



## Evaluation of Groundwater Potential And Aquifer Characteristics Using Geoelectrical Method In Billiri And Environs Part Of Sheet 173 Kaltungo Nw Northern Eastern Nigeria.

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### ABSTRACT

A total of twenty (20) vertical electrical sounding locations were occupied using the Schlumberger electrode configuration in the Billiri and its environs. The study was aimed at evaluating the aquifer characteristics and groundwater potential as well as assessing its potential risk to contaminant seepage in terms of the aquifer hydraulic properties and protective capacity of the overburden rock materials using Dar zarouk parameters. The results show a lithology that is dominated by sands of various grades with no significant delineable intercalating clay/shale impermeable bed. The study area is characterized by low values of the Protective capacities  $P_c$ , of the overburden rock materials and high aquifer porosities and transmissivities. The low value of the protective capacities makes the aquifer system in the area highly vulnerable to surface contamination. High porosity and transmissivity value of the aquifer materials implies highly permeable aquifers with significant storativity, which enhances the migration and circulation of contaminants within the groundwater system over large areas. These revelations are indications that the groundwater quality may have been impaired in the area and borehole water samples should be randomly sampled for contaminant loads based on this analysis.

**Keywords:** Dar Zarouk Parameters, Aquifer transmissivity, Protective capacity, Groundwater.

### INTRODUCTION

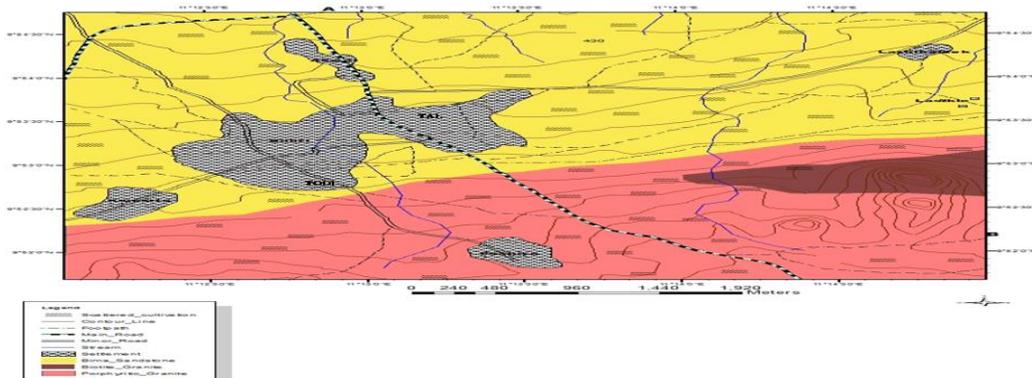
Groundwater as the main source of potable water supply for domestic, industrial and agricultural uses has been under the intense pressure of degradation and contamination due to urbanization, industrial and agricultural related activities. The impact of this trio on soil and groundwater is alarming with years of devastating effects on humans and the ecosystem. Groundwater is said to be contaminated when it is unfit for the intended purpose and therefore constitute a nuisance to the user. The study area is situated within Billiri Local Government of Gombe state and forms part of sheet 173 Kaltungo NW, Northeastern Nigeria and covers an area of about 30sqkm. The study area hosts eight (8) primary schools, federal government college Billiri, government science secondary school Billiri, Billiri main market and farms. The high commercial and industrial activities in the area have

increased environmental concern in relation to waste generation and management and groundwater contamination. The uncontrolled and indiscriminate dumping of waste materials on the land surface, landfill and water bodies has placed the groundwater at the risk of being contaminated.

#### Geology and Hydrogeology of the Study Area

The study area lies within the Gongola sub-basin which is characterized by different stratigraphic units, the units have been divided into the following formation: Bima sandstone, Yolde Formation, Pindiga Formation and Gombe sandstone (Carter et al., 1963; Benkhelil, 1989).

The area is of tropical continental [Sudan] climate. The climate consists basically of two Seasons, a rainy season and dry season. The onset of the rainy season is from April-June and ceases at the end of October, with average Rainfall of about 2.38 mm annually (table 2).



