FUDMA Journal of Sciences (FJS)
ISSN online: 2616-1370
ISSN print: 2645 - 2944
Vol. 6 No. 3, June, 2022, pp 88 - 94
DOI: https://doi.org/10.33003/fjs-2022-0603-974

ASSESSMENT OF GROUNDWATER POTENTIALS OF CRYSTALLINE BASEMENT COMPLEX AQUIFERS USING HYDRAULIC PROPERTIES IN THE USSA AREA OF TARABA STATE, NORTH-EAST NIGERIA

[1]Yohanna, A., [1]Musa, N., [1]Balogun, F. O., [2]Jabbo, J. N., *[3]Adamu, A. and [4]Galumje. S. S.

[1]Department of Geology, Federal University of Lafia, Nasarawa State, Nigeria
[2]Department of Environment, Faculty of Forestry and Environment, University Putra Malaysia,
[3]Department of Applied Geophysics, Federal University Birnin Kebbi, Nigeria
[4]Ministry of Water Resources Jalingo, Taraba State, Nigeria

*Corresponding authors' email: adamu.abubakar35@fubk.edu.ng

ABSTRACT

Hydrogeological parameters in part of the crystalline Basement Complex rock terrain were characterized using pumping test data. The goal of this research was to determine the aquifer characteristics and groundwater potentials in the area. A total of fifteen (15) wells were used during the investigation. Borehole depths in the studied area range from 40.00 to 45.00 meters. The yield varies from 0.68 l/s to 1.11 l/s. In general, which signify that the yields from wells were low to moderate. Transmissivity (T) ranges from 0.57 to 1.96, with 90 percent of the aquifers having transmissivity between 1.00 and 1.96m^2/d and only 10percent of having transmissivity below 1m^2/d. data. Transmissivity varies from low to moderate. Borehole-specific capacity ranged from 4.36 to 346 m/day. This cannot sustain a population of 121,500 people based on recommending a basic water requirement of twenty (25) litres per person per day to meet the most basic human needs. When you consider the 121,500 people that rely on these boreholes for their water, it's evident that the aquifers of the borehole have very limited production potential. The area will face a future water crisis if the population continues to expand. Around 196,553 people are expected to live there in near future according National Population Commission (NPC). This is a clear pointer that the area will face portable water crisis except government and other stakeholders involve takes drastic measures.

Keywords: Complex; Nigeria; Pumping-Production; Transmissivity; Taraba Ussa; Water

INTRODUCTION

Groundwater is a significant source of water for industry, agriculture, and home usage (Achyara, 2004; Adamu, 2019; Adamu *et al.,* 2019; Adamu *et al.,* 2020; Foster *et al.,* 2008; MacDonald *et al*, 2005; Srinivasa *et al.*, 2000). For people all across the world, groundwater is a vital source of water. Since the dawn of time, underground water has been used for residential purposes, animals, and irrigation. Because of the rising need, effective methods of delivering it has been created to bring surface water to the surface, as well as groundwater consumption has continuously grown through time. According to Chow *et al* (1980) groundwater is the water contained in void regions under the earth's surface (Bedrock cracks or pore gaps between rock and soil particles). However, according to Vincent *et al*, (2009) roundwater may be found in both unconsolidated and consolidated bedrock geologic formations. Crystalline rock makes up the aquifers in the basement. Because of their widespread distribution and accessibility, as well as the scarcity of readily accessible water, basements is particularly significant in tropical and subtropical locations. Alternative water sources are available, particularly in rural areas (Wright and Burges, 1992). Groundwater is stored in joints, cavities, and fissures in crystalline rocks, which are solid, thick rocks.

Crystalline Rocks from the basement rocks may be found in some part of Africa and Asia. They're made up of igneous and metamorphic rocks that date back 650 million years. In unfractured basement rocks, groundwater is rare, but significant aquifers emerge in fractures over bedrocks. Weathered (regolith) and fractured bedrocks contains aquifers (Offordile, 2014). The crystalline Basement Complex rocks which are predominantly granitic in composition and metamorphic rocks in various phases of metamorphism, such as gneisses, migmatites, and Biotite granites underlie Ussa and Environs (Figure 3). The aim of this research is to determine the groundwater potential of aquifers in the Ussa' Crystalline Basement. The study's findings are being made public in the aim of supporting the government, policymakers, and other stakeholders in designing suitable rural water distribution plans. The national standard of 500 persons per borehole has not been attained due to overcrowding in rural communities. Due to the harsh geologic environment, several towns, notably those in the Basement Complex terrain, lack access to portable water. Traditional water sources, such as rivers, hand-dug wells, and seepages, are unreliable since they are transient (Adamu, 2019; Adelana and McDonald, 2008).

