GEOPHYSICAL INVESTIGATION OF GROUNDWATER RESOURCES IN ABAGANA, NJIKOKA LGA, ANAMBRA STATE

A CASE STUDY USING ELECTRICAL RESISTIVITY METHOD

Chiegboka Damian

ABSTRACT

Geophysical survey using electrical resistivity method was carried out in Abagana, Anambra state in south-eastern Nigeria with a view to delineate the geoelectric properties so as to evaluate the ground water potentials and aquifer characteristics of the study area. A total of 9 vertical electrical sounding stations were established within Abagana. The Schlumberger configuration was used for the data acquisition. The half current electrode (AB/2) used range from 180 to 200m. The quantitative interpretation of the VES curve involved the use of partial curve matching and the I-D computer iteration technique. The depth sounding interpretation results were used to generate geo-electric sections from which the aquifer was delineated. The geoelectric section drawn from the result of the interpretation reveals mostly four (4) to five (5) subsurface layers which comprises of the top soil, clay soil, dry sand, sandstone, and water saturated sand with varying water storage and yielding capacity. The water table within the study area ranges from 180m to 200m from the soil surface, and the probable aquiferous zones vary from 56m to 120m in thickness. It was observed that the hydraulic conductivity varies between 0.000394011m/day and 0.029498525m/day while transmissivity values vary between 0.039401103 and 1.769911504m^2/day. Among all the VES points studied, it was observed that VES 1 has the highest tansmissivity and hydraulic conductivity compared to the other stations. In view of the foregoing, it is expected that water will flow more from aquifer in VES 1 since groundwater flow from an aquifer is directly proportional to transmissivity.

INTRODUCTION

Water is identified as the most important natural resource for the sustenance of life on earth and can be obtained mainly from surface flow as in rivers and lakes and from the subsurface in what is referred to as groundwater (Anomohanran, 2015). Fresh surface water can be assessed easily in most places except for areas in the desert regions. Despite this advantage of easy accessibility, surface water is often polluted by anthropogenic activities making groundwater to be a viable option in satisfying our demand for quality water (Wattanasen, 2008, Anomohanran, 2015b).

Various geophysical techniques or applications have been employed in groundwater exploration in many parts of the world. These include magnetic resonance sounding (MRS), remote sensing, geographic information system, gravity, seismic, electrical resistivity among others (Wattanasen, 2008, Kamble, 2012).

The electrical resistivity survey method is one of the oldest geophysical exploration techniques that have been extensively employed in environmental, engineering, hydrological, archaeological and mineral exploration surveys (Loke et al., 2013).

The vertical electrical sounding (VES) has been the most frequently used electrical resistivity tool in groundwater investigation due to its ability to provide useful information about the subsurface structure and lithology at reasonable depths (Araffa, 2015). It is also comparatively cheaper than other methods and uncomplicated. The procedure for VES survey involves two current electrodes and two potential electrodes in which the current is introduced into the subsurface by means of the two current electrodes. The two potential electrodes are then used to determine the potential built-up in the subsurface as a result of the introduced current (Loke et al., 2013). The information from the field is interpreted first by manual means to obtain the apparent resistivity and thickness of the subsurface layers. These initial parameters are then fed into computer-based software and interpreted through an iterative method that successively improves the initially given model or those obtained by curve matching technique. This is carried out until the root mean square error between the apparent resistivity and the true resistivity observed through iteration is stable or when there is no further change in layer parameters (Kumar, 2007).

The basis of the VES is anchored on the fact that current can only be transmitted by the subsurface layer because of the presence of water since the rock in itself is considered an insulator (Anomohanran, 2015). Geological formations which are able to store water are targets of groundwater exploration (Kayode, 2016). These geological formations are investigated for the following properties hydraulic conductivity, transmissivity, storativity and storage capacity (Tizro et al., 2012).

Geophysical logging of boreholes utilizing the spontaneous potential and resistivity loggings is commonly used for formation evaluation. The resistivity log is capable of estimating the resistivity of a subsurface formation and helps in the identification of subsurface geological strata (Kamble, 2012, Anomohanran, 2015). The spontaneous potential log measures the chemical differences between two adjacent formations and the formation water. The spontaneous potential log is able to distinguish between clay, sand or gravel in a geological formation (Kamble, 2012).

