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Research Article

Vertical Electrical Sounding Investigation for Delineation of Geoelectric Layers and Evaluation of Groundwater Potential in Ajagba, Asa and Ikonifin Localities of Ola Oluwa Local Government Area of Osun State, South Western Nigeria

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Abstract: Vertical Electrical Sounding (VES) surveys were carried out at Ajagba, Asa and Ikonifin communities in the north of Ola Oluwa local government area of Osun state, Nigeria in order to delineate the geoelectric layers in the area as well as evaluate the groundwater potential. The area is in the basement complex terrain of Nigeria where the occurrence of groundwater is highly unpredictable and hence requires the use of hydrologic, geophysical and geologic surveys to achieve success in groundwater development programs. The survey delineated a maximum of four geoelectric layers which may be interpreted to correspond to four geologic layers viz the topsoil, weathered basement, partly weathered/fractured basement and the fresh basement. The weathered basement and the partly weathered/fractured basement layers constitute the aquifer units. The partly weathered/fractured layer is significant in enhancing the ground water potential in this area because of its relatively low resistivity resulting from its high fracture frequency. The ground water potential in the area varies from medium to high. Groundwater development is therefore feasible in these communities.

Keywords: Basement, geoelectric layers, groundwater, layer thickness, resistivity, survey

INTRODUCTION

According to Deming (1975), more than 70% of the earth's surface is covered by water. Groundwater has been defined as that portion of water beneath the surface of the Earth (Bouwer, 1978). The principal stores of groundwater in Africa are concentrated in the earth mostly to a depth of about 400 m (Rybkina, 1978). Many communities in the world depend on groundwater extracted from weathered/fractured zones through water wells/boreholes (Clark, 1985; Olasehinde *et al*., 1998).

The supply of potable water to rural communities is one of the necessary conditions for the eradication/reduction of water borne diseases such as typhoid fever, cholera and guinea worm in Nigeria. Any water described as potable must comply with World Health Organization standards (WHO, 1984). Groundwater obtained from wells, boreholes and springs may not undergo considerable treatment before becoming potable due to the natural filtration process it has undergone through the soil horizons (Abdullahi *et al*., 2005). Because groundwater is widely known to be more hygienic than surface water, the possibility of utilizing it as a source of water supply for public use is always attractive (Abdullahi *et al*., 2005).

The occurrence of groundwater in the basement complex terrain of Nigeria is highly unpredictable and hence requires a combination of hydrologic, geophysical and geologic surveys to achieve success in groundwater development programs (Olayinka, 1990). In this study, we relied heavily on the geophysical survey technique using the electrical resistivity method to locate zones of high potential for groundwater yield.

The Vertical Electrical Sounding (VES) survey method of geophysical prospecting has been used in this study. The principle of the method is that variation in conductivity within the earth's subsurface alters the pattern of current flow within the Earth, which in turn affects the distribution of electric potential. The degree of this effect depends on the size shape, location and bulk electrical resistivity of the subsurface layers. The bulk electrical resistivity depends on the mineralogy of the rocks and its containing fluids (William, 1997).

In crystalline rocks such as those found in the basement complex terrain, electrical current is conducted mainly along cracks and fissures. When water is present in these cracks and fissures, the electrical resistivity generally decreases. Furthermore, the more porous or fissured a rock is, the lower the resistivity since this usually results in an increase in water saturation of the rock.

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According to Ohm's law, the ratio of potential drop (V) across a body through which a current (I) is flowing is called the Resistance (R). The Resistivity of the body is a product of the Resistance and the Geometric constant (which is dependent on the geometry of the body). On the field, variations in electrical resistivity across different layers are measured. An electrical current is introduced into the ground via two current electrodes. The potential difference is then measured through two separate electrodes. The separating distance determines the depth of penetration of the electrical current hence the depth investigated. The Terrameter has been in use for a long time for measuring the potential difference from which the resistivity in ohm-meters (Ωm) is computed.

