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Groundwater Mapping Using Geo electric Layer Analysis in Kimumu Area, Uasin Gishu County, Kenya

Amai Aquinata Etyang[1], Daniel Mogaka Nyaberi[2], Kudenyo Chibole[3]

Abstract

The study of using Vertical Electrical Sounding (VES) interpreted results to delineate geo electric layers and subsequent mapping the occurrence of groundwater has been made possible in the study area. This research is based on VES modeled geo electric layers compared from point to point to establish the possible water tables and thus general groundwater occurrence. The AGI Earth Imager ID inversion automated computer program was used to achieve inversion of each VES curve was obtained and resistivities and thicknesses of a geo electric model were estimated. The analyzed VES data interpretation was achieved by curve matching technique which resulted in mapping the subsurface of the area which portray H-type; $\rho_1 > \rho_2 < \rho_3$, K-type; $\rho_1 < \rho_2 > \rho_3$, A-type; $\rho_1 < \rho_2 < \rho_3$, Q-type; $\rho_1 > \rho_2 > \rho_3$, representing 3-Layer subsurface and subsequently a combination of KH types of curves representing 4-Layer in the subsurface. The shallow aquifer as from the inverted VRES data, has its water table starting from 4.406 to 8.607 metres deep and this incidentally serves the shallow wells in the area. This layer is represented by resistivities of between 12.9 Ohm-m to 99.5 Ohm-m. The second aquifer starts at a depth of 33.163 metres and this, points to the aquifer tapped by boreholes drilled in the study area.

Keywords: Groundwater, Curve matching, geoelectric models, inversion, resistivities

Introduction

Groundwater is an important, valuable and renewable natural resource which constitutes about 95% of the freshwater supply available for mankind, making it essential to human life and economic development (Foster *et al*., 2013). Access to clean water is a human right and a basic requirement for human and economic development. The knowledge of the nature and identification of subsurface condition is important in groundwater study. For sustainable use of groundwater resources, there is a need for effective protection and management of buried aquifers covered by thick sediments

The movement and storage of groundwater are influenced by lithology, thickness, and structure of subsurface geological materials (Oladimeji and Oluwaseun 2013; Datta 2020) as it is found within their pores or voids (Todd 2004; Akinlalu et al., 2017).

