Bima Journal of Science and Technology, Vol. 8(2) June, 2024 ISSN: 2536-6041

DOI: 10.56892/bima.v8i2.691

Geo-Electric Parameters, Aquifer Characterization and Groundwater Potential: A Case Study of Poshiya-Billiri and Environs Northeastern Nigeria

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ABSTRACT

In view of the importance of water to any growing population, this research work made an attempt to explore the study area for quantitative and qualitative groundwater resources that can meet up with the population growth. Fifteen Vertical Electrical Sounding (VES) locations were investigated using Omega version 2.0 resistivity meter, the field results were analyzed using Win RESIST version 1.0 while Surfer 13 Geosoft and ArcGIS version 10.7.1 softwares were utilized for contouring and map plotting respectively. The interpreted field curves delineated three to four geo-electric stratums with model resistivity and thicknesses varying from 5 to 254.6 Ω-m and 1.4 to 49.1 m respectively and most aquifers were located within the saturated fractured basement and coarse grained sandstone zones. Results of the Dar-Zarrouk analysis to characterize the aquifer system in the study area based on its vulnerability and groundwater yield shows that, the transverse resistance values for the study area ranged from 160.58 to 6375.04 Ω-m^2 and the longitudinal conductance values varies from 0.014 to 1.355 Ω^{-1}. The area is therefore interpreted to fall within poor to good protective capacity in terms of vulnerability rating. The hydraulic conductance values which ranged from 3.79 to 58.73 (m/day) and the transmissivity values of 64.17 to 1882.99 m^2/day suggested that the area is characterized by moderate to high groundwater yield. It is therefore recommended that areas south of Poshiya, Sansani and west of Komta with high aquifer transmissivity implying high groundwater yield and coincidently having good protective capacity rating should be targeted for drilling of industrial boreholes that can serve the entire community with good and safe groundwater resources.

Keywords: Vertical Electrical Sounding, Aquifer vulnerability, Hydraulic conductance, Aquifer yield, Poshiya-Billiri.

INTRODUCTION

Groundwater is the main source of water supply in many cities as well as the urban and villages. According to United Nations water report (2018), groundwater provides almost half of all drinking water worldwide, about 40% of water for irrigated agriculture and about 1/3 of water supply required for industry. This resource is increasingly under pressure due to continue urbanization, industrial usage, climate change and inadequate water management.

The population census of 2006 shows that, the entire population of Billiri Local Government Area stood at 202,608 (FRNOG 2009). The projected population for the year 2022 was 339,400 (NPCN, 2022), with this population outburst and urban growth in the study area which is dominantly underlain by Basement Complex rocks and partly sedimentary rocks, there is need to explore more areas for groundwater exploitation.

Successful exploration/exploitation of groundwater in Basement Complex terrains requires proper understanding of the geohydrological characteristics of the area. This is because drilling without preliminary and appropriate geophysical investigations might result in abortive boreholes or boreholes with poor yield (Barka and Bassey, 2015).

The availability of groundwater in an area depends on various geological factors such as rock types as well as existence of structures that can accommodate the resources. In a typical Basement Complex environment such as the study area, the occurrence of groundwater in recoverable quantity as well as its yield is controlled by geological factors such as faults, joints, weathered and fractured zones.

Therefore to target potential basement aquifers that can give bountiful supply of groundwater there is need to consider the geology, tectonic history, weathering processes, depth, composition of the weathered layer, aquifer types and groundwater flow pattern.

Water related diseases remains one of the major health condition in the world, this is because groundwater can be polluted from agricultural waste, poor sanitation and waste disposal (UN Water 2018). Therefore, in exploring for potential groundwater sites, vulnerability assessment also helps in identifying best locations for citing of boreholes thus, reducing the groundwater vulnerability to contamination (Shahab et al., 2019)

In recent times electrical resistivity survey has proven to be an effective and reliable tool in locating viable aquifers for continuous and regular water supply and those areas that are prone to contamination. This method has the advantage of non-destructive effect on the environment, cost effective, rapid and quick survey time and has less ambiguity in the interpreted results when compared to other geophysical survey methods (Todd and Mays, 2005).

Correlations between hydraulic and geo-electric parameters have been studied by many authors (Abiola et al., 2009; Opara et al., 2020; Bulus et al., 2020; Babatunde et al., 2021; Kwami et al., 2023). These correlations are important because it is used to project aquifer parameters which in-turn will facilitate spotting best locations for citing of boreholes.

Therefore, this research was carried out to explore the study area for quantitative and qualitative groundwater resources that can be used for domestic purposes. This was achieved by evaluating the aquifer vulnerability and yield using parameters such as transverse resistance, longitudinal conductance, hydraulic conductivity and transmissivity.

Geology of the Study Area

The study area Poshiya-Billiri and environs lies within longitudes $11^0 11''00'$ - $11^0 14''00'$ E and latitudes $9^0 50''00'$ - $9^0 53''00'$N, it covers a total area of about 34 km^2 (Fig. 1). Geologically, the study area is located within the Gongola arm of the northern Benue trough northeastern Nigeria. The geology of the Gongola arm of the northern Benue trough was extensively discussed by several authors among who are; Carter et al., (1963), Benkhelil, (1982), Guiraud, (1990), Zarboski et al., (1997) ; Nwajide (2013).

