Integration of GIS and Geoelectric Surveying for the Assessment of Groundwater Pollution, A Case Study of Part of Ikeja, Lagos State, West Africa, Nigeria.

Jimoh Rafiu Atanda[1], Omogunloye Olusola, Gabriel[2]

[1] Department of Water science and Engineering, UNESCO-IHE, Institute for Water Education, P.O. Box 3015 2601 DA Delft, The Netherlands.
[2] Department of Surveying and Geoinformatics Engineering, University of Lagos, Akoka, Nigeria
Author's email:jimoh2@unesco-ihe.org,geoexploreconsultants@gmail.com

Abstract

An integrated approach using GIS and geoelectric surveying has been adopted for the assessment of groundwater pollution in part of Ikeja Local Government area of Lagos State. The groundwater potential of the selected location has been demarcated into Good quality fresh water, Good quality water, Intermediate quality fresh water, and Poor quality fresh water and this was done by performing several queries with ArcGIS software 9.3. The resistivity of the Geoelectric surveying carried out in the study area varies from 15.6Ωm to 1440Ωm. Geoelectric surveying which involved vertical electrical sounding was carried out using the Abem Terrameter Sas 4000 Earth resistivity Meter and a total of ten(10) stations were chosen for the study. Curve matching techniques and Win Resist software (version 1.0) were used to process and iterate VES data; AutoCAD 2012 version was used to draw the geoelectric section in form of soil profile using the depth of each lithology and was then imported into the ArcGIS software environment to perform several queries. From the geology of the area and a nearby drillers log, fourteen (14) Geoelectric layers detected includes the Topsoil,Sand,Clayey sand, Coarse sand, Sandy clay,Clay,Clay/sand intercalation, gravelly sand,sandstone,silty clay, fine sand, clay with intercalations of thin sand layer, and coarse sand/sandstone. Groundwater pollution was noticed in VES 1, 4, 5 and 9. The pollution effect was more pronounced in VES 9 because of the leachate effect on the groundwater regime from the Olushosun Landfill characterized with sand having resistivity range from 27Ωm to 30Ωm. This indicates that the groundwater has been polluted at the surface part.

Key Words: Integrated Approach, Geoelectric layer, Groundwater Pollution, Geoeletric survey, Vertical electrical sounding, GIS.

1. INTRODUCTION

A geographic information system (GIS) integrates hardware, software, and data for capturing, managing, analysing, and displaying all forms of geographically referenced information. GIS allows us to view, understand, question, interpret, and visualize data in many ways that reveal relationships, patterns, and trends. GIS has been found to be an effective tool in the assessment and modelling of groundwater pollution. Surface resistivity methods have been employed successfully for detecting and mapping groundwater contamination under a variety of conditions. The method is based on the fact that formation resistivity depends on the conductivity of the pore fluid as well as the properties of the porous medium. Under favorable conditions, contrasts in resistivity may be attributed to mineralized ground water with a higher than normal specific conductance originating at a contamination source. Success has been reported in tracing water from landfills (Cartwright and McComas, 1968; Cartwright and Sherman, 1972; Stollar and Roux, 1975), sewage treatment effluent (Fink and Aulenbach, 1974), salt piles (Fried and Ungemach, 1971), Blending the GIS and Geophysical techniques has been proved to be an efficient tool in groundwater pollution studies.

The study area is situated in Ikeja Local government area of Lagos state and falls within the south-western Nigeria. Groundwater is a major source of water supply in Lagos state despite the provision of potable water through the state government micro water works to the people of Ikeja, the populace still depends on wells (shallow and deep) for their domestic water supply. The suitability of pose a major environmental and health concern e.g. the olososhun landfill area which is part of Ikeja has posed some threat to the groundwater regime of the area especially the shallow aquifer. Figure 1 shows the locations of the geoelectric survey points carried out for this research work.

