



Research Paper

The Hydrogeology of Chikun and Environs (Kakuri Sheet 144 NW) North Central- Nigeria

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ABSTRACT

The Hydrogeology of Chikun and Environs (Kakuri Sheet 144 NW) North Central- Nigeria was studied using geological, hydrogeological and geophysical methods. The major rock mapped within the study area include; mica schist, granitic gneiss and porphyritic granite. The petrographic analyses carried out reveals the presence of quartz, muscovite, microcline, perthite, biotite, plagioclase, and orthoclase. Results of VES interpretation reveal four to six geoelectric layers, thicknesses and their respective resistivity values that include; Top soil having the thickness and resistivity of 0 m and 391.0 Ω , sandy clay: 7.51 m and 291.0 Ω , consolidated sand: 22.12 m and 204.1 Ω , highly weathered basement: 27.57 m and 262.6 Ω , partially weathered basement: 30.85 m and 427.0 Ω , and the fresh basement: 87.50 m and 604.4 Ω . Based on hydraulic head measurements from 38 hand-dug wells, the groundwater configuration map for both dry and wet seasons were drawn to show the groundwater flow direction of the study area. The borehole performance was examined using information on hydraulic characteristics of the aquifer that include yield ranging from (15.552-88.128 m³/day), Transmissivity, T (1.779 x 10⁰- 8.96 x 10⁻¹ m²/day) and Storativity, S (1.03 x 10⁻¹-3.706 x 10⁻³) as computed from the pumping test result. The geochemical results show Total Dissolved Solids (TDS) ranging from 8-365 mg/l having a median value of 14 mg/l with an average of 70.1mg/l, Electrical conductivity (EC) ranges from 13-522 μ S/cm having a median value of 69 μ S/cm with an average of 100.1 μ S/cm, Temperature ranges from 6-30.75^oC having a median value of 13.35^o C with an average of 22^o C and pH ranges from 5.26-6.8 having a median value of 5.89 with an average of 6. The major and minor elements concentrations are mostly within the permissible limit of NIS (2007) and WHO (2011). The results show that the groundwater in the study area is potable and suitable for domestic, industrial and agricultural uses, except in some locations like Gwogofe, Damba 2, Gwagwada 3, Angwan Turai, Gudun Guya and Angwan Alkali 2 where the concentration of Pb and Cr are slightly above permissible limits. Based on the VES interpretation, VES 1, 2, 5, 8, 9, 13 and 15 can be considered for citing a borehole because of their relatively lower resistivities (between 195.3-215.1 ohm meters). Similarly, VES 3, 4, 6, 7, 10, 11, 12 and 14 are considered suitable for citing boreholes (between 213.3-259.0 ohm meters). The groundwater potential for the study area is rated low having a coefficient of T (m²/d) ranging from 10-1 within the class of T magnitude of IV when compared with Krasny's Classification of Transmissivity of Magnitude and Variation, this classification suggests that the volume of groundwater within the study area is for smaller withdrawals for local water supply (Private consumption).

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I. INTRODUCTION

Water is central to the survival of human beings as it is needed in all aspects of life (Tiwari and Ranga, 2012; Deshpande and Aher, 2012; Ranjan, 2012). Several boreholes installed with hand pumps have been drilled by various government agencies in Nigeria such as the National Water Resources Institute (NWRI) to provide potable water in order to improve the quality of life for many rural communities. Nigeria is blessed with large quantity of groundwater resources. The potential annual groundwater resources are estimated at 51.93 x 10⁹ m³, out of which the sedimentary basins account for 67% (FMWRRD, 1995). Regulations like Nigeria Integrated Water Resources Management Commission (NIWRMC, 2016) have been put in place to protect water resources in Nigeria to effectively control the indiscriminate dumping of effluents into open water bodies. These effluents come/originate from different sources like domestic, industrial and agricultural sources. As a result of this, different heavy metals have been found in concentrations well above acceptable and permissible

levels and these include: lead, copper, zinc, nickel, chromium, cadmium and iron (Olayinka and Alo 2004; Esoka and Umaru 2006, Eniola *et al.*, 2010). Degradation of water quality is most severe in the four states that contain eighty (80%) percent of the nations industries; Lagos, Rivers, Kano and Kaduna States, this has continued to pose a threat to health and economic development in Nigeria (Ajibade 2004; Olayinka and Alo 2004; Adekunle *et al.*, 2007; Adeyemi *et al.*, 2008; Mustapha, 2008; Adewolu *et al.*, 2009). However, a large part of the Nigerian population still does not have access to water of adequate quantity and quality as some individuals tend to make provision for potable water in form of hand dug wells in order to cushion the impacts felt from scarcity or non availability of boreholes or pipe borne water provided by government. According to the 2008 report of the WHO/UNICEF JMP (Joint Monitoring Programme for water supply and sanitation) the proportion of the population using water from improved sources has decreased by 3% from 1990 to 2006 (WHO/UNICEF, 2008). This research is an attempt to contribute to the knowledge of the Regional hydrogeology of Nigeria in the area of water quality.

