GLOBAL JOURNAL OF PURE AND APPLIED SCIENCES VOL. 13 NO. 1 , JANUARY, 2007 : 55 - 61
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HYDROGEOPHYSICAL STUDY OF OGBESE SOUTH WESTERN NIGERIA

M. I. OLADAPO and O. J. AKINTORINWA

(Received 8 October, 2004; Revision Accepted 3 January, 2006)

ABSTRACT

A hydrogeological study of Ogbese town in Ondo State Southwestern Nigeria has been undertaken in this study. Twenty-nine (29) Schlumberger electrical soundings (VES) were carried out with the aim of establishing the groundwater potential of the area. The Precambrian basement complex of Southwestern Nigeria underlies the area with the local geology being essentially granite-gneiss and migmatite. The computer-assisted sounding interpretation revealed two distinct geoelectric layers overlying highly resistive basement. These include the topsoil and the weathered layer. The isopach map of the overburden shows depth to the bedrock, which varies from 3m to 27m. The relatively thick overburden areas (>15m) were marked T1 and T2. The weathered layer, which is relatively thin with high clay content, constitutes the aquifer units, hence, the groundwater potential of the area is considered to be of low rating.

The overburden coefficient of anisotropy (λ) values of the area varies from 1.00 to 1.60. The area underlain by migmatite is characterized by relatively high λ values (> 1.3); while the areas underlain by the gneisses are characterized by relatively low λ values (≤ 1.3). The relatively high λ values for migmatite can be explained in term of its broad lithological differentiation.

The characteristic longitudinal conductance (Range from 0.001mhos to 0.353mhos) of the area enabled the rating of the overburden protective capacity into moderate, weak and poor. About 70% of the area falls within the weak/poor rating, this suggests a generally weak overburden protective capacity around the study area.

KEYWORDS: Sounding, geoelectric, isopach, coefficient of anisotropy, protective capacity and longitudinal conductance

INTRODUCTION

The successful exploitation of basement terrain groundwater requires a proper understanding of its geo-hydrological characteristics. This is particularly important in view of the discontinuous (localized) nature of basement aquifers (Satpatty and Kanungo, 1976). Hence, drilling programmes for groundwater development in areas of basement terrain are generally preceded by detailed geophysical investigations.

The study area is underlain by Precambrian Basement Complex rocks. These rocks are inherently characterized by low porosity and near negligible permeability. However, groundwater occurs either in the weathered mantle or in the joint and fracture systems in the un-weathered rocks (Olorunfemi and Olorunniwo, 1985; Ako and Olorunfemi, 1989, Olayinka and Olorunfemi, 1992). The highest groundwater yield in basement terrains is found in areas where thick overburden overlies fractured zones (Olorunfemi and Fasuyi, 1993). These zones are often characterized by relatively low resistivity values. Consequent upon the above, a detailed geoelectric survey covering Ogbese area of Ondo State, southwestern part of Nigeria has been carried out with an intent to determine the geoelectric parameters (layer resistivities and thicknesses) of the subsurface layers and their hydro geologic implications. The study is also aimed at evaluating the groundwater potential of the area and establishing the aquifer protection capacity of the overlying formation.

Ogbese area is without pipe borne water, hence, the source of water is essentially groundwater. It is highly important therefore to have the hydrogeophysical knowledge of the area for future planning of groundwater development for public use.

GEOMORPHOLOGY, GEOLOGY AND HYDROGEOLOGY OF THE AREA

The study area, which is situated on a major Federal highway linking the western part of the country to the North and Eastern parts, is presented in Fig 1. It is located between latitudes 7° 12 2'N and 7° 14 8'N and between longitudes 5° 19'E

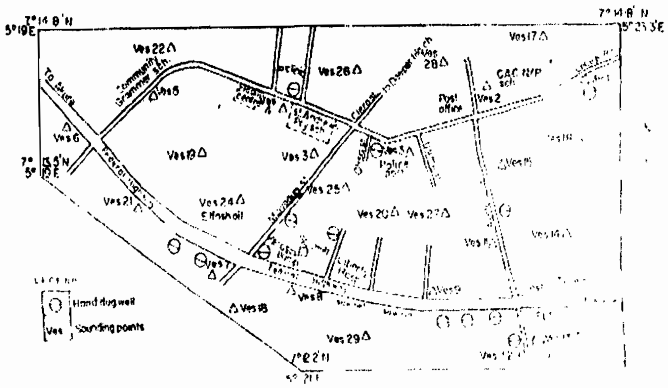

Figure 1: Location map of study area showing the VES stations

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M. I. Oladapo, Department of Applied Geophysics, Federal University of Technology, P. M. B. 704, Akure, Nigeria.
O. J. Akintorinwa, Department of Applied Geophysics, Federal University of Technology, P. M. B. 704, Akure, Nigeria.

and 5° 23.2'E. The town is situated about 20km east of Akure town.