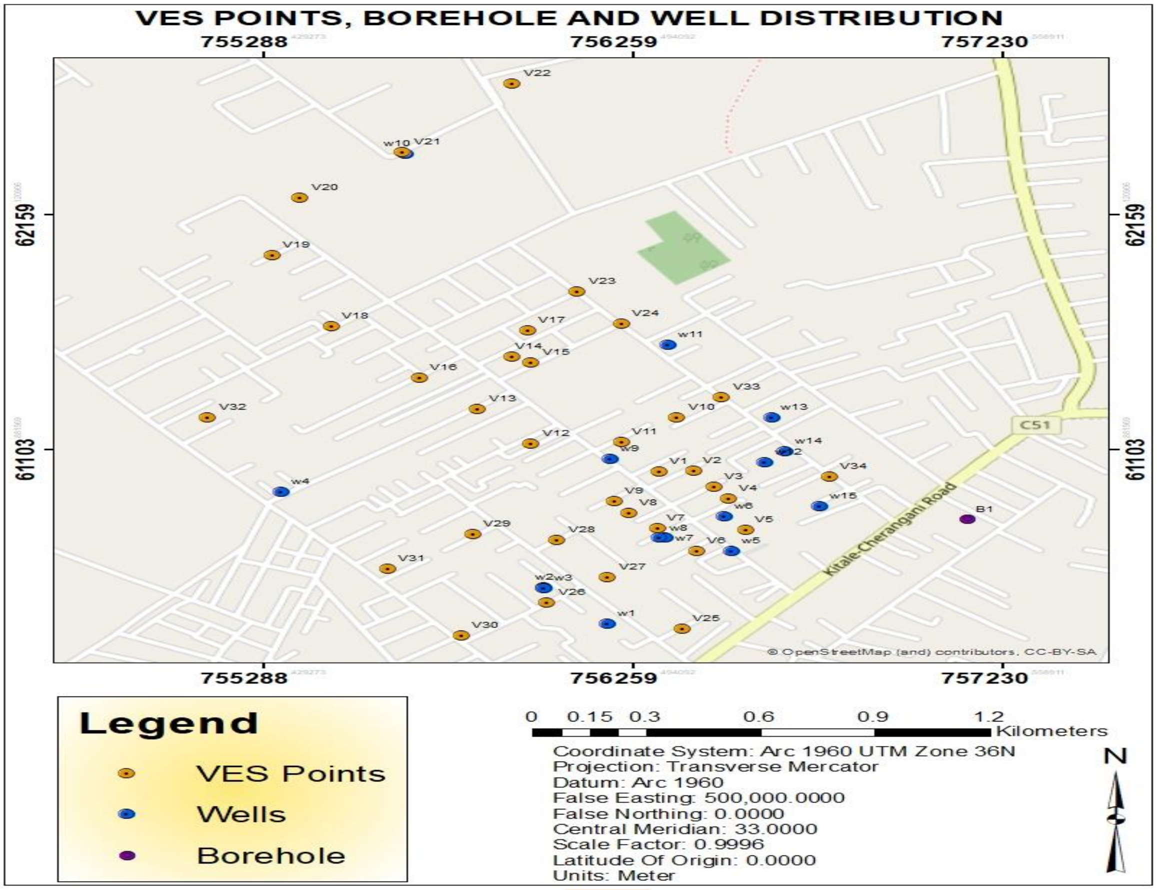
The electrical resistivity method measures both lateral and vertical variations in ground resistivity values on the earth's surface (Telford et al., 1990). The true resistivity of the subsurface layer is determined from the apparent resistivity values. Some of the factors that affect resistivity include rock types, rock texture, geological processes, water saturation, permeability, temperature, porosity, and chemistry or salinity of the saturating fluid (Oladimeji and Oluwaseun 2013). The vertical Electrical Sounding (VES) technique is applied in groundwater exploration, environmental and engineering geophysics, and to some extent in mineral exploration (Oladapo et al., 2004).

The aim of this work was achieved through the following objective: to determine the depth and thickness of the geo electric layers.

Materials and Methods

Study area

Kimumu is located in the outskirts of Eldoret town, approximately 10km north of town. It is situated in the Rift Valley and its geographical coordinates are $0^0$32`29.56`` N, $35^0$18`10.39``E, $0^0$33`32.49``N, $35^0$ 17`13.38``E, $0^0$33`03.44``N, $35^0$18`34.61``E and $0^0$33`59.29``N, $35^0$17`56.85``E. Elevation of the area varies from 2100m to 2200m.



The geology of the Rift is formed of Lava flow rocks whose origin is related to fissures and faulting (Nyaberi, M.D. 2010) associated with the formation and subsequent expansion of rift valley. The local geology is represented by lava sheets whose weathering results unto superficial sediments and soils. The geology of the area comprises a succession of Miocene-Pleistocene volcanic, mainly phonolites and trachytes. Olago, D.O. 2018 further breaks down the lithologies beneath the area based on assessment of borehole geo-logs to top hard black clay soils and sediments (≈ 10 m thick) overlying lava flows of trachytes and phonolites.

Vertical electrical sounding method

For electrical resistivity survey, Ohm's law is the basis for this technique which states that the current flowing through a metallic conductor is directly proportional to the potential difference between its terminal ends provided that temperature and the other physical conditions are kept constant.

Mathematically,

$$V = IR$$

Four-electrode array is used at the surface, one pair for introducing current into the earth and the potential difference established in the earth by the current is measured in the vicinity of current flow with the second pair. The electrode spread in use include: Wenner spread, Schlumberger spread, Three-point spread or Gradient array, Dipole–dipole spread and Lee- partition spread. The electrode most commonly used especially in groundwater exploration is the Schlumberger configuration, adopted by Conrad Schlumberger in his pioneer work. In this configuration, the four electrodes are positioned symmetrically along a straight line, the current electrodes on the outside and the potential electrodes on the insides. To change the depth range of the measurements, the current electrodes are displaced outward while the potential electrodes are left at the same position. However, when the ratio of the distance between the current electrodes to that between potential electrodes becomes too large, the potential electrodes must also be displaced outward; otherwise the potential difference becomes too small to be measured with sufficient accuracy. (Koefoed, 1979)

This method provides information on depths ranging from a few metres to hundreds beneath the surface, it is easy to use and software for interpretation are easily available. This is why this particular method was chosen.