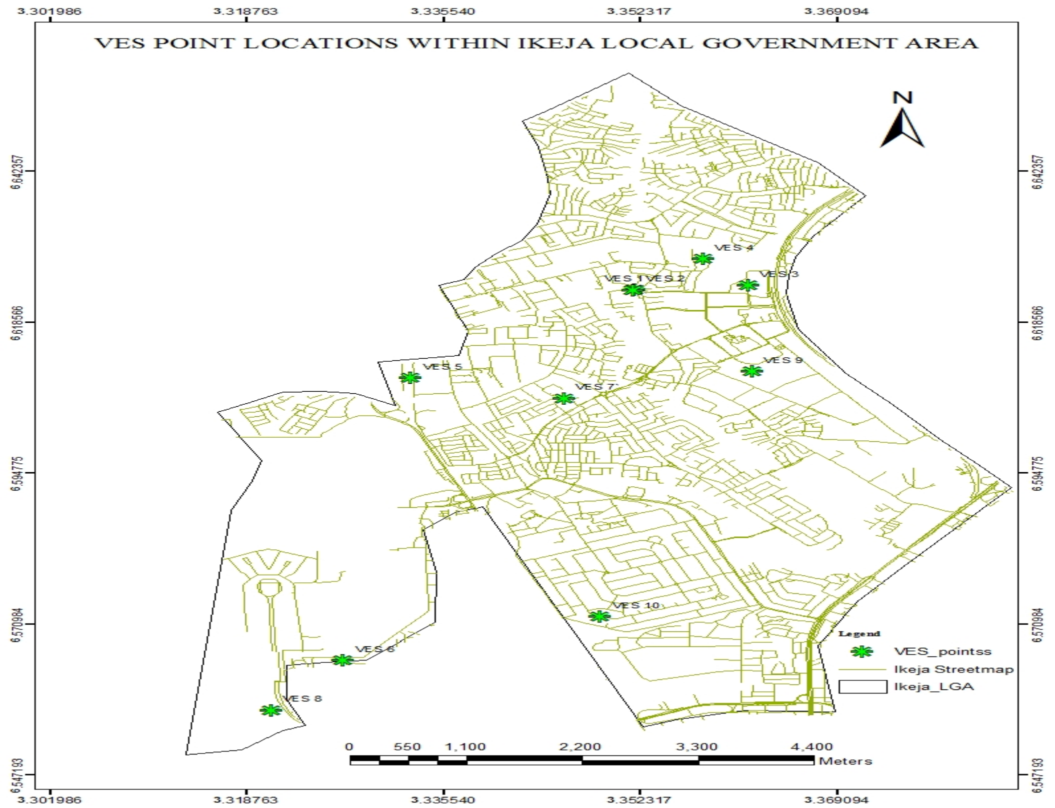

Figure 1: Locations of the VES points on the map of Ikeja local government area.

2. GEOLOGY AND HYDROGEOLOGY OF THE STUDY AREA

The study area is Ikeja, situated in the heart of Lagos metropolis on a coordinate of 6°.5833″, 3°.333″ respectively. Ikeja city is a large component of the Lagos metropolis**.** Ikeja falls within the sedimentary area located within the western part of Nigeria, a zone of coastal creek and lagoon (Elueze, et al, 2004). The area is also developed by barrier beaches associated with sand deposits (Ogbe F.G.A, 1992). The subsurface geology reveals a basic lithology of clay and sand deposits. Geologically the study area is within the coastal plain sand(Figure 2). The lithologies of the study area are grouped into Recent Sediments, Coastal Plain Sands, Ilaro Formation, Ewekoro formation and Abeokuta formation, which directly overlies the basement.

Hydrogeologically, four major aquifers are recognized within the basin. The Surface aquifer is in the recent sediments, and two major aquifers are within the Coastal plain Sands. The most prolific aquifer is within the Abeokuta formation.

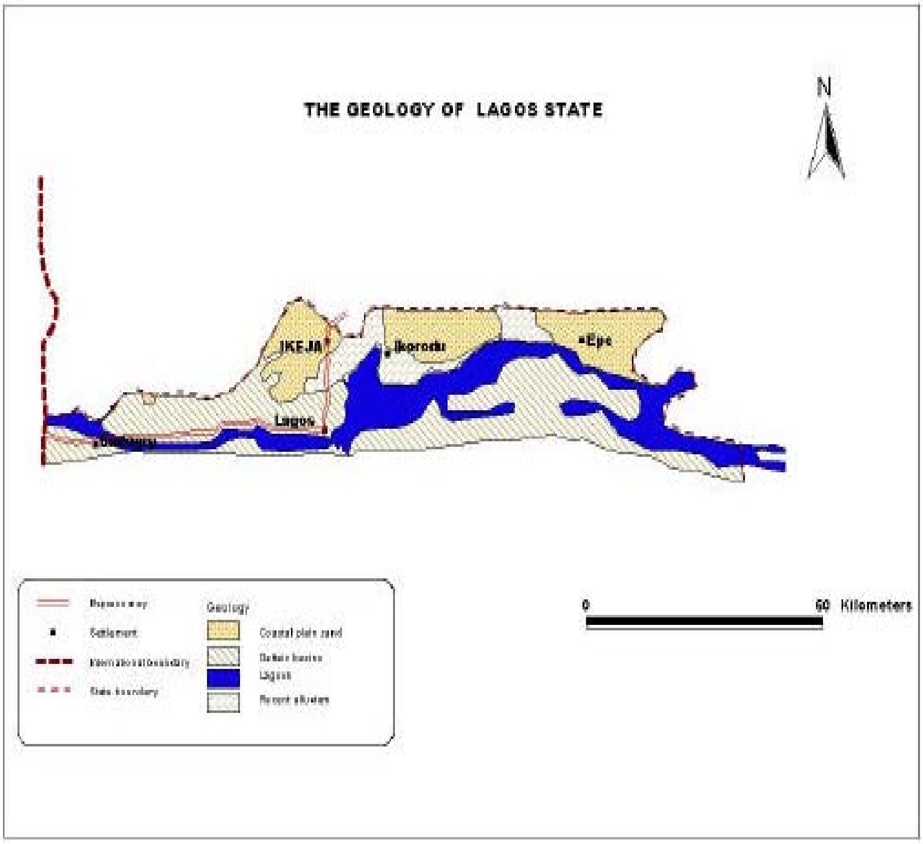

Figure 2: The geological map of Lagos state showing Ikeja

3. DATA COLLECTION AND PROCESSING

Abem Terrameter Sas 4000 earth resistivity meter was used for data collection and Garmin **72 GPS** measurement in terms of coordinates were taken to identify the spatial distribution of the vertical Electrical Sounding **(VES)** stations spread across part of the Local Government. The Schlumberger electrode configuration with maximum electrode configuration of 200m was utilized during the course of the study. The acquired data were processed and interpreted with **WinResist** iterative software. The iterated Schlumberger depth sounding curves with layered resistivity models of the data acquired at the VES stations are shown below (Figures 3-12). Several Spatial queries analysis were performed with the use of **ArcGIS** software based on the field data in terms of the resistivity, depth and thickness of each layer in reference to the Geology of the area. The queries performed are shown in figures 13 to 17.

