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Full Length Research Article

GEO-ELECTRIC INVESTIGATION OF THE GROUNDWATER POTENTIAL DISTRIBUTION WITHIN GWALE LOCAL GOVERNMENT AREA OF KANO STATE NIGERIA

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ABSTRACT
The study was conducted at Gwale local Government Area of Kano State. Static water level from open wells were collected and used as a guide for the selection of the electrode spread distance. To achieve this, two important hydraulic properties – hydraulic conductivity and transmissivity of the aquifer media in the area were computed. A geoelecric survey was carried out involving Vertical Electrical Sounding (VES) to investigate the sub-surface depth using the Schlumbeger technique. Omega resistivity meter was used and forty points were sounded in the area. Data obtained were processed using the IPI2WIN software to display results in a log-log graph. Values for transmissivity and hydraulic conductivity were computed. The data together with the coordinate of points for each station obtained using a Global positioning system (GPS), were used to plot 2D and 3D contour maps. This was done with the aid of Surfer 12 software. In conclusion, transmissivity values recorded is within a range of 4.5322m^2/day to 26.4652m^2/day, with an average value of 15.6812m^2/day. Hydraulic conductivity values range 1.4706x10^{-5}m/s to 7.9070x10^{-6}m/s with an average value of 6.9529x10^{-6}m/s. Aquifer thickness recorded a range value between 7.00 m to 45.00 m with an average of 25.54m. Groundwater yield in the study area is adequate to sustain water supply need for various uses.

Keywords: Groundwater, Hydraulic conductivity, Transmissivity, Geo-electric, aquifer.

INTRODUCTION
Underground water is one essential but necessary substitute to surface water in every society's usage. It's no doubt a hidden, replenishable resource whose occurrence and distribution greatly varies according to the local as well as regional geology, hydrogeological setting and to an extent the nature of human activities within the land. Underground water occurrence in Basement terrain is hosted within zones of weathering and fracturing which often are not continuous in vertical and lateral extent (Jeff 2006). There is a steady rise in the demand for underground water in most hard rock areas (Adanu 1994). Kano area is underlain by rocks of the Nigerian Basement Complex comprising of migmatite-gneiss complex, Younger Metasediments, Older and Younger Granites. The aquifers of the Basement Complex rocks are the regolith and the fractures in the fresh bedrock which are known to be interconnected at depth (Uma & Kehinde 1994).
In a recent hydrogeological study carried out in parts of Kano area, Bala (2008) has shown that regolith aquifer derived from schists and gneisses of sedimentary origin (orthogneisses) proved to be a difficult groundwater terrain contrary to the observations in the earlier works that not only indicated similarity in aquifer performance across the different bedrock types, but also that these aquifers compare with those in other parts of the African Shield. He also noted that wells located in areas underlain by schists and similar rocks were generally deep and the depth to the water table is deeper than in those located in the other rock types (Bala 2008). The failure rate in most groundwater project recorded in Basement Complex aquifers has informed the general acceptance of a geophysical survey as a compulsory pre-requisite to any successful water well drilling project (Danhassan & Olurunfemi 1999). The electrical resistivity method involving the vertical electrical sounding (VES) technique is extensively gaining application in environmental, underground water and engineering investigations (Abubakar & Danbatta 2012).
Geologists have used resistivity information to quantitatively assess the permeability of clay alluvium over the years (Abubakar & Danbatta 2012). From the geologic conditions, it is sometimes convenient to relate the Dar Zarrouk parameters of transmissivity and conductivity to explore for water. The yield of a bore hole can be determined from the hydraulic transmissivity. Several authors have explained the expressions used for exploration of groundwater by geo- electrical resistivity method. Geophysicists apply Physics Laws to study the earth's subsurface. Thus, groundwater flow in a porous medium is governed by Darcy's law and it is analogous to the Ohms law. The Dar-Zarrouk parameters used in this work are the conductivity (K) and the transmissivity (T). Hydraulic Conductivity (K) is a measure of the ability of a formation to transmit water. It is expressed in ms^{-1}, while transmissivity (T) is the time-rate of flow of water at the prevailing field temperature under a unit hydraulic gradient through a vertical strip of aquifer of unit width and extending through the entire saturated thickness of the aquifer. It is expressed in m^{2}d^{-1} or m^{2}s^{-1}. Darcy's law, in terms of T, can be expressed as:

$$Q=TIL \quad (1)$$

Where Q = rate of flow, I = hydraulic gradient, L = width of the flow section, measured at right angles to the direction of flow.
In a confined aquifer like that of the study area,

$$K = T/b \quad (2)$$

Where b is the saturated thickness of the aquifer and K is assumed to be an isotropic and constant across the thickness of the aquifer which may be horizontal or dipping. There exist a relationship between transmissivity (T) and resistivity (ρ). This relationship which can be expressed as K is either decreasing or increasing and it has generally been proved to contain an exponential fit between transmissivity (T) and resistivity (ρ). The present study area is located in a basement complex region with evidence of hard rocks, depending on the geologic formation of the study area, the value of K in equation 2 can be expressed as;

$$T = b \times 8 \times 10^{-6} Exp^{-(0.00013\rho)} \quad (3)$$

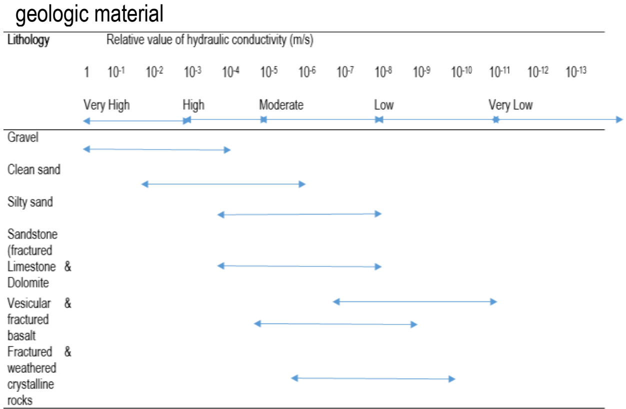
Where b = the aquifer thickness (m), ρ = the resistivity of the aquifer in (m).

Knowledge of permeability and transmissivity distribution is decisive for any groundwater development or consideration. In hydro-geologic maps, transmissivity has been the best hydraulic property to clearly express ground water potential in table 1. In this research work, the Schlumberger array technique has been used to obtain the Vertical Electric Sounding (VES) from which the thickness and resistivity of the aquifer was obtained (Mccurry 1989).

Table I: Classification of Transmissivity magnitude

S/N	Coefficient of transmissivity (m^2/day)	Designation of transmissivity	Ground Water Potential
1	1000 and above	Very High	Withdrawals of great regional importance
2	100-1000	High	Withdrawal of lesser regional importance
3	10-100	Intermediate	Withdrawal of local water supply (communities, plants)
4	1-10	Low	Smaller withdrawals for local water supply (private consumption)
5	0.1-1	Very Low	Withdrawal for local water supply with limited consumption
6	Below 0.1	imperceptible	Source for local water supply are difficult

Table II: Range of values for hydraulic conductivity for some geologic material



The study was conducted at Gwale Local Government Area of Kano State. The area lies between11°56´40´ ´to 12°1´4´´0N and longitudes 8°26´40´´ to 8°30´0´´ E.

