GROUNDWATER RESOURCES EVALUATION OF THE UPPER BIMA SANDSTONE AQUIFER IN KALTUNGO AREA AND ENVIRONS, NORTHEASTERN NIGERIA

By

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ABSTRACT

The Groundwater resources of the Upper Bima sandstone in the Kaltungo area and its surroundings have been investigated. A borehole yield range of 0.13 to 6.60 l/s with an average of 1.34 l/s were recorded for the area, while the Transmissivity and Specific capacity computed for the area ranges between 9.46 x10^{-3} to 14.23x10 (m^2/s) with an average of 3.85x10^{-1} (m^2/s) and 7.75x10^{-3} to 11.70 x10 m^2/s/m with average of 3.98x10^{-1} (m^2/s/m) respectively. This shows the area to be of low or poor groundwater resources potentials with low reserve. Lithological borehole logs interpretation reveals aquifer materials that compose of fine to medium Sandstone, Sand and Silty materials with shale and clay intercalations. Petrographic study and grain size analysis conducted on the Upper Bima Sandstone member by previous workers have revealed the sandstone of the upper Bima formation to be poorly sorted, immature with reduced porosity and of crystalline origin. These factors are most probably responsible for the poor hydrogeological condition of the Upper Bima Sandstone member, which have similar hydrogeological situations with those obtained for basement complex terrain elsewhere, hence confirming a crystalline origin for the Bima sandstone aquifers with low groundwater potentials.

Keywords: Upper Bima Sandstone, Porosity, Cement materials, Borehole specific capacity, Poor hydrogeological unit, Kaltungo.

INTRODUCTION

Groundwater resources occurrence in a given area depends primarily on certain factors which include Geology, landforms/thickness of the weathered zone, and the depth of rainfall that falls in the area. The ability of a rock to take into storage and release water relies on its porosity and permeability. For one to quantify the groundwater in a given geological environment, certain data on the hydrogeology of the area need to be known. The availability as well as the authenticity of data on pumping test is one of the major challenges in Nigeria and Africa, making it difficult for researchers to estimate accurately the groundwater resource in a given area. Mac Donald *et al* (2012), estimated a groundwater storage of 0.66 million km^3 (0.36 - 1.75 million km^3) for African aquifers and a storage reserve of 11800 km^3 with a range of 5710 to 33600 km^3 for Nigerian aquifers. The authors further showed that the large sedimentary aquifer of North Africa have the largest groundwater resources reserve, with countries like Libya, Algeria, Sudan, Egypt and Chad republic.

Schoeneich (2003) calculated the water budget for the Basin development authorities in Nigeria and estimated the dynamic water resources for the basins to be 538,282 million cubic metres per year, out of this figure the upper Benue river basin has 53,773 million cubic metres per year.

For the area of study, Offodile (2002) described the lithology of the Bima Sandstone to consists of feldspathic sandstones, grits, pebbles beds, and clays which are highly crystalline and well cemented, which made it to have hydrogeological characteristics that are similar with that of basement complex terrain, he reported a yield range of 2-8l/s with an average of between 1-5l/s which depends on the part of the Bima Formation, he concluded by considering the Bima Formation to have poor or lower groundwater potentials. Mbiimbe *et al.* (2008) investigated the groundwater potentials for parts of Bima and Yolde formations as well as the alluvium of the river course of Numan town and environs in the Benue Trough. He computed the mean aquifer properties of transmissivity and hydraulic conductivity to be $65.67m^2$/ day and $5.6x10^{-1}$m/day respectively and a mean yield of 220l/day with a groundwater reserve of $1.01x10^{10}m^3$. The Gombe state rural water supply (2003) in Abdulhakeem *et al* (2011) reported occurrence of groundwater in the weathered and fractured portion of the basement rocks of Kaltungo area, the average depth of boreholes in the basement is 30m while fractures occurred at a depth of between 12 to 24m while the yield for the fractured aquifers is between 3.3l/s and 16.7l/s and groundwater quality zones of poor and very poor class were demarcated for the Kaltungo area by the authors. Haruna *et al* (2014) analysed the concentration of fluoride in natural water from Kaltungo area which includes dug wells, boreholes and spring water. Their result revealed a higher concentration above the permissible limits of 1.5mg/l set by the (WHO 2004) with a range of 0.52 to 4.4mg/l.