DOI: 10.56892/bima.v8i2.691

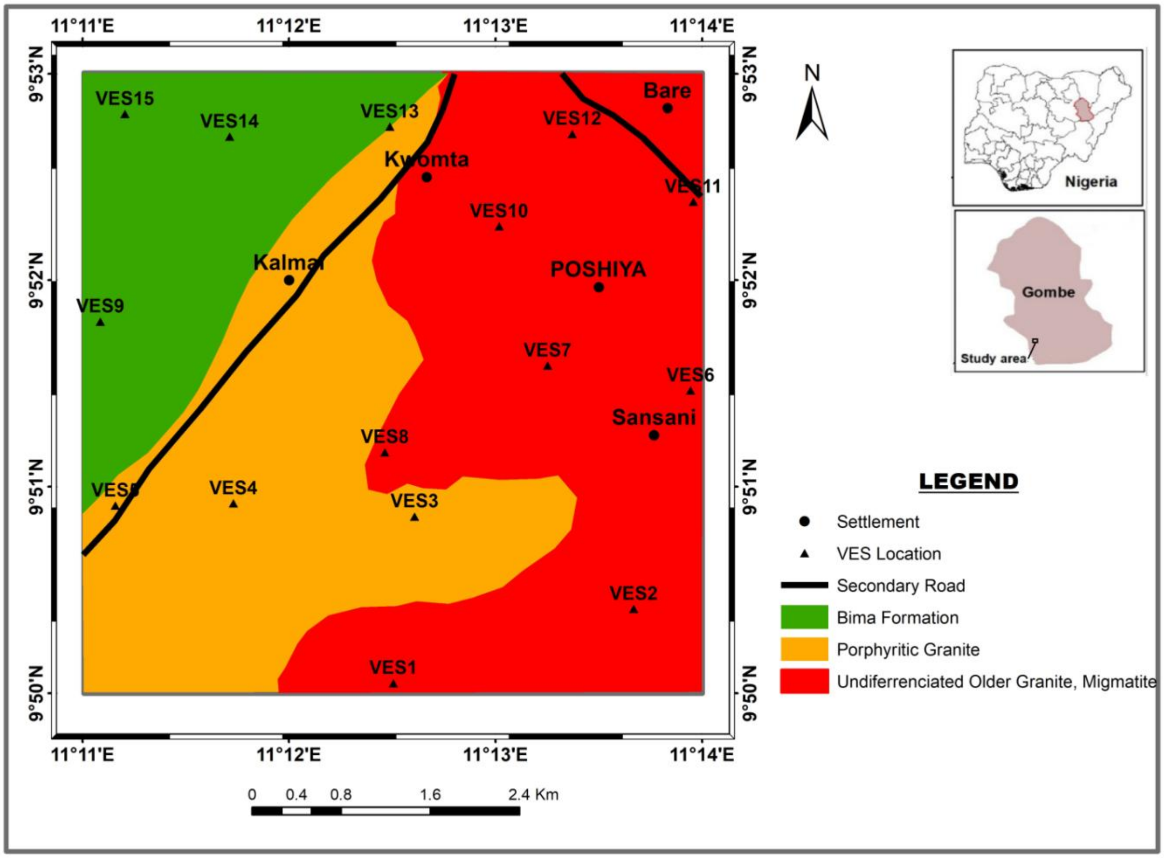

Figure 1: Geological Map of Poshiya-Billiri and environs (Modified from NGSA 2011)

The lithologies within the Gongola arm of the northern Benue trough comprises of the basement rocks (in-lier) exposed at Gombe in Liji area and Kaltungo/Billiri in the southern part of Gombe. The Basement Complex rock is believed to underlie all the Cretaceous to Tertiary sedimentary sequence in the area. The lithostratigraphic units of the Gongola arm of the northern Benue trough are made up of the Bima, Yolde, Pindiga, Gombe and Kerri-Kerri Formations.

In the study area, the lithologic units comprises of the undifferentiated Basement Complex, Porphyritic granite, and Bima Formation (Figure 1).

The undifferentiated Basement Complex exposure in the study area is a mixed rock unit consisting of granite component (granite, pegmatite, gneiss) and metamorphic host rock that are intimate admixtures coarse enough for the mixed condition to be megascopically recognizable and was described by Carter et al., (1963) as anatectic and migmatite gneiss respectively.

According to Tabale et al., (2017) the porphyritic granite found within the study area consist of a lot of pinkish orthoclase feldspar, whitish to grey quartz and biotite. The rock has large and well developed crystals of feldspar in a ground mass of quartz and biotite. Other lithologic units within Kaltungo Billiri in-lier include the porphyritic biotite granite, medium grained granite, micro granite, pegmatite, diorite, trachite andesite and basalt (Tabale et al., 2017).

Overlying unconformably the basement rock in the study area is the Bima Formation. This formation is the oldest lithological unit

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occupying the base of the Cretaceous successions in the Northern Benue Trough. The sediments were mainly derived from nearby basement rocks and were deposited under continental condition (fluvial, deltaic, lacustrian). The sedimentary structures include large scale trough cross bedding, planar cross bedding, groove marks and soft sediment deformational structures (Carter et al. 1963 and Guiraud, 1990).

MATERIALS AND METHODS

Data Acquisition

A total of fifteen Vertical Electric Sounding (VES) locations were surveyed using Omega version 2.0 resistivity meter, the locations of the VES were distributed to cover the entire study area. The VES proceedings involved acquiring apparent resistivity data which is a function of the inhomogenity of the earth. The measurement was done by injecting direct current (I) into the sub-surface through two outer current electrodes usually referred to as A-B and measuring the resultant potential difference (ΔV) at two inner electrodes known as M-N (Fig.2). The resulting potential differences is subdivided by the injected current then multiplied by the geometric factor (K) which is a function of the spacing between current and potential electrodes.

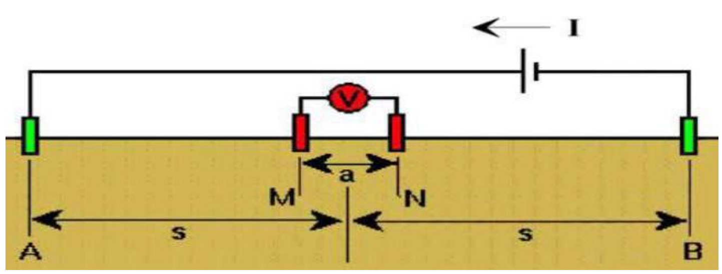


Figure 2: Schematic diagram of Schlumberger Configuration

For a geologic medium, the apparent resistivity (ρ) is calculated as a function of resistance values and the geometric factor using the ohms law (eq.1)

$$\rho = K\frac{\Delta V}{I} \quad - (1)$$

Where ρ is the apparent resistivity and is measured in Ω-m, ΔV is the potential difference measured in milli-volt (mV), I is the current measured in milli-ampere (mA) and K is the geometric factor.

