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PROTECTIVE CAPACITY ASSESSMENT OF A SHALLOW AQUIFER AT THE EASTERN PART OF ADO-EKITI, SOUTHWESTERN NIGERIA

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ABSTRACT

Vertical Electrical Soundings (VES) survey has been undertaken at the eastern part of Ado-Ekiti, southwestern Nigeria to assess the aquifer protective capacity of the overburden units of the area. The Schlumberger electrode array was adopted with a maximum current electrode spread (AB) of 300 m. Thirty-six (36) VES points was occupied and processed through a partial curve matching technique and 1-D forward modeling computer-assisted software. The interpretation revealed H, A, KH and HA-type curves and three major geoelectric layers overlying the resistive basement. The groundwater potential and overburden protective capacity maps were prepared. The groundwater in the area was categorized into high, medium and low groundwater potential zones. About 80% of the study area falls within the moderate/low groundwater potential zone while the remaining 20% constituted the high groundwater potential zone (Agric Olope area). Hence, the groundwater potential rating of other areas is considered to be low. The values of longitudinal conductance (ranging from 0.01 to 2.01 mhos) of the area enabled the overburden units to be rated into good, moderate and weak protective capacity. About 75% of the area falls within the good/moderate rating while 25% constitutes the weak/poor protective capacity rating (Agric Olope area), suggesting that the groundwater around Agric Olope is vulnerable to contamination.

Keywords: Electrode array, Basement, Geoelectric layer, Longitudinal conductance, Overburden units.

INTRODUCTION

Humans largely depend on the availability and accessibility of clean water resources in close proximity to each settled locality as it is one of the vital necessities of life (Omarova *et al.,* 2019). Water can exist as surface water which includes rivers, lakes, reservoir and ocean or groundwater which can be obtained from natural springs, well and boreholes (Carrard *et al.,* 2019). Many nations rely profoundly on groundwater asa primary source of drinking water and utilize it for agricultural and industrial purposes (Naomi *et al.,* 2019). Therefore, groundwater is a vital natural resource which aids the socio-economic development of a nation. Groundwater refers to water occupying the voids or pores within a geologic structure, which is typically free from suspended matter and organisms. It is believed to be of higher quality and portability than surface water (Hoque *et al.*, 2009). Groundwater is stored in and moves through layers of soil and rocks within the saturated zones of geologic units called aquifers (Hoque *et al.,* 2009)

Globally, some people face severe water shortages as groundwater is depleted faster than it is naturally replenished, or as a result of pollution via human activities such as landfills, septic tanks, leakages of underground gas tanks and from overuse of fertilizers and pesticides (Olaseeni *et al.*, 2020; Olaseeni *et al.,* 2021). The latter is prevalent where material above the aquifer is permeable, allowing pollutants to sink into the groundwater.

Geophysics utilizes various techniques including gravity, seismic reflection and refraction, radiometric, magnetic, electromagnetic and electrical resistivity methods to investigate innumerable aspects of groundwater systems (Keary and Brooks, 1999; and Ademilua and Eluwole, 2014). Electrical resistivity method is the most frequently used because of the availability and low cost implication.

Aquifer protection is therefore indispensable for a sustainable management and use of groundwater resources, proper location of infrastructures and the protection of the dependent ecosystems (Olorunfemi *et al.,* 1999).

Eastern part of Ado is made of various communities among which are Ita-Oku, Agric Olope and New Secretariat among others. Agric Olope area with shallow aquifer system is prone to contamination from the surface or near surface. Dwellers of Ita-Oku and its environs are having groundwater challenges due to shallow basement and depend on the Agric Olope area with shallow water table for their water supply. Hence, the shallow aquifer must be guided against contamination in order to improve the health status of the dwellers of those communities.

