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Geoelectric Investigation of Potential Underground Borehole Sites in Some Part of Nassarawa Local Government Area of Kano State, Nigeria

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Abstract
Geohydrological investigations are performed to assess the groundwater parameters for locating suitable sites for groundwater exploration. Electrical resistivity Survey carried out at Nassarawa Local government of Kano state, Nigeria in order to study the groundwater potential in the area. Vertical Electrical Sounding (VES) using Schlumberger array was carried out at fifteen (15) stations. Ohmegaterrameter was used for data acquisition. The field data obtained has been analyzed using Software which gives an automatic interpretation of apparent resistivity. The VES result revealed the heterogeneous nature of the subsurface geologic sequence. The geologic sequence beneath the study area is composed of topsoil (sandy-clay and sandy-lateritic), weathered basement, fracture basement layer and fresh basement. However, fracture basement and fresh basement do not show lateral variation in the basement resistivity. The result of the investigation revealed the various resistivity layers as a function of depth from the resistivity succession which range from 8.22m to 40.80m. The site which will provide most yields area is found base on the high thickness of the aquiferous layer.

Keywords: Vertical electrical sounding (VES), Groundwater, Depth, Aquifer, Borehole

INTRODUCTION
The importance of groundwater as a water supply source to the socioeconomic development of any nation is tremendous. However, the difficulties in exploration and exploitation usually encountered in the basement areas where aquifers are both isolated and compartmentalized, requires the use of multi-disciplinary approach involving, geological and hydro-geological mapping and geophysical investigations to ensure success **(**Bala, 2008). Groundwater is very important natural resources for sustainable development of a region (Kumar *et al*., 2014). It is the only viable source of water in many areas where development of surface water is not economically viable (Kumar *et al*., 2014). Water as renewable resource occurs in three forms; liquid, solid and gaseous (Ahilan, 2011). Water is essential for irrigation, industry and domestic purpose. Groundwater is the main source for potable water supply for domestic, industrial and agricultural uses (Ahilan, 2011). The scarcity of groundwater increases day by day due to rapid population, urbanization, industrial and agricultural related activities. The impact of trio on soil and groundwater is alarming with years of devastating effects on humans and the ecosystem (Ehirim, 2010). Study of groundwater geology is much useful for all the activities of human life. Groundwater is more advantageous than the surface water. Water scarcity problem affects the human chain and other living things. To meet out the demand of water, people are depending more on aquifers. Groundwater in alluvial and sedimentary rocks occurs in pore spaces between

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grains, while in hard rocks, it is largely due to secondary porosity and permeability resulting from weathering, fracturing, jointing and faulting activities (Kumar *et al*., 2014).

Prolonged in-situ weathering of the crystalline basement complex rocks under tropical conditions has produced a sequence of unconsolidated material whose thickness and lateral extent vary extensively **(**Adekile, 1991). The localization of groundwater within these zones is controlled by a number of factors which include the parent rock type, the depth, extent and pattern of weathering, thickness of the weathered materials, the sand/clay ratio and the degree of fracturing, fissuring and jointing (Oyawoye, 1964). These hydro-geological characteristics needs to be properly assessed and interpreted for groundwater development, modeling, well design and construction especially for localities lacking such useful information. Kano State been the second largest in population in Nigeria experience scarcity of water during the dry seasons. Nassawara local government of Kano State is among the local government in the city with large population. It is with this view in mind that this study intends to undertake the assessment of the hydro-geological characteristics in some part Nassarawa local government of Kano State in order to identify area of high groundwater potential so as to serve as point for erecting high yielding boreholes either by government, individual, Non-Governmental Organizations e. t. c.

MATERIALS AND METHOD

The geophysical investigation involves the use of vertical electric sounding (VES) method. Vertical electric sounding furnishes information concerning the vertical succession of different conducting zones and resistivities (Ekwe*et al*., 2010). By measuring the electrical resistance to a direct current applied at the surface, this geophysical method can be used to locate fracture zones, faults and other preferred groundwater/contaminant pathways; locate clay, sand channels and locate perched water zones and depth to the bedrock (Sultan, 2012). Fifteen (15) vertical electric sounding (VES) were carried out randomly in disperse points within the build-up area in some communities within Nassarawa local government. The Schlumberger electrode configuration was utilized. The quantitative interpretation involved partial curve marching technique (Zohdy, 1965) using the *ipi2win* software. The principal instrument used for this survey is the omega terrameter along with other accessories-cables, electrodes, pegs, ranging poles, hammers and measuring tape. The resistance readings are displaced on the digital readout screen and then written down on the field report book. The Schlumberger method is used in this research in the Schlumberger array; the current electrodes are spaced much further apart than the potential electrode.