The resistivity data retrieved from the Terrameter is processed, analyzed and interpreted to determine needed information such as layer thicknesses and potential of groundwater in the area.

This method provides a very reliable means of locating weathered/fractured zones in basement complex rocks, estimating their thicknesses as well as estimating the thickness of the overburden, thus facilitating drilling of productive boreholes to provide potable water all year round in these communities.
The objectives of this study includes:

- To determine the number of geoelectric/geologic layers beneath the depth sounding stations and the layer parameters (resistivity and thickness)
- To identify the aquifer units and determine their thicknesses
- To evaluate the groundwater potential and determine the feasibility of groundwater development of the survey areas

Geomorphology and geology of the area: Ola Oluwa local government area is underlain by Precambrian basement complex rocks. Although the basement rocks are concealed beneath variably thick overburden, the area is underlain by migmatite gneiss and fine to medium-grained biotite and biotite-muscovite granite.

Tectonic stress precipitated fracture/fissures, sheared or jointed basement rocks constitute the pathway for the movement of groundwater in the area. The permeability and storactivity of the groundwater system are dependent on secondary structural features such as the extent and volume of fractures and joints (fracture frequency) together with the thickness of weathering (Clark, 1985).

Fracture frequency increases with depth and reaches a maximum at between 25 and 35 m but decreases with further increase in depth (Olorunfemi and Fasuyi, 1993). The cumulative fracture frequency is maximum in granites and minimum in schist. Fracture thicknesses are maximum (>3 m) and occur most frequently within depths of 10 and 40 m.

The quality of the groundwater in the basement complex area is generally good and generally free from pathogenic bacteria and hence very rarely needs to be treated (Abdullahi *et al*., 2005). Shallow groundwater in basement areas however may have high iron content because of solution of iron from the lateritic soils.

Ola Oluwa local government area is relatively flat with gently undulating topography. Topographic elevation varies from 274 to 335 m Above Sea Level (ASL). The Oba river and its numerous tributaries which drain the survey area in a dendritic pattern constitute the surface water resource of the area.

METHODOLOGY

The VES survey was carried out using the Schlumberger array. The potential electrode spacing (AB/2) was varied from 1 to 65 m with a maximum spread length of 130 m. The PASI (E2 DIGIT) /ABEM resistivity meter was used for the data collection. The quantitative interpretation of the VES curves involved partial curve matching and computer iteration technique (Ojo, 1993). The IPI2WIN (2008) software was used for interpretation and computer modeling of the VES data.

Lithological sections exposed in open shallow hand dug wells were used to aid interpretation of the layers.

RESULTS

The survey was conducted at Olaoluwa local government area of Osun state Nigeria (Fig. 1). A total of 13 VES was carried out in the study area as follows: 5 VES in Ikonifin community (Fig. 3), 4 VES in Asa community (Fig. 2) and 4 VES in Ajagba community (Fig. 4). The apparent resistivity values versus the electrode spacing for the VES locations are presented in Table 1.

The VES curves (Plots of apparent resistivity versus current electrode separation) for the various sounding locations in the study area are presented below (Fig. 5 to 17). The calculated resistivity and thicknesses of the subsurface layers in the area as obtained from the VES curves are presented below (Table 2). The Root Mean Square (RMS) errors for the analysis were found to be very low with an average of 3.90% (Table 2). This underscores the reliability of the analysis tool for this type of work.