Statement of Research Problem

Over the years, the quality of water used for domestic purpose in Nigeria has not been given adequate attention in terms of the physico-chemical constituents, whether it is adequate, moderate or too high before consumption. This may lead to the outbreak of diseases such as cholera, typhoid, etc.

The water quality assessment in the study area becomes imperative in order to determine localities with good water quality in line with WHO standards. This becomes even more pertinent in view of the fact that the study area is located on River Kaduna downstream of Kaduna Refinery and Petrochemical Company (KRPC) plant.

Aim of the Study

The aim of this work is to study the hydrogeology of Chikun and environs, Kakuri Sheet 144 NW on a scale of 1:50,000.

Objectives of the Study

The specific objectives of this study are as follows:

- i) To produce the geological and hydrogeological maps of the study area.
- ii) Determine the groundwater flow direction at the peak of wet season and at the peak of dry season.
- iii) Determine the water quality of the study area for domestic, industrial and agricultural purposes.
- iv) Delineating groundwater potential of the study area using aquifer characteristics with a view to determine if it is low, medium or high for better management of water resources in the study area.

Study Location and Accessibility

The study area is located in Chikun Local Government Area of Kaduna State and lies between Longitudes $7^{\circ}00'$ - $7^{\circ}15'E$ and Latitudes $10^{\circ}15'$ - $10^{\circ}30' N$. The area is within Kakuri Sheet 144 NW. It covers an area of about 733.86 km² and is accessible through Kaduna-Abuja road which traversed the area from the north, and through Buruku-Birnin Gwari-Lagos road from the south. The study area has boundary with Niger State to the west. There is also a dense network of footpaths and cattle tracks that make the study area quite accessible by foot and by vehicles. (Fig. 1).

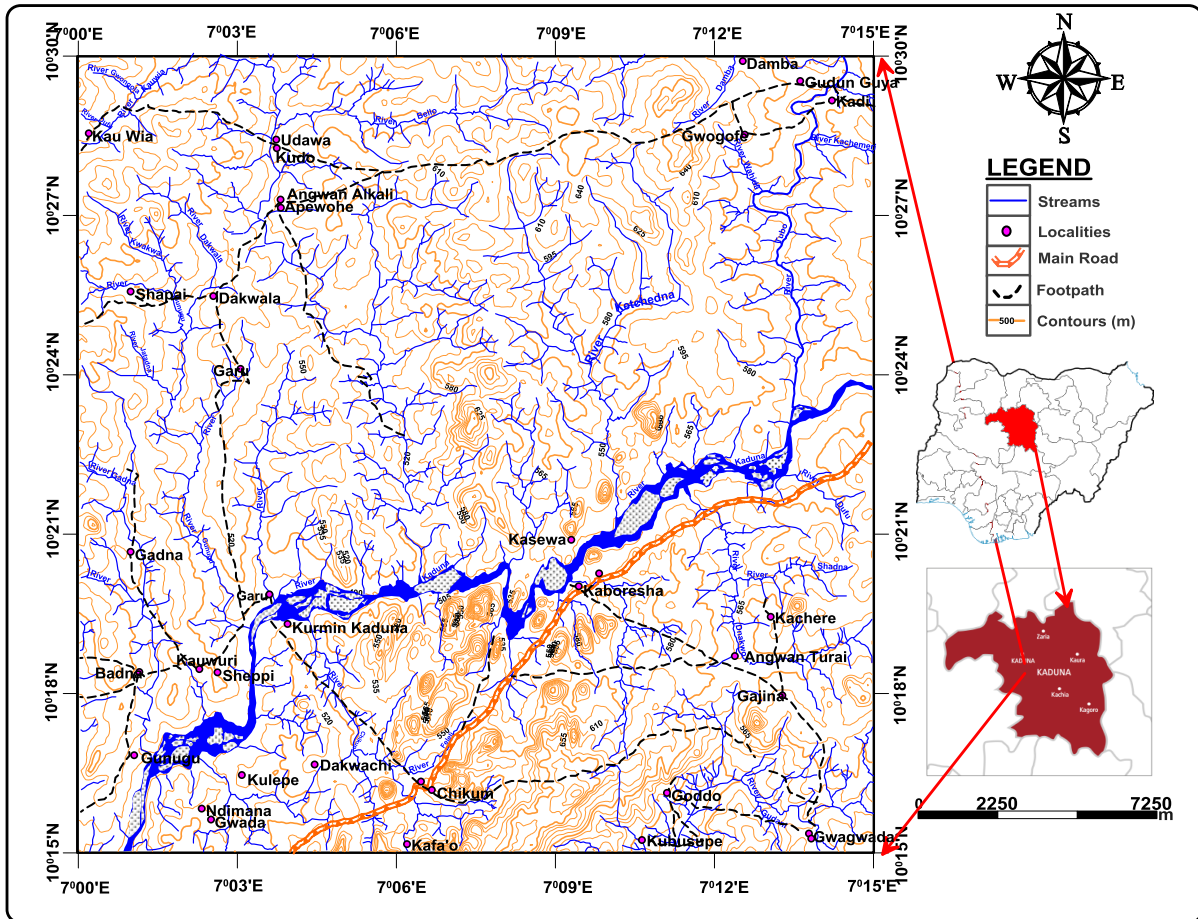


Figure 1: Location and accessibility Map of the study area (Sheet 144 NW)