This study intends to assess in details the groundwater resources potentials of the Upper Bima Sandstone in the Kaltungo area and relating that with the origin, porosity and permeability of the Bima Formation.

STUDY AREA

The area of study covers the Kaltungo town and its environs in the Gongola arm of the upper Benue trough of Northeastern Nigeria, located between latitude 9º 37´E and 10° 00´E with a longitudinal stretch of between 11º 00´N and 11° 15´N covering a total landmass of about $3671.41km^2$ (Fig. 1).

The study area is located within the tropics with Sudan type of climate with two distinct seasons the wet and dry. The wet season which commences in April and last till October (7 months) with their peak in August, the average annual rainfall is about 1550mm. The dry period is known as the harmattan, which is characterized with dust laden wind this lasts for a period of five months, November to March with an average daily temperature of 33ºC. The vegetation cover of the area is Sudan savannah type which is characterized by short grasses of 1.2-2.0metres high and sporadic thorny bushes and scattered trees.

The area is characterized with hilly and lower topography, among the hilly features are the Lawana, Kuyo and Kuto hills at the Northwestern portion of the area, the Kaltungo, Lapan and Awak peaks form the hilly topography at the Northeastern side of the study area which are all granitic. At the southeastern corner of the area the Kilang peak and the Swili hill are the dominant outcrops, while the Dadiya hills occur as a ridge mainly of sandstone. The lowland area is predominantly of sandstone and weathered materials.

