ESTIMATION OF SAND CHEMISTRY USING ELECTRICAL SOUNDING: A STUDY OF OPOLO, YENAGOA

www.akwapolyjournal.org
P-ISSN: 2536-6733 | E-ISSN: 2616-0773

Supported by: tetfund TERTIARY EDUCATION TRUST FUND
TETFund/DESS / POLY / IKOT-OSURUA/ ARJ /1-2)

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Abstract

Studies have shown that sand has a complex chemistry with unique geological and environmental significance. This paper analyses a survey conducted in the Yenagoa local government area in Bayelsa State, Nigeria, to estimate sand chemistry using vertical electrical sounding. The study aims to determine the volume of sand deposits and their chemistry in an area measuring 100 meters by 50 meters. Nine Vertical Electrical Sounding Points were acquired using Terrameter SAS 1000. The results showed that the survey area had four to six geoelectric layers with VES 1, VES 3 to VES 9 containing HA curves, while VES 2 had HK curves. The resistivity distribution ranged from 1.05 to 22.73 m, with resistivity varying from 113.8 to 1942 Ωm across the survey area. The estimated volume of sand within the survey area was approximately 688,059 tonnes, with the chemical content being suitable for domestic and building purposes. The sand deposits are also ideal for engineering and construction due to their inherent water permeability and storage ability. Further investigation is recommended to study construction sand deposits beyond the surveyed areas.

Keywords: *Sand chemistry, electrical sounding, electrical resistivity, electrode configuration, Yenagoa*

Introduction

Opolo community in Bayelsa State, Nigeria, is an essential area for sand exploration due to the lack of major rivers. Sand is a valuable substance used in constructing major civil engineering works such as airports, bridges, roads, factories, etc. Sand mining is done to extract sand from open pits, beaches, and inland dunes and dredge from ocean and river beds. The most common type of sand found in non-tropical coast and continental areas is silica, which is used in manufacturing as an abrasive used to make concrete, and it has industrial use as a raw material in glassmaking. However, over-extraction of sand can lead to groundwater depletion, erosion, and destruction of farmland and local wildlife.

The use of electrical resistivity imaging techniques is a reliable and effective method for subsurface investigation and the exploration of shallow alluvial aquifers. Vertical Electrical Sounding (VES) is a geophysical technique used to estimate subsurface properties by measuring the electrical resistivity of different layers. However, the estimation of sand depth can be challenging due to the presence of multiple subsurface layers with varying resistivities, electrode spacing and configuration, and inversion of resistivity data into meaningful sand depth values. Therefore, it is crucial to determine the optimal setup and use advanced interpretation techniques to estimate sand depth accurately. As the population increases in Bayelsa state, Niger Delta, and the need to reclaim swampy areas for infrastructural development becomes necessary, researchers should carry out detailed geological information of any site mapped for dredging should be carried out before dredging. This study aimed to estimate the volume of sand in Opolo, Yenagoa, and Bayelsa State that can be used for filling and other engineering work using the electrical resistivity method.

Objectives of the Study

1. To determine the thickness of the aquifer
2. To enhance the various curve present
3. To analyzes the volume of sand present

MATERIALS AND METHOD

Location and Accessibility of the Study Area

The area under investigation is located in Opolo community (Figure1) in Yenagoa Local Government, Bayelsa State. The area lies within Latitude 4056'15"N - 4056'25"N and Longitude 6^{o}20'45"E - 6^{0}21'0"E. The area has a good road network that links to other parts of the state along Isaac boro expressway Yenago, Bayelsa State.

Figure 1. Map of the Study Areas

Materials

The method used for this project work is both fieldwork and laboratory work. The fieldwork was done for sample collection before take it to the laboratory and after which data analysis and processing. The materials used for this study include the following: Global Position System, fieldnotes, Abem Terrameter SAS 1000, four electrodes, measuring tap, four hammers, and battery.

Data Collection

The Schlumberger array is a valuable tool for geophysical surveying, which involves placing four electrodes in a line around a central point. The outer electrodes, A and B, carry electrical current, while the inner ones, M and N, measure the potential. This method was employed to conduct Vertical Electrical Sounding (VES) at various locations in the study area. The current electrode spacing of AB/2 = 80m, and the most significant spacing used is 160m. The nine VES profiles carried out in the Opolo Community were highly informative.

Four co-linear electrodes were used during the Schlumberger array testing, with two external electrodes serving as current and two internal electrodes as potential electrodes. The potential electrodes were positioned slightly away from the centre of the electrode array, at a distance less than one-fifth of the distance between the current electrodes. The current electrode distance was increased during the test. At the same time, the potential electrode remained in the same position for a while before being raised when the observed voltage became too small to measure. A sophisticated tool, the Abem Terrameter SAS 1000, was utilized to display the resistance value of the VES point on a digital display screen, with the values recorded in a fieldwork book. The high-resolution image of about 3m from https://google.com/earth was also collected, and a sample location was obtained using the Global Positioning System (GPS) before processing the data using ArcGIS 10.6.

Data Processing

Vertical Electric Sounding Processing

Step 1. Software
PI2win+IP and Microsoft Excel 2013 software for sample parameter spreadsheet preparation.
Step 2. Method of analysis VES
The obtain apparent resistivity, ρa, values were plotted against the electrode spacing ((AB)/2) on a log-log scale to obtain the VES sounding curVES using a computer software IPI2win+IP.
The field curves were at first interpreted through partial curve matching techniques, using theoretically calculated master curves, in conjunction with the auxiliary curves of A, Q, K, and H types. This information (layer parameters) was then used to interpret the sounding data through a 1-D inversion technique (ipi2win).

Theory of Geoelectric Method of Exploration

Electrical Resistivity

The electrical resistivity of soil is the measure of its resistance to the passage of current through it (Syed and Siddiqui, 2012). Ozcep *et al.,* (2009) believe that soil electrical properties are the parameters of natural

and artificially created electrical fields in soils and influenced by the distribution of mobile electrical charges, mostly in soils.
For a simple body, the resistivity ρ (Ω m) is defined as follows:

$$\rho = R * A / L \qquad 1$$

Where R = electrical resistance (Ω), L = length of the cylinder (m) and A = cross sectional area (m2).
The electrical resistance of the cylindrical body R (Ω), is defined by Ohm's law as follows:

$$R = V / I \qquad 2$$

where V = potential (V) and I = current (A). As stated by Samouelian *et al.* (2004).
Four electrodes are usually required to measure electrical resistivity. To inject current, two electrodes called A and B are used (current electrodes). To record the resulting potential difference, two other electrodes called M and N are used (potential electrode)

