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*Full Length Research Paper*

# Geoelectric investigation of the groundwater potential of Moniya Area, Ibadan

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**Geoelectric measurements using the Vertical Electrical Sounding (VES) method were carried out in Moniya, Akinyele Local Government, Oyo State, Nigeria, using the ABEM terrameter SAS 300B . The objectives of the study were to investigate the aquifer characteristics and groundwater potential of the subsurface formations. Seventeen profiles were carried out using the Schlumberger array configuration. The data was interpreted using the conventional curve matching and computer iteration methods. Results show that four major curve types were identified, namely: A, H, KH and HA. The top layer has resistivity value ranging from 61.8 to 504.3 ohm-m showing that it consists of clayey sand and sandy clay, with maximum layer thickness of 3.5 m. The resistivity of the second layer which is the weathered zone ranges from 19.7 to 724.6 ohm-m while the thicknesses vary between 0.7 to 30.3 m. These VES stations: 9, 11, 16, and 17 are fourth layer region. The third layers constitute the weathered layer which has resistivities from 13.7 to 95.3 ohm-m while it's layer thicknesses vary from 12.6 to 44.6 m the layer will be good for well sitting. VES stations 9, 6, 7, 12, 14, and17 are the locations that will be recommended for deep well sitting, because they have highest thickness of both weathered zone and fractured zone respectively which are good for groundwater storage.**

**Key words:** Groundwater, geoelectric measurement, aquifer and fractured zone.

## INTRODUCTION

The Vertical Electrical Sounding (VES) method is a depth sounding galvanic method and has proved very useful in groundwater studies due to simplicity and reliability of the method. The electrical resistivity of rock is a property which depends on lithology and fluid contents. The resistivity of coarse-grained, well-consolidated sandstone saturated with fresh water, for example, is higher than that of unconsolidated silt of the same porosity, saturated with the same water. Similarly, the resistivities of identical porous rock samples vary according to the salinity of the saturating water. The higher the salinity of the water, the lower the resistivity of the rock, therefore, it is quite possible for two different types of rock, such as shale and sandstone, to be of essentially the same resistivity when the sandstone is saturated with saline water and the shale with fresh water. For this reason, the number and thicknesses of the geoelectric units as determined from VES measurements at a locality may not necessarily be the same as the geological ones. In this respect, geoelectric units define parastratigraphic units whose boundaries may be discordant with the stratigraphic boundaries (Krumbein and Sloss, 1963). The ultimate objecttive of VES at some locality is to obtain a true resistivity log similar to the induction log of a well at the locality, without actually drilling the well (Hamill and Bell, 1986). Groundwater accounts for about 98% of the world's fresh water and is fairly evenly distributed throughout the world. It provides a reasonable constant supply which is not completely susceptible to drying up under natural condition like surface water (UNESCO, 1978).

Groundwater in Nigeria is restricted by the fact that more than half of the country is underlain by crystalline basement rock of pre-cambian era (Kazeem, 2007). The main rock types in this geological terrain include igneous and metamorphic rock such as migmatites and granite gneisses. Dan-Hassan and Olorunfemi (1999) used the electrical resistivity method to delineate different subsurface geoelectrical layers, aquifer unit and their characteristics, the subsurface structure and its influence on the general hydrogeological condition in the north central part of Kaduna state, Nigeria. Olorunfemi and Okhue (1992) used the same method in groundwater

