GROUND WATER EXPLORATION IN BAUCHI STATE

A CASE STUDY OF AZARE TOWN

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August, 1998

GROUND WATER EXPLORATION IN BAUCHI STATE:

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BY

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A THESIS SUBMITTED TO THE GEOLOGY PROGRAMME, ABUBAKAR TAFAWA BALEWA UNIVERSITY, BAUCHI, IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF BACHELOR OF TECHNOLOGY (B. TECH.) IN APPLIED GEOLOGY.

· AUGUST, 1998.

APPROVAL PAGE

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DATE:----------

EXTERNAL EXAMINER: NAME:----------

SIGNATURE:----------

DATE:----------

QUOTATION

Go, my sons, buy stout shoes, climb the mountains, search the valleys, the deserts, the sea shores, and the deep recesses of the earth. Mark well the various kinds of minerals, note their properties and their mode of origin.

PETRIUS SEVERINUS (1571)

DEDICATION

This project is dedicated to my Father David Sara Sur. my Mother Polina David and my brother Yakubu David.

ACKNOWLEDGMENT

Blessings and glory, wisdom thanksgiving and honour, power and might be unto my God forever and ever. Amen.

My sincere appreciation goes to my supervisor Dr. E. M. Shemang Jr. for his guidance and critical review of the manuscripts.

My profound gratitude goes to Dr. S.S. Dada (Coordinator of Geology Programme) for his moral, academic and spiritual training throughout the period of my study.

Words cannot express my gratitude to Mr. and Mrs. C.I. Okonkwo, Mr. and Mrs. Bachamayo Kalla, Mr. and Mrs. Dada Kawa, Dr. and Mrs. Jideani for their prompt assistance in times of need.

I am immensely indebted to all the members of staff and students of Geology Programme A.T.B.U., Bauchi for their instruction and companionship throughout my stay in the University.

I am grateful to Dahiru Ahmed Marafa and Rotimi (WATSAN) for their tremendous contribution to the successful completion of this research.

Finally, my gratitude goes to my friends Kennedy and Maureen for their tender care and all my brethren in Deeper Life Campus fellowship A.T.B.U. for their tireless prayers.

ABSTRACT

Water resources development is one of the major factors in the development of any community. Efforts connected with exploration and exploitation of ground water need to ensure adequate supply of suitable quality and sufficient quantity of water to the people. To achieve this, surface geophysical investigation is often employed in the location of prolific borehole sites in any geological environment. This project summarises the results of geoelectrical soundings (Schlumberger configuration) carried out at 16 locations around Azare town using ABEM Terrameter SAS 300B. Results obtained form the computer aided interpretation reveal thickness to bed rock between 14 and 78m where the basement is near the surface and Thickness > 120m where it is very deep. Some of the problems Associated with the ground water development in Azare are due to Deep water table, low yield of the upper aquifers of the Kerri- Kerri formation and lack of adequate geophysical investigation of the areas.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 *General Introduction*

The demand for quantitative and qualitative drinking water has grown tremendously with civilization and increased population. This is because water is one of the most important factors in the development of any society. In an effort to provide water to the populace, the Bauchi State Government drilled about 1500 hand pump boreholes under Bauchi State Integrated Rural Development Programme out of which 40 mechanized pumps were installed.

Later in 1992 the State with the assistance of UNICEF Established the Bauchi State Water and Environmental Sanitation Project (WATSAN), the aim of which is to provide safe drinking water especially to the rural areas that are guinea-worm endemic. Beside, private organisations and companies e.g. ALKA CHEM Company Limited are engage in drilling of boreholes and ground water exploration.

However, most of these boreholes are now either in a state of poor operation or completely broken down due to lack of maintenance. Hence this indicate that the previous water schemes have not satisfied

the water requirement of the populace. Bauchi State therefore, needs to fully explore and exploit its water resources and to also review especially, its water supply schemes to support its growing agricultural development programmes, its agro-based industries and its expanding population.

Generally, in Azare area ground water occur in the Kerri-kerri formation and the weathered basement which contain water-bearing layers and zones. Water problem in the area is due to the low yield of the upper aquifers of the Kerri-kerri formation and appreciable clay component in the weathered basement whose permeabilities are mostly low.

1.2 *Location and accessibility*

Katagum Local Government is located in the northern part of Bauchi State. It is about 210 KM from Bauchi town. It lies between latitude 11° 39'N and 11° 43'N and longitudes 10° 11'E and 10°13'E. The area is flanked by Shira, Dambam, Itas and Gamawa areas of Bauchi State (Fig.1). It covers a land mass of 1228 square kilometres with a population of 188,127 people (Census, 1991).

The area is accessible because of the tarred and unterred motorable roads and numerous footpaths.

1.3 *Climate and Vegetation*

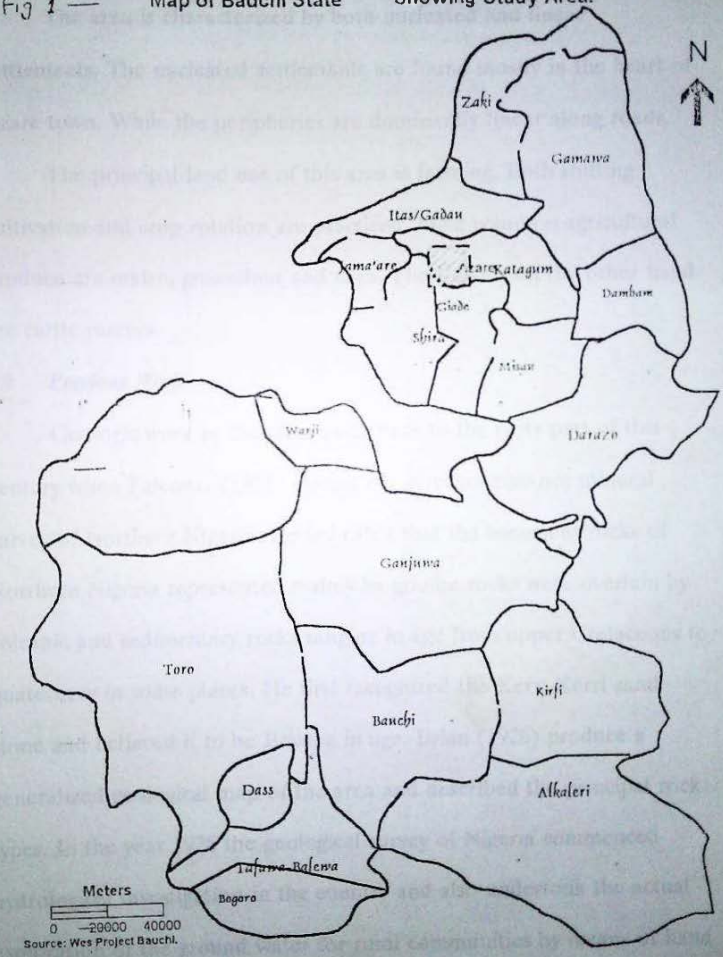
The area of study has a mean annual rainfall between 690 to 710mm. It is characterize by two distinct seasons; Wet and Dry seasons. The wet season is between April/May to September/October while the dry season conspicuously sets in from the month of October/November and lasts up to March/April. It is characterize by an arid wind moving from the North-East of the Sahara desert.

The air mass is known as Hamattan. During this period there is little cloud cover and temperature vary from 13- 32° (water surveys, 1987). The area is part of the sahel Savannah with its characteristic short grasses, thorny bushes and thick vegetation along rivers and stream channels.

1.4 *Relief and Drainage*

Katagum local government area is situated in a relatively flat terrain with loosely consolidated sands. While Azare area lies on the Kerri-Kerri formation. The relief is generally between 300-450m above sea level. There are no rivers or network of streams traversing the study area.

Fig 1 — Map of Bauchi State Showing Study Area.



1.5 *Settlement and Land use*

The area is characterized by both nucleated and linear settlements. The nucleated settlements are found mostly in the heart of Azare town. While the peripheries are dominantly linear along roads.

The principal land use of this area is farming. Both shifting cultivation and crop rotation are practiced. Most common agricultural produce are maize, groundnut and corn. The Fulanis on the other hand are cattle rearers.

1.6 *Previous Work*

Geologic work in the state dates back to the early part of this century when Falconer (1911) carried out a reconnaissance mineral survey of Northern Nigeria. He indicated that the basement rocks of Northern Nigeria represented mainly by granite rocks were overlain by volcanic and sedimentary rocks ranging in age from upper Cretaceous to quaternary in some places. He first recognized the Kerri-Kerri sand stone and believed it to be Eocene in age. Brian (1926) produce a generalized geological map of the area and described the principal rock types. In the year 1926 the geological survey of Nigeria commenced hydrological investigation in the country and also undertook the actual exploration of the ground water for rural communities by means of hand dug concrete-lined wells. Oyawoye (1962) described the general geology of Bauchi to consist of metasedimentary rocks, migmatites, granites, quartz monzonite and diorite.

Catter et al (1963) described the general geology of Bauchi. They recognized an ancient crystalline basement, represented mainly by granite rocks, overlain by sedimentary and volcanic rocks. Dupreez and Barber (1965) worked on the distribution and chemical quality of ground water in Northern Nigeria indicating that despite the large volume of water in the Kerri-kerri formation, yields are generally low because of presence of interstitial clay and silt in the sand stone.

Alolis Geo.-science(1977) working for the Federal Ministry of Water resources identified that the basement complex rocks are crossed with network of fractures, the density characteristics and course of which may vary from one area to another. Edok Eter-Mandillas Ltd. (1976-1977) investigated the various hydrological units(Kerri-kerri, Gombe Yolde, Pindiga and Bima formations) including the basement in Bauchi state with their complete borehole logs.

The 1986 water surveys unpublished report on shallow aquifer for low land irrigation in Bauchi state for Bauchi state Agricultural development Programme (BSADP) described the physical characteristics and area extent of all the low land aquifers.

Dike and Dan Hassan (1990) have indicated that the Kerri-Kerri formation has the best aquifers in Bauchi state compared to other hydrological units in the state.

1.7 *Aims and objectives*

the objectives and expected benefits of this research include the following:

a) To assess the potentials of the ground water resources of Azare town.

b) To identify and delineate the most favourable area for ground water development.

c) To provide information for the use of organisations interested in ground water resources development in the study area.

d) To satisfy one of the requirements for the award of the Degree of Bachelor of Technology (B. Tech) in applied Geology at Abubakar Tafawa Balewa University, Bauchi.

1.8 *Methodology*

Two basic approach were employed for this work:

1) Data acquisition and

2) Data interpretation.

The latter involve critical classification of the data acquired. Geophysical (Resistivity) readings were obtained and interpreted.

Most of the data were obtained from the following organisations:

a) Bauchi State Water Board (BSWB)

b) Bauchi State UNICEF Assisted Water and Sanitation Project

(WATSAN), Bauchi.

c) Ministry of works and Housing (Land and Survey dept.)

d) University Library (ATBU)

e) Previous trip to the Local Government of study.

CHAPTER TWO

2.0 GEOLOGY AND HYDROGEOLOGY

2.1 *Regional Geology*

The study area is located within the upper Benue trough. The Benue trough which is an intracontinental basin is about 1000km in length and 120km wide elongated in the NE - SW direction and overlying the Precambrian shield of the West African mobile belt (Guiraud, 1990).

Generally there are two prominent models that have evolved on the origin of the Benue Trough. One of the models (Burke, 1976; Burk et al, 1970; Hoffman et al, 1974; Olade, 1975; Wright, 1981; Filton, 1983) attributed the origin of the trough to the "Y" shaped triple junction rift model (RRR) due to the break up of the Afro-Brazilian plate in the Cretaceous. They envisaged the trough as being represented by the third failed arm of the RRR rift systems while the other arms separated to form the South Atlantic.

Benkhelil and Robineau (1980); Popoff et al, (1983); Allix (1983); however interpreted the trough as a set of pull apart sub-basins generated by sinistral displacements along pre-existing NE-SW transcurrent faults.

They argue that the regional configuration of the West Central African rift system is a series of a major NNW to NW trending extensional basins and taken up the strain which was caused by Gulf of Guinea. They showed the Trough as Wrench fault system with sinistral displacement.

The infilling of the Benue trough is characterized by the succession of continental to marine deposits ranging from Aptian to Paleocene in age. The local stratigraphy is problematic taking into account the great diversity of sediments in the early Cretaceous basin (Guirand and Rebeve, 1988). The stratigraphy of the upper Benue trough is summarise in table 1.

2.2 *Geology of the Study Area*

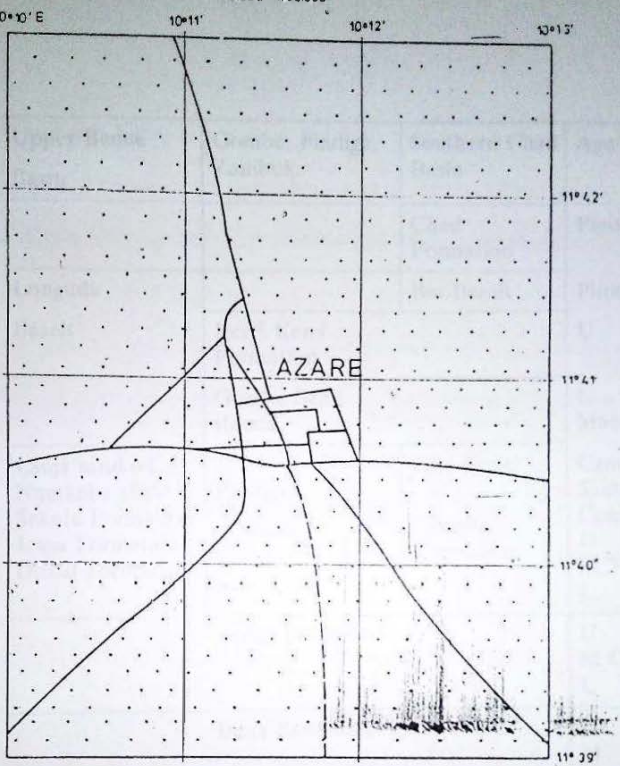
Both geologic and geophysical investigation reveals that Azare town lies on the Kerri-Kerri formation which are mostly covered by Holocene clayey sands (Edo-Eter-Mandillas, 1976). In the south and north of Azare the Kerri-Kerri sediments are frequently exposed especially on the trunk road to the north (to Gadau) the Kerri-Kerri can often be observed for over a distance of 17km (Fig. 2)

Fig 2

AZARE

GEOLOGICAL MAP

SCALE 1/50,000



Key

Kerri kerri formation

SOURCE:

EDOK-ETER MANDILAS LTD.

Upper Benue Basin	Gombe, Pindiga, Zambuk.	Southern Chad Basin	Age
		Chad Formation	Pleistocene
Longuda Basalt		Biu Basalt	Pliocene
	Kerri Kerri Formation		U
	Gombe Sand stones		L Maestritchian
Lanja sand sst. Numanha shale Sekule Formation Jessu Formation Dukul Formation	Pindiga Formation	Fika Shale Gongila Formation	Campanian Santonian Coniacian U M Turonian L
	Yolde Formation		U M Cenomanian L
	Bima Sandstones		U Albian M L U Aptian
	Volcanics, Crystalline	Basement	Jurrasic Pre-cambrian

Table 1

The stratigraphic sequence of the Upper Benue valley and southern Chad Basin (After Popoff et al, 1986).

Kerri-Kerri formation is a continental sequence and has been dated as Paleocene in age (Adegoke et al, 1978). Lithologically, it consist of friable medium-coarse sandstone and sands, gravely sands and sandy gravel's, interbedded pebbly clayey sands and sandy clay stones, fineands clay stones (Dike, 1990). It is generally low laying and appears to have been derived from a terrain of Cretaceous sediments (Carter et al, 1963). It was laid down on eleven surface of basement complex and folded Cretaceous rocks. The thickness varies from a few meters to estimated 300m at some places (Dessauvagie, 1975; Adegoke et al, 1978). This formation is unaffected by folding and dips gently to the north and north-east below Chad formation. The Kerri-Kerri formation thins west ward (i.e. towards Darazo and Misau). The contact between the basement complex and the Kerri-Kerri formation is a distinct boundary, composed mainly of conglomerate.

2.3 *Hydrogeology of the Study Area.*

The ground water in the Kerri-Kerri formation aquifers occurs mainly under water table conditions but locally semi confined and confined aquifers occur where thick and some times laterally extensive lenticular clays are interbedded with sand. Dupreez and Barber (1965) indicated that despite the large volume of water present in the saturated Kerri-Kerri formation, yields are generally low because of low

permeability of the sediments due to interstitial clay and silts in the sandstone. However, Dike and Dan Hassan (1990) concluded that the Kerri-Kerri formation easily has the best aquifers in Bauchi State when composed to other hydrological units.

