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A Probe into the Corrosivity Level and Aquifer Protective Capacity of the Main Campus of the University of Abuja, Nigeria: Using Resistivity Method

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Abstract

Resistivity method of geophysics was used in the investigation of corrosivity level (CL) and aquifer protective capacity (APC) inthe main campus of University of Abuja. Total of 12 VES stations were study in the area with AB/2 of 1–250m. ABEM SAS 300c tarrameter was used to generate the data by schlumberger array method. The interpretations were aided by IPI2Win, MS Excel and surfer softwares. The measured overburden thickness ranges from 0.396-27.2m, with a mean value of 5.407m. The longitudinal conductance of the overburden units ranges from 0.03802-1.58441mhos. VES's 1, 7, 9, 10, 11 and 12 of this present study has relatively high topsoil resistivity values which is practically noncorrosive (PNC), while VES's 2, 3, 4 and 5 have moderate corrosivity and VES's 6 and 8 have slightly corrosivity. Based on the longitudinal conductance values, fournoticeable aquifer protective capacity zones were defined, namely poor (VES's 11 and 12), weak (VES's 3, 6 and 8), moderate (VES's 1, 2, 5, 7, 9 and 10) and good (VES 4).VES's 3, 6, 8, 11, 12 of the study area maybe vulnerable to surface contamination, why VES's 1, 2, 4, 5, 7, 9 and 10 may not be vulnerable to contamination because of the variation in the APC. This study is aimed at delineating zones that are very prone to groundwater contamination from surface contaminants and subsurface soils that are corrosive to utility pipes buried underground. Hence the findings of this work will constitute part of the tools for groundwater development and management and structural/infrastructural development planning of the area.

Keywords

Soil Resistivity, Aquifers, Protective Capacity, Resistivity, University of Abuja

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1. Introduction

Water is a gift of nature and in a bounteous proportion, noticeable by its presence (surface, rain and underground) with its quality of transformation through perennial hydro geological evaporation, condensation, and precipitation [4].

The geo-electric method had solved problems of groundwater in thealluvium formation aquifer and it is said to be inexpensive and useful method. Some uses of this method in groundwater are: determination of depth, thickness and boundary of an aquifer, determination of interface saline water and freshwater porosity of aquifer, hydraulic conductivity of aquifer, transmissivity of aquifer, specific yield of aquifer, and contamination of groundwater [1]. The uses of geo-electricmethod for both groundwater resource investigation and for water quality evaluations is said to have increased dramatically over the years due to the rapid advances in microprocessors and associated numerical

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modeling solutions [5]. Geo-electric method is appropriate in mapping the thickness and to delineate the extent of aquiferious overburden and also in the determination and mapping of groundwater quality [3]. Because of the growing population of Abuja, more wastes, which are potential groundwater contaminants are being generated by the increasing population.

1.1. Objectives

To probe into the soil resistivity, aquiferous units, soil corrosivity level, longitudinal conductance and aquifer protective capacity in the main campus of the University.

1.2. Geology of the Study Area

The present study is located within latitudes 8.95780°N to 8.98752°N and longitudes 7.1758°E to 7.2365°E this area also houses University of Abuja, Main Campus, Nigeria.

The geology of the study area is generally the crystalline basement rocks. Older granite mainly porphyroblastic granite and migmatite, porphyritic granite, granite gneiss, biotite gneiss and pockets of medium-grained biotite and biotite hornblende granite constitute the dominants rocks in the area. The geological map of Abuja, which shows the various rock types underlying the area, is presented in figure 1. Generally, only small amount of water can be obtained in freshly unweathered bedrock below the weathered layers.

Groundwater is found mainly in the inconsistent weathered/transition zone and in fractures, joints and cracks of crystalline basement. Fissure systems in Nigeria rarely extend beyond 50m, as evident by available drilling data. The local water table is controlled by textural and compositional changes within the regolith vertical profile and the bedrock topography [7].