The geometric factor (K) for each VES location was calculated from the current and potential electrode spacing presented in figure 2 as:

$$K = \pi\left[\frac{(AB/2)^2 - (MN/2)^2}{MN}\right] \quad - (2)$$

The schlumberger electrode configuration with maximum AB/2 spacing equal to 100 m was utilized for the VES investigation. The choice of this configuration was prompted by its fastness, accuracy and slightly deeper depth of penetration than the use of other methods such as the Wenner configuration.

Data Processing and Analysis

Data processing of the fifteen VES starts with manual plotting of the data for each location on a log-log graph paper with the apparent resistivity (Ω-m) versus AB/2 (m) to pick the number of layers for each plot. The field data were later analyzed using the WinRESIST version 1.0 where the primary geo-electric parameters were determined. Other softwares used for data processing and analysis include

Surfer 13 Geosoft and ArcGIS version 10.7.1 for contouring and map plotting respectively.

Dar-Zarrouk Parameters

The Dar-Zarrouk parameters were introduced into the literature of electrical resistivity by Maillet (1947) where he described the relationship between the longitudinal conductance and transverse unit resistance.

Transverse resistance (Tr) in hydrogeology deals with the ability of water to flow through a unit width of an aquifer. In this study, transverse resistance was obtained as the product of aquifer resistivity and aquifer layer thickness thus, calculated as:

$$Tr = h*\rho \quad - (3)$$

Where h is the layer thickness in meters (m) and ρ is the apparent resistivity in ohm meter (Ω-m)

To determine the vulnerability of the aquifer system in the study area to contamination, the longitudinal conductance (SL) of the overburden layers were evaluated using the thickness and the resistivity of the layers thus, calculated as:

$$SL = h/\rho \quad - (4)$$

Where h is the layer thickness in meters (m) and ρ is the apparent resistivity in ohm meter (Ω-m)

The values for longitudinal conductance (SL) were used to evaluate the protective capacity for the study area based on the work of Oladapo and Akintorinwa (2007) as presented in Table 1.

Table 1: Rating of protective Capacity (Oladapo and Akintorinwa, 2007)

Longitudinal Conductance (Ω^{-1})	Protective capacity Rating
> 10	Excellence
5 –10	Very good
0.7 –4.9	Good
0.2 –0.69	Moderate
0.1 –0.19	Weak
< 0.1	Poor

Hydraulic conductance (K) which is the measure of how easily water can flow through a porous medium was also evaluated for the study area. According to Heigoid et al., (1979), hydraulic conductivity of a porous medium can be determined using the formula:

$$K = 386.40R_{wr}^{-0.93283} \quad - (5)$$

Where K is the hydraulic conductivity measured in meters per day (m/day) and R_{wr} is the aquifer resistivity in ohm meter (Ω-m)

Transmissivity (T) is referred to the capacity of an aquifer to transport water through it under hydraulic gradient. The aquifer transmissivity in this study was expressed as the product of hydraulic conductance and layer thickness:

$$T = K*h \quad - (6)$$

Where K is the hydraulic conductivity measured in meters per day (m/day) and h is the aquifer thickness in meter (m)

In this study, the transmissivity rating for the study area was classified based on the work of Offodile (1983) as presented in Table 2.

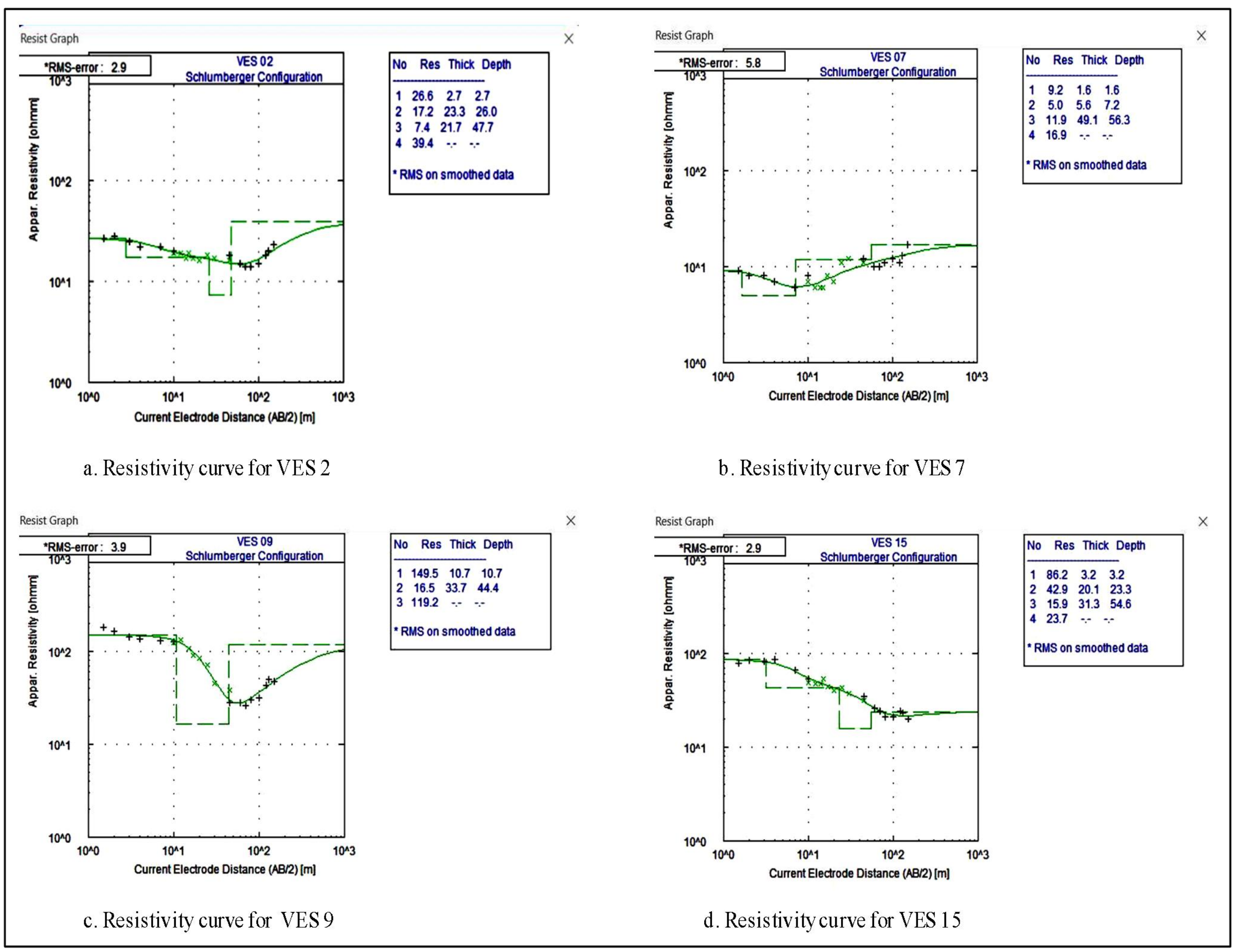
Table 2: Aquifer classification based on transmissivity values (After Offodile, 1983)

