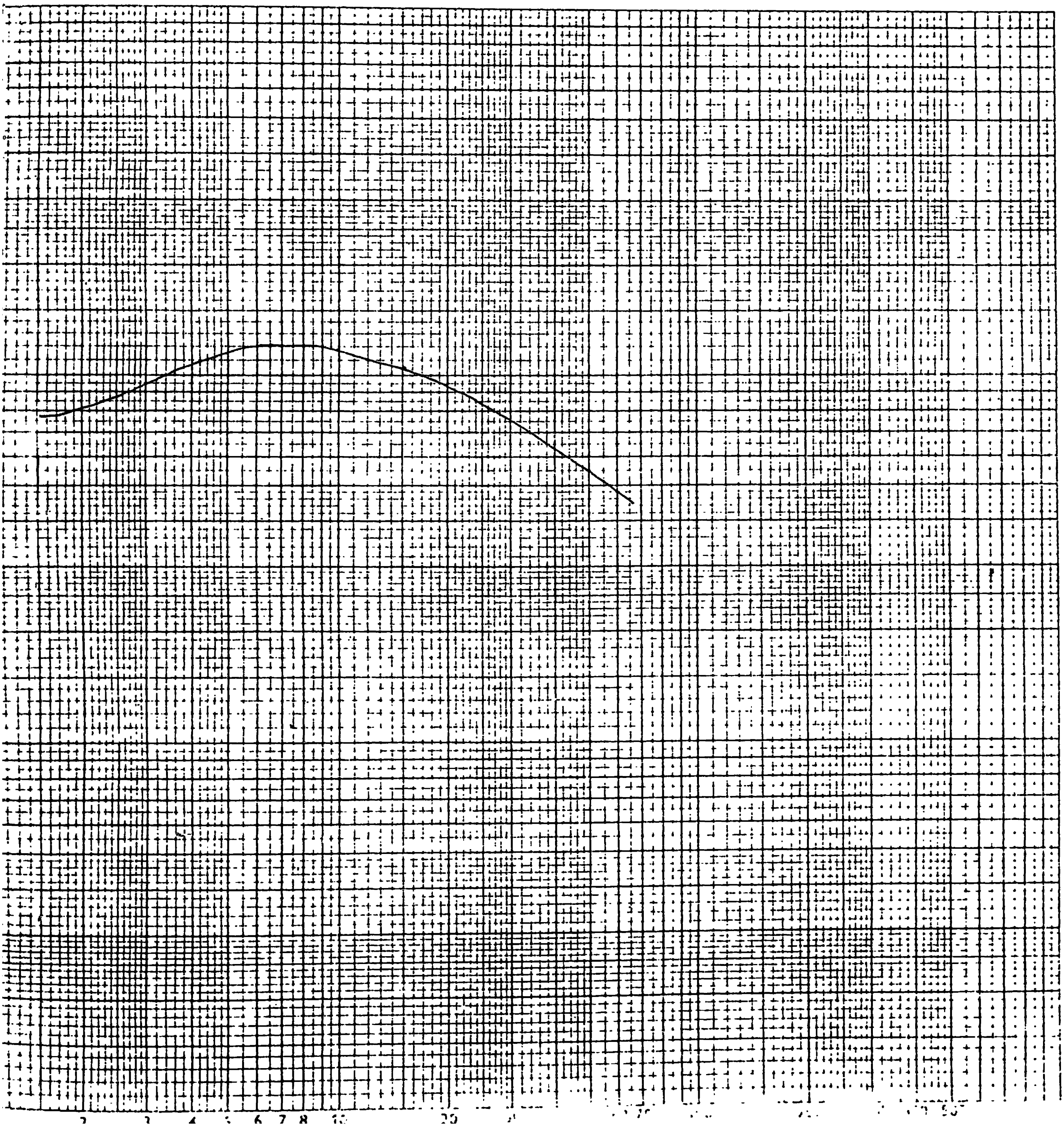
300 Ωm	580 Ωm	116 Ωm



GEOELECTRICAL SOUNDING

District: Monaragala.	Village: Buttala.
Profile no: ES-07	Date:
Measured by: P.S.K.P.	Ground elevation:
Map: wallavaya.	Coordinates:
AC ☐ DC ☐ Schlumberger electrode . array	