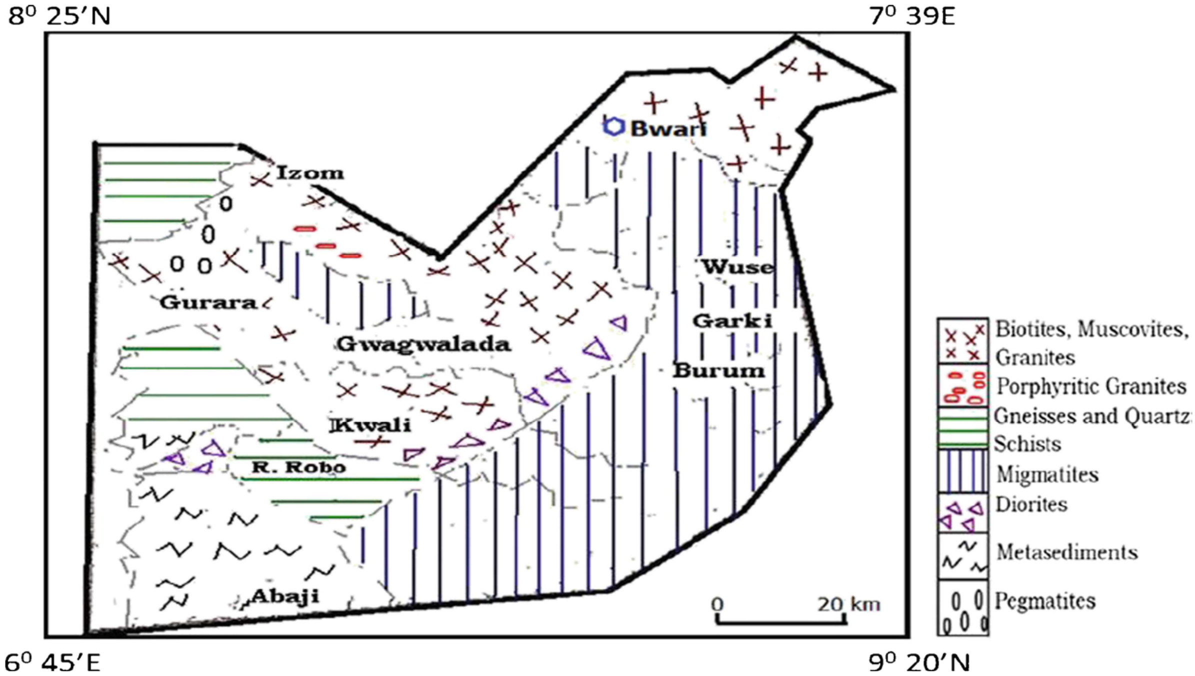

Fig. 1. Geological map of Abuja [6].

2. Materials and Methods

ABEM Tarrameter SAS 300c was used for data gathering at the field. It is made in such a way that it uses the potential difference as well as the current sent into the ground to automatically compute the resistance of the subsurface at any point, for a particular set of electrode configurations. The instrument is programmed in such that it filters self-potentials and noise from incoming signals, so that the output is actually the true resistance of subsurface, which can be used, with appropriate formulae, in the calculation of the apparent resistivity of the subsurface in ohmmeter. ABEM Tarameter SAS 300c usually comes with self-rechargeable battery, four electrodes, cables, hammer, crocodile clips and measuring tapes.

Schlumberger configuration was employed in the data gathering process which is called VES (vertical electrical sounding) [2], [3], [4], [10]. Twelve VES was acquired from the study area and with the aid of computer software (IPI2Win), the below graphs were obtained (fig. 2 and 3) [10].

The total longitudinal conductance (S) of the overburden unit at every vertical electrical sounding location was obtained from the mathematical [12] [13]:

$$S = \Sigma (h_i / \rho_i) = h_1 / \rho_1 + h_2 / \rho_2 + \ldots + h_n / \rho_n$$

Where S is the total longitudinal conductance, Σ is summation sign, h_i is thickness of the ith layer and ρ_i isresistivity of the ith layer.