From the hand-dug wells of Azare the ground water level is at a depth of between 15 and 24m. This ground water lies in the upper aquifers of the Kerri-kerri formation which have low yield. Nevertheless yields of between 6 - 0 L/S and 14 L/S have been obtained (Fig. 5a - c).

CHAPTER THREE

3.0 GEOPHYSICAL DATA ACQUISITION AND PRESENTATION.

3.1 *Principles of D.C. Resistivity Method*

In order to fully understand the principle of earth resistivity measurement, it is necessary to appreciate the behaviour of electric current moving in layered media, which is invariably the case rather than a homogenous earth and how this affects the distribution of potential within the ground.

The basis for electrical conductivity or resistivity is the ohms law which states that :

$$\Delta V = IR$$

Where ΔV = Potential difference between any two points.

I = Current flowing in the conducting medium between these points.

R = Resistance of the medium between these two points.

In the resistivity method an electric current is introduced into the ground by means of two current electrodes and the potential difference between two potentials electrodes is measured. Fig. 4a shows the current and potential distribution

Fig 4

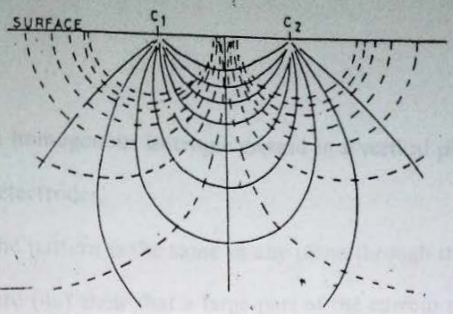


Fig. 4a Current distribution (-) and equipotential lines (---) in a vertical plane through the current electrode.

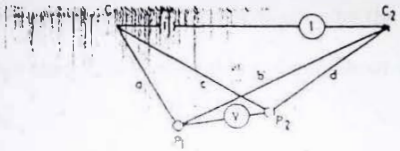


Fig. 4b A General Configuration

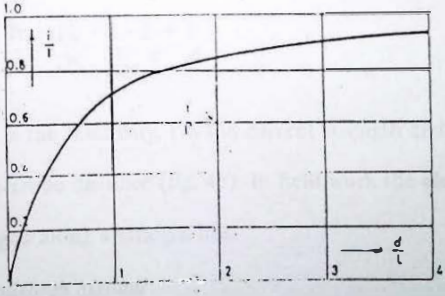


Fig. 4c Fraction of total current I which passes above a horizontal plane at depth d, expressed as a function of the distance L between two current electrodes (Arranged after C. A. Heiland).

within a homogenous isotropic ground in a vertical plane through the current electrodes.

The pattern is the same in any plane through these electrodes. The figure (4a) show that a large part of the current penetrates deeply into the ground. It is obvious that the depth of penetration increase with increasing electrode distance. The relation between the depth of penetration and electrode distance is given by the curve in figure 4c. It can be seen that 50% flows within a depth about equal to the electrode separation.

The potential difference between two arbitrary location points on the surface of a homogenous isotropic ground is given by the expression:

$$\Delta V = \frac{Ie}{2}\left(\frac{1}{a} - \frac{1}{b} - \frac{1}{c} + \frac{1}{d}\right)$$

Where e is the resistivity, I is the current strength and a,b,c, and d are the interelectrode distance (fig. 4b). In field work the electrodes are normally arranged along a straight line.

3.2 *Data Acquisition Method*

Geological mapping was done to determine the distribution of the formations in the area, to check for lineaments, faults, fractures and joints which can be related to porosity, permeability and ultimately well yield.

Field measurements using terrameter (SAS 300B) was carried out by passing electrical current into the ground through two current

electrodes and measuring the voltage or potential difference across two potential electrodes. The ratio of the voltage to current is multiplied by a geometrical factor (a function of the distance between the electrodes) to give an apparent resistivity. Both Wenner and Schlumberger array are being used in ground water exploration. However, for this research work Schlumberger array was used through out the survey. A total of 16 VES points were carried in different locations (Fig. 3).

3.3 *Data Processing and Presentation*

The data collected from the field were converted to apparent resistivities (ea) by multiplying the field values by the geometrical factor (k) which is determine from the formula.

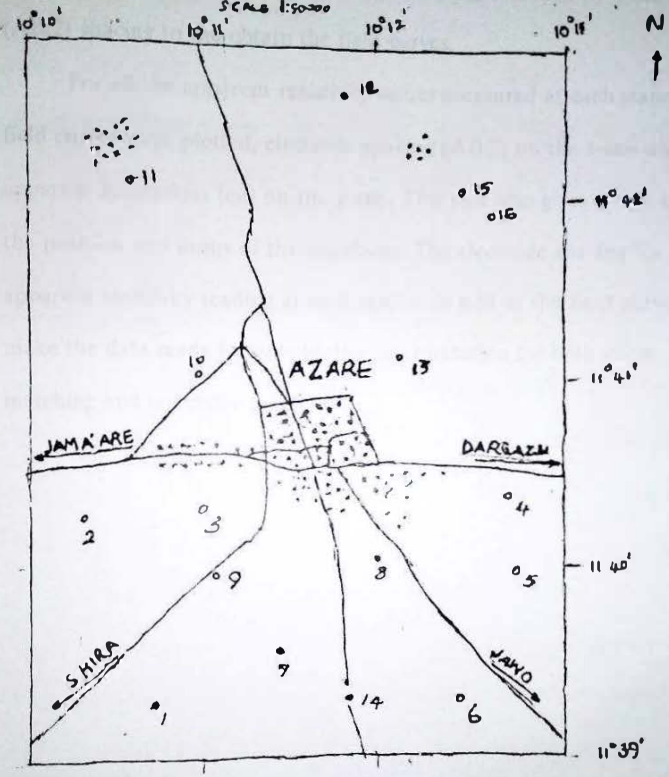
$$K = \frac{\pi (L^2 - l^2)}{2l}$$

AZARE

Fig 3

LOCATION MAP SHOWING VES POINTS

SCALE 1:50000



• VES POINT

MAIN ROAD

POPULATED AREA.

SOURCE

EDOK-ETER MANDLAS LTD – HUNTING SURVEYS LTD

The apparent resistivity (ea) is plotted against half the electrode (AB/2) spacing to the obtain the field curves.

For all the apparent resistivity values measured at each station the field curves were plotted, electrode spacing (AB/2) on the x-axis and apparent resistivities (ea) on the y-axis. This plot also gives rough idea of the position and forms of the interfaces. The electrode spacing Vs apparent resistivity reading at each station as well as the field curves make the data ready for quantitative interpretation for both curve matching and computer method.

CHAPTER FOUR

4.0 DATA INTERPRETATION AND DISCUSSION OF RESULTS.

4.1 *Data Interpretation.*

Usually, the qualitative interpretation of the VES reading is quickly followed by quantitative interpretation techniques. Several methods are used, one of which is the curve matching techniques. The resistivity curves obtained were interpreted by comparism with sets of master curves (Orellan 1966 and Rijkswaterstaat, 1969). The procedure involve drawing curves on transparent bi-logarithmic paper of the same modulus as used in the master curves after determining the number of layers the field curves represented.

In the case of two-layer curves, the field curve can be superimposed over the two-layer master curve. The transparent paper is adjusted (maintaining the coordinate axes of the two sheets parallel) until a best fit of the field curve against one of the theoretical curves is obtained. Occasionally, the field curve may have to be matched by interpretation between two of the master curves.

The resistivity mark corresponding to theoretical curve for which the match is obtained is traced onto the transparent paper. The thickness of this layer which is equal to the cross abscissa on the field graph and resistivity of the first layer which is also equal to the ordinate value on the field graph of the resistivity mark are recorded. This same procedure is applied to the three layer master curves.

In case of this work, offix computer program was used for the interpretation of the data obtained. It is an inverse method and one derives the model from the field indirectly by numerical calculation on the computer. The program input consist of parameters for a layered earth model. Guided by this input model, the computer determines the model whose theoretical geoelectric curve best fits the field data by successive interactions dictated by a numerical program. At the end, the computer outputs not only the model (determine by mathematical fit), but also the degree of confidence (reliability) in each parameter of the model (resistivities and thickness of layers) determined. The results of the interpreted data are shown in Appendix A1 - A16.

4.2 *Discussion of Results.*

From the results obtained, it is clear that study areas does not lie in the same geologic setting. This can be seen from the diversity in thickness of the various layers of the formation as displayed in the geoelectrical sections in Appendix B1, B2 and B3 respectively. VES 1,2,3,4,5,6,7 and 8 reveal a very thin top layer (averagely 3m) with very low resistivities of between 2 and 200 m. While VES 9, 10, 12, 13, 14, 15 and 16 have relatively thick top layer (between 5 and 37 m) with high resistivities ranging from 140 - 2450 m. Immediately below these zones of high resistivities it starts decreasing up to a certain point and rises again. If the terminal branch of the curve rises at an angle of about 45°

it probably represents the highly resistant crystalline basement.

Generally, the low to moderate resistivity values corresponds to zones of saturation and possible aquifers in the area. Table 2 summarises the interpreted results with thickness and their corresponding resistivities.

The depth to basement varies considerably from south to north. From table 2 VES 15, 14, 12 and 11 range in thickness from 132 - 256m deep while the thickness in the south is 198m (VES 9). Lithological logs of some selected boreholes drilled by China Geo.-engineering corporation within Azare in 1997 (Fig. 5a - c) however, reveal that the depth to basement in the central part of town is between 40 and 54 metres. The borcholes locations are shown in fig. 6

Table 2 – Summary of the Interpreted Results (Appendix A)

VES No.	1st Layer Thickness (m)	1st Layer ea (-m)	2nd Layer Thickness (m)	2nd Layer ea (-m)	3rd Layer Thickness (m)	3rd Layer ea (-m)	4th Layer Thickness (m)	4th Layer ea (-m)	5th Layer Thickness (m)	5th Layer ea (-m)	Total Thickness (m)
1	7.21	196	9.0	636	39.7	59	555.9	3252			55.9
2	1.24	1.89	12.4	31.8	>13.6	805.5					13.6
3	2.0	39	42.20	1458	>44.2	235.5					44.2
4	2.6	64.2	27.3	87.2	>29.9	888.5					29.9
5	0.9	1.82	24.0	41.2	>24.9	156.4					24.9
6	1.91	95.0	20.0	290.6	56.8	83.7	>78.7	383			78.7
7	4.42	20.6	>4.42	3311							4.42
8	1.14	1910	16.63	949	5.53	2279	105.8	85.6	>129	2033	129
9	14.19	1147	184.2	92.3	>198.1	6889.7					198.1
10	14.4	1208	57.6	68.2	>720	876.8					72
11	0.59	141	2.82	9557	151.5	107.7	>154.8	2005			154.8
12	16.73	2449	240	87	>256	645.7					256.7
13	24.29	602	33.3	13	>57.5	464.8					57.5
14	37.0	537	101.6	141	>139.2	2289					139.9
15	5.19	2230	30.8	263.5	97	82.5	>132	499			132.9
16	6.34	2231	34.6	274.4	54.9	50.4	>557	3792			95.7

Fig 5

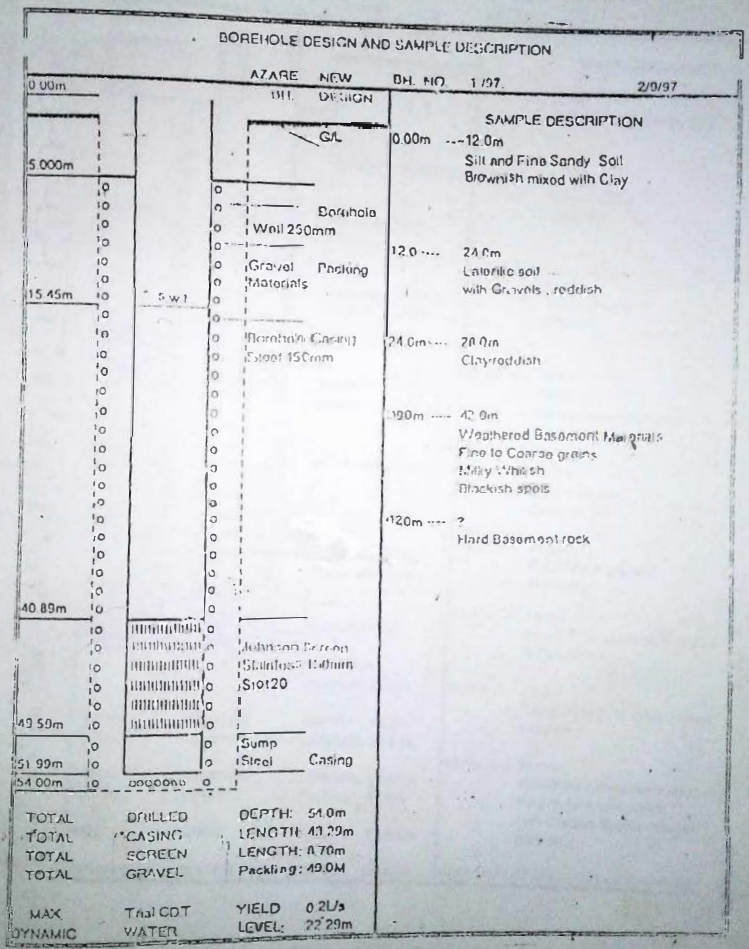

BOREHOLE DESIGN AND SAMPLE DESCRIPTION
AZARE NEW BH. NO. 1/97. 2/9/97
0.00m
DESIGN
SAMPLE DESCRIPTION
G/L
0.00m ---12.0m
Silt and Fine Sandy Soil
Brownish mixed with Clay
5.000m
Borehole
Wall 250mm
12.0 .... 24.0m
Laterific soil
with Gravels , reddish
Gravel Packing
Materials
15.45m
S.W.L
Borehole Casing
Steel 150mm
24.0m 28.0m
Clay reddish
190m 42.0m
Weathered Basement Materials
Fine to Coarse grains
Milky Whitish
Blackish spots
120m .... ?
Hard Basement rock
40.89m
Johnson Screen
Stainless Eathern
Slot20
49.59m
Sump
51.99m
Steel Casing
54.00m
TOTAL DRILLED DEPTH: 54.0m
TOTAL CASING LENGTH: 49.29m
TOTAL SCREEN LENGTH: 0.70m
TOTAL GRAVEL Packing: 49.0M
MAX Trial CDT YIELD 0.2L/s
DYNAMIC WATER LEVEL: 22.29m

