

Geol-electric Investigation of groundwater conditions: A case study of Ogwashi-Uku in Delta State, Nigeria.

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Abstract

The Ogwashi-Uku community has been grappling with water problems for many decades. This may be probably due to the topography of the area which made the aquifer very deep. The ground water potential of Ogwashi-Uku was therefore evaluated using geo-electric method to ascertain the nature of the problem.

Vertical Electrical Sounding (VES) data which were acquired from four locations evenly distributed showed that the curve types are AK, KH, HKAK and AK. The resistivity of the top soil ranges from 81 ohm-meter – 927 ohm-meter, while of the second and third layers are 96 – 1186 ohm – meter and 150 – 2977 ohm – meter, respectively.

The resistivity of the fourth layer ranges from 405 – 5105 ohm- meter. The study shows that viable aquifer is within 106m – 205m.

Finally, the study shows that the problem of ground water development in the area may have been exacerbated by improper bore hole design, completion and development.

Keywords: topography, aquifer, VES, curve types, top soil, groundwater, exacerbated.

1.0 Introduction

This paper brings into fore the challenges of water availability in Ogwashi-Uku community which has been worrisome to the inhabitants for decades. It also

describes the results obtained with DC resistivity method using vertical electrical soundings (VES) with the Schlumberger electrode array system. The ground water challenges were probably exacerbated by the topography of the area which made the water table (aquifer) very deep and absence of surface water.

In the past, Delta State Government had awarded contracts for the provision of boreholes (ground water) in some selected primary schools, but only one of every four is functioning.

The water resources of the study area are threatened by increasing population trend especially with the establishment of Delta State Polytechnic and transfer of some government agencies in recent time, thus increasing demand for water. Most of the wells in the area serve as reservoirs for rain water and water bought from tanker drivers during the dry season.

Groundwater is the water found in cracks and pore space within the soil, sand and rocks. The area where water fills the space is called the saturated zone. The top of this zone is the water table [1].

Geoelectric resistivity techniques have been successfully used as geophysical exploration tools for studying ground water conditions in different parts of the world. The resistivity of soil materials depends on many factor such as ground water content, salinity, saturation, aquifer, lithology and porosity [2]. For example, the resistivity (ρ) of a soil is related to the electrical conductivity (σ) of its water. Therefore, due to the good conductivity of ground water the resistivity of a sedimentary rock, is much lower when it is logged than in the dry state. Resistivity techniques are regularly applied because of their low cost, simple interpretation, high speed and non-invasive technology and relative success in practice.

GEOLOGY

The Ogwashi-Uku and environs constitute the Northern fringes of Delta State and located in a transition zone between the Niger delta basin underlain by the Ogwashi-Asaba formation and overlain by the Benin formation.

This formation consists of friable, loose and high porosity sands with intercalation of lignite seams. Ferralsoles are deeply weathered red and yellowish brown soils with abundant free oxides but generally without a lateritic iron pan layer. This soil type stretches from the North-Eastern part of Delta, that is, from Umunede, Abavo, Agbor in Ika South East, to Ogwashi-Uku, Nsukwa to some part of Aniocha North and South.

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The ferralsoles are mostly loams, sandy loams and in some places, sandy-clay loams. The soils are very deep, well drained with sandy clay loam subsoil with low base saturation and cation exchange capacity (CEC) [3].

The Ogwashi- Uku land type is mainly occupying underulating plains with deep incised streams.

The soils are coastal plain sand origin. These soils are very deep well drained with thick sandy surface layer and sandy clay loam subsoil. They are low base saturation and CEC [4]. The town is located at the Aniocha South Local Government Area of Delta State on latitude $6^{\circ} 13' 27''$ North and longitude $6^{\circ} 33' 57''$ East.

Geologically, the study area falls into the sedimentary terrain within the tertiary Delta and developed South-West wards out of the Anambra basin and Benue trough. It lies South of the West African shield, and West of the Oban Massif, and the Tertiary Cameroun volcanic trend [5]. The vegetation falls into the tropical rain forest of Nigeria with hot and humid climates.

Theory

The fundamental theory underlying resistivity method can be explained by the mathematical investigation of current flowing in an extended medium [6].