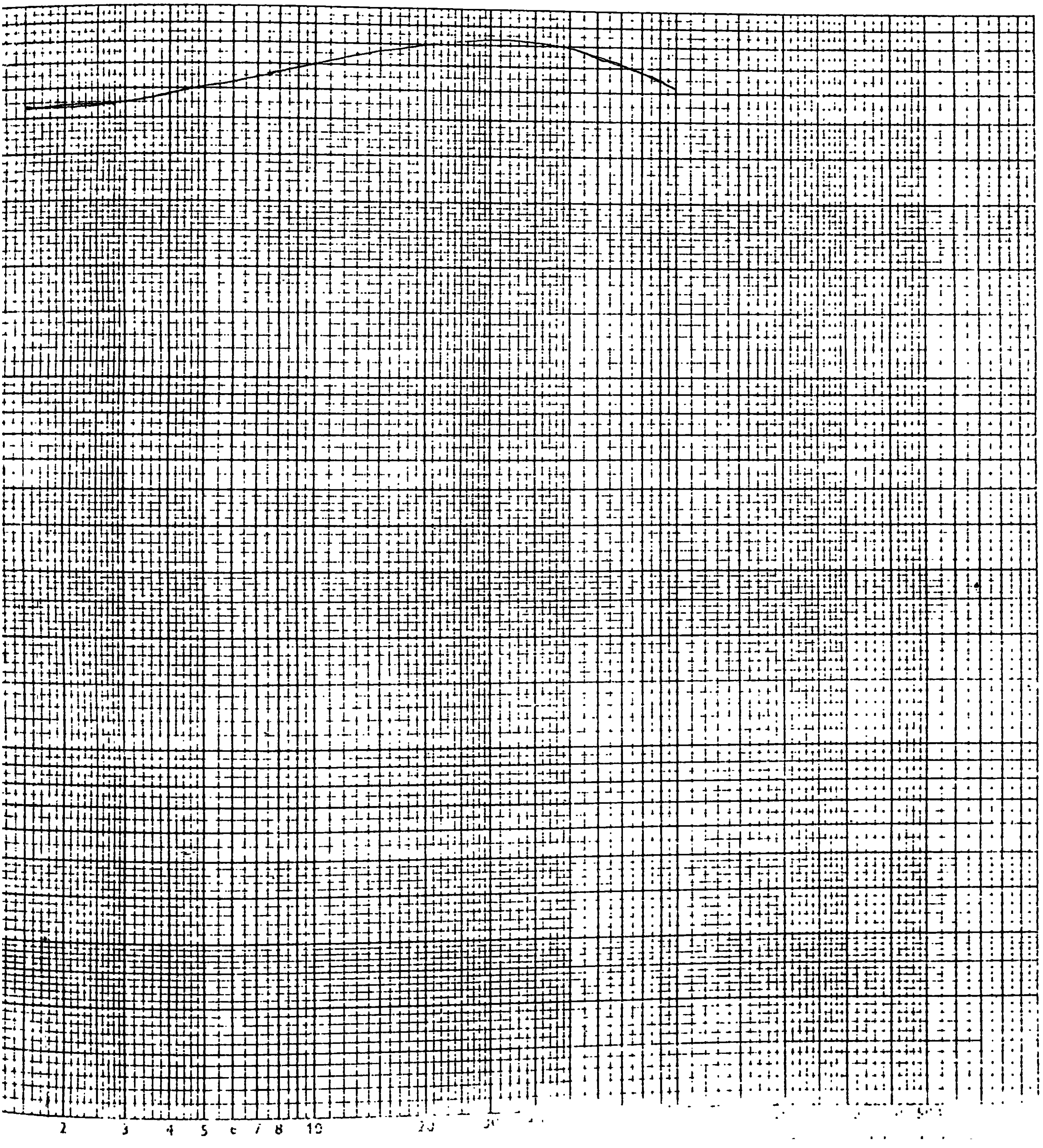
4 Ωm	148 Ωm	37 Ωm



GEOELECTRICAL SOUNDING

District: Monaragala.	Village: Buttala.
Profile no: ES-08.	Date:
Measured by: P.S.K.P.	Ground elevation:
Map: wallavaya.	Coordinates:
AC ☐ DC ☐ Schlumberger electrode array	