Description and Geology of the Study Area

The study area is located in Ado-Ekiti, the state capital of Ekiti State. It lies within Latitudes N 7.58^{o} and N 7.62^{o}and Longitudes E 5.21^{o} and E 5.26^{o} (Figure 1). The relief of the study area is a low-land surrounded by several isolated hills and the topography of the area is rugged due to the presence of crystalline basement rocks. The dry season occurs between November and March and wet season lasts between April and October, with July and September recording the highest rainfall. The study area is accessible through various foot paths and access roads .The study area lies within the Precambrian Basement Complex rock of Southwestern Nigeria (Rahaman, 1988); and is underlain principally by Migmatite-Gneiss (Figure 2)

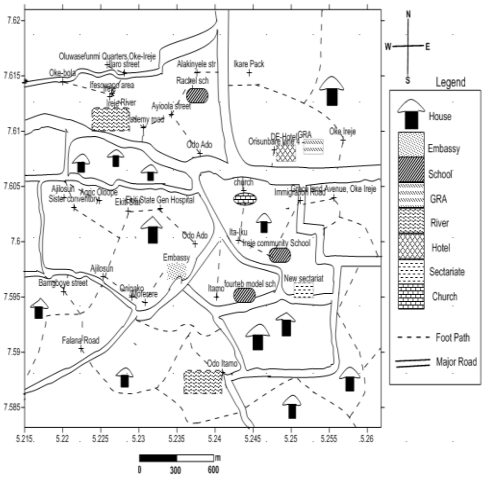


Figure 1: Base Map of the study area

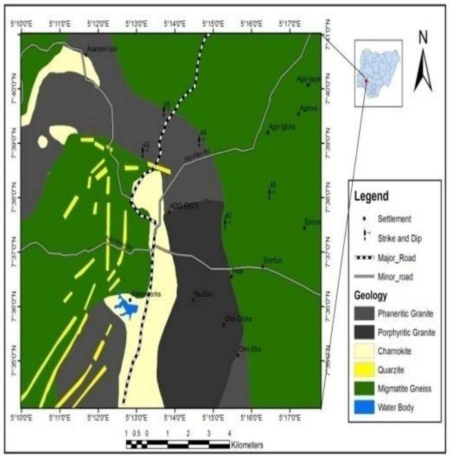


Figure 2:Geological Map of Ado-Ekiti [NGSA, 2006

METHODOLOGY

Electrical resistivity data were acquired within the study area using ABEM Resistivity meter (SAS 300). Thirty Six (36) VES stations were occupied within the study area with Vertical Electrical Sounding (VES) technique using schlumberger electrode configuration (Figure 3). The plot of apparent resistivity against the half-current electrode spacing (AB/2) on a log-log scale was interpreted qualitatively by partial curve matching. The field data was refined by computer iteration (1-D forward modelling) using WinRESIST software. Dar-Zarrouk parameters (longitudinal unit conductance (S) and transverse unit resistance (T)) were obtained from the geoelectric parameters and used for protective measure. The earth subsurface acts as a natural filter to percolating fluid. Hence, its ability to retardand filter percolating ground surface polluting fluid is a measure of its protective capacity (Olorunfemi *et al*.1999). For n layers, the total longitudinal unit conductance and transverse unit resistance are given as:

$$S = \sum_{n=0}^{i} hi/\rho i \qquad (1)$$

$$T = \sum_{n=0}^{i} hi\,\rho i \qquad (2)$$

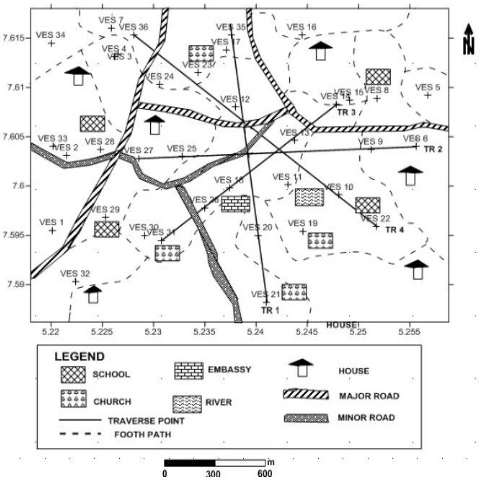
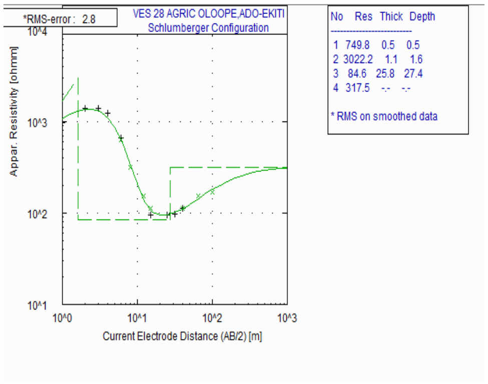


Figure 3: Data Acquisition Map from the Study Area

RESULTS AND DISCUSSION

Vertical Electrical Sounding (VES) Curve Types

The VES curve types identified within the study area vary from three layers (H-type) curve to four layers (KH-type) shown in figures 4 and 5. Table 1 depicts the results of the VES, its interpretation and presumed geological sequences. From the frequency distribution of the curve types (Figure 7), it could be observed that the H-type curve is the most dominant accounting for about 69.4%.



No	Res	Thick	Depth
1	749.8	0.5	0.5
2	3022.2	1.1	1.6
3	84.6	25.8	27.4
4	317.5	-.-	-.-

* RMS on smoothed data

Figure 4: Typical VES curve (KH-type) from the study area.

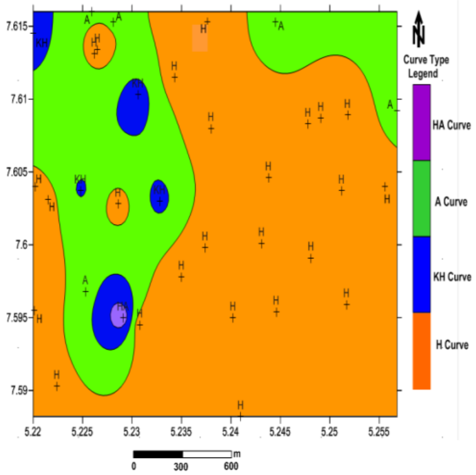


Figure 5: Curve types distribution map of the study area.

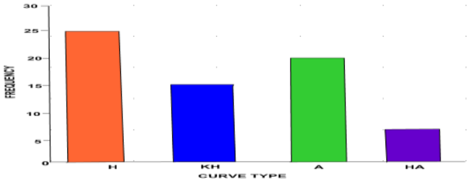


Figure 6: Frequency distribution of the curve types

Table 1: Table showing VES data Interpretation and Lithological Equivalence.