**Fig.1:** Geologic map of the study area

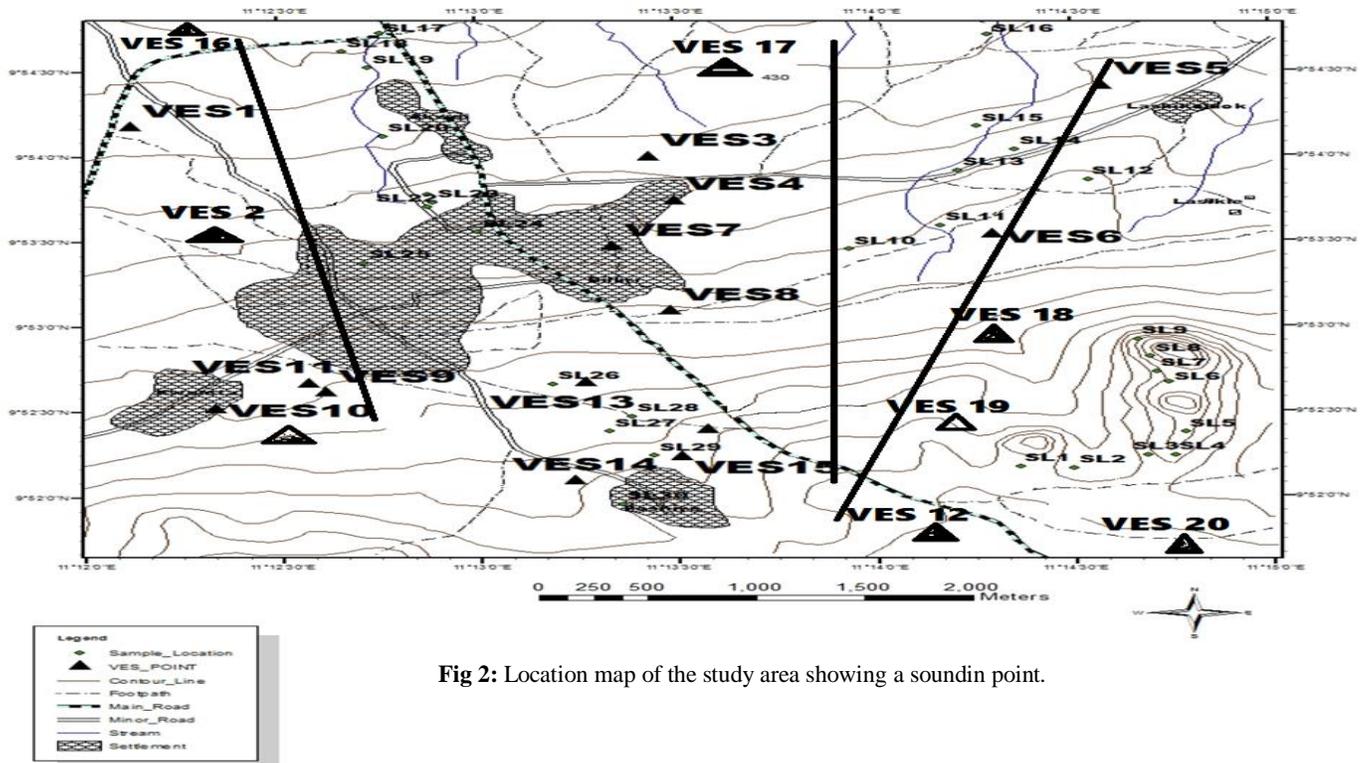


Fig 2: Location map of the study area showing a soundin point.

The water table and depth to the aquifer in the area vary from 8-24 m and 26-74 m, respectively, depending on the season and time of the year. The proximity of these to the surface makes them highly prone to contamination. Estimation of the impact of these waste materials on groundwater quality requires the determination of the transmissivity of the aquifer materials and protective capacity of the overburden rocks. Transmissivity is a major property of an aquifer and aids in the characterization of rocks as water conducting media/strata. The ability of the overburden to retard and filter percolating fluid is a measure of its protective capacity. Estimating these properties from pumping tests can be very expensive and time-consuming. Surface geoelectrical methods offer an alternative, rapid and cost-effective approach for aquifer evaluation and groundwater quality assessment using empirical relations between hydraulic and geoelectric parameters. The objective of the study is to evaluate the aquifer characteristics in terms of the Dar-Zarouk parameters and hence, the transmissivity of the aquifers and the protective capacities of the overburden rocks. The results of this investigation by inference will give a clue to the probable impairment of groundwater quality in the area.