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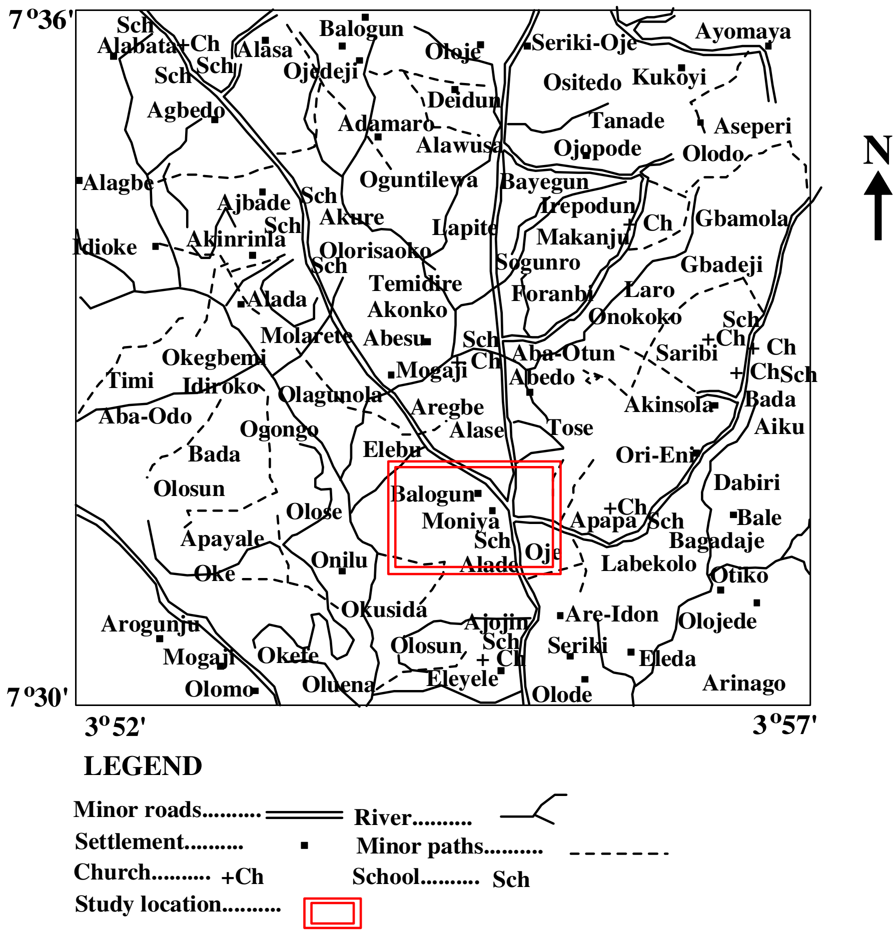


**Figure 1.** Topology map showing the study area.

investigation and determination of structural trends. The Electrical resistivity method is used in the determination of depth to bedrock and nature of superficial deposit and structural mapping. The boundary of the aquifer and zones of high yield potential have been determined (Gholam and Mohammad, 2005).

The electrical resistivity method is the most widely used geophysical method in the basement terrain. Olayinka (1990) used a multielectrode resistivity profiling array for groundwater. And Ojo et al (1990) in geophysical survey of a dam has employed this method in imaging the distribution of electrical properties of hydrogeological and dam site investigation. This method has also been used to delineate two shallow aquifer units in coastal plain of Okitipupa area, Southwestern Nigeria by Omosuyi et al. (2008).They concluded among others that based on the resistivity parameters and overall thickness of geoelectric layers overlying the aquifer units, the near surface acquifer systems in the study area are generally protected from contamination infiltrating from the surface, with the intermediate one being relatively less vulnerable. Olayinka (1991) described different methods of interpretation of Wenner resistivity pseudo section data and its application in south-west Nigeria basement complex.

Water resources of the study area are threatened by increasing population trend due to University of Ibadan satellite campus there, resulting in increase in water demand. The progressive population growth has led to shortage of portable drinking water for the area which poses a great challenge to the people living in the environment.

The present investigation is aimed at producing a geophysical survey data containing basic information necessary for sitting better yield borehole for people of the area. It will also serves as basis for more detail geophysical and geotechnical studies in the area and similar area.

## THE SITE

Akinyele Local Government is under the basement complex region of Nigeria. The studied area is bounded by longitudes $3^{0}54.96^{'}$ E and $3^{0}55.209^{'}$ E and latitude $7^{0}30.100^{'}$ N and $7^{0}30.566^{'}$ N (Figure 1). The granite rocks,

