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GEOPHYSICAL EVALUATION OF THE GROUNDWATER POTENTIAL AND AQUIFER PROTECTIVE CAPACITY IN PART OF OYE-EKITI, SOUTHWESTERN NIGERIA.

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ABSTRACT

Assessment of groundwater potential and aquifer protective capacity in part of Oye-Ekiti, Southwestern Nigeria using the electrical resistivity method of geophysical prospecting was carried out. The study involved Vertical Electrical Sounding (VES) technique using the Schlumberger array with current electrode spacing (AB/2) of 100 m. Thirty-one (31) VES locations were obtained with the aid of ABEM SAS 300 Resistivity Meter and plotted on the double log graph as VES curves. The VES curves were interpreted quantitatively by partial curve matching and assisted by 1-D forward modeling using the WinResist software. The VES interpretation results (layer and thickness) were used to generate maps of the study area. A, K, H, KH, HA, QH, AA, HKH, KQH and AKH-type curves were identified in the area. The overburden thickness ranged from thick (20 to 28 m), moderate (10 to 19.9 m) to low overburden (0 to 9.9 m). The bedrock relief shows areas of moderate/high (530.1 to 558 m) and low reliefs (514 to 530m). The groundwater in the area was categorized into high, moderate and low groundwater potential zones. About 90% of the study area falls within the low/moderate rated groundwater zone while the remaining 10% constituted the high groundwater potential zone. Hence, the groundwater potential rating of the area is considered moderately low. The values of longitudinal conductance (ranging from 0.0155 to 0.2860 mhos) of the area enabled the overburden protective capacity rating into high, fair and poor. About 30% of the area falls within the high protective rating while 70% constitutes the fair/poor protective capacity rating, suggesting that the aquifer system in the study area generally has a moderate/low overburden protective capacity.

Keywords: *Aquifer, Bedrock relief, Groundwater, Overburden thickness, Protective capacity*

INTRODUCTION

Groundwater is the most indispensable natural resource needed for human survival and happens to be a more reliable source of water for more than half the world population (Alabi *et al.,* 2010). It is also the water held in the subsurface within the zone of saturation under hydrostatic pressure below the water table (Ariyo and Banjo, 2008). Groundwater is considered to be of high quality than surface water and is the best for irrigation and drinking around the world (Hoque *et al.,* 2009). Groundwater is stored in and moves slowly through a geologic formation (Sand, gravel, sandstone, limestone and fractured crystalline rocks) that contains sufficient saturated permeable material that can yield significant quantities of water to wells and boreholes called aquifers.

Aquifers in the Precambrian Basement Complex terrain mostly occur at shallow depths, thereby under serious environmental risk, because they are vulnerable to surface or near-surface contaminants (Omosuyi, 2010), while aquifers in sedimentary terrain could also be at risk as well unless they are capped with a thick column of clay. The protection of groundwater reservoir is provided by the overlying layers, also called protective layers or aquitard of low permeability.

An aquifer overlying by poor protective capacity material will qualitatively reflect the natural ability to be contaminated by the anthropogenic or agricultural activities from the surface such as landfill, industrial waste discharge, chemicals, fertilizers, pesticide and herbicide (Mogaji, *et al.,* 2014). Effective groundwater protection is given by protective layers with sufficient thickness and low hydraulic conductivity (Aweto, 2011).

The demand for potable water for human consumption, industrial and agricultural needs is ever increasing especially in a university town like Oye-Ekiti which has witnessed tremendous growth over the years. Some students have been tested positive for the waterborne related diseases since the inceptions of the university. There is a need to determine the groundwater potential and aquifer protective capacity in part of Oye-Ekiti using the electrical resistivity method. This geophysical method has proved their effectiveness over the years in groundwater investigationin the basement complex terrain (Ayolabi *et al.,* 2004; Oladapo and Akintorinwa, 2007; Abiola *et al.,* 2009; Omosuyi and Oseghale, 2012; Oladapo and Ayeni, 2013; Oyedele *et al.,* 2017 and Olaseeni *et al.,* 2019).