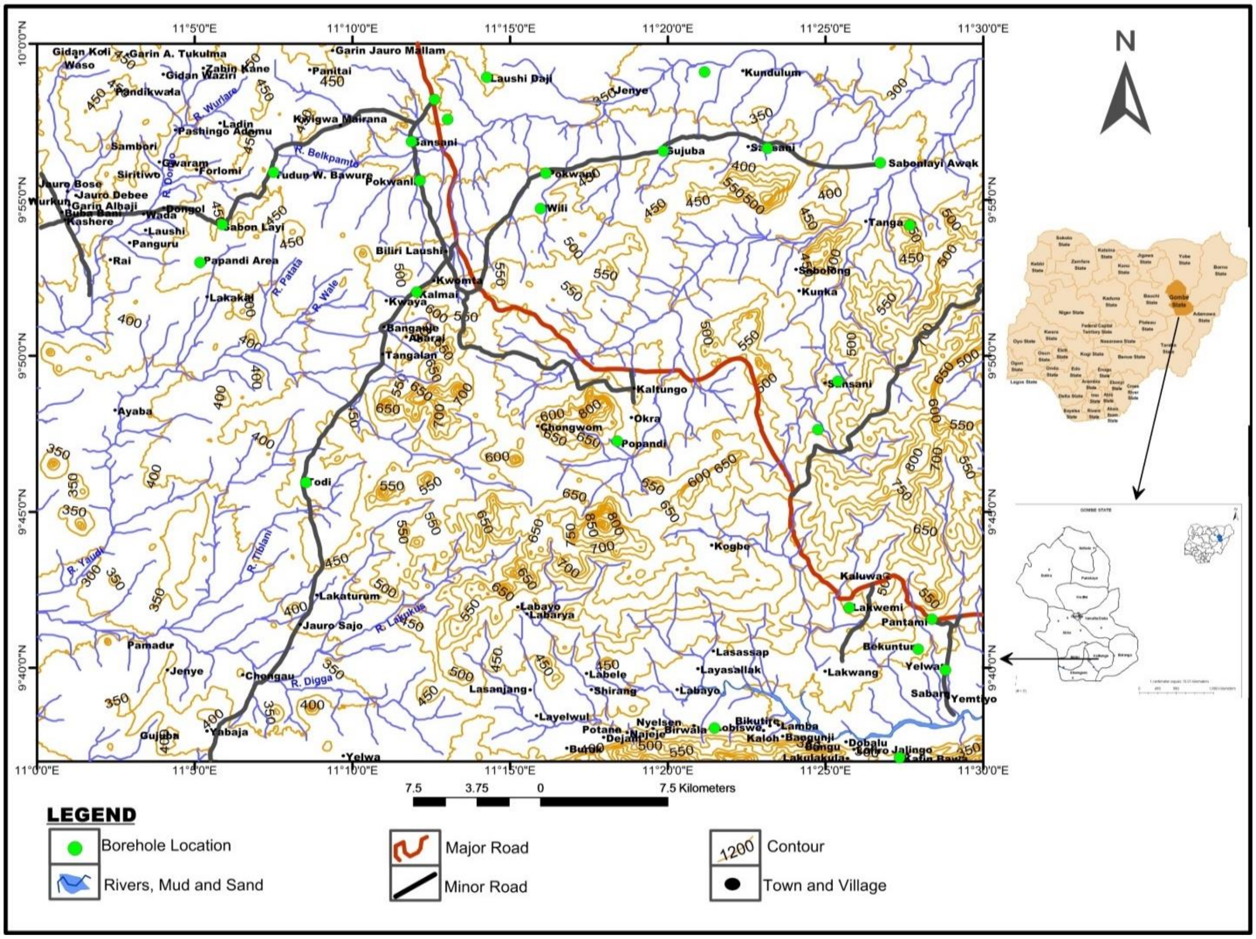

Fig. 1: Location map of the study area showing boreholes locations
Source: Adopted and modified from federal surveys of Nigeria (1975)

Geologic Setting

The Benue Trough (Fig. 2) is an intracontinental rift basin in the central West Africa that extends NE-SW, 800km in length and 150km in width (Obaje *et al*. 2004). The southern limit is the northern boundary of the Niger Delta, while the northern limit is the southern boundary of the Chad basin (Zaborski *et al*. 1997). Several authors have presented models for the genesis of the Benue Trough. Kings (1950) proposed tensional movement resulting in a rift while Stoneley (1966) proposed a graben-like structure. The RRF triple junction model leading to plate dilation and opening of the Gulf of Guinea was proposed by Grant (1971). Olade (1975) considered the Benue Trough as the third failed arm or aulocogen of a three armed rift system related to the development of hotspots. Benkhelil (1989) also Guiraud and Maurin (1992) considered wrench faulting as the dominant tectonic process during the Benue Trough evolution and defined it as a set of juxtaposed pull-apart basins generated along the pre-existing N60E strike-slip faults.

The Upper Benue Trough is the northeastern geographical subdivision of the Benue Trough (Fig. 2). The upper Benue Trough comprises the area extending from the Bashar – Mutum Biyu line as far north as the Dumbulwa – Bage high of Zaborski *et al*. (1997). From the view of most authors, the Upper Benue Trough is made up of two sub-basins: the East – west trending Yola Basin (Yola Arm) and the North – south trending Gongola Basin (Gongola Arm). The Geology and Stratigraphy of the Upper Benue Trough has been described to some extend by Carter *et al*., (1963); Reyment (1965); Kogbe (1976); Offodile (1976); Petters (1978, 1982); Popoff *et al*. (1986); Zaborski *et al*. (1997) among others.

The Early Cretaceous continental Bima Sandstone unconformably overlies the Pan African Basement rocks (Carter *et al*. 1963; Guiraud, 1990; Zaborski 1998). In most places it represents by far the greatest proportion of the lithostratigraphic successions in the Upper Benue Trough. Tukur *et al*. (2015) divided the formation into two siliciclastic members: Lower Bima Sandstone Member and Upper Bima Sandstone Member, based on sedimentological data.