**Table 1a.** Apparent resistivity values for VES 1 to 7.

| Current electrode (AB/2) m | Potential electrode (MN/2) m | Apparent resistivity ρ(Ωm) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | VES1 | VES2 | VES3 | VES4 | VES5 | VES6 | VES7 |
| 1.0 | 0.25 | 88.3 | 367.3 | 68.8 | 237.3 | 149.4 | 129.4 | 132.1 |
| 1.3 | 0.25 | 83.0 | 291.3 | 74.5 | 159.4 | 150.4 | 120.0 | 131.9 |
| 1.8 | 0.25 | 83.4 | 203.6 | 90.5 | 128.4 | 148.9 | 117.3 | 132.3 |
| 2.4 | 0.25 | 87.4 | 153.9 | 113.5 | 118.6 | 152.5 | 107.4 | 133.0 |
| 3.2 | 0.25 | 95.1 | 123.2 | 148.2 | 128.2 | 154.5 | 89.9 | 128.3 |
| 4.2 | 0.25 | 117.6 | 115.6 | 185.4 | 138.7 | 162.9 | 82.9 | 99.4 |
| 4.2 | 1 | 121.9 | 119.3 | 228.1 | 162.1 | 144.6 | 87.0 | 127.9 |
| 5.5 | 1 | 145.1 | 110.3 | 226.9 | 178.7 | 163.9 | 77.1 | 121.2 |
| 7.5 | 1 | 178.3 | 112.9 | 249.4 | 212.1 | 200.5 | 70.4 | 130.9 |
| 10 | 1 | 203.3 | 109.1 | 310.9 | 243.9 | 237.0 | 65.7 | 129.9 |
| 13 | 1 | 222.6 | 88.4 | 400.6 | 320.6 | 270.8 | 59.8 | 126.2 |
| 13 | 2.5 | 229.9 | 110.1 | 364.6 | 272.1 | 285.8 | 65.7 | 125.5 |
| 18 | 2.5 | 256.3 | 120.5 | 409.2 | 400.8 | 305.5 | 66.2 | 124.7 |
| 24 | 2.5 | 268.5 | 125.5 | 440.8 | 452.7 | 370.6 | 64.3 | 121.1 |
| 32 | 2.5 | 277.6 | 156.5 | 493.7 | 588.1 | 412.3 | 70.5 | 133.2 |
| 42 | 2.5 | 264.8 | 232.8 | 565.6 | 739.2 | 434.1 | 85.8 | 154.8 |
| 55 | 2.5 | 334.5 | 268.8 | 662.4 | 850.5 | 485.2 | 89.4 | 188.6 |
| 55 | 5 | 329.6 | 263.1 | 678.6 | 859.9 | 520.9 | 97.5 | 201.1 |
| 75 | 5 | | | 850.5 | | | 129.4 | |
| 100 | 5 | | | | | | | |

which are member of the older granite suit occupy a large part of the total area of Akinyele Local Government. Three principal petrographic varieties are recognized, the fine-grained biotite granite, medium to coarse grained, non-porphyritic biotite – hornblende granite and coarse – porphyritic biotite-hornblade granite.

## MATERIALS AND METHODOLOGY

In carrying out the geoelectric survey the ABEM Terrameter SAS 300B was used.

The resistivity survey was completed with 17 profiles across the studied area using Schlumberger array with maximum current electrode separation (AB/2) of 100 m. However in most sounding points electrode spread were limited to 55 m due to obstruction encountered at such places. To perform a vertical sounding, measurements are taken for increasing electrode apertures, maintaining the sounding point (Telford et al., 1982; Vogelsang, 1995; Osella et al., 2002)

The apparent resistivity values obtained from field measurements (Tables 1a to c) were plotted against the electrode spacing on bilogarithm coordinates and a preliminary interpretation of each VES curve was carried out using partial curve-matching involving two-layer master curves and the appropriate auxiliary charts. The layer resistivities and thicknesses obtained served as layered model parameters input for the iteration algorithm using the software 'RESIST" on computer (Zohdy, 1989).

## RESULTS AND DISCUSSION

Four major curve types were identified, namely: A, H, KH and HA, as shown in Table 2. VES 1, 3, and 5 are Type A while also VES 2, 4, 6, 7, 8, 10, 12, 13, and 14 are Type H VES 9, 10, and 16 are Type KH and only VES 17 is of Type HA.

The apparent resistivity curves reveal a dominant curve Type H over the entire area. The dominant of this curve type shows that a homogenous subsurface succession and in most sounding curves the same layer were found. Figures 2 (a to d), show typical geoelectric curves representative of the curve Types A, H, KH and HA respectively.

The top layer has resistivity value ranging from 61.8 to 504.3 ohm-m showing that it consists of clay sandy clay and clayey sand with maximum layer thickness of 3.5 m. The top soil contributes to the development of groundwater, because it is the passage for the flow of surface water to the fractured layer. The rocks above the water table are in the zone of aeration. The topsoil generally consists of three parts: the belt of soil water at the top, the intermediate vadose zone, and the capillary fringe at the bottom. The difference in compaction of the clayey sand is responsible for the variation in the resistivity values.

The resistivity of the second layer which is weathered zone ranges from 19.7 to 724.6 ohm-m while the thickness varies between 0.7 to 30.3 m.