The study area falls within Nassarawa local government of Kano state, northern part of Nigeria. Located at approximately latitude 10^o 40 ' N to 12^o 48 ' N and longitude 07^o 43′ E to 10^0 20 ' E.

Kano State’s mean annual rainfall ranges from over 1,000mm in the extreme south to a little less than 800mm in the extreme north. The rains usually last for three to five months with mean temperature ranges from 26°C to 33°C. There are four seasons within the state; a dry and cool season, (mid-November to February), marked by cool and dry weather plus occasional dusty; the dry and hot season, (March to mid-May) when temperatures climb up to 40°C and which is a transition period between the cold and the wet season; the wet and warm season, (mid-May to September), is the proper wet season when the lowest temperature is recorded; and a dry warm season, (October to mid-November) marked by high humidity and high temperature next to hotness.

The region features savanna vegetation and a hot, semi-arid climate. Kano sees on average about 873 mm of precipitation per year, the bulk of which falls from June through September. Kano is typically very hot throughout the year, though from December through February, the city is noticeably cooler. Nighttime temperatures are cool during the months of December, January and February, with average low temperatures ranging from 11°C to 14°C.

Vegetation in this area is tropical savannah characterized by sparse shrub and interrupted by large isolated trees. There is more continuous cover of grasses in the rainy season mean annual precipitation for the area ranges between 980-1150mm.

The Northern Nigerian Basement Complex comprises three groups of rocks namely, migmatites and (high grade) gneisses derived from Birrimain sedimentary rocks through high grade metamorphism and granitization; the Younger Metasediments of Upper Proterozoic age which are low grade metamorphic rocks that were folded along with the migmatite and gneisses during the Pan-African orogeny; and the Older Granite series which were intruded during the Pan-African orogeny (McCurry, 1989). In the study area, (Hazell *et al*., 1988) also reports the occurrence of rocks of the Younger Granites series (Falconer, 1911), so termed because they are Jurassic in age (Figure 1), as well as volcanic, and occasional younger dykes and flows. Kano Agricultural and Rural Development Authority, KNARDA (1989) identifies the individual members of the Older Granite suite, but rocks of the Younger Metasediments and those of the migmatite-gneiss complex were simply grouped as the migmatite gneiss complex in some places.

In electrical resistivity method anomalies of the subsurface conduction depend on electrical conductivity contrast between the conductor and the host rock. Details on conductivity (electrical property) of earth material can be found in Telford *et al* (1976), Keller and Frischnecht (1977). There are many methods of observing these anomalies in electrical surveying some of this material make use of naturally occurring field within the earth while others require the introduction of artificially generated source into the ground. The resistivity method uses artificial source field. Artificially generated electric current are driven into the ground any variation in the subsurface resistivity (conductivity) alters the distribution of the electric potential the resulting potential differences there are measured at the surface any variation observed from the pattern of potential differences expected from uniform earth are deviation from the uniform earth these deviations represent the geological target of resistivity exploration.

Generally, four electrode arrays are used at the surface, one pair for introducing current into the earth and the potential difference establish in the earth by the current is measured in the vicinity of current flow with the second pair.

A great number of electrode arrangements have been used for resistivity exploration (Adamu, 1994). The most used electrode arrangement is warner and Schlumberger, three-point speed, lee-partition spread and dipole-dipole spread method (Telford *et al*., 1976). Any of these electrode arrangements may be used to study lateral variation of resistivity or variation in resistivity with depth (Keller and Frischnecht, 1977). In studying lateral variation such as those associated with dyke-like structures of faults a fixed separation is maintained between the various electrodes and the array is moved as a whole along the transverse line this is called a horizontal profiling or trenching. In studying the variation of resistivity with depth as in case of layered medium, the center of electrodes spread is often kept fixed while the electrode spacing is changed.

