International Journal of Engineering, Management and Humanities (IJEMH)
Volume 6, Issue 3, May-June, 2025 pp: 151-160 ISSN: 2584-2145 www.ijemh.com

Delineation of groundwater potential zones using integrated Vertical Electrical Sounding and geospatial techniques in the basement complex of Ijesha Isu, Southwestern Nigeria

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Date of Submission: 21-05-2025 Date of Acceptance: 01-06-2025

Abstract
A combination of multi-criteria evaluation parameters has been deployed to delineate groundwater potential zones using integrated Vertical Electrical Sounding and geospatial techniques in the basement complex of Ijesha Isu, Southwestern Nigeria.The area is underlain by migmatite-gneiss, the amphibolities, biotite gneiss and the granitic components of the basement complex terrain with suspect groundwater prospects. Wenner vertical electrical soundings (VES) were conducted at 22 stations. The VES interpretation delineated the topsoil, weathered basement/ partly weathered/fractured basement and the fresh basement bedrock with resistivity values ranging from 19 - 304, 16 - 417 and 8 -2784 Ω-m, respectively. The GIS model integrated features ofbedrock resistivity, weathered basement resistivity and the overburden thickness using ArcMap 10.2.2 for spatial analysis. The thematic maps were synthesized to enable zonation into very low, low, moderate and high groundwater potential zones. High groundwater potential zone covers an area of 1.32 km^2 of the study area. Moderate groundwater potential zone covers an area of 1.85 km^2 with Low and very low groundwater potential zones covering an area of 0.18 km^2 and 0.004 km^2 respectively. A weighted combination of attributes would enhance the hitherto low success rate of groundwater targeting in a typical hard rock terrain.

Keywords: geoelectrical characteristics, GIS model, groundwater potential, MCE, weighting

I. Introduction

Ijesha-Isu Ekiti is underlain by the Precambrian basement complex rocks of Southwestern Nigeria. The town depends on rain water, surface water and groundwater for water supplies. The surface water is usually not available all year round owing to the seasonal flow regime of rivers draining the area; and where available and accessible, cannot guarantee the required water quality status required for most domestic activities. Most homes depend on water from wells whose overall yield and quality are influenced by the alternating wet and dry seasons among other factors [1 - 3]. In a typical hard rock terrain, groundwater is restricted to the fractures and the weathered zones.The hydraulic properties are characterized by extreme variations over short distances which often limit water development in the area to low-yielding well [4 - 6]. With the marked low success ratio of drilling for potable water inhard rock terrain the use of Geophysics is often compelling, particularly in the absence of lineaments extracted from imagery [1, 7, 8].

According to [6] the poor understanding of the hydrogeological characteristics of the Basement Complex environment is significantly responsible for borehole failures in the terrain. The groundwater potential of a basement complex area is influenced by a complex inter-relationship involving the geology, post emplacement tectonic history, weathering processes and depth, nature of the weathered layer, groundwater flow pattern, recharge and discharge processes [9, 10].Improvements in the understanding of this relationship will be fundamental to the planning and management of groundwater resources in crystalline basement terrain and reduction of development cost [4].It is important to evaluate the overall resource and aquifer occurrence more precisely to assist development efficiency and longer-term sustainability.

Vertical Electrical Resistivity Sounding (VES) offers a compact tool for locating promising areas for water boreholes/wells amidst prevailing structural disposition. It has proved very popular with groundwater studies due to the simplicity of the

International Journal of Engineering, Management and Humanities (IJEMH)
Volume 6, Issue 3, May-June, 2025 pp: 151-160 ISSN: 2584-2145 ww.ijemh.com

technique, the ruggedness of the instrumentation and the success rate [5, 9] .Geographic Information System (GIS) provides an efficient integration environment. With the implementation of GIS, large volume of geospatial data and information are maintained in a standard format, revised and updated with additional features. Sustainable development and management are thus facilitated at real time [1,11].

Thisintegrated approach presentsa detailed evaluation of the groundwater prospects of Ijesha-Isu Ekiti using geoelectric data in a GIS environment.

II. Location Description and Geology

The study area, Ijesa Isu Ekiti, lies between latitudes 7º45'N and 7º 46'N and longitudes 5º 25'E and 5º 26'E in Ikole Local Government area of Ekiti, State, Southwestwern Nigeria. The area enjoys high annual rainfall of about 1500mm being within the tropics. The area is underlain by migmatite-gneiss, the amphibolities, biotite gneiss and the granitic components of the Precambrian basement complex of southwestern Nigeria. The regolith and fractured bedrocks constitute the aquifers for groundwater. Development of the bedrock component requires interaction with storage available in overlying or adjacent saturated regolith, or other suitable formations such as alluvium [1, 12,13].

III. Material and Methods

The geoelectric data acquisition was carried out usingWenner array of Vertical Electrical Sounding (VES) to delineate the subsurface lithological configuration, aquifer characteristics and depth to bedrock. Twenty Two (22) VES points (Fig. 1) were fully occupied for data acquisition. The instrument used for the resistance measurement was the ABEM Terrameter SAS 300 B with ABEM 2000 Booster. A Garmin 12-Channel Global Positioning System (GPS) handheld receiver was used to obtain the Eastings (Longitude), Northings (Latitude) and Elevation above mean sea level of each point of interest during the fieldwork. The VES data were interpreted quantitatively by partial curve matching and 1-D computer iteration using the computer algorithm RESIST Version 1.0 [14] to obtain the layer resistivity values and corresponding thicknesses. The curves were inspected to determine the number and nature of the layering [15,16].ArcMap 10.2.2 was employed for derivation and re-classification of the thematic layers for spatial analysis. Different classes in each thematic map were assigned a knowledge-based hierarchy of weights [17]. These weights ranged from 1 to 4 for groundwater potential evaluation.In each thematic map, highest weight is given to the class that is most favourable to potential and lowest weight is given to the class that is least favourable for groundwater accumulation.