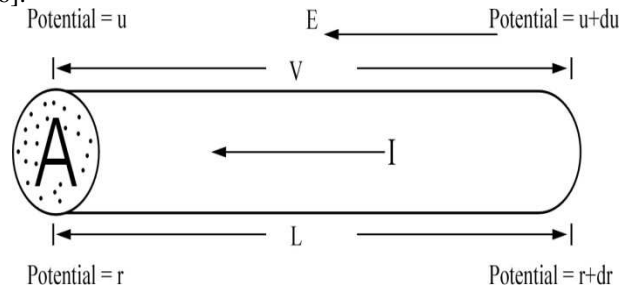


Fig 1: Parameters used to define Ohm's law for a straight conductor.

$$\text{Electric Field } E = \frac{-du}{dr} = \frac{V}{L} \text{ or } V = EL$$

$$\text{Current density } J = \frac{\text{current}}{\text{area}} = \frac{I}{A} \text{ or } I = JA$$

From $V = EL$ and $I = JA$

Then using ohms law, $V = IR$, substituting for V , I and R

$$\therefore EL = JA \cdot \rho \frac{L}{A}$$

It follows that $E = J\rho$ (1)

Equation (1) is known as the point form of ohm's law.

where E = electric field, J = current density and σ = conductivity

The form in equation (1) is useful in calculating the formulas used in resistivity methods of electrical surveying. However, the quantities that are measured are V and I .

The assumptions are that:

(i) The subsurface is homogeneous and isotropic and

(ii) A steady state situation makes $\nabla \cdot J = 0$

Since $\nabla \cdot J = 0$ and $J = \sigma E$

$$\therefore \nabla \cdot (\sigma E) = 0$$

$$\Rightarrow \sigma \nabla \cdot E + E \cdot \nabla \sigma = 0$$

but $\nabla \sigma = 0$

$$\sigma \nabla \cdot E = 0 \text{ but } E = -\nabla V$$

$$\Rightarrow \sigma \nabla \cdot (-\nabla V) = 0$$

or $-\sigma \nabla^2 V = 0$

$$\sigma \nabla^2 V = 0$$
 (2)

This implies that the potential obeys Laplace's equation.

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In Polar coordinates and since medium is homogeneous and isotropic, then $\frac{\partial}{\partial \theta}, \frac{\partial}{\partial \psi} = 0$ and Laplace's equation has only one term i.e

$$\frac{\partial}{\partial \theta} = 0 \quad \text{and} \quad \frac{\partial}{\partial \psi} = 0$$

$$\frac{1}{r^2} \frac{\partial}{\partial r} \left(r^2 \frac{\partial V}{\partial r} \right) = 0$$

Integrating we have;

$$r^2 \frac{\partial V}{\partial r} = A$$

$$\frac{\partial V}{\partial r} = \frac{A}{r^2}$$

Integrating again, we get

$$V = \frac{-A}{r} + B$$

Where B is an integration constant.

Using the boundary condition that its potential is zero at infinite distance

If $r \rightarrow \infty$ then $V=0$ and hence $B = 0$

$$V = \frac{-A}{r} \tag{3}$$

If we consider any surface enclosing the current source, that current crossing the surface is the current through the electrode.

$$dI = Jds$$

$$I = \int \underline{J} \cdot d\underline{s}$$

We consider a hemisphere of radius a enclosing the electrode.

$$E = \frac{-dV}{dr}$$

Electric field

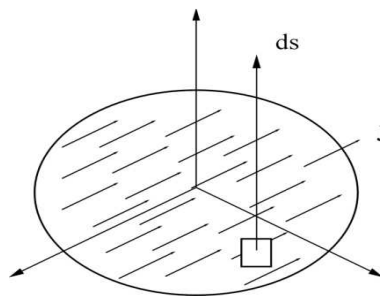


Fig 2: Hemisphere enclosing the electrode.

