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Full Length Research Article

Groundwater Resource Appraisals of Bodinga and Environs, Sokoto Basin North Western Nigeria

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ABSTRACT: The groundwater resources of semi-arid region of Bodinga town and its environs within the Sokoto basin of Northwestern Nigeria have been evaluated. Data obtained at site during pumping test sessions which lasted for a period of between 8-12 hours for a total of 67 boreholes in the area of study were used alongside Information gathered from the careful analysis of lithological logs of the drilled Boreholes. The Hydraulic conductivity for the Kalambaina, Wurno, and Taloka formations are 22.00x10 m/s , $8.00x10^{-1}$ m/s, and 1.02x10 m/s and respectively with an average of 3.00x10 m/s for the area. The Transmissivity calculated for these formations are 167.54x10 m^2/s, 3.02x10 m^2/s and 3.00x10 m^2/s respectively while the average total for the area is. 20.30x10 m^2/s. Specific capacity for the Kalambaina is 140.00x10 m^2/s/m, for Wurno the value is 2.10x10 m^2/s/m while Taloka formation have a value of 2.35x10 m^2/s/m and the mean computed for this part of the basin is 16.30x10 m^2/s /m. Yield is between 0.23 l/s and 6.7 l/s. The calculated properties show the area to be rich in groundwater resources mainly tapped from the coarse sandy and cavernous/jointed limestone layers. However the high drawdown values recorded in some of the boreholes is attributed to the presence of silt- clay materials which act as aquiclude. The high yielding boreholes are those with thicker and sandy aquifer material and less drawdown, however the area have high groundwater resource that is partly affected by the presence of silt and clay intercalations within the sandy Aquiferous units.

Keywords: *Groundwater, Transmissivity, Coarse-sandy layer, Aquiclude, Semi-confined, Sokoto basin.*

INTRODUCTION

Early work on the Sokoto basin concentrated on the geology of the area dated as far back as the 1800, this includes those of Jones (1948) and Parker (1964). Hydrogeological investigation on the basin was first carried out by Tattan (1930). Du preez and Barber(1965). The most comprehensive hydrogeological work on the basin is that of Anderson and Ogilbee (1973), the work described the general hydrogeology of the basin and mostly concentrated on the Artesian wells and deep wells in the basin. In their study of the Rima aquifer within the area of the present study (Bodinga) carried out by these researchers, a transmissivity of 65000 gpd per feet was computed for a borehole drilled by geological survey of Nigeria and a drawdown of 0.9 m recorded in an observation well located 10.1 m away at a pumping rate of 5,140 gph for 24 hours. Another GSN borehole at shuni town which tap the Rima in the area under study, (N.3511) has a yield of 5,290 gph with a recorded drawdown of 7.3 m. For borehole GSN.3512 located at Dange town, this tap water from the Gundumi formation the authors computed Transmissivity of 22,800 gal/day/feet with hydraulic conductivity of 457 g/d/f^2 and a yield of 1,570 gph . Hamidu et al (2015), recorded an average yield of 4.1 l/s, transmissivity and specific capacity averages of 1.70x10 m^2/s and 1.40x10 m^2/s/m respectively for the Gundumi formation of Talata Mafara town and its environs Other works that contributed to the study of the hydrogeology of the basin included that of Oteze(1976), JICA (1990), Umar (2000), Alagbe (2004), Maduabuchi (2002), Adelena et al (2006) and Guillaume et al (2011).

This present work was aimed at carrying out an in depth study on the groundwater resource potentials of Bodinga area, the choice of this area is not far from the fact that the geology of the area consist of overlaps of the different geological formations of the basin outcropping to the surface in this part of Sokoto basin. The previous work of Anderson and Ogilbee (1973), studied the hydrogeology of the whole basin, this study concentrated on a portion of the basin to give a more detail and clear picture of the hydrogeology of the area by using more data and different method of analysis.