Transmissivity (m^2/day)	Classification of well
>500	High potential
50 - 500	Moderate potential
5 - 50	Low potential
0.5 - 5	Very low potential
< 0.5	Negligible potential

RESULTS AND DISCUSSION

Field Curves Analysis

The interpreted field curves (Fig.3) and the computed results for all the field curves (Table 3) revealed the geo-electric structure for the study areas as comprising of three to four geo-lithologic units with model resistivity varying between 5 to 254.6 Ω-m. The lithologic units presented on Table 3 were inferred from available litho-log sections of existing boreholes in the study area.



a. Resistivity curve for VES 2

b. Resistivity curve for VES 7

c. Resistivity curve for VES 9

d. Resistivity curve for VES 15

Figure 3: Resistivity curves for some selected VES locations

Bima Journal of Science and Technology, Vol. 8(2) June, 2024 ISSN: 2536-6041

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Table 3: Summary of Geo-electric Parameters obtained from the Study Area

VES point	Longitude (dms)	Latitude (dms)	No. of layers	Resistivity of layers (Ωm)	Thickness of layers (m)	Curve type	Inferred lithologies
1	11°12' 30.29"	9°50'02.86"	3	254.6, 142.3,78.6	4, 44.8, -	Q	Weathered top soil, weathered basement, fractured basement.
2	11°13' 40.11"	9°50' 24.4"	4	26.6, 17.2, 7.4, 39.4	2.7, 23.0, 21.7, -	QH	Sandy top soil, weathered basement, fractured basement, fractured basement.
3	11°12' 36.46"	9°50' 51.31"	3	26.0, 16.4, 60.4	1.4, 37.2, -	HA	Sandy top soil, weathered basement, fractured basement, fractured basement.
4	11°11' 43.78"	9°50' 55.14"	3	7.5, 34.4, 56.8	5.9, 22.2, -	A	Sandy top soil, weathered basement, fractured basement
5	11°11' 09.52"	9°50' 54.49"	3	89.4, 72.3, 21.4	1.9, 9.0, -	Q	Sandy top soil, weathered basement, fractured basement.
6	11°13' 56.64"	9°51' 27.95’’	3	162.0, 94.9, 38.8	2.2, 17.3, -	Q	Sandy top soil, weathered basement, fractured basement.
7	11°13' 15.11"	9°51' 35.19"	4	9.2, 5.0, 11.9. 16.9	1.6, 5.6. 49.1, -	HA	Sandy top soil, weathered basement, fractured basement, fractured basement.
8	11°12' 27.80"	9°51' 09.95"	3	169.3, 48.3, 23,2	5.1, 14.0, -	Q	Weathered top soil, weathered basement, fractured basement.
9	11°11' 05.19"	9°51' 47.94"	3	149.5, 16.5, 119.2	10.7, 33.7, -	H	Weathered top soil, weathered basement, fractured basement.
10	11°13' 01.03"	9°52' 15.64"	3	56.6, 32.2, 10.3	5.8, 34.7, -	Q	Sandy top soil, weathered basement, fractured basement.
11	11°13' 58.52"	9°52' 22.80"	3	77.2, 34.5, 18.8	8.5, 25, -	Q	Sandy top soil, weathered basement, fractured basement.
12	11°13' 22.30"	9°52' 42.51"	4	88.9, 33.4, 94.7, 14.9	1.4, 4.8, 13.7, -	HQ	Sandy top soil, weathered basement, fractured basement, fractured basement.
13	11°12' 29.31"	9°52' 44.60"	3	74.6, 44.8, 14.1	3.1, 32.2, -	Q	Sandy top soil, weathered basement, fractured basement.
14	11°11' 42.73"	9°52' 41.71"	4	68.4, 39.5, 17.6, 21.5	2.2, 19.2, 33.9, -	QH	Sandy top soil, silty sandstone, coarse grained sandstone, weathered sandstone,
15	11°11' 12.32"	9°52' 48.30"	4	86.2, 42.9, 15.9, 23.7	3.2, 20.1, 31.3,-	QH	Sandy top soil, silty sandstone, coarse grained sandstone, weathered sandstone,

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The first layer with resistivity range of 7.5 to 254.6 Ω-m and thickness varying from 1.4 to 10.7 m represent the topsoil but in few VES locations (1 and 8) it represents weathered top soil. The second layer constitutes the weathered basement and in VES locations 14 and 15 it is made up of silty sandstone. The layer presented a model resistivity and a thickness range from 5 to 142.3 Ω-m and 4.8 to 44.8 m respectively. The third layer which gave a model resistivity between 7.4 to 119.2 and thickness of 13.7 to 49.1m mostly corresponds to the saturated fractured and coarse grained sandstone zones. The fourth layer with resistivity range of 14.9 to 39.4 Ω-m has a thickness ranging to infinity. Five curve types were delineated in the study area these include Q, QH, H, HA and A with Q curve types dominating.

All VES locations investigated in the study area have good prospect for groundwater exploitation except for VES locations 4, 5 and 8 which depicts an increasing resistivity values. In areas with good prospect for groundwater exploitation the weathered, fractured and coarse grained sandstone lithologies constitutes the aquifer system.

Dar-Zarrouk Parameters

Equations 3 to 6 were utilized for the computation of Dar-Zarrouk parameters to investigate the study area for: Transverse resistance, longitudinal conductance, hydraulic conductivity and transmissivity. The information derived from these computations was used to characterize the aquifer system in the study area based on its vulnerability and groundwater yield. Summary of aquifer parameters for the study area were presented in Table 4.