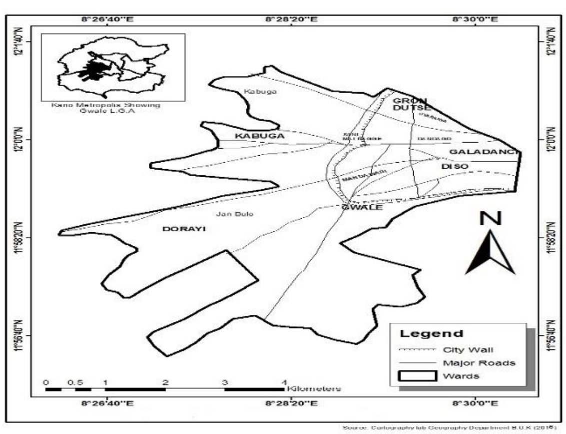


Figure 1: Map of Gwale local government

The Northern Nigerian Basement Complex comprises of three major groups of rocks namely, migmatites and (high grade), gneisses derived from Birrimain sedimentary rocks through high grade metamorphism and granitization, the Younger Metasediments of Upper Proterozoic age which are low grade metamorphic rocks that were folded along with the migmatite and gneisses during the Pan-African orogeny; and the Older Granite series which were intruded during the Pan-African orogeny (Mccurry 1989). In their study, Hazell et al. (1988) reported the occurrence of rocks of the Younger Granites series, they are so termed because they are Jurassic in age as well as volcanic, and occasionally of younger dykes and ridges. KNARDA (1989) identified the individual members of the Older Granite suite, but rocks of the Younger Metasediments and those of the migmatite-gneiss complex were simply grouped as the migmatite- gneiss complex in some places.

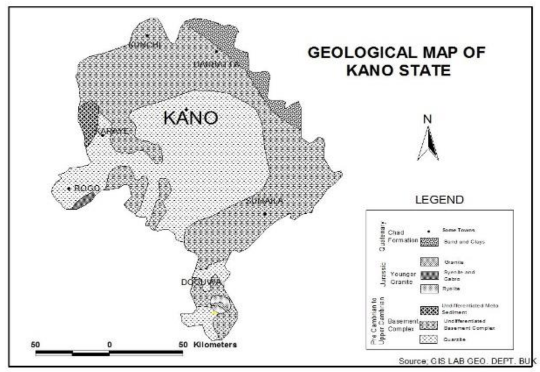


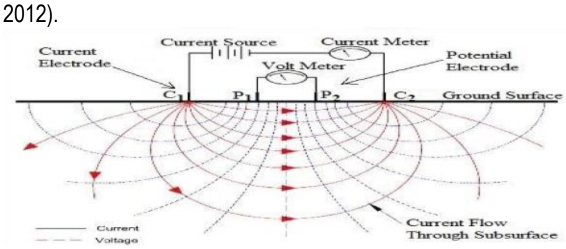
Figure 2: Geological Map of Kano State

The study area is a fast growing community in terms of population, business activities, agricultural, municipal, industrial purposes, sanitation and purposes of buildings, hospitals and personal hygiene which require high demand for more water for such uses. This has impacted on the growing demand for portable water. Kano State is within the basement complex of northern Nigeria. That is why it is important to initiate a proper groundwater resource and exploration program to delineate the water potential regions of aquifer units within the study area.

METERIALS AND METHODS

The schulmberger technique which is best for probing depth was used to acquire the Vertical Electrical Sounding (VES) data. This technique has long been used to source for water in any type of geologic setting. In this study, Omega resistivity meter was used and forty points was sounded in areas.

The resistivity measurements are normally made by injecting current into the ground through two current electrodes (C1 and C2) as in Fig.3.1, and measuring the resulting voltage difference at two potential electrodes (P1 and P2)(Abubakarb & Danbatta 2012).