Conductivity is constant everywhere on the hemisphere.

$$I = \int \underline{J} \cdot d\underline{s} = \frac{\sigma A}{a^2} \times 2\pi a^2$$

$$\therefore I = 2\pi \sigma A$$

$$\therefore A = \frac{I}{2\pi\sigma} \tag{4}$$

$$V = \frac{A}{r}$$

From eq (3)

Substituting for A in (3), we have

$$V = \frac{I}{2\pi\sigma r} \tag{5}$$

Since $\sigma = \frac{1}{\rho}$ (5)

$$V = \frac{\rho I}{2\pi r} \tag{6}$$

METHODOLOGY

Electrical Resistivity method was applied using ABEM AC Terrameter with current electrode spread up to 600m apart so that AB/2 = 300m (fig 3). The terrameter was capable of measuring current and potential difference and displaying their ratio as the measured resistance. The schlumberger array of Vertical Electrical Sounding (VES) was increased to a√2 after each sounding from AB/2 = 2.00m.

The electrode potential spacing CD was varied from 0.8 – 20m as the need arose.

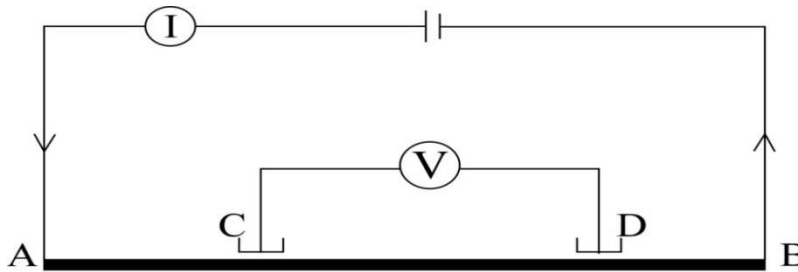


Fig 3: Four Electrode system for Electrical sounding

so that CD/2 = 10m. four VES soundings were utilized from locations distributed in a North-South-East Pattern

The theory is based on the fact that resistivities of rocks and soils are influenced by groundwater which act as electrolytes. [6].

Any subsurface variation in Conductivity alters the current flow which in turn affects the potential distribution.

The arrangement consists of a pair of current electrode and a pair potential electrodes, which are driven into the ground in the site in which the Resistivity survey is taking place, to make a good contact in straight line [7]. Current was passed into the earth through the terrameter to produce electric field within the subsurface with electric potentials.

The Resistivity measured is called apparent Resistivity because some terrains showed inhomogenous subsurface and anomalies in apparent resistivity values. The requirement that CD<0.2AB was complied with. The field procedure consisted in expanding AB while CD was fixed. This process yields a rapidly decreasing potential difference across CD.

At this point a new value for CD is used, typically 2 to 4 times larger than the preceding value and the survey was continued.

FIELD PROCEDURES

Four Vertical Electrical sounding data were acquired from four (4) Locations evenly distributed within Ogwashi-Uku in a North-South-East pattern.

Interpretation of data was done qualitatively and quantitatively and bringing to bare the knowledge of the local geology of the area.

The apparent resistivity values were plotted against half the current electrode spacing on bi-log graph. The curves of best fit were then traced and the data obtained from the smooth curves (smoothed values) were noted. Qualitative and quantitative interpretations of the field curves were carried out by inspection to obtain the types of curves and by partial curve matching.

The resistivity values and thicknesses obtained from the partial curve matching were improved upon by employing an iterative computer programme.

Layer parameters were consequently modified iteratively until subsequent iterations yield no improvement on the root mean square (r.m.s) error in the percentage. The r.m.s error in the tests showed 1.98%.

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The six layers that were generated by the computer were grouped into relevant geologic depth intervals called geoelectric sections and the resulting layer parameters were then interpreted geologically.

Owing to the undulating characteristics of the location, a global positioning system GPS (Garmin GPS Map 76 Csx) was included in the instrumentation to measure the coordinates (longitude and latitude) as well as measure the elevation of the VES points (Table 1).

Table 1: Coordinates and Elevations of locations.

VES No	Location (Name)	Longitude	Latitude	Elevation (m)
1	Delta State Polytechnic	006°33'49.4 ¹¹	06°13'24.7 ¹¹	238.00
2.	Abu-Anor Primary School	006°31'27.8 ¹¹	06°10'329 ¹¹	200.00
3.	Ikelike Primary School	006°31'38.6 ¹¹	06°10'42.1 ¹	199.00
4.	General Hospital	006°30'53.8 ¹¹	06°11'05.0 ¹	199.00

The curve types, the resistivity of the sediments and the lithology logs from nearby bore holes were used in conjunction with the knowledge of the local geology of the study area as guides in the interpretation and analysis of the geologic sections in terms of sustainable water supply. [8]

The resistivity data was interpreted using the IP2WIN RESIST programming software.