**Theoretical Basis**

The combination of the thickness and resistivity of the geoelectric layers into single variables; the Dar-Zarouk parameters of Transverse resistance ( R ) and Longitudinal conductance ( S ), can be used as a basis for the evaluation of

aquifer properties such as transmissivity and protective capacity of the overburden rock materials.

For a horizontal, homogenous and isotropic layer, the Dar-Zarouk parameters of transverse Resistance ( R ) and longitudinal conductance ( S ) are obtained as:

$$St = \sum_{t=1}^n \frac{hi}{\rho_i} \quad (1)$$

$$Rt = \sum_{t=1}^n \rho_i hi \quad (2)$$

Where  $\rho_i$  and  $hi$  are the layer resistivity and thickness of the  $i$ th layer. The aquifer transmissivity.

T is expressed as the product of the hydraulic conductivity ( k ) and layer thickness ( h ).

$$T = kh \quad (3)$$

For clean saturated aquifers whose natural fluid characteristics are fairly constant (that is, no

Appreciable impact on the general groundwater quality by surface contaminants loads), the Hydraulic conductivity is proportional to the resistivity of the aquifer. This implies that in the absence of a pumping test data, the aquifer hydraulic conductivity K can be approximated to the true resistivity of the aquifer derived from the geoelectric investigation (Hubbard and Rubin, 2002). Therefore,  $T = kh = \rho h$  (4)

But the product of the resistivity to its thickness is the transverse resistance ( R ), which is Numerically equal to the transmissivity ( T ).

$$T=R \dots\dots\dots(5)$$

The longitudinal conductance (S) gives a measure of the impermeability of a confining Clay/shale layer. Such layers have low hydraulic conductivity (k) and low resistivity. Protective Capacity (Pc) of the overburden layers is proportional to its longitudinal conductance (S).

$$P_o = S = \sum_{i=1}^n \frac{h_i}{\rho_{pc}} \dots\dots\dots(6)$$

The relation between formation factor (FF), aquifer porosity and geoelectric parameters is Expressed by

$$f = \frac{1.0}{\Phi^2} = \frac{\rho_w}{\rho_a} \dots\dots\dots(7)$$

Where  $\Phi$  = aquifer porosity and are respectively, the resistivity of the aquifer and Groundwater The value of groundwater resistivity in the area is 84.7 ( $\Omega$ m) at 27°C.