II. MATERIALS AND METHODS

The methodology employed for this study was in five stages, consisting of desk study, field work, lineament extraction, laboratory work and evaluation of the field and laboratory data. Instruments used include; Geologic compass, Pasi automatic resistivity/Sp meter, geologic hammer, masking tape, polyethylene sample bottles, TDS meter, thermometer, nitric acid, pH meter, sample bag, measuring tape, field note book, marker pen, plastic drawing bucket attached with rope and GPS and topographic sheet 144 on a scale of 1:50,000.

III. RESULTS

The data were assessed with respect to the geology, hydrogeology and groundwater quality and usability in the study area according to World Health Organization (WHO, 2011) and Nigeria Standard for Drinking Water Quality (NSDWQ) 2007 standards. The types of groundwater in the area were determined using piper Trilinear diagram (After Piper, 1994).

Geology of the study area

The study area is underlain by rocks of the basement complex. The distribution of the various rock types is as shown in the geological map of the area (Fig.2). Three main rock types were identified in the study area, they include; Granitic gneiss, porphyritic granite and mica schist. The rock units are distributed such that the porphyritic granite terrain is found at the northwestern part of the study area, the mica schist is found at the centre and towards the western part of the study area and the granitic gneiss appears at the southeastern part of the map and their field relationship is that they all have clear cut boundaries with each other without any interference by other minor outcrop exposures.

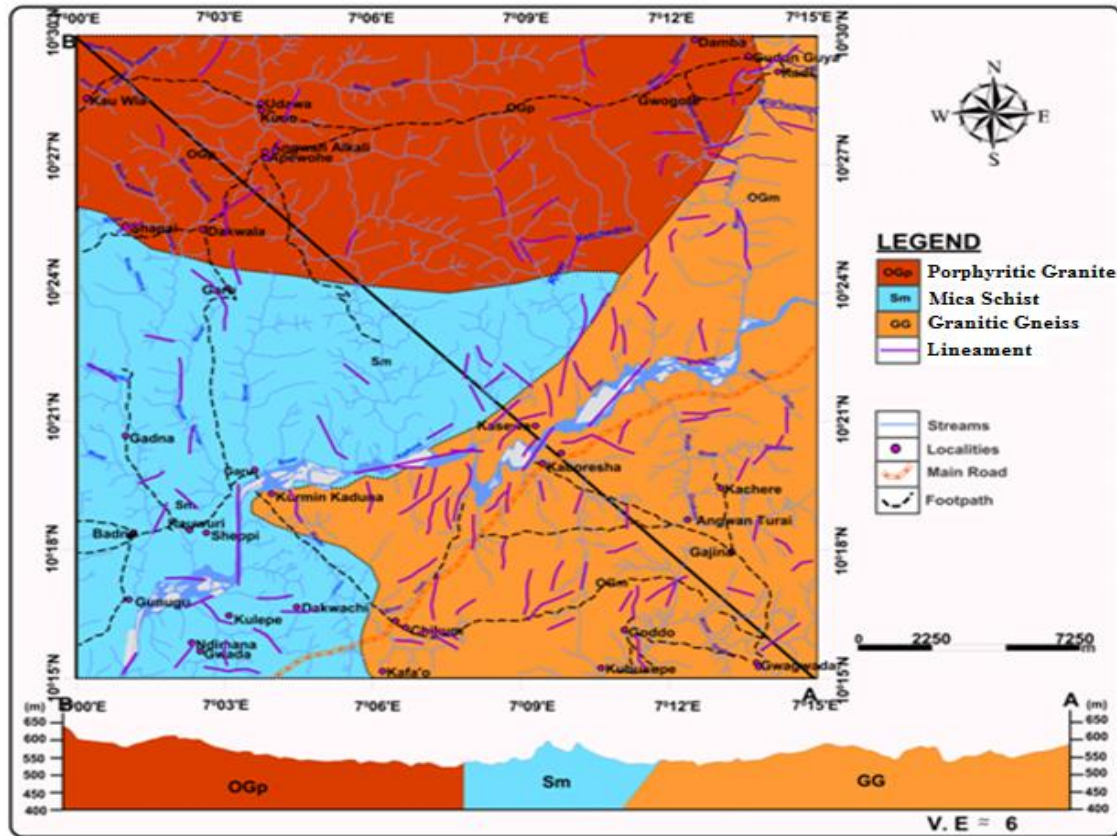


Figure 2: Geological map of Kakuri, Sheet 144 NW (Study Area) with sampling points on a scale of 1:50,000.