Fig 5b

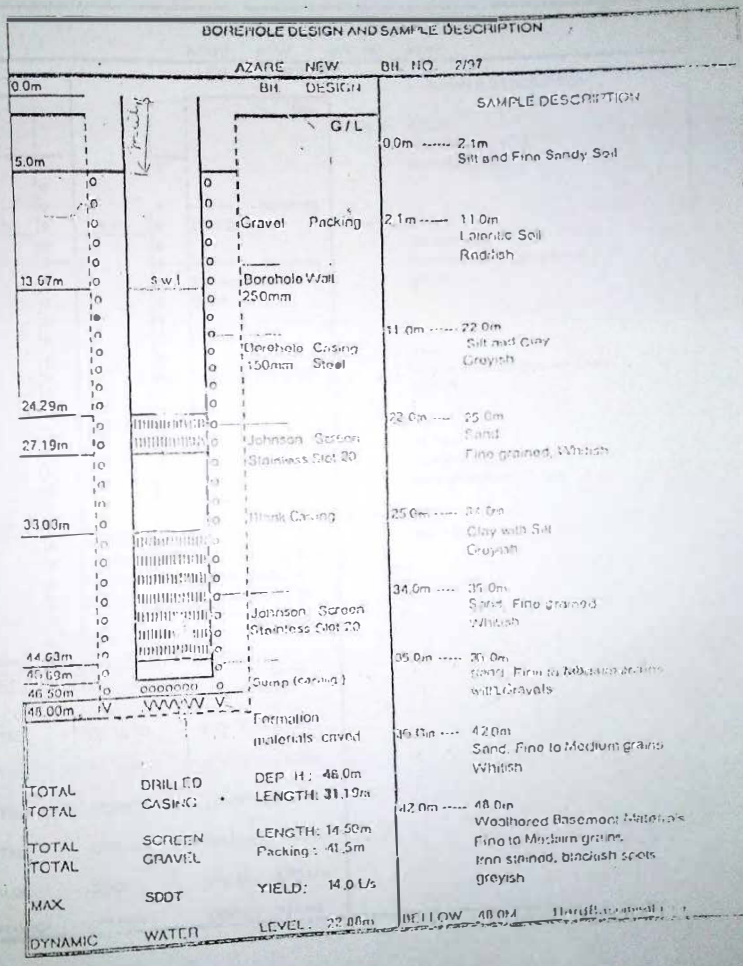
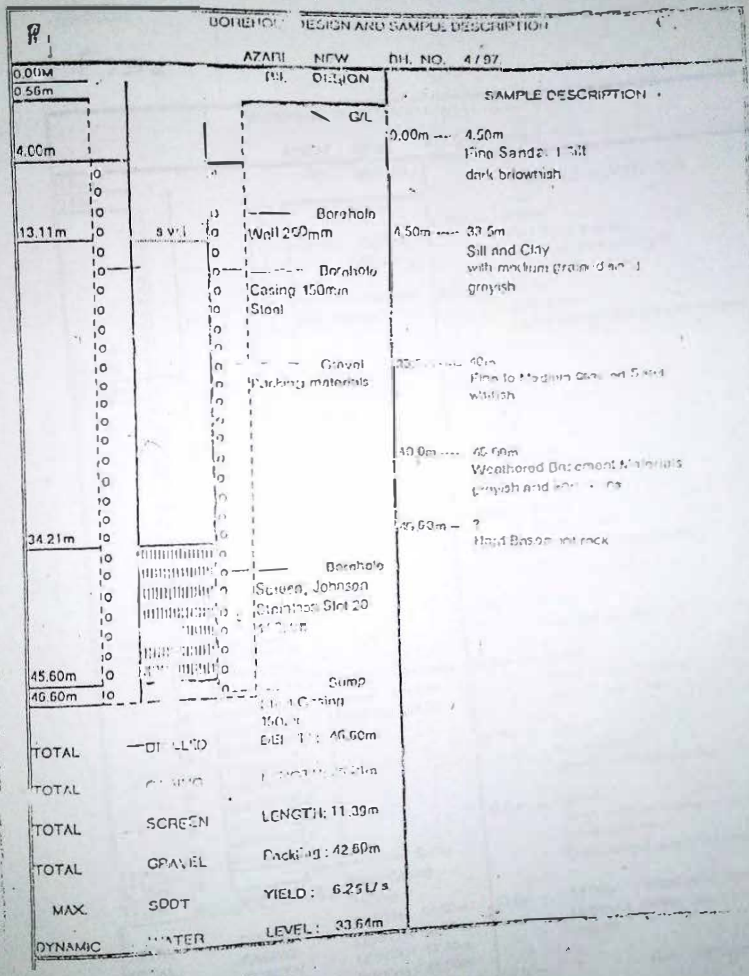
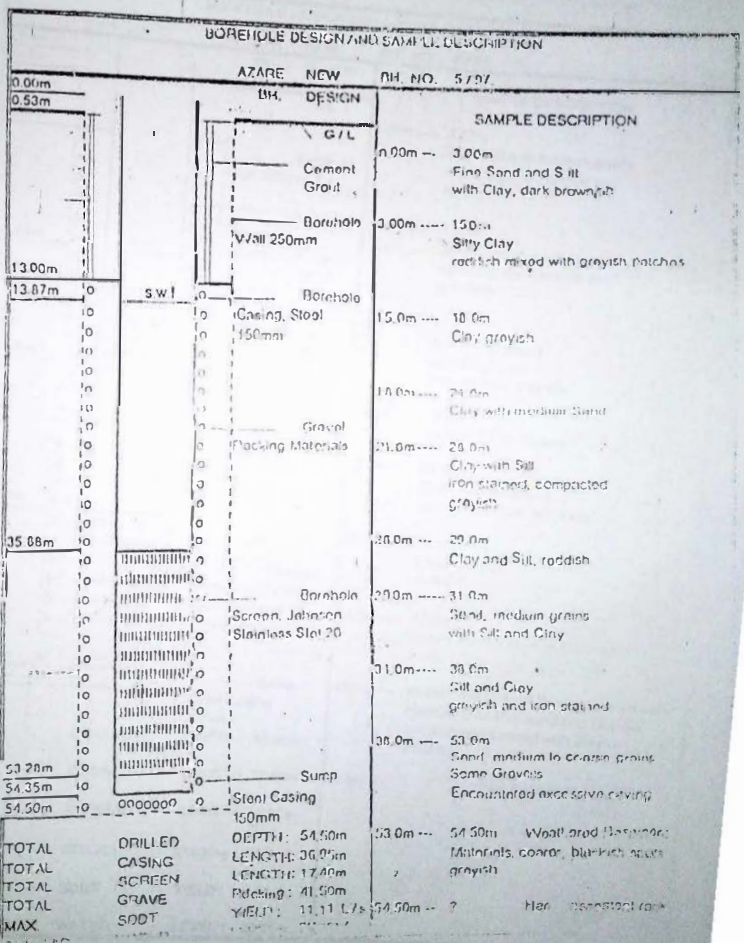

BOREHOLE DESIGN AND SAMPLE DESCRIPTION
AZARE NEW BH. NO. 2/97
BH. DESIGN
SAMPLE DESCRIPTION
0.0m
G/L
5.0m
Gravel Packing
S.W.L
13.67m
Borehole Wall 250mm
Borehole Casing 150mm Steel
24.29m
27.19m
Johnson Screen Stainless Slot 20
33.03m
Blank Casing
Johnson Screen Stainless Slot 20
44.63m
46.69m
46.80m
46.00m
Sump (casing)
Formation materials caved
TOTAL DRILLED DEPTH: 46.0m
TOTAL CASING LENGTH: 31.19m
TOTAL SCREEN LENGTH: 14.50m
TOTAL GRAVEL Packing: 41.5m
MAX SDDT YIELD: 14.0 L/s
DYNAMIC WATER LEVEL: 22.00m
0.0m ----- 2.1m
Silt and Fine Sandy Soil
2.1m ----- 11.0m
Laterite Soil
Reddish
11.0m ----- 22.0m
Silt and Clay
Greyish
22.0m ---- 25.0m
Sand
Fine grained, Whitish
25.0m ---- 34.0m
Clay with Silt
Greyish
34.0m ---- 35.0m
Sand, Fine grained
Whitish
35.0m ----- 39.0m
Sand, Fine to Medium grains
with Gravels
39.0m ---- 42.0m
Sand, Fine to Medium grains
Whitish
42.0m ----- 48.0m
Weathered Basement Materials
Fine to Medium grains,
Iron stained, blackish spots
greyish
BELLOW 48.0M Hard Basement

Fig 5e


BOREHOLE DESIGN AND SAMPLE DESCRIPTION
AZARI NEW BH. NO. 4/97
BH. DESIGN
SAMPLE DESCRIPTION
0.00M
0.56m
4.00m
13.11m
34.21m
45.60m
46.60m
G/L
Borehole Wall 200mm
Borehole Casing 150mm Steel
Gravel Packing materials
Borehole Screen, Johnson Stainless Slot 20
Sump
0.00m — 4.50m
Fine Sand
dark brownish
4.50m — 33.5m
Silt and Clay
with medium gravel and
greyish
40m
Fine to Medium Gravel and Sand
Whitish
40.0m — 45.60m
Weathered Basement Materials
greyish and
45.60m — ?
Hard Basement rock
TOTAL DRILLED
TOTAL
TOTAL SCREEN LENGTH: 11.39m
TOTAL GRAVEL Packing : 42.60m
MAX. SPOT YIELD : 6.25 L/s
DYNAMIC WATER LEVEL : 33.64m

F19 d


BOREHOLE DESIGN AND SAMPLE DESCRIPTION
AZARE
BH. NEW DESIGN
BH. NO. 5/87
SAMPLE DESCRIPTION
0.00m
0.53m
13.00m
13.87m
35.88m
53.20m
54.35m
54.50m
S.W.L
G/L
Cement Grout
Borehole Wall 250mm
Borehole
Casing, Steel 150mm
Gravel Packing Materials
Borehole
Screen, Johnson Stainless Slot 20
Sump
Steel Casing 150mm
0.00m — 3.00m
Fine Sand and Silt with Clay, dark brownish
3.00m —— 15.0m
Silty Clay reddish mixed with greyish patches
15.0m —— 18.0m
Clay, greyish
18.0m —— 24.0m
Clay with medium Sand
21.0m —— 28.0m
Clay with Silt iron stained, compacted greyish
28.0m — 29.0m
Clay and Silt, reddish
29.0m —— 31.0m
Sand, medium grains with Silt and Clay
31.0m —— 38.0m
Silt and Clay greyish and iron stained
38.0m —— 53.0m
Sand, medium to coarse grains Some Gravels
Encountered excessive caving
53.0m — 54.50m Weathered Basement Materials, coarse, blackish and greyish
54.50m — ? Hard
TOTAL DRILLED
TOTAL CASING
TOTAL SCREEN
TOTAL GRAVE
TOTAL SOOT
MAX
DEPTH: 54.50m
LENGTH: 36.05m
LENGTH: 17.40m
Packing: 41.50m
YIELD: 11.11 L/s

Figs e

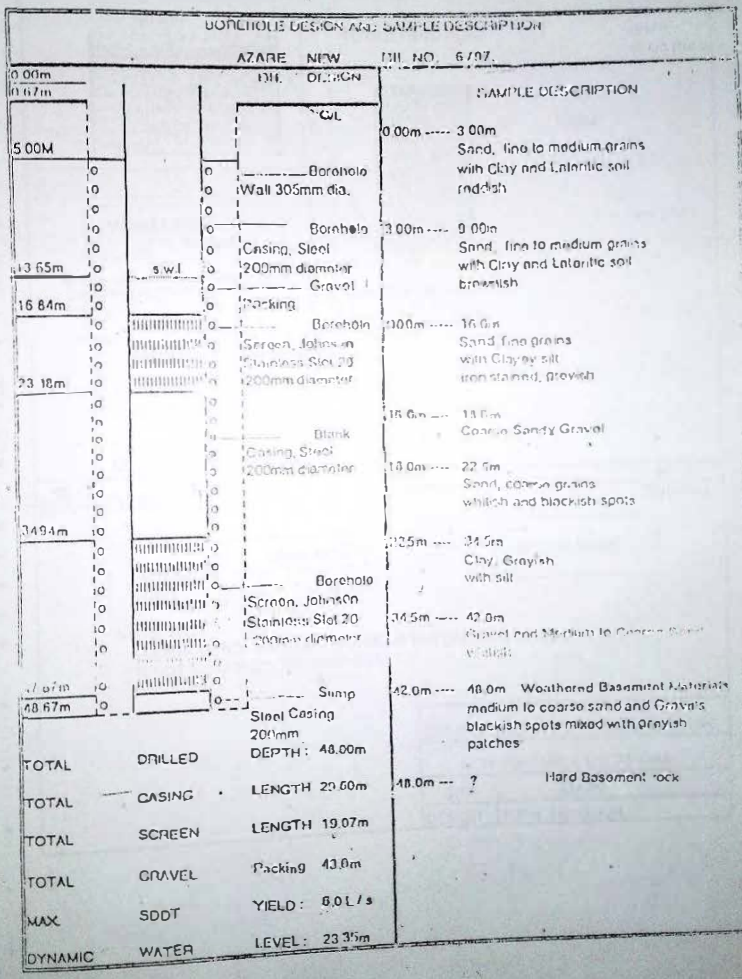
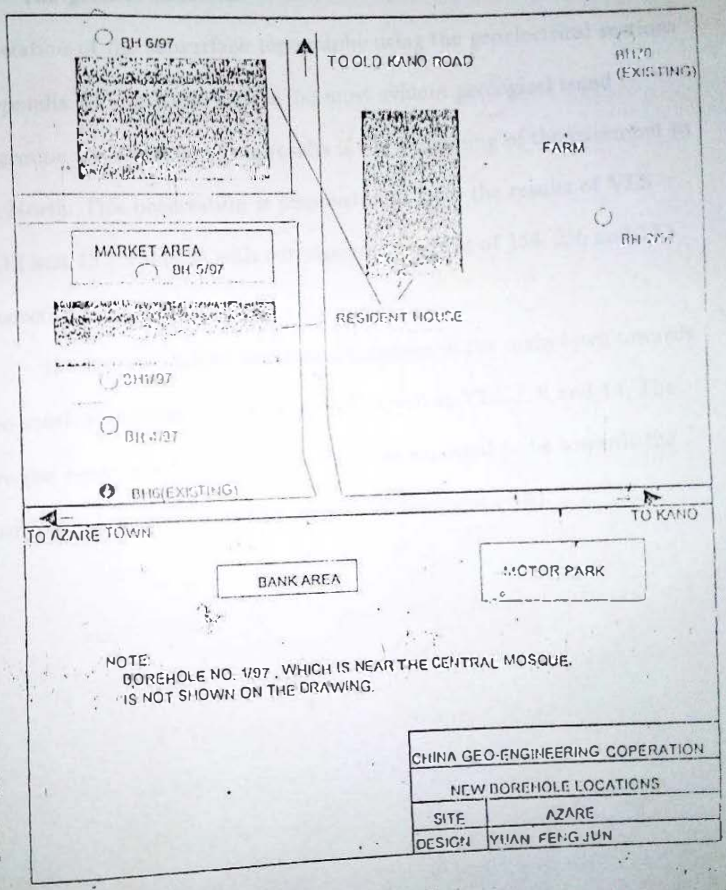

BOREHOLE DESIGN AND SAMPLE DESCRIPTION
AZARE NEW
BH. NO. 6707
BH. DESIGN
SAMPLE DESCRIPTION
0.00m
0.67m
GL
5.00M
Borehole
Wall 305mm dia.
Borehole
Casing, Steel
200mm diameter
Gravel
Packing
Borehole
Screen, Johnson
Stainless Slot 20
200mm diameter
Blank
Casing, Steel
200mm diameter
Borehole
Screen, Johnson
Stainless Slot 20
200mm diameter
Sump
Steel Casing
200mm
13.65m
S.W.L
16.84m
23.18m
34.94m
47.67m
48.67m
0.00m ---- 3.00m
Sand, fine to medium grains with Clay and Lateritic soil reddish
3.00m ---- 9.00m
Sand, fine to medium grains with Clay and Lateritic soil brownish
9.00m ---- 16.0m
Sand, fine grains with Clayey silt iron stained, greyish
16.0m ---- 18.0m
Coarse Sandy Gravel
18.0m ---- 22.5m
Sand, coarse grains whitish and blackish spots
22.5m ---- 34.5m
Clay, Grayish with silt
34.5m ---- 42.0m
Gravel and Medium to Coarse Sand whitish
42.0m ---- 48.0m Weathered Basement Materials medium to coarse sand and Gravels blackish spots mixed with greyish patches
48.0m --- ? Hard Basement rock
TOTAL DRILLED DEPTH : 48.00m
TOTAL CASING LENGTH 29.60m
TOTAL SCREEN LENGTH 19.07m
TOTAL GRAVEL Packing 43.0m
MAX SDDT YIELD : 6.0 L/s
DYNAMIC WATER LEVEL : 23.35m

Fig 6


BH 6/97
TO OLD KANO ROAD
BH 2/97
(EXISTING)
FARM
MARKET AREA
BH 5/97
RESIDENT HOUSE
BH 4/97
BH6(EXISTING)
TO AZARE TOWN
TO KANO
BANK AREA
MOTOR PARK
NOTE:
BOREHOLE NO. 1/97 , WHICH IS NEAR THE CENTRAL MOSQUE.
IS NOT SHOWN ON THE DRAWING.
CHINA GEO-ENGINEERING COPERATION
NEW BOREHOLE LOCATIONS
SITE
AZARE
DESIGN
YUAN FENG JUN

4.3 *Deduction of Results*

The general behaviour of the VES curves does not permit easy correlation of the subsurface topography using the geoelectrical sections (Appendix B1 -3). Nevertheless the most evident geological trend determine from the sounding results is the deepening of the basement to the North. This observation is demonstrated from the results of VES 11,12 and 15 (Table 2) with corresponding depths of 154, 256 and 132 respectively.

In contrast shallow depths are common in the main town towards the south with some few exceptions observed in VES 8, 9 and 14. The ground water flow in the area is therefore expected to be towards the north since the flow is mainly control by basement relief.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS.

CONCLUSION

The proper application of geoelectrical method of investigating ground water cannot be overemphasized if sinking of dry boreholes is to be avoided. This is because it helps us to assess the ground water potentials of an area and also delineate the most favourable area for ground water development. It is relatively cheap and produce valuable subsurface information which otherwise would only be obtained from a very large number of boreholes. In conclusion, the probability of getting prolific wells are more likely to be found north of Azare than in the southern part with the exception of VES 8, 9 and 14 (Table 2) which have average thickness of 155m.

RECOMMENDATION

Thus I recommend that drilling of borcholes should be completed in the decomposed portion of the basement where the overburden is shallow since the upper aquifers of the Kerri-kerri formation generally have low yield. In addition detail geophysical investigation should be done in the area so as to determine the configuration of the subsurface for more success in water exploration.