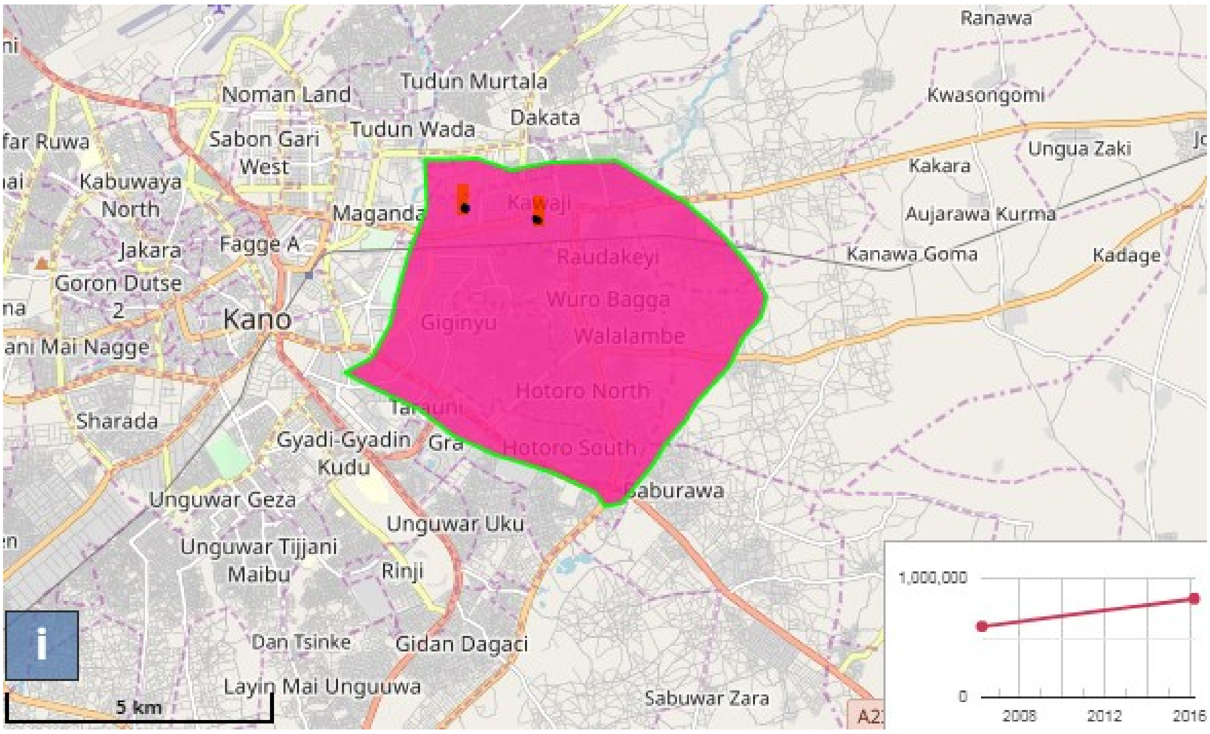


Figure 1: Some part of Kano state map locating the study area (Google map).