DESCRIPTION OF THE STUDY AREA

The study area is located at Oye in Ekiti State. It falls within latitudes N07^{0}48’10.7” to N07^{0}47’59.1” and longitudes E005^{0}19’50” to E005^{0}19’48.3” (Figure 1). The study area falls within the Tropical Rain Forest of southwestern Nigeria with distinct wet and dry seasons. The dry season comes up between November and April while the wet season prevails between May and October (Ngomanda *et al.,* 2009). The study area is underlain by a crystalline rock of the Precambrian Basement Complex of southwestern Nigerian. The major lithologic units in Oye and its environment are granite, migmatite-gneiss and charnockite (Figure 2). They occur in hilly or low-lying form.The study area is accessible through footpaths, few minor roads and two major roads. The major roads serve as the main access for the movement of students and staff within Federal University Oye-Ekiti.

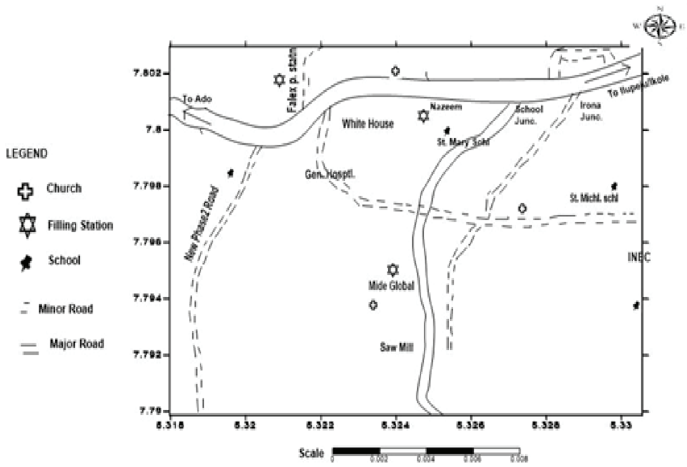


Figure 1: Base Map of the Study Area

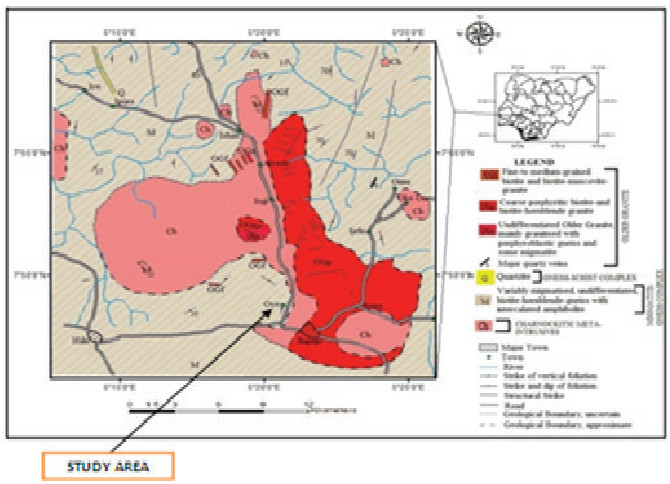


Figure 2: Geological Map of Ekiti State showing the Study Area (Adebayo and Fatoba, 2018)

MATERIALS AND METHODS

Vertical Electrical Sounding (VES) of geophysical technique was carried out using Schlumberger array. The current electrode spread (AB/2) was varied between 1 and 100 m. Thirty-one (31) VES data were acquired (Figure 3). The apparent resistivity values obtained from the data were plotted against their respective current electrode spacing on a log-log graph. The field curves were interpreted by partial curve matching (Orellana and Mooney, 1996), assisted by 1-D forward modelling using WinResist software which reduced the interpretation errors to acceptable levels. The VES interpretation results (layer resistivity and thickness) were used to generate maps. The Dar-

Zarrouk parameter (longitudinal unit conductance) at each VES station was obtained from first-order geoelectric parameters (layer resistivities and thicknesses) using the equation below (Henriet,1975).

$$\sum_{i=1}^{n} \frac{h_i}{\ell_i} \quad \ldots\ldots\ldots\ldots\ldots\ldots 1$$

Where hi is the layer thickness and ℓi is the apparent resistivity of the layer.