IV. Results and Discussion

The geoelectric type curves in the area are presented in Fig.2. They are A, H, KH, HA and Q type curves with the H-Curve being the mostpredominant accounting for 45.4%. This is a consequence of the degree of weathering and fracturing as typical of the basement complex terrain. The analysis of the type curves indicated that the area under study has both weathered layer aquifers and fractured layer aquifers [18,19].

The geoelectric characteristics are summarized in Table 1. The spatial distributions of the Geoeletric parameters are presented in Figs.3 - 8. The resistivity of the topsoil varies from 19 Ohm-m to 304 Ohm-m with a mean of 79.8 Ohm-m and Standard Deviation of 68.7 Ohm-m. The skewness of 1.7 shows that the spatial distribution is not uniform. The wide resistivity range is a consequence of the variable composition of this layer. The thickness of the topsoil varies from 1.1 m to 8.6 m with a mean of 3.9 ± 2.6 m. TheWeathered Basement Resistivity values range from 16 Ohm - m to 417 Ohm-m.The values indicate varying degree of weathering/fracturing and water saturation.The thickness of the layer ranges from 3.2 – 19.6 m.

The Bedrock resistivity varies from 8 Ω-m to 2784 Ω-m; indicating decreasing impact of weathering /fracturing with corresponding reduction of the groundwater potentials. Localized variations may be attributed to differences in the bedrock mineralogy and structures. The Overburden Thickness varies from 4.3 to 25.3 m.

The isopach map of overburden, Fig.7, shows that the southwestern and southeastern regionsare characterized by basement highs/ridgeswith thin overburden cover generally lessthan 10m. Thresholding produced three classes of overburden thickness of < 10m, 10 – 20m and 20 -30m with poor, medium and high groundwater potential respectively (Fig.8).The northern flank records increasing value of overburden thickness towards the central portion of the study area thus creating basement depressions at the central portion and Irepodun. An isolated depression has been demarcated along the southern flank of the area.Basement depressions are diagnostic of troughs which are groundwater collecting centres or groundwater convergent zones.Conversely, zones

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with relatively thin overburden are indicative of basement highs/ridges as shown in the map of overburden thickness (Fig.9). Such zones are diagnostic of crests. They are thus groundwater radiating zonesor groundwater divergent zones [9,20].

Maximum possible regolith thickness is required for adequate storativity, transmissivity, greater drawdown and hence increasing the well yield. The resistivity range 20 – 100 Ohm-m is associated with optimum weathering and groundwater potential while resistivity range of 100-150 Ohm-m are indicative of Medium aquifer conditions and potential. Limited weathering and poor potential could be expected when the weathered basement resistivity falls within the range of 150 – 300 Ohm-m. Clayey formations only offer limited aquifer potential.

Basement fractures contribute significantly to groundwater yield in a typical basement complex area. Fractures influence the groundwater yield more than weathered layer probably because of the relatively high permeability. Subsurface features are therefore good prospective targets for groundwater in the basement area such as the study area [9, 21].

Fractured Bedrock (Resistivity of less than 750 Ohm-m) is indicative of high fracture and permeability as a result of weathering with high aquifer potential. Reduced influence of weathering is felt in areas of 750 – 1500 Ohm-m and hence medium aquifer potential. A range of 1500 – 3000 Ohm-m with a resultant low aquifer potential, reflects fairly low effect of weathering. Bedrock characterized by resistivity of >3000 Ohm-m is suggestive of little or no weathering of the bedrock with negligible aquifer potential [15,21]

Groundwater Potential Evaluation

[9] remarked that although the yield of a borehole depends to some extent on the saturated thickness of the aquifer and hence the overburden thickness, the properties of the weathered aquifer most especially its storage and discharge capacities based on its porosity and permeability and the underlying fractured basement column more strongly influence the groundwater yield.It is therefore difficult to rely solely on isolated parameters for groundwater potential evaluation [22 - 24]. A weighted combinationof relevant geoelectric parameters according to their relative importance to groundwater occurrence and accumulation is facilitated in a GIS environment. The thematic maps were synthesized in a GIS environment using the weighting combination (Table 2) for the resulting groundwater potential map, Fig.10.High groundwater potential zone covers an area of 1.32 $km^2$of the study area. Moderate groundwater potential zone covers an area of 1.85km^2 with Low and very low groundwater potential zones covering an area of 0.18$km^2$and 0.004 km^2 respectively(Table 3)

V. Conclusions

A geoelectric assessment of the Groundwater Potentials of Ijesha – Isu has been conducted in a GIS platform. Thematic maps of the geoelectric parameters obtained from the inverted Vertical Electrical Sounding Data were prepared, re-classified and rated in terms of hydro-geologic importance. Integration of the attributes of the Bedrock Resistivity, Weathered Basement Resistivity and the Overburden Thickness in a GIS environmentenabled the categorization of Ijesa- Isu Ekiti into Very Low, Low and Medium and High groundwater potential zones. These are feasible. Relevant geologic structures delineated from the distribution of the subsurface resistivity included ridges and bedrock depressions which are of significant hydro-geologic importance. The bedrock depressions being the groundwater collecting centres are priority areas for groundwater development.