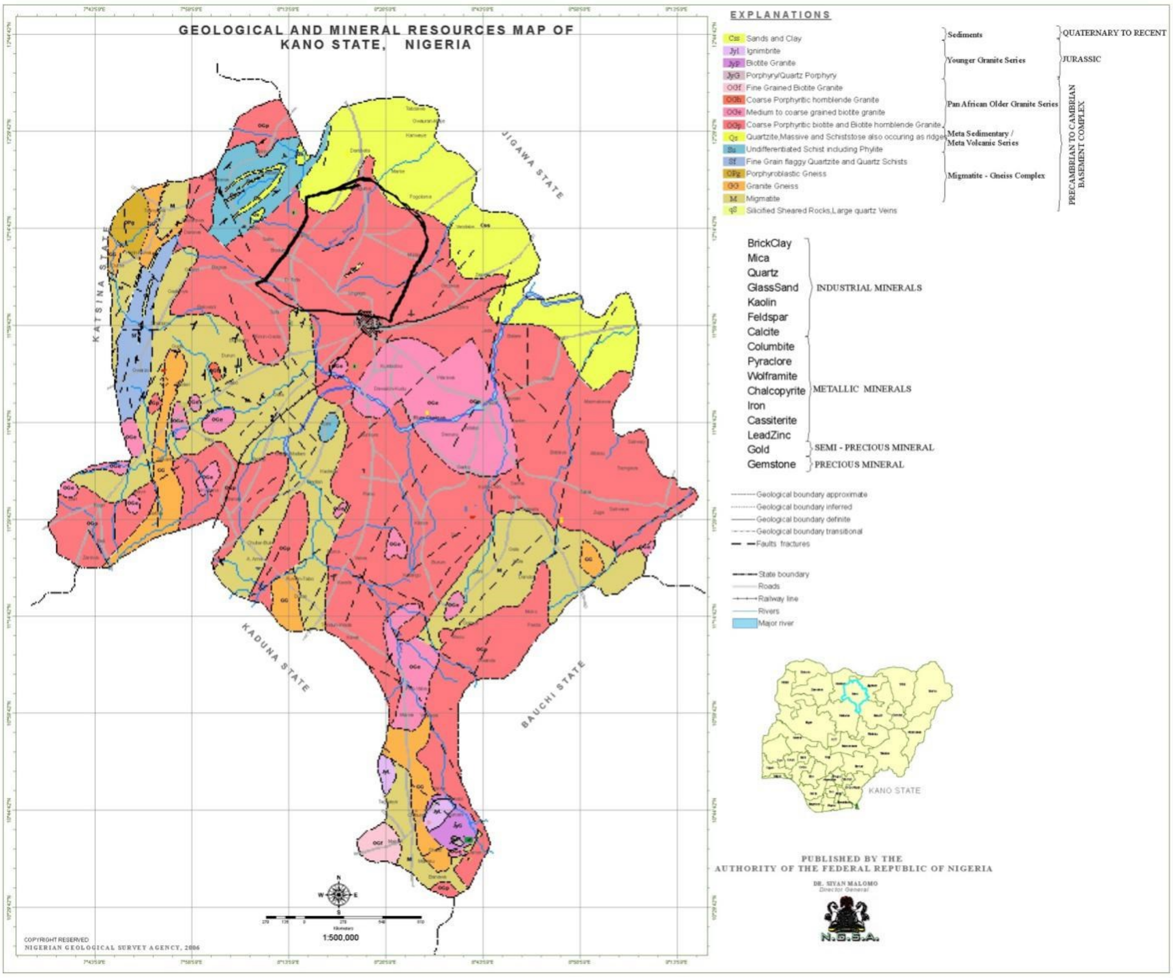


Figure 2: Geological map of Kano state with the location of the study area (NGSA, 2009).

RESULTS AND DISCUSSION

In many engineering and environmental studies, the subsurface geology is very complex where the resistivity can change rapidly over short distances. The resistivity sounding method might not be sufficiently accurate for such situations. However, the technique is extensively used in geotechnical surveys to determine overburden thickness and also in hydrogeology to define horizontal zones of porous strata.

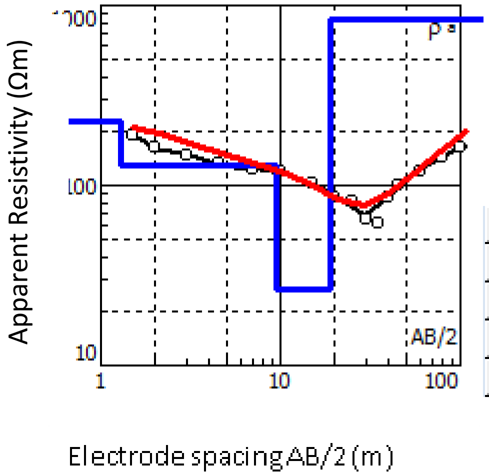
For better understanding, the results of investigation are usually presented in the form of digitized interpreted field curves. However, the topsoil and the weathered basement are regarded as the overburden while the bedrock consists of the fracture and the fresh basement rocks (Oladapo, 2013). Therefore, in accordance with above fact, fifteen digitized field curves (Figure 3-17) were interpreted as follow:

In the figure 3-13 below, the interpreted field curves show maximum of four layers. The resistivities of the various layer varies with their depth. The first layers are the topsoil which consist of the sandy silt, sandstone and laterite. The resistivities of this layer ranges from 167**Ω**m to 735**Ω**m while the depth varies from 1.08 m to 2.61 m. underlying the first layers is the second layers with resistivities ranges from 59.9**Ω**m to 422**Ω**m and the depth 1.36 m to 20.5m. These layersarereferred to as the weathered laterite. The third layer is the weathered basement with the resistivities ranging from 22.6**Ω**m to 109**Ω**m and depth of 6.6 m to 34.7 m. however, the fourth layer is the fracture basement layer with resistivities ranging from 661**Ω**m to 914**Ω**m. This result closely agreed with that of Shemang, (1990) and Baimba, (1978) from the characteristic resistivities of rock material within the basement area.

In figure 14 and 16 below, the interpreted field curves also show maximum of four layers. The first layer which is the topsoil consist of fresh laterite with resistivities of 1593**Ω**m and 1138**Ω**m and depth of 1.91 m and 1.47 m. The second layer is the weathered laterite with resistivities of 216**Ω**m and 485**Ω**m and depth of 2.13 m and 3.90 m. The third layer is the weathered basement layer with resistivities of 404**Ω**m and 168**Ω**m and depth of 20.1 m and 24 m. However, the fourth layer is the fresh basement layer with the resistivities of 3840**Ω**m and 3287**Ω**m. From the characteristic resistivity values of rock material within the basement area by Aboh, (2001). The result above agreed with the resistivity of rock material within the basement area.