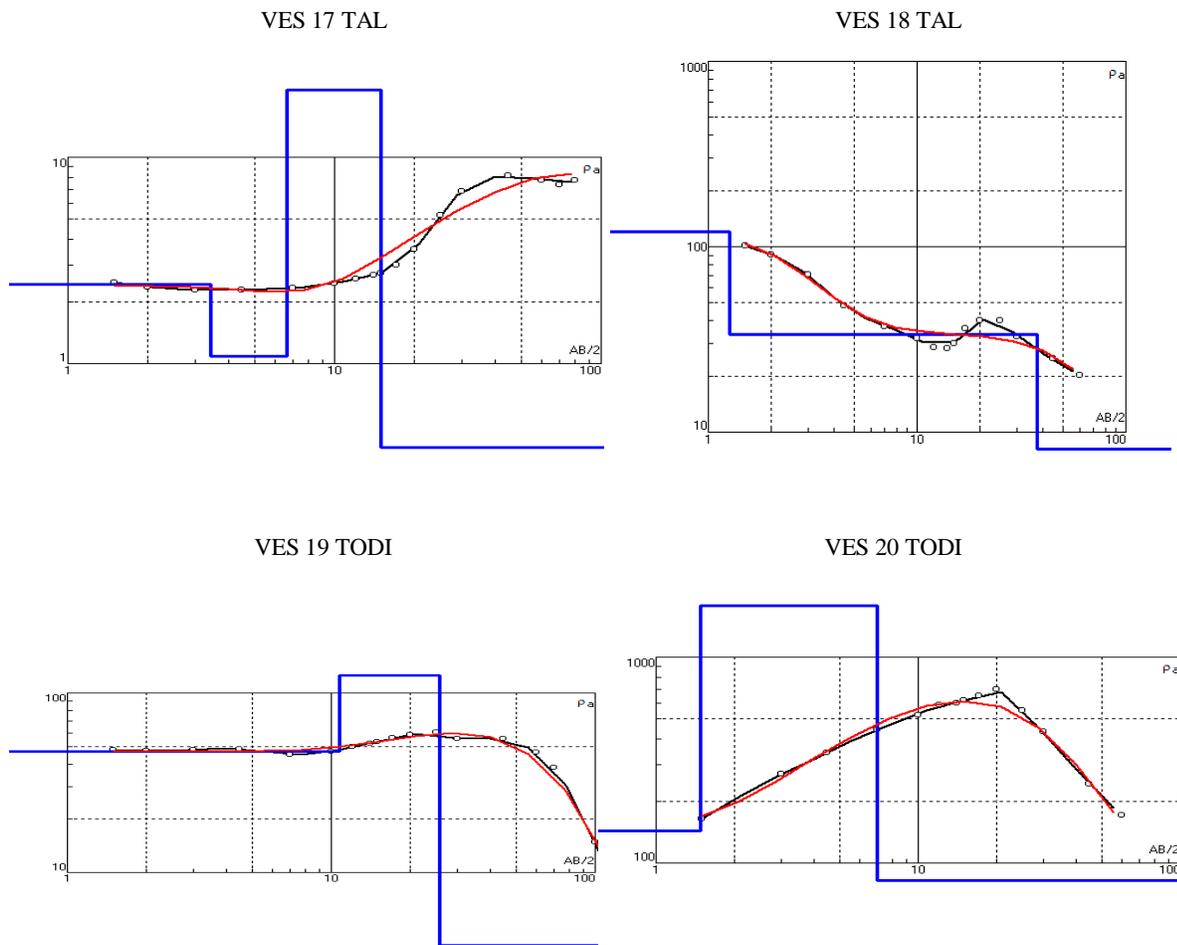
**METHODOLOGY**

The method employed in the present study is the Vertical Electrical Sounding. A total of twenty (20) VES positions were occupied using the Schlumberger electrode array and the Abem 7 interpretable geoelectric layers (Fig 3).

Teremeter 1000C, aided with a 2000C booster for better penetration. The electrode spacing used has a maximum spread of  $AB/2 = 400$  m and  $MN/2 = 50$  m, with regard to the target depth of between 67-150 m. Only the current electrodes are moved more often during measurements until the measurable signal becomes very small. The potential electrodes are then expanded along the transverses, mostly along major roads. One (1) VES position was occupied close to an existing water borehole to constrain and minimize the ambiguity of interpretation. Resistance values R at each VES point was recorded and apparent resistivity values  $\rho_a$  ( $\Omega$ m) were determined using the appropriate geometric factor (K).

**RESULTS**

The apparent resistivity data  $\rho_a$  (m) from field measurements were inverted using IPI2WIN resistivity sounding interpretation software version 3.0 (2003) which is based on Zohdy(1973), to determine the true resistivity and depths of subsurface formations. The resulting model curves have RMS errors of <5% and exhibit HK, KH and QH type curves with 5-



**Fig. 3: Interpreted Geoelectric model curves**

The model results were quantitatively interpreted in terms of the true resistivity of the rock formations and with the aid of the lithologic log of nearby borehole penetrated to depths greater than 60 m. The general model interpretation shows that the geoelectric section consists essentially of laterite, clayey sands,

and fine to coarse sands. These compare favourably well with the lithologic log of the borehole Table 1. The aquifer and Dar-Zarouk parameters of the interpretable geoelectric sections are presented in Table 2