The longitudinal unit conductance/protective capacity rating was classified after Adelusi, 2009 as >0.5 (highly protected), 0.1-0.5 (fairly protected), 0.05-0.1 (poorly protected) and <0.05 (highly protected).

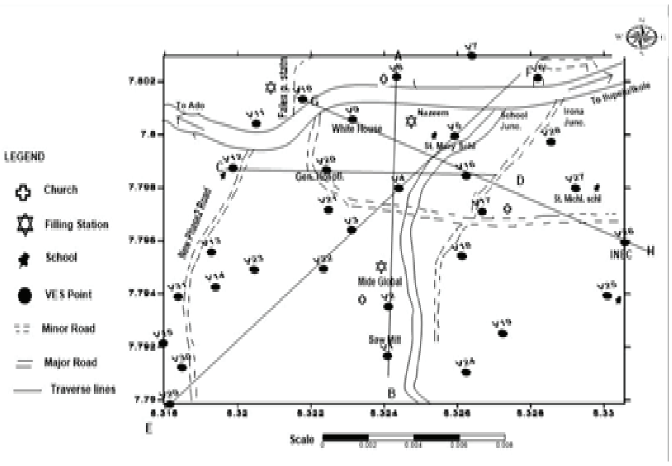
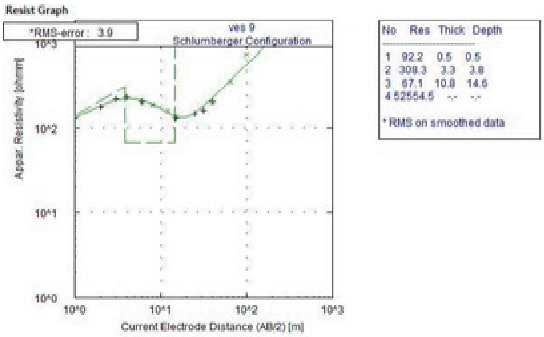


Figure 3: Geophysical Data Acquisition Map

RESULTS AND DISCUSSION

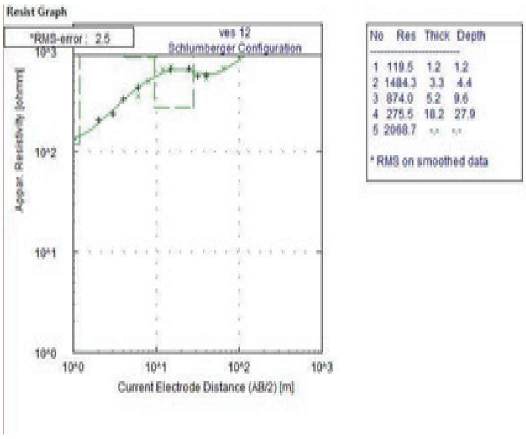
GEOELECTRIC CHARACTERISTICS

VES curves (Figure 4a and 4b) and maps of overburden thickness, bedrock relief, groundwater potential, longitudinal conductance/protective capacity were generated. Different curves obtained from the study area are three-layer (A, K and H), four-layer (KH, HA, QH and AA) to five-layer (KQH, HKH and AKH) type curves. The KH and HKH curves thus propose subsurface geoelectric configurations favorable for groundwater accumulation (Oladapo, 2004). The A-type curves indicate non-permeable zones which are characterized by an increase in the resistivity from topsoil to the bedrock. Geoelectric interpretation results (layer resistivity and thickness) were summarized and presented in Table 1.