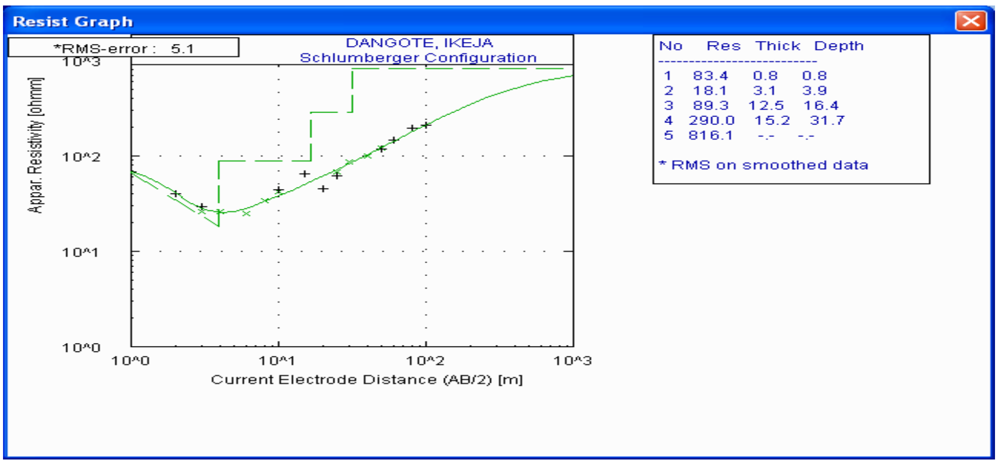

Figure 3: The Schlumberger depth sounding curve beneath the surveyed area at Dangote, Ikeja

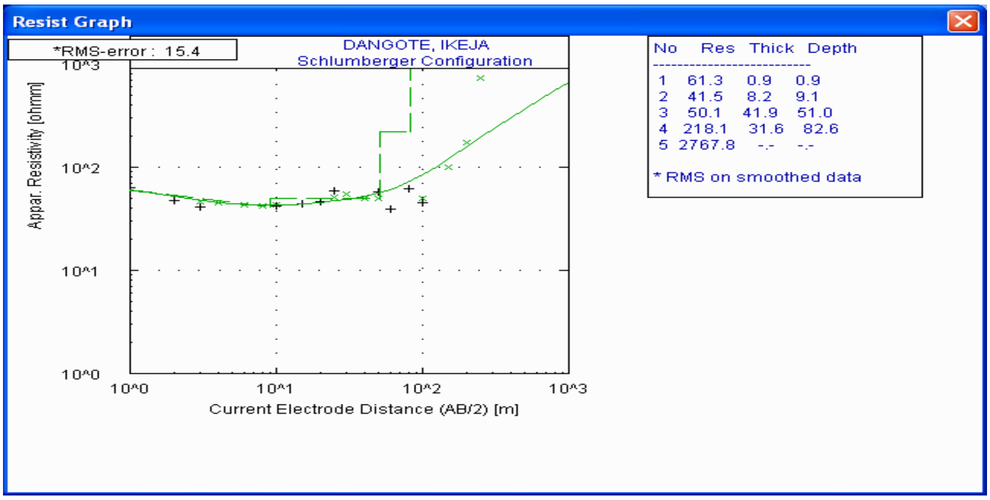

Figure 4.:The Schlumberger depth sounding curve beneath the surveyed area at Dangote ,Ikeja

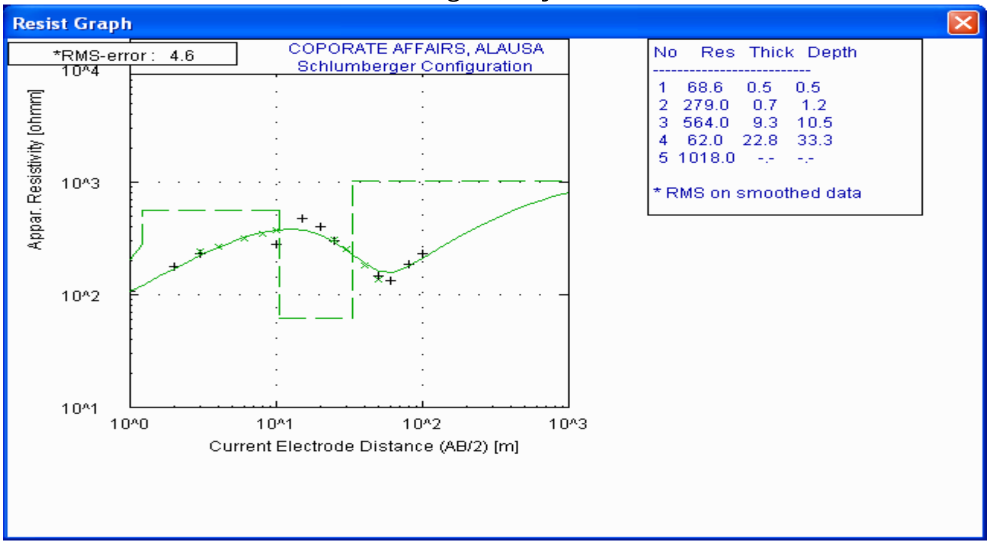

Figure 5 :The Schlumberger depth sounding curve beneath the surveyed area at coporate affairs ,Ikeja