**Table 2:** Lithologic Log and Interpreted Geoelectric sections of the study area

DESCRIPTION	LITHOLOGIC LOG	DEPTH ft(m)		GEOELECTRIC SECTION	Depths (m)
Soft, brownish lateritic clayey sandy silt-clay		0.0 (0.00) -	Top soil		0m
Soft, reddish brown lateritic clayey silty sand		32.2 (16.0) -		Lateritic sand	
Medium-dense, reddish brown, poorly graded clayey, silty sand		65.6 (20.0) -	Lateritic sand		4.04m
Dense, reddish-brown, well graded clayey silty sand and gravels		92.45 (30.0) -	Sand		8.48m
Medium-dense, brownish, poorly graded sands with ferruginized sandstone bodies		131.24 (40.0)	Coarse Sand		19.68m
Medium-dense light brown poorly graded sands		164.9 (50.0)			53.90m
Medium-dense whitish poorly graded sands		196.86 (60.0)	Sand		
Medium-dense whitish poorly graded sands		200.00	Sand		128.0m

**Table 3:** Computed aquifer and Dar-Zarouk parameters of the geoelectric sections

VES No	VES Location	Layer Resistivity (Ωm) ρ <sub>a</sub>	Aquifer Depth (m)	Aquifer Thickness (m)	Protective Capacity Pc (Siemens)	Transmissivity T (Ωm <sup>2</sup> )	Porosity Φ (%)
1	Awai	109.4	18.5	14.2	1.297x10 <sup>-1</sup>	1.553x10 <sup>3</sup>	87.9
2	Awai	151.1	74.0	55.1	3.646x10 <sup>-1</sup>	8.32x10 <sup>3</sup>	74.8
3	Bare	517.9	24.2	17.1	3.333x10 <sup>-2</sup>	8.770x10 <sup>4</sup>	40.4
4	Bare	371.5	52.7	45.1	1.211x10 <sup>-1</sup>	1.671x10 <sup>4</sup>	47.7
5	Lashikoldok	340.8	26.8	11.0	3.227x10 <sup>-2</sup>	3.748x10 <sup>3</sup>	49.8
6	Lashikoldok	266.4	12.2	7.6	2.852x10 <sup>-2</sup>	2.024x10 <sup>3</sup>	56.3
7	Lasikle	231.1	24.8	11.2	4.846x10 <sup>-2</sup>	2.588x10 <sup>3</sup>	60.5
8	Lasikle	254	8.83	8.37	3.295x10 <sup>-2</sup>	2.125x10 <sup>3</sup>	57.7
9	Kwomta	405.6	46.3	46.3	0.141x10 <sup>-1</sup>	1.877x10 <sup>4</sup>	45.6
10	Kwomta	285	26.0	23.1	8.105x10 <sup>-3</sup>	6.583x10 <sup>3</sup>	54.5
11	G.S.S.S Billiri	721	37.8	3.38	4.687x10 <sup>-3</sup>	2.406x10 <sup>2</sup>	34.2
12	G.S.S.S Billiri	637.9	16.2	18.7	2.935x10 <sup>-2</sup>	1.192x10 <sup>4</sup>	36.4
13	Kentengereng	247.4	20.9	14.6	5.901x10 <sup>-2</sup>	3.612x10 <sup>3</sup>	58.5
14	Kentengereng	189.3	30.9	19.3	1.119x10 <sup>-1</sup>	2.201x10 <sup>3</sup>	66.8
15	Poshiya	140.2	31.9	15.7	5.198x10 <sup>-1</sup>	4.741x10 <sup>2</sup>	77.7
16	Poshiya	126	25.8	15	1.190x10 <sup>-1</sup>	1.890x10 <sup>3</sup>	81.9
17	Tal	132	21.4	13	9.848x10 <sup>-2</sup>	1.716x10 <sup>3</sup>	80.1S
18	Tal	173.5	37.5	36.3	2.092x10 <sup>-2</sup>	6.298x10 <sup>3</sup>	69.8
19	Todi	123	200	23.7	1.926x10 <sup>-1</sup>	2.915x10 <sup>3</sup>	82.9
20	Todi	181.9	209	32	1.759x10 <sup>-1</sup>	5.820x10 <sup>3</sup>	68.2