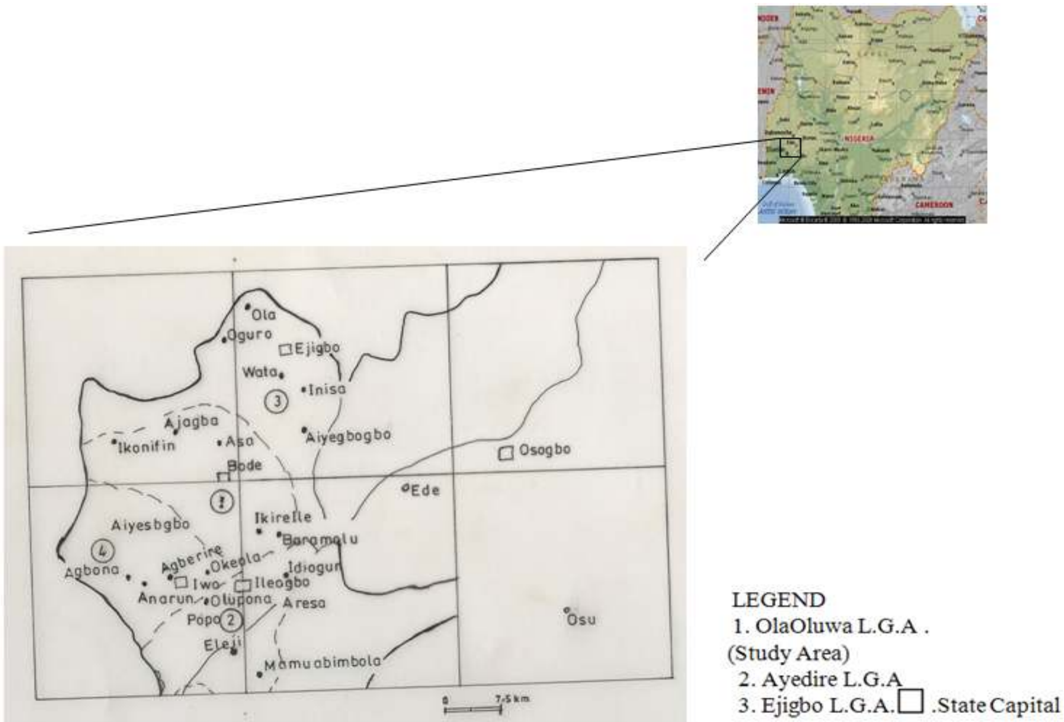

Fig. 1: Map of Nigeria showing location of study area (inset) administrative map of part of Osun State showing the surveyed communities