Hydrogeochemistry (Water Quality)

Chemical characteristics

Table 1: Concentration of major, minor and trace elements in the water samples

SAMPLE ID	LOCATION	pH	EC(μ S/cm)	TDS (mg/l)	T ($^{\circ}$ C)	K ⁺ (mg/l)	Na ⁺ (mg/l)	Mg ²⁺ (mg/l)	Ca ²⁺ (mg/l)	Fe ²⁺ (mg/l)	Cr (mg/l)	Pb (mg/l)	Hg (mg/l)	NO ₃ ³⁻ (mg/l)	Cl ⁻ (mg/l)	SO ₄ ²⁻ (mg/l)
1	Gwogofe	5.8	36	25	20.75	5.3	3.8	2.36	0.54	0.075	0.088	0.186	6.427	7	16	1.27
2	Damba 1	6.6	155	109	20.09	1.3	7.1	3.8	12.34	0.135	0.087	0.088	5.008	21	16	3.5
3	Damba 2	6.04	28	20	20.75	2.7	5.7	0.67	0.39	0.032	0.212	0.128	5.265	14	16	1.43
4	Chikun1	5.94	13	9	20.09	3.9	1.4	0.79	1.02	0.051	0.131	0.038	4.045	7	12	2.22
5	Chikun2	6.4	22	15	20.85	2.6	3.7	0	0	0.009	0.095	0.077	4.61	7	12	2.07
6	Gwagwada 1	6.56	522	365	20.75	3.2	4.9	15.6	60.29	0	0.05	0.054	2.246	14	99.97	2.22
7	Gwagwada 2	6.8	373	261	30.75	30.75	4.7	15.96	36.24	0	0.197	0.088	2.555	14	51.98	9.06
8	Gwagwada 3	6.58	246	172	20.7	2.9	1.5	13.21	17.7	0.023	0.208	0.251	2.505	21	75.98	2.38
9	AngwanTurai	5.95	123	86	20.75	5.3	2.6	3.68	6.43	0.048	0.052	0.1	5.631	14	21.99	2.22
10	GudunGuya	6.52	29	20	20.7	0.9	5.9	0.82	0.91	0.038	0.159	0.145	6.904	7	17.99	2.54
11	Angwan Alkali 1	5.26	109	08	6	1.3	1.5	1.71	0	0.005	0.12	0.009	3.282	7	10	3.5
12	Angwan Alkali 2	5.73	13	9	20.8	2.8	1.2	0	0	0	0.129	0.005	3.516	35	8	2.54
13	Kudo	6.17	53	37	20.7	2.6	1.3	1.34	1.91	0.031	0.093	0.13	5.45	21	19.99	2.38
14	Kurmin Kaduna	6.86	128	90	20.7	4.7	1.9	1.69	14.84	0.095	0.018	0.115	6.954	21	33.99	2.86
15	Gajina 1	5.85	34	24	20.8	6	5.9	2.33	0.57	0.072	0.113	0.077	3.128	7	12	2.86
16	Gajina 2	5.74	20	14	20.75	2.7	5.1	0.57	0	0.262	0.13	0.02	3.183	7	14	3.5
17	Gajina 3	5.79	20	14	20.8	2.4	4.5	1.16	0	0.675	0.149	0.036	3.348	7	19.99	2.86
18	Dakwachi	6.26	20	14	20.9	4	4.9	0.54	0	0.033	0.081	0.108	6.266	7	16	2.86
19	Kulepe	6.75	38	27	20.9	2.6	7.9	0.79	4.61	0.114	0.143	0.083	6.427	7	12	2.07
20	SabonKauWia	6.4	121	85	20.7	1.4	1.9	3.08	8.13	0	0.218	0.122	5.845	21	41.99	2.54
AVERAGE		6	100.1	70.1	22	3	4	4	4	0	0.124	0.078	4.63	13.3	29.75	2.844

Characteristics of the groundwater

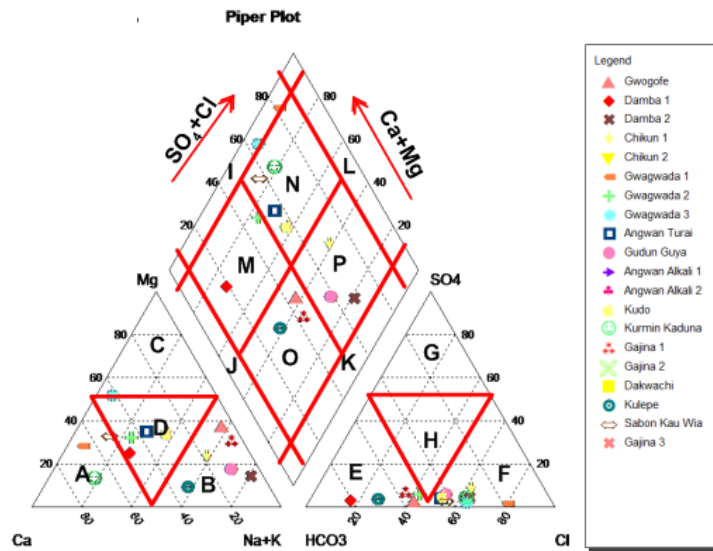


Figure 3: Piper Trilinear Diagram of the relative Cation and Anion composition of groundwater samples of Kakuri NW (After Piper 1994).