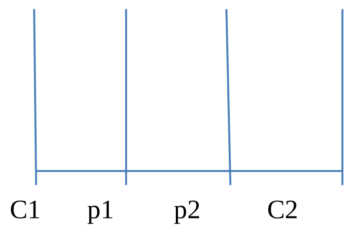


Figure 1 Current-potential electrode configuration

The data collection by VES method was realized by deploying the Schlumberger array with the use of the Abem SAS 1000 Terrameter resistivity meter. In the Schlumberger array four electrodes; A and B (current electrodes), and M and N (potential electrodes) are used in probing the subsurface and 34 data sets were collected with VES.

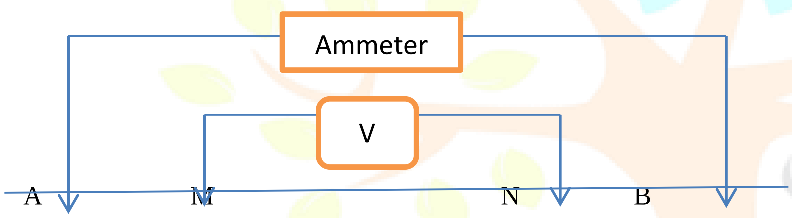


Figure 2 General configuration of the four surface electrodes in linear resistivity surveys with current delivered through the electrodes A and B, and voltage readings are made through M and N. (Rhett H. 2001).

The software (Earth Imager 1D) was used in VES data analysis considers application of data in the form V/I, while the field data is collected in the format of resistivity, thus conversion of data sets is necessary.

Data processing

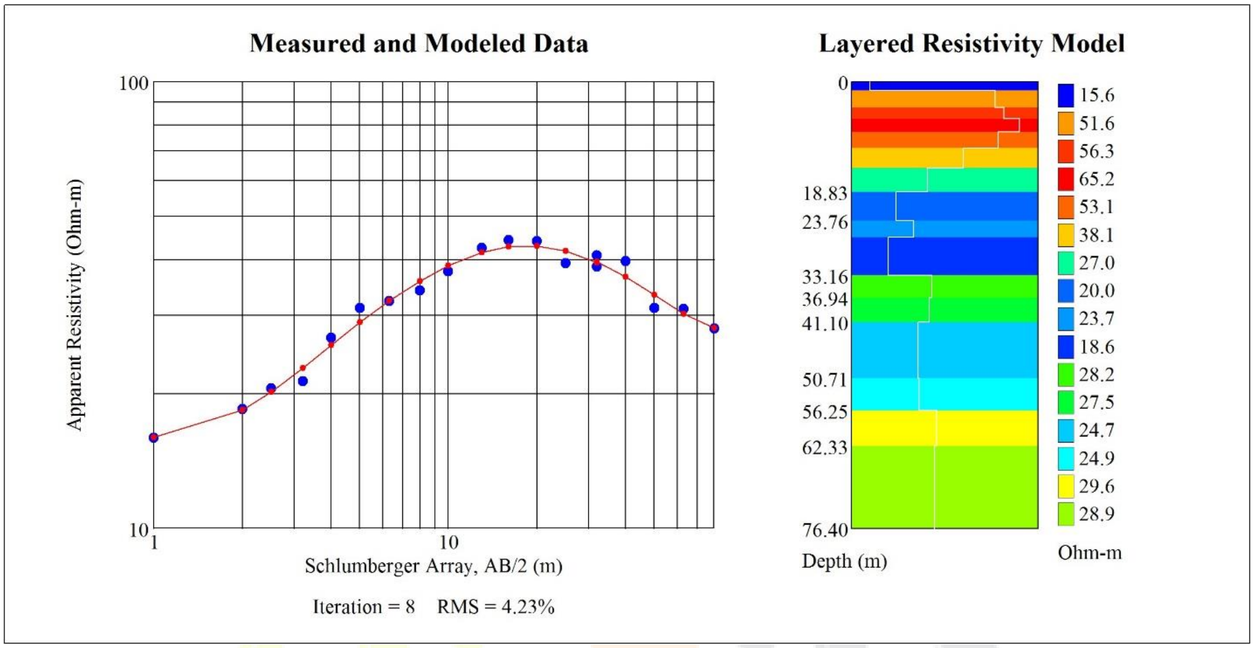
Thirty four (34) VES measurements were conducted using the Schlumberger array of electrical resistivity method, with a maximum spread length (AB) of 180 m. The data were acquired using ABEM SAS 1000 Terrameter. Typically, four electrodes were utilized for resistivity measurements; two current electrodes for passing direct current, whilst a different pair of electrodes measures the potential difference between the current electrodes. The apparent resistivity value is determined as the product of the resistance resulting from the potential measurement with an appropriate geometrical factor (Telford et al. 1990).