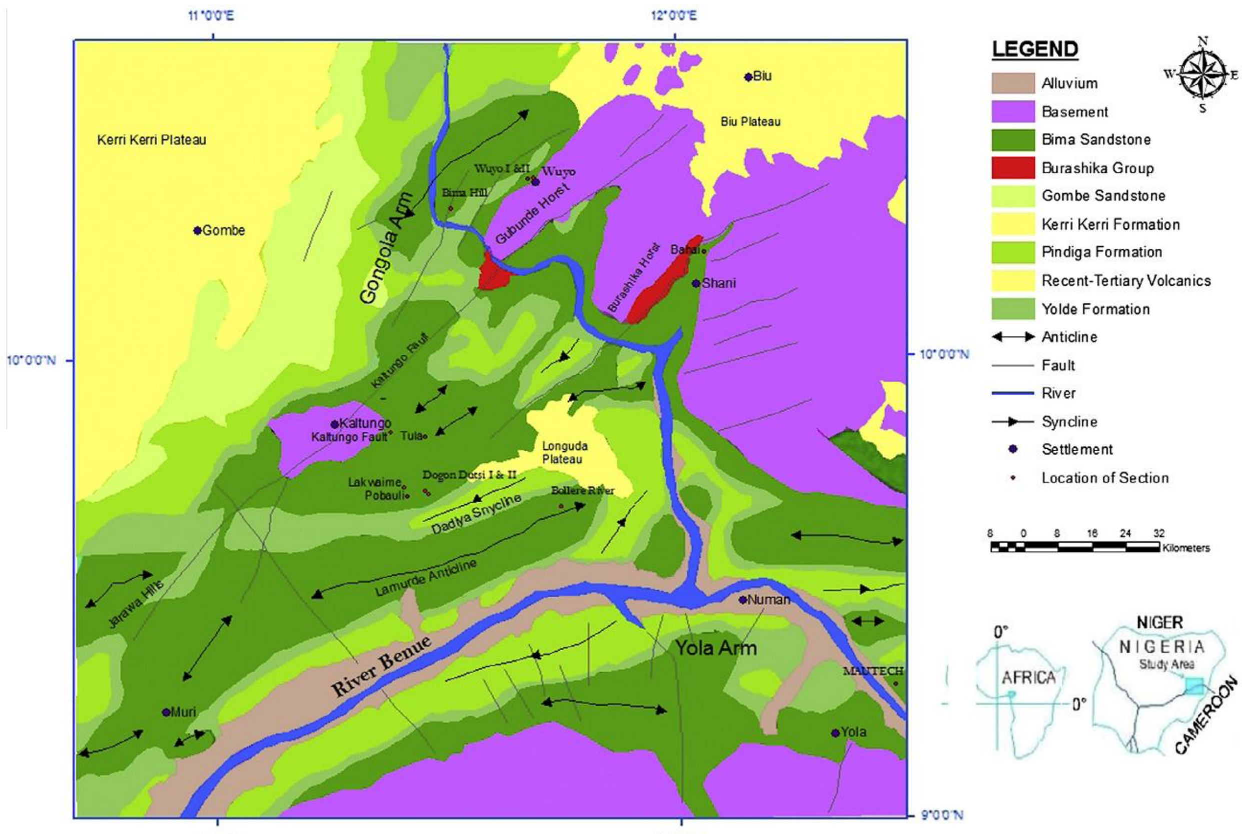

Fig. 2: Geologic map of the Upper Benue Trough with location of the studied sections. (After Tukur, *et al*. 2015)

Tukur *et al*. (2015) gives the following lithological description of the Bima Sandstone members, The Lower Bima Sandstone Member comprises of purple; dark and greenish mudstones; tabular cross bedded sandstone; trough cross bedded sandstone, parallel laminated sandstone; massive sandstone; sedimentary breccias; carbonate paleosol; and ferruginised paleosol lithofacies with total thickness of 62 – 250m.While the Upper Bima Sandstone Member is predominantly tabular cross bedded with minor components of rippled sandstone; parallel laminated sandstone; greenish mudstone; and massive sandstone lithofacies up to 1050 m thick. According to Saka (2012) the sediments of the Bima formation were derived from juxtaposed basement suites of older granite and gneisses which were subjected to humid conditions that accelerated the weathering processes. A simplified stratigraphic subdivision of the Gongola Basin is presented in Figure 3.

The above sequence overlies the basement complex unconformably which outcrops in the area of study as coarse porphyritic granite, Biotite granite and Basalts (Rahaman, 1976).