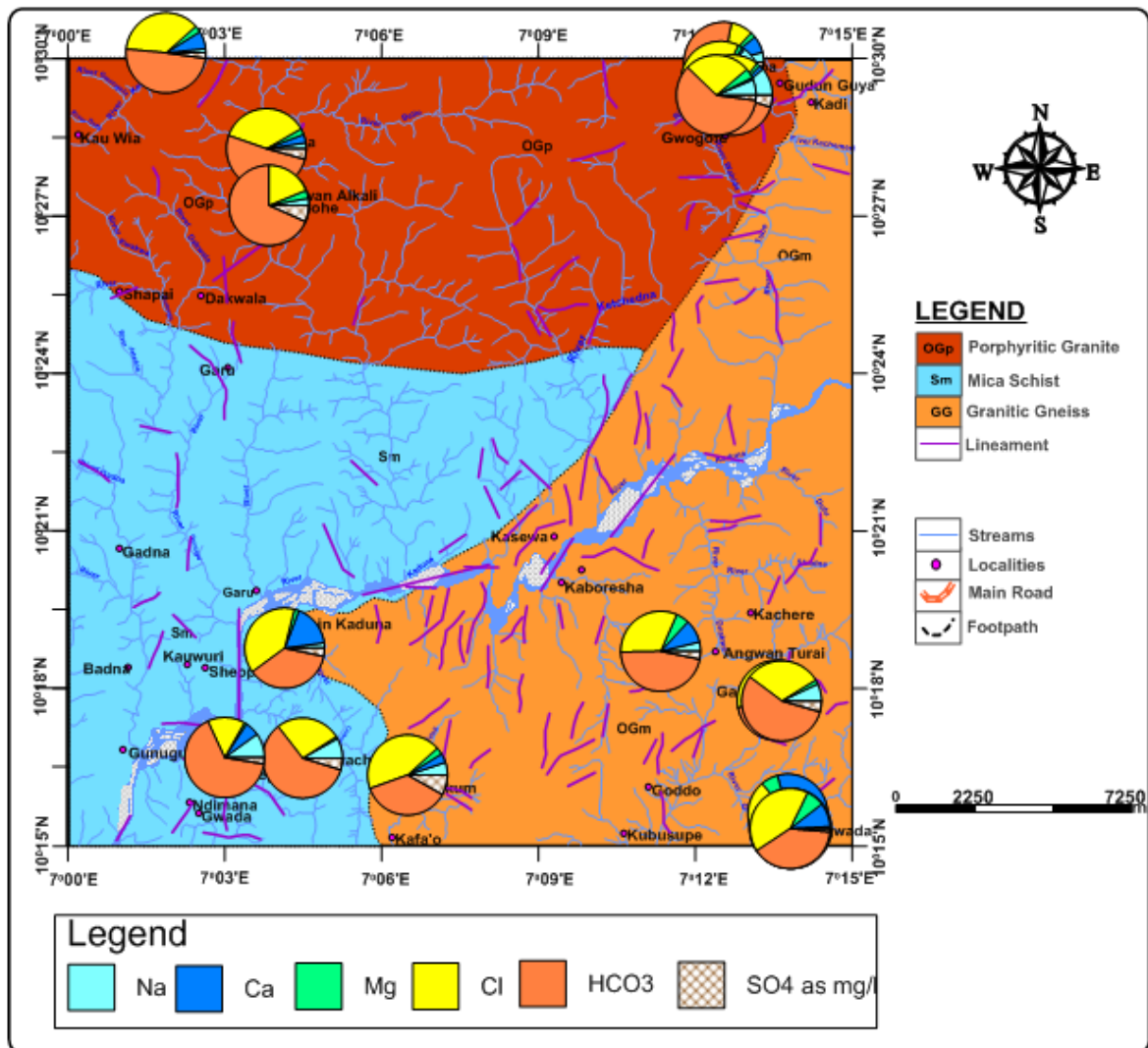


Figure 4: Groundwater Type of Kakuri NW, Superimposed on the Geological Map

Geophysical Assessment

Geophysical investigation data was collected for fifteen (15) locations where the survey was done. Vertical Electrical Sounding (VES) techniques was employed with full Schlumberger Electrode Array Configuration, using the Pasi Automatic Resistivity/Sp Meter. The half-current electrode separation AB/2 ranges between 1.0 and 70.0m and the target depth of investigation was between 50 – 58 m while half-potential electrode separation MN/2 was between 0.5 and 7.5m. The instrument and survey technique were geared towards good data resolution and subsurface investigation for proper delineation of the geo-electric layers and their geological equivalence. However the results show that the study area comprises of 4-6 geo-electric layers. The sequence of the layers is as follows: Top soil, sandy clay, consolidated sand, highly weathered basement, partially weathered/fractured basement and the fresh basement. Nevertheless, the thickness of the various layers for the study area as a whole could not be determined since the measurements were not carried out along a profile. The thickness of the layers for each VES point probed.