Table 4: Summary of aquifer parameters for the study area

VES No.	Aquifer Thickness h(m)	Apparent resistivity of Aquifer ρ (Ω-m)	Transverse resistance Tr = hρ (Ω-m^2)	Longitudinal conductance S = h/ρ (Ω^{-1})	Hydraulic conductivity $K=386.40R_{rw}^{-0.93283}$ (m/day)	Transmissivity T =Kh (m^2/day)
1	44.8	142.3	6375.04	0.016	3.79	169.79
2	21.7	7.4	160.58	1.355	59.73	1296.14
3	37.8	16.4	619.92	0.053	28.43	1074.65
4	22.2	34.4	763.68	0.787	14.25	316. 35
5	9.0	72.3	650.7	0.021	7.13	64.17
6	17.3	94.9	1641.77	0.014	5.53	95.67
7	49.1	11.9	584.29	1.120	38.35	1882.99
8	14.0	48.3	676.2	0.030	10.38	145.32
9	33.7	16.5	556.05	0.072	28.27	952.70
10	34.7	32.2	1117.34	1.102	15.15	525.71
11	25.0	34.5	862.5	0.110	14.21	355.5
12	13.7	94.7	1297.39	0.144	5.54	75.90
13	32.2	44.8	1442.56	0.042	11.14	358.71
14	33.9	17.6	596.64	0.486	26.62	902.42
15	31.3	15.9	497.67	0.469	29.26	915.84

Transverse resistance and longitudinal conductance

Transverse resistance which in aquifer system study is defined as the ability of water to flow through a unit width of an aquifer sometimes reflects the trasmissivity of an aquifer. Studies have shown that zones with high transverse resistance values are expected to give higher borehole yield (Opera et al., 2012).

The computed values of transverse resistance from the study area (Table 3) gave values ranging from 160.58 to 6375.04 Ω-m^2. From the map of transverse resistance over the study area (Figure 4), areas of high transverse resistance represented by red, yellow to dark blue colours located in the northern part of Poshiya, around Sansani and to its southwestern part. The area is covered by VES locations 1,6,10, 12 and 13 have transverse resistance values ranging from 1117.34 to 6375.04 Ω-m^2.

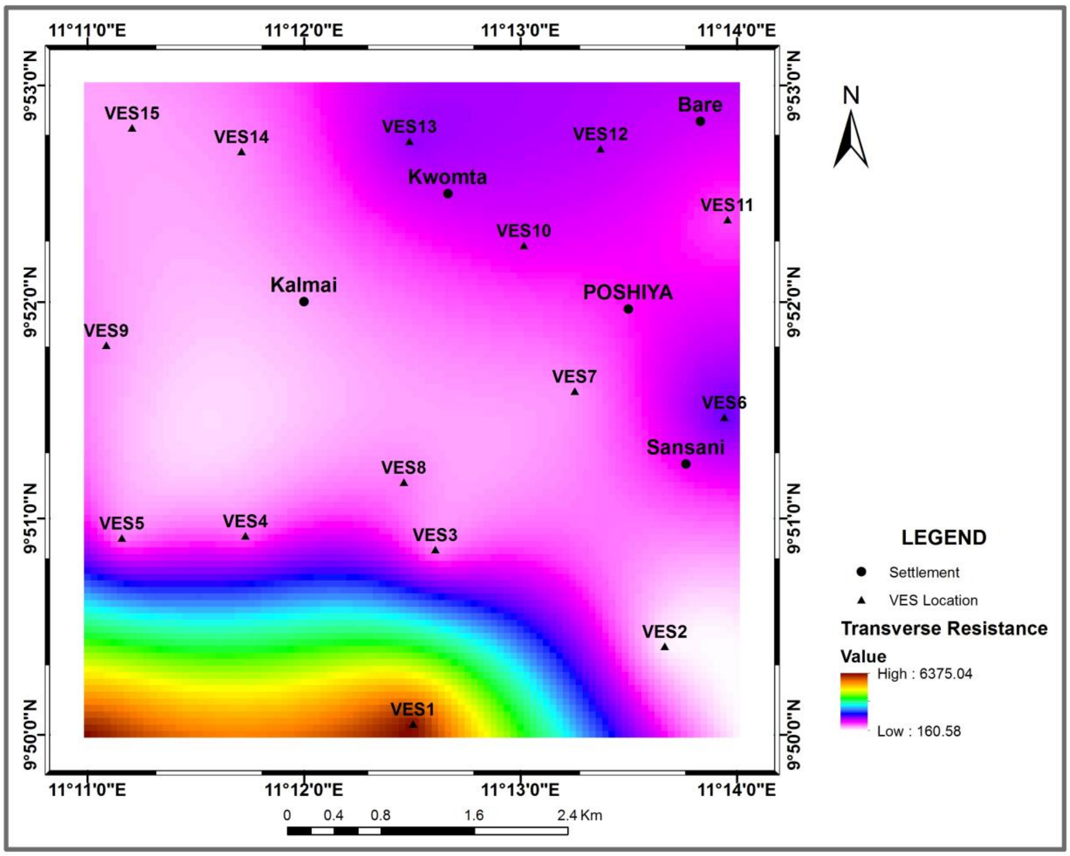

Figure 4: Transverse resistance map of the study area

To the central part of the study area (Figure 4) passing through Kalmai, there appears a northwest to southeast trending belt represented by light blue colour occupied by VES locations 3,4,5,7,8,9,14, 15 and also VES location 11 to the northeastern part of Poshiya. These constitute areas with moderate transverse resistance where the values ranged from 497.67 to 862.5 Ω-m^2. Area with low transverse resistance located directly south of Sansani (VES location 2) with transverse resistance value of 160.58 Ω-m^2 is represented by a very light blue colour (Figure 4).

Eze (2012), suggested that transverse resistance values of less than 200,000 Ω-m^2 did not always indicate low groundwater yield but, it could be related to in-adequate aquifer thickness or aquifer that is dominated by finer sediments. In the case of the study area, the general low transverse resistance values could be attributed to in-adequate aquifer thicknesses.