The essentials of the geology of the study area are shown in Fig. 2. The area is underlain by basement complex rocks, which include granite-gneiss and migmatite. The bedrock is shallow at the northeastern end of the area, as shown in the near surface and surface outcropping of the bedrock. The topography of the area is relatively flat and it is thickly vegetated. The groundwater is primarily recharged by precipitation of rain water.

River Ogbese, which is the major river in the area, flows in an approximately North-South direction. The area experiences high annual rainfall and hence there is constant recharge of the groundwater.

METHOD OF STUDY

The electrical resistivity method involving vertical electrical sounding (VES) technique was utilized for the study. Schlumberger electrode configuration with current electrode (AB) spacing varying from 1 to 130m was adopted. Twenty-nine (29) VES stations were occupied as shown in Fig 1. Ground resistance measurements were made with the R-50 resistivity meter. The typical VES curves obtained from the study area are shown in Fig. 3.

The curves were quantitatively interpreted by partial curve matching using two layer model curves and the corresponding auxiliary curves. The field curves were iterated using a computer algorithm, RESIST version 1.0 (Vander Velper, 1988).

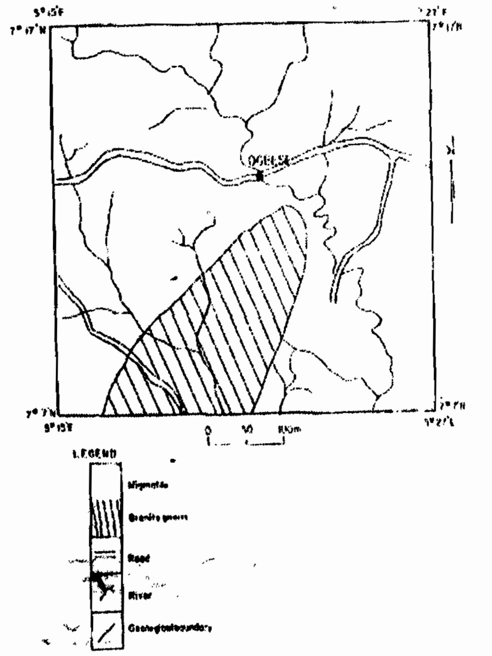

Figure 2: Geological map of the study area.