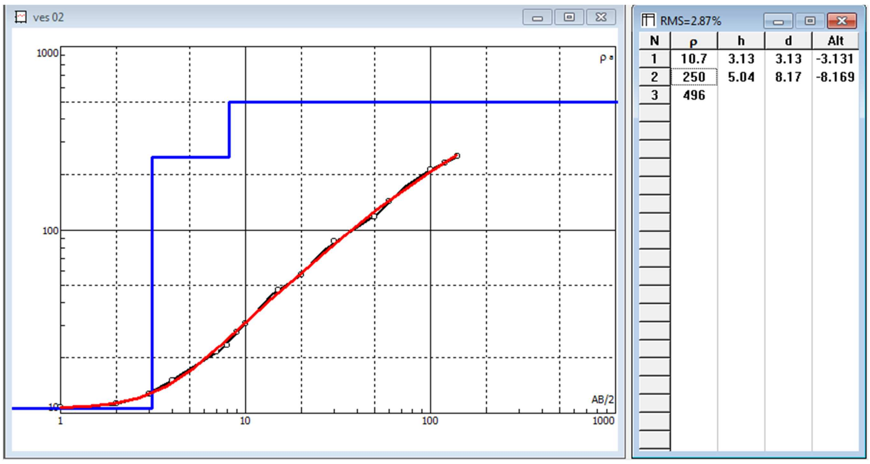

Fig. 2. VES TWO.

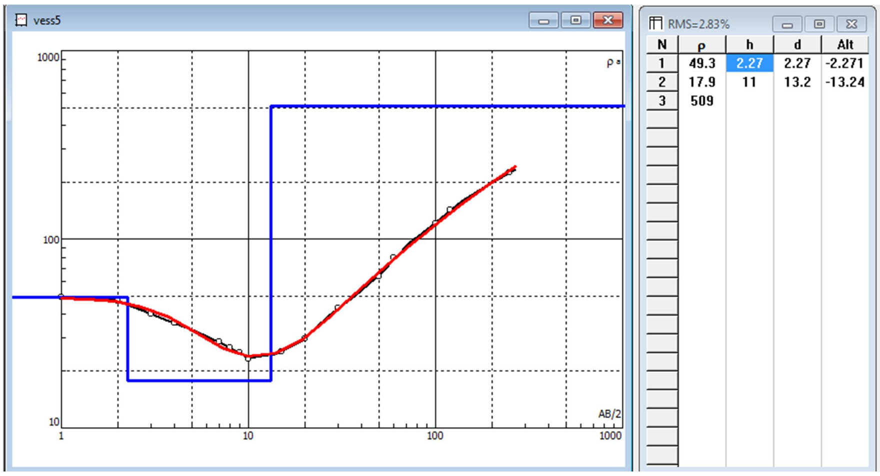

Fig. 3. VES FIVE.

Table 1. Summary of curve s[10].

VES	Layer	Resistivity (Ωm)	Thickness(m)	Depth(m)	Probable Lithology	Curve types	Coordinates
	1	430	0.5	0.5	Topsoil		Latitudes
	2	173	5.63	6.13	Lateritic clay		8.98752N
1	3	145	56.8	63	Weathered basement	QH	
	4	245	-	-	Fractured basement		Longitudes 7.18518E
	1	10.7	3.13	3.13	Topsoil		Latitudes
2	2	250	5.04	8.17	Weathered basement	A	8.98033N
	3	496	-	-	Fractured basement		Longitudes 718332E
	1	37.9	2.48	2.48	Topsoil		Latitudes
3	2	24.9	1.94	4.46	Weathered basement	A	8.97653N
	3	188	-	-	Fractured basement		Longitudes 7.1758E
	1	47.3	0.396	0.396	Topsoil		Latitudes
4	2	15.8	24.9	25.3	Weathered basement	H	8.98059N
	3	14547	-	-	Fresh basement		Longitudes 7.1970E
5	1	49.3	2.27	2.27	Topsoil	H	Latitude

VES	Layer	Resistivity (Ωm)	Thickness(m)	Depth(m)	Probable Lithology	Curve types	Coordinates
	2	17.9	11	13.2	Weathered basement		8.97926N
	3	509	-	-	Fractured basement		Longitude 7.1970E
	1	178	1.56	1.56	Topsoil		Latitude
	2	61.2	7.52	13.2	Lateritic clay		8.97456N
6	3	87.2	54	63.1	Weathered basement	HA	
	4	70069	-	-	Fresh basement		Longitude 7.21042E
	1	184	3.42	3.42	Topsoil		Latitude
	2	30.6	1.17	4.59	Lateritic clay		8.97107N
7	3	152	92.5	97	Weathered basement	HK	
	4	20.5	-	-	Fractured basement		Longitude 7.21009E
	1	128	2.99	2.99	Topsoil		Latitude
	2	36.2	4.01	6.99	Lateritic clay		8.96905N
8	3	661	4.08	11.1	Weathered basement	HK	
	4	85.9	-	-	Fractured basement		Longitude 7.20941E
	1	488	3.45	3.45	Topsoil		Latitude
	2	275	23.8	27.2	Lateritic clay		8.96248N
9	3	541	118	146	Weathered basement	HK	
	4	146	-	-	Fractured basement		Longitude 7.2365E
	1	1941	0.921	0.921	Topsoil		Latitude
	2	90.8	3.16	4.08	Lateritic clay		8.96021N
10	3	6.24	2.55	6.64	Weathered basement	QH	
	4	51.7	-	-	Fractured basement		Longitude 7.23471E
	1	1992	0.51	0.51	Topsoil		Latitude
	2	492	2.11	2.62	Lateritic clay		8.95951N
11	3	98.4	5.1	7.72	Weathered basement	QH	
	4	192	-	-	Fractured basement		Longitude 7.23211E
	1	1849	0.83	0.83	Top Soil		Latitude
	2	896	2.59	3.44	Lateritic Layer		8.95780N
	3	248	8.6	12	Weathered Layer		
12						QH	
	4	427	-	-	Fractured basement		Longitude 7.23053E
							Latitude