Acknowledgments

The authors gratefully acknowledge all useful suggestions regarding this work.

References

[1]. Popoola K, Talabi AO, Afolagboye LO, Oyedele AA, Ojo AA, (2020). Groundwater potential evaluation in the basement complex terrain of Ekiti East Local Government Area, Southwestern Nigeria. International Journal of Energy and Water Resources, https://doi.org/10.1007/s42108-019-00053-5 Springer

[2]. Talabi AO, (2018). Estimated volume of water in shallow wells of Ekiti State, Southwestern Nigeria: implications on groundwater sustainability. Arabian Journal of Geoscience, 11, 1–9. https ://doi.org/10.1007/s1251 7-018-4031-3.

[3]. Rahaman MA, (1988). Recent advances in the study of the Basement Complex of Nigeria. In Oluyide et.al. (eds) Precambrian Geology of Nigeria Publication. Geological Survey of Nigeria, Kaduna, p. 157-163.

[4]. Wright CP, (1992). The hydrogeology of crystalline basement aquifers in Africa. In:

CP Wright and W C Burgess (eds). Hydrogeology of crystalline basement aquifer in Africa. Geological Society of London Special Publication. 66, p. 1–27.

[5]. Oyedele AA, Ayodele OS, Olabode OF, (2019). Groundwater quality assessment and characterization of shallow basement aquifers in parts of ado ekiti metropolis, Southwestern Nigeria. SN Applied Sciences, https://doi.org/10.1007/s42452-019-0683-1 Springer Nature

[6]. Ojo JS, Olorunfemi MO, Akintorinwa OJ, Bayode S, Omosuyi GO, Akinluyi FO, (2015). GIS Integrated Geomorphological, Geological and Geoelectrical Assessment of the Groundwater Potential of Akure Metropolis, Southwest Nigeria. Journal of Earth Sciences and Geotechnical Engineering, 5(14) p. 85-101.

[7]. Oyedele AA, (2019). Use of remote sensing and GIS techniques for groundwater exploration in the basement complex terrain of Ado Ekiti, SW Nigeria. Springer Applied Water Science. p. 9:51 https://doi.org/10.1007/s13201-019-0917-9.

[8]. Bayewu OO, Oloruntola MO, Mosuro GO, Laniyan TA, Ariyo SO, Fatoba JO, (2017). Geophysical evaluation of groundwater potential in part of southwestern basement complex terrain of Nigeria. Applied Water Science, 7(8) p. 4615–4632. https ://doi. org/10.1007/s1320 1-017-0623-4.

[9]. Olorunfemi MO, Ojo JS, Akintunde OM, (1999). Hydrogeophysical Evaluation of the Groundwater Potential of Akure Metropolis, South-Western Nigeria. Journal of Mining and Geology, 35(2) p. 207 – 228.

[10]. Prabu P, Rajagopalan B, (2013). Mapping of Lineaments for Groundwater Targeting and Sustainable Water Resource Management in Hard Rock Hydrogeological Environment Using RS- GIS, Climate Change and Regional/Local Responses, Chapter 10 p. 235 – 247.

[11]. Hagos Y, Bedaso Z, Kebede M, (2024). Delineating groundwater potential zones using geospatial and analytical hierarchy process techniques in the upper omo-gibe basin, Ethiopia. Revue Internationale de Géomatique, 33(1), 399-425. https://doi.org/10.32604/rig.2024.053975

[12]. Clark L, (1985). Groundwater abstraction from basement complex area of Africa. Quarterly Journal of Engineering Geology and Hydrogeology, 18 p. 25–34. https ://doi.org/10.1144/GSL. QJEG.1985.018.01.05.

[13]. Bayowa OG, Olorunfemi MO, Akinluyi FO, Ademilua OL, (2014). Integration of Hydrogeophysical and Remote Sensing Data in the Assessment of Groundwater Potential of the Basement Complex Terrain of Ekiti State, Southwestern Nigeria. Ife Journal of Science, 16(3) p. 353 – 363

[14]. Vander-Velpen BPA, (2004). Win RESIST Version 1.0. MSc Research Project, ITC, Deft, Netherlands.

[15]. Ariyo SO, Adeyemi GO, (2011). Integrated geophysical approach for groundwater exploration in hard rock terrain-A case study from Akaka area of southwestern Nigeria. International Journal of Advanced Scientific and Technical Research, 2(1) p. 376–395.

[16]. Olayinka AI, Amidu SA, Oladunjoye MA, (2004). Use of electromagnetic profiling and resistivity sounding for groundwater exploration in the crystalline basement area of Igbeti, southwestern Nigeria. Global Journal of Geological Sciences, 2(2) p. 243–253.

[17]. Oyedele EA, Olayinka AI, (2012). Statistical evaluation of groundwater potential of Ado-Ekiti Southwestern Nigeria. Transnational Journal of Science and Technology, 2(6) p. 110–127.