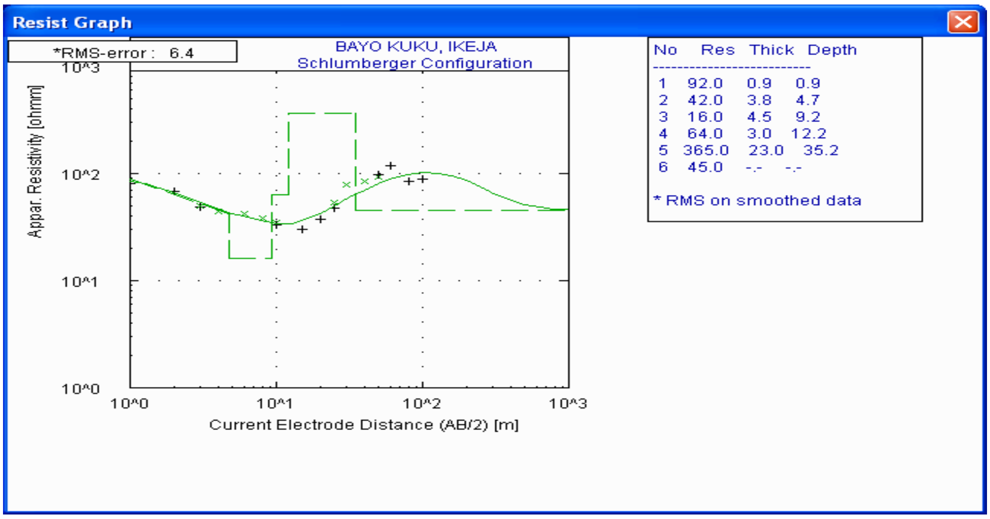

Figure 6:The Schlumberger depth sounding curve beneath the surveyed area at Bayo Kuku ,Ikeja

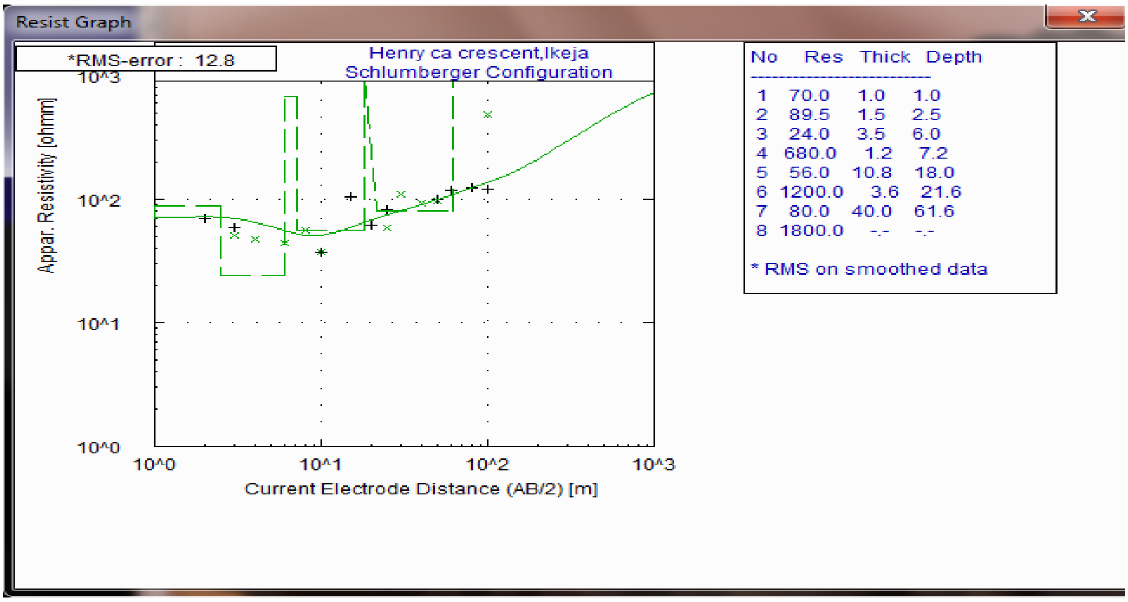

Figure 7: The Schlumberger depth sounding curve beneath the surveyed area at Henry Carr crescent, Ikeja

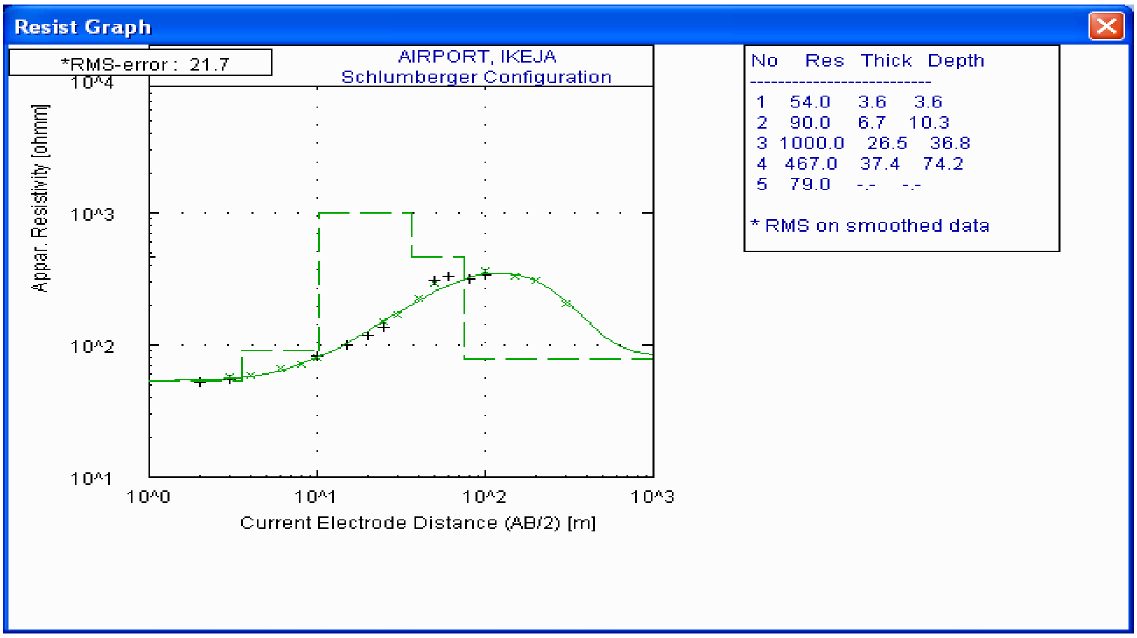

Figure 8:The Schlumberger depth sounding curve beneath the surveyed area at Lagos airport ,Ikeja