Table 2. Longitudinal conductance and overburden values for each station.

VES Station	Total longitudinal conductance (mho)	Overburden
1	0.42543	6.13
2	0.31268	3.13
3	0.14335	2.48
4	1.58441	0.396
5	0.66057	2.27
6	0.13164	1.56
7	0.66537	4.59
8	0.14024	6.99
9	0.33161	27.2
10	0.44393	4.08
11	0.05637	2.62
12	0.03802	3.44

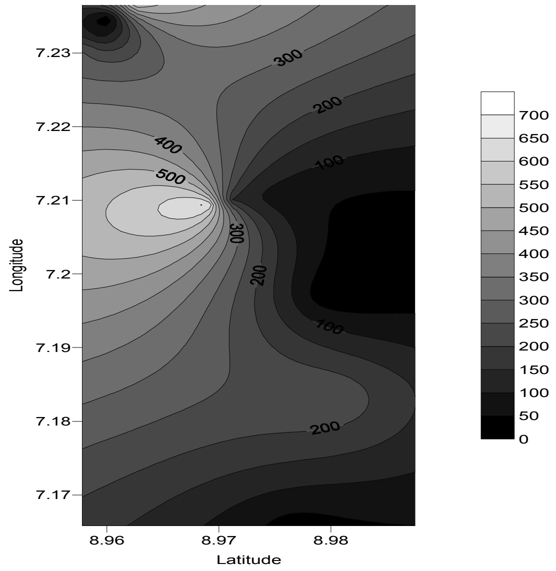

Fig. 4. Iso resistivity of weathered basement.

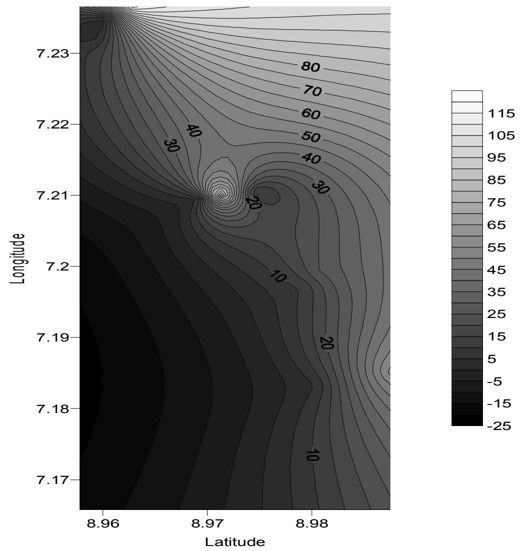

Fig. 5. Isopachof weathered basement.