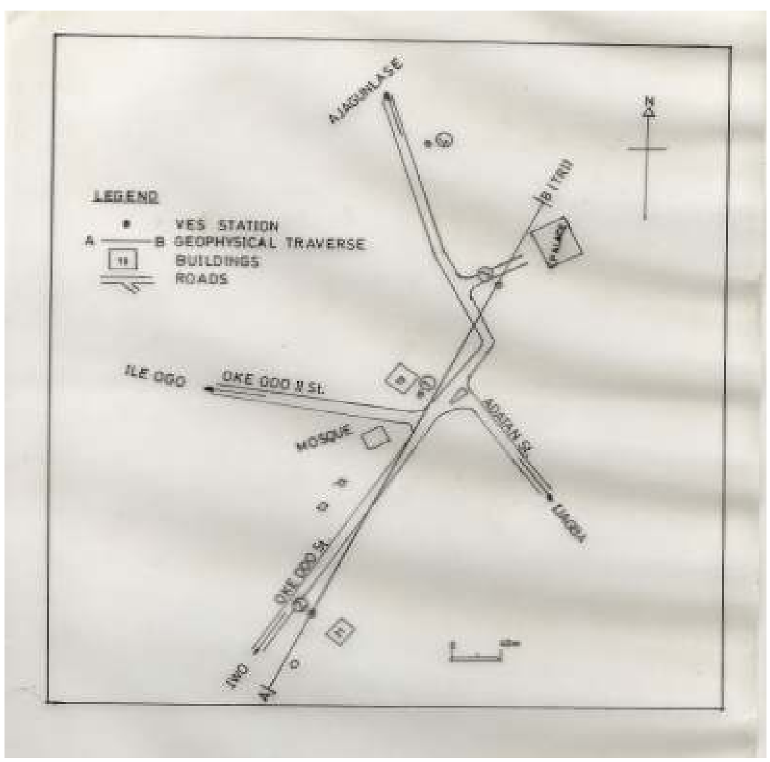

Fig. 2: Sketch map of Asa community showing the VES stations

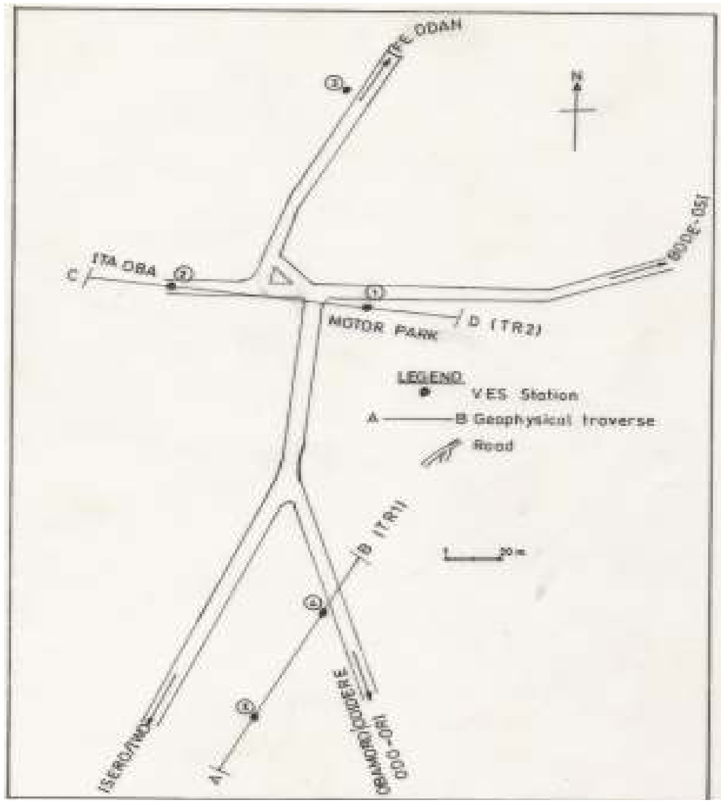

Fig. 3: Sketch map of Ikonifin community showing the VES stations

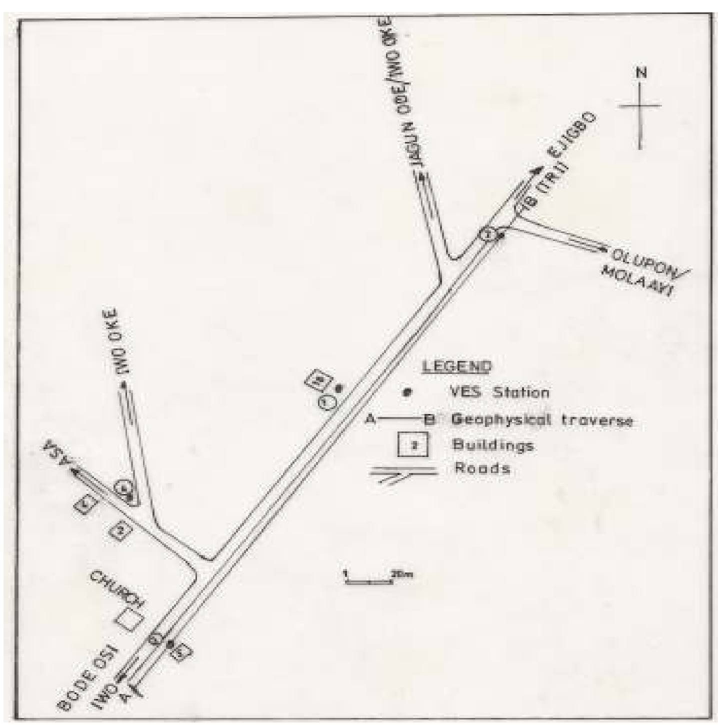

Fig. 4: Sketch map of Ajagba community showing the VES stations

Table 1: Apparent resistivity values for different electrode spacing in the study area