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The four electrode Schlumberger array with a maximum current electrode spacing AB of 100m was used for this survey. An Omega resistivity meter was used to measure and record the resistance of the subsurface. For each electrode combination for which a sounding was made and reading of resistance R of the volume of earth material within the electrical space of the electrode configuration was obtained. The product of configuration factor K and R was then made to obtain the apparent resistivity of the said earth material.
This was subsequently done on all the point data obtained for each VES station to give the set of apparent resistivity values supplied for computer modelling using IPI2WIN software for the iteration to obtain the geo-electrical parameters. The manner in which apparent resistivity values increase or decrease with each electrode separation forms the basis for quantitative interpretation of the electrical resistivity data.
To change the depth range under investigation the distance AB is progressively moved outwards symmetrically, keeping MN fixed. However when the ratio AB/MN becomes too large the potential drop across MN becomes too small to be measured within reasonable accuracy. This necessitates increasing MN. At any AB/2, readings should be made at several MN/2 values in order to indicate the presence of lateral non-homogeneity

The data collected was processed using the IPI2WIN software. This software was able to display a processed result in a log-log graph. From the result, the weathered aquifer was identified with its resistivity as shown in Table III. By using equations 2 and 3, values for transmissivity and hydraulic conductivity were computed (see Table III). These data, together with the coordinate of points for each station was plotted using a Garmin global positioning system (GPS) and obtained a 2 and 3 dimensional contour maps as shown in Fig. 3, 4, 5, 6 and 7 below, this was done with the aid of Surfer 12 software.

RESULTS

Results obtained from the vertical electrical sounding is presented in the Table below, showing co-ordinates of VES points with the estimated thickness of the aquifer, its associated resistivity values, and the computed total and average values for hydraulic conductivity and transmissivity according to the equations (2) and (3). These data were used to obtain contour maps for the resistivity, aquifers thickness, hydraulic conductivity and transmissivity as represented by Fig. 3, 4, 5, and 6 respectively.
Transmissivity values recorded are within a range of 4.5322m^2/day to 26.4652m^2/day, with an average value of 12.6812m^2/day. Hydraulic conductivity values range from 1.4706x10^{-5}m/s to 7.9070x10^{-6} m/s with an average value of 6.9529x10^{-6} m/s. Aquifer thickness recorded at a range of value between 7.00 m to 45.00m with an average of 25.54m.

Table III: VES points with calculated hydraulic conductivity and transmissivity values