INTERPRETATION OF DATA

TABLE 2: VES 1 Lithology for Delta State Polytechnic, Ogwashi-Uku

Layer No.	App. Resistivity (ohm-m)	Thickness (m)	Depth (m)	Lithology
1	896	1.19	1.19	Lateritic Top soil
2	1186	5.41	6.60	Sub-soil(lateritic)
3	2977	13.75	20.36	Dry sandy layer
4	1025	17.30	37.67	Sandy clay/clayey sand
5	6925	79.33	117.0	Very dry sand/sandstone layer
6	491		117.0	Sandy aquifer

TABLE 3: VES 2 Lithology for Abu-Anor Primary School, Ogwashi-Uku

Layer No.	App. Resistivity (ohm-m)	Thickness (m)	Depth (m)	Lithology
1	81.0	0.982	0.982	Lateritic Top soil
2	704.0	2.09	3.08	Sub-soil(lateritic)
3	150.0	27.08	30.16	Clayey horizon
4	914.0	174.4	204.6	Dry sand/sandstone layer
5	370.0	-	204.6	Saturated sandy layer (aquifer)

TABLE 4: VES 3 Lithology for Ikelike Primary School, Ogwashi-Uku

Layer No.	App. Resistivity (ohm-m)	Thickness (m)	Depth (m)	Lithology
1	927.0	1.06	1.06	Lateritic Top soil
2	96.0	1.24	2.30	Sub-soil(lateritic)
3	1535.0	1.84	4.12	Clayey horizon
4	405.0	60.21	64.33	Dry sandy/sandstone layer
5	3006.0	82.90	147.23	Saturated sandy layer
6	223.0	-	147.23	Aquifer

TABLE 5: VES 4 Lithology for General Hospital, Ogwashi-Uku

Layer No.	App. Resistivity (ohm-m)	Thickness (m)	Depth (m)	Lithology
1	365.0	1.83	1.83	Lateritic Top soil
2	1072.0	2.29	4.12	Sub-soil(lateritic)
3	434.0	4.99	9.12	Clayey layer
4	5105.0	53.62	62.74	Dry sandy layer
5	45783.0	43.17	105.90	Very sandy/sandstone sandy layer
6	2615.0	-	-	

TABLE 6: Depth and Positions of Aquifers

VES NO.	LOCATION	DEPTH TO THE AQUIFER (M)	CORDINATES		ELEVATION (Meters)
			LONGITUDE	LATITUDE	
1	Delta State Polytechnic	117.0	006°33'49"11.4	06°13'29"11.7	238.0
2	Abu – Anor Primary School	205.0	006°31'27"11.8	06°10'32"11.9	200.0
3	Ikelike Primary School	147.0	006°31'38"11.6	06°10'42"11.1	199.0
4	General Hospital	106.0	006°30'53"11.8	06°11'05"11.0	199.0

Table 7 Existing Bore Hole Log Location: Ancomek Hotels, Ogwashi- Uku (9 Kilometers from VES 1)

Depth (m)	Lithology
27	Lateritic top soil, reddish
34	Dry sandy soil, brownish fine
40	Clayey sand
43	Sandy, fine grained
60	Sandy, whitish fine/medium grained
64	Sandy clay
67	Sandy, gravelly whitish
85	Sandy, partly clayey
91	Clayey grayish
100	Sandy, clayey
109	Clayey
119	Clayey
134	Sandy, fine grained, whitish saturated, partly clayey
152	Sandy, fine grained, whitish saturated.

Results

The Geo-electric sections for the sites show that there are six distinct layers to depth of penetration. The resistivities of top soil formations are generally between 365Ωm and 927Ωm at the general hospital (Table 5), Ikelike Primary School (Table 4), and Delta State Polytechnic (Table 1), while it is as low as 81Ωm at Abu-Anor Primary School (Table 2). The average thickness of top layer of soil is 1 meter (Table 4). The top soil is thickest at the general hospital where it is 1.83 metres. This top layer is red laterite underlain by a thick red lateritic burden whose thickness ranges from 1.24 meters at Ikelike Primary School (Table 4) to 5.41 meters at Delta State Polytechnic (Table 2).