The rate of groundwater contamination depends on permeability, porosity, composition and overburden thickness of the geologic materials overlying the aquifer system. To evaluate the vulnerability of the aquifer system within the study area, the longitudinal conductance of the overburden layers were determined. Table 4, revealed that the longitudinal conductance for the study area varies from 0.014 to 1.355 Ω^{-1} and using the longitudinal conductance values from Table 4, the study area was rated on the basis of its protective capacity (Table 5).

Table 5: Protective capacity rating of aquifers in the study area

VES No.	Longitudinal conductance (Ω^{-1})	Protective capacity
1	0.016	Poor
2	1.355	Good
3	0.053	Poor
4	0.787	Good
5	0.021	Poor
6	0.014	Poor
7	1.120	Good
8	0.030	Poor
9	0.072	Poor
10	1.102	Good
11	0.110	Weak
12	0.144	Weak
13	0.042	Poor
14	0.486	Moderate
15	0.469	Moderate

The statistical representation of these values on a pie chart (Figure 5) show that, 27 % of the study area falls within areas that have good protective capacity rating, while about 26 % constitutes the weak to moderate protective capacity rating and the remaining 47 % have poor protective capacity rating. This suggests that the study area is characterized by poor to good protective capacity in terms vulnerability rating.

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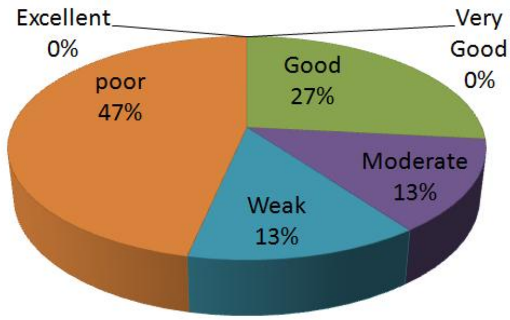

Figure 5: Pie Chart representation of aquifer protective capacity in the study area.

The longitudinal conductance map of the study area (Figure 6) shows that, areas covered by VES locations 2, 4 and 7 represented by red and yellow colours, constitutes areas with good protective capacity. Areas south of Poshiya, Sansani and the western part of Sansani are rated to have good protective capacity rating. Areas rated to have weak to moderate protective capacity covered by VES locations 10, 11, 12, 14 and 15 and are depicted by a lemon green to dark blue colour are located around Bare and the northwestern part of Kwomta (Figure 6). Areas covered by VES locations 1, 3, 5, 6, 8, 9 and 13 represented by light blue colour have poor protective capacity (Figure 6).

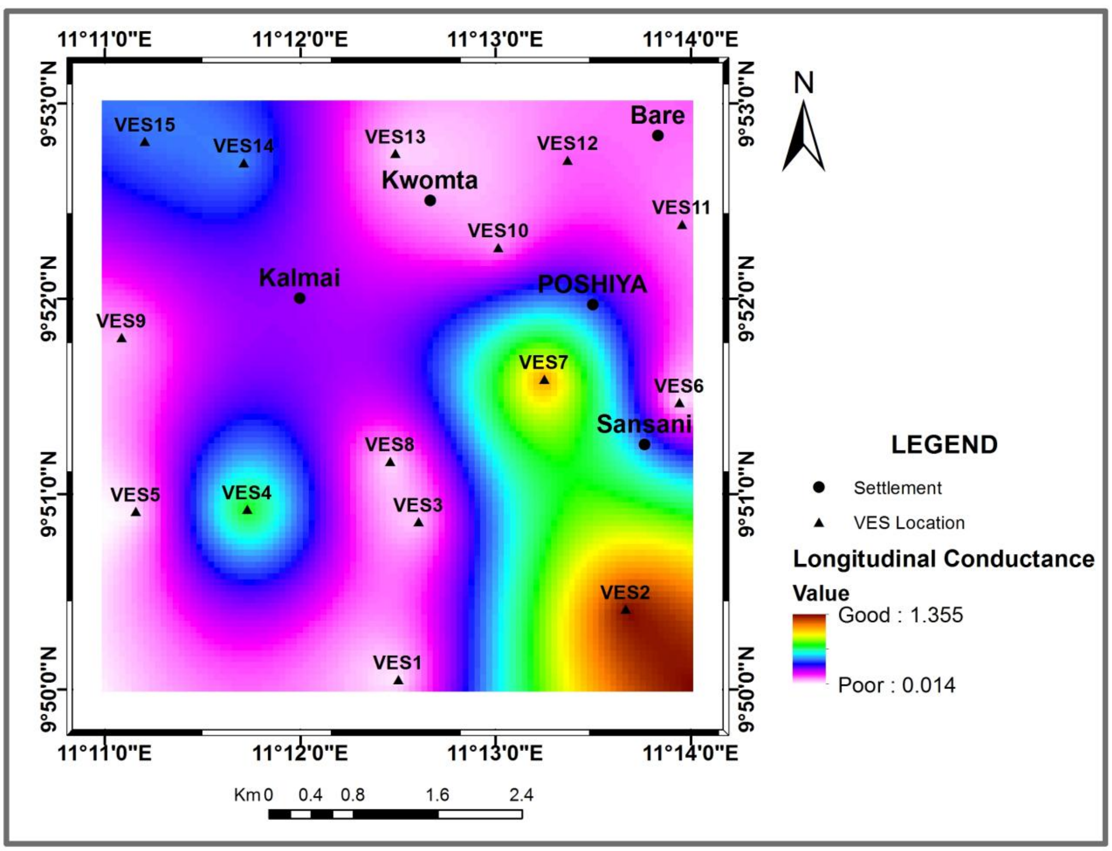

Figure 6: Longitudinal conductance map of the study area

Areas delineated to fall within good aquifer protective capacity rating suggest that the materials that makes up the overburden even though sandy soil from the inferred lithologies, still contains significant amount of clayey to silty materials. These materials will act as impervious to semi-impervious layers that can stop further infiltration of contaminants dissolved in water from the surface. This phenomenon envisaged good protective capacity rating therefore; aquifers around these areas (south of Poshiya, Sansani and western part of Sansani) have good protective capacity hence making them less vulnerable to surface contamination.