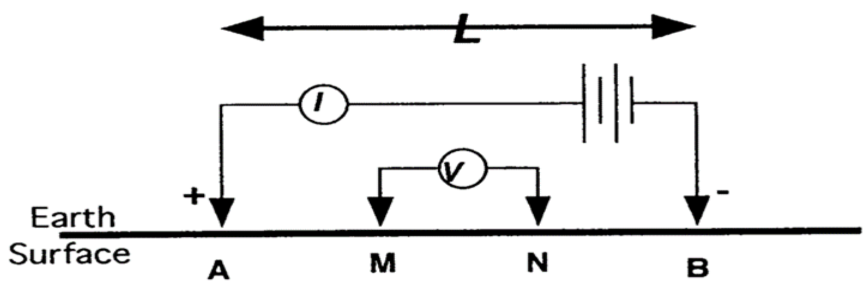

Figure 3.1: Schlumberger Array Configuration

AB = Currentt Electrodes
MN= Potential Electrodes
L= Length (m)
I= Electric current (Ampere)
V= Potential Difference (Volt)
For field measurement of electrical resistivity, Hersir and Flovenz (2013) mentioned that the measured apparent resistivity will be transformed into a mod of the true resistivity structure since the apparent resistivity does not show the true resistivity structure of the Earth. Vertical Electric Sounding is used when resistivity variation with depth is of concern (Mariita, nd, 2015). This method can be applied to the Vertical electrical sounding resistivity survey method. Giao *et al.* (2002) explain for the VES method, the electrode spacing is gradually extended on both sides apart from the central point.

Relationship between Geology and Resistivity

Variations in the resistivity of subsurface materials are primarily a function of lithology, clay content, fluid content, porosity, and degree of water saturation in the rock. Resistivity values in earth materials and rock types are shown in Figures 3.2 and 3.3. Most materials are considered to be conductors or insulators. Electric current flow in the subsurface is primarily electrolytic. Electrolytic conduction involves the passage of charged particles using groundwater. Charged particles move through liquids that infill the interconnected pores of the permeable mass of soil (Robinson *et al.,* 1988). The values of resistivity measured in the field are calculated as the average of the two equipotential surfaces and are known as apparent resistivity (ρa).

Figure 3.2: The estimated range of resistivity values of common rock types (Keller and Frisschknecht 1966).

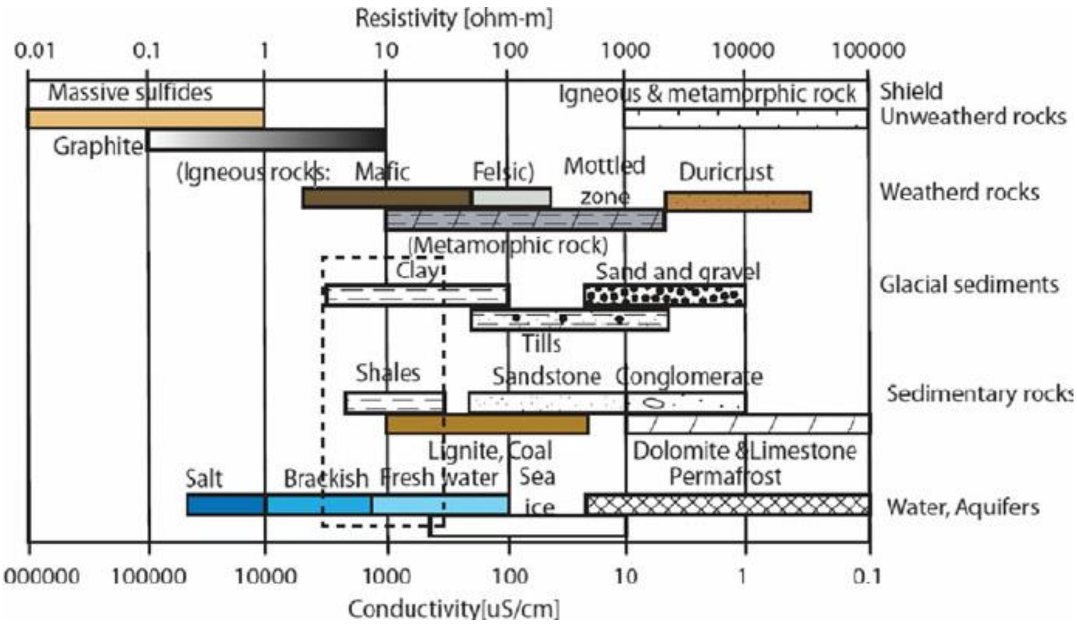

Figure 3.3 Resistivities of some common rocks, minerals, and chemicals (Robinson et al., 1988).

Results And Discussion

Results

This chapter discusses the results and interpretation of the results. The Following result for the Study area such as the Resistivity, the thickness of the bed, depth, longitudinal conductance, and protectivity capacity area found below.

VES No	LAYERS	APPARENT RESISTIVITY (?m)	THICKNESS h(m)	DEPTH d(m)	RMS ERROR (%)	CURVE TYPE	LITHOLOGY	LONGITUDE (E)	LATITUDE (N)
	1	28.99	1.53	1.53	0.17		Top Soil		
VES 1	2	5.19	2.19	3.72		HA	Clay		
	3	33.87	1.19	4.91			Silty Sand		
	4	113.8	5.94	10.86			Fine-Medium Sand		
	5	34.6	20.63	31.49			Silty Sand		
	6	220.2					Fine-Medium Sand	6.346999	4.939944
VES 2	1	38	0.6	0.6	0.28	HK	Top Soil		
	2	9.92	0.79	1.39			Silty sand		
	3	5.38	1.83	3.22			Clay		
	4	118.5	4.24	7.46			Fine-Medium Sand		
	5	32.89	9.81	17.27			Silty Sand		
	6	0.08					Clay	6.348019	4.939871
VES 3	1	31.18	1.19	1.19	0.31	HA	Top Soil		
	2	12.28	1.61	2.7			Clay		
	3	34.06	12.53	15.33			Silty Sand		
	4	214.3	16.04	31.36			Fine-Medium Sand		
	5	2.02					Clay	6.349250	4.939965
VES 4	1	29.81	1.31	1.31	0.14	HA	Top Soil		
	2	8.01	1.56	2.87			Clay		
	3	9.79	3.41	6.28			Silty Sand		
	4	315.7	7.44	13.72			Fine-Medium Sand		
	5	48.56	16.28	30			Silty Sand		
	6	6.12					Clay	6.346454	4.939524
VES 5	1	48.88	0.6	0.6	0.10	HA	Top Soil		
	2	25.12	0.79	1.39			Silty sand		
	3	4.09	1.83	1.22			Clay		
	4	121.4	4.24	7.46			Fine -Medium Sand		
	5	274.7	9.81	17.27			Fine- Medium Sand		
	6	24.81	22.73	40			Silty Sand		
	7	47.96					Silty Sand	6.348536	4.938645
VES 6	1	43.24	1.01	1.01	0.9	HA	Top Soil		
	2	28.28	0.09	1.11			Silty Sand		
	3	3.77	1.81	2.92			Clay		
	4	684.2	3.17	6.089			Fine- Medium Sand		
	5	41.29	11.18	17.27			Silty Sand		
	6	55.03					Silty Sand	6.349328	4.938575
VES 7	1	41.33	0.6	0.6	0.03	HA	Top Soil		
	2	24.22	0.79	1.39			Silty Sand		
	3	9.79	6.07	7.46			Clay		
	4	62.71	9.81	17.27			Silty Sand		
	5	194.2	22.73	40			Fine- Medium Sand		
	6	178.2					Fine-Medium Sand	6.347128	4.938711
VES 8	1	494.8	0.24	0.24	0.27	HA	Top Soil		
	2	1.1	0.54	0.78			Clay		
	3	466.8	1.047	1.83			Fine- Medium	6.348096	4.939371

Table 4.2: Summary of result for Aquifer depth, thickness, Aquifer apparent

resistivity from the study area.