The study area (Abagana) falls within Anambra State, Nigeria. Researchers from relevant professional fields have carried out geological and geophysical exploration on groundwater resources in similar areas to ascertain aquifer productivity and basic parameters. Though contributions made by these researchers are remarkable, there is still need for more work. Therefore, in order to satisfy this high demand for water in the study area the research posed on unveiling the basic aquifer parameters in the study area. The aim of this study is to employ the use of the electrical resistivity method to estimate the aquifer parameters such as hydraulic conductivity, longitudinal conductance, transmissivity, depth, thickness, and transverse resistance in Abagana and environs. Also, Researchers has presented the need for adequate exploration and exploitation of groundwater to serve various purposes of the growing populace within Njikoka and its environs has become pertinent since the record of massive borehole failures due to indiscriminate drilling seems to be on the increase.

The reliance on surface water alone for agricultural, industrial, and domestic purposes has posed significant challenges, especially during prolonged dry seasons. Consequently, there is a pressing need to diversify the water sources available to the community, and groundwater presents a promising solution.

STUDY AREA

The study area (Abagana) falls within Anambra State, Nigeria and it is located between latitude 06°011 N to 06°183 N and longitude 006°059 E to 006°983 E. Abagana has a landmass of approximately 9.2 square kilometers and is bounded in the north by Abba, Ukpo, and Enugu Agidi towns, in the South by Nimo Owelle and Eziowelle towns, in the East by Enugwu Ukwu town and in the west by Umunnachi and Ifitedunu towns.