KH-curve

Figure 4a: Typical VES Curve from the Study Area



KQH-curve

Figure 4b: Typical VES Curve from the Study Area

Table 1: VES Interpretation Results

VES	VES Curve Type	Layer Number	Resistivity(ohm-m)	Thickness(m)	Depth(m)	Lithology
1	KH	4	170	0.8	0.8	Topsoil
			295	2.0	2.9	Lateritic layer
			95	7.1	9.9	Weathered layer
			2481			Fresh basement
2	KH	4	61	0.6	0.6	Topsoil
			1010	5.0	5.6	Fresh basement
			212	18.1	23.7	Fractured basement
			9200			Fresh basement
3	KH	4	127	1.0	1.0	Topsoil
			537	9.3	10.3	Lateritic layer
			124	11.4	21.8	Weathered layer
			2432			Fresh basement
4	A	3	42	1.5	1.5	Topsoil
			167	21.3	22.8	Weathered layer
			5505			Fresh basement

5	A	3	138	1.6	1.6	Topsoil
			290	20.3	21.9	Weathered layer
			1067			Fresh basement
6	HA	4	175	0.5	0.5	Topsoil
			51	2.4	2.8	Weathered layer
			120	14.9	17.7	Weathered layer
			622			Fresh basement
7	HA	4	58	0.9	0.9	Topsoil
			22	2.1	3.0	Weathered layer
			357	13.2	16.2	Partly weathered layer
			881			Fresh basement
8	A	3	34	1.0	1.0	Topsoil
			60	1.8	2.8	Weathered layer
			1147			Fresh basement
9	KH	4	92	0.5	0.5	Topsoil
			308	3.3	3.8	Lateritic layer
			67	10.8	14.6	Weathered layer
			52555			Fresh basement
10	A	3	108	1.1	1.1	Topsoil
			149	19.5	20.6	Weathered layer
			542			Fresh basement
11	AKH	5	164	1.3	1.3	Topsoil
			278	1.6	2.9	Weathered layer
			773	4.9	7.8	Fresh basement
			98	9.0	16.8	Fractured basement
			3285			Fresh basement
12	KQH	5	120	1.2	1.2	Topsoil
			1484	3.3	4.4	Fresh basement
			874	5.2	9.6	Fresh basement
			276	18.2	27.9	Fractured basement
			2069			Fresh basement
13	KH	4	79	0.3	0.3	Topsoil
			1440	0.7	1.0	Fresh basement
			376	9.3	10.3	Fractured basement
			728			Fresh basement
14	H	3	195	5.2	5.2	Topsoil
			106	1.8	6.9	Weathered layer
			1010			Fresh basement
15	HKH	5	274	1.1	1.1	Topsoil
			211	1.5	2.6	Weathered layer
			1278	5.3	8.0	Fresh basement
			266	19.2	27.2	Fractured basement
			3865			Fresh basement
16	KH	4	68	1.1	1.1	Topsoil
			287	3.1	4.2	Weathered layer
			101	12.9	17.1	Weathered layer
			7425			Fresh basement
17	AA	4	111	1.3	1.3	Topsoil
			338	4.7	6.0	Lateritic layer
			89	6.7	12.6	Weathered layer
			27567			Fresh basement

18	H	3	369	0.8	0.8	Topsoil
			157	5.9	6.7	Weathered layer
			1713			Fresh basement
19	K	3	62	0.3	0.3	Topsoil
			1037	0.9	1.3	Fresh basement
			272			Fractured basement
20	A		131	0.3	0.3	Topsoil
			311	11.7	12.0	Weathered layer
			1743			Fresh basement
21	QH	4	2283	1.1	1.1	Topsoil
			723	7.5	8.6	Lateritic layer
			180	19.1	27.7	Weathered layer
			7088			Fresh basement
22	A	3	32	1.0	1.0	Topsoil
			105	4.4	5.4	Weathered layer
			401			Weathered layer
23	AA	4	212	0.8	0.8	Topsoil
			235	0.9	1.7	Weathered layer
			369	21.4	23.1	Weathered layer
			1056			Fresh basement
24	A	3	81	1.1	1.1	Topsoil
			499	18.1	19.2	Weathered layer
			1868			Fresh basement
25	HA		174	1.0	1.1	Topsoil
			141	6.6	7.6	Weathered layer
			796	17.5	25.1	Laterite
			867			Fresh basement
26	A	3	54	0.9	0.9	Topsoil
			329	17.5	18.4	Weathered layer
			4116			Fresh basement
27	KH	4	251	0.7	0.7	Topsoil
			666	2.9	3.6	Lateritic layer
			107	5.1	8.7	Weathered layer
			2697			Fresh basement
28	A	3	37	0.6	0.6	Topsoil
			168	11.7	12.3	Weathered layer
			2048			Fresh basement
29	KH	4	107	1.0	1.0	Topsoil
			472	1.3	2.3	Lateritic layer
			274	10.1	12.3	Weathered layer
			3095			Fresh basement
30	H	3	323	1.2	1.2	Topsoil
			314	3.7	4.9	Weathered layer
			1035			Fresh basement
31	A	3	41	1.0	1.0	Topsoil
			121	5.0	5.0	Weathered layer
			460			Weathered layer