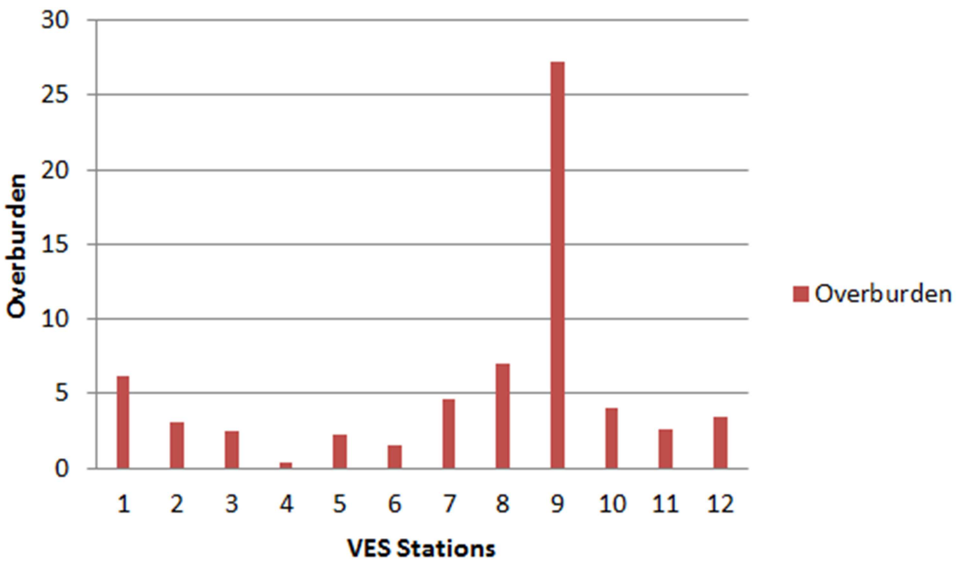

Fig. 6. A graph showing the variation of overburden over the study area.

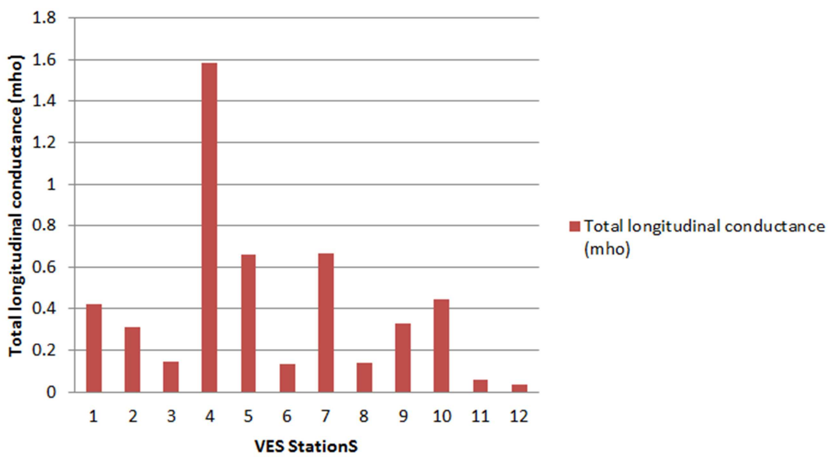

Fig. 7. A graph of longitudinal conductance of the study area.

3. Results and Discussions

3.1. Aquifer of the Study Area

The weathered zone thickness diagram (figure 5) shows the thickness of the weathered layer underneath with the highest thickness of about 118m (VES 9) and the lowest thickness with about 1.94m (VES 3) with average of 32m. Thus the thickness of weathered layer for the study area is high enough for ground water accumulation. The weather layer/basement is the aquifer unit in the study area

3.2. Soil Corrosivity Level

Topsoil constitutes the layer within which normal civil engineering foundations and utility pipes are buried. The thickness of this layer ranges from 0.4 to 3.45 m while the resistivity ranges from 10.7 to 1941Ωm in the study area. The topsoil (table 1) resistivity values obtained from the interpretations of the VES results were used to evaluate the corrosivity of the subsoils. Topsoil resistivity values were classified in terms of soil corrosion based on soil resistivity classification model (see table 3 below). Topsoil resistivity values range from 10.7 to 1941 Ωm, with a mean value of 445.27 Ωm and the topsoil corrosivity varied from 'practically noncorrosive' to 'moderately corrosive'.

Table 3. Classification of soil resistivity in terms of corrosivity [5].

Soil resistivity (Ωm)	Soil corrosivity
< 10	Very strongly corrosive (VSC)
10–60	Moderately corrosive (MC)
60–180	Slightly corrosive (SC)
> 180	Practically noncorrosive (PNC)

VES's 1, 7, 9, 10, 11, and 12of the study area has reasonably high topsoil resistivity values which is 'practically noncorrosive (PNC), while VES's 2, 3, 4 and 5 have moderate corrosivity topsoil and VES's 6 and 8 have slightly corrosivity (table 1, table 3).

Table 4. Longitudinal conductance/aquifer protective capacity rating [11].