S/N	Long	at	Aquifer Depth(m)	Aquifer App. Resistivity (mΩ)	Aquifer Thickness
VES1	6.346999	4.939944	10.86	113.8	5.94
VES2	6.348019	4.939871	7.46	118.5	4.24
VES3	6.349250	4.939965	31.36	214.3	16.04
VES4	6.346454	4.939524	13.72	315.7	7.44
VES5	6.348536	4.938645	17.27	274.7	9.81
VES6	6.349328	4.938575	6.089	684.2	3.17
VES7	6.347128	4.938711	40	1942	22.73
VES8	6.348096	4.939371	1.83	466.8	1.05
VES9	6.348002	4.937945	11.86	351	6.93

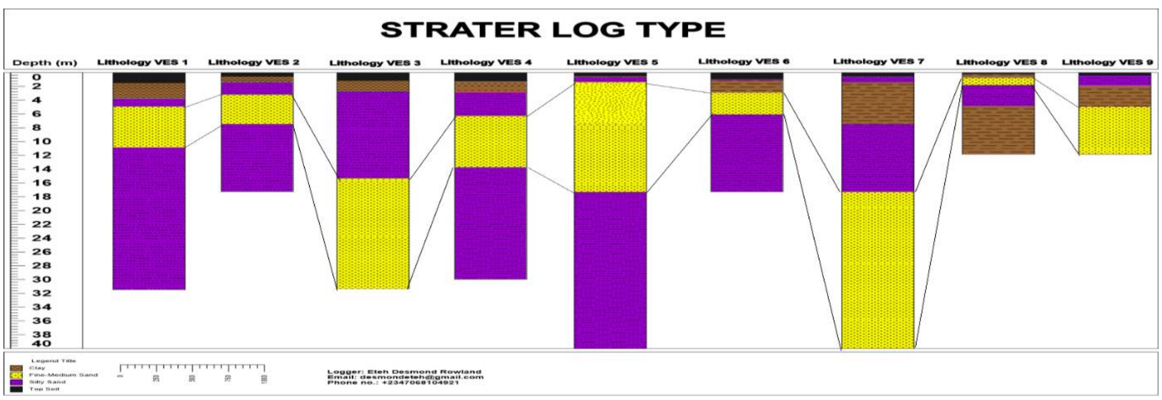

Figure 4.1: Borehole Resistivity Strater log of the study area

Discussion

VES 1 Interpretation

Figure 4.2a and Table 4.3 are located at longitude 6.34699 and latitude 4.939944. The results show that the stratigraphic sequence consists of six layers (within the depth of investigation) in which the model resistivity of the fourth layer is higher than that of the upper and lower layers. The resistivity curve obtained in this area is predominantly HA type (Figure 4.2a) and the stratigraphic sequence consists of topsoil, Clay, Silty Sand, Fine-Medium Sand, Silty Sand, and Fine-Medium Sand (Table 4.3). The resistivity cross section correlated well with the borehole information

(Figure 4.1a). The resistivity and thickness of the topsoil are 28.99 Ωm and 1.53 m, but they are 5.19 Ωm and 2.19 m in the Clay layer underlying the topsoil (Table 4.2) and compared with Figure 3.3. The resistivity and thickness of the Silty Sand layer (third layer) are 33.87 Ωm and 1.19 m, respectively. The resistivity and thickness of the Fine-Medium Sand layer which serves as the aquifer is 113.8 Ωm when compared with Figures 3.2 and 5.94 m. The resistivity and thickness of the silty sand are 34.6 Ωm and 20.63 m respectively, while the resistivity of the Fine-Medium Sand is 2202 Ωm.

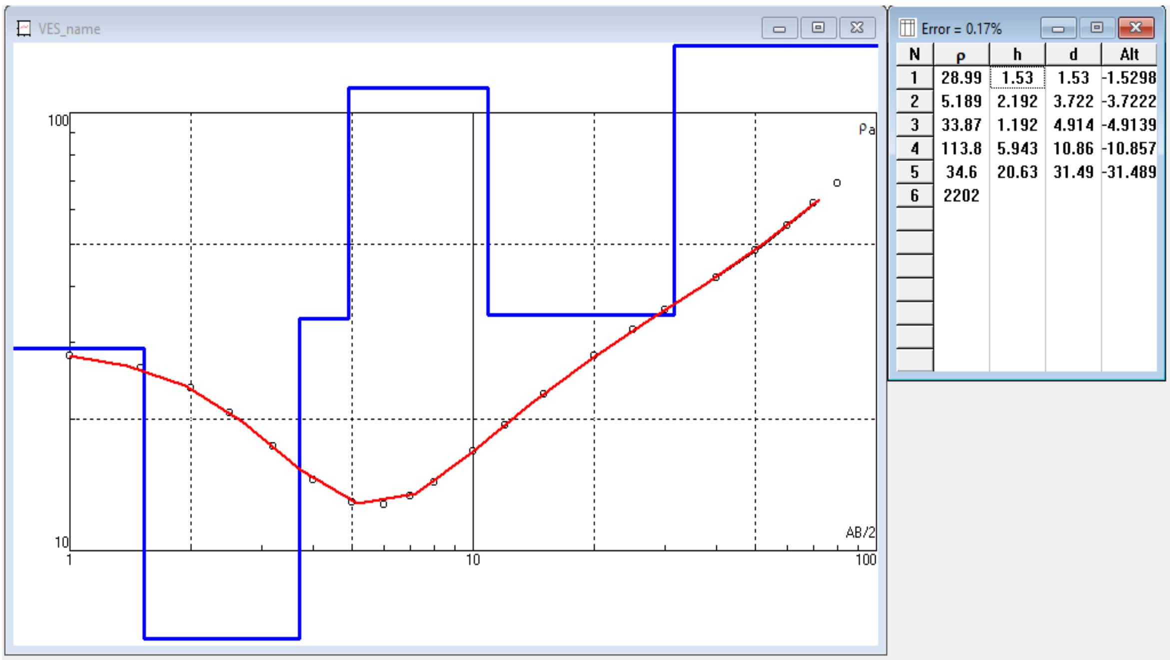

Figure 4.2a: VES 1 quantitative interpretation from IPI2win

Table 4.3: Result summary from VES 1

Layers	Resistivity(Ωm)	Thickness h (m)	Depth d (m)	Rms Error (%)	Curve Type	Lithology
1	28.99	1.53	1.53			Top Soil
2	5.19	2.19	3.72			Clay
3	33.87	1.19	4.91			Silty Sand
4	113.8	5.94	10.86	0.17	HA	Fine-Medium Sand
5	34.6	20.63	31.49			Silty Sand
6	2202					Fine-Medium Sand