S/N	VES points co-ordinate Northing	Easting	Aquifer thicknes s (m)	Resistivity (Ωm)	Hydraulic conductivity (m/s)	Transmissivity m^2/s	m^2/day
1	11.988706	8.500785	8.00	153.00	6.5571x10^{-6}	5.2456x10^{-5}	4.5322
2	11.988227	8.49577	13.00	237.00	5.8788x10^{-6}	7.6424x10^{-5}	6.6030
3	11.988025	8.498738	12.50	27.63	7.7178x10^{-6}	9.6473x10^{-5}	8.3353
4	11.987978	8.497838	13.00	155.20	6.5383x10^{-6}	8.4998x10^{-5}	7.3438
5	11.985179	8.495602	15.00	43.00	7.5653x10^{-6}	1.1348x10^{-4}	9.8047
6	11.985439	8.494113	25.00	42.40	7.5696x10^{-6}	1.8924x10^{-4}	16.3503
7	11.984109	8.493959	31.00	139.43	6.6739x10^{-6}	2.0689x10^{-4}	17.8753
8	11.983851	8.495999	15.50	88.00	7.1348x10^{-6}	1.1059x10^{-4}	9.5549
9	11.984552	8.493858	31.00	84.13	7.1713x10^{-6}	2.2231x10^{-4}	19.2076
10	11.984848	8.492332	10.00	100.83	7.0172x10^{-6}	7.0172x10^{-5}	6.0629
11	11.96964	8.483709	35.00	66.38	7.3386x10^{-6}	2.5685x10^{-4}	22.1918
12	11.969806	8.485738	10.00	93.00	7.0889x10^{-6}	7.0889x10^{-5}	6.1248
13	11.971832	8.485771	35.00	40.80	7.5869x10^{-6}	2.6554x10^{-4}	22.9427
14	11.971685	8.484219	22.00	36.28	7.6314x10^{-6}	1.6789x10^{-4}	14.5057
15	11.981471	8.490327	10.00	198.50	6.1805x10^{-6}	6.1805x10^{-5}	5.3399
16	11.982176	8.490023	10.00	180.00	6.3309x10^{-6}	6.3309x10^{-5}	5.4699
17	11.979448	8.486592	20.00	9.00	7.9070x10^{-6}	1.5814x10^{-4}	13.6633
18	11.981964	8.487809	38.00	25.46	1.4706x10^{-5}	2.9411x10^{-4}	25.4111
19	11.982189	8.486945	27.00	208.00	6.1044x10^{-6}	1.6482x10^{-4}	14.2404
20	11.9828	8.484969	45.00	149.00	6.5913x10^{-6}	2.9661x10^{-4}	25.6271
21	11.979329	8.486087	13.00	31.88	7.6753x10^{-6}	9.9779x10^{-5}	8.6209
22	11.978793	8.484472	22.00	34.91	7.6450x10^{-6}	1.6819x10^{-4}	14.5316
23	11.989155	8.488494	10.00	68.00	7.3232x10^{-6}	7.3232x10^{-5}	6.3272
24	11.988877	8.484967	12.00	54.25	7.4553x10^{-6}	8.9463x10^{-5}	7.7296
25	11.990959	8.481225	15.00	77.00	7.2380x10^{-6}	1.0857x10^{-4}	9.3804
26	11.990935	8.478074	7.00	119.50	6.8490x10^{-6}	4.7943x10^{-5}	4.1423
27	11.988862	8.477077	15.00	75.00	7.2567x10^{-6}	1.0885x10^{-4}	9.4046
28	11.986962	8.48137	10.50	84.43	7.1684x10^{-6}	7.5268x10^{-5}	6.5032
29	11.980588	8.472454	10.00	52.00	7.4771x10^{-6}	7.4771x10^{-5}	6.4602
30	11.978367	8.474222	40.00	84.50	7.1678x10^{-6}	2.8671x10^{-4}	24.7717
31	11.975622	8.476459	12.00	94.50	7.0752x10^{-6}	8.4902x10^{-5}	7.3355
32	11.972495	8.472507	23.00	235.42	5.8909x10^{-6}	1.3549x10^{-4}	11.7063
33	11.975486	8.471527	40.50	43.19	7.5632x10^{-6}	3.0631x10^{-4}	26.4652
34	11.979119	8.47028	30.00	78.71	7.2220x10^{-6}	2.1666x10^{-4}	18.7194
35	11.968084	8.473718	23.00	60.70	7.3930x10^{-6}	1.7004x10^{-4}	14.6915
36	11.965815	8.478903	15.50	54.78	7.4503x10^{-6}	1.1548x10^{-4}	9.9775
37	11.955811	8.47275	30.00	78.00	7.2287x10^{-6}	2.1686x10^{-4}	18.7367
38	11.956049	8.474192	31.00	114.83	6.8906x10^{-6}	2.1361x10-4	18.4559
39	11.956394	8.475312	16.00	157.33	6.5200x10^{-6}	1.0432x10-4	9.0132
40	11.956822	8.476615	20.00	42.00	7.5745x10^{-6}	1.5149x10-4	13.0887
	COMPUTED TOTAL		821.50	3717.97	278.1188x10^{-6}		507.2483
	COMPUTED AVERAGES		25.54	92.95	6.9529		12.6812