	Apparent resistivity (ohm-m)												
	Ikonifin community					Asa community				Ajagba community			
Electrode separation (AB/2) (m)	VES 1	VES 2	VES 3	VES 4	VES 5	VES 1	VES 2	VES 3	VES 4	VES 1	VES 2	VES 3	VES 4
1	46	46	243	46	67	163	57	51	125	115	189	112	325
2	44	36	214	61	58	209	63	60	95	78	116	116	357
3	44	33	163	58	58	181	57	52	73	62	79	88	215
4	41	30	127	61	51	161	49	53	68	57	65	69	161
6	41	27	94	63	38	102	45	63	63	53	64	66	129
6	40	30	96	70	40	81	45	59	68	57	64	72	114
8	45	28	87	76	32	68	44	60	70	61	66	65	115
12	48	31	83	90	28	77	42	72	84	71	74	66	145
15	55	36	91	92	30	99	49	78	72	85	81	76	170
15	51	40	88	87	32	88	46	71	105	95	84	68	152
25	70	59	167	111	44	122	72	98	130	139	103	91	226
32	80	72	223	121	59	148	93	129	163	169	125	127	306
40	94	75	165	146	66	191	116	176	138	226	154	166	377
40	88	86	181	118	61	186	94	131	218	208	156	126	302
65	117	116	249	167	91	281	159	239	-	312	221	210	398

Table 2: Geoelectric layer resistivities and thicknesses obtained in the VES locations in the survey area

			Layer resistivity (ohm-m)				Layer thickness (m)			
Community	VES location	RMS errors	1	2	3	4	1	2	3	4
Ajagba	1	2.06	151.0	56.5	11435		0.733	10.300	∞	
	2	2.95	327.0	82.3	388.0		0.744	9.800	∞	
	3	4.32	73.1	180.0	37.8	7469	0.500	0.423	12.50	∞
	4	5.91	192.0	632.0	55.8	1612	0.500	0.348	6.32	∞
Asa	1	2.99	83.3	203.0	20.2	575	0.500	0.912	3.14	∞
	2	2.68	37.7	64.4	25.4	3903	0.500	0.960	10.10	∞
	3	5.12	35.4	22.7	26.5	13055	1.000	0.635	11.80	∞
	4	5.57	368.0	156.0	371.0		0.725	12.600	∞	
Ikonifin	1	2.23	38.5	29.1	136.0		1.900	5.280	∞	
	2	3.64	63.1	31.3	620.0		1.280	8.910	∞	
	3	6.67	279.0	91.4	36.8	1204	1.380	2.880	3.68	∞
	4	3.86	36.4	54.5	114.0	1263	0.500	6.810	28.20	∞
	5	2.68	66.4	18.1	580.0	642	2.660	9.600	10.70	∞

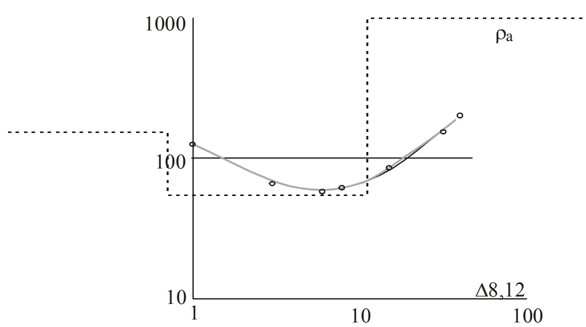

Fig. 5: Typical depth sounding curve showing synthetic curve (red) and number of layers (blue) at Ajagba, VES 1