VES 2 Interpretation

Table 4.4 and Figure 4.2b are located at longitude 6.348019 and latitude 4.939871. The results show that the stratigraphic sequence consists of six layers (within the depth of investigation) in which the model resistivity of the fourth layer is higher than that of the upper and lower layers. The resistivity curve obtained in this area is predominantly HK type (Figure 4.2b), and the stratigraphic sequence consists of topsoil, Silty sand, Clay, Fine-Medium Sand, Silty Sand, and Clay (Table. 3). The resistivity cross section correlated well with the borehole information (Figure 4.1). The resistivity and thickness of the top soil is 38 Ωm and 0.6 m, but they are 9.92 Ωm and 0.79 m in the Silty sand layer underlying the top soil (Table 4.4). The resistivity and thickness of the Clay layer (third layer) is 5.38 Ωm when compared with Figure 3.3 and 1.83 m respectively. The resistivity and thickness of the Fine-Medium Sand layer that serves as the aquifer are 118.5 Ωm and 4.24 m, respectively. The resistivity and thickness of the Silty Sand is 32.89 Ωm and 9.81 m respectively, while the resistivity of the Clay is 0.08 Ωm.

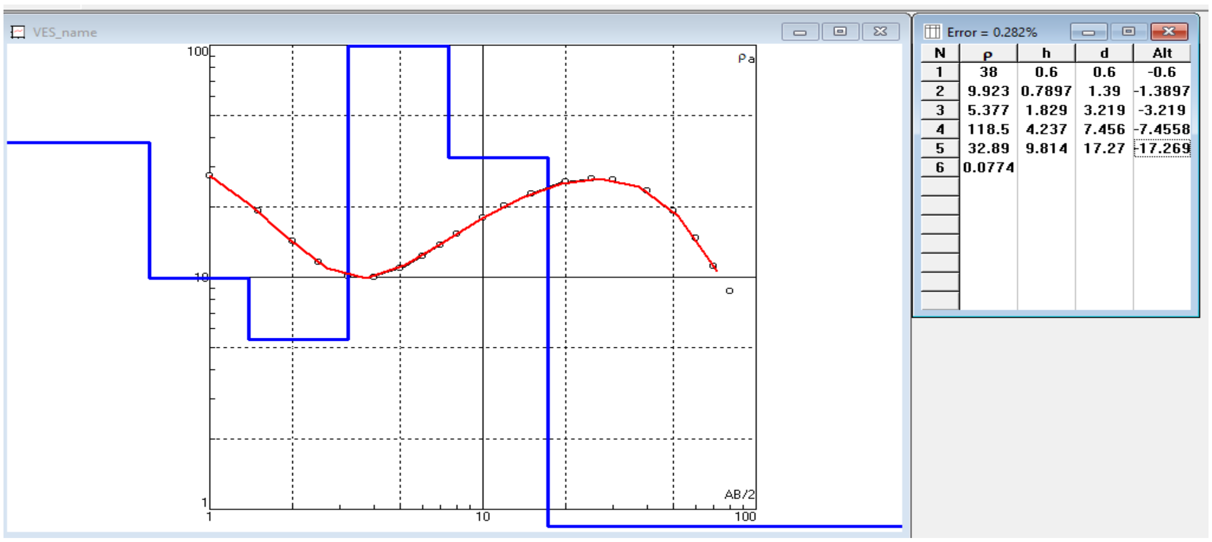

Figure 4.2b: VES 2 quantitative interpretation from IPI2win

Table 4.4: Result summary from VES 2

Layers	Resistivity(Ωm)	Thickness h (m)	Depth d (m)	Rms Error(%)	Curve Type	Lithology
1	38	0.6	0.6			Top Soil
2	9.92	0.79	1.39			Silty sand
3	5.38	1.83	3.22	0.28	HK	Clay
4	118.5	4.24	7.46			Fine-Medium Sand
5	32.89	9.81	17.27			Silty Sand
6	0.08					Clay

VES 3 Interpretation

VES 3 (Figure 4.2c) is located at longitude 6.349250^{0} and latitude 4.939965^{0}. The results show that the stratigraphic sequence consists of five layers (within the depth of investigation) in which the model resistivity of the fourth layer is higher than that of the upper and lower layers. The resistivity curve obtained in this area is predominantly of the HA type (Figure 4.2c), and the stratigraphic sequence consists of top soil, Clay, Silty Sand, Fine-Medium Sand, and Clay (Table 4.5). The resistivity and thickness of the topsoil are 31.18 Ωm and 1.19 m, but they are 12.28 Ωm and 1.61 m in the Clay layer underlying the topsoil (Table 4.5). The resistivity and thickness of the Silty Sand (third layer) are 34.06 Ωm and 12.53 m, respectively. The resistivity and thickness of the Fine-Medium Sand layer, which serves as the aquifer, are 214.3 Ωm and 16.04 m, respectively, while the resistivity of the Clay is 2.02 Ωm.

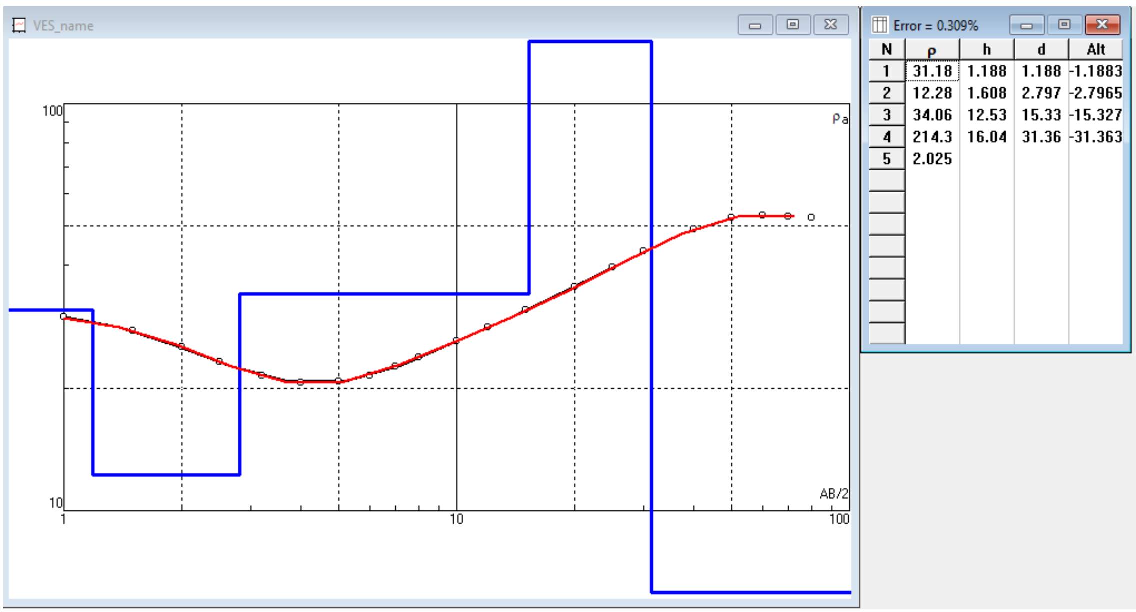

Figure 4.2c: VES 3 quantitative interpretation from IPI2win

Table 4.5 : Result summary from VES 3

Layers	Resistivity(Ωm)	Thickness h (m)	Depth d (m)	Rms Error (%)	Curve Type	Lithology
1	31.18	1.19	1.19			Top Soil
2	12.28	1.61	2.7			Clay
3	34.06	12.53	15.33	0.31	HA	Silty Sand
4	214.3	16.04	31.36			Fine-Medium Sand
5	2.02					Clay