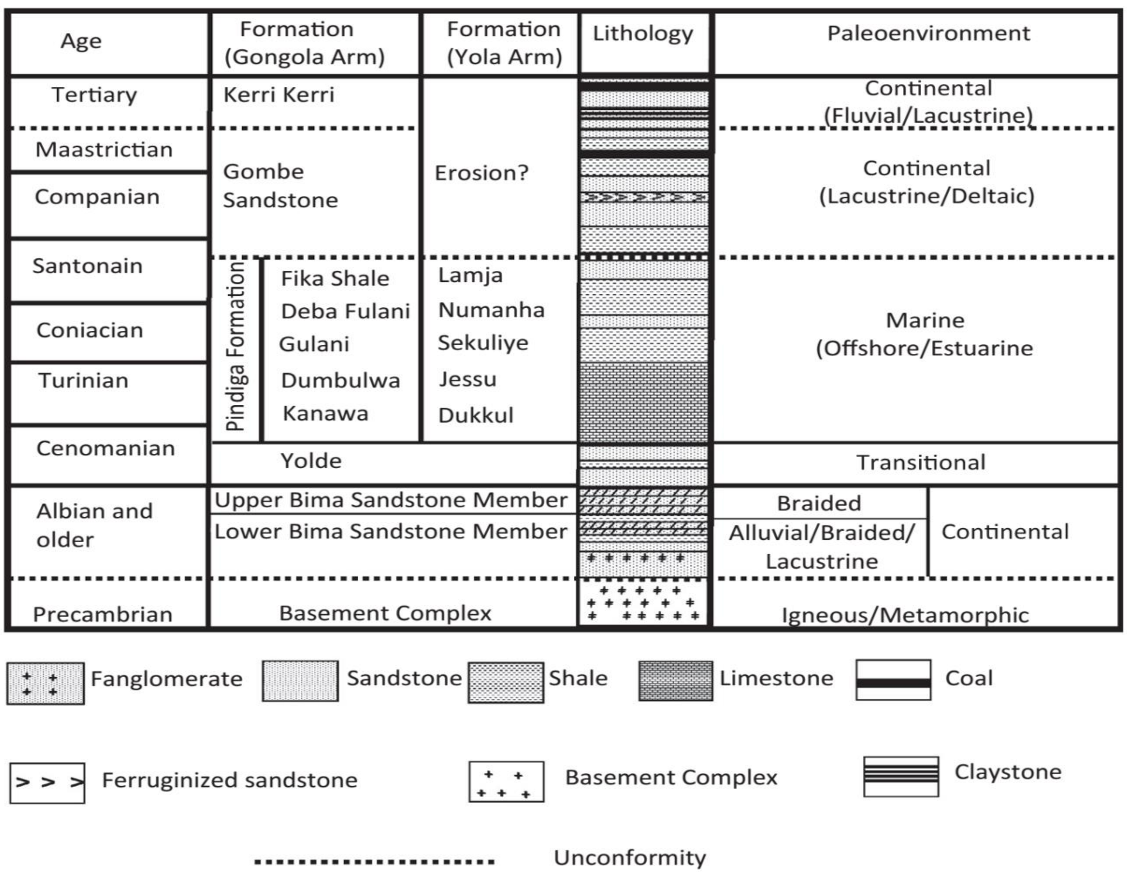

Fig. 3: Lithostratigraphic succession of the Upper Benue Trough, with two subdivision of the Bima Sandstone (after Tukur *et al.* 2015)

MATERIALS AND METHODS

A total of fifty four (54) lithological borehole logs of drilled boreholes that tap water from upper Bima Member of the continental Cretaceous Bima Sandstone drilled by the former Bauchi State Agricultural Development programme (BSADP) between 1980 and 1988, and some data obtained for recently drilled boreholes in the year 2013 by Bran and Lube engineering limited were analysed for this study. The logs were analysed to evaluate the groundwater resources potentials of the upper Bima sandstone member around Kaltungo area. To accomplish this, the aquifer properties of specific capacity and Transmissivity (T) were determined using the Logan (1964) equation for phreatic aquifer which is given as:

$$T = a \times \left(\frac{Q}{s}\right)$$

The results obtained were related with the porosity and permeability of the upper Bima sandstone member, also results from sedimentary and crystalline complex areas were compared with those from this investigation and conclusions were drawn.

Where T= Transmissivity of Aquifer (m^2/s)
a= Dimensional constant = 1.22
Q = Yield of well (l/s)
s= Drawdown recorded in the pumping well (m)

