



Assessment of Aquifer Protective Capacity of Groundwater Around Tirwun and Environs, Bauchi State, Northeastern Nigeria.

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ABSTRACT

An assessment of the aquifer protective capacity of groundwater resources can be achieved through a variety of geophysical means of investigation. Geoelectric investigations were conducted around Tirwun and environs in Bauchi State, Nigeria. Ten (10) vertical electrical soundings (VES) were acquired using an Allied Omega resistivity meter in northeastern Nigerian Basement rock. By using geoelectric sections, the subsurface was classified into three (3) layers, namely: topsoil, weathered zone (clay, sandy-clay, and sand fill fractures), and fresh basement. The analysis of the materials above the aquifers showed that longitudinal conductance (S) values ranged from 0.08438 to 0.73449 (mhos). Hence, classifying the area into weak (0.1 to 0.19), moderate (0.2 to 0.69) and good protective capacity (>0.7) mhos. Weathered/fractured basement aquifers were identified as the major aquiferous units in the study area. The aquifers are characterized by thick-thin overburden with moderate-poor protective capacity, which also exhibits low transverse unit resistance (on average 763.1046 ohms), which implies that the materials above the aquifers serve as seals and shield the aquiferous units. Therefore, areas with weak-poor protective capacity are

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1. Introduction

Groundwater exploration within the Basement Complex rocks is usually carried out with the use of Vertical Electrical Sounding (Palacky, 1989). A thorough knowledge of the hydrogeological characteristics of the aquifer units, such as pollution susceptibility, is necessary for the successful exploitation of basement terrain groundwater.

As groundwater becomes more important, as a source of uncontaminated water, improved hydrogeological knowledge, new groundwater exploration techniques, and data processing methods must be efficient to facilitate investigations and evaluation of groundwater resources (Kosinski et al., 1981; Ayers 1989).

This is particularly important given the localized nature of the Basement aquifers (Satpatty and Kanugo, 1976). The studied area has witnessed a tremendous social economic transformation in recent years coupled with the increased population with attendant human activities due to rapid urbanization. Though, compelling most residents to depend largely on hand-dug wells and motorized boreholes for their domestic water supply. Due to rapid urbanization, waste generation has increased; hence a common feature in the Area is that refuse dumps are ubiquitous. Underlying the study area are rocks from the Precambrian Basement Complex.

As a result, these rocks have low porosity and very low permeability by nature. Generally, thick overburden overlying fractures is responsible for the highest groundwater yields in Basement terrain (Ademilua et al., 2013). Groundwater is susceptible to pollution if leakage from buried underground storage tanks occurs or if leachate from decomposed refuse dumps infiltrates. This necessitates evaluating the protective capacity of overburdened materials within the study area to determine the level of safety of the hydrogeologic system. For evaluating the protective capacity and near-surface materials of the aquifer, the electrical resistivity method was employed. The use of this information will aid in the planning, development, and management of groundwater resources.

2. LOCATION AND CLIMATE

The study area lies within the geographical coordinates of $10^{\circ} 15' 05''\text{N}$ to $10^{\circ} 22' 0''\text{N}$ and $9^{\circ} 50' 55''\text{E}$ to $9^{\circ} 53' 24''\text{E}$. The area is slightly laid out from the Bauchi metropolis, accessed through a federal highway that links Bauchi to Maiduguri to the east of Bauchi metropolis, and several primary roads and footpaths and a railway track (Fig. 1).

The area's tropical climate is usually characterized by dry and dusty northeasterly trade wind, which originates from the Sahara Desert (Harmattan) dry dust-bearing wind. They usually experienced harmattan between December and February. The highest humidity and rainfall are recorded in August and September (Mustapha & Adamu, 1991). The area is characterized by two main seasons: the rainy and the dry season. The rainy season is usually experienced between April to September, and the dry season is from October to March. The area is characterized by mean annual rainfall of about 700-1300mm stated by the Bauchi State Agricultural Development Programme (BSADP, 1983). The vegetation is the Savannah type, composed of scattered trees, which grow near water sources, shrubs, and mainly flat-lying grasses. The plants in such a setting are mostly xerophytes and can adapt to long periods of the dry season.