In figure 15 and 17 below, the first layer which is the topsoil consist of sandy clay silt sandy with resistivities of 77.2**Ω**m and 147**Ω**m and depth of 1.84 m and 1.35 m. the second layer consist of the weathered laterite with resistivities of 15.9**Ω**m and 52.9**Ω**m and depth of 1.26 m and 8.65 m. The third layer is the weathered basement layer with resistivities of 51**Ω**m and 15.9**Ω**m and depth of 13.9 m and 39.7 m. The fourth layer consist of the fracture basement layer with resistivities of 155**Ω**m and 596**Ω**m.

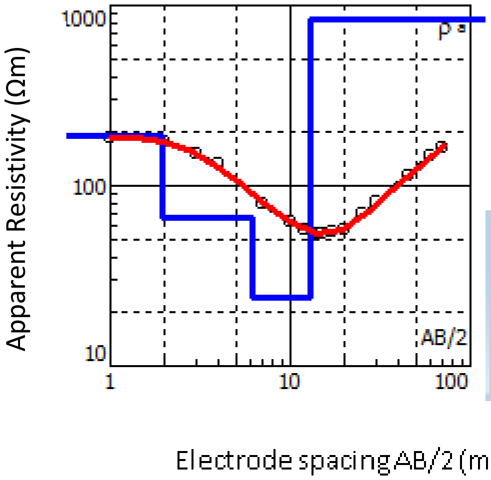
VES 1: Alh. Idris Custom Street Tarauni



N	ρ	h	d	Alt
1	224	1.29	1.29	-1.29
2	129	8.22	9.51	-9.51
3	26.5	9.44	19	-18.95
4	836			

FIGURE 3: Digitized model of interpreted VES 1

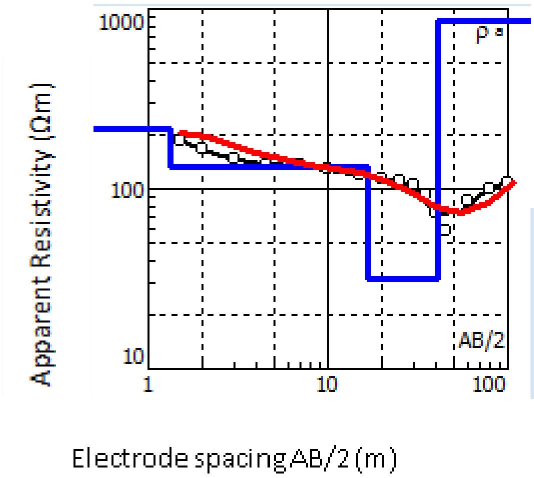
VES 2: Kawo bus stop (Northing: 1209601.0, Easting: 81227.0)



N	ρ	h	d	Alt
1	190	1.94	1.94	-1.945
2	66.4	4.24	6.19	-6.19
3	23.7	6.6	12.8	-12.79
4	836			

FIGURE 4: Digitized model of interpreted VES 2

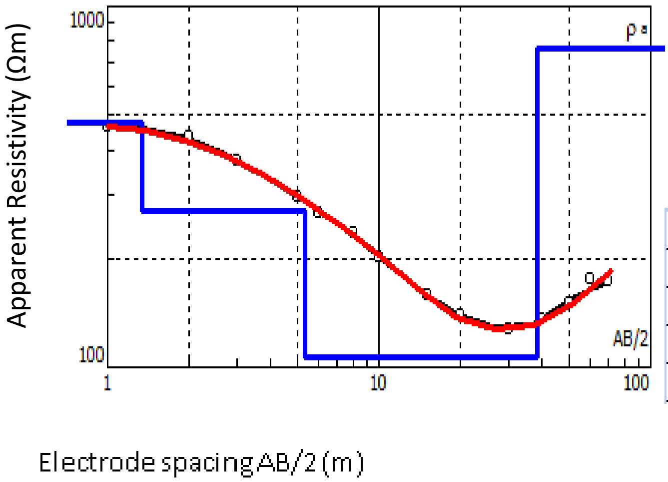
VES 3: Sauna street Giginyu



N	ρ	h	d	Alt
1	218	1.33	1.33	-1.33
2	131	15.3	16.6	-16.63
3	31.4	24.2	40.8	-40.83
4	858			