The VES Stations 9, 11, 16, and 17 are fourth layer region In these stations the third layers constitute the weathered zone, which has resistivities from 13.7 to 95.3 ohm-m while it's layer thickness varies between 12.6 to

**Table 1b.** Apparent resistivity values for VES 8 to 12.

| Current electrode (AB/2) m | Potential electrode (MN/2) m | Apparent resistivity ρ(Ωm) | | | | |
|---|---|---|---|---|---|---|
| | | VES 8 | VES 9 | VES 10 | VES 11 | VES 12 |
| 1.0 | 0.25 | 123.5 | 116.4 | 177.2 | 162.0 | 90.1 |
| 1.3 | 0.25 | 102.6 | 120.0 | 144.8 | 168.5 | 82.6 |
| 1.8 | 0.25 | 88.5 | 123.5 | 113.1 | 170.0 | 82.5 |
| 2.4 | 0.25 | 83.3 | 137.7 | 111.1 | 174.2 | 82.1 |
| 3.2 | 0.25 | 77.1 | 155.4 | 113.2 | 173.1 | 78.4 |
| 4.2 | 0.25 | 74.0 | 170.2 | 103.2 | 187.8 | 48.1 |
| 4.2 | 1 | 94.6 | 208.9 | 127.6 | 219.2 | 62.9 |
| 5.5 | 1 | 89.8 | 239.4 | 108.2 | 216.0 | 58.6 |
| 7.5 | 1 | 84.6 | 249.6 | 102.9 | 195.9 | 49.2 |
| 10 | 1 | 94.6 | 256.0 | 116.1 | 154.4 | 39.6 |
| 13 | 1 | 108.8 | 269.1 | 140.1 | 130.1 | 31.1 |
| 13 | 2.5 | 110.8 | 312.4 | 115.1 | 158.4 | 40.8 |
| 18 | 2.5 | 137.9 | 261.5 | 130.5 | 82.6 | 24.2 |
| 24 | 2.5 | 155.5 | 222.3 | 127.1 | 53.4 | 23.1 |
| 32 | 2.5 | 182.0 | 194.7 | 142.1 | 36.7 | 21.1 |
| 42 | 2.5 | 210.4 | 182.1 | 162.5 | 27.5 | 23.8 |
| 55 | 2.5 | 260.6 | 165.5 | 165.5 | 24.6 | 28.1 |
| 55 | 5 | 310.7 | 168.9 | 168.0 | 32.8 | 19.3 |
| 75 | 5 | | 178.7 | 178.3 | 39.6 | 36.3 |
| 100 | 5 | | | | 50.1 | 41.7 |

**Table 1c.** Apparent resistivity values for VES 13 to17.

| Current electrode(AB/2) m | Potential electrode(MN/2) m | Apparent resistivity ρ(Ωm) | | | | |
|---|---|---|---|---|---|---|
| | | VES 13 | VES 14 | VES 15 | VES 16 | VES 17 |
| 1.0 | 0.25 | 101.3 | 307.5 | 187.4 | 130.0 | 147.3 |
| 1.3 | 0.25 | 82.5 | 297.7 | 201.5 | 135.5 | 118.5 |
| 1.8 | 0.25 | 67.9 | 279.1 | 212.4 | 147.2 | 79.8 |
| 2.4 | 0.25 | 57.1 | 272.8 | 214.0 | 163.3 | 78.1 |
| 3.2 | 0.25 | 58.8 | 242.6 | 240.0 | 190.0 | 79.7 |
| 4.2 | 0.25 | 64.3 | 236.2 | 280.2 | 187.4 | 82.1 |
| 4.2 | 1 | 77.4 | 248.6 | 270.2 | 212.8 | 98.7 |
| 5.5 | 1 | 79.9 | 218.5 | 308.3 | 232.8 | 85.9 |
| 7.5 | 1 | 89.1 | 195.9 | 339.6 | 221.8 | 90.0 |
| 10 | 1 | 97.2 | 193.7 | 343.6 | 210.4 | 87.5 |
| 13 | 1 | 112.6 | 187.6 | 326.6 | 187.8 | 79.9 |
| 13 | 2.5 | 119.9 | 187.7 | 298.6 | 206.9 | 78.9 |
| 18 | 2.5 | 130.5 | 191.4 | 258.2 | 167.9 | 82.9 |
| 24 | 2.5 | 143.9 | 188.3 | 215.1 | 157.7 | 95.7 |
| 32 | 2.5 | 143.7 | 178.2 | 189.9 | 174.8 | 122.1 |
| 42 | 2.5 | 145.5 | 180.7 | 180.9 | 203.6 | 155.8 |
| 55 | 2.5 | 161.0 | 191.8 | 181.9 | 234.4 | 198.8 |
| 55 | 5 | 150.8 | 195.9 | 174.6 | 246.8 | 215.6 |
| 75 | 5 | 164.3 | 237.7 | 175.2 | 301.8 | |
| 100 | 5 | | | | | |

44.6 m the layer will be good for groundwater exploration. Also, in VES Stations 9, 11, 16, and 17 the fourth layer, which is the fresh basement is described by high resistivity value up to 1088.7 ohm-m in VES 9,