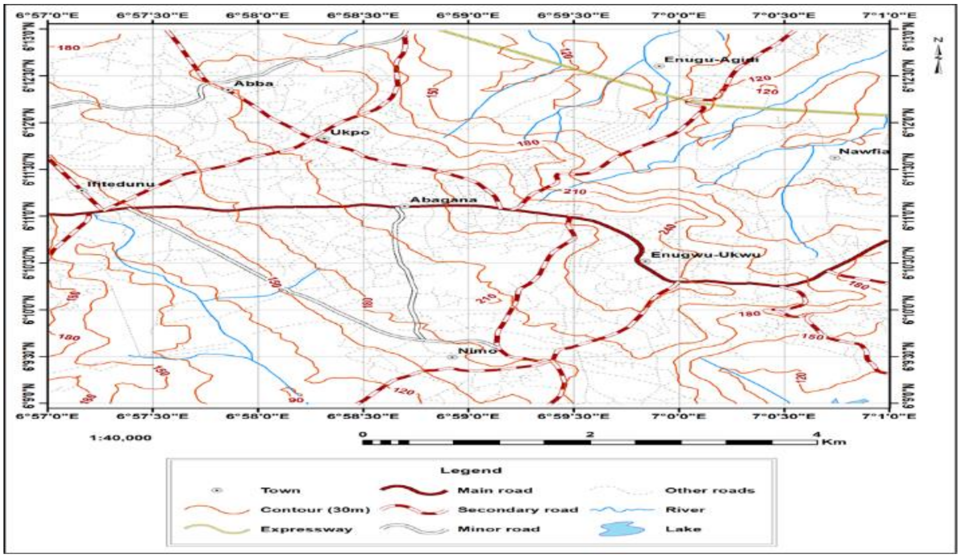

Figure 1: Topographic map of the study area

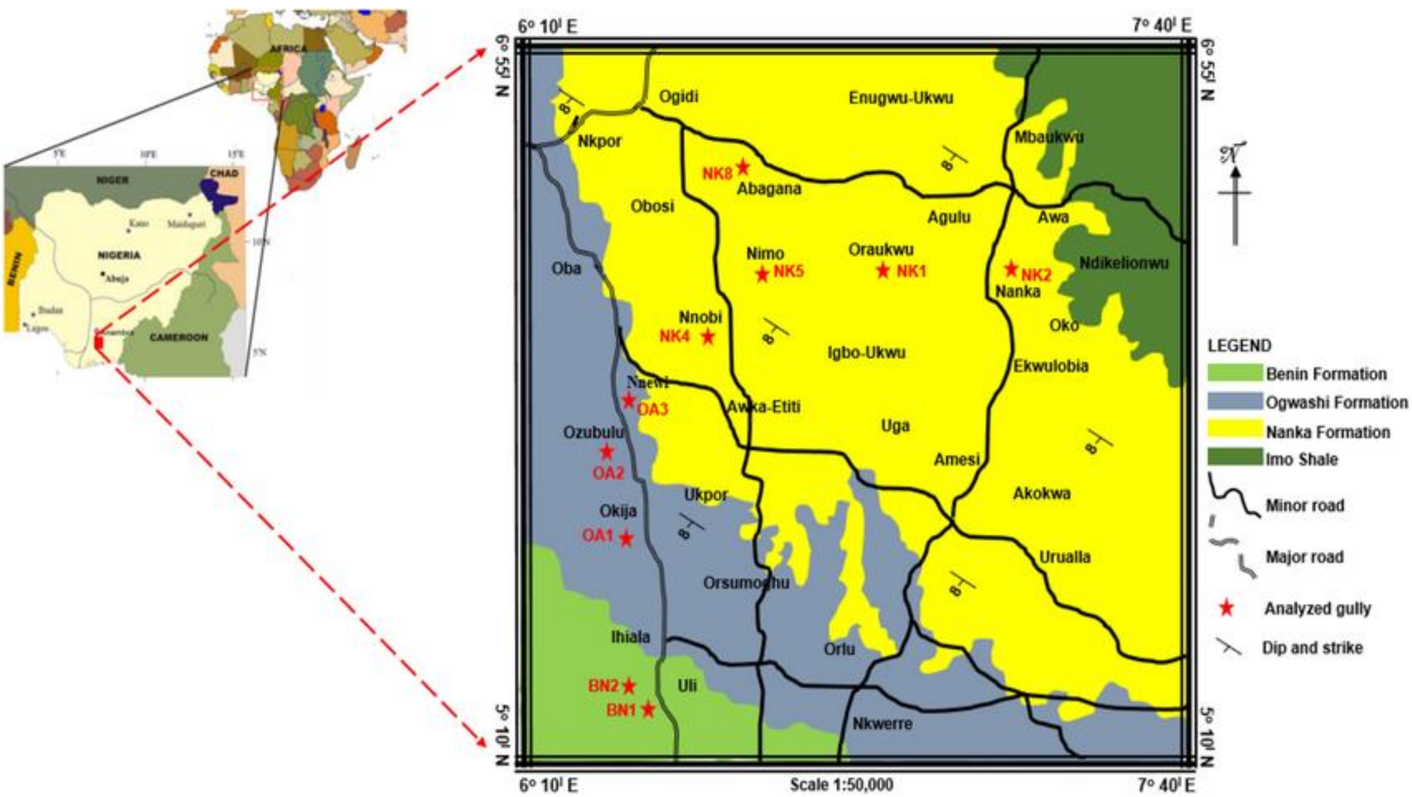

Fig 2: Geological map of the study area (Egbueri and Igwe 2020)

METHODOLOGY

Introduction

The most common and widely used geophysical survey method is the electrical resistivity method. In groundwater exploration, depth to bedrock determination, sand and gravel exploration etc., and the electrical resistivity method can be used to obtain quickly and economically details about the location, depth and resistivity of the subsurface formation. The basis of the method is that when current is applied by the conduction into the ground through electrode, any subsurface variation in conductivity alters the current flow within the Erath and this in turn affect the distribution of the electric potential. The degree to which the potential at the surface is affected depends upon the size, location, shape and conductivity of the materials within the ground. It is therefore possible to obtain information about the subsurface distribution of these materials from measurements of the electrical potential made at the surface.

This usual practice is to pass current into the ground by means of two electrodes and to measure the potential difference between a second pair placed in line between them. From the values of the potential difference, the current applied and also the electrode separation a quantity termed the apparent resistivity can be calculated. In homogenous ground, this is the true ground resistivity but usually it represents a weighted average of the resistivity of all the formation through which the current passes. It is the variation of this apparent resistivity with change in electrode spacing and position that gives information about the variation in subsurface layering.

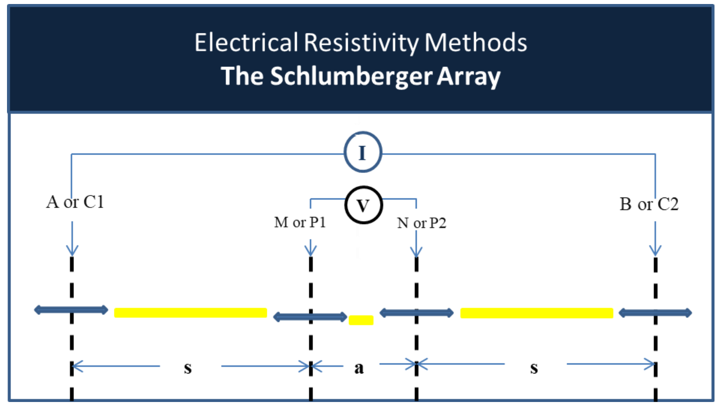

Fig 3: Schlumberger Array (modified after Hassan 2017)