Top soils and laterites constitute the first layer and it consists mainly of unsaturated materials above the water table which has relatively high resistivity.

Sandy clay (regolith): This is the second layer in the geo-electric section made up of sands and clayey materials.

The third layer in the geo-electric section consists of mainly coarse sand.

Highly weathered rock: This layer is composed of saturated material. It has relatively low to moderate resistivity value and it is the main aquiferous zone in the study area.

The sixth layer in the geo-electric section is unsaturated and contains sizeable amount of clay. And the last layer which is the fresh basement comprises mainly of unweathered and unfractured rock as shown on a generalized geo-electric profile from VES 1 to VES 15. Fig.5, while Fig. 6 shows lithologic logs of boreholes in the study area.

It was observed that 3 out of the 15 VES points in the study area are made up of 4 layers, 7 VES Points have 5 layers and 4 VES point has 6 layers and 1 has 7 layers, all with different ranges of resistivity values and layer thickness. The percentage correlation between the water well and the VES points in the study area is 78.8%

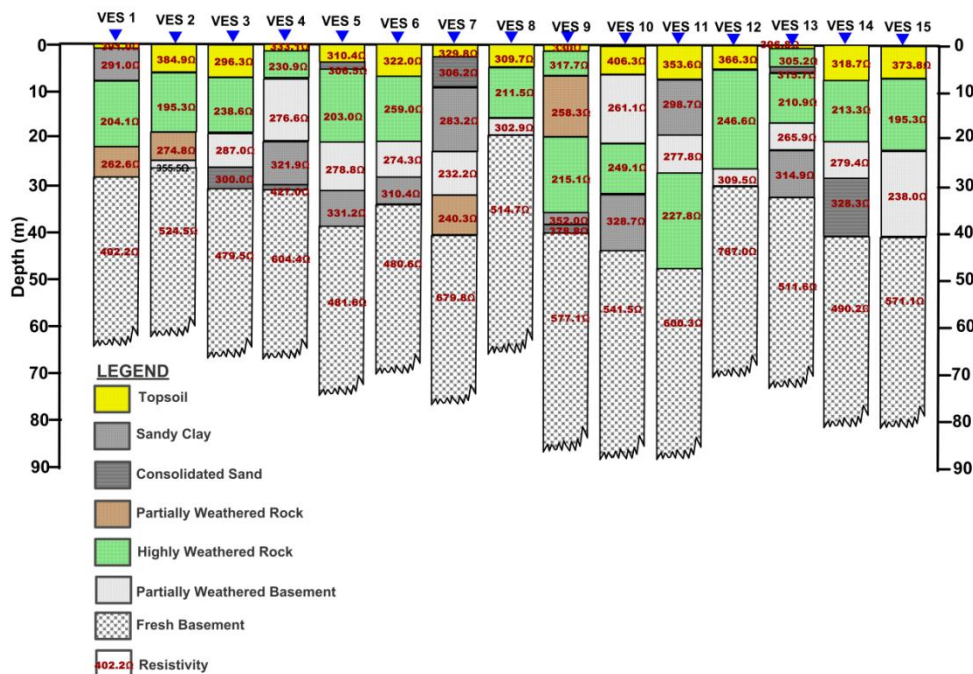


Figure 5: Generalized Geo-electric section across the three lithologic units of the study area showing the probable aquiferous zones