VES 4 Interpretation

Table 4.6 and Figure 4.2d are located at longitude 6.349328 and latitude 4.939524. The results show that the stratigraphic sequence consists of six layers (within the depth of investigation) in which the model resistivity of the fourth layer is higher than that of the upper and lower layers. The resistivity curve obtained in this area is predominantly of the HA type (Figure 4.2d) and the stratigraphic sequence consists of Topsoil, Clay, Silty Sand, Fine-Medium Sand, Silty Sand, and Clay (Table 4.6). The resistivity cross section correlated well with the borehole information (Figure 4.1). The resistivity and thickness of the top soil are 29.81 Ωm and 1.31 m, but they are 8.01 Ωm and 1.56 m in the Clay layer underlying the top soil (Table 4.6). The resistivity and thickness of the Silty Sand layer (third layer) are 9.79 Ωm and 3.41 m, respectively. The resistivity and thickness of the Fine-Medium Sand layer that serves as the aquifer are 315.7 Ωm and 7.44 m. The resistivity and thickness of the Silty Sand is 48.56 Ωm and 16.28 m respectively, while the resistivity of the Clay is 6.12 Ωm.

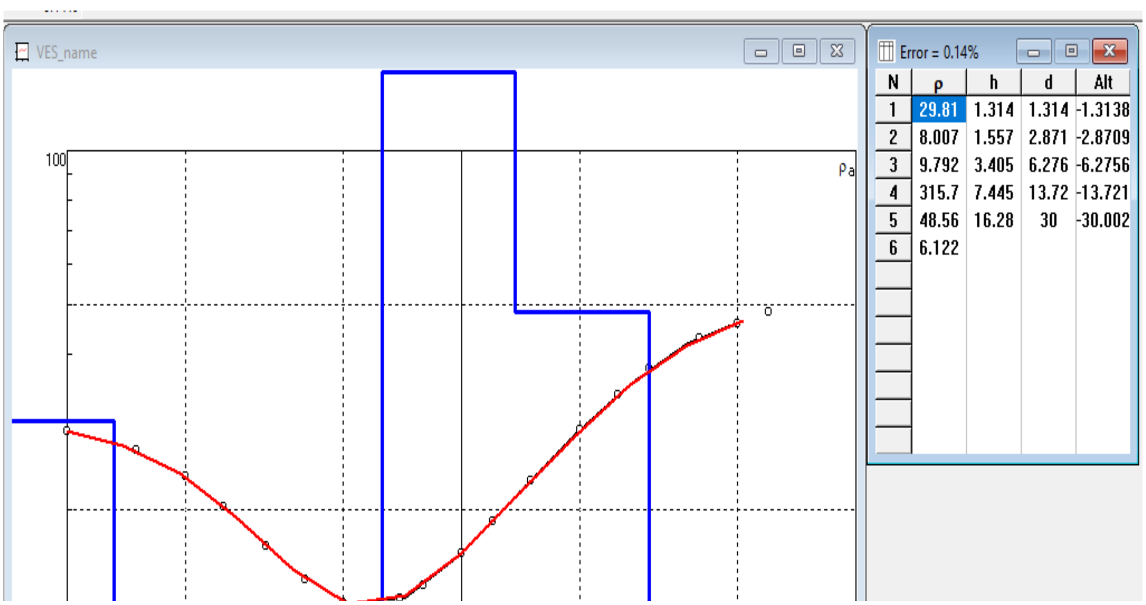

Figure 4.2d: VES 4 quantitative interpretation from IPI2win

Table 4.6: Result summary from VES 4

LAYERS	RESISTIVITY (Ωm)	THICKNESS h (m)	DEPTH d (m)	RMS ERROR	CURVE TYPE	LITHOLOGY

				(%)		
1	29.81	1.31	1.31			Top Soil
2	8.01	1.56	2.87			Clay
3	9.79	3.41	6.28			Silty Sand
4	315.7	7.44	13.72	0.14	HA	Fine-Medium Sand
5	48.56	16.28	30			Silty Sand
6	6.12					Clay

VES 5 Interpretation

Table 4.7 and Figure 4.2e are located at longitude 6.348536 and latitude 4.938645. The results show that the stratigraphic sequence consists of seven layers (within the depth of investigation) in which the model resistivity of the fifth layer is higher than that of the upper and lower layers. The resistivity curve obtained in this area is predominantly HA type (Figure 4.2e) and the stratigraphic sequence consists of Topsoil, Silty sand, Clay, Fine -Medium Sand, Fine- Medium Sand, Silty Sand, and another layer of Silty Sand (Table 4.7).

The resistivity cross section correlated well with the borehole information (Figure 4.2). The resistivity and thickness of the top soil are 48.88 Ωm and 0.6 m, but they are 25.12 Ωm and 0.79 m in the Silty sand layer underlying the topsoil (Table 4.6). The resistivity and thickness of the Clay layer (third layer) is 4.09 Ωm and 1.83 m, respectively. The resistivity and thickness of the first Fine-Medium Sand layer is 121.4 Ωm and 4.24 m. The resistivity and thickness of the second Fine-Medium Sand layer which serves as the aquifer is 274.7 Ωm and 9.81m. The resistivity and thickness of the Silty Sand is 24.81 Ωm and 22.73 m, while the resistivity of the half space silty sand layer is 47.96 Ωm.