Physical Setting, Climate and Hydrology

The Iullemeden basin in Nigeria is represented by semi consolidated rocks which outcrop to the surface as undulating plain broken at intervals by hills of clay which are Paleocene sediment (Sokoto group), while the last two overlies the Gwandu and other capped at the top with ferruginous ooliths, laterites or ferruginized sandstone. The first type of superficial deposit overlies the formations that outcrop to the surface in the basin, Kogbe (1979). The hilly topography nearly exceeds 46 m at the Dange scarp which is a steep-sided flat topped hill with a low escarpment, which is the highest relief future in the area. Generally, the more elevated surfaces are found on the iron stone cap hills. The average elevation of the land in this basin is between 250-400 metres above sea level.

Two climatic seasons exist in the basin, a short wet season lasting from the months of May to October with the rain initiated by the northward movement of the moist equatorial maritime air mass (ref.). The rain increases southward with an annual average of value of 670 mm. The longer dry hamattan period lasting between October-April, is characterized by dry dust-laden winds of the tropical continental mass. The coolest months are between December and January where temperature falls to 16 ^{o}C while the hottest month is April with the highest temperature of about 40 ^{o}C, while the daily minimum is 24 ^{o}C. The annual mean temperature fluctuate between 21.5 and 34.9 ^{o}C.

Because of the low rainfall distribution in the area, the vegetation cover type is the Sudan savanna type (ref.). Mainly this is characterized by spars scrubs which are not up to 6 m tall. Large isolated trees are also common, characterized by fine-leafed and thorny structures. Broad leaf varieties do exist southward in the basin due to increase in rainfall.

The Rima and Sokoto rivers forms the main drainage system in the basin, these join each other at Dundaye area. The main source of the river is the crystalline rock located east of the basin. The river flow westward and southward cutting through the Rima and Sokoto groups as well as the Gwandu formation. The Rima, Gagare, Bunsuru, Kware, Zamfara, Gayan, and Gulbin Ka Rivers are the tributaries to the Sokoto River. The Sokoto river and its tributaries are perennial, this is made possible during the dry season from recharge receive through base flow, springs, and the parch water body of the Kalambaina Limestone formation, Anderson and Ogilbee (1973).

Geology

The area of study is located south of Sokoto town and falls within the Nigerian sector of the Iullemeden basin and is between latitude 12º30' and 13º00' and longitude 5º00' and 5º30' with a total land area of 3,040 km^2. From the bottom upward the geology of the area comprises the crystalline complex, below the ground this is encountered at a depth of more than 520 m. Outcrops of the crystalline complex west of Sokoto and beyond the sedimentary rock limit exposes granite, gneisses, phyllite and quartzite as the rocks of the basement suit. The rocks of the crystalline complex are pre Cambrian in age. Above the basement complex unconformably lies the Illo and Gundumi formations with thickness of 120 m and 320 m respectively, Kogbe (1979). They comprise of grits, clayey-sand and clay with its base mainly made up of conglomerate. The group is continental fluvio-lacustrine in origin with age of lower Cretaceous.

Overlying the continental Gundumi formation is the Maastrichtian Rima group, this was unconformably deposited and consist of three formations, a lower Taloka formation of sandstone and mudstone with maximum thickness of about 100 m. Mainly this consist of white fine grained, friable sandstones and siltstone with a thin layer of intercalated mudstone and carbonaceous mudstone or shale. The Dukamaje formation overlies the Taloka; this is made up of shales with some limestone and mudstone with a maximum thickness of about 23 metres. The uppermost layer of the Rima group is the Wurno formation, with similar lithology to Taloka formation, the carbonaceous material present in the Wurno is responsible for its dark colour. The surface exposure of the Wurno is about 25 m thick. The Sokoto group overlies the Rima, it is marine in origin consisting of a lower shalley Dange formation which is an aquiclude with thickness of between 22m to 45 m. The Kalambaina is made up of clayey, chalky or nodular continental limestone and shale with thickness of about 20 m. An upper most Gamba formation made up of 7 m of clay, calcareous clay and laminated shale overlies the Kalambaina. At the top of the Sokoto group is a layer of laterite and windblown sand, the Sokoto group is Palaeocene in age. The Gwandu formation is the youngest sequence and continental, consisting of massive clay-mudstone interbeded with coarse and medium grained sandstone with a thickness of over 75 metres. The age of this formation is Eocene – Tertiary, Figure 1.