Longitudinal conductance (mhos)	Aquifer protective capacity rating
> 10	Excellent
5–10	Very good
0.7–4.49	Good
0.2–0.69	Moderate
0.1–0.19	Weak
< 0.1	Poor

3.3. Aquifer Protective Capacity

Aquifer protective capacity (APC) is the capacity of the overburden unit to impede and filter percolating ground surface polluting liquid into the aquiferous unit [1]. The second order geoelectric parameter, longitudinal conductance (Dar Zarrouk parameter) was evaluated from the primary/first order parameters (thickness and resistivity) of the geoelectric subsurface layers which were used in the classification of the APC of the area. Highly impervious materials such as clay and shale usually have high longitudinal conductance values (resulting from their low resistivity values) while pervious materials such as sand and gravels have low longitudinal conductance values (resulting from their high resistivity values). While high longitudinal conductance value corresponds to excellent and good APC, low longitudinal conductance values are associated with poor and weak APC.

Based on longitudinal conductance values, overburden units can be classified into excellent, very good, good, moderate, weak and poor aquifer protective capacity. Overburden units with longitudinal conductance value >10 mhos give an excellent APC and longitudinal conductance values ranging from 5 to 10 mhos give rise to very good APC. Longitudinal conductance values in the range of 0.7–4.9 mhos and 0.2–0.69 give rise to good and moderate APC ratings, respectively. Weak and poor APC ratings are defined by longitudinal conductance in the range of 0.1–0.19 and <0.1, respectively (table 4).

Table 2 presents the spatial distribution of the longitudinal conductance of the overburden units of the study area, with highest and lowest values at VES 4 and VES 12 respectively (fig. 7). In order to categorize the aquifer protective capacity of the area, aquifer protective capacity rating model (after [1], [11]) was employed. Four aquifer protective capacity zones, weak 0.1–0.19, poor < 0.1, moderate 0.2–0.69 and good 0.7–4.49 were delineated. The good and medium aquifer protective capacity zones coincide with zones of considerable overburden thicknesses with clayey column and low resistivity while the weak and poor zones coincide with zones of shallow or thin overburden and high electrical resistivity. VES's 3, 6, 8, 11, and 12 of the study area are covered by poor and weak APC zones and they may be vulnerable to surface contamination sources (leakage from underground petroleum storage tanks, infiltration of leachates from decomposing of open refuse dumps and diffuse pollution from agricultural activities) in the area. The good (VES's 4, 5, 7) and moderate (VES's 1, 2, 9, 10) APC zones of the study area have higher attenuation property on contaminated fluids so that in the face of contamination such zones are apparently safe.

4. Conclusions and Recommendation

Geo-electrical investigation has been applied to corrosivity level and aquifer protective capacity study of the main campus of University of Abuja, Abuja, Nigeria. The results revealed the competence of electrical resistivity surveys in delineating different zones of soil corrosivity level of the topsoil units and the aquifer protective capacity of the overburden units.

In evaluating soil corrosivity level and protective capacity of layers beyond the shallow coastal aquifer, 12 VES points were probed at the main campus of University of Abuja, Abuja, Nigeria. The results of the investigation show that VES's 1, 7, 9, 10, 11, and 12 of the study area with high resistivity (ρ >180 Ωm) topsoil are precisely noncorrosive [table 1], while VES's 2, 3, 4, 5, 6 and 8 of the study area contains corrosive topsoil with low resistivity (ρ <180 Ωm) [table 1]. These zones may be corrosive and alikely "hot spots" for pipelines breakdown. In event of leakages from buried pipelines in these zones, the overlying layers may not be able to avert direct infiltration of hydrocarbon into the aquifer due to the common poor protective capacity of the study area.

Four noticeable aquifer protective capacity zones were defined, namely poor (VES's 11 and 12), weak (VES's 3, 6 and 8), moderate (VES's 1, 2, 5, 7, 9 and 10) and good (VES 4). The rating was based on longitudinal conductance values. Vertical electrical sounding stations, whose computed longitudinal conductance values range from 0.7 to 4.9 mhos, 0.2 to 0.69 mhos, 0.1 to 0.19 mhos and <0.1 mhos are respectively classified as good, moderate, weak and poor aquifer protective capacity zones. Poor and weak aquifer protective capacity zones are very vulnerable to contamination, while areas of moderate and good aquifer protective capacity zones are less vulnerable to contamination.

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