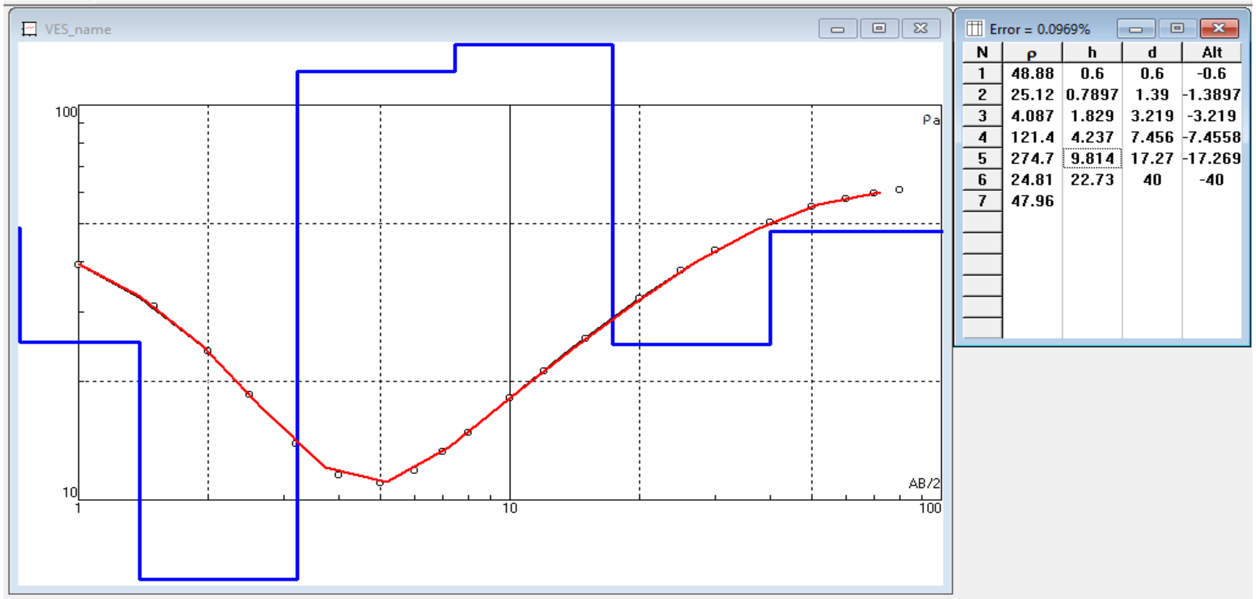

Figure 4.2e: VES 5 quantitative interpretation from IPI2win

Table 4.7: Result summary from VES 5

LAYERS	RESISTIVITY(Ωm)	THICKNESS h (m)	DEPTH d (m)	RMS ERROR (%)	CURVE TYPE	LITHOLOGY
1	48.88	0.6	0.6			Top Soil
2	25.12	0.79	1.39			Silty sand
3	4.09	1.83	1.22			Clay
4	121.4	4.24	7.46	0.1	HA	Fine -Medium Sand
5	274.7	9.81	17.27			Fine- Medium Sand
6	24.81	22.73	40			Silty Sand
7	47.96					Silty Sand

VES 6 Interpretation

Table 4.8 and Figure 4.2f are located at longitude 6.349328 and latitude 4.938575. The results show that the stratigraphic sequence consists of seven layers (within the depth of investigation) in which the model resistivity of the six layers is higher than that of the upper and lower layers. The resistivity curve obtained in this area is predominantly HA type (Figure 4.2f) and the stratigraphic sequence consists of Top Soil, Silty sand, Clay, Fine -Medium Sand (Table 4.8). The resistivity cross section correlated well with the borehole information (Figure 4.1a). The resistivity and thickness of the top soil is 43.24 Ωm and 1.01 m, but they are 28.28 Ωm and 0.09 m in the Silty sand layer underlying the topsoil (Table 4.8). The resistivity and thickness of the Clay layer (third layer) is

3.77 Ωm and 1.81 m, respectively. The resistivity and thickness of the fouth layer, Fine-Medium Sand layer, which serves as the aquifer is 684.2 Ωm and 3.17 m. The resistivity and thickness of the silty sand are 41.29 Ωm and 11.18 m, respectively, while the resistivity of the half-space silty sand layer is 55.03 Ωm.

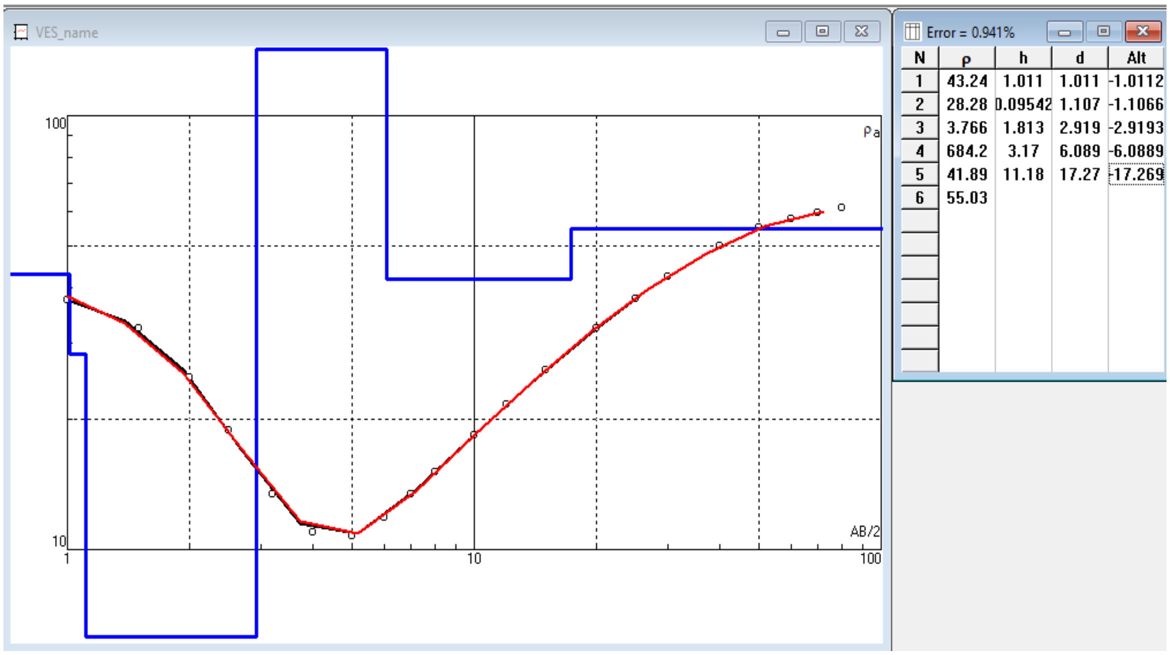

Figure 4.2f: VES 6 quantitative interpretation from IPI2win

Table 4.8 : Result summary from VES 6

LAYERS	RESISTIVITY(Ωm)	THICKNESS h (m)	DEPTH d (m)	RMS ERROR (%)	CURVE TYPE	LITHOLOGY
1	43.24	1.01	1.01			Top Soil
2	28.28	0.09	1.11			Silty Sand
3	3.77	1.81	2.92			Clay
4	684.2	3.17	6.089	0.9	HA	Fine- Medium Sand
5	41.29	11.18	17.27			Silty Sand
6	55.03					Silty Sand

VES 7 Interpretation

VES 7 (Figure 4.2g), is located at latitude 4.9387110 N and longitude 6.3471280 E. The results show that the stratigraphic sequence consists of six layers in which the model resistivity of the fifth layer is higher than that of the upper and lower layers. The resistivity curve obtained in this area is predominantly HA type (Figure 4.2g), and the stratigraphic sequence consists of Topsoil, Silty sand, Clay, Fine -Medium Sand, Fine- Medium Sand, Silty Sand, and another layer of Silty Sand (Table 4.9). The resistivity cross section correlated well with the borehole information (Figure 4.1a). The resistivity and thickness of the topsoil are 41.33 Ωm and 0.6 m, but they are 24.22 Ωm and 0.79 m in the Silty sand layer underlying the top soil (Table 4.9). The resistivity and thickness of the Clay layer (third layer) are 9.79 Ωm and 6.07 m respectively. The resistivity and thickness of the silty sand (fourth layer) are 62.71 Ωm and 9.81 m. The resistivity and thickness of the Fine-Medium Sand (fifth layer) are 1942 Ωm and 22.73 m, while the resistivity of the half-space Fine-Medium Sand layer is 178.2 Ωm.