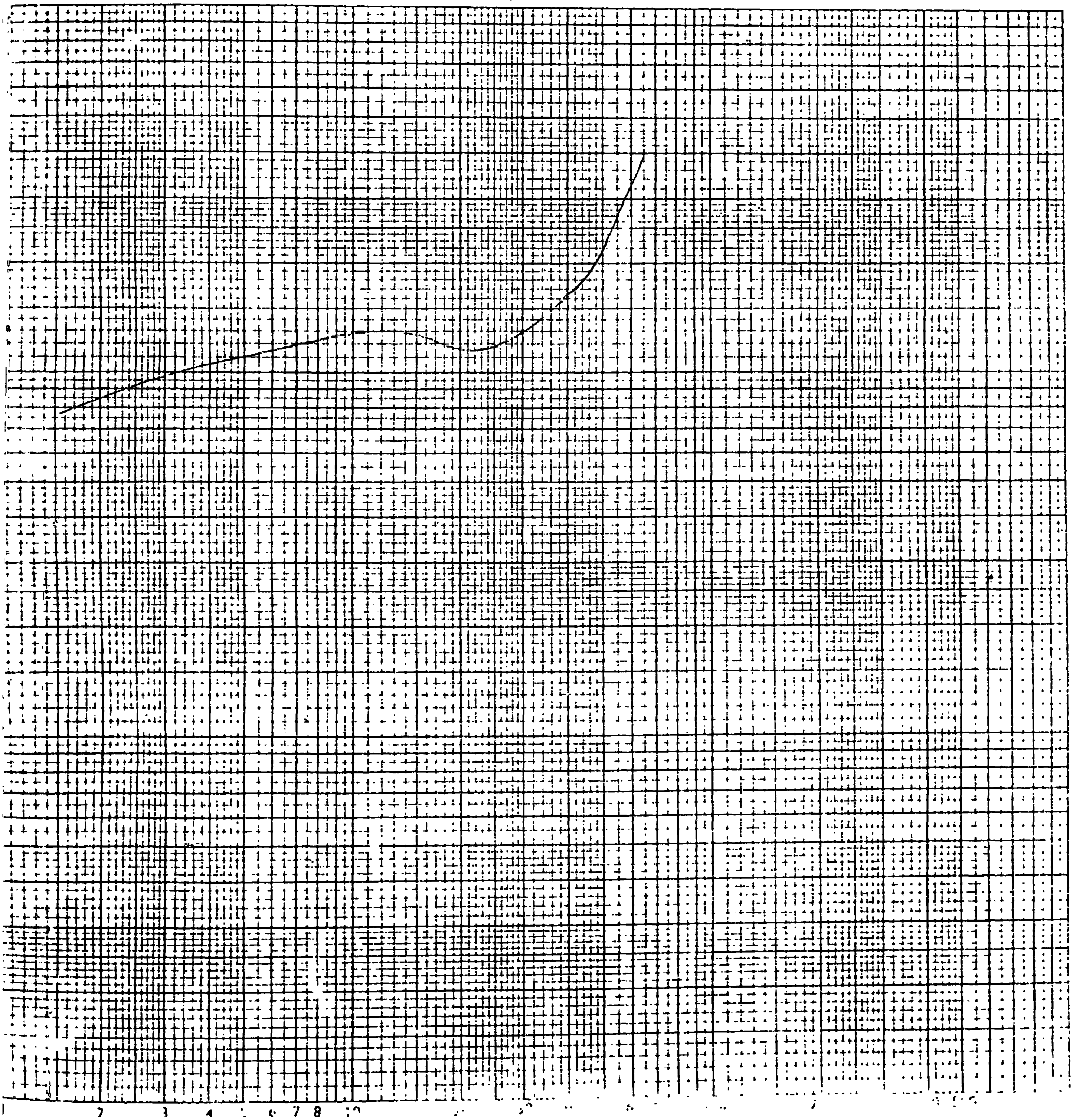
5 Ωm	787.5 Ωm	262.5 Ωm



ELECTRICAL SOUNDING

District: Monaragala.	Village: Buttala.
Profile no: ES - 09.	Date:
Measured by: P.S.K.P.	Ground elevation:
Map: Wallavaya.	Coordinates:
AC ☐ DC ☐ Schlumberger electrode array	

85 Ωm	170 Ωm	42.5 Ωm	1400 Ωm



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