RESULT

VES 1

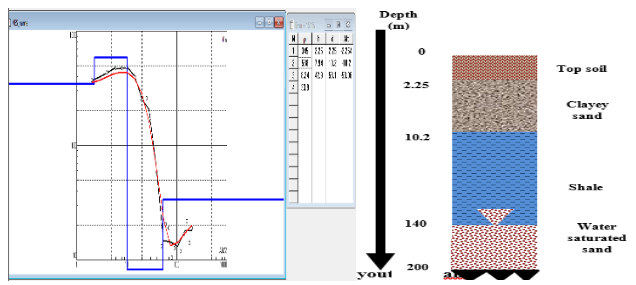

Fig 4.1 Geoelectric Curve and Layers of Umudunu new layout

Table 4.10: Geo-electric parameters of VES 1

Layers	Apparent resistivity (Ωm)	Thickness (m)	Depth (m)	Inferred Lithology
1	345	2.25	2.25	Top Soil
2	588	7.94	10.2	Clayey Sand
3	8.24	129.8	140	Shale
4	33.9	60	200	Water Saturated Sand

VES 2

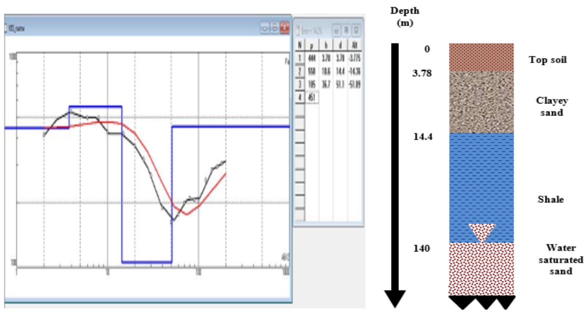

Fig 4.2 Geoelectric Curve and Layers of Girl's Secondary School Abagana

Table 4.11: Geo-electric parameters of VES 2

Layers	Apparent resistivity (Ωm)	Thickness (m)	Depth (m)	Inferred Lithology
1	444	3.78	3.78	Top Soil
2	558	10.6	14.4	Clayey Sand
3	105	125.6	140	Shale
4	451	40	180	Water Saturated Sand

VES 3

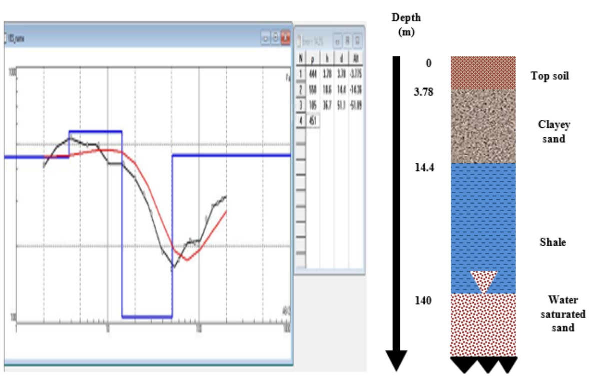

Fig 4.2 Geoelectric Curve and Layers of Girl's Secondary School Abagana

Table 4.12: Geo-electric parameters of VES 3

Layers	Apparent resistivity (Ωm)	Thickness (m)	Depth (m)	Inferred Lithology
1	251	2.38	2.38	Top Soil
2	974	11.6	14	Dry Sand
3	2230	86	100	Sandstone
4	2538	100	200	Water Saturated Sand

VES 4

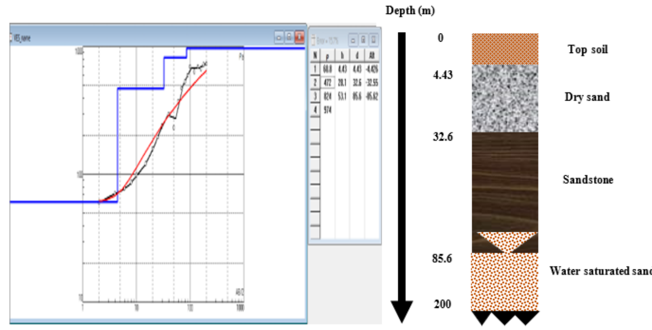

Fig 4.4 Geoelectric Curve and Layers of Ezi-icheke Nimo Road Umudunu Abagana

Table 4.13: Geo-electric parameters of VES 4

Layers	Apparent resistivity (Ωm)	Thickness (m)	Depth (m)	Inferred Lithology
1	60.8	4.43	4.43	Top Soil
2	472	28.1	32.6	Dry Sand
3	824	107.4	140	Sandstone
4	974	60	200	Water Saturated Sand