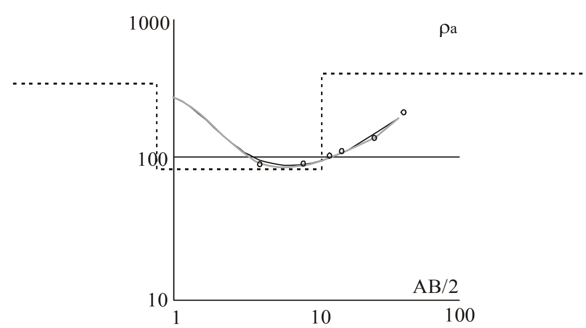

Fig. 6: Typical depth sounding curve showing synthetic curve (red) and number of layers (blue) at Ajagba VES 2

INTERPRETATION AND DISCUSSION OF RESULTS

The Geoelectric parameters (Resistivity and Thickness) of the subsurface layers obtained from the VES sounding curves are interpreted in terms of the lithologic type and the groundwater potential. The Geoelectric parameters and the interpreted lithologic types are presented in Table 3. The Lithology types observed are clayey sand, weathered basement, partly weathered/fractured basement and fresh basement.

At Ajagba, the weathered/fractured layer with a relatively low resistivity and high thickness constitutes

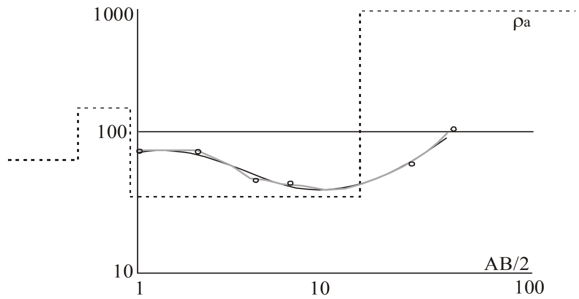

Fig. 7: Typical depth sounding curve showing synthetic curve (red) and number of layers (blue) at Ajagba VES 3

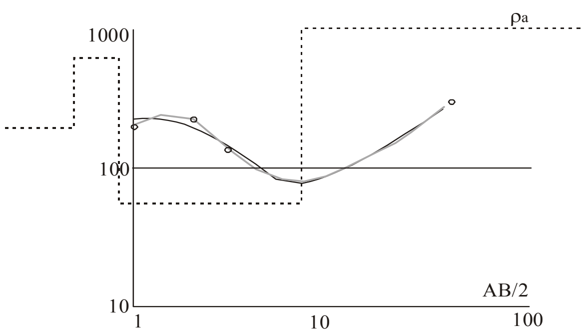

Fig. 8: Typical depth sounding curve showing synthetic curve (red) and number of layers (blue) at Ajagba VES 4

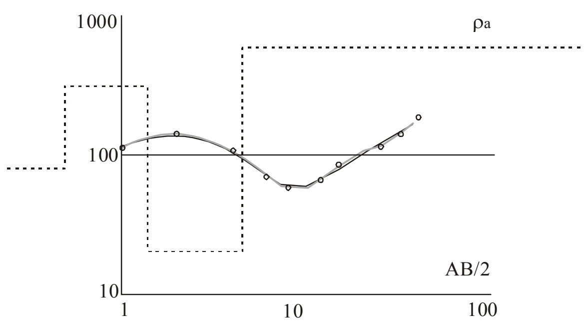

Fig. 9: Typical depth sounding curve showing synthetic curve (red) and number of layers (blue) at Asa VES 1

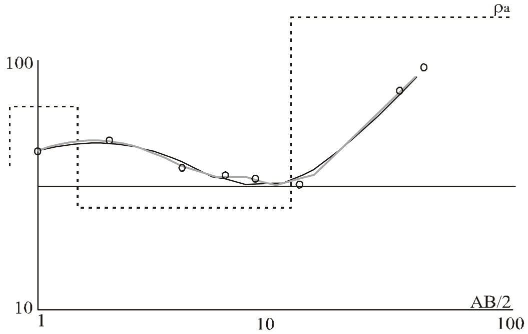

Fig. 10: Typical depth sounding curve showing synthetic curve (red) and number of layers (blue) at Asa VES 2