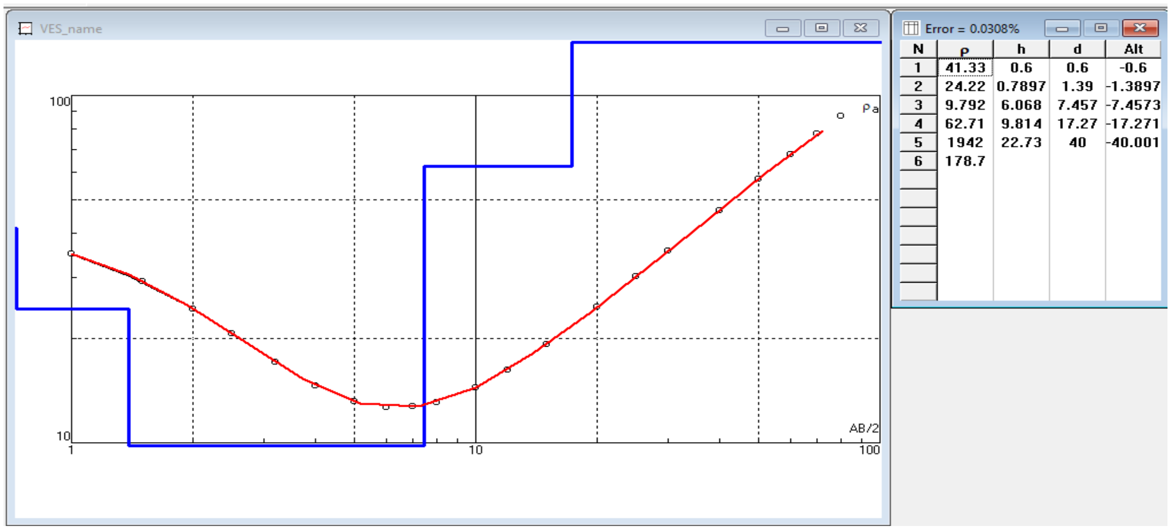

Figure 4.2g: VES 7 quantitative interpretation from IPI2win

Table 4.9 : Result summary from VES 7

LAYERS	RESISTIVITY(Ωm)	THICKNESS h (m)	DEPTH d (m)	RMS ERROR (%)	CURVE TYPE	LITHOLOGY
1	41.33	0.6	0.6			Top Soil
2	24.22	0.79	1.39			Silty Sand
3	9.79	6.07	7.46			Clay
4	62.71	9.81	17.27	0.03	HA	Silty Sand
5	1942	22.73	40			Fine- Medium Sand
6	178.2					Fine-Medium Sand

VES 8 Interpretation

VES-8 (Figure 4.2h) is located at 4.9393710 N and 6.3480960 E.The results show that the stratigraphic sequence consists of six layers in which the model resistivity of the third layer is higher than that of the

upper and lower layers. The resistivity curve obtained in this area is predominantly Hk type (Figure 4.2h), and the stratigraphic sequence consists of Topsoil, Silty sand, Clay, Fine -Medium Sand, Fine- Medium Sand, Silty Sand, and the another layer of Silty Sand (Table 4.1a0). The resistivity and thickness of the top soil are 494.8 Ωm and 0.24 m, but they are 1.1 Ωm and 0.54 m in the clay sand (Figure 3.3) underlying the top soil (Table 4.1a0). The resistivity and thickness of Fine-Medium Sand (third layer) is 466.8 Ωm and 1.05 m, respectively. The resistivity and thickness of the silty sand (fourth layer) are 62.56 Ωm and 3.03 m. The resistivity and thickness of the clay (fifth layer) are 2.86 Ωm and 7 m, while the resistivity of the half-space clay layer is 0.63 Ωm.

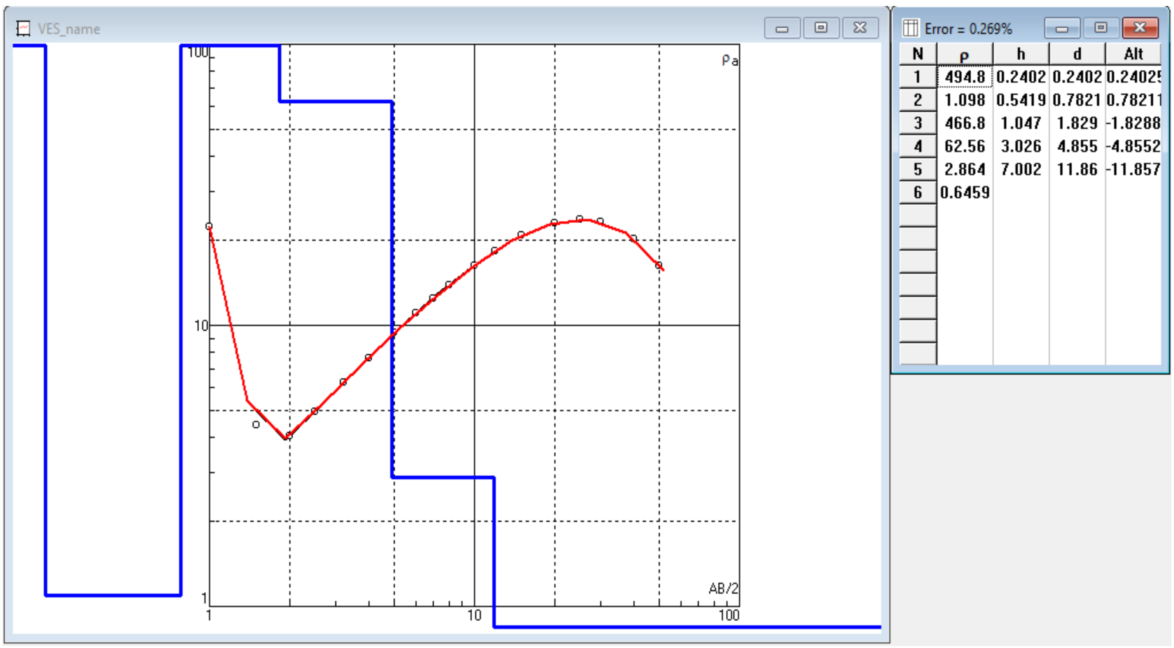

Figure 4.2h: VES 8 quantitative interpretation from IPI2win

Table 4.1a0: Result summary from VES 8

LAYERS	RESISTIVITY(Ωm)	THICKNESS h (m)	DEPTH d (m)	RMS ERROR (%)	CURVE TYPE	LITHOLOGY
1	494.8	0.24	0.24			Top Soil
2	1.1	0.54	0.78			Clay
3	466.8	1.047	1.83	0.27	HK	Fine- Medium Sand
4	62.56	3.03	4.85			Silty Sand
5	2.86	7	11.86			Clay
6	0.63					Clay