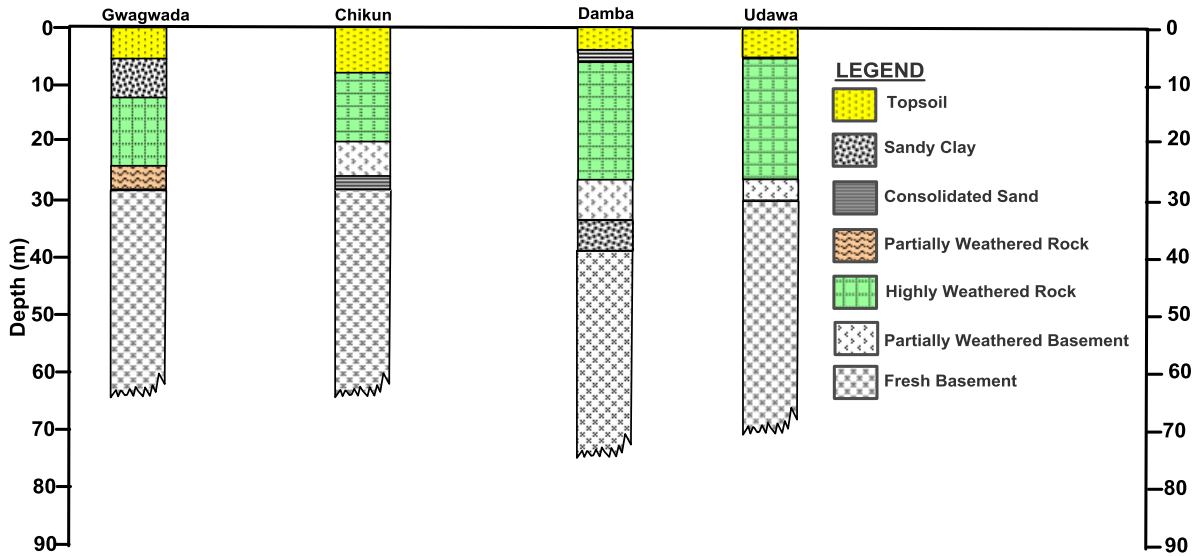


Figure 6: Lithologic logs of boreholes in the study area

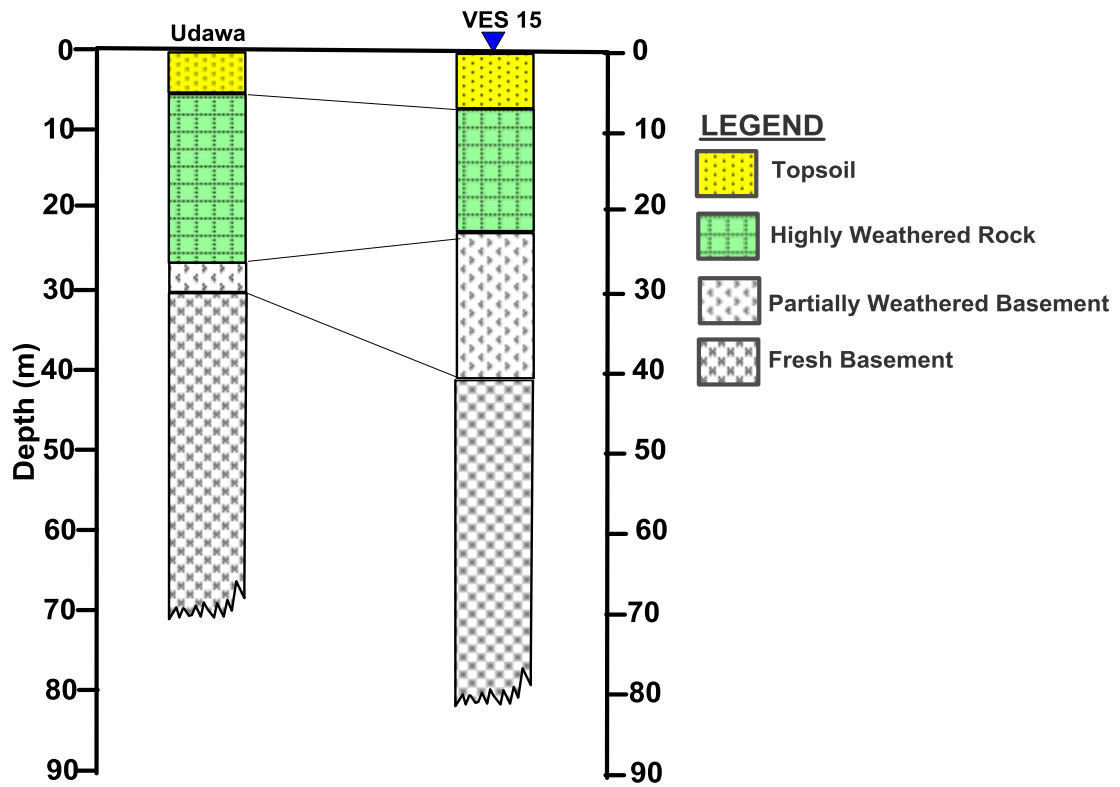


Figure 7: Correlation of VES with lithology in the study area

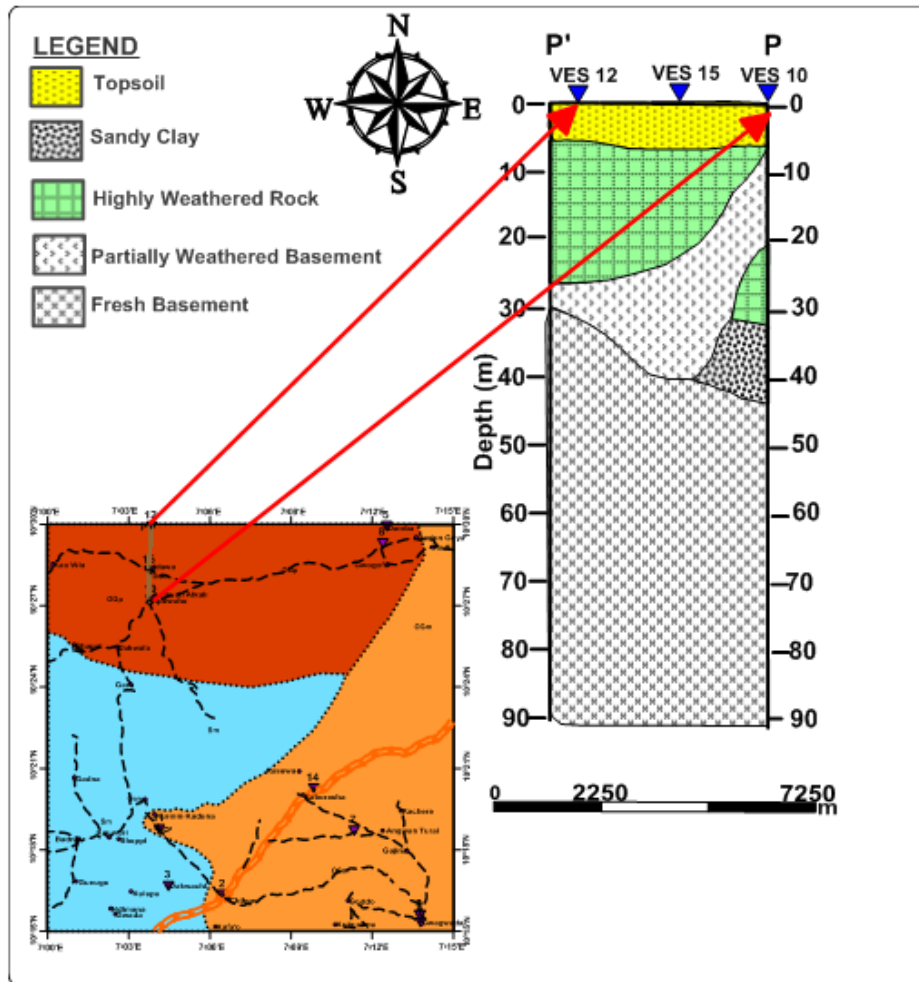


Figure 8: Geo-electric cross section across P' to P

Table 2: Krasny's Classification of Transmissivity of Magnitude and Variation (After Krasny, 1993)

Coefficient of transmissivity (m ² /d)	Class of transmissivity magnitude	Designation of transmissivity magnitude	Nonlogarithmic Specific capacity q in l/s m	Logarithmic Index Y	Groundwater supply potential	Very approximate expected discharge in l/s of a single well at 5 m drawdown
1,000	I	Very high	10	7.0	Withdrawals of great regional importance	>50
100	II	High	1	6.0	Withdrawals of lesser regional importance	5 - 50
10	III	Intermediate	0.1	5.0	Withdrawals for local water supply (small communities, plants, etc.)	0.5 - 5
1	IV	Low	0.01	4.0	Smaller withdrawals for local water supply (private consumption, etc.)	0.05 - 0.5
0.1	V	Very low	0.001	3.0	Withdrawals for local water supply with limited consumption	0.005 - 0.05
	VI	Imperceptible			Sources of local water supply are difficult (if possible) to ensure	<0.005

The hydraulic characteristics were compared with Krasny's classification of transmissivity of magnitude and Variation and it show that transmissivity of the boreholes in the study location falls within the 10-1 coefficient of T (m²/day), Class IV of T magnitude corresponding to low designation of T magnitude whose groundwater supply potential is for smaller withdrawals for local water supply (private consumption).

IV. CONCLUSION

Field study has shown the major lithological units in the study area to be mica schist, granitic gneiss and porphyritic granite. Geological structures such as joints, are common in the study area with prominent structural trends to be NE/SW.