The resistivity of the second layer varies from 96Ωm at Ikelike (Table 4) to 1185Ωm at Delta State Polytechnic (Table 2). The third layer is dry sand in Delta State Polytechnic (Table 2) and Ikelike Primary School (Table 4) with resistivities of 2977Ωm and 1535Ωm. However, the third layer in Abu-Anor Primary School (Table 3) and general hospital (Table 5) is a clayey horizon with resistivities of 150Ωm and 434Ωm respectively.

The geo-electric section in Delta State Polytechnic shows that the layer with a resistivity of 491Ωm is water bearing (Table 2) thus the aquifer at the Delta State Polytechnic is within 117 metres from the surface.

Conclusion

The study concludes that the aquifers in Ogwashi-Uku are generally deep and are within the range 106.0 – 205metres.

The bore hole depths found from the study agrees with the data from the water board put at (152.0m – 244.0m).[9].

The bore hole depths (Table 6) also agree with the previous work of Okolie et al [10]. The study found that the aquifer at Ogwashi-Uku is 140m – 180m.

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Offodile [11] asserted that the study area is underlain by the Ogwashi-Uku – Asaba formation and is also part of the Anambra basin. The Ogwashi-Asaba formation in which Ogwashi-Uku falls within has good hydrogeological prospects.

The aquifers in Ogwashi-Uku generally reveals a lateritic top soil underlain by a subsoil, also lateritic, a dry sandy layer underlain by a sandy clay/clayey sand, and underlain by a very dry sand/ sandstone layer and a sandy aquifer. This lithology is in agreement with that of an existing borehole log (Table 7) at Ancomek Hotels. Owing to the types of VES curves obtained, the study recommends that boreholes efforts should be concentrated in the North and South parts of Ogwashi-Uku.