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DATA SET: AZARE 1

CLIENT: ATBU
LOCATION: AZARE
COUNTY: AZARE, BAUCHI STATE
PROJECT: DEPTH PROBING
ELEVATION: 0.00
SOUNDING COORDINATES: X: 0.0000 Y: 0.0000

DATE: -
SOUNDING: 1
AZIMUTH: -
EQUIPMENT: SAS 300 B

Schlumberger Configuration

FITTING ERROR: 8.971 PERCENT

L #	RESISTIVITY (ohm-m)	THICKNESS (meters)	ELEVATION (meters)	LONG. COND. (Siemens)	TRANS. RES. (Ohm-m^2)
			0.0		
1	196.7	7.21	-7.21	0.0366	1420.5
2	636.6	9.00	-16.22	0.0141	5733.0
3	59.38	39.77	-56.00	0.669	2362.1
4	3252.2				

ALL PARAMETERS ARE FREE

No.	SPACING (m)	RHO-A (ohm-m) DATA	RHO-A (ohm-m) SYNTHETIC	DIFFERENCE (percent)
1	1.00	204.0	196.7	3.53
2	1.50	192.0	196.9	-2.57
3	2.00	200.7	197.2	1.73
4	3.00	200.0	198.3	0.834
5	4.00	203.1	200.3	1.36
6	5.00	204.0	203.3	0.334
7	7.00	200.1	212.1	-6.00
8	10.00	225.0	229.9	-2.19
9	15.00	270.2	259.1	4.10
10	20.00	285.2	276.0	3.22
11	30.00	270.0	272.0	-0.742
12	40.00	252.3	242.6	3.87
13	50.00	214.0	209.8	1.95
14	70.00	168.8	165.1	2.20
15	100.0	176.0	154.1	13.42
16	150.0	220.0	197.8	10.05
17	200.0	341.0	256.2	24.86

CURRENT RESOLUTION MATRIX NOT AVAILABLE

* UNDR - Rusafaya Project *

DATA SET: AZARE 2

CLIENT: ATBU
LOCATION: AZARE
COUNTY: AZARE, BAUCHI STATE
PROJECT: DEPTH PROBING
ELEVATION: 0.00
SOUNDING COORDINATES: X: 0.0000 Y: 0.0000

DATE: -
SOUNDING: 2
AZIMUTH: -
EQUIPMENT: SAS 300 B

Schlumberger Configuration

FITTING ERROR: 8.973 PERCENT

L #	RESISTIVITY (ohm-m)	THICKNESS (meters)	ELEVATION (meters)	LONG. COND. (Siemens)	TRANS. RES. (Ohm-m^2)
			0.0		
1	1.89	1.24	-1.24	0.653	2.35
2	31.88	12.49	-13.73	0.392	398.4
3	805.5				

ALL PARAMETERS ARE FREE

No.	SPACING (m)	RHO-A (ohm-m) DATA	RHO-A (ohm-m) SYNTHETIC	DIFFERENCE (percent)
1	2.00	2.65	2.96	-11.73
2	3.00	3.84	4.10	-6.81
3	6.50	7.89	7.91	-0.273
4	8.00	10.00	9.37	6.24
5	10.00	11.58	11.22	3.09
6	16.00	17.28	16.38	5.20
7	20.00	20.75	19.71	4.98
8	25.00	24.82	23.89	3.71
9	30.00	28.68	28.12	1.94
10	40.00	35.99	36.65	-1.84
11	50.00	43.00	45.17	-5.04
12	65.00	57.00	57.73	-1.29
13	80.00	63.38	69.97	-10.40
14	100.0	76.56	85.76	-12.02
15	150.0	117.6	122.8	-4.45
16	200.0	201.0	156.8	21.96

CURRENT RESOLUTION MATRIX NOT AVAILABLE

DATA SET: AZARE 3

CLIENT: ATBU
LOCATION: AZARE
COUNTY: AZARE, BAUCHI STATE
PROJECT: DEPTH PROBING
ELEVATION: 0.00
SOUNDING COORDINATES: X: 0.0000 Y: 0.0000

DATE: -
SOUNDING: 3
AZIMUTH: -
EQUIPMENT: SAS 300 B

Schlumberger Configuration

FITTING ERROR: 7.243 PERCENT

L #	RESISTIVITY (ohm-m)	THICKNESS (meters)	ELEVATION (meters)	LONG. COND. (Siemens)	TRANS. RES. (Ohm-m^2)
			0.0		
1	349.9	2.02	-2.02	0.00580	709.7
2	1458.4	42.26	-44.28	0.0289	61634.8
3	235.5				

ALL PARAMETERS ARE FREE

No.	SPACING (m)	RHO-A (ohm-m) DATA	RHO-A (ohm-m) SYNTHETIC	DIFFERENCE (percent)
1	1.00	378.7	356.2	5.92
2	1.50	340.0	369.4	-8.67
3	2.00	358.2	390.9	-9.15
4	3.00	440.0	452.7	-2.90
5	4.00	538.0	525.8	2.25
6	5.00	635.5	598.5	5.81
7	7.00	764.4	726.6	4.94
8	10.00	910.0	873.1	4.05
9	15.00	952.4	1033.5	-8.51
10	20.00	1090.0	1130.3	-3.70
11	30.00	1120.0	1220.0	-8.93
12	40.00	1077.3	1231.3	-14.29
13	50.00	1197.0	1197.1	-0.0139
14	70.00	949.7	1057.5	-11.35
15	100.0	820.0	805.6	1.75
16	150.0	461.3	501.1	-8.61
17	200.0	334.7	355.7	-6.25

CURRENT RESOLUTION MATRIX NOT AVAILABLE

* UNDR - Rusafaya Project *

DATA SET: AZARE 4

CLIENT: ATBU
LOCATION: AZARE
COUNTY: AZARE, BAUCHI STATE
PROJECT: DEPTH PROBING
ELEVATION: 0.00
SOUNDING COORDINATES: X: 0.0000 Y: 0.0000

DATE: -
SOUNDING: 4
AZIMUTH: -
EQUIPMENT: SAS 300 B

Schlumberger Configuration

FITTING ERROR: 9.959 PERCENT

L #	RESISTIVITY (ohm-m)	THICKNESS (meters)	ELEVATION (meters)	LONG. COND. (Siemens)	TRANS. RES. (Ohm-m^2)
			0.0		
1	64.26	2.69	-2.69	0.0419	173.0
2	87.27	27.30	-30.00	0.312	2383.1
3	388.5				

ALL PARAMETERS ARE FREE

NO.	SPACING (m)	RHO-A (ohm-m) DATA	RHO-A (ohm-m) SYNTHETIC	DIFFERENCE (percent)
1	1.00	65.70	64.36	2.02
2	1.50	71.60	64.63	9.73
3	2.00	65.60	65.08	0.786
4	3.00	60.00	66.54	-10.90
5	4.00	60.60	68.49	-13.03
6	5.00	63.70	70.61	-10.85
7	7.00	68.10	74.54	-9.46
8	10.00	80.00	78.96	1.29
9	15.00	90.00	83.78	6.90
10	20.00	96.00	87.59	8.75
11	30.00	105.0	95.95	8.61
12	40.00	112.7	106.4	5.52
13	50.00	128.0	118.5	7.35
14	70.00	166.0	144.0	13.23
15	100.0	180.0	178.6	0.751
16	150.0	239.6	223.0	6.92
17	200.0	312.6	254.9	18.43

CURRENT RESOLUTION MATRIX NOT AVAILABLE

DATA SET: AZARE 5

CLIENT: ATBU
LOCATION: AZARE
COUNTY: AZARE, BAUCHI STATE
PROJECT: DEPTH PROBING
ELEVATION: 0.00
SOUNDING COORDINATES: X: 0.0000 Y: 0.0000

DATE: -
SOUNDING: 5
AZIMUTH: -
EQUIPMENT: SAS 300 B

Schlumberger Configuration

FITTING ERROR: 7.329 PERCENT

L #	RESISTIVITY (ohm-m)	THICKNESS (meters)	ELEVATION (meters)	LONG. COND. (Siemens)	TRANS. RES. (Ohm-m^2)
			0.0		
1	1.82	0.991	-0.991	0.544	1.80
2	41.23	24.00	-25.00	0.582	990.0
3	156.4				

ALL PARAMETERS ARE FREE

No.	SPACING (m)	RHO-A (ohm-m) DATA	RHO-A (ohm-m) SYNTHETIC	DIFFERENCE (percent)
1	1.00	2.08	2.18	-5.22
2	2.00	3.60	3.44	4.25
3	3.00	5.13	4.90	4.29
4	5.00	7.10	7.64	-7.61
5	6.50	9.70	9.48	2.18
6	10.00	12.33	13.26	-7.60
7	10.00	13.77	13.26	3.64
8	16.00	18.61	18.53	0.405
9	20.00	21.84	21.49	1.58
10	25.00	25.78	24.80	3.76
11	30.00	29.70	27.84	6.23
12	40.00	37.64	33.45	11.11
13	50.00	43.20	38.71	10.37
14	65.00	50.66	46.15	8.89
15	80.00	57.51	53.06	7.73
16	100.0	66.29	61.43	7.32
17	150.0	88.16	78.56	10.88

CURRENT RESOLUTION MATRIX NOT AVAILABLE

DATA SET: AZARE 6

CLIENT: ATBU
LOCATION: AZARE
COUNTY: AZARE, BAUCHI STATE
PROJECT: DEPTH PROBING
ELEVATION: 0.00
SOUNDING COORDINATES: X: 0.0000 Y: 0.0000

DATE: -
SOUNDING: 06
AZIMUTH: -
EQUIPMENT: SAS 300 B

Schlumberger Configuration

FITTING ERROR: 4.344 PERCENT

L #	RESISTIVITY (ohm-m)	THICKNESS (meters)	ELEVATION (meters)	LONG. COND. (Siemens)	TRANS. RES. (Ohm-m^2)
			0.0		
1	95.08	1.91	-1.91	0.0201	182.1
2	290.6	20.01	-21.92	0.0688	5816.5
3	83.76	56.82	-78.75	0.678	4760.1
4	383.0				

ALL PARAMETERS ARE FREE

No.	SPACING (m)	PHO-A (ohm-m) DATA	PHO-A (ohm-m) SYNTHETIC	DIFFERENCE (percent)
1	1.00	100.8	96.72	4.04
2	1.50	99.70	100.0	-0.386
3	2.00	104.2	105.4	-1.17
4	3.00	116.0	120.1	-3.60
5	4.00	136.8	136.7	0.0255
6	5.00	156.6	152.4	2.62
7	7.00	180.5	178.4	1.13
8	10.00	210.0	205.1	2.31
9	15.00	250.1	228.8	8.51
10	20.00	241.6	237.3	1.77
11	30.00	240.0	230.9	3.78
12	40.00	220.7	211.0	4.38
13	50.00	192.0	188.9	1.58
14	70.00	154.3	155.3	-0.684
15	100.0	154.0	136.9	11.04
16	150.0	150.0	148.4	1.04
17	200.0	175.3	171.8	1.96

DATA SET: AZARE 7

CLIENT: ATBU
LOCATION: AZARE
COUNTY: AZARE, BAUCHI STATE
PROJECT: DEPTH PROBING
ELEVATION: 0.00
SOUNDING COORDINATES: X: 0.0000 Y: 0.0000

DATE: -
SOUNDING: 07
AZIMUTH: -
EQUIPMENT: SAS 300 B

Schlumberger Configuration

FITTING ERROR: 7.452 PERCENT

L #	RESISTIVITY (ohm-m)	THICKNESS (meters)	ELEVATION (meters)	LONG. COND. (Siemens)	TRANS. RES. (Ohm-m^2)
			0.0		
1	20.59	4.42	-4.42	0.214	91.10
2	3411.0				

ALL PARAMETERS ARE FREE

No.	SPACING (m)	RHO-A (ohm-m) DATA	SYNTHETIC	DIFFERENCE (percent)
1	1.00	22.60	20.66	8.56
2	6.50	31.00	31.67	-2.17
3	8.00	34.19	37.50	-9.70
4	10.00	50.54	45.97	9.03
5	10.00	51.54	45.97	10.79
6	13.00	64.29	59.18	7.93
7	16.00	77.80	72.49	6.81
8	20.00	95.33	90.12	5.45
9	30.00	136.5	133.4	2.22
10	40.00	174.8	175.7	-0.543
11	60.00	244.7	257.3	-5.17
12	80.00	338.0	335.3	0.786
13	100.0	453.0	409.9	9.49

CURRENT RESOLUTION MATRIX NOT AVAILABLE

DATA SET: AZARE 8

CLIENT: ATBU
LOCATION: AZARE
COUNTY: AZARE, BAUCHI STATE
PROJECT: DEPTH PROBING
ELEVATION: 0.00
SOUNDING COORDINATES: X: 0.0000 Y: 0.0000

DATE: -
SOUNDING: 08
AZIMUTH: -
EQUIPMENT: SAS 300 B

Schlumberger Configuration

FITTING ERROR: 7.190 PERCENT

L #	RESISTIVITY (ohm-m)	THICKNESS (meters)	ELEVATION (meters)	LONG. COND. (Siemens)	TRANS. RES. (Ohm-m^2)
			0.0		
1	1910.1	1.14	-1.14	6.020E-04	2196.6
2	949.4	16.63	-17.78	0.0175	15793.2
3	2279.0	5.53	-23.31	0.00243	12607.1
4	85.62	105.8	-129.1	1.23	9064.4
5	2033.8				

ALL PARAMETERS ARE FREE

N...	SPACING (m)	RHO-A (ohm-m) DATA	RHO-A (ohm-m) SYNTHETIC	DIFFERENCE (percent)
1	1.00	1662.0	1632.6	-10.26
2	1.50	1653.0	1714.0	-3.69
3	2.00	1743.0	1574.9	9.63
4	4.00	1297.0	1184.4	8.67
5	5.00	1234.0	1098.0	11.01
6	7.00	994.2	1019.3	-2.52
7	10.00	850.0	980.0	-15.30
8	15.00	882.0	956.8	-8.49
9	20.00	927.0	937.3	-1.11
10	30.00	910.0	867.7	4.64
11	40.00	725.0	756.6	-4.36
12	50.00	635.0	629.0	0.953
13	70.00	440.7	405.6	7.98
14	100.0	208.0	220.6	-6.08
15	150.0	140.8	146.0	-3.65
16	200.0	161.8	157.3	2.74
17	300.0	220.5	216.2	1.94
18	400.0	288.8	278.1	3.71

DATA SET: AZARE 9

CLIENT: ATBU
LOCATION: AZARE
COUNTY: AZARE, BAUCHI STATE
PROJECT: DEPTH PROBING
ELEVATION: 0.00
SOUNDING COORDINATES: X: 0.0000 Y: 0.0000

DATE: -
SOUNDING: 09
AZIMUTH: -
EQUIPMENT: SAS 300 B

Schlumberger Configuration

FITTING ERROR: 7.036 PERCENT

L #	RESISTIVITY (ohm-m)	THICKNESS (meters)	ELEVATION (meters)	LONG. COND. (Siemens)	TRANS. RES. (Ohm-m^2)
			0.0		
1	1147.7	14.19	-14.19	0.0123	16297.0
2	92.35	184.2	-198.4	1.99	17018.2
3	6889.7				

ALL PARAMETERS ARE FREE

No.	SPACING (m)	RHO-A (ohm-m) DATA	RHO-A (ohm-m) SYNTHETIC	DIFFERENCE (percent)
1	3.00	1173.0	1144.2	2.45
2	4.00	1183.0	1140.9	3.55
3	5.00	1191.0	1138.0	4.44
4	7.00	1174.0	1123.3	4.31
5	10.00	1150.0	1083.6	5.77
6	15.00	906.5	972.8	-7.30
7	20.00	755.0	827.0	-9.53
8	30.00	529.0	537.5	-1.62
9	40.00	305.5	334.5	-9.52
10	50.00	240.3	218.8	8.98
11	70.00	137.0	129.2	5.67
12	100.0	110.0	104.8	4.71
13	150.0	96.10	106.5	-10.89
14	200.0	107.0	117.5	-9.88
15	300.0	165.0	152.1	7.80
16	400.0	212.0	194.7	8.12
17	500.0	235.8	239.9	-1.73
18	700.0	311.3	330.8	-6.24

DATA SET: AZARE 10

CLIENT: ATBU
LOCATION: AZARE
COUNTY: AZARE, BAUCHI STATE
PROJECT: DEPTH PROBING
ELEVATION: 0.00
SOUNDING COORDINATES: X: 0.0000 Y: 0.0000