**Table 2.** Layer resistivity, thickness and curve type.

| VES stations | Layer | Resistivity (Ohm-m) | Thickness (m) | Depth (m) | Curve type |
|---|---|---|---|---|---|
| 1 | 1 | 79 | 2.0 | 2.0 | A |
| | 2 | 323 | --- | --- | |
| 2 | 1 | 504 | 0.6 | 0.6 | H |
| | 2 | 103 | 15.3 | 15.9 | |
| | 3 | 587 | --- | --- | |
| 3 | 1 | 62 | 1.1 | 1.6 | A |
| | 2 | 477 | 15.0 | 16.1 | |
| | 3 | 1524 | --- | --- | |
| 4 | 1 | 484 | 0.4 | 0.4 | H |
| | 2 | 103 | 3.3 | 3.7 | |
| | 3 | 1475 | --- | --- | |
| 5 | 1 | 141 | 2.8 | 2.8 | A |
| | 2 | 332 | 9.2 | 12.0 | |
| | 3 | 603 | --- | --- | |
| 6 | 1 | 130 | 1.4 | 1.4 | H |
| | 2 | 61 | 24.3 | 25.7 | |
| | 3 | 314 | --- | --- | |
| 7 | 1 | 130 | 1.0 | 1.0 | H |
| | 2 | 122 | 25.8 | 26.8 | |
| | 3 | 436 | --- | --- | |
| 8 | 1 | 141 | 0.6 | 0.6 | H |
| | 2 | 69 | 5.9 | 6.5 | |
| | 3 | 341 | --- | --- | |
| 9 | 1 | 109 | 1.8 | 1.8 | KH |
| | 2 | 725 | 3.1 | 4.9 | |
| | 3 | 138 | 44.6 | 49.6 | |
| | 4 | 1089 | --- | --- | |
| 10 | 1 | 249 | 0.4 | 0.4 | H |
| | 2 | 107 | 10.8 | 11.2 | |
| | 3 | 196 | --- | --- | |
| 11 | 1 | 162 | 1.3 | 1.3 | KH |
| | 2 | 218 | 6.4 | 7.7 | |
| | 3 | 14 | 17.7 | 25.3 | |
| | 4 | 119 | --- | --- | |
| 12 | 1 | 83 | 3.5 | 3.5 | H |
| | 2 | 20 | 30.3 | 33.8 | |
| | 3 | 90 | --- | --- | |
| 13 | 1 | 125 | 0.6 | 0.6 | H |
| | 2 | 50 | 2.4 | 3.0 | |
| | 3 | 175 | --- | --- | |

**Table 2.** Contd.

| | | | | | |
|---|---|---|---|---|---|
| 14 | 1 | 309 | 1.5 | 1.5 | H |
| | 2 | 176 | 31.5 | 33.1 | |
| | 3 | 393 | --- | --- | |
| 15 | 1 | 171 | 1.3 | 1.3 | K |
| | 2 | 501 | 4.1 | 5.4 | |
| | 3 | 167 | --- | --- | |
| 16 | 1 | 125 | 1.1 | 1.1 | KH |
| | 2 | 277 | 5.1 | 6.2 | |
| | 3 | 95 | 12.6 | 18.7 | |
| | 4 | 649 | --- | --- | |
| 17 | 1 | 307 | 0.4 | 0.4 | HA |
| | 2 | 58 | 0.7 | 1.1 | |
| | 3 | 83 | 20.4 | 21.5 | |
| | 4 | 1309 | | --- | |