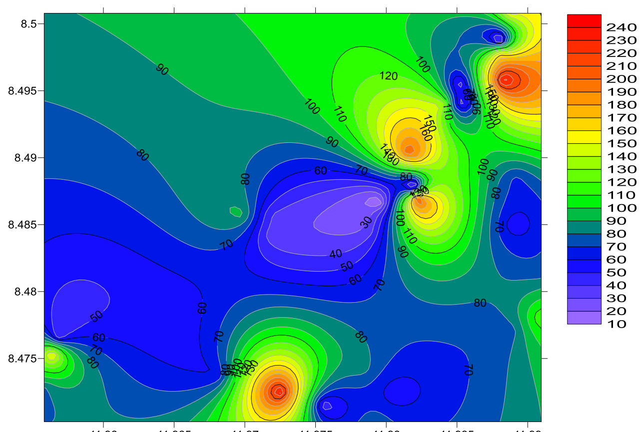

Figure 3: Resistivity contour map

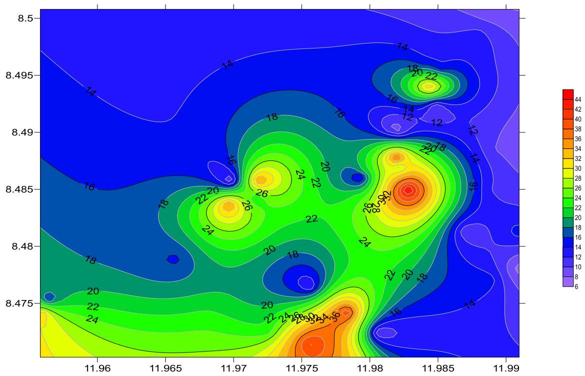

Figure 4: Aquifer thickness contour map

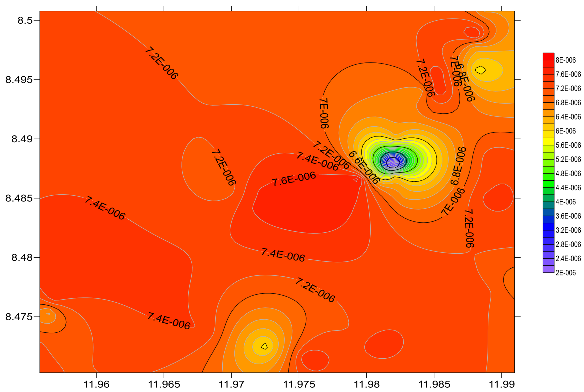

Figure 5: Conductivity contour map

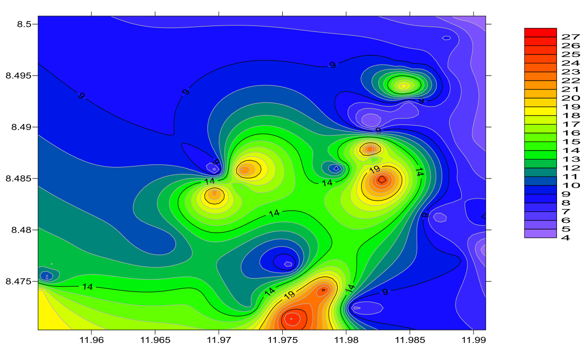

Figure 6: Transmissivity contour map (m^2/day)