Description of the Study Area

The Ussa local government area is situated in Taraba State, Nigeria's northeast, between latitudes 06° 55" 00" N to 07° 15' 00" N, and longitudes 09° 50" 00" E to 10° 15" 00" E (Figure 1). The territory has an international boundary with the Republic of Cameroon. Ussa LGA includes the towns and localities of Kpambo Kufi, Lissam, Mobayi, Acha, Fikyu, Lumbu, Yamsa Addo, Kpambo, Lissam sambo, and Ussa. The local government has a population of 121,500 people, with a density of 128.4 persons per square kilometer. The population of Ussa and its environs is today estimated to be 196,553 people, with a 2.9 percent yearly population change (National Population Commission (NPC), 2014). The Ussa LGA is 1495 square kilometers in size and averages 31 degrees Celsius in temperature. The Donga River runs through the LGA, which receives an estimated total annual rainfall of 1450 mm. River Ussa is a tributary of River Donga, one of the most promising tributaries of River Benue .The topography of the area consists of both low lands and high lands (Figure 1 and 2).

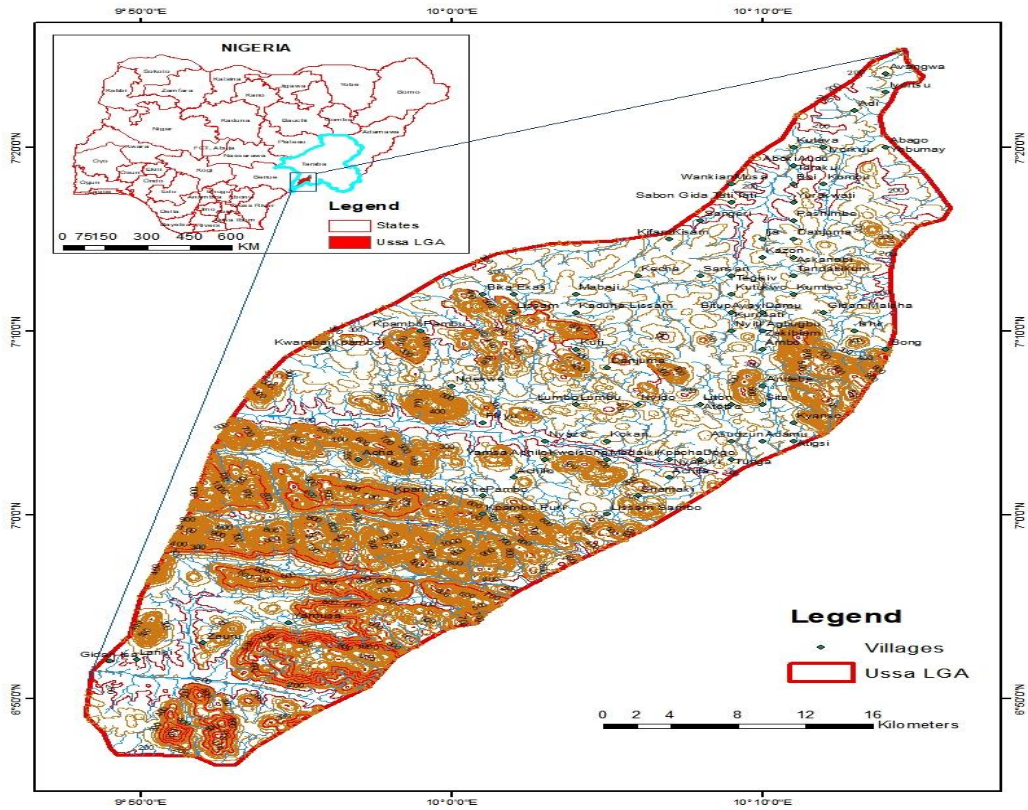

Figure 1: Topographic map of the Study Area (Adopted from Google earth, 2018)