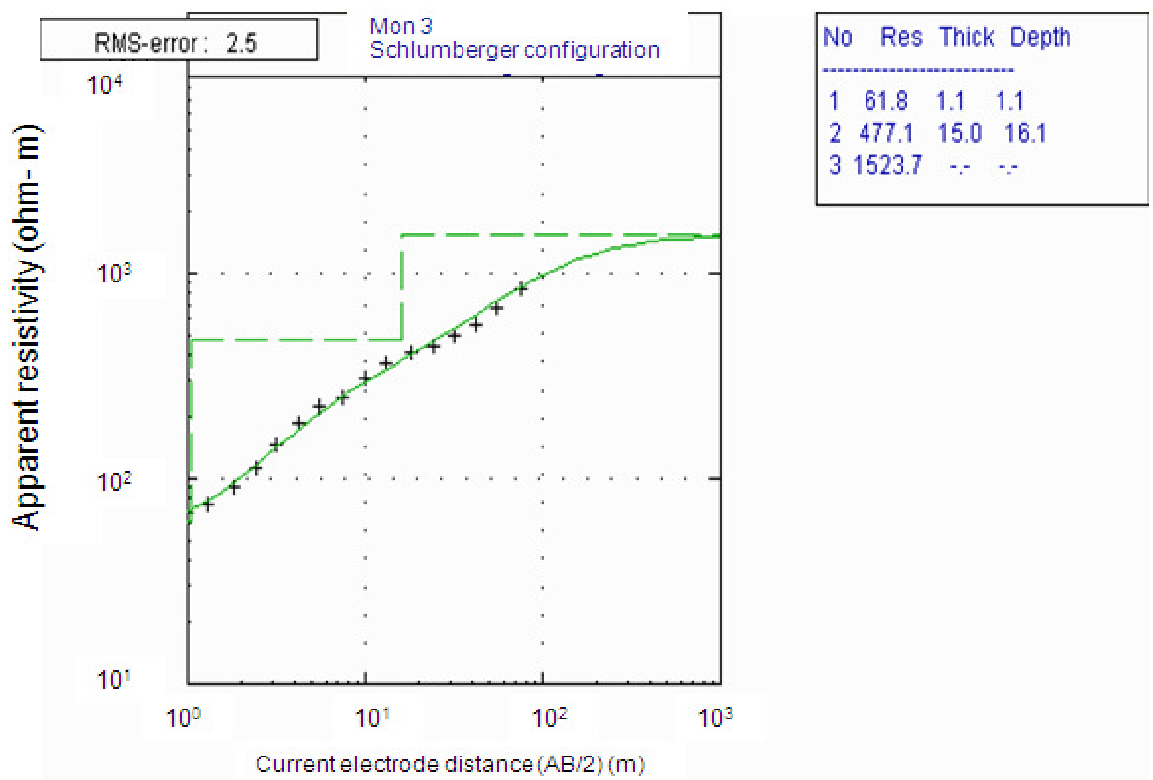


**Figure 2a.** Typical a VES curve type.

1309.4 ohm-m in VES 17 and 649.1 ohm-m in VES 16. It is made up of high resistivity rock in all fourth layer formation that forms the bed rock except in VES 15. The rock in these zones is hard with no permeability and no water bearing. The geoelectric section shows that the depth to the bedrock varies across fourth layer sounding stations