FIGURE 5: Digitized model of interpreted VES 3

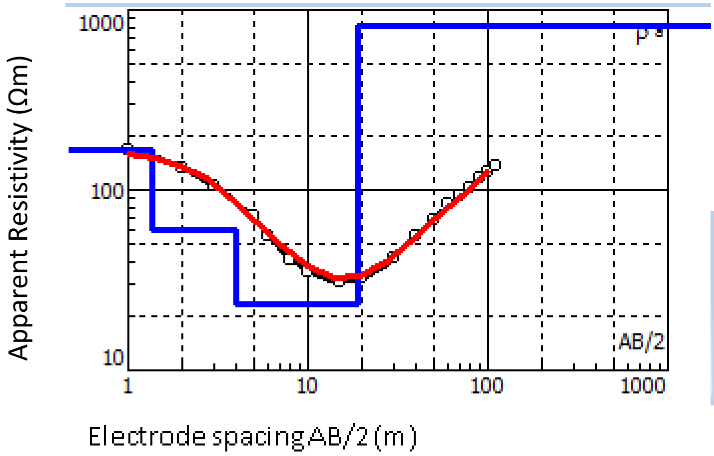
VES 4: Fire service street Giginyu



N	ρ	h	d	Alt
1	478	1.34	1.34	-1.342
2	271	4.01	5.36	-5.356
3	107	33	38.4	-38.38
4	764			

FIGURE 6: Digitized model of interpreted VES 4

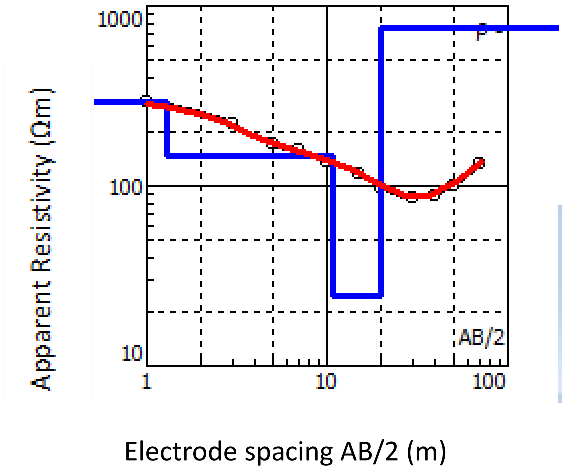
VES 5: Audunasani street Kawaji (Northing: 1159107.0, Easting: 831627.0)



N	ρ	h	d	Alt
1	167	1.35	1.35	-1.352
2	59.9	2.63	3.98	-3.981
3	23.3	14.8	18.8	-18.81
4	815			

FIGURE 7: Digitized model of interpreted VES 5

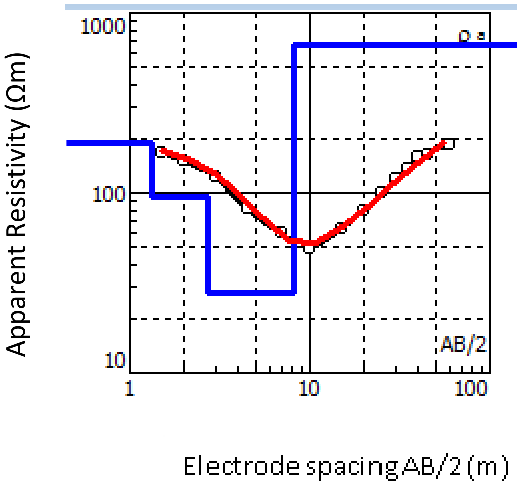
VES 6: Gama primary South



N	ρ	h	d	Alt
1	293	1.29	1.29	-1.29
2	147	9.62	10.9	-10.91
3	24.6	9.13	20	-20.04
4	755			

FIGURE 8: Digitized model of interpreted VES 6

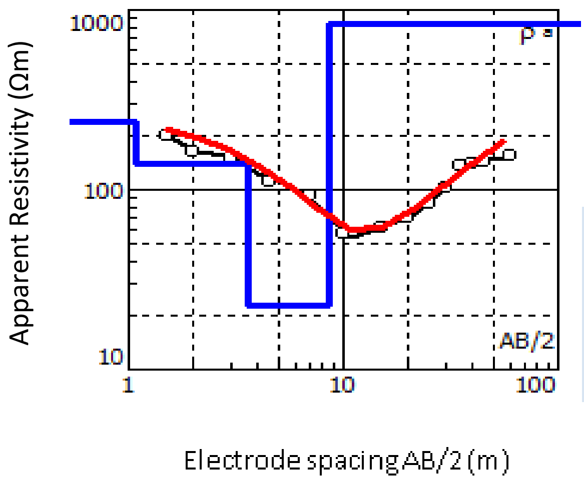
VES 7: Hajiyakulu street gama



N	ρ	h	d	Alt
1	188	1.33	1.33	-1.325
2	95.6	1.36	2.69	-2.687
3	27.9	5.53	8.22	-8.22
4	661			