[18]. Ademilua LO, Olorunfemi MO, (2000). A Geoelectric/Geologic Estimation of the Groundwater Potential of the Basement Complex area of Ekiti and Ondo States of Nigeria. The Journal of Technoscience, 4: 4-18.

[19]. Oladapo MI, Akintorinwa OJ. (2007). Hydrogeophysical study of Ogbese, southwestern Nigeria. Global Journal of Pure and Applied Science, 13(1) p. 55–61.

[20]. Jayeoba A, Oladunjoye MA, (2013). Hydro-geophysical evaluation of groundwater potential in hard rock terrain of southwestern Nigeria. RMZ – M&G, 60 p. 271–285.

[21]. Sharma SP, Baranwal VC (2005). Delineation of groundwater-bearing fracture zone in a hard rock area integrating Very Low Frequency electromagnetic and resistivity data. Journal of Applied Geophysics, 57 p. 155–166.

[22]. Chatterjee S, Dutta S, (2022). Assessment of groundwater potential zone for sustainable water resource management in south-western part of Birbhum District, West Bengal.

Applied Water Science, 12(3):40. doi:10.1007/s13201-021-01549-4.

[23]. Kedir EG, (2023). Groundwater potential assessment and sustainable management. Environmental monitoring and assessment, 195(7):891. doi:10.1007/s10661-023-11521-1.

[24]. Ajayi OG, Nwadialor IJ, Odumosu JO, Adetunji OO, Abdulwasiu IO, (2022). Assessment and delineation of groundwater potential zones using integrated geospatial techniques and analytic hierarchy process. Appied Water Science, 12(12):276. doi:10.1007/s13201-022-01802-4.

Table 1: Summary of Geoelectric Characteristics

Parameters	Min	Max	Mean	Std. Deviation	Skewness
Anisotropy	1	1.8	1.2	0.2	1.9
Top soil Resistivity	19	304	79.6	68.7	1.7
Top soil Thickness	1.1	8.6	3.9	2.6	0.6
Weathered Basement Resisitivity	16	417	103.27	103.83	1.7
Weathered Basement Thickness	3.2	19.6	10	3.9	0.4
Overburden Thickness	4.3	25.3	14.5	4.7	0.1
Bedrock Resistivity	8	2784	645.6	706.3	2.1

Table 2: Multi-criteria Evaluation parameters for generation of Groundwater potential.

Geoeletric Parameters	Classes	Scale value	Weight
Bedrock Resistivity	<750 750-1500 1500-3000 >3000	4 3 2 1	45
Weathered Basement Resistivity	<20 20-100 100-150 150-300 >300	3 4 3 2 1	30
Overburden Thickness	<10 10-20 20-30 >30	1 2 3 4	25

Table 3: Classification of groundwater potential zones (after integration of thematic layer).

Groundwater Potentiality	Area in (Km^2)	Percentage
Very Low	0.004	0.1
Low	0.18	5.4
Medium	1.85	55.2
High	1.32	39.3

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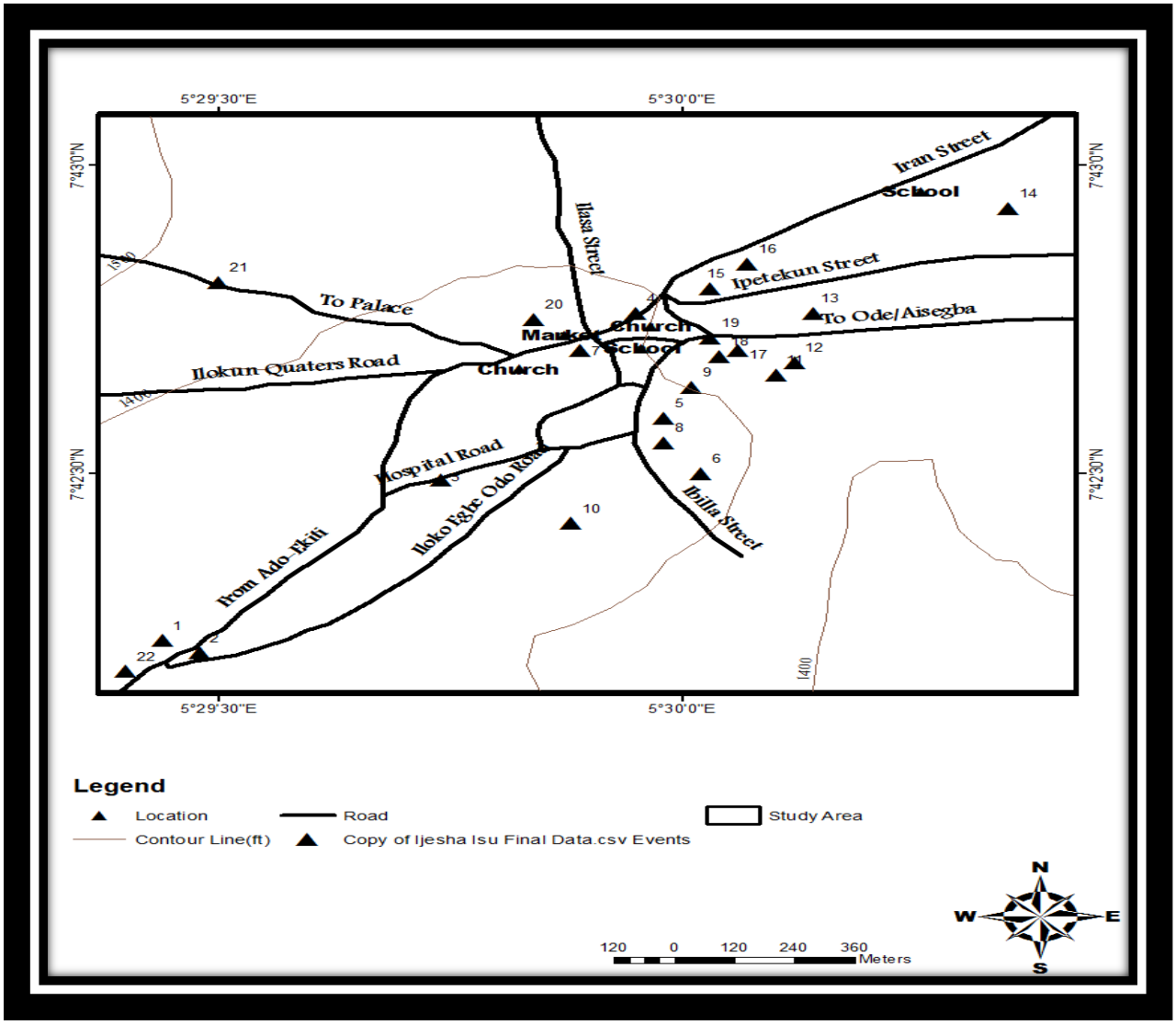