OVERBURDEN THICKNESS MAP

The overburden thickness of the study area varies between 0 and 28 m (Fig. 5). The map showed that the northwestern part (VES 3, 4, 5, 12, 21 and 23) and the area around VES 2 and 25 of the study area are associated with high overburden thickness that is greater than 20 m. Materials overlying the bedrock around VES 8, 14, 18, 19, 22, 27, 30 and 31 have thin overburden. The remaining parts of the study area are underlain by moderate overburden thickness (10 – 19.9 m). The moderate overburden thickness characterizing the study area implies moderate groundwater storage capacity therefore suggesting moderate to low groundwater potential of the study area.

BEDROCK RELIEF MAP

The bedrock map shows the relief of the bedrock of the area (Fig. 6). The eastern and western parts of the study area indicate low bedrock relief (514 to 530 m) and moderate to high bedrock relief ranging from 530.1 to 558 m are observed in the remaining parts of the study area. The groundwater water accumulation in this study area tends towards low relief regions.

GROUNDWATER POTENTIAL MAP

The groundwater resources of the study area are classified into high, moderate, and low potential zones (Fig. 7). In this study, zones where overburden thickness is greater than 20 m and of low bedrock relief are considered zones of high groundwater potentials. The western parts of the study area constitute the high and low potential zones. The remaining parts of the study area are classified under a moderate groundwater potential zone. It was observed that about 90% of the area falls within the moderate/low groundwater potential rating while only about 10% constitutes the high potential rating. This suggests a moderately low groundwater prospect of the study area.