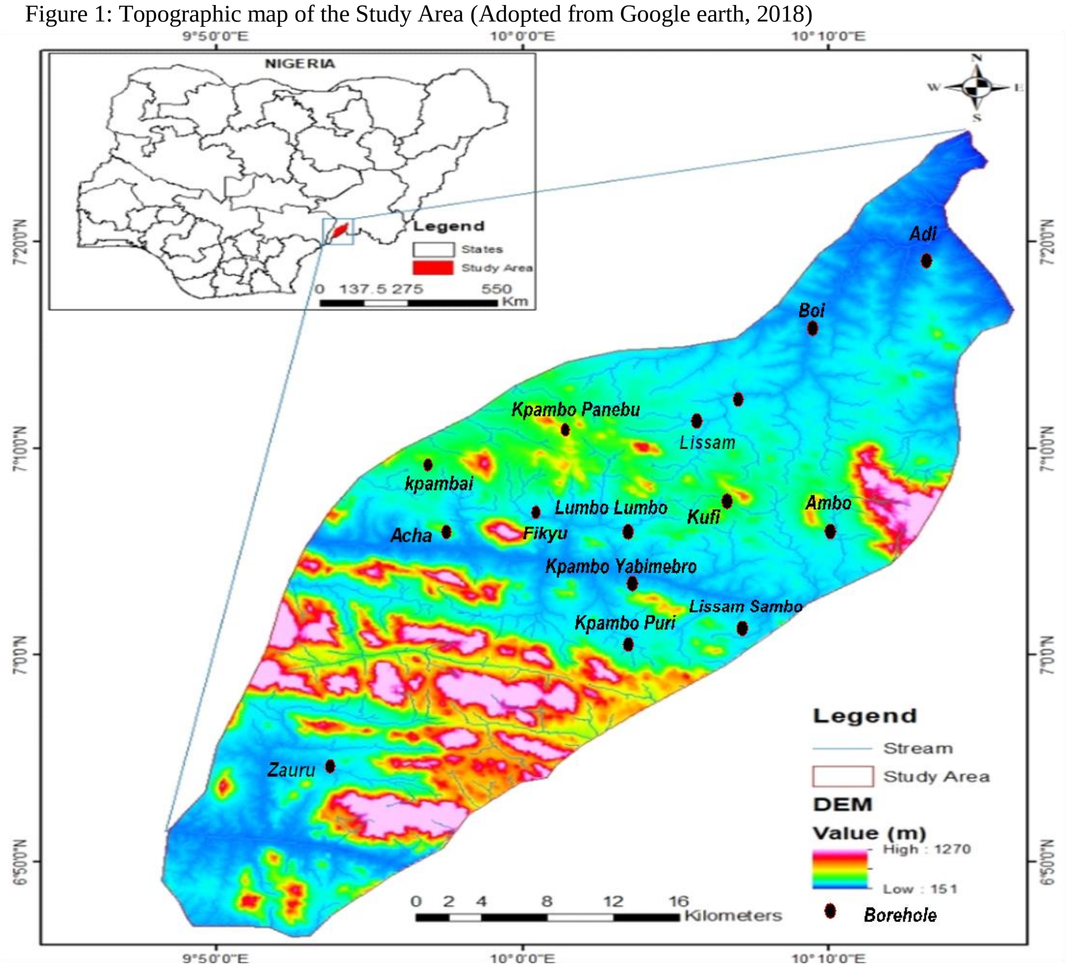

Figure 2: Digital elevation model map of the study area showing Boreholes locations (National Map Downloader, 2022)

Geology of the Study Area

Taraba State's geology and geological history are both simple and complicated. The Basement Complex and sedimentary strata form the subsurface of Taraba State, each of which covers a unique portion of the state (Oruonye and Abbas, 2011). Sedimentary rocks may be found in the basins of the Benue River and its principal tributaries,such as the Donga and Taraba rivers, whereas rocks of the Basement Complex covers the rest of the state. The Basement Complex is made up of Pre-Cambrian rocks, whie Sedimentary rocks vary from Albian to Recent (Jeje, 1978). The majority of the Basement Complex area is covered with gneisses, migmatite, phyllites, schists, and pegmatites, as well as other undifferentiated Basement Complex rocks. Undifferentiated Basement Complex rocks, particularly migmatite, are often porphyroblast and range from coarsely mixed gneisses to fine grained rocks with varied grain sizes. The majority of the outcrops in the area undifferentiated Precambrian igneous and metamorphic rocks (Macleod *et al*, 1971; Grant, 1971). They can be classified as either basic or intermediate intrusives rocks (Obaje, 2009). The Older Granites have textures that range from fine to medium to coarse grains (Turner, 1964). Some doleritic and pegmatitic rocks occur as intrusive dykes and vein bodies in other limited occurrences of minor rock types (Oruonye and Abbas, 2011). Basement Complex have these occurrences (Turner, 1964; McCurry, 1964). Between the early Cretaceous and contemporary times, the Basement Complex rocks of the area were subjected to several regressions and transgressions, resulting in the deposition of sedimentary rocks (Carter *et al*, 1963; Du-Preeze and Barber, 1965). The first of them is from the Albian period. These rocks are found in a range of environments, including terrestrial, marine, deltaic, estuarine, lagoonal, and fluviomarine environments (Jeje, 1978; Ogezi, 2002).