Fig.1: Study Area Map showing the VES Points.

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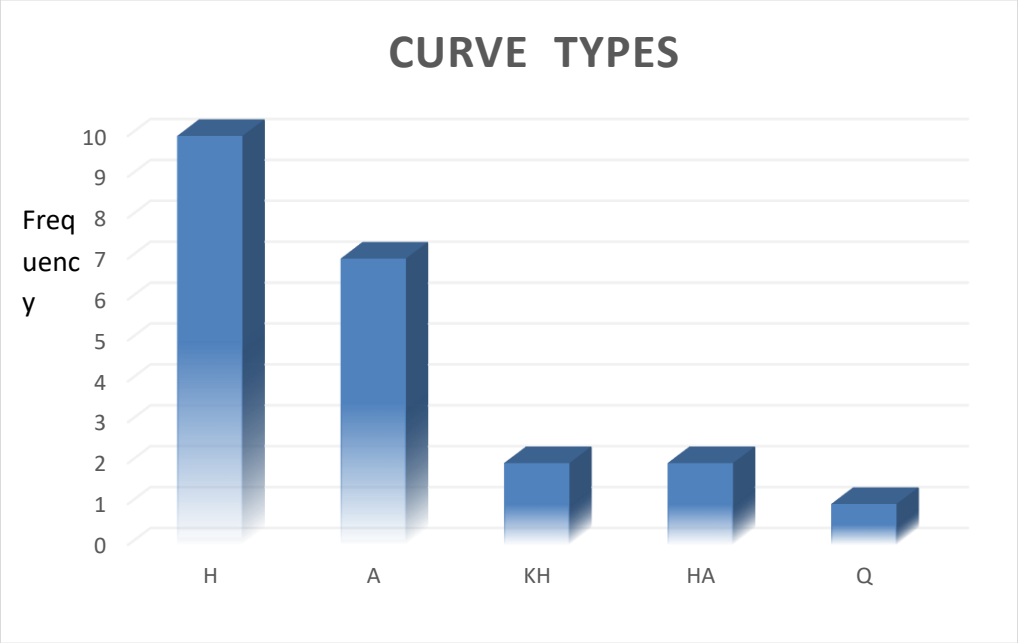

Fig.2: Geoelectric Curve Types.