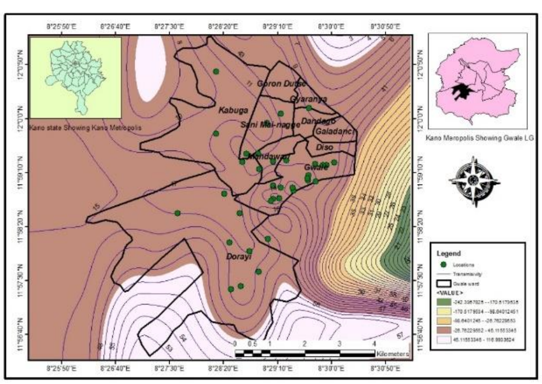

Figure 7: Transmissivity Contour Map using ArcGIS software 10.12

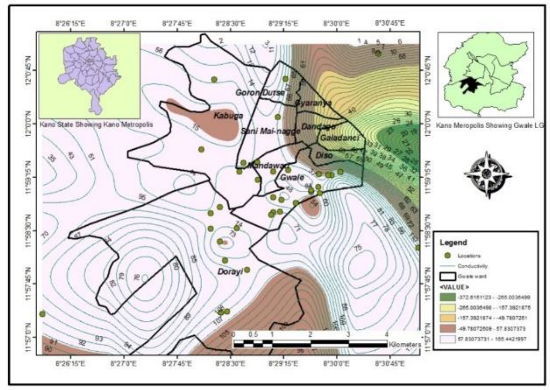

Figure 8: Hydraulic Conductivity Map using ArcGIS software 10.13

DISCUSSIONS

Results obtained from the vertical electrical sounding was documented in Table III showing co-ordinates of VES points with the estimated thickness of the aquifer, its associated resistivity values, and the computed total and average values for hydraulic conductivity and transmissivity according to the equations (2) and (3). These data were used to obtain contour maps for the aquifers thickness, resistivity, hydraulic conductivity and transmissivity. They are represented by Fig. 3, 4, 5, and 6.

Transmissivity values recorded are within a range of 4.5322m^2/day to 26.4652m^2/day, with an average value of 12.6812m^2/day. Hydraulic conductivity values range from $1.4706x10^{-5}$m/s to $7.9070x10^{-6}$ m/s with an average value of $6.9529x10^{-6}$ m/s. Aquifer thickness recorded at a range of value between 7.00 m to 45.00m with an average of 25.54m.

Thus, on the basis of the result of the study area table III, the average transmissivity values(4.5322m^2/day to 26.4652m^2/day), can be classified to have 'intermediate' transmissivity (table I). This shows the distribution of groundwater potential on the basis of its transmissivity, were reflected in the transmissivity contour map figure 6. Relatively higher potential for water is located at the middle extending toward south, north, west directions and greater portion at the middle of the study area, low potential is at the north, east and west direction. This area is estimated to cover probably about 55% of the entire study area. Furthermore, location indicating transmissivity values of less than 10.00 m^2/day represented by the blue colour are classified as the 'low transmissivity' potential areas, they occupy approximately 45% of the study area. When the transmissivity map is compared with the study area map, areas with intermediate groundwater potential for local use include; Dorayi, Sani Mainage, Mandawari and some part of Galadanchi, Goron Dutse while Kabuga is located in the low groundwater potential area. Groundwater in the study area occurs within two aquifers - the weathered basement and highly decomposed granitic rock. The Fig. 8 shows the distribution of the conductivity of the study area Goron-Dutse has the highest value. The aquifer-thickness contour map has shown good correlation when compared to the transmissivity contour map. Transmissivity is characteristic of fluids and the aquifer material but also depends on the saturated thickness. This shows that thicker aquifers can support the storage and yield of more groundwater, which in-turn implies good water potentials. 3-D model for the transmissivity and hydraulic conductivity distribution in the area clearly illustrates potential areas of higher groundwater yield with respect to areas with low yield. On a broad scale, the groundwater potential of this area ranges in quantity from large withdrawal for local water supply (as community consumption) to smaller withdrawal for local supply (private consumption) according to Table I.

In conclusion, hydrogeological parameters are important in ground water prospecting. The conventional methods of obtaining this parameters involves drilling (which is usually expensive), however, a less expensive and faster method of obtaining this parameter was used in this research work to determine the ground water potential of the study area. The geology of the study area has encouraged the use of this technique to determine hydraulic conductivity and transmissivity values of the area. The result has been compared with previous standard values. Transmissivity values recorded have a range of 4.5322m^2/day to 26.4652m^2/day. Average transmissivity value computed was 12.6812 m^2/day. The ground water potential of this study area has been determined to be from intermediate to low on the transmissivity scale. Areas like Sani Mainage, Dorayi, Mandawari, and some part of Galadanchi, Goron-Dutse has been found to have intermediate groundwater potential for local use, while Kabuga is located in the low groundwater potential area. In these research it implies that the groundwater yield is adequate to sustain water supply need of areas like Mandawari, Dorayi, Sani Mainage and some part of Galadanchi, Goron-Dutse. Otherarae like and Kabuga will have just enough water for private use

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