VES NO	RESISTIVITY (Ωm)	THICKNESS(m)	DEPTH(m)	CURVE TYPE	LITHOLOGICAL CHARACTERISTICS
1	136	0.8	0.8	H	Topsoil
	63	11.3	12.1		Weathered layer
	281	---	---		Partly Weathered Basement
2	227	0.8	0.8	H	Topsoil
	49	2.8	3.7		Weathered layer
	319	---	---		Partly Weathered Basement
3	161	0.8	0.8	H	Topsoil
	110	8.0	8.8		Weathered layer
	444	---	---		Partly Weathered Basement
4	273	0.8	0.8	H	Topsoil
	126	23.6	24.4		Weathered layer
	569	---	---		Partly Weathered Basement
5	100	0.6	0.6	A	Topsoil
	234	8.0	8.6		Weathered layer
	8423	---	---		Fresh basement
6	217	2.8	2.8	H	Topsoil
	19	5.8	8.6		Weathered layer
	1154	---	---		Fresh basement
7	45	1.3	1.3	A	Topsoil
	71	8.4	9.7		Weathered layer
	135	---	---		Partly Weathered Basement
8	156	1.3	1.3	H	Topsoil
	55	7.4	8.7		Weathered layer
	929	---	---		Fresh basement
9	52	1.5	1.5	H	Topsoil
	13	27.2	28.7		Weathered layer
	138	---	---		Fresh basement
10	46	1.0	1.0	H	Topsoil
	11	3.2	4.2		Weathered layer
	1633	---	---		Fresh basement
11	55	1.6	1.6	H	Topsoil
	9	7.0	8.5		Weathered layer
	901	---	---		Fresh basement
12	53	0.7	0.7	H	Topsoil
	25	5.3	6.1		Weathered layer
	750	---	---		Fresh basement
13	54	1.5	1.5	H	Topsoil
	31	5.5	7.0		Weathered layer
	374	---	---		Partly Weathered Basement
14	172	0.7	0.7	H	Topsoil
	59	3.4	4.1		Weathered layer
	3740	---	---		Fresh basement
15	164	0.6	0.6	H	Topsoil
	29	7.2	7.8		Weathered layer
	845	---	---		Fresh basement
16	22	1.0	1.0	A	Topsoil
	26	7.5	8.5		Weathered layer
	807	---	---		Fresh basement
17	35	0.8	0.8	A	Topsoil
	43	9.7	10.6		Weathered layer
	1379	---	---		Fresh basement
18	110	0.8	0.8	H	Topsoil
	10	3.0	3.8		Weathered layer
	821	---	---		Fresh basement
19	445	1.3	1.3	H	Topsoil
	21	3.7	5.0		Weathered layer
	6865	---	---		Fresh basement
20	234	0.8	0.8	H	Topsoil
	6	2.2	2.9		Weathered layer
	2194	---	---		Fresh basement
21	77	0.9	0.9	H	Topsoil
	7	4.2	5.1		Weathered layer
	576	---	---		Fresh basement

22	323	1.1	1.1	H	Topsoil
	18	4.0	5.2		Weathered layer
	1627	---	---		Fresh basement
23	44	1.1	1.1	H	Topsoil
	12	17.8	18.9		Weathered layer
	191	---	---		Fresh basement
24	27	0.6	0.6	KH	Topsoil
	143	1.3	2.0		Laterite
	15	5.8	7.8		Weathered layer
	353	---	---		Fresh basement
25	157	0.6	0.6	KH	Topsoil
	617	0.7	1.3		Weathered layer
	43	4.2	5.5		Fractured layer
	455	---	---		Fresh basement
26	83	0.8	0.8	H	Topsoil
	15	2.8	3.5		Weathered layer
	358	---	---		Fresh basement
27	602	0.8	0.8	H	Topsoil
	249	7.4	8.3		Weathered layer
	2894	---	---		Fresh basement
28	750	0.5	0.5	KH	Topsoil
	3022	1.1	1.6		Laterite
	85	25.8	27.4		Weathered layer
	318	---	---		Partly Weathered Basement
29	62	1.6	1.6	A	Topsoil
	64	9.9	11.4		Weathered layer
	244	---	---		Partly Weathered Basement
30	82	1.1	1.1	HA	Topsoil
	45	2.0	3.1		Partly fractured layer
	383	2.4	5.5		Weathered layer
	10207	---	---		Fresh basement
31	108	1.6	1.6	H	Topsoil
	30	5.6	7.2		Weathered layer
	695	---	---		Partly Weathered Basement
32	151	1.0	1.0	H	Topsoil
	57	5.3	6.3		Weathered layer
	267	---	---		Partly Weathered Basement
33	563	0.7	0.7	H	Top soil
	117	8.9	9.6		Weathered layer
	5555	---	---		Fresh basement
34	65	0.8	0.8	KH	Topsoil
	167	1.8	2.6		Laterite
	28	6.4	9.0		Weathered layer
	350	---	---		Fresh basement
35	130	1.3	1.3	H	Topsoil
	24	12.3	13.6		Weathered layer
	2136	---	---		Fresh basement
36	12	4.1	4.1	A	Topsoil
	18	4.4	8.4		Weathered layer
	323	---	---		Fresh basement