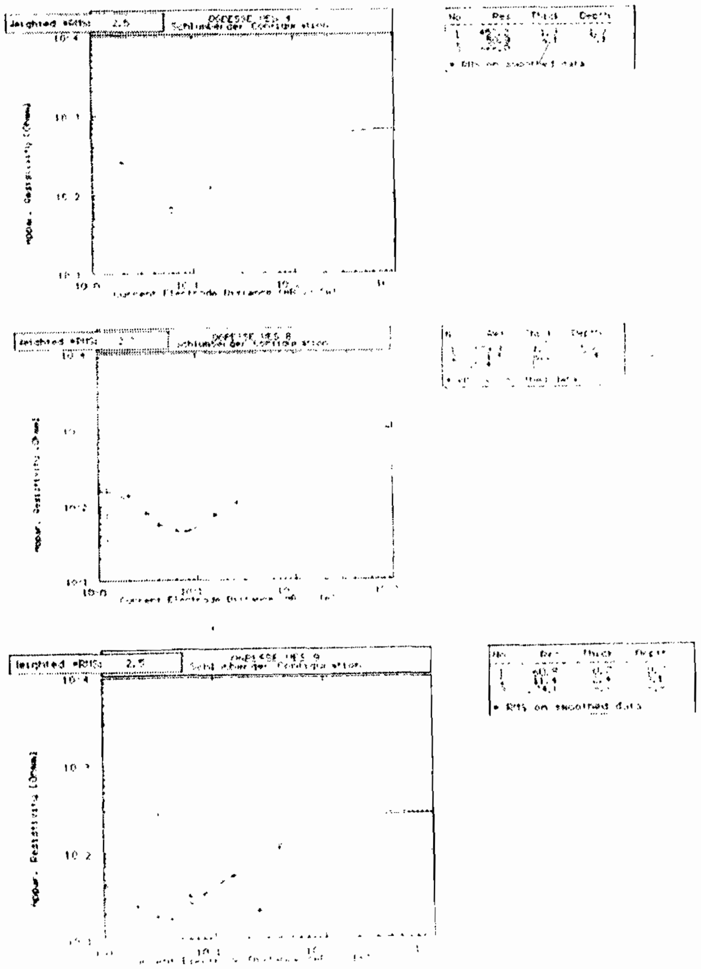

Figure 3: Typical sounding curves obtained from the study area.

RESULTS AND DISCUSSION

The results of the interpreted field curves are presented as geoelectric sections and maps. The observed depth sounding curves range from 3-layers to 4-layer types. The H, A, HA and KH type curves were observed across the study area.

The predominant curve type is H. A summary of the results for all the sounding stations is presented in table 1.

Geoelectric Sequences

The geoelectric sections delineate a subsurface sequence composed of topsoil, weathered layer and fresh basement (Fig. 4). The topsoil ranges in composition from clay, sandy clay and clayey sand with resistivity varying from 38 to 1000Ω-m (Fig 6) and the thickness ranges from 0.4 to 2m. The composition of the weathered layer is clay and sandy clay with resistivity varying from 11 to 194Ω-m (Fig 8) and thickness range from 2 to 26m. The resistivity of the presumed bedrock, which is, fractured in some places ranges from 666 to ∞ Ω-m

Isopach and Isoresistivity maps of the topsoil

The thickness and the resistivity maps of the topsoil are presented in Figs 5 and 6 respectively. The thickness ranges from 0.4m at northeastern part of the study area to 2m

Table 1 Summary of Results from Computer Modeling

VES Stations	Layer Resistivity (Ω-m)				Layer Thickness (m)			Curve Type	Longitudinal Conductance (S) (Ω⁻¹)	Coefficient of Anisotropy (λ)
	ρ_1	ρ_2	ρ_3	ρ_4	h_1	h_2	h_3			
1	246	69	∞		1.3	5.6		H	0.086443973	1.132353758
2	94	32	125		0.6	4.4		H	0.143882979	1.065339822
3	114	23	3195		1.7	3.6		H	0.17143402	1.299267941
4	457	51	666		1.0	6.1		H	0.121796027	1.36228224
5	202	40	1154		1.0	4.1		H	0.107450495	1.229630358
6	69	16	279		1.0	6.8		H	0.439492754	1.133305862
7	254	22	∞		1.0	3.5		H	0.163027917	1.632422127
8	179	32	1174		1.2	6.2		H	0.200453911	1.229860075
9	61	11	274		0.7	2.4		H	0.229657228	1.285042198
10	38	200	1000		1.0	10.3		A	0.077815789	1.130728041
11	39	16	∞		2.0	2.0		H	0.176282051	1.100881057
12	72	22	∞		1.7	4.9		H	0.246338384	1.140971425
13	636	16	∞		1.1	6.3		H	0.39547956	2.404273343
14	389	11	∞		1.3	4.4		H	0.403341902	2.62274393
15	250	24	∞		1.8	8.3		H	0.353033333	1.498910626
16	116	43	∞		0.9	8.2		H	0.198456295	1.046523891
17	609	2522	36	622	0.4	0.7	7.8	KH	0.000934372	1.245538562
18	1000	194	284		1.0	6.8		H	0.036051546	1.172293744
19	105	64	∞		0.8	4.3		H	0.074806548	1.016407343
20	423	77	2017		0.8	5.7		H	0.075917227	1.181819483
21	104	88	442		0.8	4.8		H	0.062237762	1.001711109
22	718	54	∞		0.8	13.6		H	0.252966058	1.263587374
23	239	45	∞		1.2	11.9		H	0.269465365	1.136306067
24	415	39	∞		1.0	12.2		H	0.333178869	1.258255735
25	171	97	∞		1.5	24.2		H	0.258256466	1.009031279
26	339	73	∞		0.9	12.6		H	0.175257607	1.085312956
27	292	30	∞		0.8	9.3		H	0.312739726	1.253601355
28	218	16	∞		1.0	4.8		H	0.304587156	1.633772339
29	315	82	225	∞	1.1	12.9	13.1	HA	0.160809137	1.073389326