DATE: -
SOUNDING: 10
AZIMUTH: -
EQUIPMENT: SAS 300 B

Schlumberger Configuration

FITTING ERROR: 9.470 PERCENT

L #	RESISTIVITY (ohm-m)	THICKNESS (meters)	ELEVATION (meters)	LONG. COND. (Siemens)	TRANS. RES. (Ohm-m^2)
			0.0		
1	1208.7	14.42	-14.42	0.0119	17439.5
2	68.20	57.64	-72.07	0.845	3931.6
3	876.8				

ALL PARAMETERS ARE FREE

No.	SPACING (m)	RHO-A (ohm-m) DATA	RHO-A (ohm-m) SYNTHETIC	DIFFERENCE (percent)
1	3.00	960.0	1206.3	-25.65
2	4.00	1071.4	1203.4	-12.32
3	5.00	1188.6	1198.8	-0.855
4	7.00	1347.3	1183.2	12.17
5	10.00	1358.0	1141.2	15.96
6	15.00	1147.3	1023.5	10.78
7	20.00	852.2	867.5	-1.80
8	30.00	535.0	554.8	-3.70
9	40.00	327.8	334.3	-1.97
10	50.00	210.3	209.9	0.218
11	70.00	124.1	121.0	2.44
12	100.0	112.0	114.5	-2.25
13	150.0	148.3	150.5	-1.44
14	200.0	197.3	189.5	3.95
15	300.0	279.6	259.5	7.16
16	400.0	324.1	319.1	1.53
17	500.0	350.7	370.3	-5.56
18	700.0	403.5	453.6	-12.41
19	1000.0	524.2	545.0	-3.96
20	1500.0	707.9	644.0	9.02

DATA SET: AZARE 11

CLIENT: ATBU
LOCATION: AZARE
COUNTY: AZARE, BAUCHI STATE
PROJECT: DEPTH PROBING
ELEVATION: 0.00
SOUNDING COORDINATES: X: 0.0000 Y: 0.0000

DATE: -
SOUNDING: 11
AZIMUTH: -
EQUIPMENT: SAS 300 B

Schlumberger Configuration

FITTING ERROR: 9.172 PERCENT

L #	RESISTIVITY (ohm-m)	THICKNESS (meters)	ELEVATION (meters)	LONG. COND. (Siemens)	TRANS. RES. (Ohm-m^2)
			0.0		
1	141.0	0.594	-0.594	0.00422	83.84
2	9557.3	2.82	-3.41	2.953E-04	26973.9
3	107.7	151.5	-154.9	1.40	16335.2
4	2005.8				

ALL PARAMETERS ARE FREE

No.	SPACING (m)	RHO-A (ohm-m) DATA	RHO-A (ohm-m) SYNTHETIC	DIFFERENCE (percent)
1	2.00	384.5	444.7	-15.67
2	3.00	580.0	641.7	-10.65
3	4.00	755.0	819.5	-8.55
4	5.00	1014.0	977.1	3.63
5	7.00	1359.0	1232.0	9.33
6	10.00	1624.0	1477.3	9.03
7	15.00	1759.0	1606.4	8.67
8	20.00	1657.0	1520.5	8.23
9	30.00	1350.0	1120.1	17.02
10	40.00	677.4	735.0	-8.51
11	50.00	456.8	469.5	-2.76
12	70.00	212.3	220.1	-3.63
13	100.0	120.0	135.4	-12.86
14	150.0	138.6	131.8	4.87
15	200.0	157.7	149.1	5.41
16	300.0	210.0	198.1	5.66
17	400.0	262.3	252.3	3.84
18	500.0	320.7	305.7	4.70
19	700.0	409.2	405.7	0.878

DATA SET: AZARE 12

CLIENT: ATBU
LOCATION: AZARE
COUNTY: AZARE, BAUCHI STATE
PROJECT: DEPTH PROBING
ELEVATION: 0.00
SOUNDING COORDINATES: X: 0.0000 Y: 0.0000

DATE: -
SOUNDING: 12
AZIMUTH: -
EQUIPMENT: SAS 300 B

Schlumberger Configuration

FITTING ERROR: 9.887 PERCENT

L #	RESISTIVITY (ohm-m)	THICKNESS (meters)	ELEVATION (meters)	LONG. COND. (Siemens)	TRANS. RES. (Ohm-m^2)
			0.0		
1	2449.3	16.73	-16.73	0.00683	40991.6
2	87.68	240.2	-257.0	2.74	21066.6
3	645.7				

ALL PARAMETERS ARE FREE

No.	SPACING (m)	RHO-A (ohm-m) DATA	RHO-A (ohm-m) SYNTHETIC	DIFFERENCE (percent)
1	1.00	2526.0	2448.7	3.05
2	1.50	2350.0	2448.4	-4.18
3	2.00	2350.0	2447.7	-4.16
4	3.00	2348.1	2445.6	-4.15
5	4.00	2344.0	2441.6	-4.16
6	5.00	2339.1	2435.3	-4.11
7	7.00	2381.0	2413.6	-1.37
8	10.00	2700.0	2353.7	12.82
9	15.00	2265.0	2175.3	3.95
10	20.00	1994.0	1918.2	3.79
11	30.00	1540.0	1330.1	13.62
12	40.00	752.0	838.9	-11.55
13	50.00	455.0	511.9	-12.52
14	70.00	210.0	212.2	-1.06
15	100.0	143.0	110.9	22.42
16	150.0	82.30	95.77	-16.37
17	200.0	86.20	98.21	-13.94
18	300.0	110.0	111.4	-1.35
19	400.0	131.5	130.3	0.912
20	500.0	143.3	151.1	-5.42

DATA SET: AZARE 13

CLIENT: ATBU
LOCATION: AZARE
COUNTY: AZARE, BAUCHI STATE
PROJECT: DEPTH PROBING
ELEVATION: 0.00
SOUNDING COORDINATES: X: 0.0000 Y: 0.0000

DATE: -
SOUNDING: 13
AZIMUTH: -
EQUIPMENT: SAS 300 B

Schlumberger Configuration

FITTING ERROR: 7.540 PERCENT

L #	RESISTIVITY (ohm-m)	THICKNESS (meters)	ELEVATION (meters)	ONG. COND. (Siemens)	TRANS. RES. (Ohm-m^2)
			0.0		
1	602.3	24.29	-24.29	0.0403	14635.2
2	13.07	33.94	-58.24	2.59	443.9
3	464.8				

ALL PARAMETERS ARE FREE

No.	SPACING (m)	RHO-A (ohm-m) DATA	RHO-A (ohm-m) SYNTHETIC	DIFFERENCE (percent)
1	1.00	612.0	602.0	1.62
2	1.50	612.0	602.0	1.62
3	2.00	609.0	602.0	1.13
4	3.00	600.0	601.9	-0.324
5	4.00	546.2	601.6	-10.12
6	5.00	538.2	601.0	-11.66
7	7.00	600.0	599.2	0.128
8	10.00	603.0	593.8	1.52
9	15.00	586.0	576.1	1.68
10	20.00	557.0	546.7	1.83
11	30.00	478.0	460.0	3.75
12	40.00	375.0	358.5	4.39
13	50.00	308.0	265.2	13.88
14	70.00	121.0	137.1	-13.37
15	100.0	60.00	63.65	-6.08
16	150.0	55.60	53.35	4.03
17	200.0	74.30	66.06	11.07
18	300.0	90.00	93.01	-3.35
19	400.0	107.0	117.2	-9.59
20	500.0	132.0	139.0	-5.37

DATA SET: AZARE 14

CLIENT: ATBU
LOCATION: AZARE
COUNTY: AZARE, BAUCHI STATE
PROJECT: DEPTH PROBING
ELEVATION: 0.00
SOUNDING COORDINATES: X: 0.0000 Y: 0.0000

DATE: -
SOUNDING: 14
AZIMUTH: -
EQUIPMENT: SAS 300 B

Schlumberger Configuration

FITTING ERROR: 6.978 PERCENT

L #	RESISTIVITY (ohm-m)	THICKNESS (meters)	ELEVATION (meters)	LONG. COND. (Siemens)	TRANS. RES. (Ohm-m^2)
			0.0		
1	537.9	37.07	-37.07	0.0689	19943.1
2	141.3	101.6	-138.7	0.719	14371.8
3	2289.7				

ALL PARAMETERS ARE FREE

No.	SPACING (m)	RHO-A (ohm-m) DATA	RHO-A (ohm-m) SYNTHETIC	DIFFERENCE (percent)
1	1.00	537.2	537.8	-0.119
2	1.50	517.0	537.8	-4.02
3	2.00	537.0	537.8	-0.153
4	3.00	500.0	537.7	-7.55
5	4.00	462.2	537.7	-16.31
6	5.00	488.7	537.6	-10.01
7	7.00	515.2	537.3	-4.28
8	10.00	560.0	536.4	4.19
9	15.00	573.5	533.3	7.00
10	20.00	569.7	527.7	7.37
11	30.00	508.0	508.0	-0.0160
12	40.00	478.0	478.2	-0.0458
13	50.00	441.0	441.9	-0.223
14	70.00	331.0	367.2	-10.95
15	100.0	260.0	284.7	-9.53
16	150.0	214.0	238.6	-11.53
17	200.0	236.7	253.8	-7.25
18	300.0	345.0	335.0	2.88
19	400.0	456.2	424.5	6.95
20	500.0	538.7	509.2	5.47

DATA SET: AZARE 15

CLIENT: ATBU
LOCATION: AZARE
COUNTY: AZARE, BAUCHI STATE
PROJECT: DEPTH PROBING
ELEVATION: 0.00
SOUNDING COORDINATES: X: 0.0000 Y: 0.0000

DATE: -
SOUNDING: 15
AZIMUTH: -
EQUIPMENT: SAS 300 B

Schlumberger Configuration

FITTING ERROR: 9.841 PERCENT

L #	RESISTIVITY (ohm-m)	THICKNESS (meters)	ELEVATION (meters)	LONG. COND. (Siemens)	TRANS. RES. (Ohm-m^2)
			0.0		
1	2230.1	5.19	-5.19	0.00233	11585.0
2	263.5	30.80	-35.99	0.116	8118.4
3	82.53	97.42	-133.4	1.18	8040.8
4	499.1				

ALL PARAMETERS ARE FREE

No.	SPACING (m)	RHO-A (ohm-m) DATA	SYNTHETIC	DIFFERENCE (percent)
1	1.00	2133.0	2226.7	-4.39
2	1.50	2025.0	2220.1	-9.63
3	2.00	2060.0	2208.0	-7.18
4	3.00	2180.0	2161.8	0.830
5	4.00	2231.0	2083.4	6.61
6	5.00	2131.0	1974.7	7.33
7	7.00	1804.0	1695.2	6.02
8	10.00	1310.0	1246.6	4.83
9	15.00	738.0	710.2	3.76
10	20.00	408.1	451.7	-10.70
11	30.00	264.0	290.1	-9.90
12	40.00	249.1	244.6	1.78
13	50.00	235.0	216.7	7.77
14	70.00	186.3	174.2	6.47
15	100.0	136.0	137.2	-0.919
16	150.0	115.4	123.3	-6.88
17	200.0	129.8	133.8	-3.13
18	300.0	160.0	169.8	-6.16
19	400.0	185.3	204.6	-10.45

* UNDR - Rusafaya Project *

DATA SET: AZARE 16

CLIENT: ATBU
LOCATION: AZARE
COUNTY: AZARE, BAUCHI STATE
PROJECT: DEPTH PROBING
ELEVATION: 0.00
SOUNDING COORDINATES: X: 0.0000 Y: 0.0000

DATE: -
SOUNDING: 16
AZIMUTH: -
EQUIPMENT: SAS 300 B

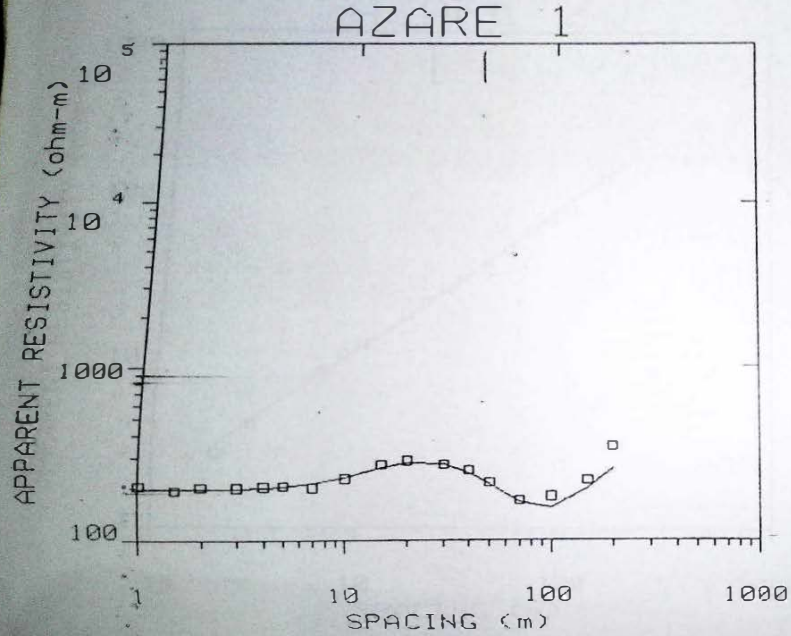
Schlumberger Configuration

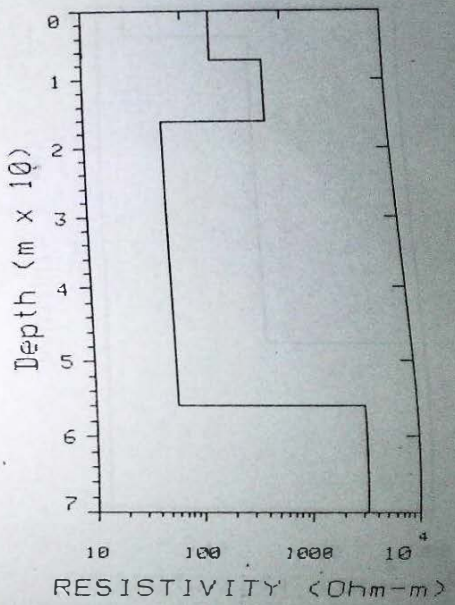
FITTING ERROR: 9.012 PERCENT

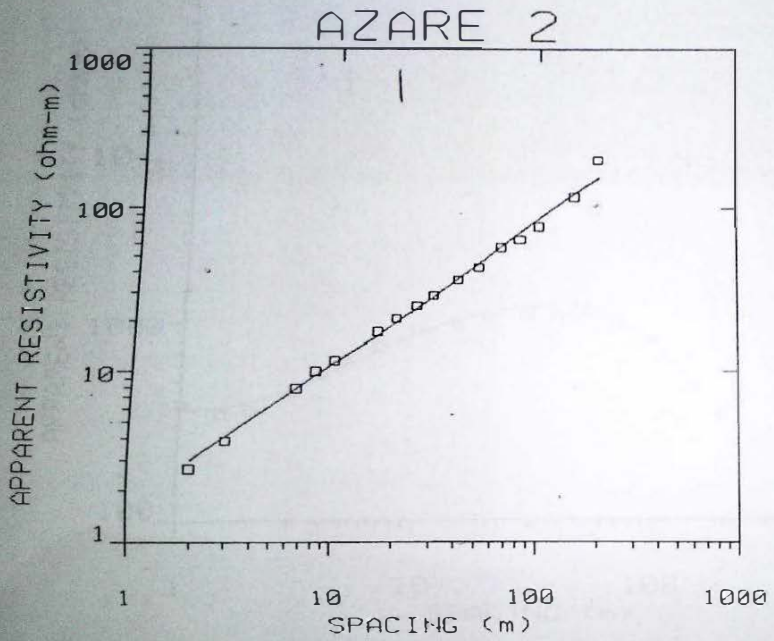
L #	RESISTIVITY (ohm-m)	THICKNESS (meters)	ELEVATION (meters)	LONG. COND. (Siemens)	TRANS. RES. (Ohm-m^2)
			0.0		
1	2231.0	6.34	-6.34	0.00284	14152.4
2	274.4	34.60	-40.94	0.126	9496.5
3	50.43	54.97	-95.92	1.09	2772.5
4	379.2				