Areas that were delineated to fall within regions with poor protective capacity rating suggest that these areas have thin overburden cover with absent or near absent of clayey and silty materials or the overburden materials are highly weathered hence, it could not act as an impervious layer to surface contaminants. This was evident from the interpreted results (Table 3) where the overburden thickness range from 1.4 to 5.9 m and at VES location 9 the 10.7 m thick overburden materials comprises of weathered top. Secondly, from the inferred lithologies, the study area comprises of sandy to weathered top soil, these lithologies indicate absence of clayey materials that could act as filters to the underlying aquifer. Therefore, aquifers within these areas are vulnerable to contamination perhaps contaminants from improper disposal of refuse or agricultural waste.

Hydraulic conductance and Transmissivity

To measure the ease at which water can flow through a porous material within the aquifer system in the study area, the hydraulic conductance of aquifers were determined. From Table 4, the hydraulic conductance values ranged from 3.79 60 58.73 (m/day). Projecting these values to produce a map (Figure 7), areas of high hydraulic conductance which also signifies areas with high permeability (high ease of water flow), represented by red, yellow to lemon green colour were covered by VES locations 2, 3, 7, 9, 14 and 15.

These areas covered the southeastern part of the study area around Poshiya and Sansani. The moderate hydraulic conductance represented by dark blue colour (Figure 7) and covered by VES locations 4, 8, 10, 11 and 13 can be seen to occupy the central and northern part of the study area around Kalmai and Kwomta respectively. The southwestern part of the study area occupied by VES locations 1, 5, 6 and 12 and were depicted by light blue colour on the map constitutes areas with low hydraulic conductance. The low hydraulic conductance is an indication of low permeability (low ease of water flow) within the aquifers system in this areas.

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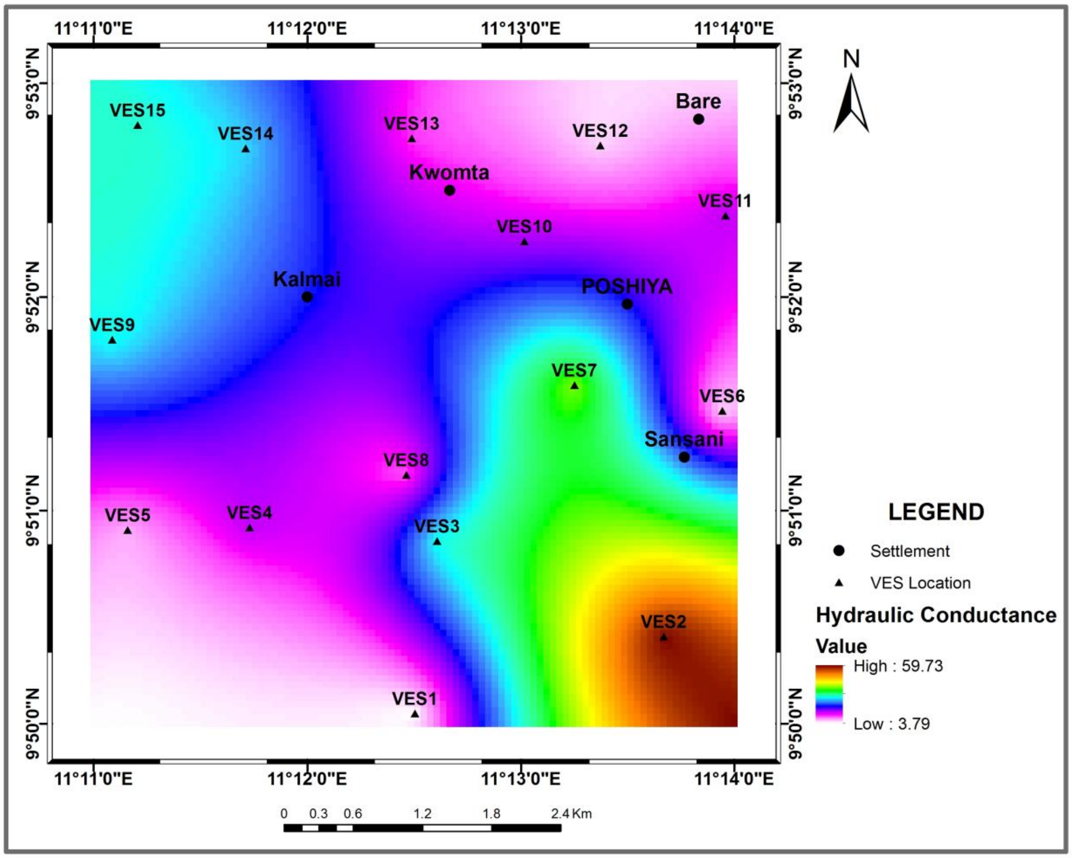

Figure 7: Hydraulic conductance map of the study area

Transmissivity (T) is the measure of the rate at which groundwater is transmitted through a unit width of an aquifer, and high transmissivity are associated with areas of high hydraulic conductance. From Table 4, the computed transmissivity values for the study area varied from 64.17 to 1882.99 m^2/day. Rating the aquifer potential in the study area based on transmissivity values (Table 6), and its statistical representation using pie chart (Figure 8), the study area constitutes 47 % high and 53 % moderate potential aquifer systems.

Bima Journal of Science and Technology, Vol. 8(2) June, 2024 ISSN: 2536-6041

DOI: 10.56892/bima.v8i2.691

Table 6: Aquifer potential rating in the study area

VES No.	Transmissivity (m^2/day)	Aquifer potential
1	169.79	Moderare
2	1296.14	High
3	1074.65	High
4	316. 35	Moderate
5	64.17	Moderate
6	95.67	Moderate
7	1882.99	High
8	145.32	Moderate
9	952.70	High
10	525.71	High
11	355.5	Moderate
12	75.90	Moderate
13	358.71	Moderate
14	902.42	High
15	915.84	High

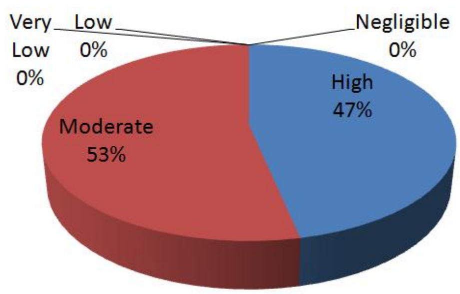

Figure 8: Pie chart representation of aquifer potentials in the study area

The map plot representation of the transmissivity values (Figure 9) shows a good correlation with that of hydraulic conductance (Figure 7) where areas with high hydraulic conductance values indicates high transmissivity and same applies to area with low hydraulic conductance values.