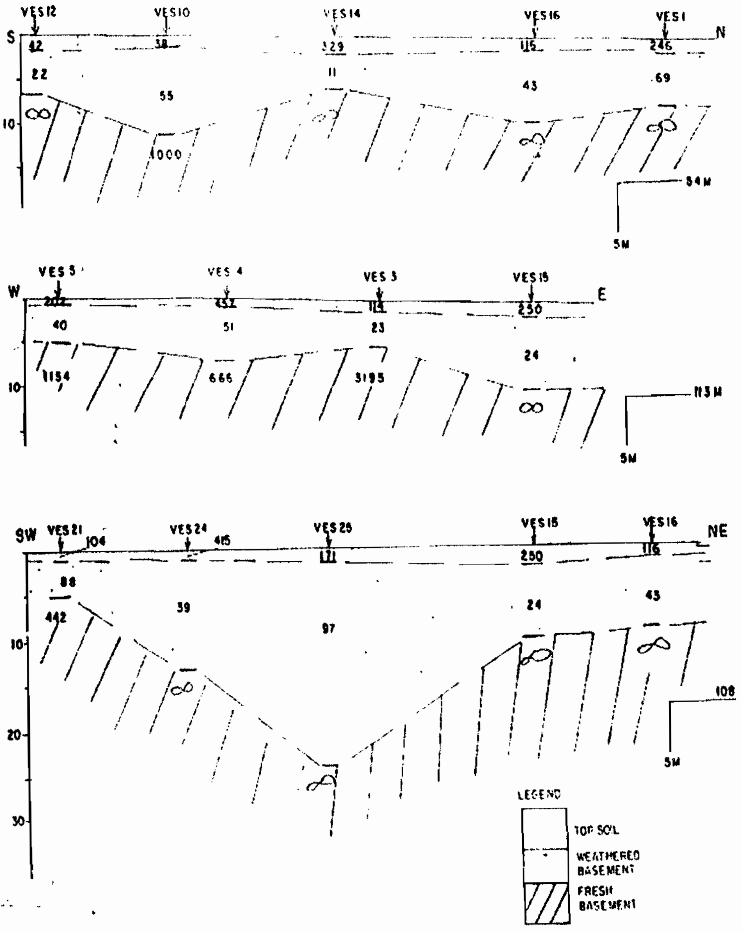

Figure 4: Geoelectric section along S-N and W-E

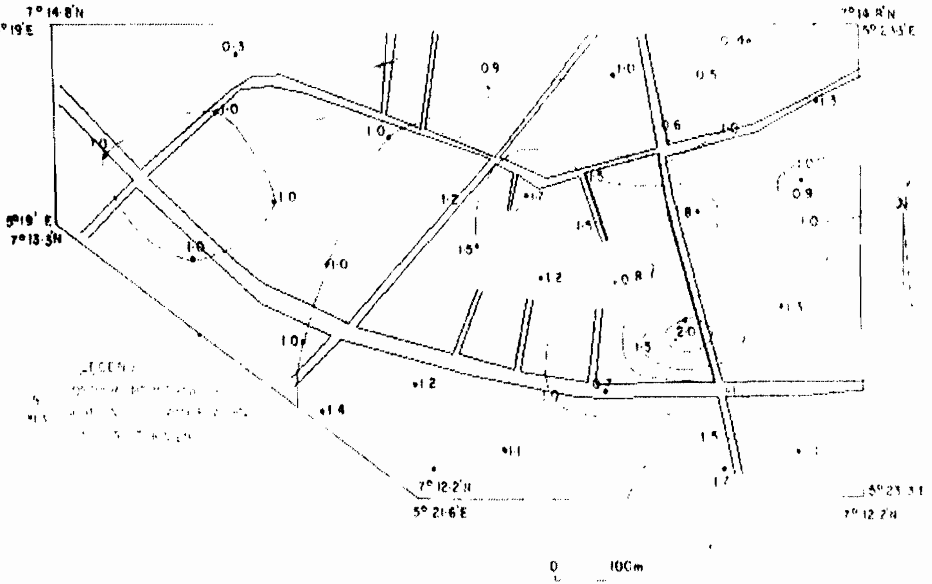

Figure 5: Isopach map of the topsoil.