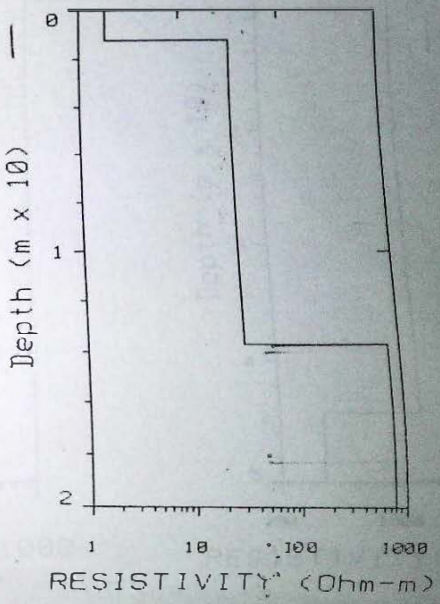
ALL PARAMETERS ARE FREE

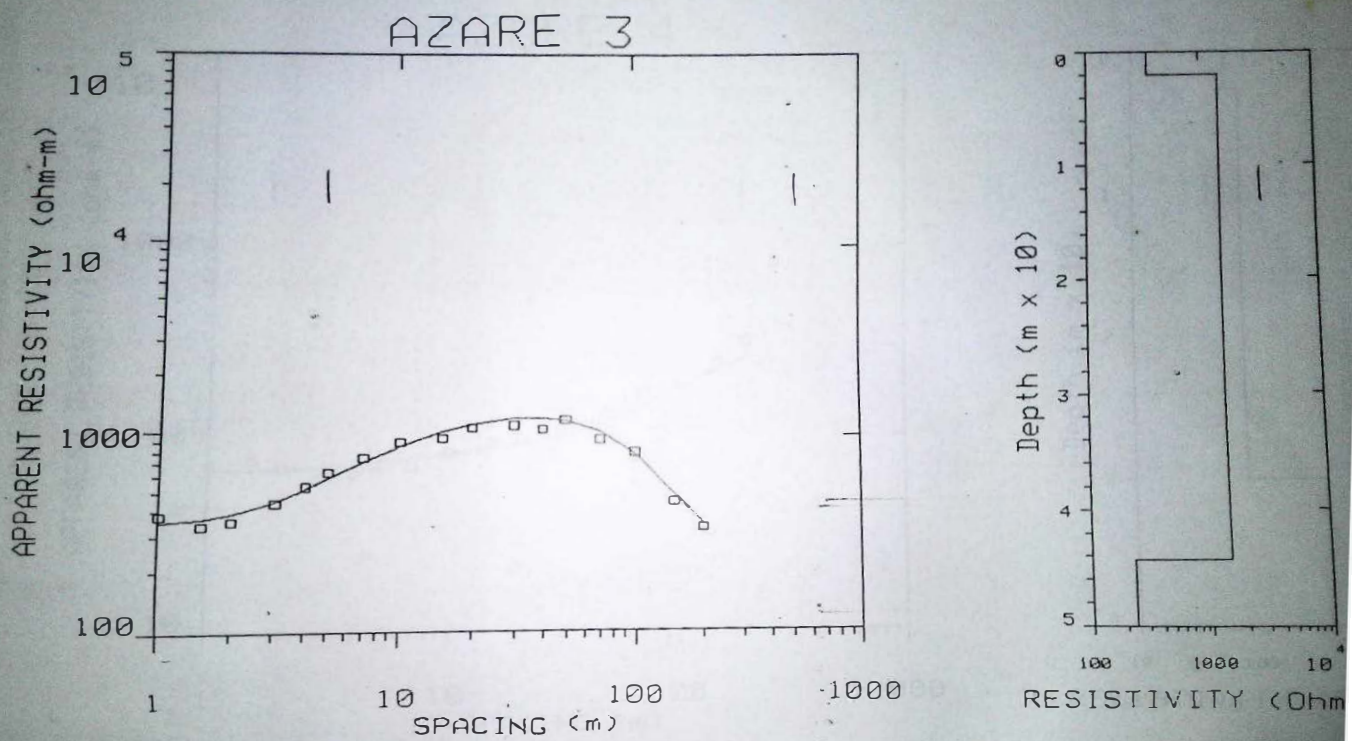
NO.	SPACING (m)	RHO-A (ohm-m) DATA	RHO-A (ohm-m) SYNTHETIC	DIFFERENCE (percent)
1	1.00	1775.5	2229.0	-25.54
2	1.50	1924.6	2225.3	-15.62
3	2.00	1967.1	2218.5	-12.77
4	3.00	2180.0	2192.0	-0.553
5	4.00	2362.0	2145.1	9.18
6	5.00	2076.0	2076.6	-0.0300
7	7.00	1883.0	1883.3	-0.0191
8	10.00	1519.0	1519.6	-0.0449
9	15.00	995.0	970.2	2.48
10	20.00	626.0	626.6	-0.111
11	30.00	340.0	352.3	-3.63
12	40.00	278.0	272.2	2.05
13	50.00	250.0	233.2	6.69
14	70.00	188.0	180.0	4.25
15	100.0	130.0	132.4	-1.88
16	150.0	105.0	113.7	-8.33
17	200.0	116.0	125.4	-8.12
18	300.0	156.0	160.3	-2.81
19	400.0	198.0	190.4	3.83

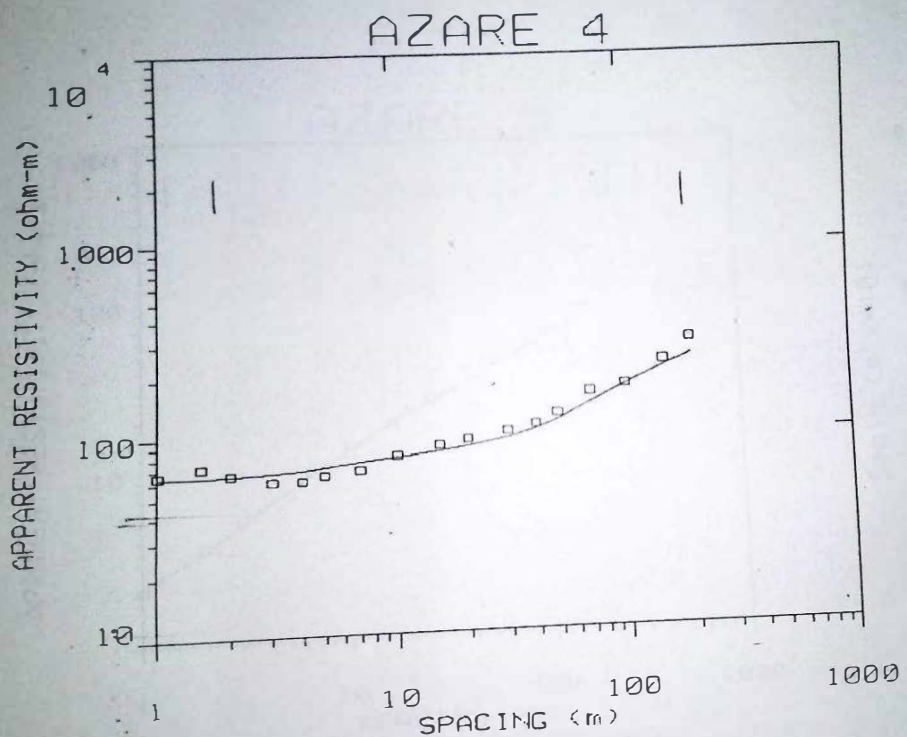

AZARE 1
APPARENT RESISTIVITY (ohm-m)
10^5
10^4
1000
100
1
10
100
1000
SPACING (m)

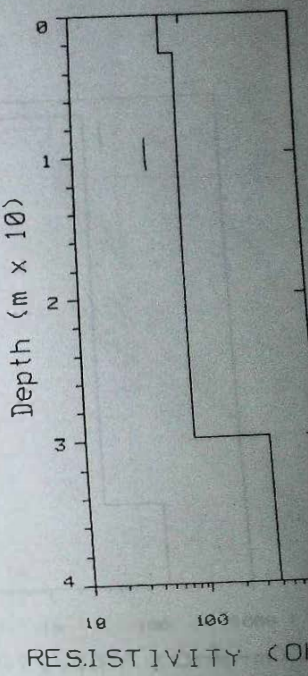

Depth (m x 10)
0
1
2
3
4
5
6
7
10
100
1000
10^4
RESISTIVITY (Ohm-m)

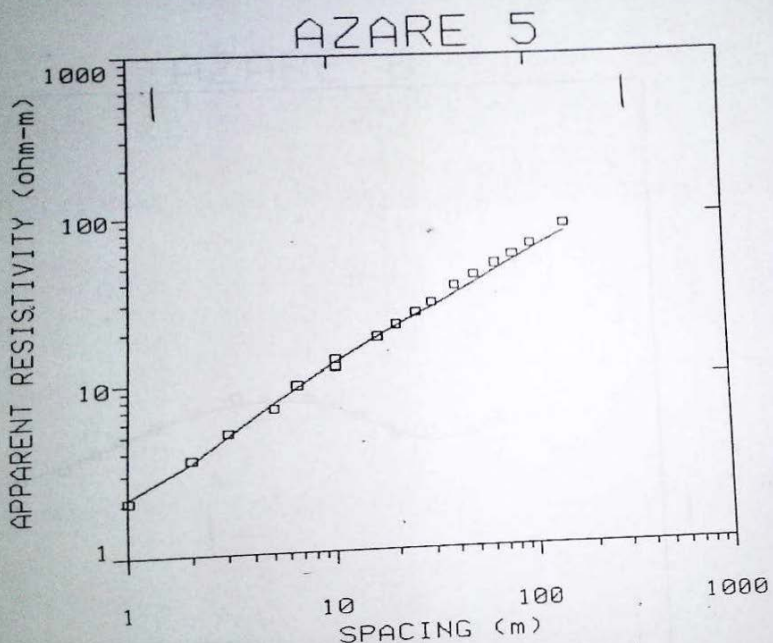

AZARE 2
1
APPARENT RESISTIVITY (ohm-m)
1000
100
10
1
1
10
100
1000
SPACING (m)

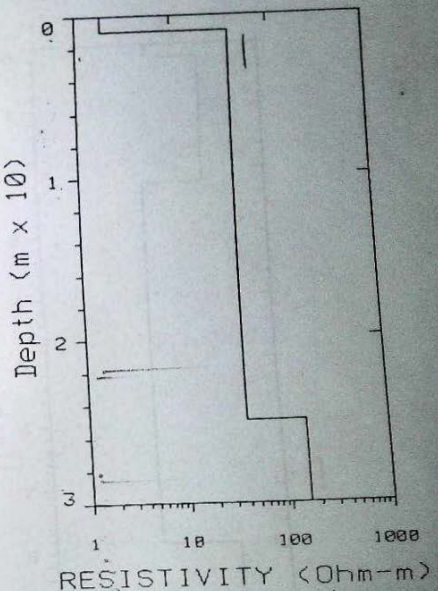

Depth (m x 10)
0
1
2
1
10
100
1000
RESISTIVITY (Ohm-m)

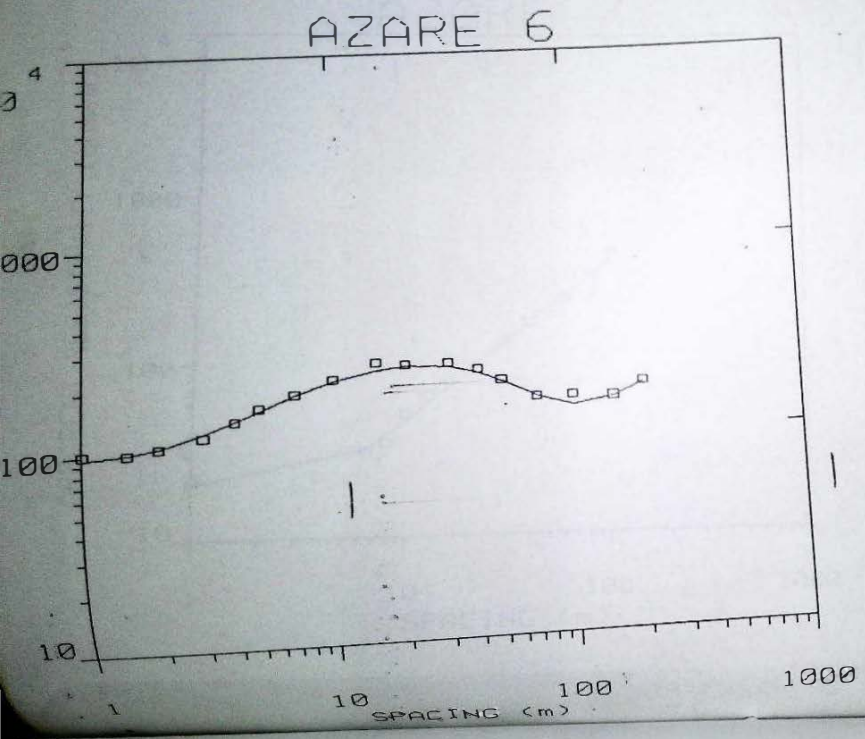

AZARE 3
APPARENT RESISTIVITY (ohm-m)
10^5
10^4
1000
100
1
10
100
1000
SPACING (m)
Depth (m x 10)
0
1
2
3
4
5
100
1000
10^4
RESISTIVITY (Ohm

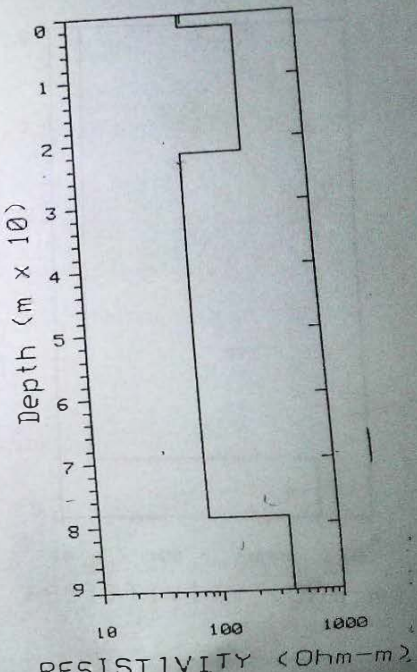

AZARE 4
APPARENT RESISTIVITY (ohm-m)
10 4
1000
100
10
1
10
100
1000
SPACING (m)