VES 5

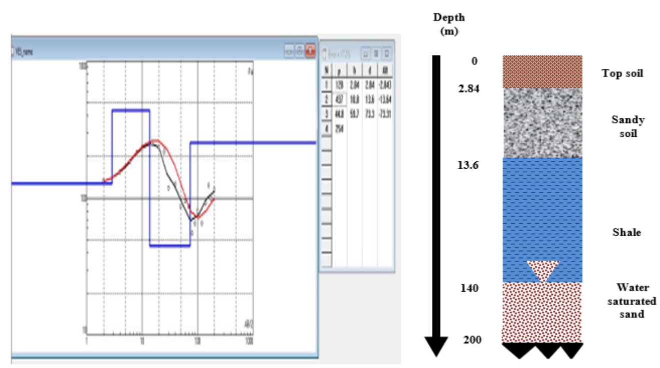

Fig 4.5 Geoelectric Curve and Layers of Abagana Local Government Area

Table 4.14: Geo-electric parameters of VES 5

Layers	Apparent resistivity(Ωm)	Thickness (m)	Depth (m)	Inferred Lithology
1	128	2.84	2.84	Top Soil
2	437	10.8	13.6	Dry Sand
3	44.8	126.4	140	Shale
4	254	60	200	Water Saturated Sand

VES 6

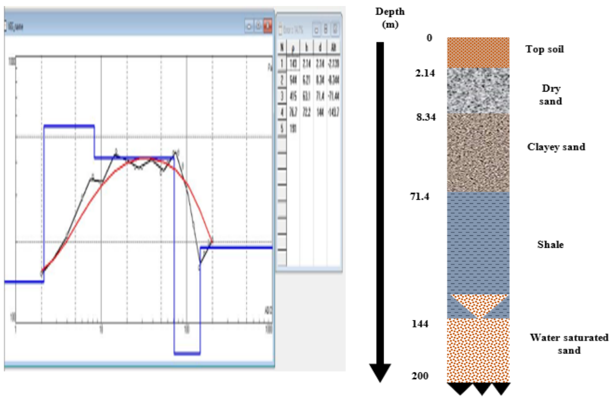

Fig 4.6 Geoelectric Curve and Layers of Stella Maris Secondary School Abagana

Table 4.15: Geo-electric parameters of VES 6

Layers	Apparent resistivity (Ωm)	Thickness (m)	Depth (m)	Inferred Lithology
1	143	2.14	2.14	Top Soil
2	544	6.21	8.34	Dry Sand
3	415	63.1	71.4	Clayey sand
4	76.7	72.6	144	Shale
5	191	56	200	Water Saturated Sand

VES 7

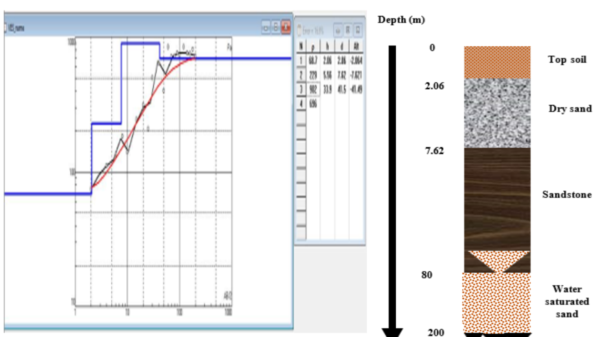

Fig 4.7 Geoelectric Curve and Layers of Etiti Umudunu Village, Ozugba road Abagana

Table 4.16: Geo-electric parameters of VES 7

Layers	Apparent resistivity (Ωm)	Thickness (m)	Depth (m)	Inferred Lithology
1	68.7	2.06	2.06	Top Soil
2	229	5.56	7.62	Dry Sand
3	902	72.38	80	Sandstone
4	696	120	200	Water Saturated Sand

VES 8

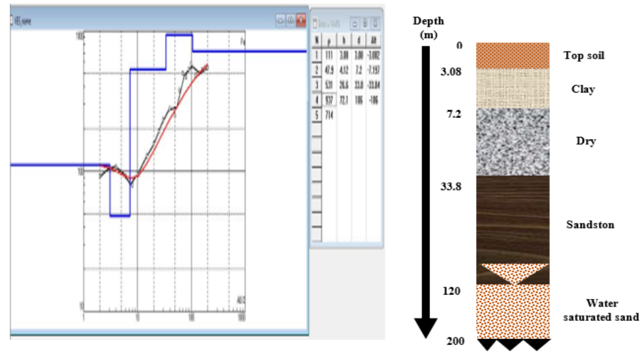

Fig 4.8 Geoelectric Curve and Layers of St Peter's Anglican Church Abagana

Table 4.17: Geo-electric parameters of VES 8

Layers	Apparent resistivity (Ωm)	Thickness (m)	Depth (m)	Inferred Lithology
1	111	3.08	3.08	Top Soil
2	47.9	4.12	7.2	Clay
3	531	26.6	33.8	Dry Sand
4	937	86.2	120	Sandstone
5	714	80	200	Water Saturated Sand