The Middle Benue Basin/trough, also known as the Sub-group Makurdi and Wukari Basins, is one of the sedimentary sequence rocks that covers over half of Nigeria's surface area. Marine facies are overlain by continental sediments, which are ultimately overlain by basal continental facies (Du-Preeze and Barber, 1965). Basal continental facies are overlain by marine facies, which are then overlain by continental sediments. Sedimentary materials that fill the Basin varies in thickness, and several display full single or multiple development cycles typified by base continental facies overlain by marine facies, which are then overlain by continental sediments. These many geologic rock types provide the state with a plethora of important mineral resource opportunities. Within the area of study, fifteen boreholes were subjected to a pumping test, and were acquired from Zion geophysical services (Figure 2) . The geology of the area comprises of majorly three rock types: biotite granite. Granite gneiss and migmatite gneiss (Figure 3).

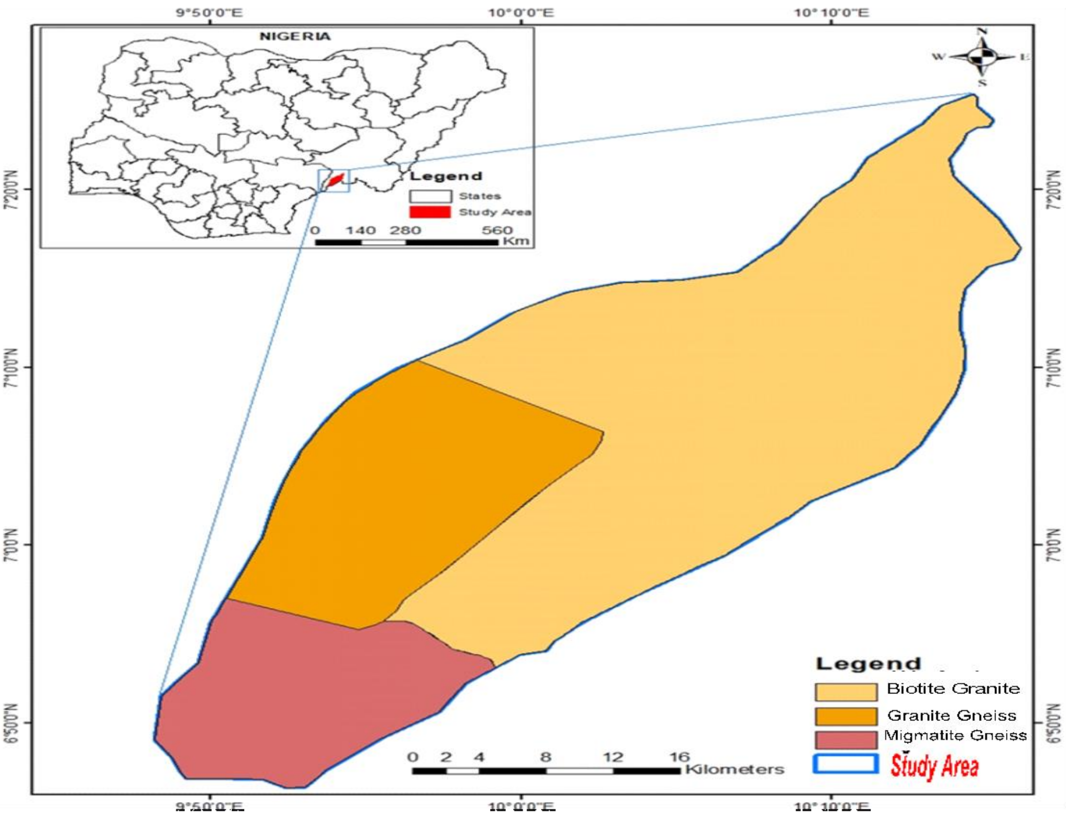

Figure 3: Geological map of Ussa and Environs (NGSA, 2014).