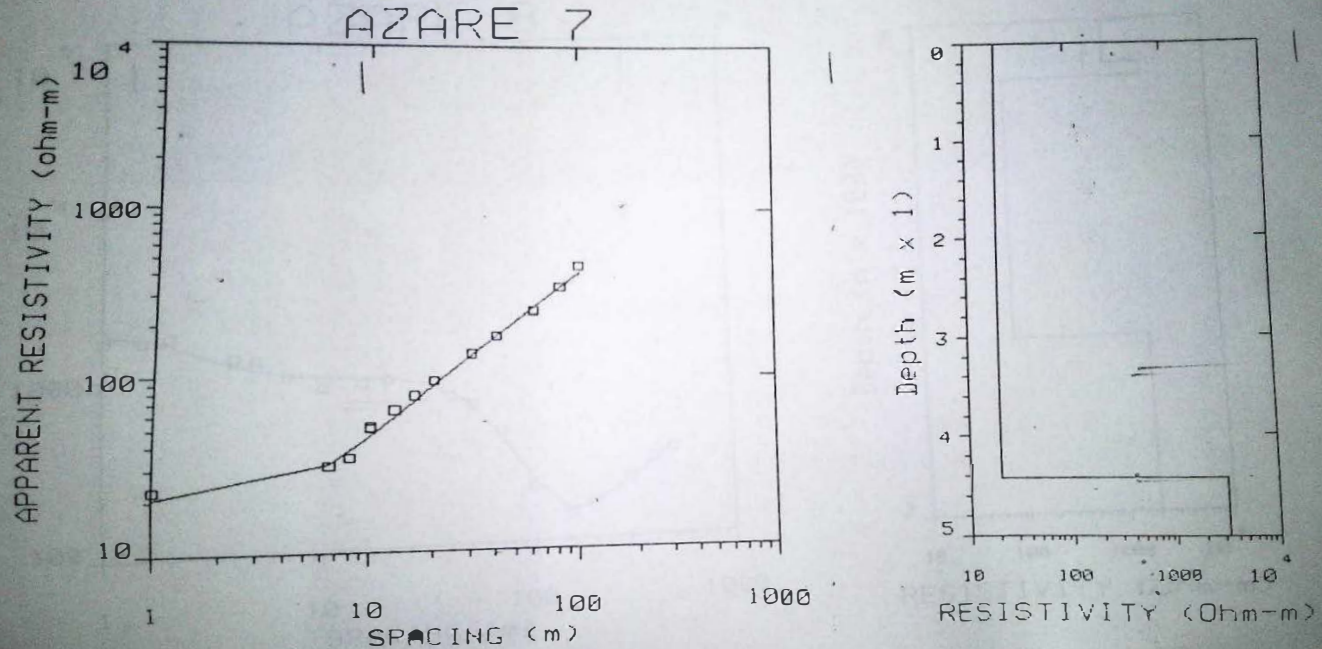

Depth (m x 10)
0
1
2
3
4
10
100
RESISTIVITY (O

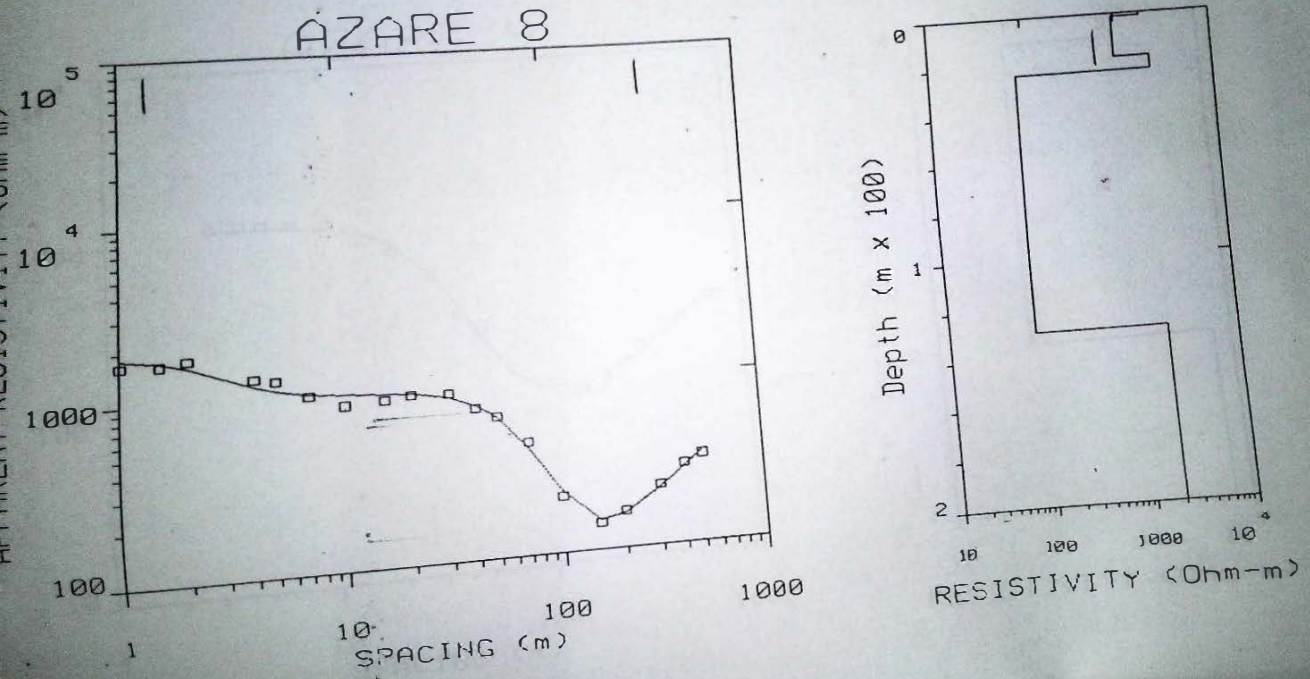

AZARE 5
APPARENT RESISTIVITY (ohm-m)
1000
100
10
1
1
10
100
1000
SPACING (m)

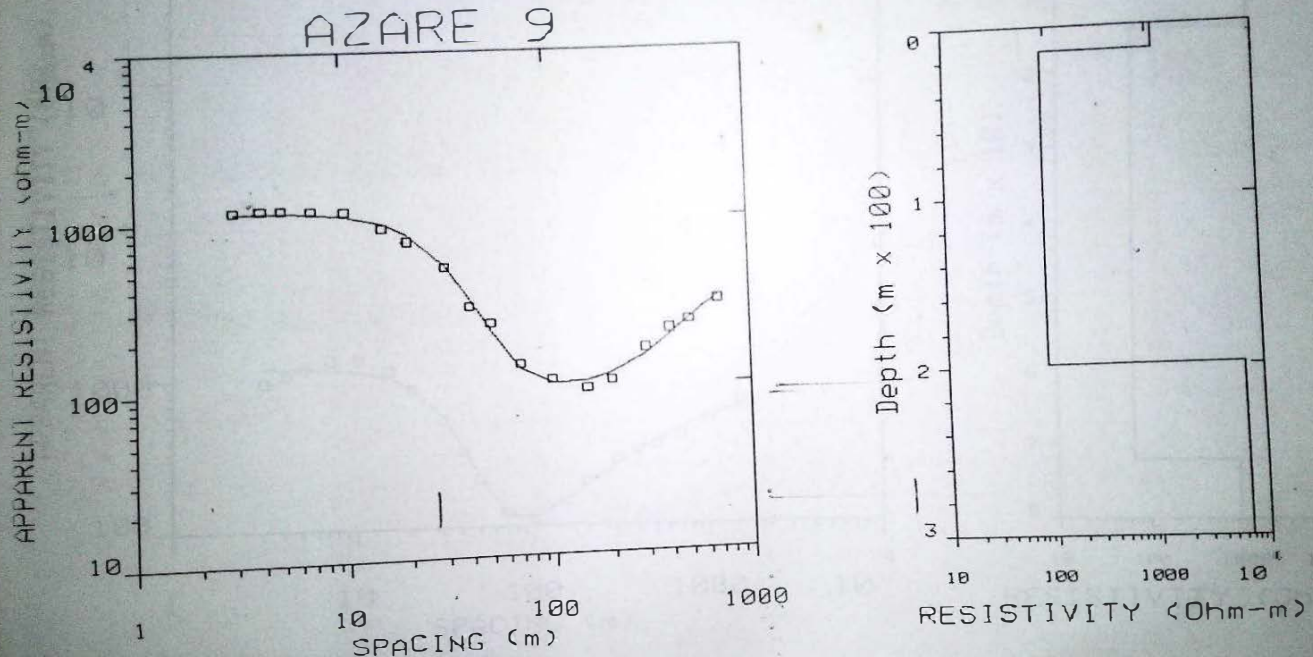

Depth (m x 10)
0
1
2
3
1
10
100
1000
RESISTIVITY (Ohm-m)

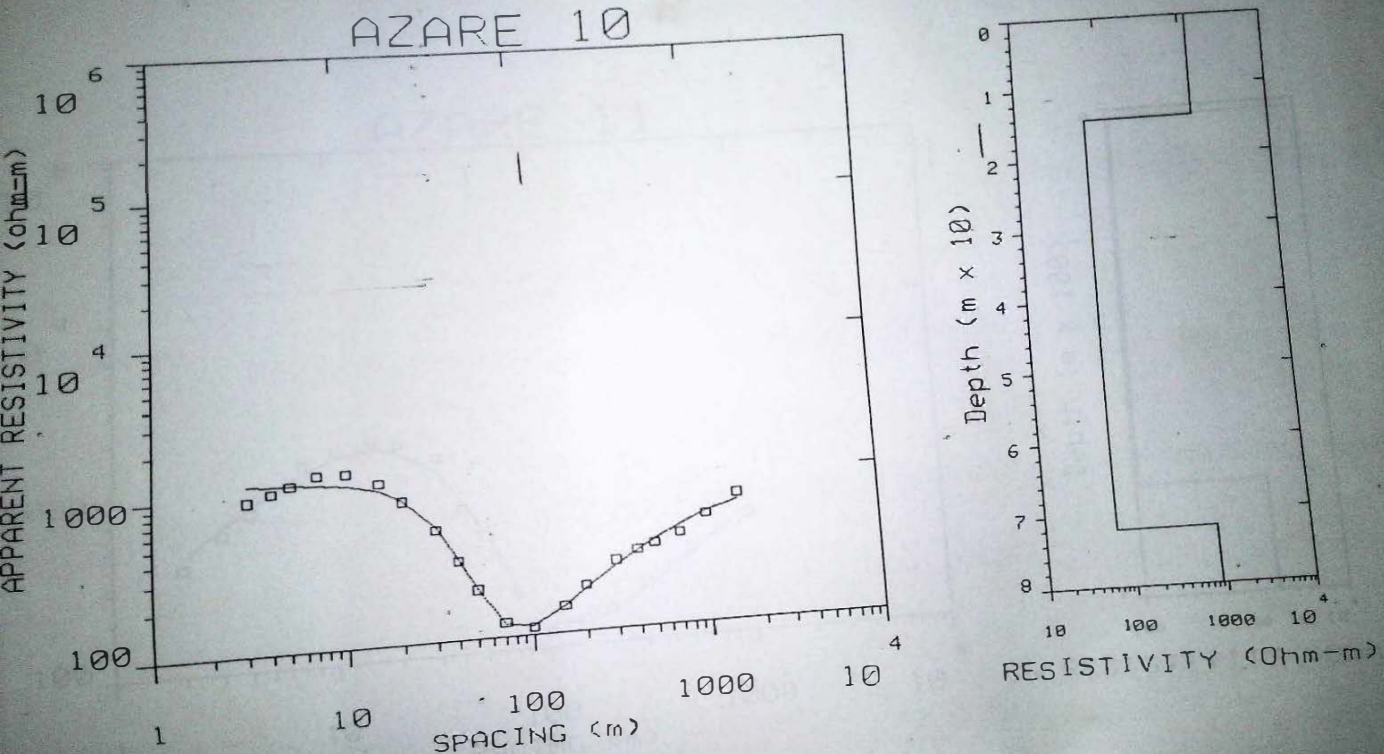

AZARE 6
4
000
100
10
1
10
100
1000
SPACING (m)

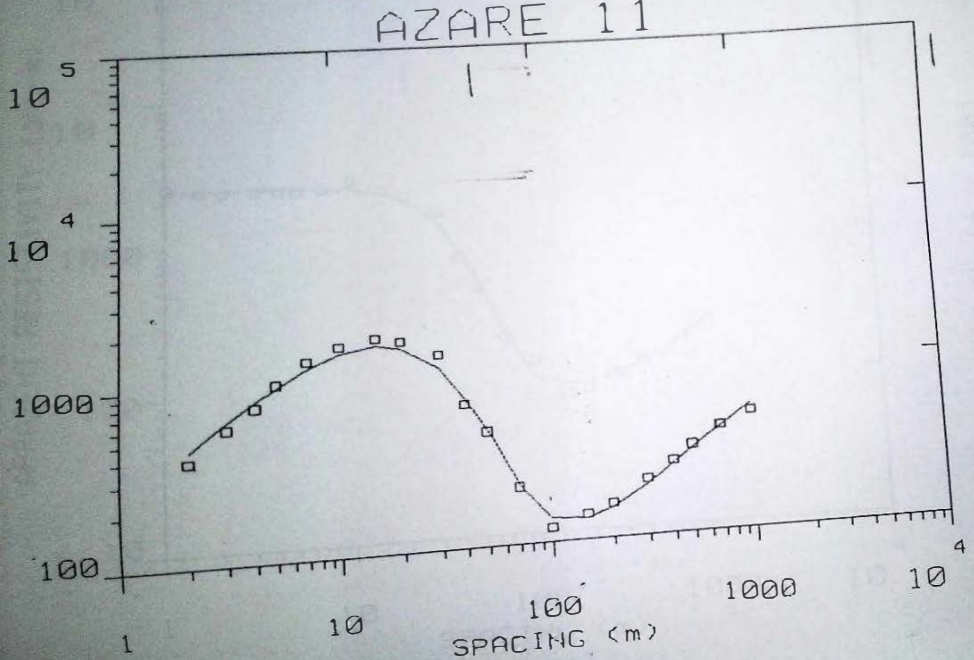

0
1
2
3
4
5
6
7
8
9
Depth (m x 10)
10
100
1000
RESISTIVITY (Ohm-m)

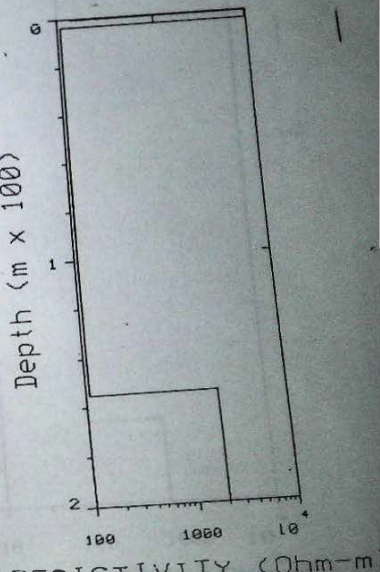

AZARE 7
APPARENT RESISTIVITY (ohm-m)
10 4
1000
100
10
1
10
100
1000
SPACING (m)
Depth (m x 1)
0
1
2
3
4
5
10
100
1000
10 4
RESISTIVITY (Ohm-m)

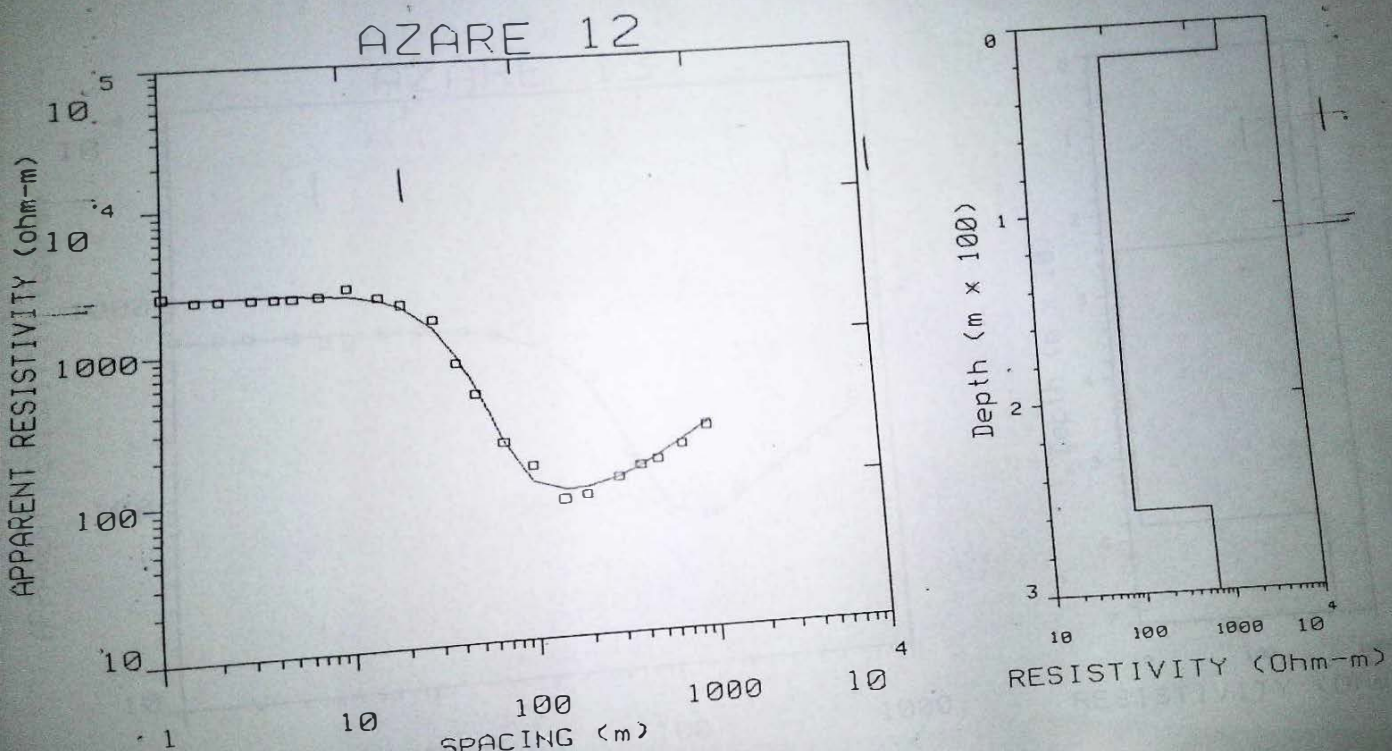

AZARE 8
10 5
10 4
1000
100
1
10
100
1000
SPACING (m)
0
1
2
Depth (m x 100)
10
100
1000
10 4
RESISTIVITY (Ohm-m)