DOI: 10.56892/bima.v8i2.691

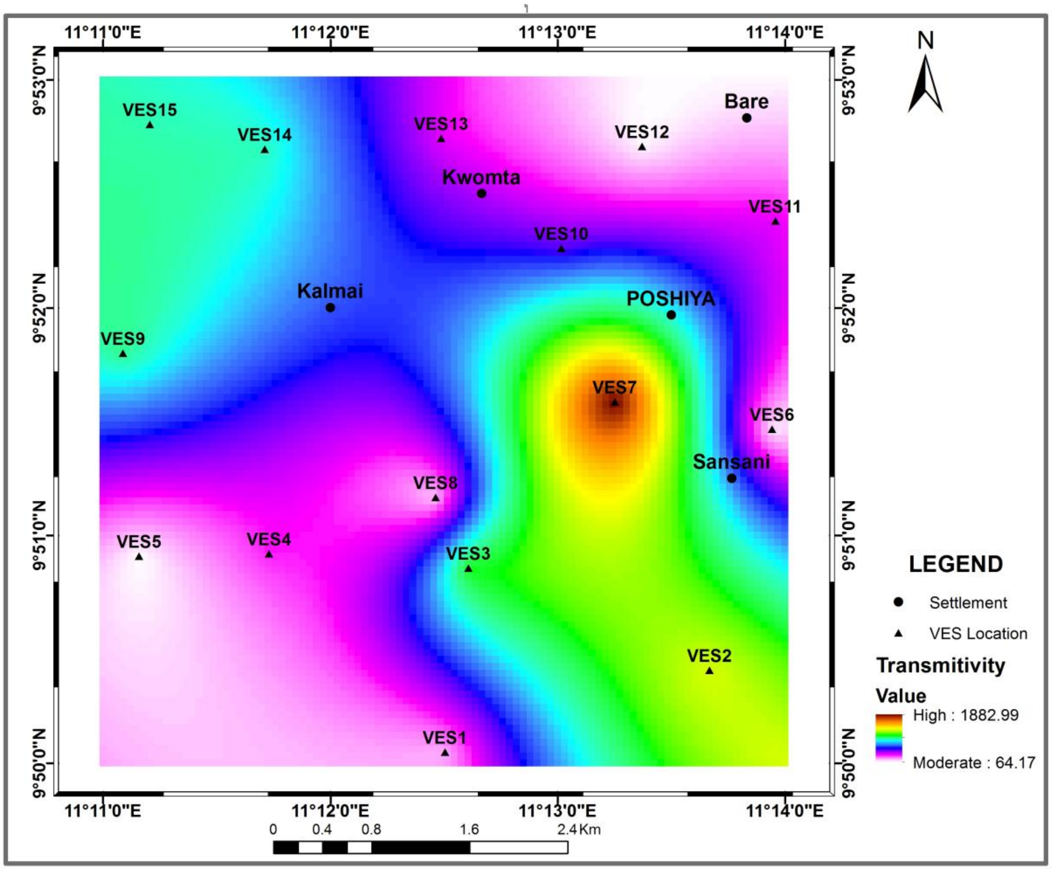

Figure 9: Transmissivity distribution map of the study area

From Figure 9, areas of high transmissivity represented by red, yellow to lemon green colours were covered by VES locations 2, 3, 7, 9, 14 and 15. The high transmissivity values in this part of the study area shows that, the aquifer system have high water yield and this can be attributed to the thick aquifer system with high interconnected fractures and joints or aquifers that are found within coarse grained sandstones.

This is evident from this study where the aquifer systems are mostly found within the fractured basement/coarse grained sandstone varying in thickness between 21.7 to 49.1m. This revealed that aquifers locate at the northwestern and southeastern part of the study area example west of Komta and south of Poshiya and Sansani respectively have high groundwater yield.

Areas with moderate transmissivity represented by dark to ligh blue colours (Figure 9) and enclosed within VES locations 1, 4, 5, 6, 8, 11, 12 and 13 were seen to occupy the central, northern and northeastern parts of the study area around Kalmai, Kwomta and Bare respectively. The moderate transmissivity values can be attributed to aquifers that are located within weathered basement zones and have moderate groundwater yield.

CONCLUSION

The interpreted resistivity field curves gave a modeled resistivity values ranging from 5 to 254.6 Ω-m and a maximum depth probe of about 62 m was gained in the study area. The study also delineated about five curve type example Q, QH, H, HA and A with the Q-curve type dominating. This result implies that the fresh basement rock in the study area lays at depth beyond 62 m in some part of the study area, this is also a good indicator that the aquifer system in the study area comprising of weathered basement, fractured basement and coarse grained sandstone are thick enough to constitute a good aquifer system.

The interpreted result of the longitudinal conductance shows that 47% of the study area has poor protective capacity rating and this can be associated with thin overburden devoid of clayey and silty materials and even highly weathered top soil. This evaluation shows that almost halve of the study area are prone to contamination. Therefore, to minimize the risk of contaminants infiltrating into the aquiferous zones in these areas there is need for improved sanitation by reducing the rate of indiscriminate waste disposal and also regular groundwater monitoring should be carried out to check the safety of groundwater for domestic consumption.

The study also revealed that, the study area falls within moderate to high groundwater yield based on the aquifer transmissivity values. It is therefore recommended that areas south of Poshiya, Sansani and west of Komta with high aquifer transmissivity implying high groundwater yield should be targeted for drilling of industrial boreholes that can serve the entire community. Coincidentally, these areas have moderate to good protective capacity rating this implies that the aquifers in this region are less vulnerable to contamination hence; groundwater in these areas is safe for domestic consumption.

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