Using Schlumberger configuration with a spreading interval of 1.6m, 2.0m, 2.5m, 3.2m,4m, 5m, 6.3m, 8m, 10m, 13m, 16m, 20m, 25m, 32m, 40m, 50m, 63m, 80m, electrical resistivity measurements were carried out in the field.

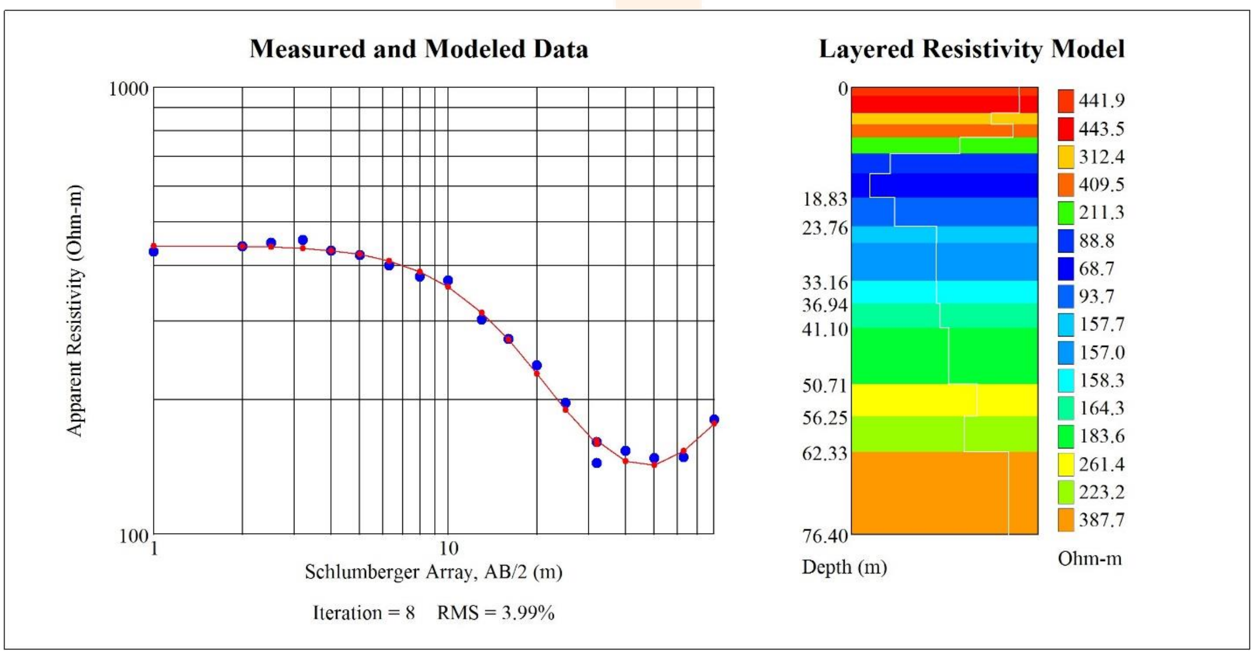
VES data were processed and interpreted using The Advanced Geosciences Inc. (AGI) Earth Imager ID inversion automated computer program to achieve inversion of each Vertical Electrical Sounding curve. The analyzed Vertical Electrical Sounding data interpretation was achieved by curve matching technique.