The thickness of the overburden is an important

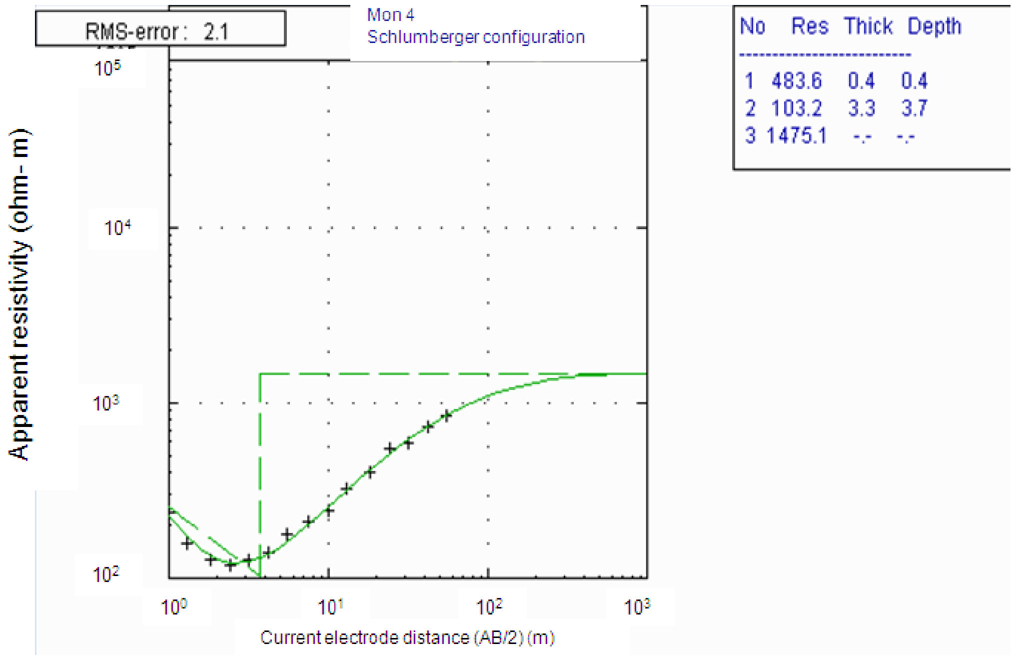


**Figure 2b.** Typical H VES curve type.

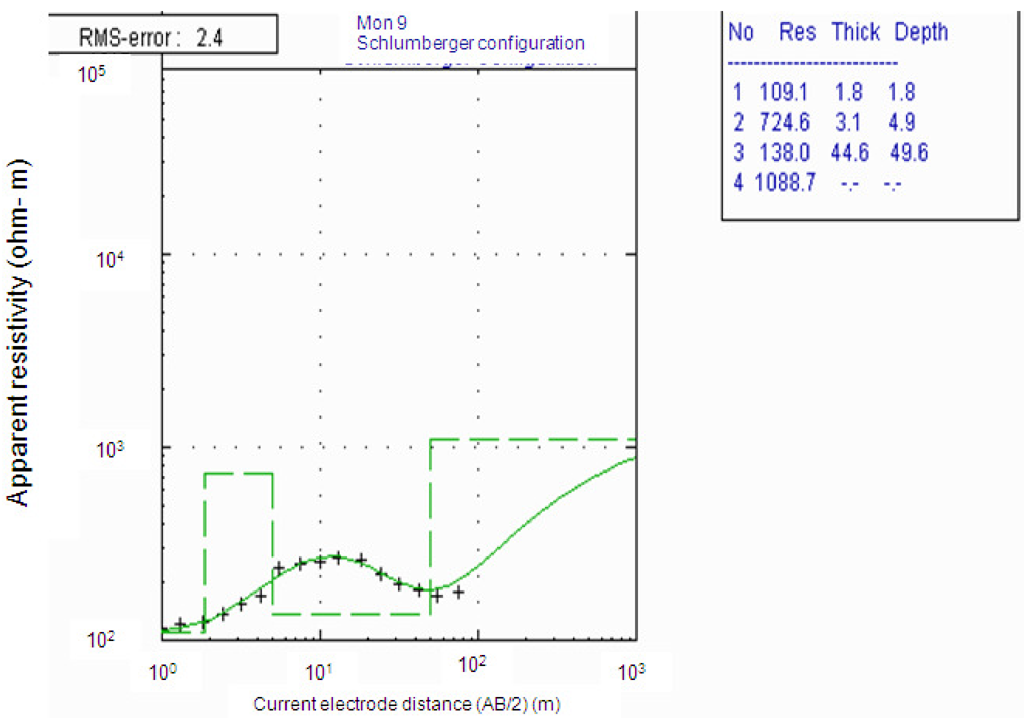


**Figure 2c.** Typical KH VES curve type.

hydrogeologic consideration in groundwater development in the basement terrain, because water gets into the saturated zone through the overburden. The thickness of the overburden ranges from 3.0 to 49 m in the studied area.

The weathered zone beneath VES 9 has the highest thickness of about 44.6 m and VES 1 having the lowest thickness with about 2.0 m. Thus the thickness of the weathered layer for the study area is high enough to form groundwater accumulation and therefore recommended