MATERIALS AND METHODS

A total of fifteen (15) sites were selected for pumping tests within the study area so as to determine aquifer physical and hydraulic parameters: aquifer thickness and transmissivity respectively in order to characterize their aquifers. The recovery test method was used for the determination of transmissivity as drawdown observations were made in the test well (pumping well) itself, and there was no need of an observation well (Elenna *et al*, 2018). A 1Horse power submersible pump was installed into the well and pumping was done for 3 hours and stopped. After the pumping had stopped, the water level in the test well was allowed to rise due to recovery of the ground water level. Residual drawdowns (S) were measured in the test well at different

instants of time (t) after the pumping was stopped. The measured values of S were plotted on arithmetic scale against the values of [$\frac{t}{t'}$] on a log scale. The best-fit line was drawn through the plotted points. From the plot, the value of the difference of residual drawdown (ΔS) per log cycle of [$\frac{t}{t'}$] was found. Subsurface stratification, casing and screen placements, static water levels, and aquifer textural characteristics are all factors that were considered, while data on aquifer pumping tests for each borehole, three to four stages, drawdown tests, single-stage, and recovery measurements were observed. The hydraulic characteristics of aquifers such as hydraulic conductivity (K), and specific capacity (SPC), discharge rate (yield) were computed from the transmissivity value. The value of transmissivity (T) was determined using this expression as given by Arora (2002).
:

$$T = \frac{2.303Q}{4\pi \Delta S} \quad (1)$$

Where Q is the rate of discharge (m^3/sec). ΔS represents the variation in drawdown over a single log cycle, t = time elapsed since the starting of the pumping (min) and t' = time elapsed since the stopping of the pumping (min) (Arora, 2002). Because some borehole are restricted and others are semi-confined, this formula is beneficial. The eleven borehole have an average drawdown of roughly 10.75m. The hydraulic conductivity (K) was estimated using the following formula:

$$K = \frac{T}{b} \quad (2)$$

Where T = as in (1) above b = aquifer thickness (equivalent to the total screen length) (Abimiku *et al.,* 2014).

$$C = \frac{Q}{S} \quad (3)$$

The specific capacity (Sc), a measure of well productivity, was computed from:

$$S = Sy + bS_C \quad (4)$$

Where S = Storativity, Sy = Specific yield, Sc = the specific capacity, and b = Aquifer thickness (Uliana, 2005).

RESULTS AND DISCUSSION

One primary hydrogeological unit defined the groundwater systems in the study area: the crystalline Basement, Crystalline rocks define this unit. Boreholes were almost always dug in disintegrating crystalline rocks in the Basement. All of the examined boreholes are located in the Basement hydrogeological unit (table 1). Boreholes are 40 to 45 meters deep on average, with a mean depth of 44 meters. In the region, the average static water level is 4.35 meters, with static water levels ranging from 2.1 to 9.10 meters. Borehole yields vary from 56.16 to 96.21 m^3/d, with an average of 79.00 m^3/d. Transmissivity ranges from 0.57 to 2.41, with a mean value of 1.4. With an average conductivity of 0.17, the conductivity ranges from 0.03 to 0.21. The average Storativity is 160.45, with a range of 112.4 to 192.5. The dynamic water level in the region varies between 11.20 meters and about 20 meters, with an average of 16.11 meters, while the drawdown varies between 9.00 meters and 18.00 meters, with an average of 11.47 meters. The aquifer thickness in the area of study ranges from 9.00 meters to approximately 17.00 meters, with an average of 12.00 meters. The screening interval used in the construction of boreholes in the region ranges from 15.00-33.00 meters to around 24.00-33.00 meters, with an average of 21.00-31.00 meters. Pegmatite, aplite, and quartz veins cut through the migmatite and gneisses that were drilled at various depths. The yield or discharge (Q) values were typically low to moderate (table 1), which varies from 0.68 l/s to 1.11 l/s. The average discharge yield of the boreholes in the area was 0.92 l/s. The overall production of the borehole was 5.56 l/s. According to Gleick (2000), Mussa, (2019) people in africa and sub-Saharan countries use between 15 and 20 L of water per person per day, with some of them living in arid and semi-arid regions using even less water, recommending a basic water requirement of 25 L per person per day to meet the most basic human needs. Based on this cannot sustain a population of 121,500, showing that borehole water is insufficient to meet the people's water demands. The fact that most people in the study area get their water from groundwater sources, it does not guarantee sustainable use of the resource. Sometimes there is overexploitation, which may result in such consequences as continuous drops in groundwater levels over long time periods, large seasonal drops in water levels in wells and the drying up of wells in the dry season. Economically, if some or all the aforementioned consequences happen, there will be an increase in cost of groundwater extraction. The aforementioned undesirable consequences appear when abstraction exceeds recharge. Reportedly, aquifer overexploitation is no longer a myth as it is happening everywhere in the world with several discernible environmental consequences (Custodio, 1992, Esteller and Diaz-Delgado 2002). Provision of safe drinking water supply is one of the most commendable and effective health interventions, which reduce the mortality caused by water-borne diseases by an average of 70%. Therefore, despite groundwater being reliable and important as a resource, groundwater quality is another aspect that must be looked at to assess its significance to communities (Mussa, 2019). Based on the borehole yield classification (table 2), the groundwater potential in the area is classifies into low to moderate (Carruthers and Smith, 1992, Olorunfemi, 2008, Bayowa *et al*., 2014)