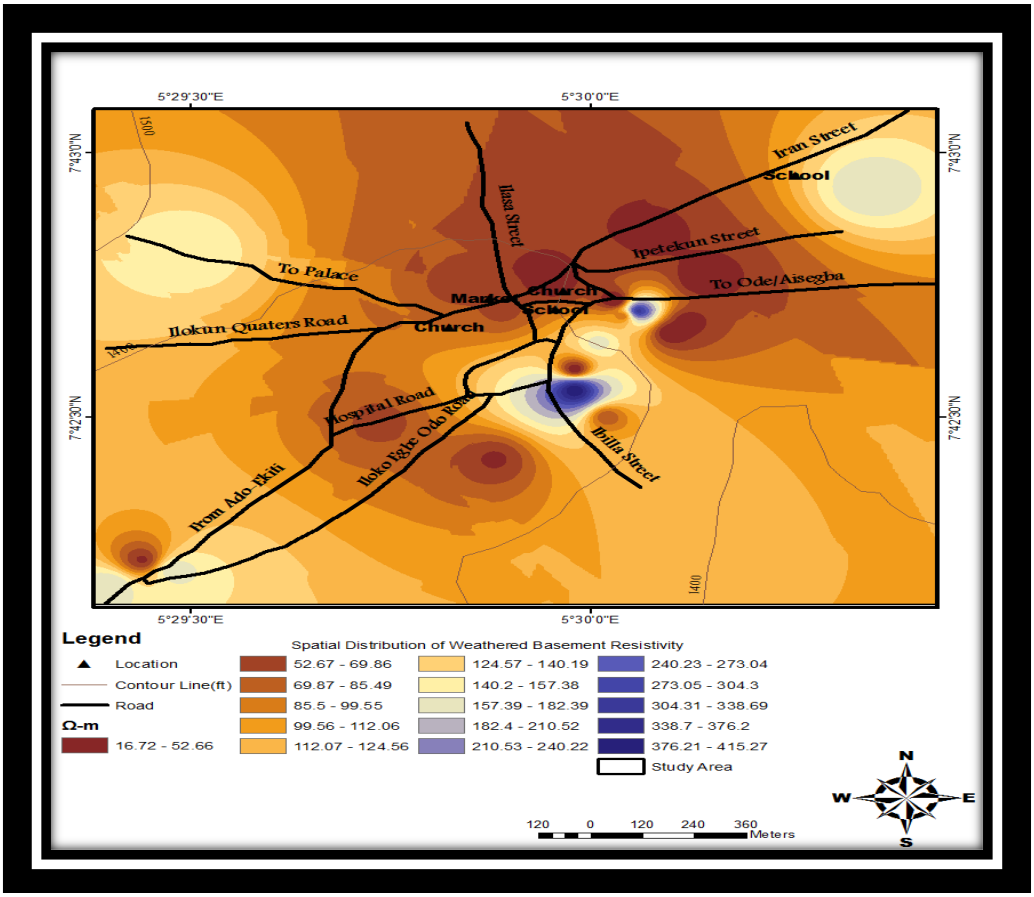

Fig.3: Spatial distribution of Weathered Basement Resistivity.

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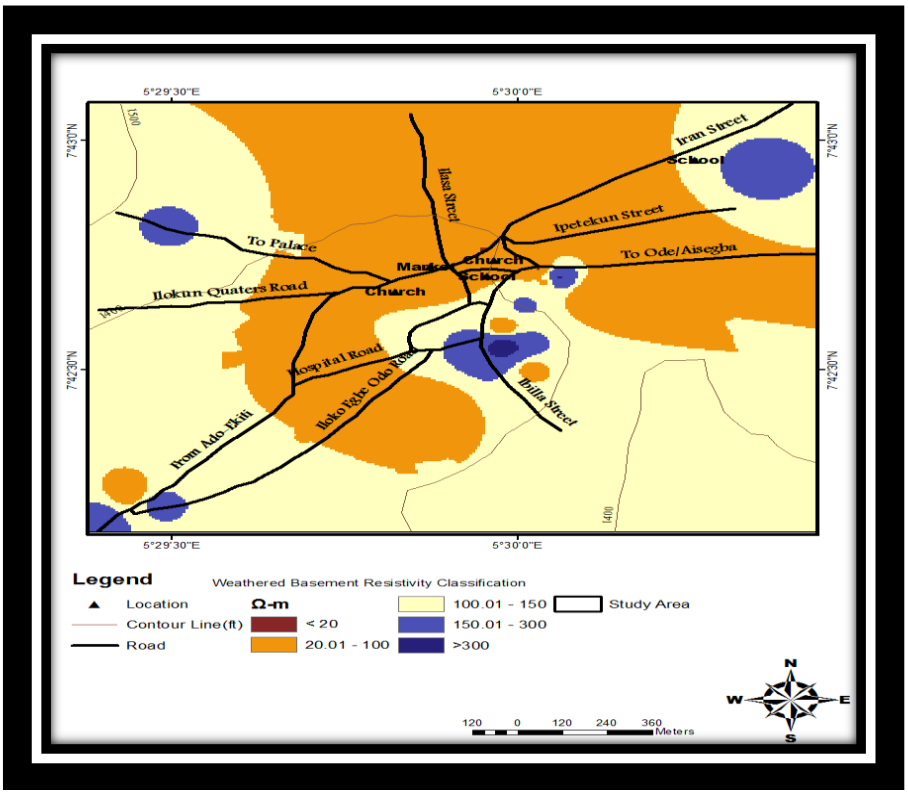

Fig.4: Classification of Weathered Basement Resistivity.