Results and discussion

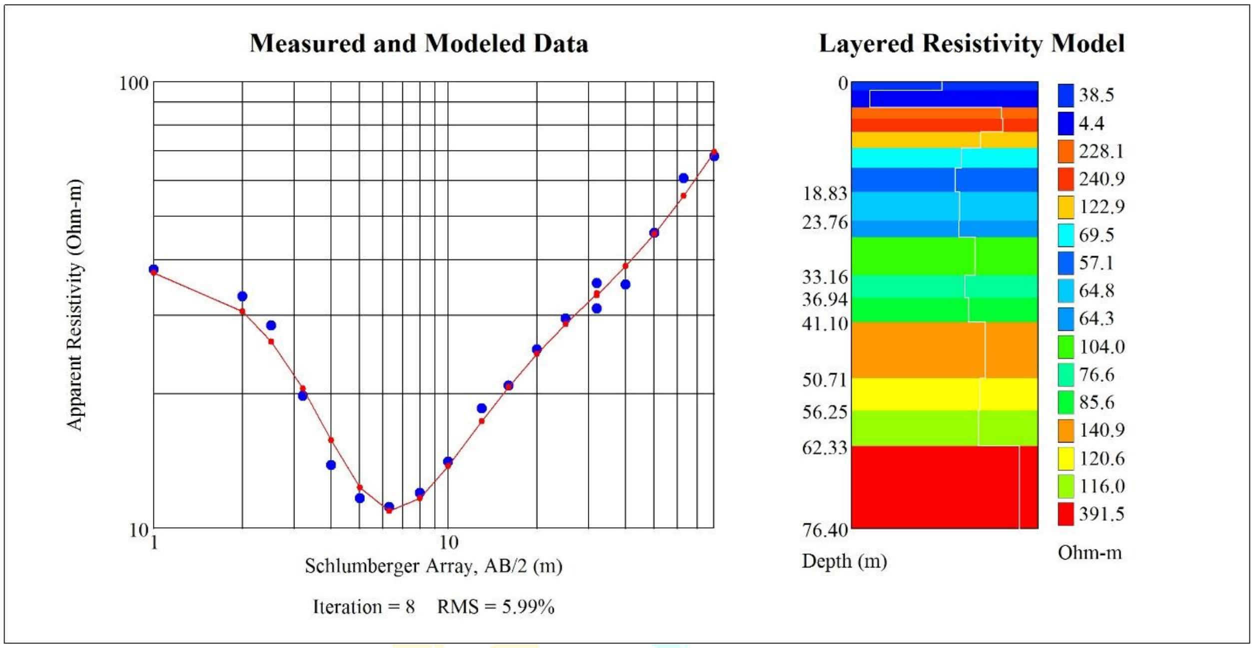
The data were processed using excel to convert them into the required V/I statistics. The data were analyzed by using the AGI Earth Imager ID inversion software to obtain the true resistivity values through the inversion modeling. The inversion procedure resulted into both modeled curves and corresponding modeled resistivity values which were then analyzed further through plotting using surfer software (C.G, Software, 2002). The use of surfer helped by combining several points in a straight line considering the depth (X-values), the horizontal (Y-values) and the resistivity values with depth (Z-values), whose consequence was a vertical and lateral correlation between the points. The analyzed VES data interpretation using the curve matching technique that is, the comparison between the standard curves and the inversely generated VES curves was carried out. The curves are based on a three-layered earth classified into H, K, A and Q type curves, based on shape, where their correlation with apparent resistivity they are given as: H-type; ρ1 > ρ2 < ρ3, K-type; ρ1 < ρ2 > ρ3, A-type; ρ1 < ρ2 < ρ3, Q-type; ρ1 > ρ2 > ρ3, and subsequently a combination of the above is used to represent several layers in the subsurface.