Table 1: Hydraulic Characteristics of Boreholes from Crystalline Basement Rocks of Ussa and Environs

S/N	Name of location	Formation	Borehole depth (m)	Screen interval (m)	Aquifer thickness (m)	Static Water level (m)	Dynamic water level (m)	Drawdown (m)	Yield (l/s)	Transmissivity (m^2/d)	Conductivity K(m/d)	Spacific Capacity (m/d/m)	Storativity	Borehole Diameter (mm)
1	Kpambai	Basement	45	21-40	19	3.0	21.0	18	0.65	0.57	0.03	2.96	112.4	125
2	Kpambo	Basement	45	23-35	12	3.5	13.5	10	1.00	1.58	0.18	7.20	172.8	125
3	Lissam	Basement	45	24-33	9	2.1	18.10	16	0.68	0.67	0.18	6.53	117.5	125
4	Fikyu	Basement	45	15-24	9	6.0	20.0	14	0.88	1.26	0.07	10.69	192.4	125
5	Kufi	Basement	40	21-30	9	3.0	16.0	13	0.88	1.07	0.14	8.46	152.3	125
6	Boi	Basement	45	15-33	18	3.0	15.0	8	0.77	1.52	0.084	3.69	132.8	125
7	Acha	Basement	40	21-30	9	3.2	15.20	12	0.93	1.22	0.14	8.91	160.4	125
8	Kpambo	Basement	40	24-36	12	4.2	11.20	7	1.07	2.41	0.20	7.67	184.2	125
9	Kpambo	Basement	45	21-33	12	4.0	14.0	10	0.96	1.52	0.13	6.93	166.3	125
10	Lissam.S	Basement	45	21-38	17	8.1	20.1	11.9	0.91	1.20	0.70	4.6	156.4	125
11	Lissam	Basement	45	24-36	12	6.20	18.2	12	0.96	1.26	0.11	6.86	164.7	125
12	Lumbo L	Basement	45	21-32	11	9.1	18-10	9	1.11	1.96	0.18	8.75	192.5	125
13	Ambo	Basement	45	20-30	10	3.0	15.00	12	0.84	1.19	0.12	7.82	156.4	125
14	Adi	Basement	45	24-36	12	4.2	11.0	7.1	1.07	2.40	0.21	7.67	184.2	125
15	Zauru	Basement	45	21-30	9	3.1	15.20	12	0.91	1.22	0.14	8.91	161.4	125
Mean value			44	21-31	12.00	4.35	16.11	11.47	0.92	1.40	0.17	7.18	160.45	125.00

Table 2: Classification of Borehole Yield in terms of Groundwater Potential in the Basement Complex areas (Adopted from: Caruthers and Smith 1992, Olorunfemi, 2008 and Bayowa *et al.*, 2014)

S/N	Borehole Yield Range (l/s)	Groundwater Potential
1	0 – 0.49	Very Low
2	0.5 – 0.99	Low
3	1.0 – 1.49	Moderate
4	1.5 – 2.5	High
5	> 2.5	Very High