3. THE GEOLOGY

The study area is underlain by rocks of the Precambrian Basement Complex of Nigeria. The central lithologic units are the Bauchite (Fayalite-quartz-monzonite); the biotite-hornblende-granite; the porphyroblastic biotite-granites, granulites and

undifferentiated migmatites and gneisses (Fig. 2) (Ferre & Caby, 2007). In most parts of the area, these rocks are covered by unconsolidated weathered materials consisting of laterites, clays, sands, and gravels. The unconsolidated weathered overburden materials are of two types: alluvium and eluvium. River Course Alluvium, the low-lying plains of the study area, are essentially mantled by lateritic pebbly soils resulting from in-situ weathering of the crystalline rocks.

The eluvium, however, consists essentially of gravels and sands, which are very good aquifers with very high yields to wells. The processes in the formation of deep weathering that led to the development of lateritic profiles as the overburden from the eluvium, Exposures of fayalite-quartz-monzonite (Bauchite) and Biotite hornblende-granite occur at almost all the locations. Fayalite – Quartz – Monzonites (Bauchite) Fayalite-bearing quartz monzonites have been described in the Bauchi area (Oyawoye, 1970). Outcrops of these rocks show that they have been fractured due to tectonism. Thus, fractures, fissures, joints, and fracture zones exist. The prominent fault zones trend towards the NE-SW and N-S zones (Oyawoye (1970).