VES 9

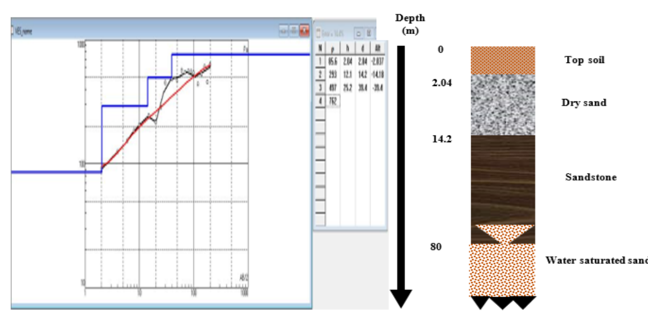

Fig 4.9 Geoelectric Curve and Layers of Opposite Open University, Cemetery road Umualaocha Umudunu Village Abagana

Table 4.18: Geo-electric parameters of VES 9

Layers	Apparent resistivity (Ωm)	Thickness (m)	Depth (m)	Inferred Lithology
1	85.6	2.04	2.04	Top Soil
2	293	12.1	14.2	Dry Sand
3	497	65.8	80	Sandstone
4	762	120	200	Water Saturated Sand

SUMMARY OF RESULTS

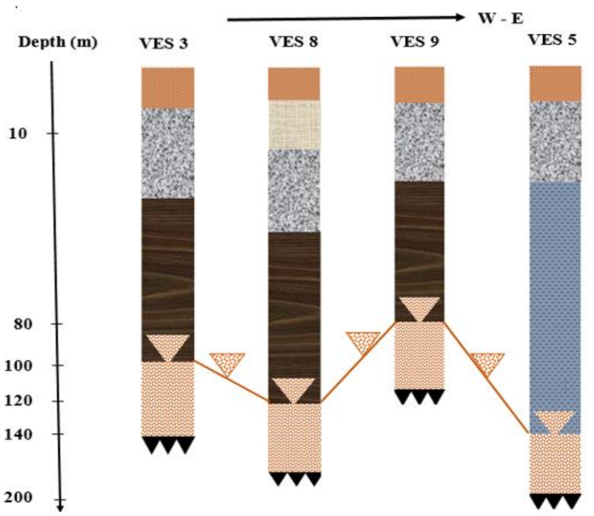

Fig 4.10 Correlation of Geo-electric layers along West-East Direction

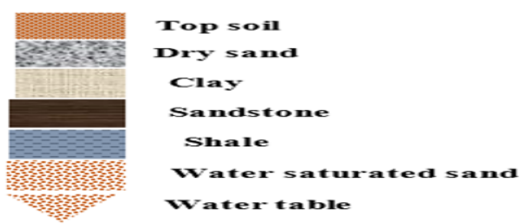

Fig 4.10.1: Legend of the Geoelectric Section.

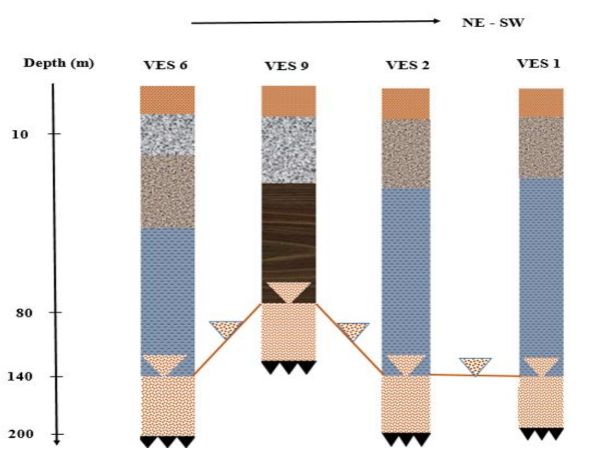

Fig 4.11 Correlation of Geo-electric layers along North east-South west Direction