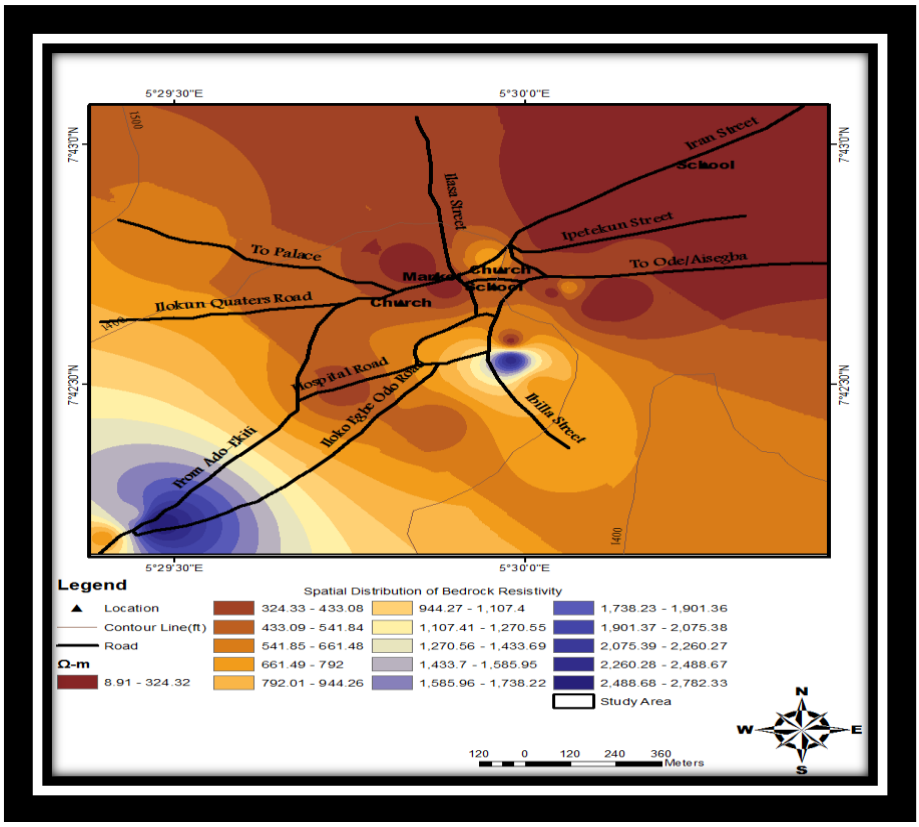

Fig.5: Spatial Distribution of Bedrock Resistivity.

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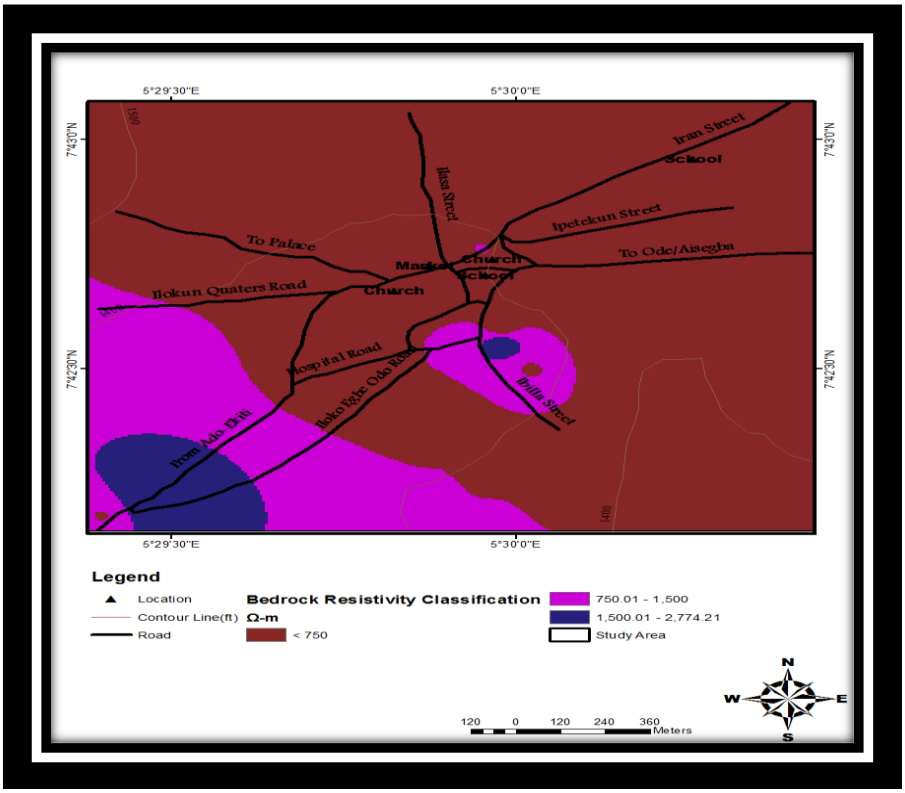

Fig.6: Classification of Bedrock Resistivity.

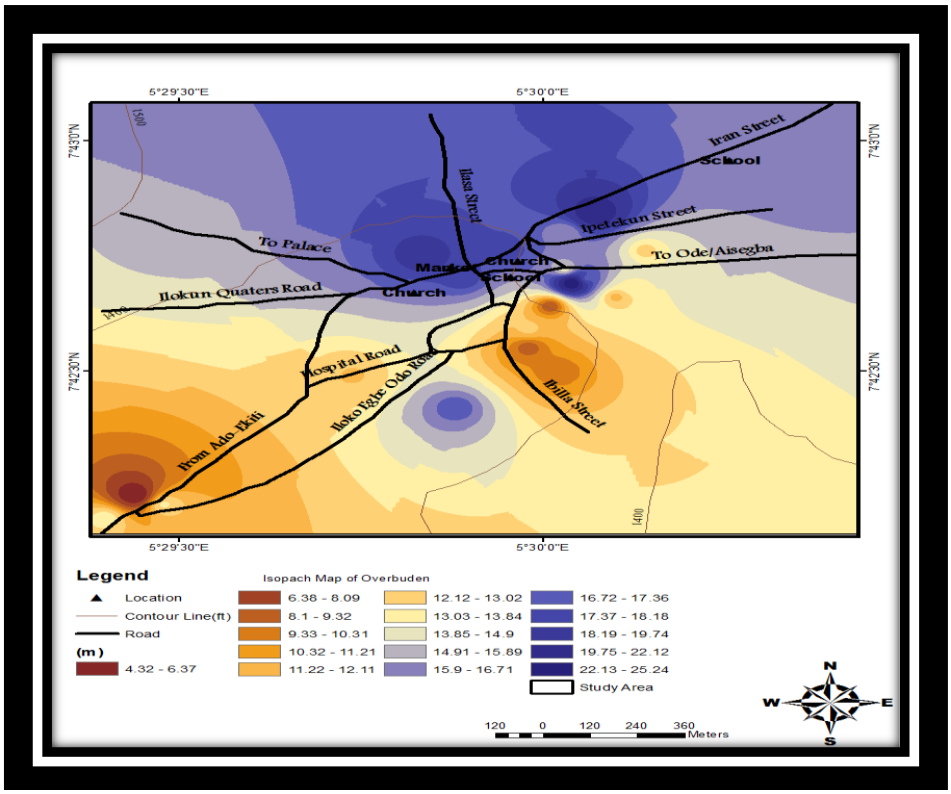

Fig.7: Isopach Map of Overburden.