The main aquiferous zones occur between the 4th and 6th geoelectric layers with a resistivity range of 814 to 3035  $\Omega\text{m}$ , depths varying from 46.10 m to 92.18 m, and layer thickness in excess of 23 m. The longitudinal conductance (S) and hence, the protective capacity (Pc) of the overburden rock materials range from  $4.68 \times 10^{-3}$  to  $1.52 \times 10^{-2}$  Siemens. The low values of the protective capacities  $<1.0$  Siemens, is an indication of overburden rock materials with no significant impermeable clay/shale overlying strata. This is an indication of high infiltration rates of surface contaminants into the aquifer. This is interpreted as overburden layers with a smaller capacity of protection to contaminants and probable risk to soil and groundwater contamination. The transverse resistance R and hence, the transmissivity of this aquiferous zones vary from  $1.34 \times 10^4$  to  $1.64 \times 10^5 \Omega\text{m}^2$ . These values are  $>400 \Omega\text{m}^2$  and correspond to zones where the thicknesses and resistivities of the aquifer are large. The high transmissivities suggest that the aquifer materials are highly permeable to fluid movement within the aquifer, which possibly may enhance the migration and circulation of contaminants in the groundwater aquifer system. The computed porosities of the groundwater aquifers vary from 39.31 to 90.2%. The high porosity values are due to the unconsolidated nature of the aquifer materials. High porosities are associated with aquifers of relatively low resistivity, fine to medium grained sands and high water content.

## DISCUSSION

The geoelectric survey gave interpreted resistivity model sections with aquiferous zones occurring generally between the 4th and 6th geoelectric layers at the depth range of 8.5 m to 74 m. The relative proximity of these aquiferous layers to the surface has serious implications on the groundwater quality in relation to the aquifer transmissivities and protective capacity of the overburden rock materials in the area. The protective high storativity of the aquifers in the area. The low protective absence of significant overburden impermeable rock material (clay /shale), which can impede contaminant infiltration. The implication of this is that any surface contaminant travels down at a faster rate and goes into storage into the aquifer with relative ease and with unprecedented impact on the general groundwater quality over time. The aquiferous zones exhibit high transverse resistance (R) values. The high R values are associated with zones of high transmissivity and, hence highly permeable to fluid movement. The fact that the aquiferous materials in the

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study area are highly permeable and relatively shallow, suggests that the groundwater has a high propensity of being contaminated over a large area once the aquifer receives a load of contaminant dose from any surface source. The estimated aquifer porosities are very high in the study area. This is due to the unconsolidated and friable nature of the aquifer materials with little or no clay materials. High porosities are associated with aquifers of relatively low resistivity, fine to medium grained sands and high water content. The high porosities imply capacities of the overburden rock materials and the high aquifer transmissivities and porosities will aid the seepage of contaminant loads and migration within the groundwater aquifer system at a relatively shorter time. Groundwater potential in the area is high due to the high transmissivities and thicknesses of the aquifer, which is suitable for the development of boreholes for potable water supply.capacity of the overburden rock materials in the area is very low. The low values of the protective capacity are due to the

## CONCLUSION

The study area is characterized by low values of the protective capacities of the overburden rock materials which make the aquifer system in the area highly vulnerable to contamination. A high transmissivity value of the aquifer materials implies highly permeable aquifers which enhances the migration of contaminants within the groundwater system over large areas, while the high aquifer porosities imply aquifers of high storativity and better yield. These revelations are indications that the groundwater quality may have been impaired in the area and borehole water samples should be randomly sampled for contaminant loads based on this analysis.

## RECOMMENDATION

It is recommended that this technique should be employed mostly in urban areas before borehole are drilled so as to give insight into the vulnerability of the aquifers in the area to contamination from the surrounding soak away and refuse dumps.

## AUTHORS CONTRIBUTIONS

Both authors were involved in the data acquisition, analysis and interpretation of the present study.

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