FIGURE 9: Digitized model of interpreted VES 7

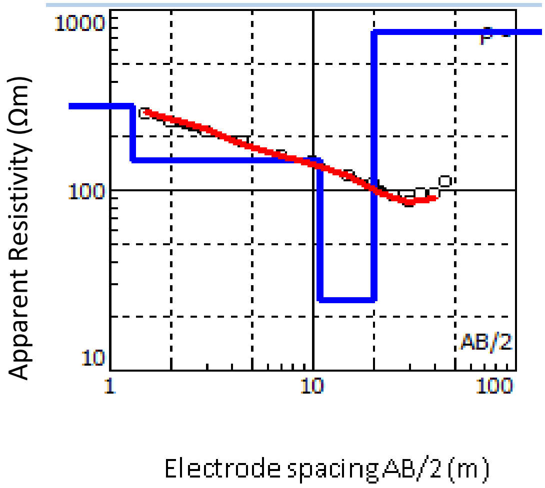
VES 8: Sule kai kai street Raudakeyi



N	ρ	h	d	Alt
1	237	1.08	1.08	-1.08
2	139	2.5	3.58	-3.58
3	22.6	5.06	8.64	-8.64
4	836			

FIGURE 10: Digitized model of interpreted VES 8

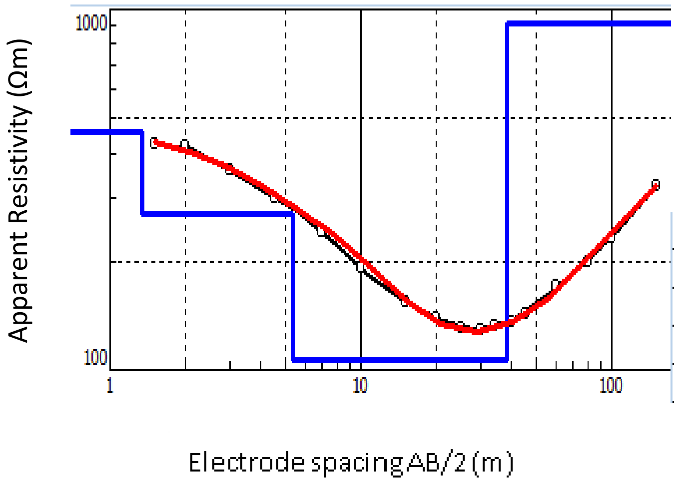
VES 9: Walalambe primary



N	ρ	h	d	Alt
1	293	1.29	1.29	-1.292
2	147	9.62	10.9	-10.91
3	24.6	9.13	20	-20.04
4	755			

FIGURE 11: Digitized model of interpreted VES 9

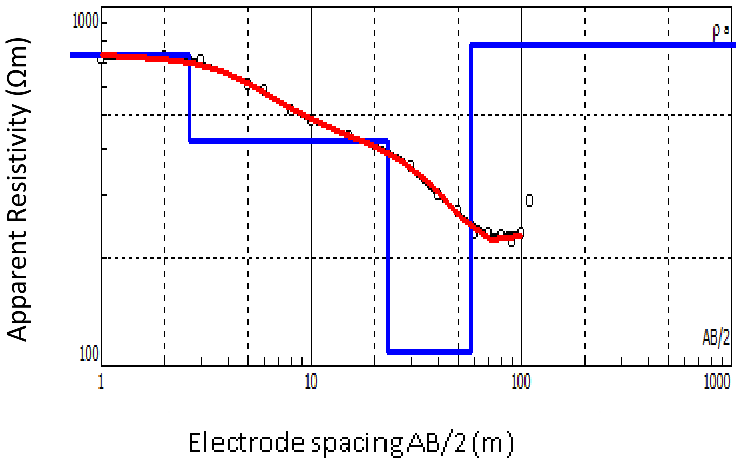
VES 10: Rahama Street Wurobagga



N	ρ	h	d	Alt
1	478	1.34	1.34	-1.34
2	271	4.01	5.35	-5.35
3	107	33	38.3	-38.35
4	914			

FIGURE 12: Digitized model of interpreted VES 10

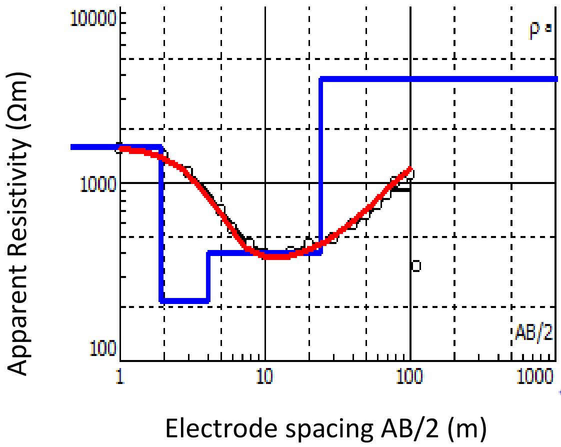
VES 11: Gwagwarwa clinic Hotoro South



N	ρ	h	d	Alt
1	735	2.61	2.61	-2.609
2	422	20.5	23.1	-23.12
3	109	34.7	57.8	-57.8
4	783			