The major aquifer unit in the study area is the highly weathered aquifer forming the major aquifer unit in the study area.

Results of water analyses show that the chemical quality of groundwater in the study areas is within the permissible limit by NIS (2007) and WHO (2011) of the analyzed elements, except for Pb and Cr. Generally, groundwater samples from the study area is classified as being excellent for irrigation purpose

The transmissivity of boreholes in the study area when compared with Krasny's transmissivity of magnitude and variation shows that the groundwater supply potential in the study area is for smaller withdrawals for local water supply (private consumption).

V. Recommendations

- i) Management of factors that bring about higher concentration of lead and chromium in some parts of the study area.
- ii) The groundwater potential of the study area is low based on Krasny's classification, modalities should be put in place to sustainably manage the situation for future use.
- iii) Analysis for microbial concentration of the groundwater in the study area should also be carried out as a routine process.
- iv) Surface water inform of overhead tanks should be built to enhance rural water supply in the study area in general.

Contribution to Knowledge

- i) Geological map of Kakuri, sheet 144 NW on a scale of 1: 50,000 has been updated.
- ii) Groundwater configuration maps showing the direction of groundwater flow for both wet and dry season have been produced which gave an insight of the direction of recharge and discharge of groundwater in the study area.
- iii) The groundwater quality in terms of chemical concentration in the study area has been determined and documented, such that areas with suitable water quality can be developed for use.
- iv) The groundwater yield of the study area has been tied up to the rock types in the study area.

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