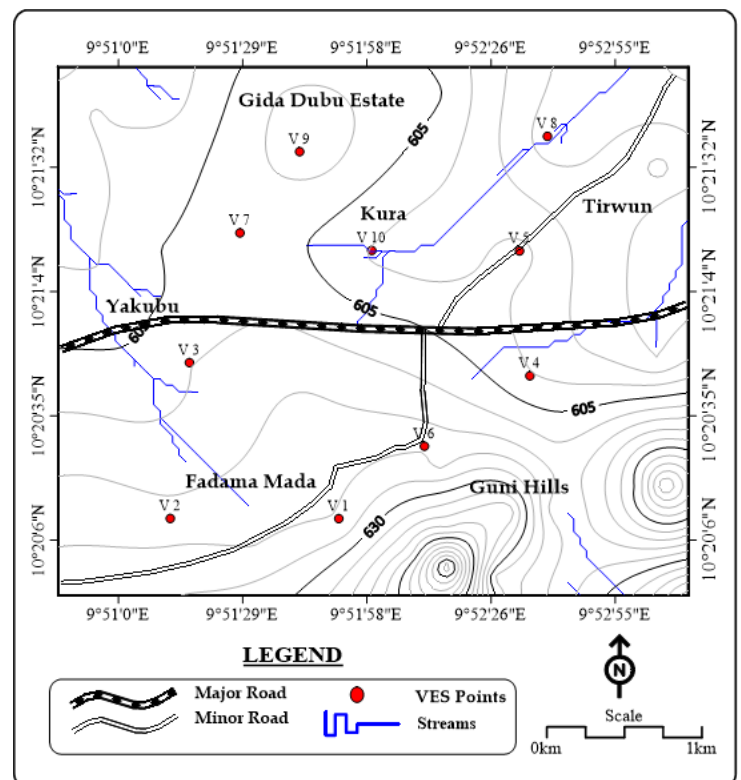


Figure 1: Base map showing VES points

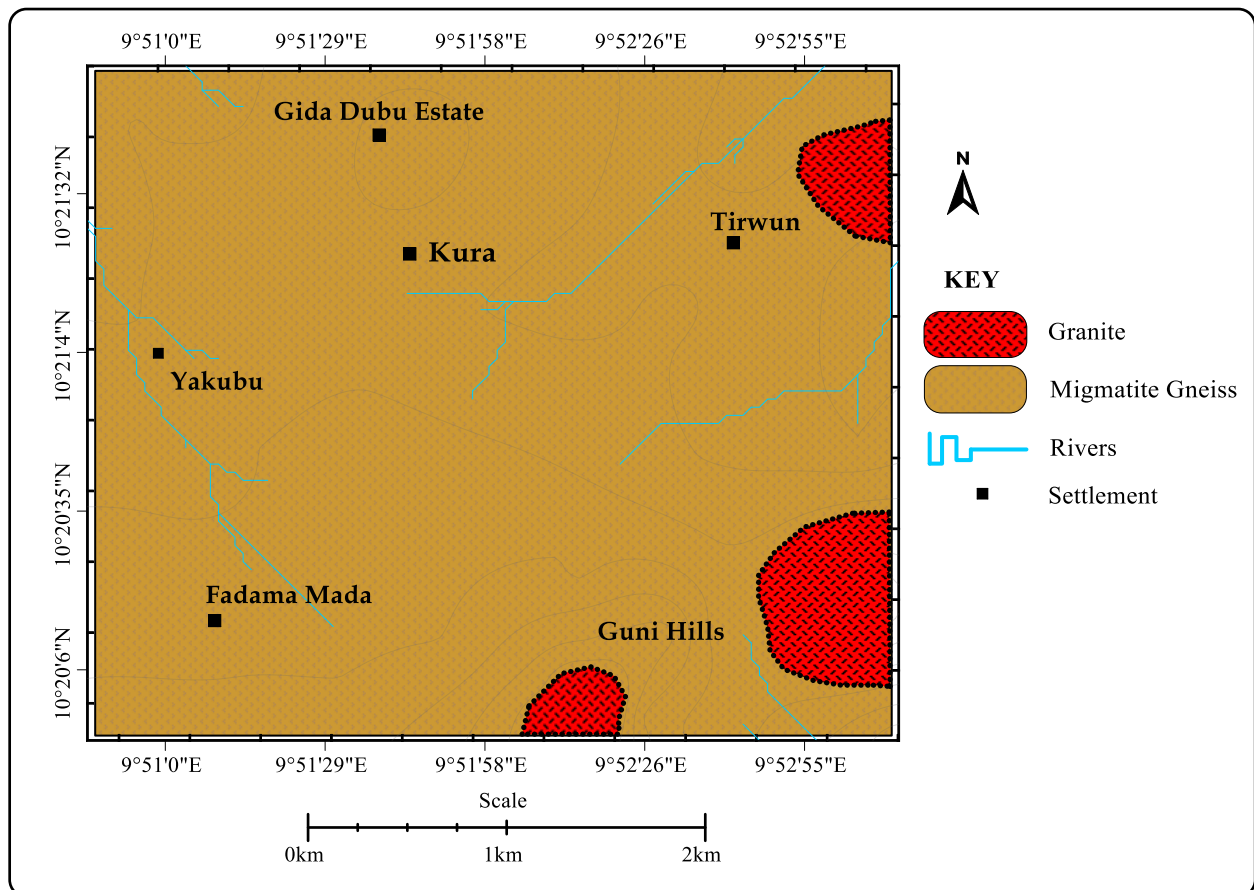


Figure 2: Geologic Map of the Area

4. MATERIALS AND METHODS

Ten (10) Vertical Electrical (VES) points were employed utilizing the Schlumberger electrode configuration (Fig. 3). The current electrode spacing was varied from 0-100m with potential fixed at a maximum of 20m. Measurement were made with an Allied Omega Earth

Resistivity Meter. The VES data (Table 1) were utilized in generating filed curves. The data was later subjected to further analysis by a computer aided iteration software IPI2WIN. The software can produce modelled curves, adjust field data and interpret geo-electric layers (Fig. 4).

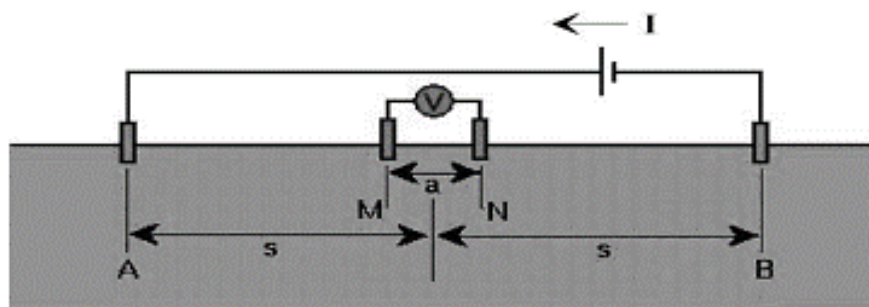


Figure 3: Configuration of Schlumberger Array

Table 1. Summary of Geo-Electric data

VES no.	Resistivity of Layers (Ωm)				Layer Thickness (m)			Curve Types
	1	2	3	4	1	2	3	
1	209	34.9	8148	-	0.897	7.653	-	H
2	330.6	41.07	782.1	-	0.9125	11.968	-	H
3	129	11.99	33614	-	2.53	2.194	-	H
4	352.3	59.33	479	-	0.621	5.11	-	H
5	64.13	35.19	448.8	-	1.32	6.542	-	A
6	150	42.5	403	-	2.25	7.39	-	H
7	183.4	40.35	244.6	-	1.338	6.618	-	H
8	119.1	53.685	1603	-	0.639	17.44	-	A
9	206	76.4	1194	-	0.5605	5.605	-	H
10	115	118	4151	-	3.93	11.67	-	A