GROUNDWATER POTENTIAL EVALUATION

The observed weathered layer thickness (Figure 7) and nature of the weathered layer resistivity (Figure 8) are important parameters in the groundwater potential evaluation of a basement complex terrain. Weathered layer thickness ranges from 2 to 27 m and weathered layer resistivity ranges from 10 to 400 Ωm across the study area. The groundwater prospects of the study area are zoned into high, moderate and low potentials (Figure 9). In this study, zones where thickness of the aquifer is greater than 10 m and of low clay content (average resistivity values between 100 and 300 Ohm-m) are considered zones of high groundwater potentials.

Areas with VES 3, 4, 5, 27 and 28 constitute the high groundwater potential zones (Agric Olope area). Moderate groundwater potential zones are classified in areas with VES 1, 2, 7, 8, 12, 13, 14, 15, 19, 29, 30, 31, 32 and 33 while VES 6, 9, 10, 11, 17, 18, 20, 21, 22, 23, 24, 25, 26, 35 and 36,fall within the low groundwater potential rating.

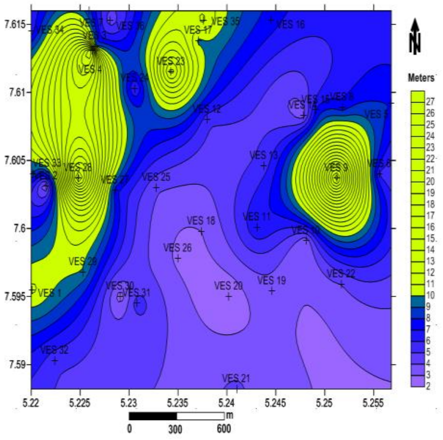


Figure 7: Weathered layer thickness map from the study area

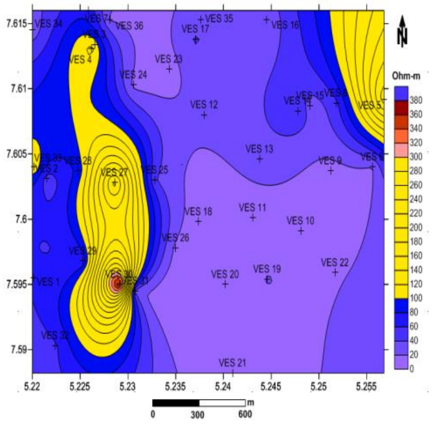


Figure 8: Weathered layer Resistivity map of the study area

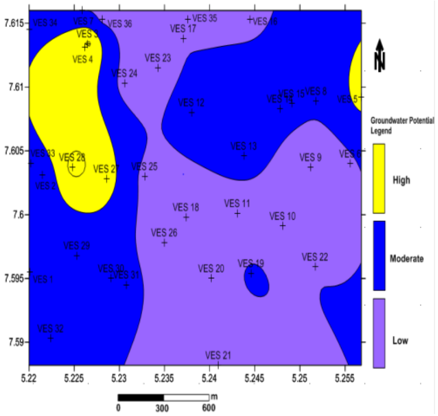


Figure 9: Groundwater potential map of the study area

PROTECTIVE CAPACITY EVALUATION

Longitudinal unit conductance(S) and transverse unit resistance (T) obtained from the geoelectric layer parameters were used to determine the overburden protective capacity of the aquifer in the region. The values of longitudinal conductance(S) obtained from the study area range from 0.03 to 2.09 mhos (Figure 10).