FIGURE 13: Digitized model of interpreted VES 11

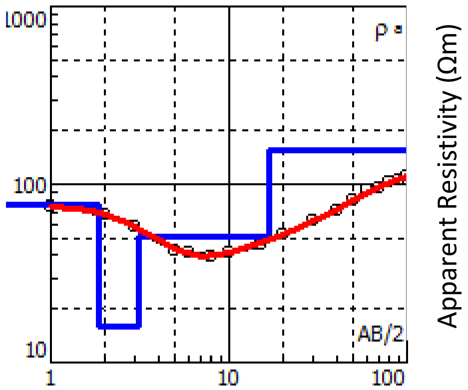
VES 12: Yahaya Isah Street Bridget



N	ρ	h	d	Alt
1	1593	1.91	1.91	-1.909
2	216	2.13	4.04	-4.043
3	404	20.1	24.1	-24.1
4	3840			

FIGURE 14: Digitized model of interpreted VES 12

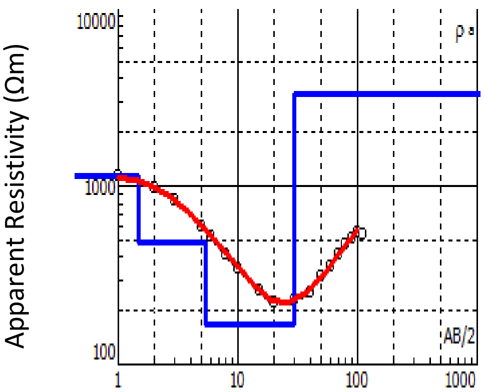
VES 13: TsamiyarBoka Street Hotoro North



ρ	h	d	Alt
77.2	1.84	1.84	-1.84
15.9	1.26	3.1	-3.1
51	13.9	17	-16.99
155			

FIGURE 15: Digitized model of interpreted VES 13

VES 14: Hotoro Primary



N	ρ	h	d	Alt
1	1138	1.47	1.47	-1.474
2	485	3.9	5.38	-5.376
3	168	24	29.4	-29.38
4	3287			

FIGURE 16: Digitized model of interpreted VES 14

VES 15: Dangana Street Wurobagga

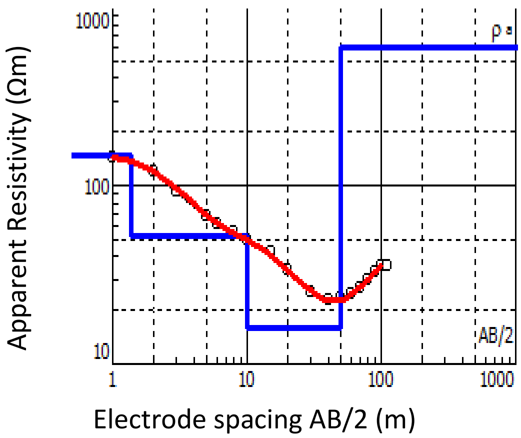


FIGURE 17: Digitized model of interpreted VES 15

From characteristics of resistivity of weathered and fracture basement layers of the VES points, this shows that the weathered and the fractured basement are believed to be the major component of the aquifer in this study area where fresh groundwater is expected to be in abundance. The fracture basement could contribute to the aquifer system where fracture density is high and its thickness is considerably large (Zume, 1999). In determining areas with suitable and exploitable ground water with the resistivity of the subsurface, a low resistivity indicates a highly conductive formation and usually groundwater zones are very conductive (Ajayi and Hassan, 1988). In this research the layer of interest is the weathered and fracture basement which are layers that possibly contain the groundwater as indicated by its high conductivity value. The resistivity sound curves of the VES points clearly identify the depth of the aquifer layer of this research to be from 8.22 to 40.80m. Therefore, from the model interpretation of the VES points it is clearly seen that the depth to the basement rock, the aquiferous layer and areas for erecting boreholes are clearly identified.

CONCLUSION

The vertical electrical sounding was used to investigate the ground water potential of the study area. Fifteen vertical electrical sounding were carried out with the aim of determining favorable site to erect a high yielding borehole which will serve as a source of water supply in some parts of Nassarawa local government. However,base on the discussion of the result above, the most suitable VES points to erect high yielding borehole in the area are VES 1, VES 2, VES 3, VES 5, VES 6, VES 7, VES 8, VES 9, VES 13 and VES 15 which shows high conductive value in there weathered and fracture basement.

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