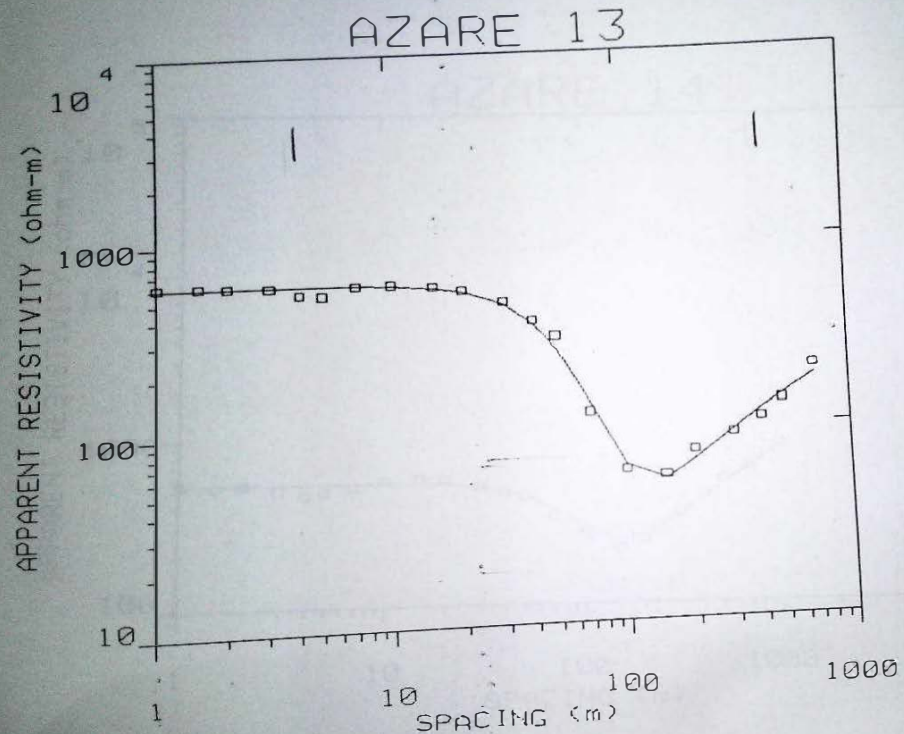

AZARE 9
APPARENT RESISTIVITY (ohm-m)
10^4
1000
100
10
1
10
100
1000
SPACING (m)
Depth (m x 100)
0
1
2
3
10
100
1000
10^4
RESISTIVITY (Ohm-m)

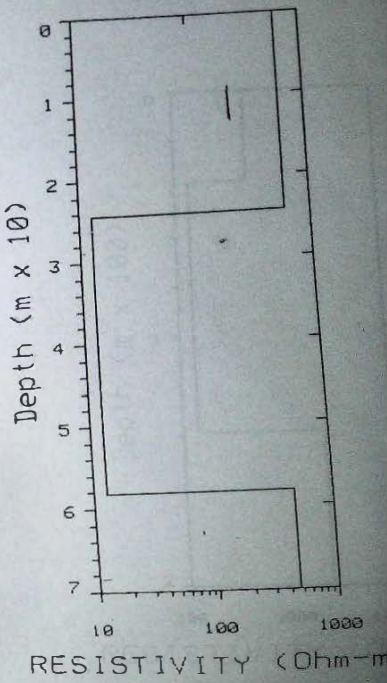

AZARE 10
APPARENT RESISTIVITY (ohm-m)
10^6
10^5
10^4
1000
100
1
10
100
1000
10^4
SPACING (m)
Depth (m x 10)
0
1
2
3
4
5
6
7
8
10
100
1000
10^4
RESISTIVITY (Ohm-m)

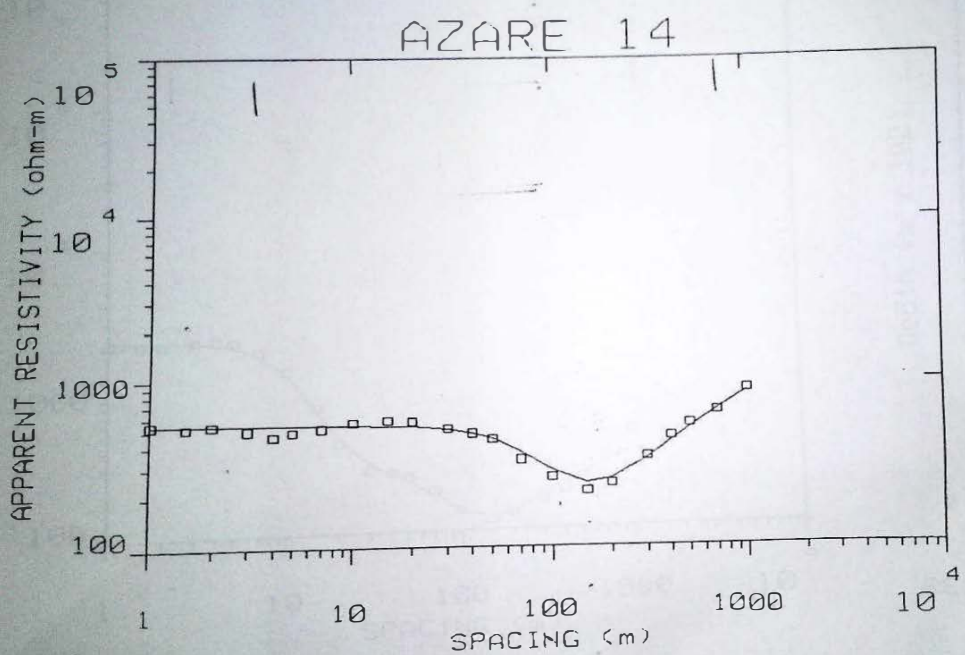

AZARE 11
10^5
10^4
1000
100
1
10
100
1000
10^4
SPACING (m)

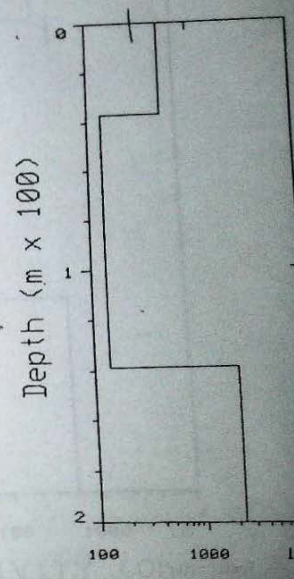

0
1
2
Depth (m x 100)
100
1000
10^4
RESISTIVITY (Ohm-m)

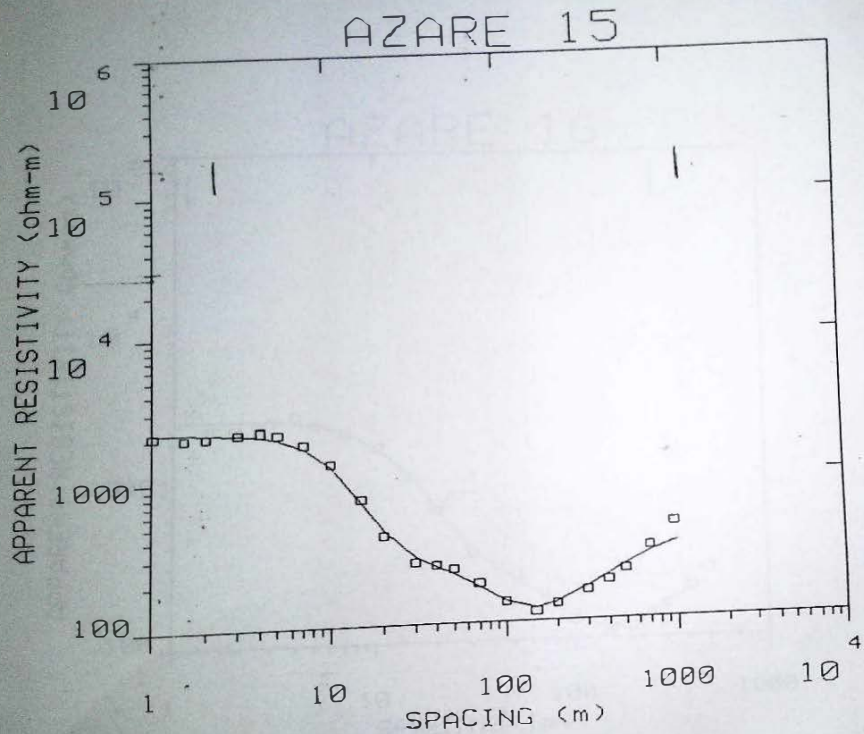

AZARE 12
APPARENT RESISTIVITY (ohm-m)
10^5
10^4
1000
100
10
1
10
100
1000
10^4
SPACING (m)
Depth (m x 100)
0
1
2
3
10
100
1000
10^4
RESISTIVITY (Ohm-m)

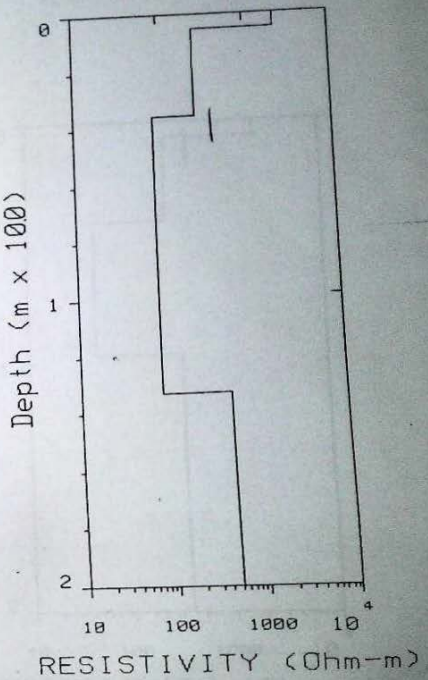

AZARE 13
APPARENT RESISTIVITY (ohm-m)
10 4
1000
100
10
1
10
100
1000
SPACING (m)

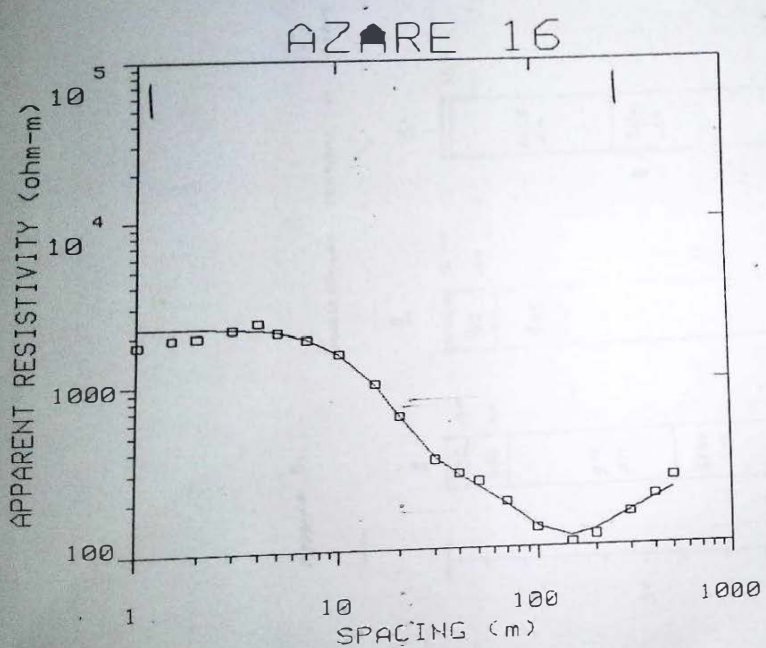

Depth (m x 10)
0
1
2
3
4
5
6
7
10
100
1000
RESISTIVITY (Ohm-m

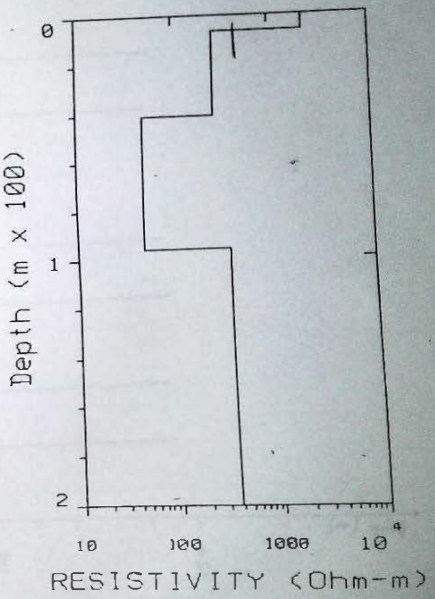

AZARE 14
APPARENT RESISTIVITY (ohm-m)
10 5
10 4
1000
100
1
10
100
1000
10 4
SPACING (m)


Depth (m x 100)
0
1
2
100
1000
RESISTIVITY (O


AZARE 15
APPARENT RESISTIVITY (ohm-m)
10 6
10 5
10 4
1000
100
1
10
100
1000
10 4
SPACING (m)

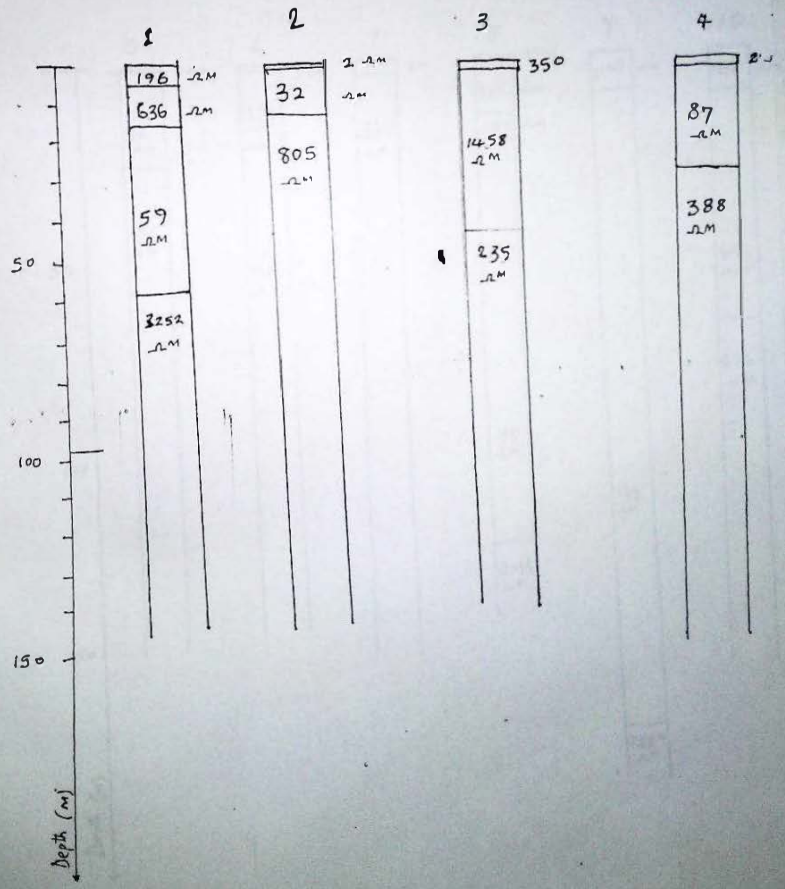

0
1
2
Depth (m x 100)
10
100
1000
10 4
RESISTIVITY (Ohm-m)


AZARE 16
APPARENT RESISTIVITY (ohm-m)
10^5
10^4
1000
100
1
10
100
1000
SPACING (m)

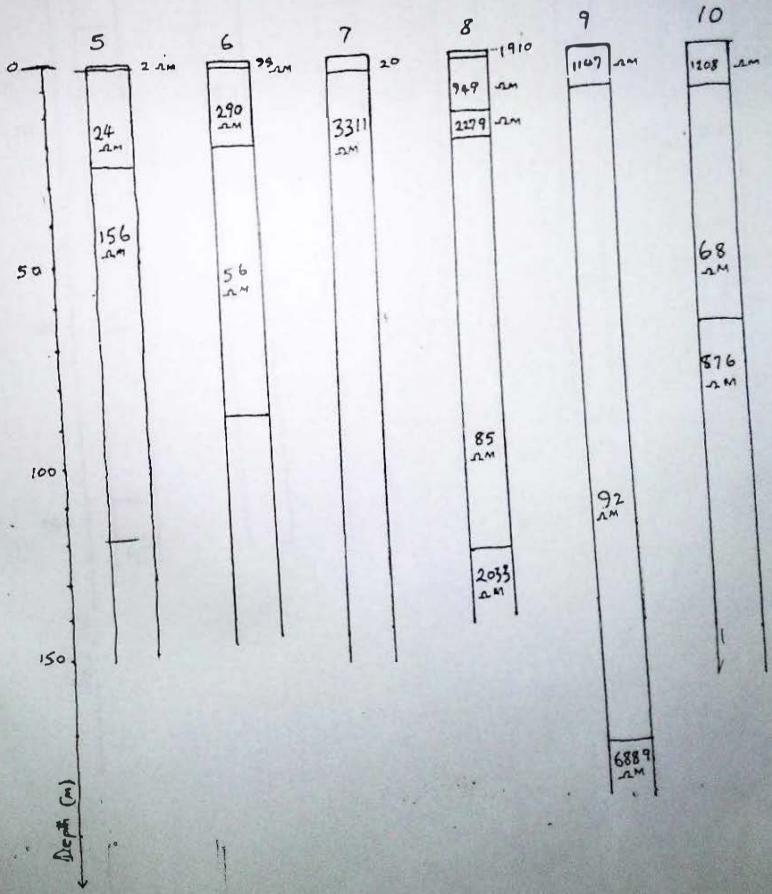

Depth (m x 100)
0
1
2
10
100
1000
10^4
RESISTIVITY (Ohm-m)

Appendix B1

Geoelectrical sections in Azare town



Appendix B2 Geoelectrical Sections in Azare town



Appendix B3 Geoelectrical sections in Azare town