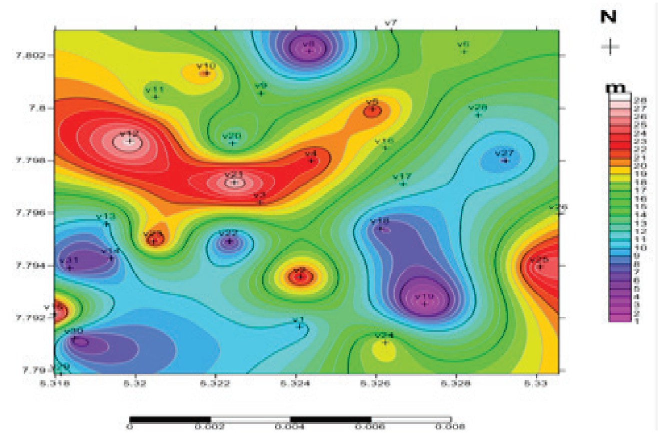


Figure 5: Overburden Isopach Map

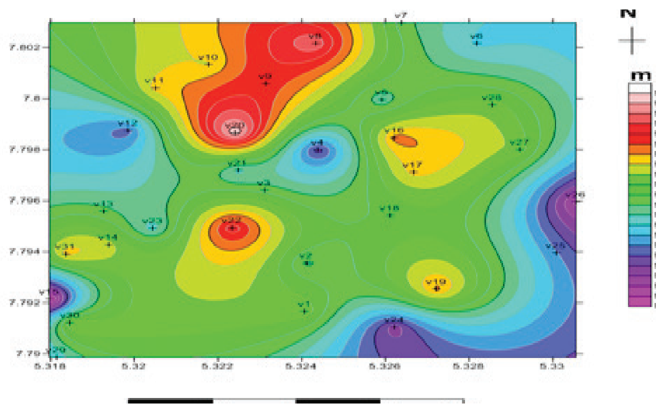


Figure 6: Bedrock Relief Map

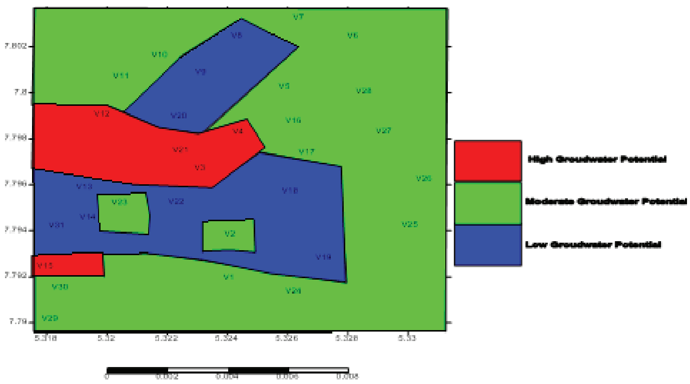


Figure 7: Groundwater Potential Map

AQUIFER PROTECTIVE CAPACITY EVALUATION

The characteristic longitudinal unit conductance map (Figure 8) prepared from equation 1, was used for the overburden protective capacity rating of the study area. The total longitudinal unit conductance values can be utilized in evaluating overburden protective capacity in an area (Olorunfemi *et al.*, 1999). The longitudinal unit conductance (S) values obtained from the study area, ranging from 0.0155 to 0.2860 mhos. The protective capacity rating was done with reference to the classification of Adelusi, 2009 in table 2. The southern and western parts of the area have high protective capacity rating with longitudinal unit conductance from 0 - 0.04 mhos while other portions of the area are fairly to poorly protected. The protective capacity rating map further reveals that about 30% of the area falls within the high protective capacity rating, 10% falls within the poor protective capacity rating, 60% of the area falls within the fair protective capacity rating.

Table 2 longitudinal unit conductance/protective capacity rating after Adelusi, 2009

Longitudinal unit conductance (mhos)	Protective capacity rating
>0.5	Highly protected (clay)
0.1-0.5	Fairly protected
0.05-0.1	Poorly protected
<0.05	Highly protected (laterite)

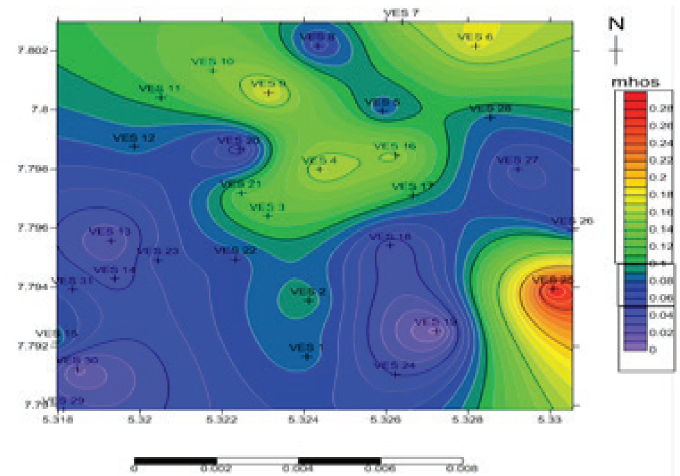


Figure 8: Longitudinal Unit Conductance Map/ Protective Capacity Map of the Study Area

CONCLUSION

The electrical resistivity survey was carried out in some areas in Oye-Ekiti, Ekiti State, Southwestern, Nigeria. This was done to evaluate the groundwater potential and aquifer protective capacity of the area. The overburden thickness varies from 0 - 28 m where depth greater than 10 m and medium bedrock relief constitutes about 85% of the area. This indicates a moderate/low groundwater potential of the study area. Based on the longitudinal unit conductance, the study area has a poor protective capacity (10%), fair protective capacity (60%), and high protective capacity (30%). This indicates that the overburdens in the area are made up of pervious geologic materials through which surface and near-surface contaminants can infiltrate. Hence, the aquifer in the area is vulnerable to the surface and near-surface contaminants. Groundwater development in the study area must be planned around the zones of high aquifer protective capacity to avoid contamination from sources such as septic tanks and petroleum tanks.

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