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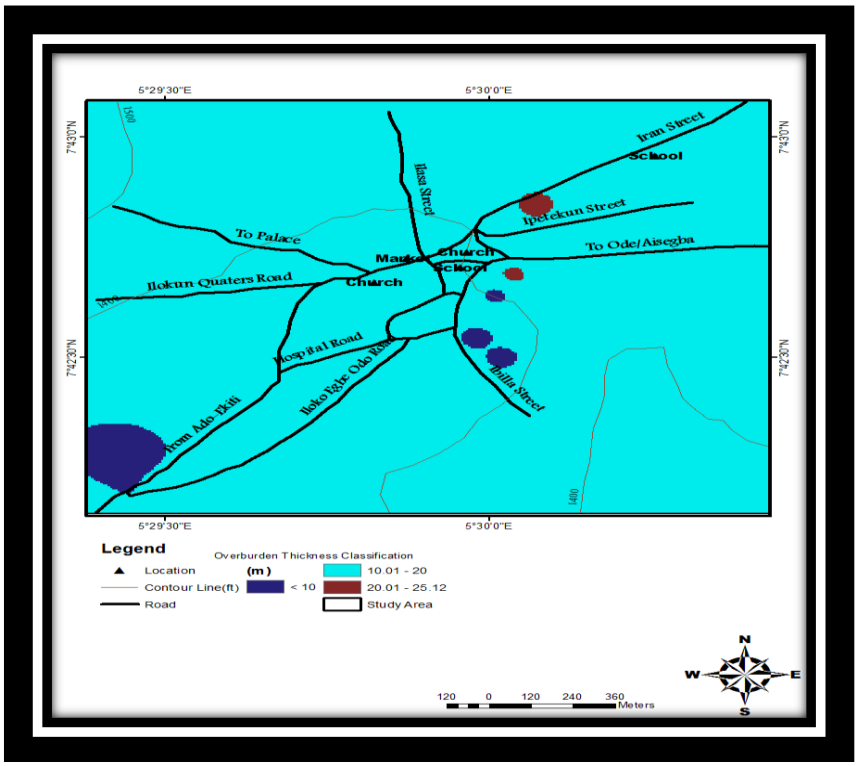

Fig.8: Classification of Overburden Thickness

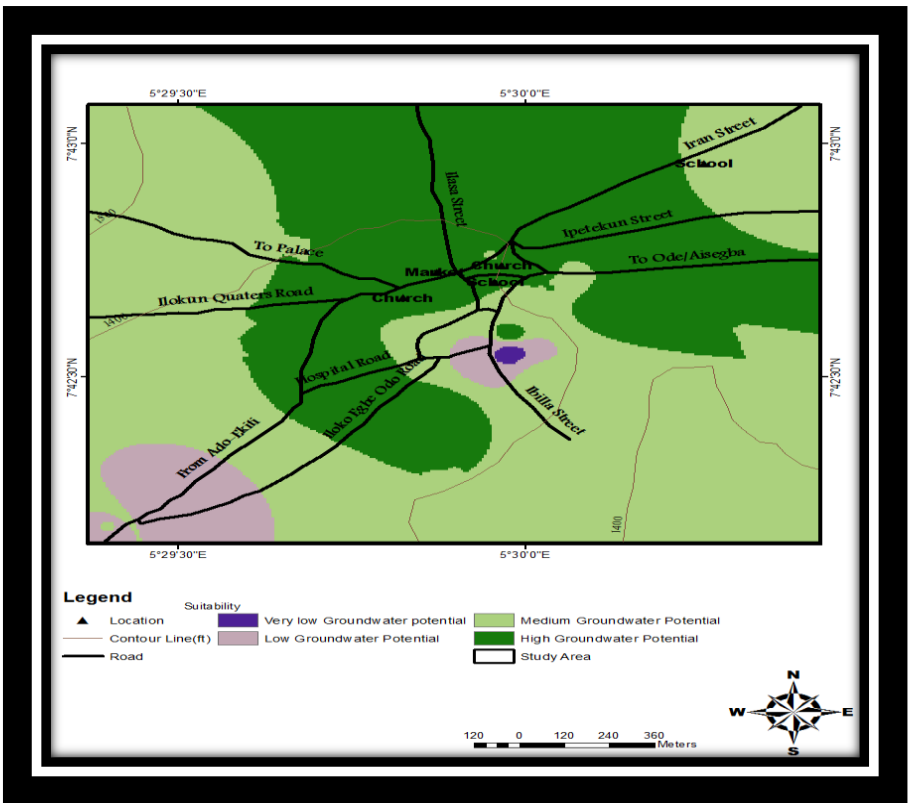

Fig. 9: Groundwater Potential Map of the Study Area.