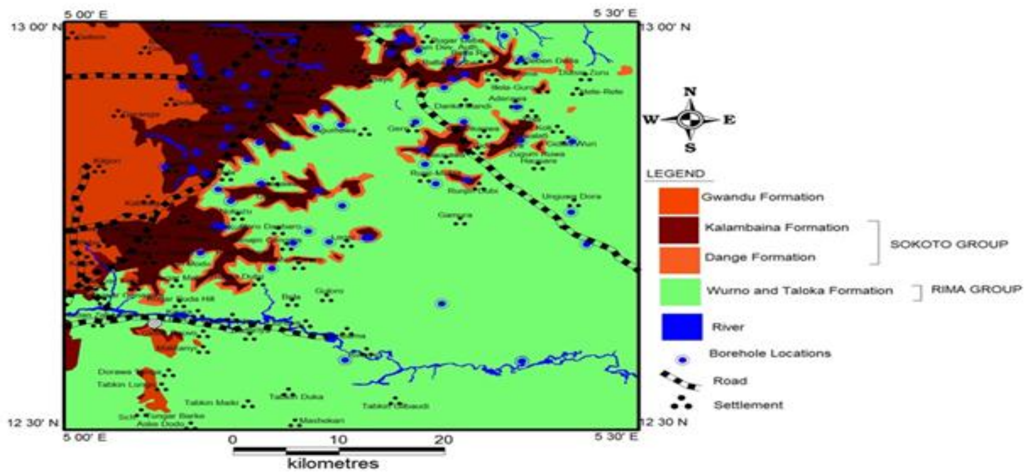

Figure 1: Subsurface Geology Map Of The Area Of Study Showing The Location Of Boreholes

For the Rima group and Gwandu formation, the water producing layers are the coarser sandy zone which should be thick enough to give the desire higher yield. From table 1 It will be noticed that higher yield are obtained from boreholes that has low drawdown values, thicker water bearing zones, coarse and clay free layers. It was also observed that the lower the drawdown the thicker the aquifer, and the coarser the aquifer material, the more the water stored and transmitted from the aquifer in the borehole. Also the low drawdown shows that the rate of discharge in these boreholes nearly equals the recharge which shows also that the aquifers in such locations are porous and highly permeable especially the limestone aquifer of the Kalambaina formation due to the presence of solution cavities that serve as conduits for the free flow or transmission of water resulting from high permeability created by the secondary opening in the limestone.

Generally, in this area of study the water producing layers are the fine, medium, Coarse Sand and Cavernous Jointed limestone layers. From the

MATERIALS AND METHOD

The borehole data used for this study were obtained from the completion report of the drilled boreholes prepared by Wardrop engineering consultant to the Sokoto Agricultural and Rural Development Authority (S.A.R.D.A). The information covers the different sedimentary formations in the Sokoto basin. Data such as aquifer thickness, borehole depth, and material composition of the water producing units, were all deduced from the lithological borehole logs of the 67 boreholes drilled in the area of study. These data were analysed alongside the information gathered during the pumping test at site which include borehole yield, drawdown, static water level and pumping rate. The pumping test lasted for a period of between 8 to 12 hours depending on the time at which the individual borehole been pumped achieved equilibrium, with pumping rate ranging between 7 and 75 lpm which depends on the yield of the pumping well and on the borehole response to water abstraction. The information on the yield and drawdown were substitute in the Logan (1964) empirical relation to compute the Transmissivity and Specific capacity. This is giving by

$T = a \times (Q/s)$ where T= Transmissivity (m^2/s)
a = dimensional constant =1.22
Q = yield of borehole = (l/s)
S= Recorded maximum drawdown in the Pumpingwell.

The Hydraulic conductivity was computed using $K = T/b$ where:
K = Hydraulic conductivity (m/s)
b = Thickness of aquifer or screen length used.