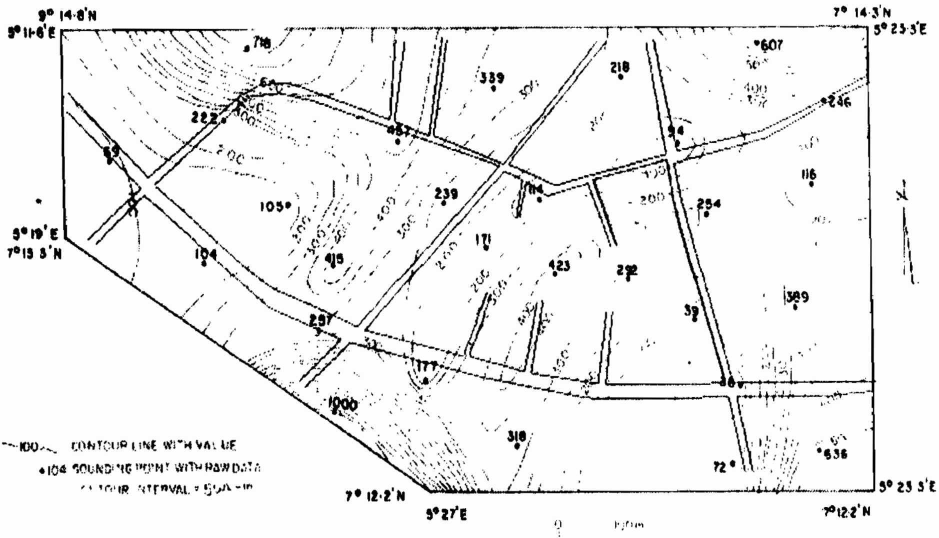

Figure 6: Isoresistivity map of the topsoil

at its southern part. The isoresistivity map shows resistivity values ranging from 38 to 1000Ω-m. This reveals the variation in composition of the topsoil from clay, sandy clay, clayey sand and laterite. The zones with high resistivity values correspond to zones of relatively thick overburden (Figs. 6 and 9). The topsoil has limited hydrogeologic significance due to its small thickness.

Isopach and Isoresistivity maps of the weathered layer

The isopach and isoresistivity maps of the weathered layer are shown in Figs. 7 and 8 respectively. The thickness of the weathered layer varies from 2 to 26m with the highest thickness at the central and southern parts of the area. These zones are marked X1 and X2 in Fig. 7. The weathered layer constitutes the main aquifer in the area (Olorunfemi and Fasuyi, 1993). The resistivity values vary from 11Ω-m to 194Ω-m. The weathered layer is predominantly clay that is constantly saturated but may not transmit sufficient amount of water for abstraction due to its low permeability.

Isopach map of the overburden

The map of depths to the top of the fresh bedrock (overburden thickness) beneath the sounding stations is shown in Figure 9. The overburden is assumed to include the topsoil and the weathered basement. The depth to the bedrock varies from 3m to 27m. The isopach map reveals area with relatively thick overburden labelled T_1 and T_2 (>15m). All other zones are of thin overburden (<15). Generally, areas with thick overburden and a low percentage of clay in which the intergranular flow has either a dominant or important role are known to have high groundwater potential particularly in a basement complex area (Okhue and Olorunfemi, 1991). From the isoresistivity map of the topsoil and weathered layer (Figs 6 and 8), it is observed that the clay content of the overburden is high, which informed the low groundwater potential rating of the study area.