VES 9 Interpretation

VES 9 (Figure 4.2i), is located at latitude 4.9379450 N and longitude 6.3480020 E. The results show that the stratigraphic sequence consists of six layers in which the model resistivity of the sixth layer is higher than that of the upper and lower layers. The resistivity curve obtained in this area is predominantly HA type (Figure 4.2i), and the stratigraphic sequence consists of Topsoil, Silty sand, Clay, Fine -Medium Sand, Fine-Medium Sand, Silty Sand, and another layer of Silty Sand (Table 4.9). The resistivity cross section correlated well with the borehole information (Figure 4.1a). The resistivity and thickness of the topsoil are 52.36 Ωm and 0.45 m, but they are 6.91 Ωm and 1.39 m in the Silty sand layer underlying the top soil (Table 4.9). The resistivity and thickness of the Clay layer (third layer) is 1.07 Ωm and 0.14 m, respectively. The resistivity and thickness of the Clay (fourth layer) are 2.05 Ωm and 2.94 m. The resistivity and thickness of the Fine-Medium Sand (fifth layer) are 351 Ωm and 6.93 m, respectively, while the resistivity of the half-space Fine-Medium Sand layer is 1353 Ωm.

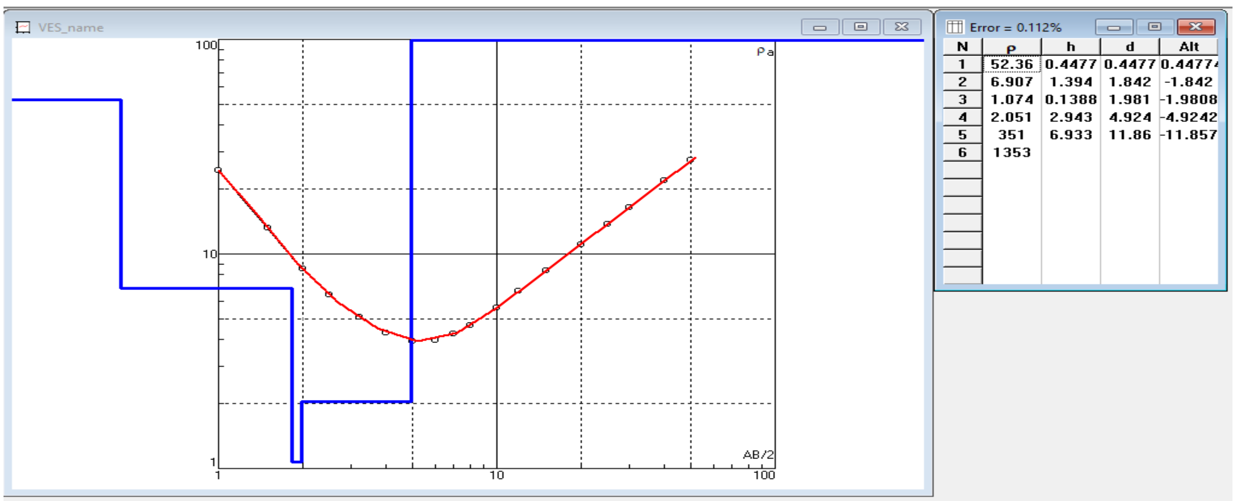

Figure 4.2i: VES 9 quantitative interpretation from IPI2win

Table 4.1a1: Result summary from VES 9

LAYERS	RESISTIVITY(Ωm)	THICKNESS h (m)	DEPTH d (m)	RMS ERROR (%)	CURVE TYPE	LITHOLOGY
1	52.36	0.45	0.45			Top Soil
2	6.91	1.39	1.84			Silty Sand
3	1.07	0.14	1.98			Clay
4	2.05	2.94	4.92	0.27	HA	Clay
5	351	6.933	11.86			Fine-Medium Sand
6	1353					Fine-Medium Sand

Determination of sand using VES

A geophysical survey was carried out in Opolo in order to study and estimate the volume of sand to ascertain whether it could be dredged commercially. Nine geo-electrical profiles were acquired. Vertical electrical sounding models made at VES stations were used to obtain geo-electrical sections of different profiles in a rectangle shape of 100 m by 50 m. The results of the nine (9) vertical electrical soundings (VES) conducted are presented in Table 4.1 and Table 4.2. The area shows that four to six geological layers are present at each VES profile in the study area.

The survey result shows an area that consists mostly of sand, indicating a considerable quantity of sand that can be dredged from the area of study.

Calculation of Sand Quantification

The shape of the study area is a rectangle.
The Area of a rectangle = Length x Width.
The Depth of the layer is taken as the total thickness.
The volume of the rectangle = Area x thickness
The mass of sand occupying the area = Density x volume

Volume of sand estimation from VES values for Opolo

Area = Length x Width
Where L= 100 m, W=50m
Therefore, the Area of the study area = 100 x 50
Area = 5000m^2
Average thickness of the nine VES =

$$\frac{5.94 + 4.24 + 16.04 + 7.44 + 9.81 + 3.14 + 22.73 + 1.05 + 6.93}{9} = \frac{77.32}{9}$$

= 8.59 m

Therefore, the volume of the rectangle = Area x thickness
= 5000 x 8.59 = 42,950 m^3

The Mass of sand occupying the study area = Density x volume
Density of sand = 1.602gcm^{-3}
Density = 1.602 x 1000 = 1602kgm $^{-3}$
Mass = 1602 x 42,950
= 68,805,900 kg
= 688,059 tonnes
Hence the quantity of sand present in the mapped area is 688059 tonnes.

Conclusion and Recommendations

The research focuses on refining the accurate sand depth estimation methodology using Vertical Electrical Sounding (VES). The method considers geological complexity, electrode arrangement and interpretation techniques to develop a more robust approach to estimating sand depth. By analyzing field data collected from different geological settings, the study aims to enhance subsurface characterization.

The research shows that sand deposits can be dredged economically for domestic and construction purposes. The study contributes significantly to the chemistry, geology, geophysics, and subsurface exploration by offering an improved methodology for unveiling the chemistry of sand, integrating chemistry, geological, geophysical, and interpretational aspects, and developing and applying advanced inversion algorithms. Based on the findings, the study recommends developing and utilizing advanced inversion algorithms, conducting extensive testing with different electrode spacing and configurations, incorporating complementary geophysical data, and tailoring the estimation methodology to the specific geological characteristics of the study area.

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