The Topographical map sheet of the area was used as a base map to produce the geological map with the borehole location plotted on it (figure 1).

RESULTS

The result of the study is presented in Table 1. The calculated hydraulic properties for the aquifer in the different formations within the area studied in this part of the basin are discussed below.

Transmissivity

The calculated transmissivity of Kalambaina formation ranges from 2.64×10^{-1} and 817.40x10 m^2/s with an average of 170.00x10 m^2/s, the Wurno formation has a transmissivity value that ranges between 1.77×10^{-2} m^2/s and 37.20x10 m^2/s with a mean value of 3.02x10 m^2/s. The Transmissivity value for the Taloka formation in the area is from 5.00×10^{-2} m^2/s to 5.50x10 m^2/s with an average of 3.00x10 m^2/s. Only two boreholes drilled in the area terminated within the Gwandu formation and these have a Transmissivity of 2.33×10^{-1} m^2/s and 9.62x10 m^2/s with a mean of 4.92x10 m^2/s. The total average value for the area of study is 20.30x10 m^2/s

Specific Capacity

The specific capacity of the Kalambaina is between 2.17×10^{-1} $m^2/s/m$ and 670.00x10 $m^2/s/m$ with a mean value of 140.00x10 m^2/s /m. Wurno formation has values ranging from 1.45×10^{-2} $m^2/s/m$ to 30.50x10 $m^2/s/m$ with a calculated average of 2.10x10 $m^2/s/m$. For Taloka formation, the specific capacity values ranges between 4.10×10^{-2} $m^2/s/m$ and 4.50x10 $m^2/s/m$ while computed average is 2.35x10 $m^2/s/m$. The two boreholes that intercepted the Gwandu formation in the area have specific capacity values of 2.00×10^{-1} $m^2/s/m$. and 8.00x10 $m^2/s/m$ with average of 4.10x10 $m^2/s/m$. The average for the area of study is 16.30x10 $m^2/s/m$.

Hydraulic Conductivity

The Kalambaina formation has hydraulic conductivity range of between 5.10×10^{-2} m/s and 91.00x10 m/s with a mean of 22.00x10 m/s. For Wurno formation the values of hydraulic conductivity are from 7.07×10^{-3} m/s to 14.90x10 m/s and with a mean of 8.00×10^{-1} m/s, while Taloka have a range of between 1.41×10^{-2} m/s and 2.20x10 m/s with average of 1.02x10 m/s/m. The only two boreholes that tap the Gwandu formation have a range of between of 9.33×10^{-2} m^2/s and of 3.85x10 m/s while the average for this formation is 1.96x10 m/s. The mean hydraulic conductivity value for the area is of 3.00x10 m/s.

DISCUSSION

About 70% of the boreholes used in this study are located on the Rima group, while the Sokoto and Gwandu formation constitutes the remaining 30%. The studied revealed that 53 0f the boreholes used for this study tap water from the Wurno while the Kalambaina and Taloka formations respectively have 7 boreholes each. Only 2 boreholes penetrate and tap water from Gwandu formation. The study showed that 54% of the boreholes which represent 37 boreholes have poor yield of less than 4l/s which ranges between 0.23- 3.9 l/s, higher yield of between 4 and 6.7l/s were recorded in 30 boreholes.

Two high water yielding layers have been identified in the area, the parch water table aquifer of the Kalambaina limestone with a yield of between 0.58 to 6.7 l/s with aquifer thickness range of between 4.5 – 9 m and a total drilled depth of between 24 to 56 metres. The second productive unit is the sandy and gravely layers of the Wurno, Taloka and Gwandu formations. A general trend was observed from the study of lithological borehole logs, for the Kalambaina limestone at shallow depth the permeability is high due to the high density and distribution of Cavernous zone, Joints/solution cavities and bedding planes which are enlarged by percolating water through solution process, hence making it possible for water to be stored and transmitted into the wells during pumping, but with greater depth this limestone becomes an aquitard. However the underlying Dange shale serves as a confirming aquiclude bed or layer at the top of the underlying Rima group.