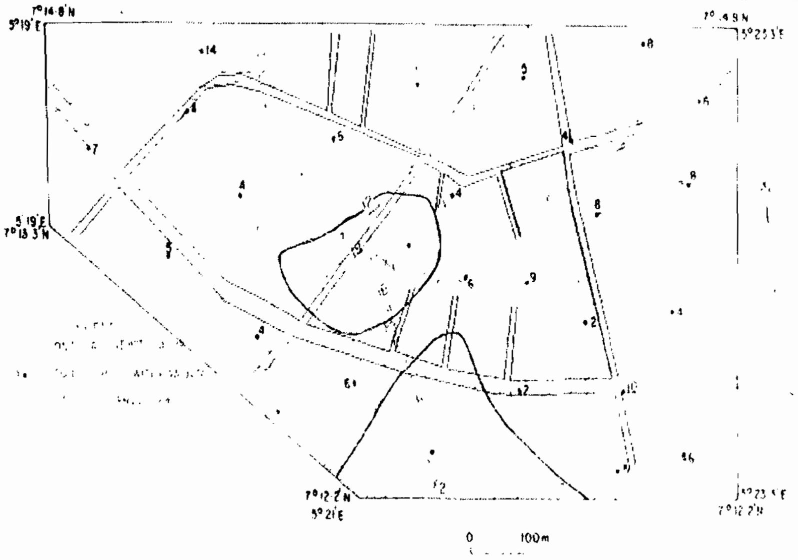

Figure 7: Isopach map of the weathered layer

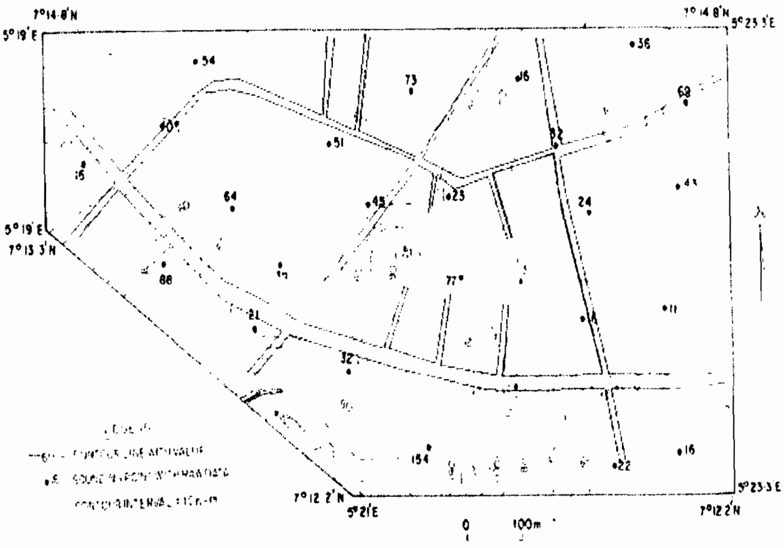

Figure 8: Isoresistivity map of the weathered layer

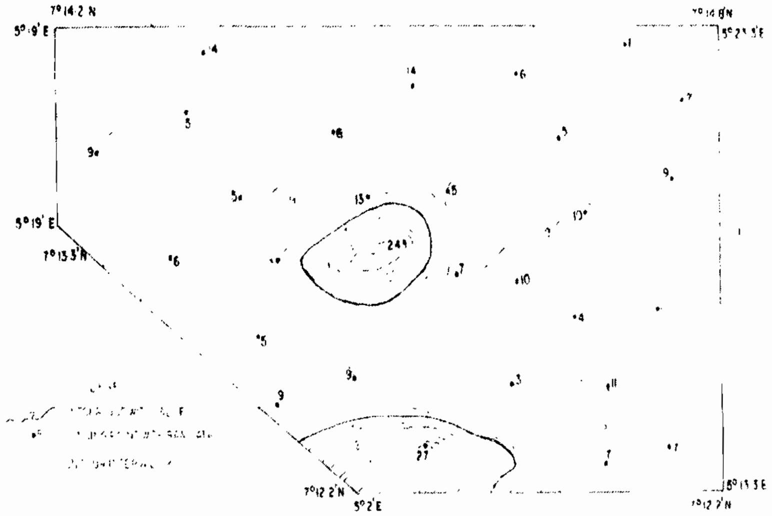

Figure 9: Isopach map of the overburden

Co-efficient of Anisotropy

The overburden coefficient of anisotropy (λ) was calculated for each VES station using the layer resistivities (ρ) and thickness (h) obtained from the VES interpretation results The relevant equations as defined by Keller and Frischknecht, 1966 and Zohdy et al, 1974 are of the form;

$$\lambda = \sqrt{\frac{\rho_t}{\rho_l}} = \sqrt{\frac{\sum \rho_i h_i \sum \frac{h_i}{\rho_i}}{\left(\sum h_i\right)^2}}$$

where

ρ_t is the transverse resistivity

ρ_L is the longitudinal resistivity

i is the summation limit which varies from 1 to n-1, the nth layer represent the infinitely resistive bedrock.