According to Oladapo and Akintorinwa (2007) in Table 2, the protective capacity of the overburden could be zoned into excellent, good, moderate, weak and poor protective capacity. Zones where the conductance is greater than 10 mhos are considered as zones of excellent protective capacity.

Table 2: Longitudinal Conductance/Protective capacity rating (Oladapo and Akintorinwa, 2007)

Longitudinal Conductance (S) (mhos)	**Protective Capacity Rating**
>10	Excellent
5-10	Very good
0.7-4.9	Good
0.2-0.69	Moderate
0.1-0.19	Weak
<0.1	Poor

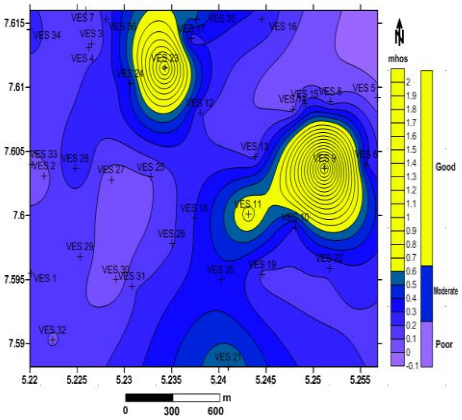


Figure 10: Longitudinal Conductance map of the study area

The highly impervious clayey overburden, which is characterized by relatively high longitudinal conductance and moderate to low transverse resistance ((Figure 11) offers protection to the underling aquifer (Figure 12).

The protective capacity of the study area is rated into good, moderate and weak protective capacity. About 75% of the area falls within the good/moderate rating while 25% constitutes the weak/poor protective capacity rating and fall within Agric Olope area

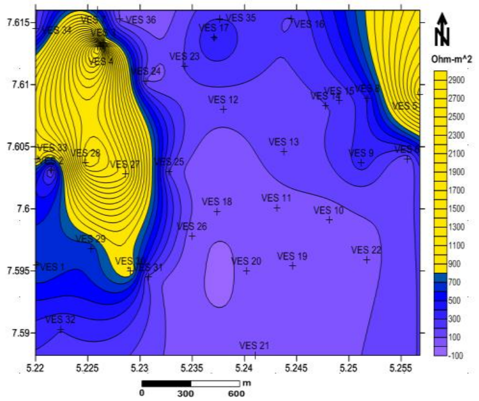


Figure 11: Transverse resistance map of the study area

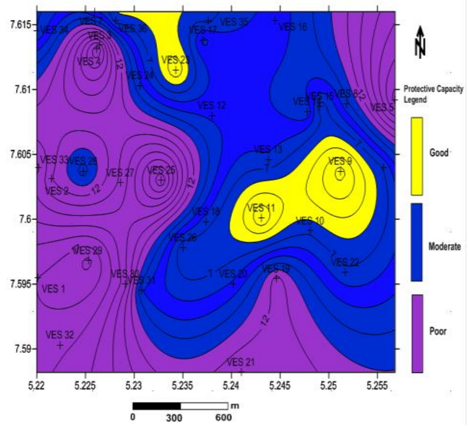


Figure 12: Overburden Protective Capacity map of the study area.

CONCLUSION

In this study, the protective capacity evaluation of the rock units around Agric Olope, Ado-Ekiti, southwestern Nigeria was undertaken using 36 Schlumberger Vertical Electrical Soundings (VES). The curve type varied from simple three-layer A and H-types to four-layer KH and HA. VES interpretation revealed subsurface sequence composing of topsoil, weathered layer, partially weathered/fractured basement and the fresh basement. The weathered layer constituted the aquifer unit in the area.

About 80% of the study area falls within the low/moderate ground water potential zone while Agric Olope area (remaining 20%) constituted the high groundwater potential zone.

The groundwater in Agric Olope area is of weak protective capacity (about 25%) and therefore vulnerable to pollution.

Alternative source of water should be made available for the Agric Olope area.

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