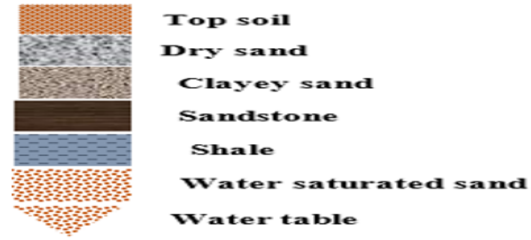

Fig 4.11.1 Legend of the Geoelectric Section

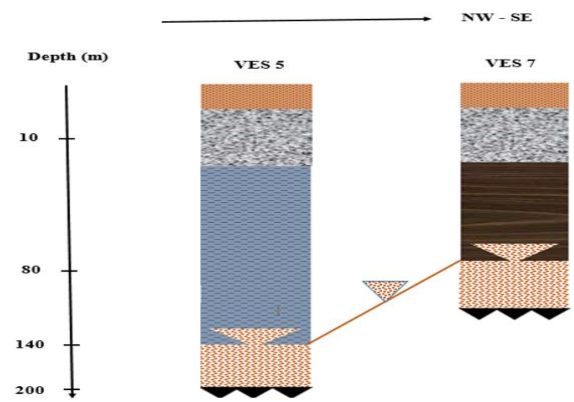

Fig 4.12 Correlation of Geo-electric layers along North West-South East Direction

Fig 4.12.1 Legend of the Geoelectric Section

VES Location	**Calculated Transmissivity (m^2/day)**	**Description**	**Hydraulic conductivity (m/day)**	**Description**
VES 1	1.769911504	High transmissivity	0.029498525	Moderate
VES 2	0.133037694	Moderate transmissivity	0.002217295	Moderate
VES 3	0.039401103	Low	0.000394011	Low

		transmissivity		
VES 4	0.061601643	Low transmissivity	0.001026694	Moderate
VES 5	0.236220472	Moderate transmissivity	0.003937008	Moderate
VES 6	0.293193717	Moderate transmissivity	0.005235602	Moderate
VES 7	0.172413793	Moderate Transmissivity	0.001436782	Moderate
VES 8	0.112044818	Moderate transmissivity	0.00140056	Moderate
VES 9	0.157480315	Moderate transmissivity	0.001312336	Moderate

Table 4.19 Summary of Transmissivity and hydraulic conductivity rating of the VES locations.

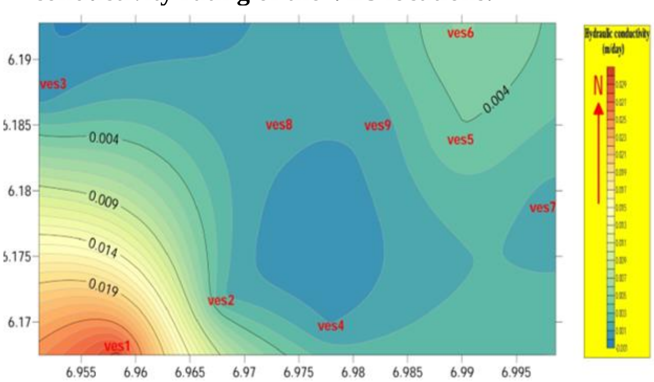

Fig 4.13: Hydraulic conductivity map of the study area

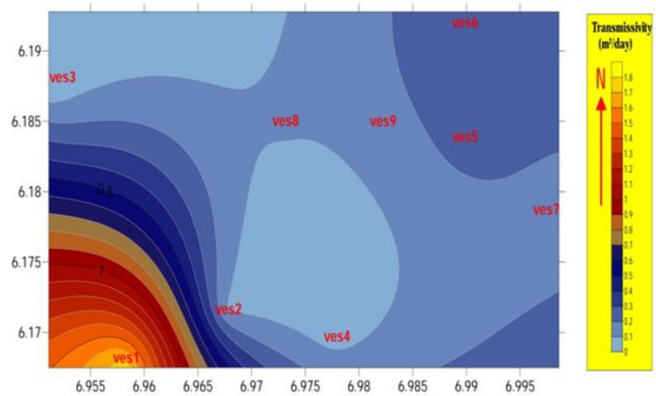

Fig 4.14: Transmissivity map of the study area

VES Station	Latitude (X)	Longitude (Y)	Depth to water table (m)	Elevation (m)	Depth to water table with reference to MSL (m)
1	6.000139	6.007917	140	130	-10
2	6.000833	6.001074	140	140	0
3	6.000713	6.010028	100	170	70
4	6.001435	6.010741	140	250	110
5	6.000102	6.006282	140	250	110
6	6.001731	6.003551	144	230	86
7	6.002037	6.017755	80	230	150
8	6.000306	6.006176	120	200	80
9	6.002639	6.014769	80	230	150