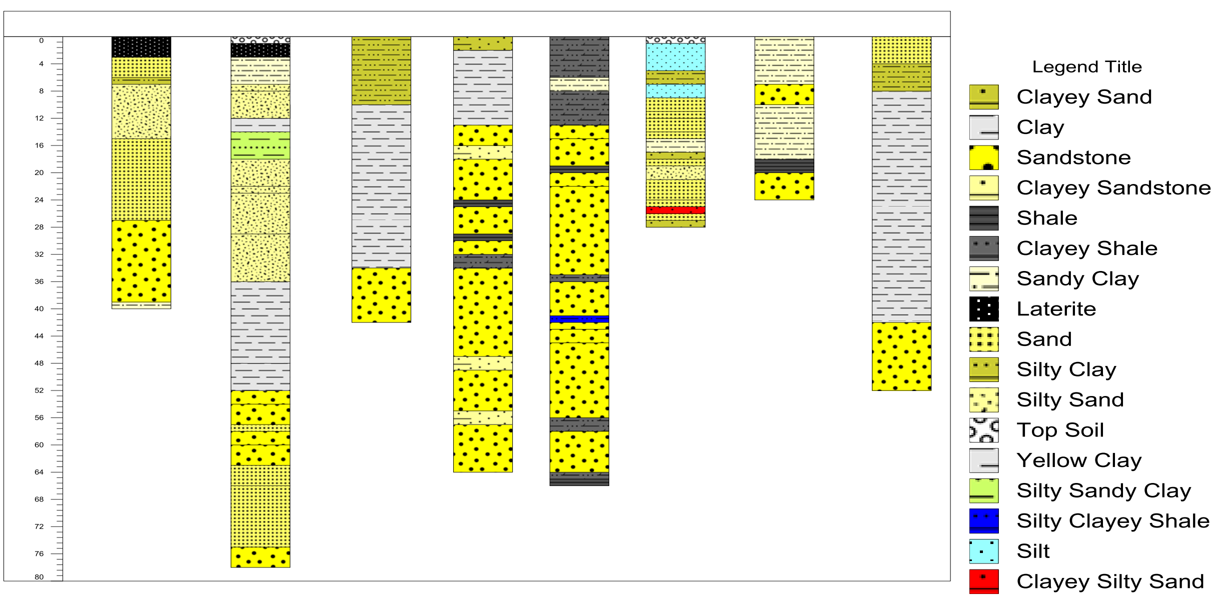

Fig. 4: Lithological Boreholes logs for selected boreholes from the area of study

RESULTS AND DISCUSSION

The result obtained shows that the Transmissivity values ranged from 9.46 x10^{-3} to 14.23x10m^2/s with an average value of 3.85x$10^{-1}m^2/s$ (Table 1).

Table 1: Summary of Hydraulic properties of Upper Bima Sandstone Aquifers in the Kaltungo Area, Northeastern Nigeria.