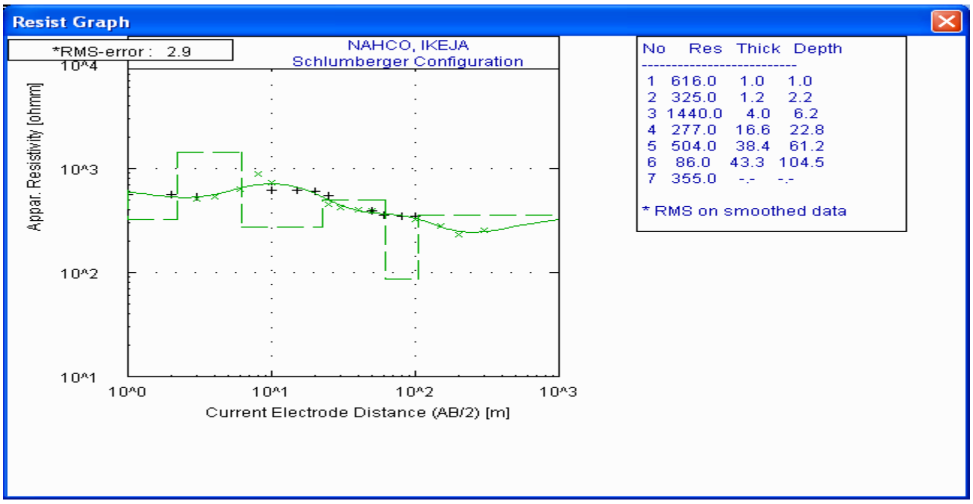

Figure 9:The Schlumberger depth sounding curve beneath the surveyed area at NAHCO ,Ikeja

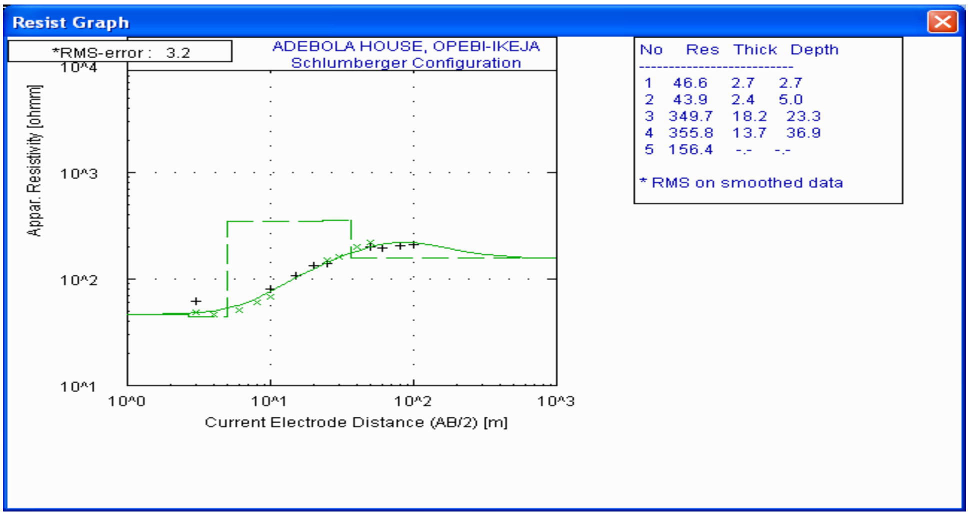

Figure 10 :The Schlumberger depth sounding curve beneath the surveyed area at Adebola House,Opebi ,Ikeja

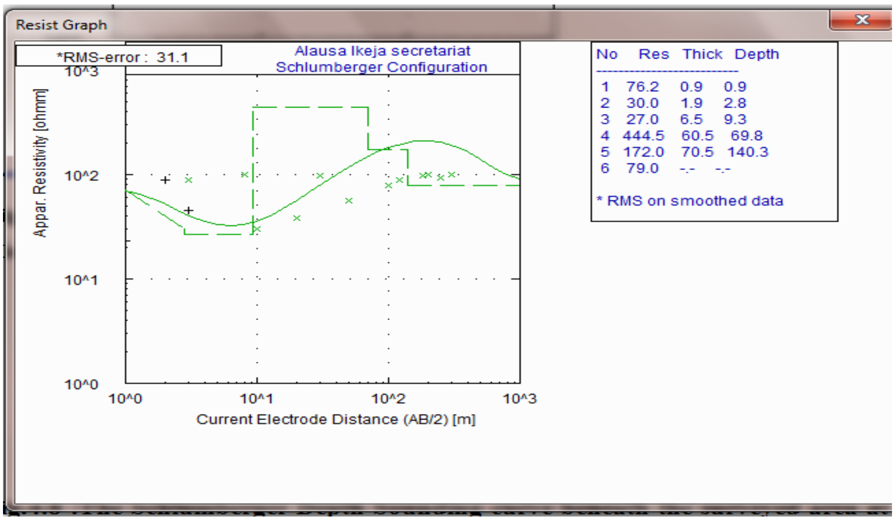

Figure 11: The Schlumberger depth sounding curve beneath the surveyed area at Alausa Secretariat,Ikeja