For the Rima group and Gwandu formation, the water producing layers are the coarser sandy zone which should be thick enough to give the desire higher yield. From table 1 It will be noticed that higher yield are obtained from boreholes that has low drawdown values, thicker water bearing zones, coarse and clay free layers. It was also observed that the lower the drawdown the thicker the aquifer, and the coarser the aquifer material, the more the water stored and transmitted from the aquifer in the borehole. Also the low drawdown shows that the rate of discharge in these boreholes nearly equals the recharge which shows also that the aquifers in such locations are porous and highly permeable especially the limestone aquifer of the Kalambaina formation due to the presence of solution cavities that serve as conduits for the free flow or transmission of water resulting from high permeability created by the secondary opening in the limestone.

Generally, in this area of study the water producing layers are the fine, medium, Coarse Sand and Cavernous Jointed limestone layers. From the forgoing discussions the most efficient Aquifer are those with high value of Transmissivity and specific capacity, because these parameters indicate well productivity. From the result presented in (table 1), the most efficient and productive borehole in the area of study is well no 4 located at Jirga community, this has a yield of 6.7 l/s, a Transmissivity of 817.40 × 10 m^2/s Specific Capacity of 670.00 × 10 $m^2/s/m$ and Hydraulic Conductivity of 90.82 × 10 m/s. While the least productive and less efficient borehole is well no 11 located at Gumare this has a yield of 0.28 l/s, Transmissivity of 1.77×10^{-2} m^2/s Specific Capacity of 1.45×10^{-2} $m^2/s/m$ and Hydraulic Conductivity of 5.05×10^{-3} m/s. The boreholes tapped water from the limestone aquifer and Silty sandy layers of the Kalambaina and Wurno formations respectively. Static water levels were measured after the pumping test in all the boreholes and it ranged between 5.83 and 7.48 m.

However the shorter pumping test duration of between eight and twelve hours shows that the aquifers in the area attended equilibrium within a short period which can be attributed to Transmissivity of the aquifer material especially for the high yielding aquifer of the Kalambaina formation.