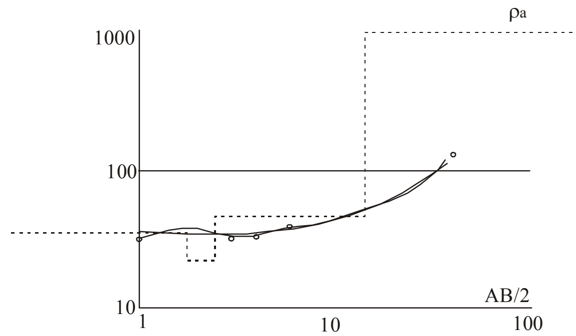

Fig. 11: Typical depth sounding curve showing synthetic curve (red) and number of layers (blue) at Asa VES 3

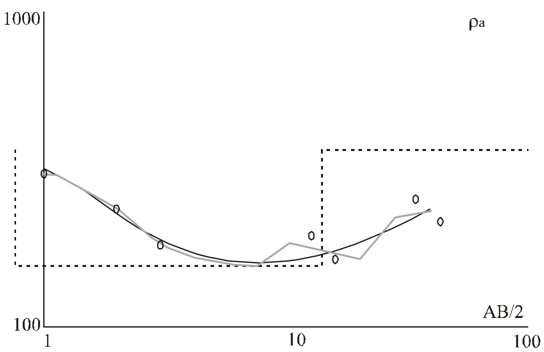

Fig. 12: Typical depth sounding curve showing synthetic curve (red) and number of layers (blue) at Asa VES 4

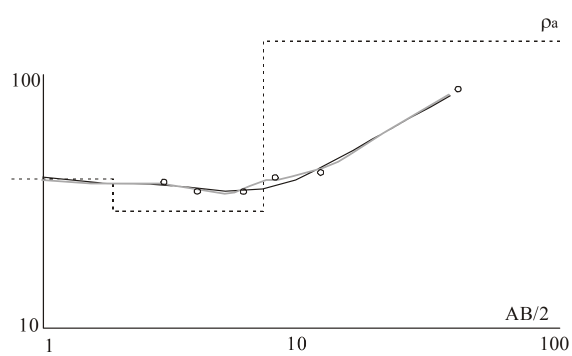

Fig. 13: Typical depth sounding curve showing synthetic curve (red) and number of layers (blue) at Ikonifin VES 1

the major aquifer unit although they make minor contributions to the groundwater potential. The groundwater potential is rated medium to high.

The weathered layer and partly weathered/fractured basement constitute the aquifer units at Asa. The weathered layer has low groundwater discharge capacity because it is very thin, clayey and has low permeability. However the partly weathered/fractured

Table 3: Geoelectric parameters (resistivity and thickness) of the subsurface layers and the interpreted lithologic types in the study area

Community	Layer No.	Resistivity (ohm-m)	Thickness (m)	Lithologic type
Ajagba	1	73.1-327	0.500-0.744	Clayey sand
	2	56.5-632	0.348-10.300	Weathered basement
	3	37.8-11435	7.150-13.400	Partly weathered/fractured basement
Asa	1	35.4-368	0.500-1.000	Clayey sand
	2	22.7-203	0.635-12.600	Weathered basement
	3	20.2-371	3.180-11.800	Partly weathered/fractured basement
	4	575-∞	4.640-13.325	Fresh basement
Ikonifin	1	36.4-279	0.500-2.660	Clayey sand
	2	18.1-91.4	2.880-9.600	Weathered basement
	3	36.8-620	3.680-∞	Partly weathered/fractured basement
	4	642-∞	7.180-35.410	Fresh basement