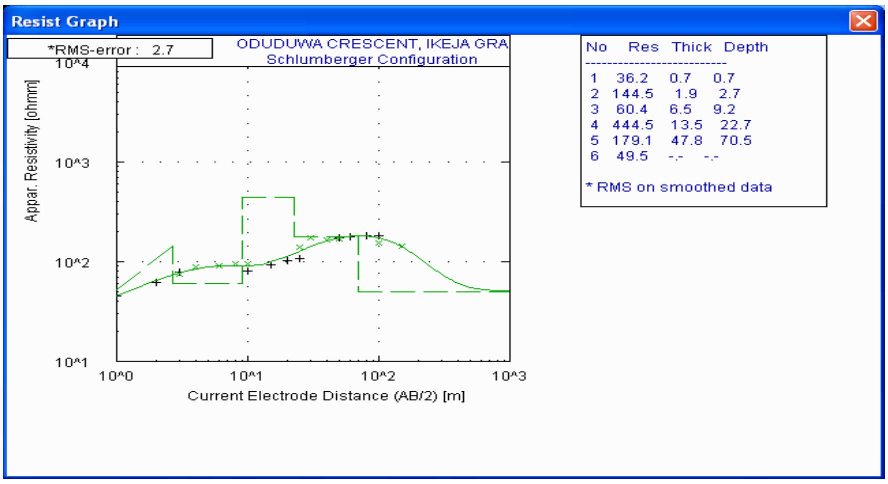

Figure 12: The Schlumberger depth sounding curve beneath the surveyed area at Oduduwa Crescent ,Ikeja

4. SPATIAL QUERRY ANALYSIS

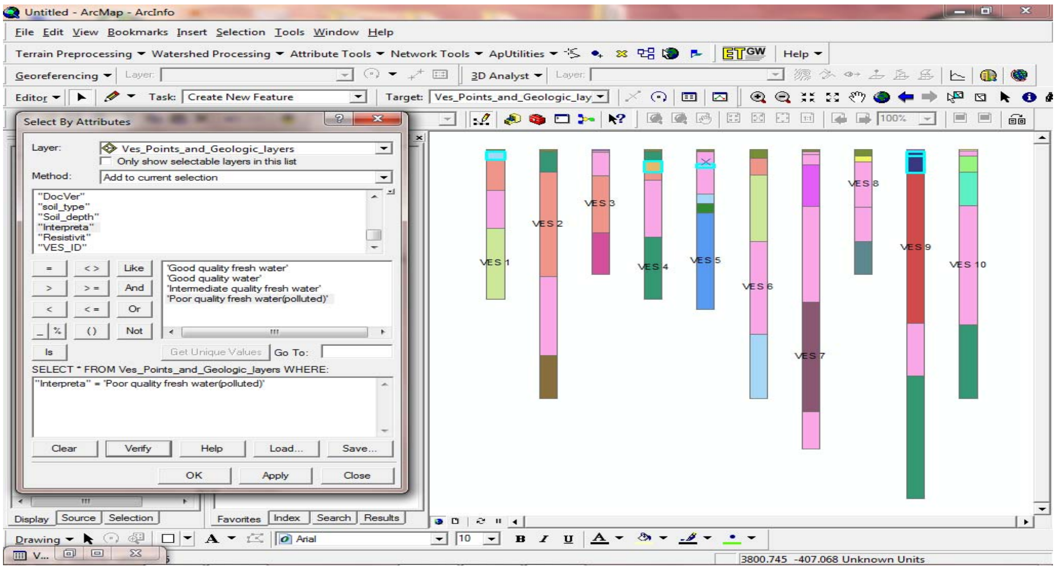

Figure 13: 2D Query model showing the layers of geoelectric sections containing poor quality fresh water (polluted) presented as light blue around the geoelectric layers.

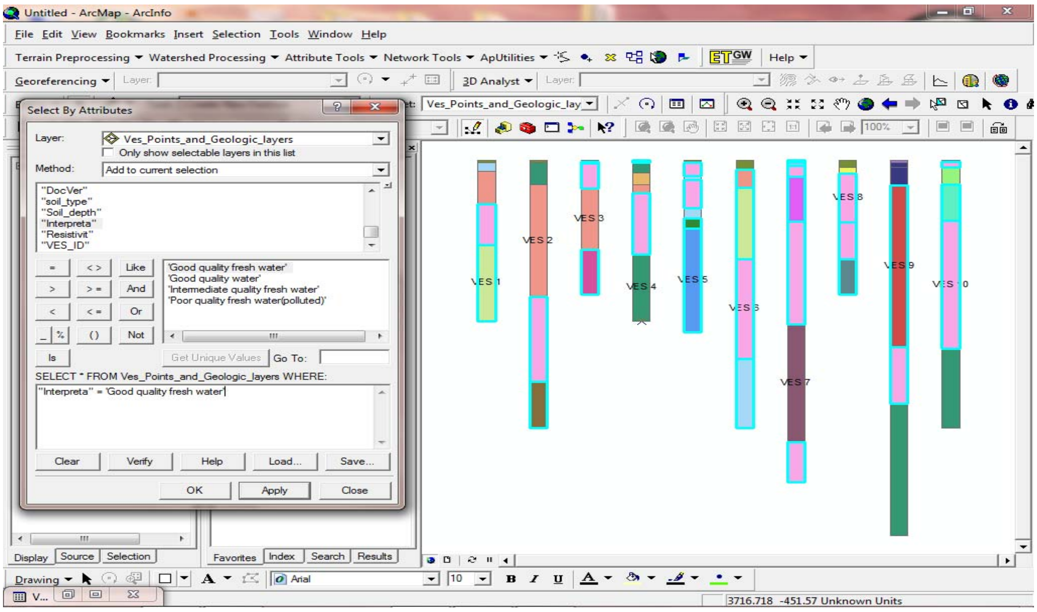

Figure 14: 2D Query showing layers of geoelectric section containing good quality fresh water presented by the light blue colour as seen around the geoelectric layers.