Coefficient of anisotropy has been used to delineate lithological contacts in typical basement terrains (Olorunfemi and Okhue, 1992) The overburden coefficient of anisotropy map (Fig. 10) shows λ values varying from 1 00 to 1.6. These values fall within the range obtained for areas underlain by metamorphic rocks in the southwestern Nigeria (Olorunfemi and Olorunniwo, 1985; Olorunfemi et al, 1991). In the study area, two rock types were identified namely migmatite and granite gneiss A comparison of the anisotropy map with the existing geologic map (Fig 2) with emphasis on the areas where the basement rocks outcrop, shows that the area underlain by the migmatite is characterized by relatively high λ values that are generally greater than 1 3 while the area underlain by the gneisses show λ values that are generally less than or equal to 1.3 The relatively high λ values for migmatite can be explained in term of its broad lithological differentiation

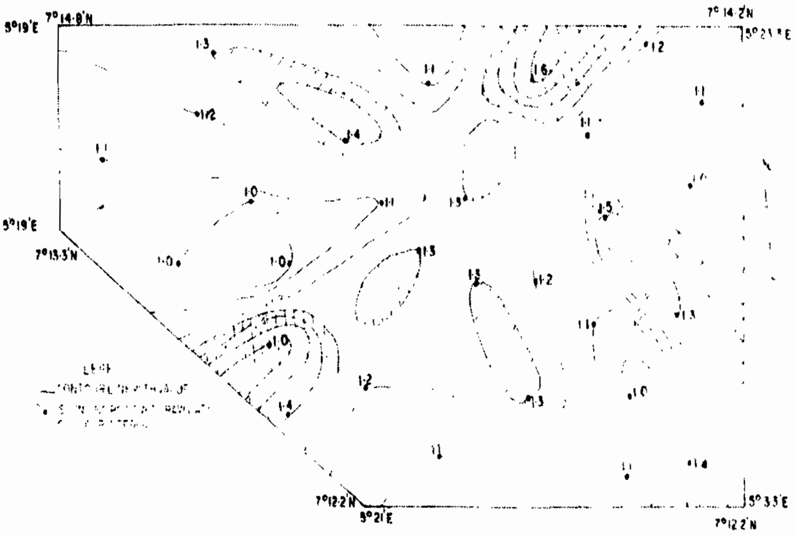

Figure 10: Coefficient of An isotropy map of the overburden

Conductance Map

The longitudinal layer conductance (S) of the overburden at each VES station was obtained from the equation

$$S = \sum_{i=1}^{n} h_i / \rho_i$$

The S values obtained from the study area range from 0.001 mhos to 0 353mhos (Fig 11) The protective capacity of an overburden could be considered proportional to the ratio of thickness to the resistivity i.e. the longitudinal conductance (S) Herriet (1976). Clayey overburden, which is characterized by relatively high longitudinal conductance, offers protection to the underlying aquifer by filtration and retardation of infiltrating solution into the aquifer The characteristic longitudinal conductance enabled the overburden protective capacity rating of the study area as shown in Figure 11 using Oladapo et al, (2004) classification in table 2 The figure presents a view of the protective capacity of the overburden, zoned into moderate, weak and poor protective capacity Zones where the conductance is greater than 0 2mhos are considered zones of moderately protective capacity, the portion, which has conductance ranging from 0.10mhos to 0.2mhos, is classified under weak protective capacity Zones where the conductance is less than 0.1mhos is considered as poor aquifer protective capacity The conductance map of the study area (Fig 11) shows that about 70% of the area falls within the weak/poor overburden protective capacity, while about 30% constitutes the moderate protective capacity rating This suggests that the areas are underlain by materials of weak overburden protective capacity