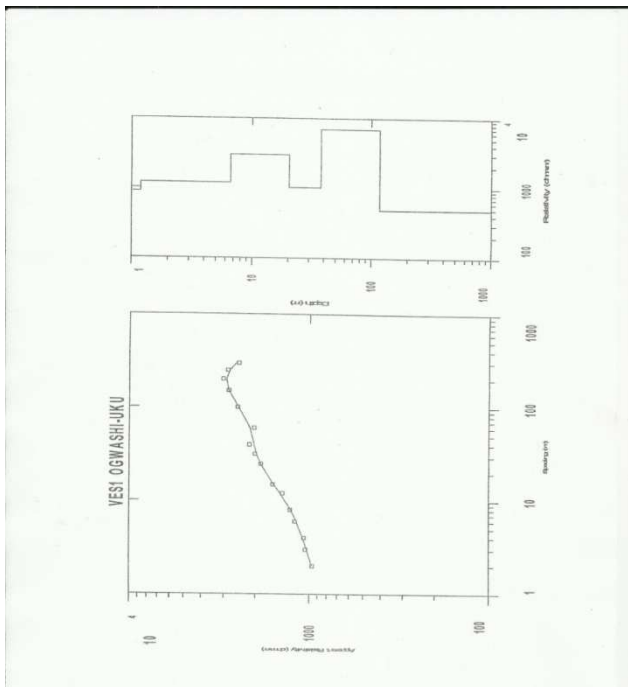


Fig 4 Sounding Curves for VES 1 AK type

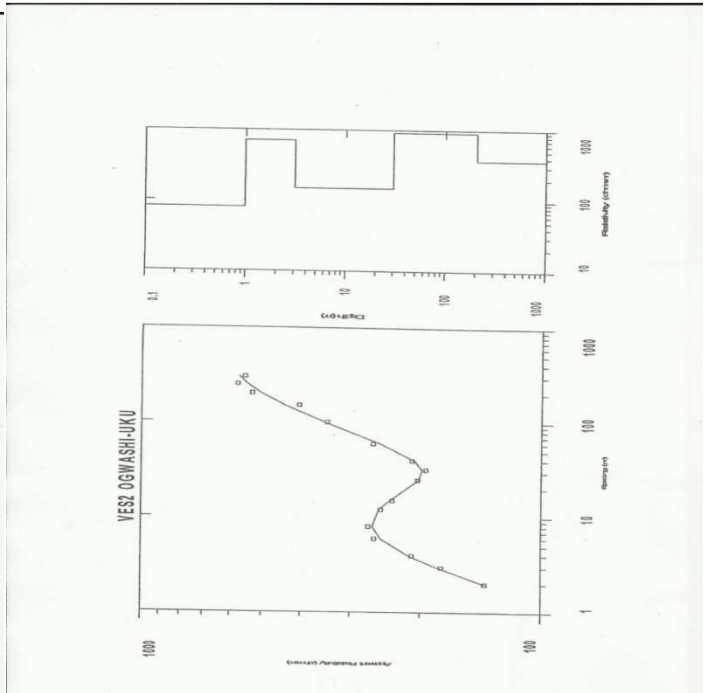


Fig 5 Sounding Curves for VES 2 KH type

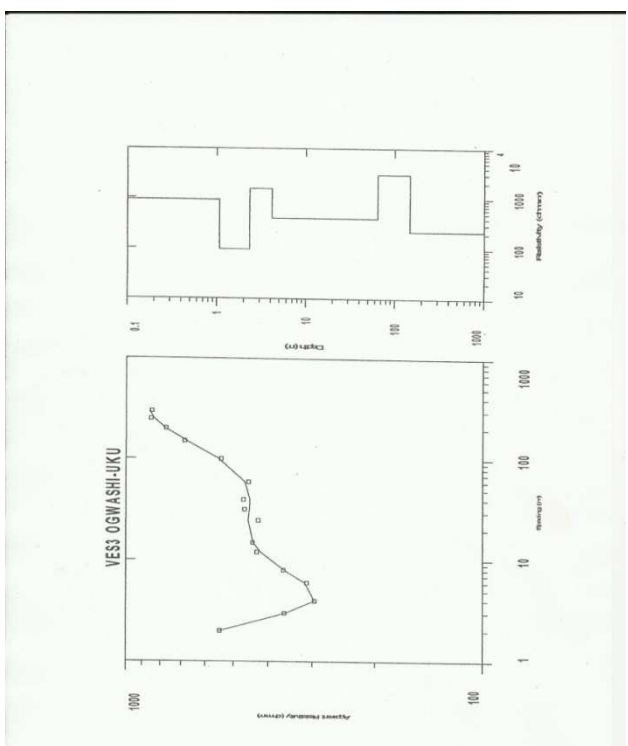


Fig 6 Sounding Curves for VES 3 HK AK type

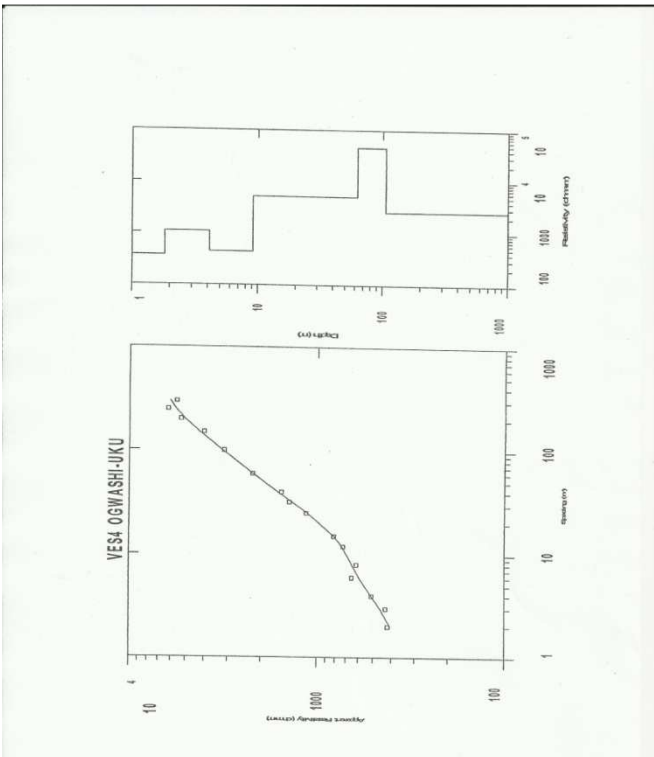


Fig 7 Sounding Curves for VES 4 AK type

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