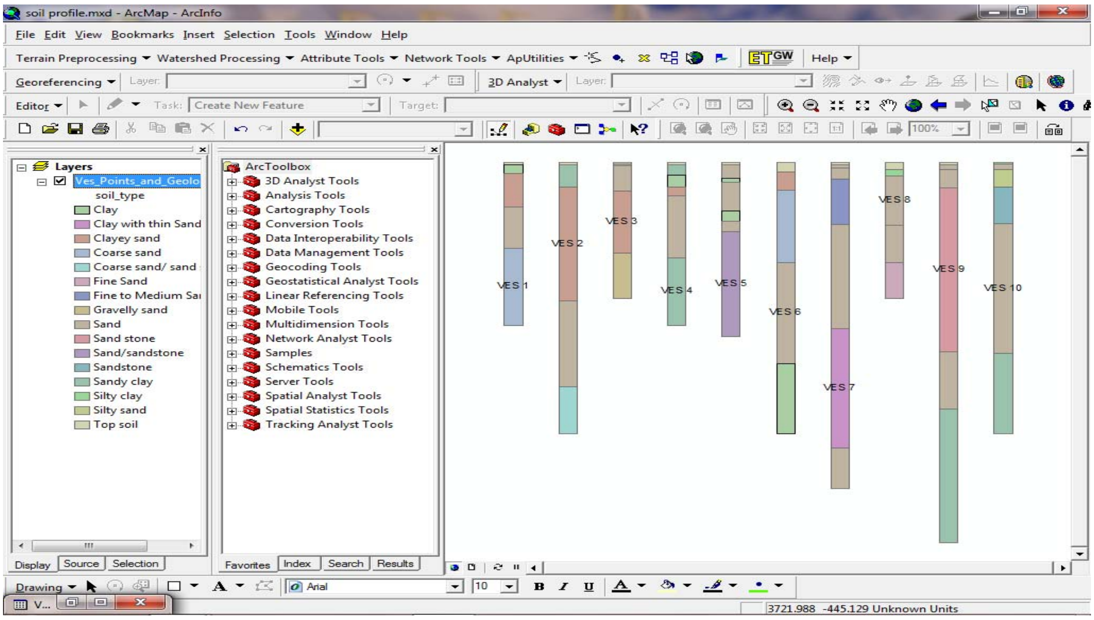

Figure 15: 2D Query model showing the distribution of VES stations and geologic layers.

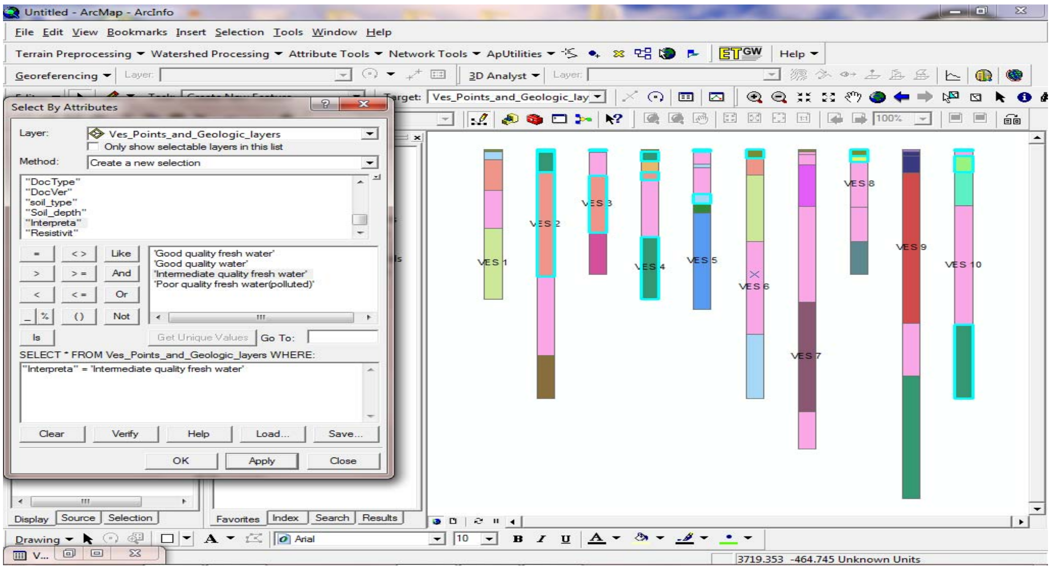

Figure 16: 2D Query model showing layers of geoelectric section containing intermediate quality fresh water presented as light blue around the geologic layers