Table 4.20 Summary of rating of the VES locations

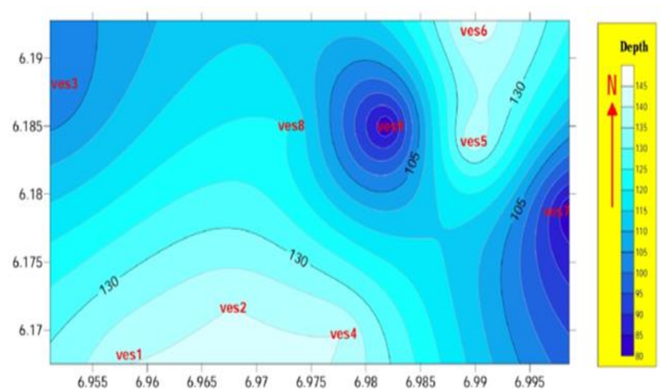

Fig 4.15: Depth to the aquifer map of the study area

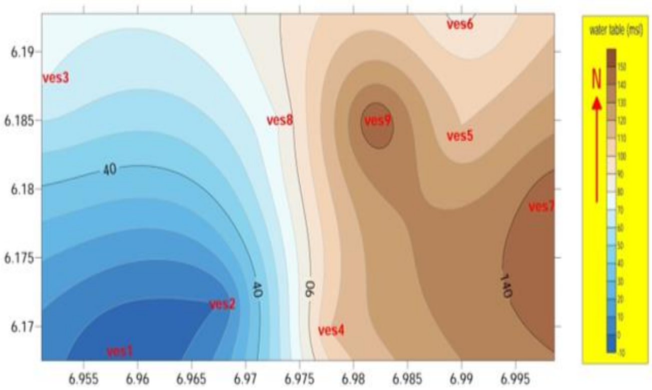

Fig 4.16: Water table map of the study area

SUMMARY OF RESULT

Stations with thicker aquifer (e.g., Stations 3, 7, and 9) might provide substantial groundwater storage. It was observed that the hydraulic conductivity varies between 0.000394011m/day and 0.029498525m/day while transmissivity values vary between 0.039401103 and 1.769911504m^2/day. From the map and data above, it was observed that VES 1 has the highest transmissivity and hydraulic conductivity compared to the other stations. This suggests that station 1 may have favorable conditions for groundwater movement and extraction. The higher values indicate that water may flow more easily through the aquifer at this location, potentially making it an important area for groundwater exploration.

Station 1, 2, 4, 5, and 6 all have depth to the water table of 140 to 144 meters. This suggests relatively consistent water table level across the study area. These consistent depths to the water table across the stations listed above may indicate the presence of a potential aquifer at that level.

Station 7 and Station 9 stand out with a depth to water table of 80 meters and relatively high elevation of 230meters. This suggests a potentially important location in terms of groundwater investigation as it has shallower water table compared to other stations.

ACKNOWLEDGEMENT

The Author appreciates the guidance received by his Project Supervisor and the team of the Department of Applied Geophysics, Nnamdi Azikiwe University, Awka, Nigeria, who put effort during the field work exercise.

REFERENCE

Anomohanran, O. (2015). Hydrogeophysical investigation of aquifer properties and lithological strata in Abraka, Nigeria J. Afr. Earth Sci.

Anomohanran, O. (2015b). Hydrogeophysical and hydrogeological investigations of groundwater resources in Delta Central, Nigeria J. Taibah Univ. Sci.

Araffa, S.A.S. (2015). Integrated geophysical interpretation for delineating the structural elements and groundwater aquifers at central part of Sinai Peninsula, Egypt J. Afr. Earth Sci.

Egbueri, J.C., and Igwe, O, (2020). Development of a novel numerical indicator (DLPI) for assessing the detachability and liquefaction potentials of soils from erosion-prone areas.

Kamble, O. (2012). Geosounding Principles. I. Resistivity Sounding Measurements. Amsterdam: Elsevier Scientific Publishing.

Kumar, D. (2007). Reducing ambiguities in Vertical electrical sounding interpretations: A geostatistical application. J. Appl. Geophys.

Kayode, J.S. (2016). Geo-electrical investigation of near surface conductive structures suitable for groundwater accumulation in a resistive crystalline basement environment: a case study of Isuada, southwestern Nigeria J. Afr. Earth Sci.

Loke, M. H., Chambers, J. E., Rucker, D. F., Kuras, O., and Wilkinson, P. B. (2013). Recent developments in the direct-current geoelectrical imaging method. J. Appl. Geophys.95,135–156. doi: 10.1016/j.jappgeo.2013.02.017.

Tizro, A. T., Voudouris, K., and Basami, Y. (2012). Estimation of porosity and specific yield by application of geoelectrical method – a case study in western Iran. J. Hydro. 454–455, 160–172.doi: 10.1016/j.jhydrol.2012.06.009.

Wattanasen, K. (2008). Direct and indirect methods for groundwater investigations: a case-study of MRS and VES in the southern part of Sweden. Appl. Geophys.