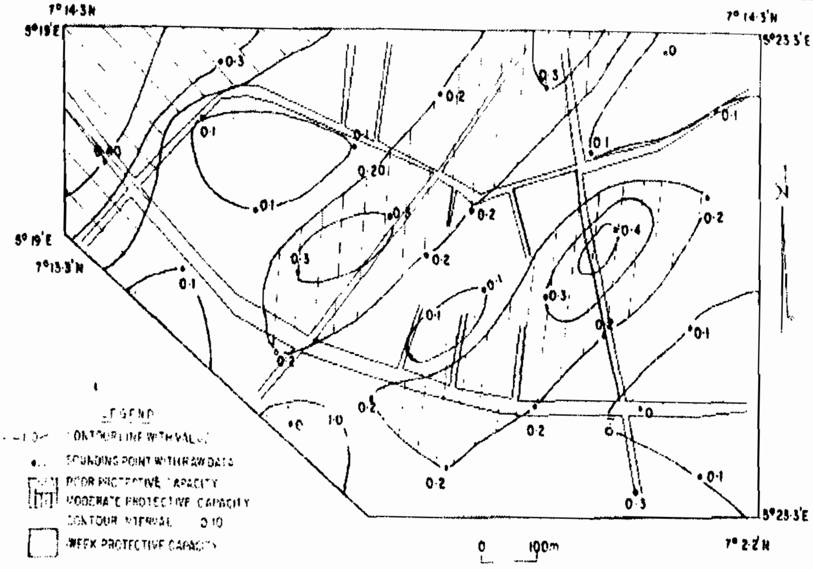

Figure 11: Conductance map showing the overburden protective capacity

Table 2: Modified Longitudinal Conductance/Protective Capacity Rating (After Oladapo et al, 2004)

Longitudinal Conductance (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

CONCLUSION

From the standpoint of the hydro-geophysical investigation, results have been presented from the geoelectrical study of the Ogbese area, southwestern Nigeria. The computer assisted sounding interpretation reveal subsurface sequence composing topsoil with limited hydrologic significance, weathered layer and fractured/fresh basement. The weathered layer constitutes the sole aquifer unit. The groundwater yield of this aquifer is determined by the degree of the clay content of the weathered column. Low groundwater yield is encountered when the aquifer unit is clayey. This aquifer unit is relatively thin and clayey, with low permeability and groundwater discharge capacity. Hence, the groundwater potential of the area is considered to be of low rating. However, groundwater development through regulated motorized pump is marginally feasible in central and southern parts of Ogbese. From the conductance map, materials of weak protective capacity underlie most of the area. The aquifer units in the area are of weak protective capacity; therefore vulnerable to pollution if there is leakage of buried storage tanks.

REFERENCES

Ako, B.D. and Olorunfemi, M.O., 1989. Geoelectric survey for groundwater in the Newer Basalt of Vom, Plateau State. Journal of mining and geology 25: 247- 250.

Keller, G.V. and Frischnecht, F.C., 1996. Electrical methods in Geophysical prospecting. Paragamon Press, Oxford, PP. 523.

Okhue, E. T. and Olorunfemi, M.O., 1991 Electrical Resistivity investigation of a typical basement complex area. The Obafemi Awolowo University campus case 1 study. Journal of Mining and Geology, 27 (2) 66-70

Oladapo, M. I., Mohammed, M. Z., Adeoye, O. O. and Adetola, B. A. 2004. Geoelectric investigation of the Ondo state housing coporation estate, Ijapo, Akure, SW., Nigeria, Journal of Mining and Geology, 40 (1): 41-18

Olayinka, A I. and Olorunfemi, M.O., 1992 Determination of geoelectical characteristic in Okene Area and Implication for boreholes setting. Journal of Mining and Geology, 28 403-412

Olorunfemi, M.O. and Fasuyi, S.A., 1993 Aquifer types and the geoelectric/hydrogeologic characteristics of part of the central basement terrain of Nigeria (Niger State). Journal of African Earth Science 16: 403-317

Olorunfemi, M.O and Okhue, E T, 1992 Hydrogeological and geologic significance of a geoelectric survey at Ile-Ife, Nigeria Journal Min Geol 28 221-229

Olorunfemi, M O., Olarewaju, V O and Alade, O, 1991 On the electrical anisotropy and groundwater yield in a basement complex area of S W Nigeria journal of African Earth sciences, 12 (3): 467-472

Olorunfemi, M.O. and Olorunniwo, M.A., 1985. Geoelectric parameters and aquifer characteristics of some parts of southwestern Nigeria Geologia Applicata E Idrogeologia, 20: 99-109

Vander Velper, B P A, 1988 Resist version 1 0 M Sc Research project. ITC, Delf, Netherland