First-order geoelectric parameters derived from the iteration were utilized in deriving the second-order geoelectric parameters or the Dar Zarrouck parameters (Maillet, 1974). The second-order parameters of interest in this study are, Longitudinal unit conductance (S) and Transverse unit resistance (T). The second-order parameters are derived thus (Zohdy et al., 1974). For n layers:

The longitudinal unit conductance $S = \sum_{i=1}^n \frac{h_i}{\rho_i}$ i

The total transverse unit resistance: $T = \sum_{i=1}^n h_i \rho_i$ ii

Using the longitudinal unit conductance/protective capacity rating (Table 2). The longitudinal unit conductance values were classified into weak/poor, moderate and good protective capacity. The values of the overburden thickness, longitudinal unit conductance and resistivity values of the second layer were utilized in generating the layer thickness and aquifer protective capacity maps of the study area (Table 3).

Table 2. Classification after Oladapo and Akintorinwa, (2007)

Total Longitudinal Conductance (mhos)	Unit Protective Rating	Capacity
<0.10	Poor	
0.1-0.19	Weak	
0.2-0.69	Moderate	
0.7-4.90	Good	
5.0-10.0	Very Good	
>10.0	Excellent	

Table 3. Summary of the Derived Secondary Parameters with Rating

VES no.	Longitudinal Conductance (mhos)	Traverse Unit Resistance (Ω)	APC Rating
1	0.223575534	454.5627	Moderate
2	0.294165052	793.19826	Moderate
3	0.202598225	352.67606	Moderate
4	0.087891136	521.9546	Poor
5	0.206488277	314.86458	Moderate
6	0.188882353	651.575	Weak
7	0.171310399	512.4255	Weak
8	0.339611304	1039.42854	Moderate
9	0.076084748	543.685	Poor
10	0.133072218	1829.01	Weak

5. RESULT AND DISCUSSION

Based on the layer parameters (i.e., resistivity and thickness), longitudinal unit conductance (S), and transverse unit resistance (T), the nature of the materials overlaid on the mapped aquifers was evaluated to determine whether they prevented infiltration of unwanted fluids. According to Olorunfemi et al. (1999), earth materials act as a natural filter to percolating fluids; therefore, their ability to protect the ground surface from polluting fluids is an indication of their protective capacity. In other words, the geologic materials overlying an aquifer may serve as a seal to prevent polluting fluids from percolating into it. The study area overburden protective capacity rating was calculated using the longitudinal unit conductance (see Table 4) derived from equation (i). The clayey overburden offers protection to the underlying aquifer because of its high longitudinal conductance (Abiola et al., 2009).

In the study area, longitudinal unit conductance (S) values range from 0.08438 to 0.73449 (mhos). As a result of its relatively high longitudinal conductivity, clay material protects the underlying aquifer. Using Oladapo and Akintorinwa (2007)'s classification of longitudinal unit conductance values, we were able to categorize the study area into poor, weak, and moderate protective capacity zones. Thus, zones in which the conductance is greater than 0.2 to 0.69 (mhos) are considered zones of moderate protective capacity. Whereas, portion having conductance in the range of 0.2 to 0.69 (mhos) were classified as zone of moderate protective capacity; and area with values ranging from 0.1 to 0.19 (mhos) exhibiting weak protective capacity while the zones where the conductance value is less than 0.1 (mhos) were considered to have poor protective capacity. Thus, this research has discovered that the overburden materials around the north-eastern (i.e., Tirwun) and south-western (i.e., Fadaman Mada) portions of the study area have moderate-weak protective capacity.

The north-western (i.e., Gida Dubu) and south-eastern (i.e., Guni Hills) portions have weak to poor protective capacity materials. Furthermore, the study further reveals that about 70% of the area falls within the weak/poor overburden protective capacity, while about 30% constitutes the moderate/weak protective capacity rating (Fig. 6).