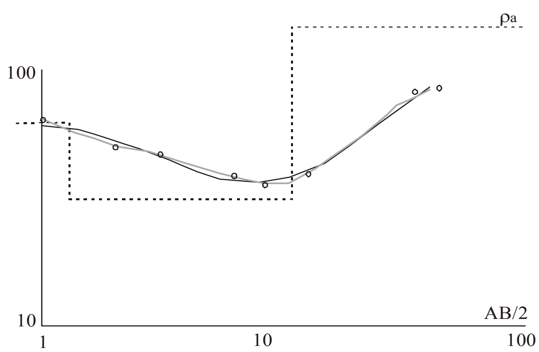

Fig. 14: Typical depth sounding curve showing synthetic curve (red) and number of layers (blue) at Ikonifin VES 2

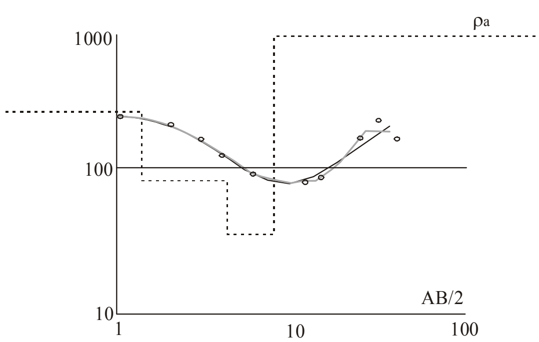

Fig. 15: Typical depth sounding curve showing synthetic curve (red) and number of layers (blue) at Ikonifin VES 3

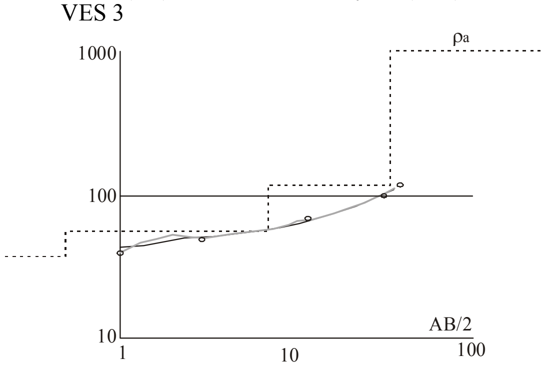

Fig. 16: Typical depth sounding curve showing synthetic curve (red) and number of layers (blue) at Ikonifin VES 4

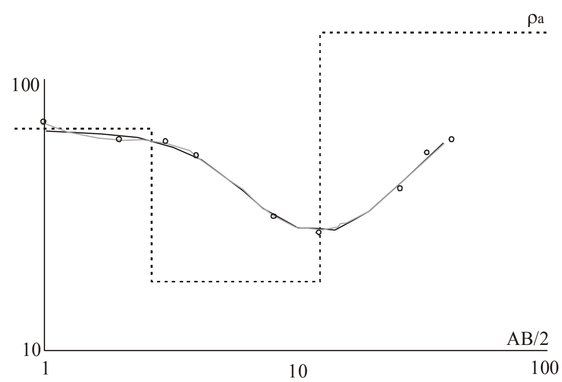

Fig. 17: Typical depth sounding curve showing synthetic curve (red) and number of layers (blue) at Ikonifin VES 5

layer is fairly thick and thus enhances the groundwater yield. The groundwater potential is rated medium.

The groundwater potential at Ikonifin is of medium to high level. The more permeable partly weathered/fractured layer has a high yield capacity as found in the other two communities.

CONCLUSION

The Electrical Resistivity sounding survey delineated three to four subsurface layers in the study area viz the topsoil, weathered layer, partly weathered/fractured basement and fresh basement. The weathered layer and partly weathered/fractured basement constitute the aquifer units. The weathered layer is relatively thin and clayey in all the localities with low groundwater discharge capacity. The partly weathered/fractured basement is relatively thick and permeable and has high groundwater discharge capacity. Groundwater development is therefore feasible in the area.

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