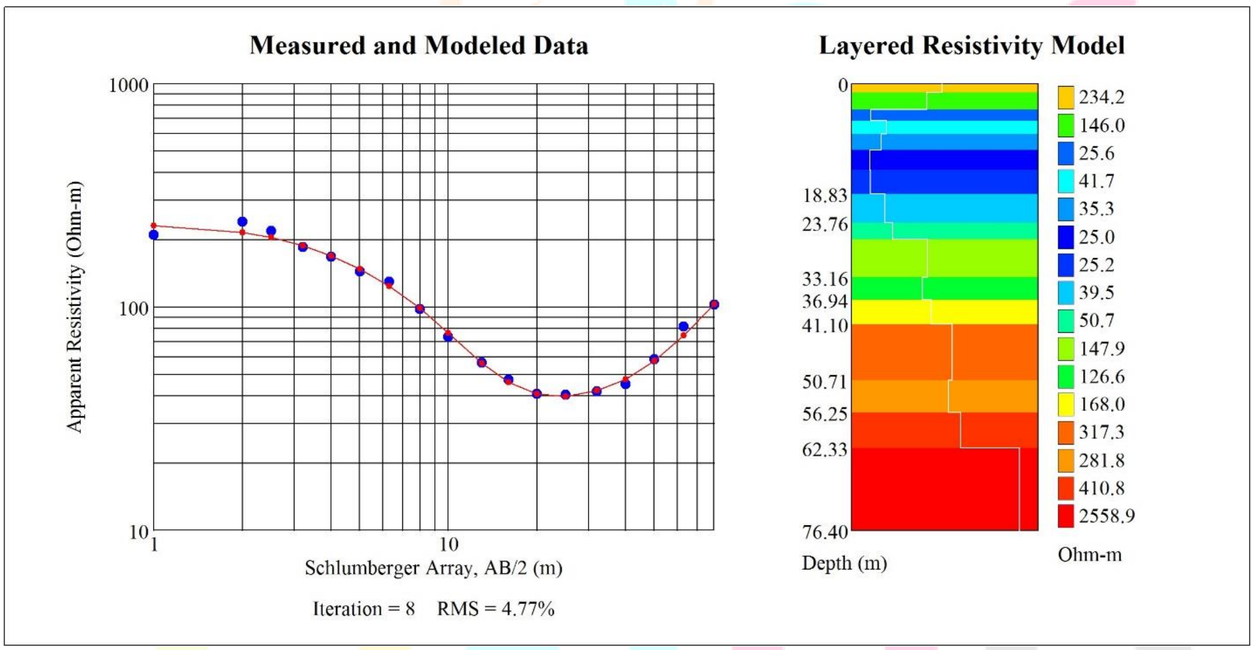
K Curve for VES 4



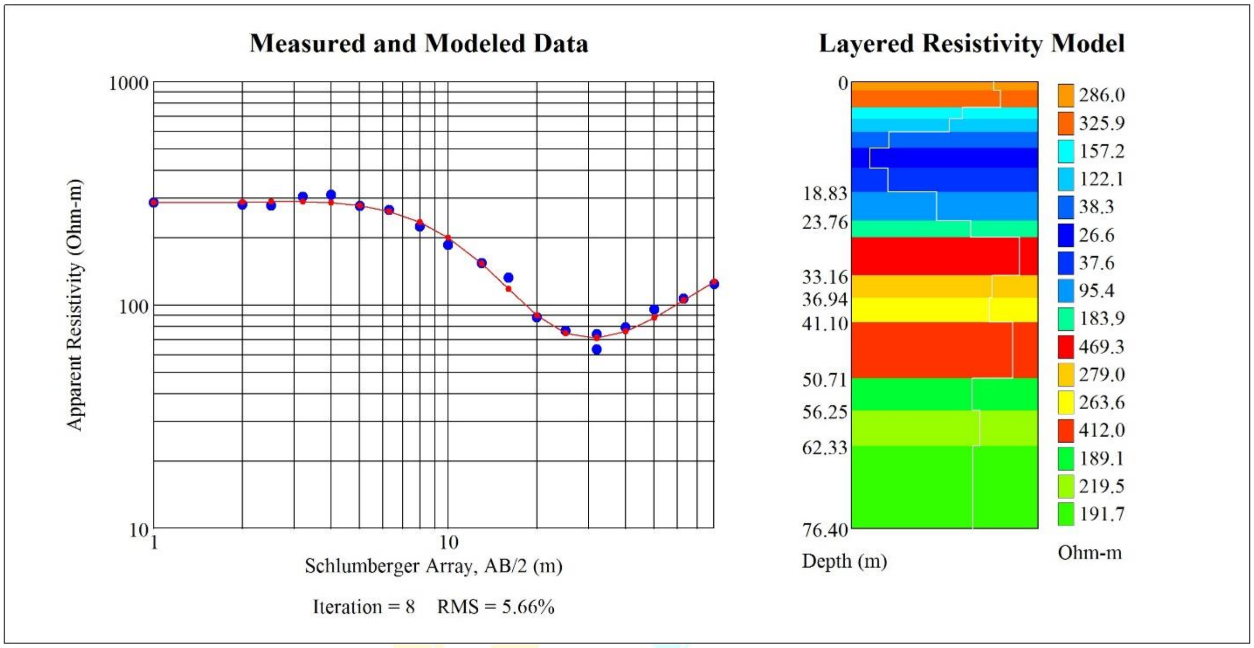
QH Curve for VES 5



HA Curve for VES 6



H Curve for VES 8



KH Curve for VES 20

Table 1

Correlation between VES 34 geo electric data and log of BH about 100 metres				
S/NO	**Geo electric Depth**	**Log Depth**	**Resistivity**	**Geology**
1,	0-1.537	0-3	246.079	Hard black clay
2,	1.537-4.406		106.667	
3,	4.406-6.307	3-9	8.598	Clay with boulders
4,	6.307-8.607		20.672	
5,	8.607-11.39		103.734	
6,	11.39-14.757	9-49	413.138	Fresh hard phonolite
7,	14.757-18.831		781.269	
8,	18.831-23.761		820.599	
9,	-23.761-26.602		202.687	
10,	26.602-33.163		241.615	
11,	33.163-36.944		143.999	
12,	36.944-41.103		123.879	
13,	41.103-50.71		125.75	
14,	50.71-56.245		97.833	Fractured Phonolite Medium size
15,	56.245-62.334		108.841	
16,	62.334-76.4		160.198	
		85-120		highly weathered trachytes
		120-128		clay slightly weathered
		128-149		fresh hard phonolite

The borehole has its lithologic log given in Table 1 above and it is located along profile 34 and the correlated VES curve is type H. The lithologies are dominated by either compacted rocks or soils, insinuating a scenario of compression experienced in this part of the subsurface. The expose by the borehole shows a good correlation between the modeled resistivity values and the specific lithologies within the interrelated depths.

Conclusion

There is exuded evidence from this study that the application of VES is able to help map the lateral and the vertical changes in the subsurface of any area but the evidence of the specific lithologies has to be supported by availability of borehole log control data.

VES data collected was modeled using the AGI Earth Imager ID inversion automated computer program and VES curve types were generated. The geophysical investigation carried out in Kimumu has revealed the lithology in the area and mapped the subsurface which portrays H-type; $\rho_1 > \rho_2 < \rho_3$, K-type; $\rho_1 < \rho_2 > \rho_3$, A-type; $\rho_1 < \rho_2 < \rho_3$, Q-type; $\rho_1 > \rho_2 > \rho_3$, representing 3-Layer subsurface and subsequently a combination of KH types of curves representing 4-Layer in the subsurface. The shallow aquifer as from the inverted Vertical Electrical Sounding data has its water table starting from 4.406 to 8.607 metres deep and this incidentally serves the shallow wells in the area. This layer is represented by resistivity of between 12.9 Ohm-m to 99.5 Ohm-m. The second aquifer starts at a depth of 33.163 meters and this point to the aquifer tapped by boreholes drilled in the study area.

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