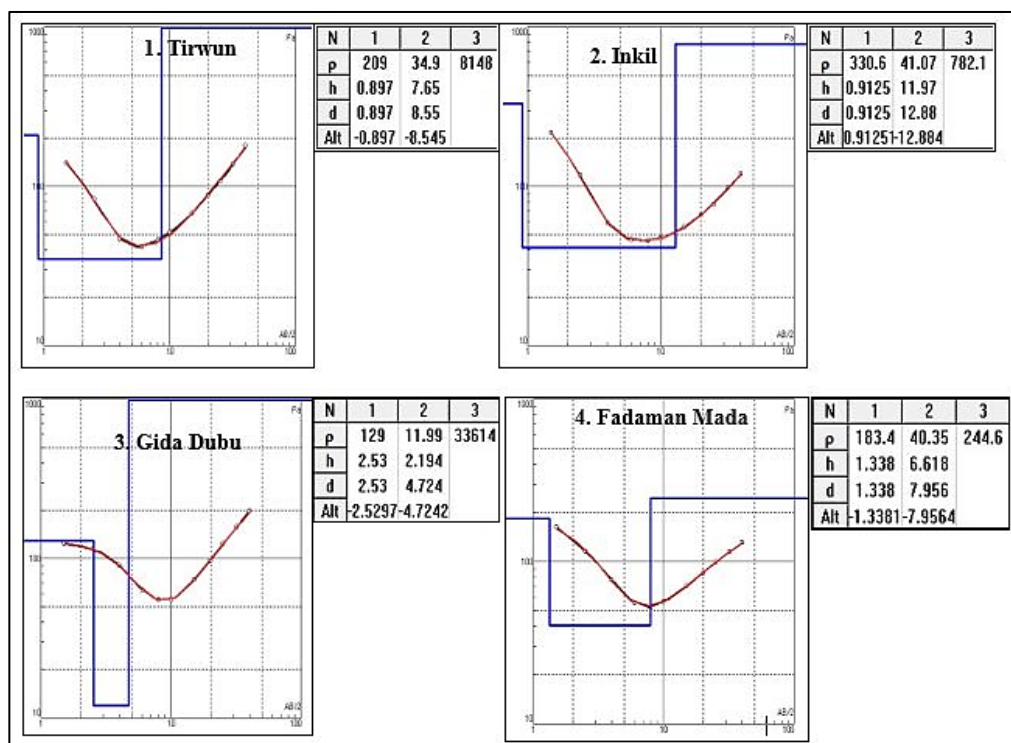


Figure 4: Vertical Electrical Sounding curves

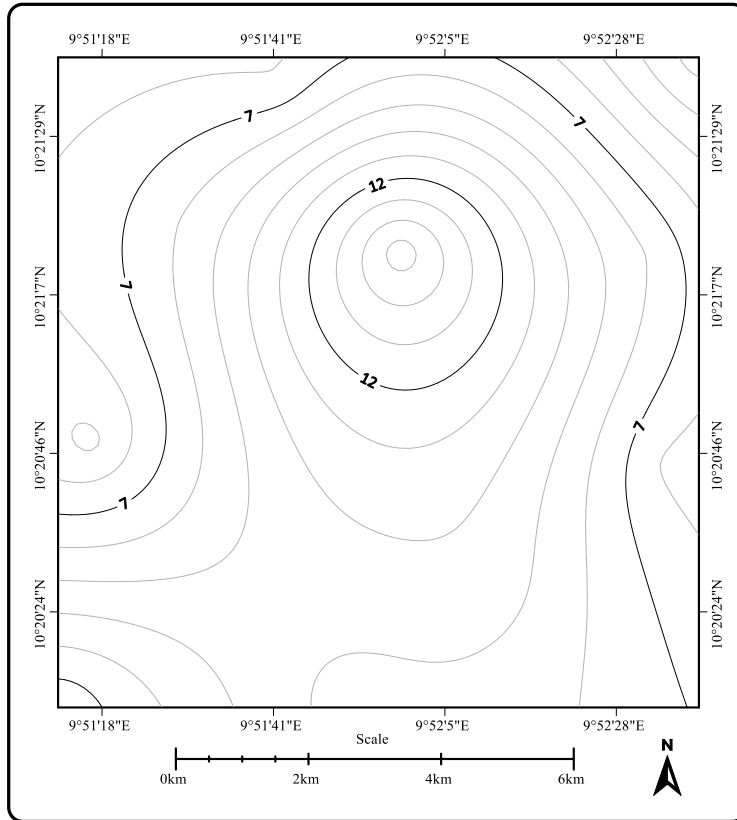


Figure 5: Overburden Thickness Map

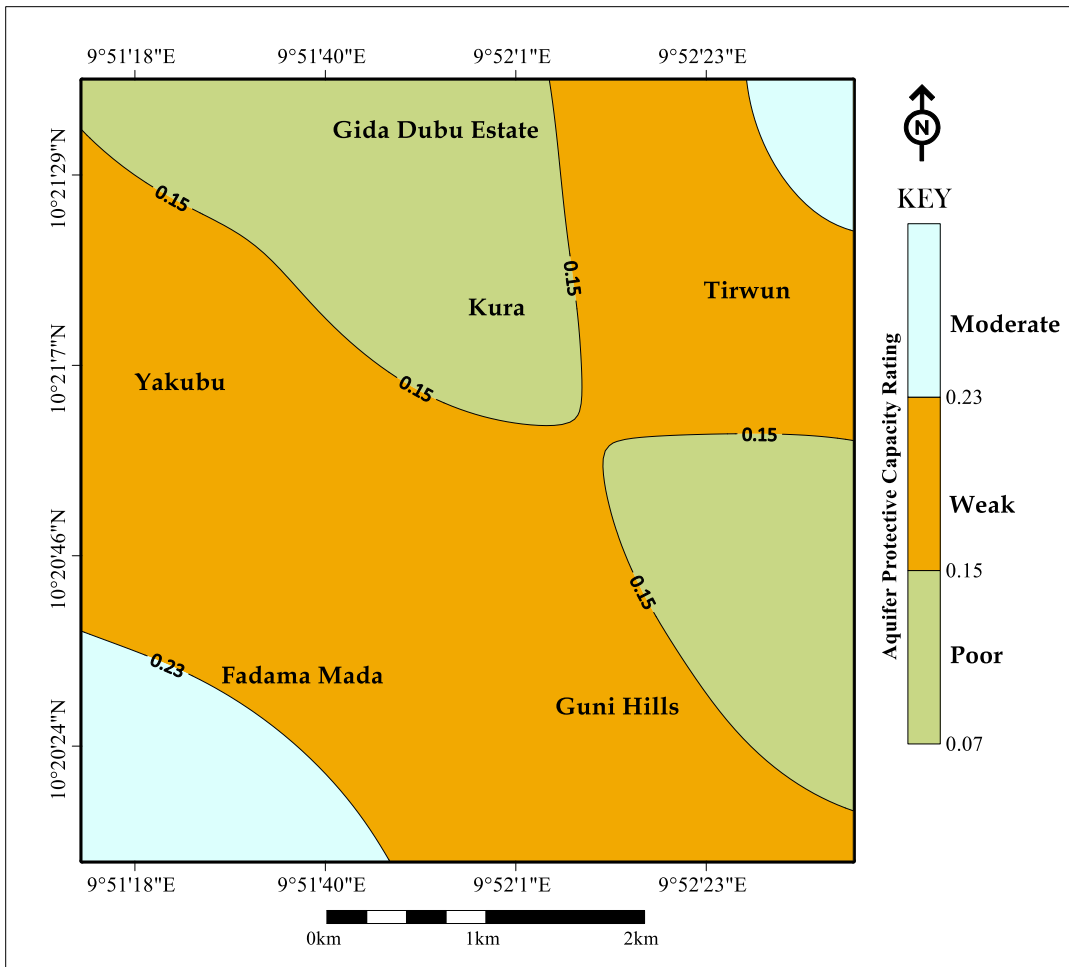


Figure 6: Aquifer Protective Capacity Rating of the study Area

6. CONCLUSION

Conclusively, the aquifer protective capacity evaluation of the study area was undertaken using 10 Vertical Electrical Soundings (VES) points, traversed across the area. The VES data interpretation involved quantitative partial curve matching and computer modeling using IPI2WIN program software. Hence, the curve types obtained were mostly the H-type with little of the A-type. The weathered/fractured zones are the only aquifer unit delineated during the investigation. The resistivities and thicknesses of each sounding point were used to generate secondary order parameters (Dar Zarrouk parameters) i.e., the longitudinal unit conductance (S), and the transverse unit resistance (T). Additionally, three layers were majorly delineated which include; the topsoil, weathered/fractured zones, and the fresh basement. The study also revealed that most parts of the area are underlain by materials of weak to moderate protective capacity. Consequently, highly vulnerable zones include the northwestern to eastern regions of the study area. For effective groundwater development programs in the study area, it is suggested that pre-drilling geophysical investigations be cautiously conducted for hygienic and environmental purposes.

Conflict of Interest: The authors wish to state that there is no conflict of interest.

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