S/N	Community	Borehole Depth(m)	Static water level (m)	Draw Dawn(m)	Screen length(m)	Yield (l/s)	Transmissivity (m^2/s)	Specific capacity(m^2/s/m)
1	Fantami	64	53.07	2.87	7	0.20	$8.50x10^{-2}$	$7.00x10^{-2}$
2	Dorawa	36	16.69	2.84	9	1.40	$6.0x10^{-1}$	$5.00x10^{-2}$
3	Sabonlayi	24	2.28	12.43	9	0.16	$1.57x10^{-2}$	$1.30x10^{-2}$
4	Bandara	51	40.45	6.09	8	0.70	$1.40x10^{-1}$	$1.15x10^{-1}$
5	Kafin bawa	60	17.62	11.17	9	1.13	$1.23x10^{-1}$	$1.01x10^{-1}$
6	Lakweme	40	19.16	4.16	5	2.20	$6.45x10^{-1}$	$5.30x10^{-1}$
7	Sabara	39	21.76	4.36	9	1.83	$5.12x10^{-1}$	$4.20x10^{-1}$
8	Lobiswe	43	5.02	7.79	8.5	0.86	$1.35x10^{-1}$	$1.10x10^{-1}$
9	Wili	42	32.12	0.60	8.5	2.08	4.23x10	3.47x10
10	Shenge-shenge	52	11.37	10.11	9	2.16	$2.61x10^{-1}$	$2.14x10^{-1}$
11	Popandi	44	10.74	3.21	9	0.20	$7.60x10^{-2}$	$6.23x10^{-2}$
12	Balam	42	22.44	6.14	9	0.70	$1.40x10^{-1}$	$1.14x10^{-1}$
13	Nahufa	42	20.47	7.30	9	0.50	$8.36x10^{-2}$	$6.84x10^{-2}$
14	Awak	38	18.65	0.83	7	1.82	2.68x10	2.20x10
15	Chublung	38	27.46	1.57	9	1.33	1.03x10	$8.50x10^{-1}$
16	Kwarsu	36	17.49	5.74	9	0.66	$1.40x10^{-1}$	$1.15x10^{-1}$
17	Bayili	37	9.27	5.04	6	0.46	$1.11x10^{-1}$	$9.13x10^{-2}$
18	Bule	24	11.11	2.45	9	0.46	1.38x10	1.13x10
19	Burwai	58	45.12	4.65	9	0.40	$1.05x10^{-1}$	$8.60x10^{-2}$
20	Kaltin	59	27.94	10.56	5	1.83	$2.11x10^{-1}$	$1.73x10^{-1}$
21	Lantaren	78	9.90	8.82	8	5.50	$7.61x10^{-1}$	$6.24x10^{-1}$
22	Bwara	67	3.30	11.42	4	2.50	$2.70x10^{-1}$	$2.20x10^{-1}$
23	Bundebunde	79.5	24	2.49	5	6.60	3.23x10	2.65x10
24	Yabde	144	19.14	42.56	5	0.33	$9.46x10^{-3}$	$7.75x10^{-3}$
25	Nahuta	46	22.61	5.09	4	0.66	$1.60x10^{-1}$	$1.30x10^{-1}$
26	Todi	18	8.89	3.21	5	0.58	$2.20x10^{-1}$	$1.81x10^{-1}$
27	Kalmai	44	22.98	14.37	5	0.16	2.81x10	2.30x10
28	Lawiltu	32	35.23	1.86	5	1.66	3.80x10	3.10x10
29	Lawishi daji	48	32.34	4.92	10	0.41	2.50x10	2.02x10
30	Kwibah	30	14.70	2.77	9	0.26	$1.15x10^{-1}$	$9.40x10^{-2}$
31	Pakwangli	40	18.19	5.45	5	1.25	$2.05x10^{-2}$	$1.70x10^{-2}$
32	Ladongor	52	35.15	5.41	6	1.06	$2.40x10^{-1}$	$2.00x10^{-1}$
33	Amtawalam	39	14.15	8.96	5	0.30	$4.10x10^{-2}$	$3.35x10^{-2}$
34	Lamugu	18	8.40	0.41	9	0.90	$6.00x10^{-2}$	$5.00x10^{-2}$
35	Mosso	42	15.50	3.09	8	4.50	$3.54x10^{-1}$	$3.00x10^{-1}$
36	Lakalembu	24	11.10	2.87	9	0.16	$6.80x10^{-2}$	$5.60x10^{-2}$
37	Kanadi	34	9.79	4.20	13	0.30	$8.71x10^{-2}$	$7.14x10^{-2}$
38	Pandin kude	29	11.69	3.80	9	0.23	$7.40x10^{-1}$	$6.05x10^{-2}$
39	Tudunwada	40	2.77	23.67	5	0.53	$2.73x10^{-2}$	$2.24x10^{-2}$
40	Kentenkereng	40	23.67	2.08	5	2.16	1.26x10	1.04x10
41	Sansani	28	12.58	4.18	9	1.23	$3.60x10^{-1}$	$3.00x10^{-1}$
42	Gada uku	33	7.81	6.34	7	1.83	$3.52x10^{-1}$	$3.00x10^{-1}$
43	Laberpito	77	20.19	20.13	6.5	1.16	$7.03x10^{-2}$	$6.00x10^{-2}$
44	Degri	40.5	17.38	11.15	6.5	0.58	$6.35x10^{-2}$	$7.03x10^{-2}$
45	Kukuriya awya	46	16.12	13.75	7	0.20	$1.80x10^{-2}$	$1.46x10^{-2}$
46	Bekuntin	31	11.68	3.06	9	2.58	$1.03x10^{-2}$	$8.43x10^{-1}$
47	Tarmana jeji	42	30.08	1.14	9	1.25	1.34x10	1.10x10
48	Gujuba	35	26.53	0.73	5	1.08	1.80x10	1.50x10
49	Beltubo	45	27.45	3.21	9	1.11	$4.22x10^{-1}$	$3.50x10^{-1}$
50	Pokwangali	54	40.03	0.50	9	5.83	14.23x10	11.70x10
51	Pobishi	66	43.73	6.33	5	0.13	$2.51x10^{-2}$	$2.05x10^{-2}$
52	Kushi	52	4.00	40.91	8	0.48	$1.43x10^{-2}$	$1.20x10^{-2}$
53	Kokde	64	16.00	29.2	9	0.58	$2.40x10^{-2}$	$2.00x10^{-2}$
54	Laushi Daji	60	16.00	28.05	9	0.95	$4.14x10^{-2}$	$3.40x10^{-2}$
	Averages			**6.63**	**7.6**	**1.34**	**$3.85x10^{-1}$**	**$3.98x10^{-1}$**