CONCLUSION

The study determined the hydrogeological characteristics of the area's aquifers in terms of borehole depths, water-bearing zones, estimated yields, water levels, transmissivity, hydraulic conductivity, specific capacity, and Storativity based on the results of pumping test analysis of boreholes in the area. Because of differences in lithology, physiography, and structures, groundwater is found at various depths across the area. A comprehensive investigation of all probable aquifers in the Crystalline Basement of Ussa and neighboring areas, as well as a wide evaluation of hydrogeological conditions, were included in the research. In general, yields from borehole dug in the area were low to moderate. The borehole produce an average of 79.66m^3/day. Borehole specific capacities in the study area were measured, and the findings revealed that they ranged from 4.36 to 346 m^3/day. The transmissivity of the aquifers ranges from 0.57 to 1.96 m^3/d, according to estimate based on pumping test results, with around 90 percent of the area having a transmissivity of 0.57 to 1.96 m^3/d and the yield of 0.68 l/s to 1.11 l/s. This cannot sustain a population of 121,500 people based on recommending a basic water requirement of 25 litre per person per day to meet the most basic human needs. When you consider the 121,500 people that rely on these boreholes for their water, it's evident that the aquifers in the 15 borehole studied have very limited production potential. These areas will suffer future water problems if the population continues to expand. The predicted population is 196,553, indicating that the area would suffer a serious water shortage unless the government and other stakeholders act quickly.

Conflict of Interest

The authors state that there were no commercial or financial ties that may be considered as a possible conflict of interest during the research.

REFERENCES

Abimiku, E.S., Dadan-Garba, A., and Adepetu, A. (2019). Assessment of Groundwater Potentials in Ningi Area of Bauchi State, Nigeria. International Journal of Research and Scientific Innovation Volumevi, Issue (VI) pp. 155-157.

Adamu, A., and Sununusi, H. (2020). Subsurface Investigation within Quaternary Alluvium Formation Using Electrical resistivity imaging in Birnin Kebbi, NW, Nigeria. J. Geol. Geophy. 10.493, Vol. 10, No. 2, pp. 158-166.

Adamu, A. (2019a). Electrical resistivity mapping of Aquiferous zones within Gudi-Takalau area of Birnin Kebbi metropolis. ATBU Journal of Environmental Technology, *AJET*, Vol. 11, No. 6, pp. 133-142.

Adamu, A., Fahad, A., Ologe, O., Sagagi, Y.M., and Shamsudeen, A. (2019b). Electrical resistivity Investigation of Kaolinitic and Laterite deposits within Birnin Kebbi and Environs, NW, Nigeria. Savannah Journal of Pure & Appl. Sci., www.sjbas.com, ISSN: 2093 - 2335, Vol. 1, No. 1, pp. 160-168.

Adelana, S.M. A and MacDonald, A.M. (2008). Groundwater research issues in Africa. In: Adelana, S.M.A. & MacDonald, A.M. (eds) Applied Groundwater Studies in Africa. IAH Selected papers on hydrogeology. 13 CRC Press Balkema, Leiden, the Netherlands.

Achyara, G. (2004). The role of economic analysis in groundwater management in semi-arid regions the case of Nigeria. Hydrogeology Journal, 12, 33-39.

Arora, , K. R. (2002). Irrigation, Water Power and Water Resources Engineering. A. K. Jain Publishers,Nai Sarak Delhi.

Bayowa O.G., Olorunfemi M.O., Akinluyi F.O., and Ademilua O.L. (2014). Integration of hydrogeophysical and remote sensing data in the Assessment of groundwater potential of the basement complex Terrain of ekiti state, southwestern nigeria. *Ife Journal of Science* vol. 16, no. 3 pp 353-363

Babatola, J. O. (1997). Rural Water Supply: Issues, Problems, and Prospects.Water Resources Journal of NAH, 8 (1), 19-25.

Carter, J.D., Barber W, Tait EA (1963). "The geology of parts of Adamawa, Bauchi and Bornu Provinces in Northeastern Nigeria". Bull. No. 30, Geol. Surv. of Nigeria, 108.

Carruthers, A.M. and Smith, I.F. (1992). The use of ground Electrical Methods for siting Water Supply boreholes in shallow Crystalline Basement Terrains. In: Wright, E.P and Burgess, W.G. (eds.), *The hydrogeology of crystalline Basement Aquifers in Africa*. Special Publication 66, Geological Society London. pp. 183-230.

Chow, V.T., Maidment, D.R. and Mays, L.W. (1980). Applied Hydrology. McGraw-Hill, New York, USA.

Custodio, E. (1992). Hydrological and Hydrochemical Aspects of Aquifer Overexploitation. Selected Papers on Aquifer Overexploitation; The International Association of Hydrogeologists: Hannover, Germany,; Volume 3, pp. 3–28.

Du Preez J.W, Barber W (1965). ''The Distribution and Chemical quality of groundwater in Northern Nigeria''. Bull. 36. Geological Survey of Nigeria, 93.