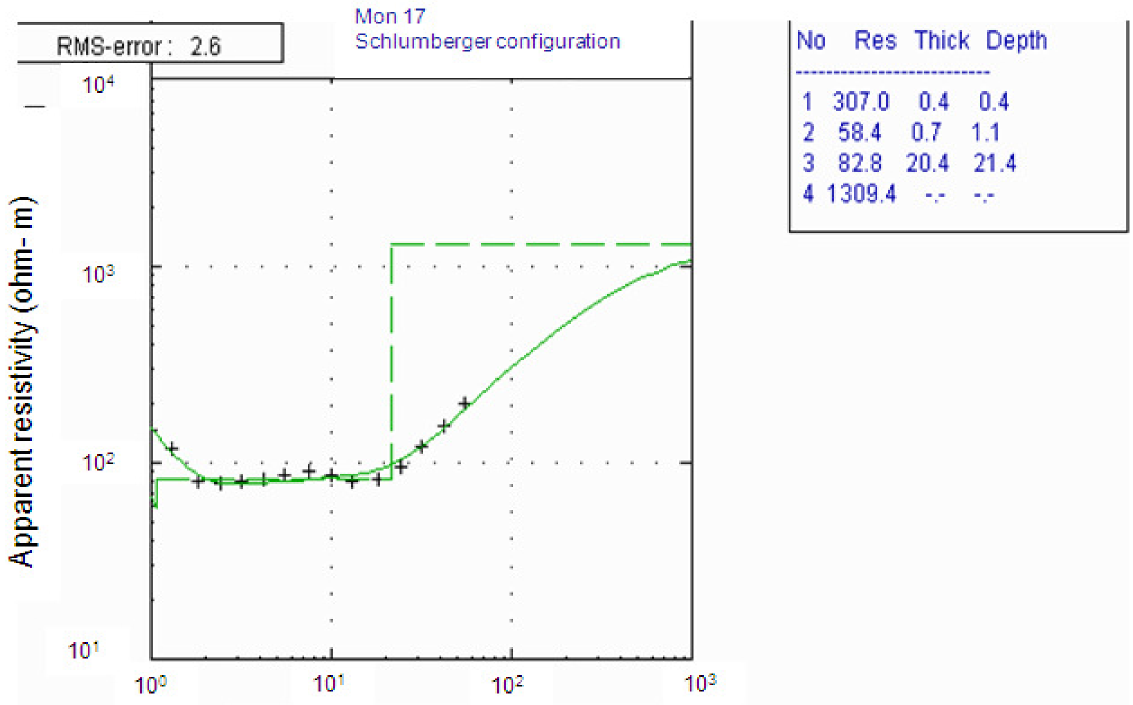


**Figure 2d.** Typical HA VES curve type.

for a borehole sitting.

VES stations 9, 6, 7, 12, 14, and17 are the locations that will be recommended for groundwater exploitation, because they have highest thickness of both weathered zone and fractured zone respectively which are good for groundwater storage.

VES 9 is highly recommended as priority location for sitting borehole, because it has thick sequence of weathered zone and fractured basement, which are good for groundwater accommodation. If the fractured are interconnected and thus permeable, the thicknesses of the weathered zone in this section give advantage on this over others. The location will be good for maximum groundwater development.

Also, VES 9 has an advantage over other VES(s) because the cost of drilling through VES 9 will be cheaper than drilling through VES 6,7,11,12,14, and 17 which of harder rock and difficult to drill.

In VES stations 2, 3, and 11 groundwater yield could be high but it will not be up to that of VES 9, 6, 7, 12, 14, and 17. However they can not be recommended for groundwater development because the dip of the locations and the thickness of the area could affect the yield.

Locations of VES 4, 5, 8, and 16, can not be recommended for groundwater development because they will produce minimum groundwater yield, due to the dip and the thickness of the weathered zone.

VES Locations 1, 10, 13, and 15 have the lowest thickness and the lowest probable groundwater yield and are therefore not recommended.

## Conclusion

The results of geoelectric investigation carried out over part of Moniya, Akinyele Local Government Area revealed maximum of four subsurface layers: thin top layer, the alluvium, the aquifer and the bedrock respectively.

### REFERENCE

Dan-Hassan MA, Olorunfemi MO (1999). Hydro-geophysical investigation of a basement terrain in the north central part of the Kaduna state, Nigeria. J. Min. Geol., 35(2): 189-206.

Hamill L, Bell F (1986) Groundwater Resources Development. Britain Library Cataloguing in Publication Data London, pp. 151-158

Kazeem AS (2007). Lithostratigraph of Nigeria. An overview. Workshop on Geothermal Reservation Engineering, Stanford University, Stanford, California, 32: 1-4.

Krumbein WC, Sloss LL (1963). Stratigraphy and Sedimentation. W.H. Freeman and Co., San Francisco, p. 660.

Ojo JS, Ayangbesan TA, Olorunfemi MO (1990). Geophysical survey of dam site. A case study. J. Min. Geol., 26(2): 201-206

Olayinka AI (1990). Case histories of multi-electrode resistivity profiling array for groundwater in basement complex areas of Kwara state, Nigeria. J. Min. Geol., 26(1): 27-34

Olayinka AI (1991). Methods of interpreting Wenner resistivity Pseudosection data. J. Min. Geol., 27(1): 67-75.

Olorunfemi MO, Okhue ET (1992). Hydrogeology and geology significance of geoelectric survey at Ile – Ife, Nigeria. J. Min. Geol., 28(2): 221-229.

Omosuyi GO, Ojo JS, Olorunfemi MO (2008). Geoelectric Sounding to Delineate Shallow Aquifer in the Coastal Plain Sands of Okitipupa Area, Southwestern Nigeria. Pacific J. Sci. Technol., 9(2): 562-577.
Osella A, Matias de la Vega, Eugenia L (2002).Characterization of a contaminant plume due to a hydrocarbon spill using geoelectric methods. JEEG, 7(2): 78-87.
Telford WM, Geldart LP, Sheriff RE, Keys DA (1982). Applied Geophysics, Cambridge University Press, Cambridge, U.K.
UNESCO (1978). World water balance and water resources of the earth.
Vogelsang D (1995). Environmental Geophysics: A practical guide. Springer – Verlag, Berlin, Germany.
Zohdy AAR (1989). A new method for the automatic interpretation of Schlumberger and Wenner sounding curves. Geophys., 54: 245-253.