Computed specific capacity ranges from $7.75 x 10^{-3}$ to 11.70 $x10m^2/s/m$ with an average value of $3.98 x 10^{-1} m^2/s/m$. A yield ranging from 0.13 to 6.6l/s with an average value of 1.34l/s was obtained for the study area (Table 1). Aquifer thicknesses deduced from the logs ranges between 3 and 13m with an average of 5.22m (Fig. C and Table 1).

Lithological borehole logs analysis (Figure 3) reveals a composition of fine, medium to coarse grained sandstone, clayey sandstone, shaly sandstone, sand and clayey or shaly sandy material with an average thickness of 5.22 m. The above calculated aquifer properties sand yield recorded shows the upper Bima sandstone aquifer to be a low yielding or poor water bearing formation.

The low yield of the Bima sandstone in the study area may be due to poor sorting, low porosity and permeability and immature nature of the formation. The suggestion is based on the previous works of Haruna *et al*. (2012a and 2012b), Abubakar (2014), Samaila and Singh (2010) and Samaila (2007) were they show that Bima sandstone is poorly sorted, immature with low porosity and permeability based on petrographic study and grain size analysis. Samaila and Singh (2010) calculated the cement percentage composition range for the upper Bima member to be between 2 – 20% while porosity loss due to compaction, cementation and compaction index to be 18.18%. This loss of porosity due to pore space fillings, by cementing materials and compaction has also greatly reduces the groundwater storing and yielding abilities of the Bima formation.

The origin of the Bima formation is another factor that gives rise to the low water content in the Upper Bima member, being continental and not marine, it was derived from the weathering of basement rocks notably the granites and gneisses under tropical humid condition deposited close to their sources which gives it a poorly sorted clayey, angular to subangular and immature features hence making it to acquire hydrogeological characteristics of the parent materials from which it was formed. Gluyas (2005) pointed out that sorting within sand is controlled by both provenance and sedimentary process and sorting of the sand controls its initial porosity while the grain size and sorting control initial permeability, he went further to show that porosity lost depends largely on how well sorted the sand is, poorly sorted sand will have more porosity lost. Well sorted sands are therefore more porous than poorly sorted sand in the same vein loosely packed sands are more porous than tightly packed sands.

Comparing the mean yield of 1.34l/s and a range of 0.13 to 6.6l/s obtained in the area with yields ranges of 2.5-30l/s, 2.6 – 13l/s, obtained for the Chad and Ajali formations respectively, it can be noticed that the yields of boreholes in the area are too low. Also a higher yield of 54,000l/hr was recorded for the Gwandu formation of the Sokoto sector of the Iullemmeden basin Offodile (2002). This is also comparably higher than the results from this study. Yield greater than 20l/s are obtainable for the Saharan aquifer of North Africa which are believed to be actively recharged more than 5000 years ago (MacDonald *et al.*, 2012). This value can be regarded as the standard for sedimentary basin aquifers in the African continent. MacDonald *et al* (2005) gave a moderate to high yield range of 1-20l/s for consolidated sandstone aquifer. However the computed result from the area are comparable and agrees with findings obtained by other researchers on basement complex terrains elsewhere, notably the works of Chilton *et al* (1984), Bala and Ike (2001), Hamidu *et al* (2013), Hamidu *et al* (2014) and Bala *et al* (2011), while there is a great difference between the results obtained from this study with the result from other sedimentary terrains.

CONCLUSION

The Groundwater potentials of the upper member of the Bima sandstone of Kaltungo area and its environs have been investigated; the formation has poor or low groundwater reserve and potentials with low yield. Being a continental formation with a crystalline origin, this condition has attributed to the reduction in the porosity and permeability of the aquifer materials due to the occupation of the pore spaces by cement materials notably clay, iron oxide and matrix consequently resulting in the blocking of the pathways for the free and easy accumulation and movement of groundwater from the formations into boreholes and wells hence reducing the overall groundwater reserve of the area, this makes it to behave hydrogeological like a basement aquifer with a limited groundwater potential.

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