Elenna,O.A, Nnaemeka, M. C and Chukwudi, E. C(2018).Assessment of Aquifer Characteristics and Delineation of Groundwater Potential Zones in Afikpo-North

Local Government Area, Southeastern Nigeria. Scientific Research Journal (SCIRJ), Volume VI, Issue V pp 14-21.

Esteller, M.V.; Diaz-Delgado, C (**2002**). Environmental effects of aquifer overexploitation: A case study in the highlands of Mexico. Environ. Manag, 29, 266–278.

Foster, S.S.D., Tuinhof A, & Garduno, H. (2008), Groundwater in Subsahara Africa – A Strategic Overview of development issues. In Adelana, S.M.A. & MacDonald, A.M. (eds) Applied Groundwater Studies in Africa. IAH Selected Papers on Hydrogeology. 13, CRC Press/Balkenia, Leiden, the Netherlands.

Geological Survey Agency of Nigeria (2014): The Geological survey agency of Nigeria, Federal Ministry of Mines and power.

Gleick, P.H (2000).The Biennal Report on Freshwater Resources; Island Press: Washington, DC, USA.

Grant, N.K. (1971). ‘‘A compilation of radiometric age from Nigeria’’.J. Mining Geol., 6:37-54.Nigeria, Federal Ministry of Mines and power.

Jeje, L.K. (1978). "Aspects of Geomorphology of Nigeria".InOguntoyinbo, J.A.S. Macleod WN, Turner DC, Wright EP (1971). The Geology of the Jos Plateau, Geol. Surv. Nigeria, Bull. No. 32, 18.

MacDonald, A.M., Cobbing, J. & Davies J. (2005). Developing Groundwater for rural development supply in Nigeria. British Geological Survey Commissioned Report CR/05/219N.

Macleod, W.N., Turner, D.C., Wright, E.P. (1971). The Geology of the Jos Plateau, Geol. Surv. Nigeria, Bull. No. 32, 18.

McCurry. P (1976). "A Generalized review of the Geology of the Precambrian to Lower Paleozoic Rocks, Northern Nigeria": In Kobe CA. (ed), Geology of Nigeria. Elizabethan Press, Lagos, 13-38.

Mussa, K.R, Mjemah,I.C and Walraevens,K. (2019). Quantification of Groundwater Exploitation and Assessment of Water Quality Risk Perception in the Dar Es Salaam Quaternary Aquifer, Tanzania. *Water* **2019**, *11*(12), pp2552.

National Population Commission, NPC, (2014)

National Map Downloader (2022)

Obaje N.G. (2009). The Basement Complex. In: Geology and Mineral Resources of Nigeria. Lecture Notes in Earth Sciences, vol 120. Springer, Berlin, Heidelberg.

Ogezi E. A (2002). ‘‘Geology’’In Africa Atlases, Nigeria.Les Editions J.A., Paris, France, pp 60-61.

Offodile, M.E. (2014). Hydrogeology: Groundwater Study and Development in Nigeria. Mecon Geology and EngineeringServices Ltd, Jos, Nigeria.

Olorunfemi, M. O. (2008). Voyage on the skin of the Earth: A Geophysical Experience. An Inaugural Lecture delivered at the Obafemi Awolowo University, Ile-Ife,th Nigeria, Tuesday, 11 March,,*Inaugural Lecture series 211*, ObafemiAwolowo University Press Ltd; Ile- Ife.Nigeria. pp. 1-2.

Oruonye E .D. and Abbas B. (2011). The Geography of Taraba State, Nigeria. LAP Publishing Company, Germany.

Srinivasa, R.Y., Reddy, T.V.K. and Nayudu, P.T. (2000). Groundwater targeting in a hard rock-terrian using fracture pattern modeling, Niva River Basin, Andr. Pradesh, India. Hydrogeology Journal, 8 (5) 494-502.

Turner, D.C. (1964). Notes on Fieldwork on the basement rocks of1:250,000 sheets 7 & 8. Geol. Surv. Of Nig. Report.No. 5503.

Uliana, M.M.(2005). Ground Water Hydrology. Wiley online dictionary.

Vincent, W.U., Jaclyn A.B., William, W.D., Dennis, B.W. and Christopher C.S. (2009). Groundwater Development: Basic Concepts for Expanding CRS Water Programs. Catholic Relief Services, Baltimore, United States.Online. Available at:www.crsprogramquality. org.

Wright, E. P., and Burgess, W. G. (eds). (1992). Hydrogeology of Crystalline Basement Aquifers in Africa Geological SocietySpecial Publication No 66, pp 1-27.