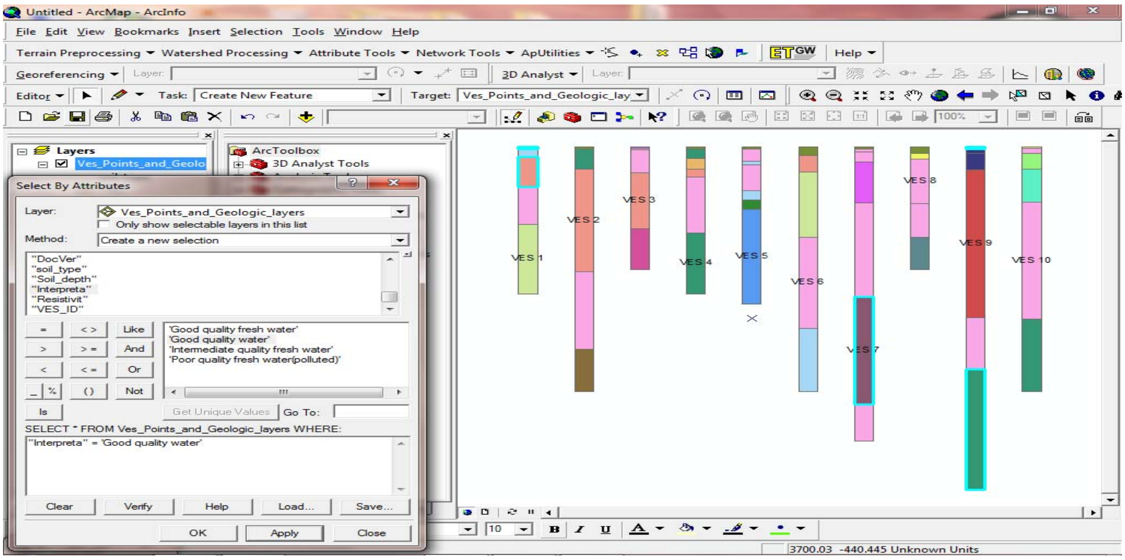

Figure 17: 2D Query showing layers of geoelectric section containing good quality fresh water presented by the light blue colour around the geologic layers.

5. DISCUSSION OF RESULTS

In terms of the geology, coupled with the borehole logs of a nearby well of the area, a total of fourteen **(14)** geoelectric layers were delineated from the study, namely: the Topsoil, Sand, Clayey Sand, Coarse Sand, Sandy clay, Clay, Gravelly sand, Sandstone, Clay/sand intercalations, clay with intercalations of thin sand, Silty Clay, Silty Sand, Fine sand and Coarse Sand/Sandstone respectively. From the apparent resistivity model of the curves and information from a borehole log and published resistivity data (Telford et al; 1990), their equivalent geologic units has been delineated. The aquifer units are Coarse Sand, Sandstone, Fine Sand and Gravelly Sand. The second layer in VES 1 represents Clay with resistivity value of 18 ohm-m and thickness of 3.2m considered as poor quality fresh water which is highly polluted and the fourth layer is characterized with sand having resistivity value of 290 ohm-m and layer thickness of 15.3 envisaged as Good quality fresh water zone. The fifth geoelectric layer is coarse sand having resistivity values of 806 ohm-m considered as Good quality fresh water.

The third layer in VES 4 is clay consisting of a resistivity value of 15.6 ohm-m and thickness of 4.5m considered as poor quality fresh water. This layer has been highly polluted. The fifth layer in this VES is Sand with a resistivity of 365ohm-m and a thickness of 23.0m considered as a good aquifer with

Good quality fresh water. The third layer in VES 5 is clay having a low resistivity of 24 ohm-m and a thickness of 3.5 m. This layer is a polluted region considered having poor quality fresh water. The second layer and the third layer of VES 9 delineate sand with resistivity ranging from 27.0 ohm-m to 30.0 ohm-m. These layers are highly polluted due to the leachate effect from the Olososun landfill around Oregun, Ikeja.

6. CONCLUSION AND RECOMMENDATIONS

The Geoelectric survey carried out in the study area has proved to be an effective tool in the assessment of the groundwater pollution. Application of GIS as a database tool has also been very useful when integrated with geophysical methods. Most of the surface aquifers that are very nearer to the Oloshosun landfill has been polluted by the adjoining leachate of the Landfill thereby posing a threat to the groundwater of the area. This effect was noticed in **VES 9** and this occurs between the depths of **2.8m** to about **9.3m**. Between these depths, the possibility of the shallow aquifer to be polluted is very high. The surface aquifer has also been polluted in **VES 5** to the depth of about **6.0m**.

It is geologically recommended that in **VES 2, 3,6,7,8** and **10**, a deep borehole could be drilled to provide good sources of water, especially in **VES 2,** and also a deeper borehole can be drilled in **VES 9** to a depth of 200m. A further mapping of the fresh water and salt water interface in the coastal aquifers should be carried out concurrently to further delineate possible sub-surface pollution plume to better understand the groundwater conditions of Ikeja and its environs. Other methods that could provide solution to pollution problems of the study area include geochemical analysis of boreholes, wells, and geophysical well logging of the existing boreholes.

7. ACKNOWLEDGEMENT

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8. REFERENCES

1. Cartwright, and M.R.McComas 1968, "*Geophysical surveys in the vicinity of sanitary landfills in northern Illinois*", Groundwater .V.6.no 5,pp 23-30
2. Cartwright K and F.B Sherman, Jr. 1972, "*Electrical earth resistivity surveying in Landfill investigations*", Reprinted from proceedings of the 10th annual engineering and soils engineering symposium, Moscow, Idaho, pp 77-92.
3. Fink,W.B and D.B.Aulenbach 1974, "*Protracted recharge of treated sewage into sand, part 11,tracing the flow of contaminated groundwater with a resistivity survey*". Groundwater .V.12.No 4,pp 219-223.
4. Fried,J,J and P.O Ungemach.1971, "*Note: a dispersion model for a quantitative study of the groundwater pollution by salt-water research*", V.5.PP.491-495
5. Jones, H.A and Hockey, R.D., 1964, "*The geology of part of south western Nigeria*", Geol. Survey. Nigeria,Bull. 31:1-101.
6. Nuhu George Obaje (2009), "*Geology and Mineral Resources of Nigeria*".
7. Kampsax-Kruger and Sshwed Associates, "*Underground water resources of the Metropolitan Lagos*", Final Report to Lagos State Ministry of Works, 1977; 170p.