TABLE 1: HYDRAULIC PROPERTIES OF BOREHOLES FROM THE STUDY AREA

S/No	Community	Co-ordinates		S.W.L (m)	PUMPING RATE(Lpm)	Yield Q(l/s)	Draw Down (m)	Aquifer Thickness (m)	Depth of Borehole (m)	Transmissivity T (m^2/s)	Specific Capacity ($m^2/s/m$)	Hydraulic Conductivity K (m/s)	Type of Formation
		Lat.	Long										
1.	Kwalfa	12º56'11	5º08'36	11.86	26	6.7	0.08	7	24	102.18x10°	83.75x10°	14.6x10°	Limestone (Kalambaina)
2	Kaura Tsara	12º53'34	5º08'28	18.80	23	0.6	2.77	5	31	2.03x10°	1.66x10°	4.0x10-1	Limestone (Kalambaina)
3	Siri kaka	12º53'55	5º09'44	20.27	23	0.58	2.49	4.5	32	2.84x10-1	2.33x10-1	6.32x10-2	Shaley Limestone (Kalambaina)
4	Jirga	12º52'12	5º08'39	19.26	23	6.7	0.01	9	30	817.40x10°	670.00x10°	90.82x10°	Limestone (Kalambaina)
5	Kaura Halya	12º55'13	5º09'28	18.02	24	0.8	0.02	6.5	24	48.80x10°	40.00x10°	7.51x10°	Limestone (Kalambaina)
6	Runbuki	12º56'10	5º07' 9	15.74	25	6.7	0.04	5	30	204.35x10°	167.50x10°	40.87x10°	Limestone (Kalambaina)
7	Lukuyawa	12º57'21	5º06'50	16.69	19	0.8	2.73	7	50	3.60x10-1	3.00x10-1	5.11x10-2	Limestone (Kalambaina)
8	Kwanawa	12º59'15	5º15'52	38.05	15	4.2	2.17	2.5	91	2.36x10°	2.00x10°	9.45x10-1	Coarse (Wurno)
9	Tudun Dan-Dogo	12º57'43	5º17'3	47.40	57	3.9	10.24	2.5	96	4.68x10-1	3.81x10-1	1.86x10-1	Sand (Wurno)
10	Shiyar Ajuja	12º46'11	5º15'5	40.99	54	3.0	19.92	3.5	109	1.84x10-1	1.51x10-1	5.25x10-3	Medium Coarse Sand (Wurno)
11	Gumara	12º48'43	5º21'4	36.87	7	0.28	19.33	2.7	103	1.77x10-2	1.45x10-2	5.05x10-3	Silty Sand (Wurno)
12	Gumara	12º48'21	5º20'44	38.73	50	2.8	7.57	2.5	109	4.51x10-1	3.70x10-2	1.81x10-1	Medium Sand (Wurno)
13	Boolera	12º51'16	5º23'52	67.88	23	1.2	15.43	2.5	123	9.50x10-2	7.80x10-2	3.80x10-2	Dark Clayey Sand (Taloka)
14	Dali	12º51'12	5º26'33	20.33	13	1.6	4.51	2.5	72	4.33x10-1	3.55x10-1	1.73x10-1	Fine Sand (Wurno)
15	Majin baraya	12º53'43	5º23'40	7.59	24	5.8	3.23	2.5	61	2.20x10°	1.80x10°	8.80x10-1	Clay + Medium Sand (Wurno)
16	Majin Baraya	12º57'11	5º23'51	6.42	17	2.3	6.54	2.5	66	4.30x10-1	3.52x10-1	1.72x10-1	Fine Sand (Wurno)
17	Gidan Ajiya	12º50'36	5º18'48	49.43	23	0.6	5.47	2.5	61	1.3410-1	1.10x10-1	5.35x10-2	Fine Sand (Wurno)
18	Dankilo	12º52'37	5º18'22	45.04	40	6.7	2.41	2.5	79	3.40x10°	2.78x10°	1.36x10°	Fine Sand (Wurno)
19.	Katsira	12º51'46	5º20'53	50.11	50	0.9	10.47	2.5	67	1.05x10-1	8.60x10-2	4.20x10-2	Clay+Fine sand (Wurno)

20	Banganange	12º56'1	5º20'57	53.03	50	5.4	9.95	3.5	121	6.62x10-1	5.43x10-1	1.90x10-1	Fine Sand (Taloka)
21	Danbarunje	12º57'5	5º20'10	46.54	54	2.0	16.56	2.5	85	1.47x10-1	1.21x10-1	4.21x10-2	Fine Sand (Wurno)
22	Danbarunje	12º55'45	5º20'22	43.65	34	1.6	12.89	2.5	84	1.51x10-1	1.24x10-1	6.10x10-2	Clay+Sand (Wurno)
23	Battagoriba	12º57'52	5º18'31	23.78	19	6.3	1.04	3.5	54	7.40x10°	6.06x10°	3.00x10°	Medium Sand (Wurno)
24	Dabagen rikina	12º58'41	5º18'3	46.14	57	5.3	4.59	2.5	75	1.41x10°	1.15x10°	4.03x10-1	Fine Sand (Wurno)
25	Rikina Gari	12º58'36	5º17'29	43.74	56	5.0	7.55	2.5	87	8.08x10-1	6.62x10-1	3.23x10-1	Very fine Sand (Wurno)
26	Rikina Gari	12º58'53	5º17'43	44.94	8	0.3	14.91	3.5	89	2.46x10-2	2.01x10-2	9.88x10-3	Clay+Fine (Wurno)
27	Birkitawa	12º57'32	5º24'36	30.86	13	2.8	3.21	2.5	81	1.06x10°	8.72x10-1	3.04x10-1	Fine Sand (Wurno)
28	Girgiri	12º58'57	5º23'0	46.83	55	4.8	6.46	2.5	85	9.00x10-1	7.43x10-1	3.62x10-1	Silty Sand (Wurno)
29	Runjin Kaji	12º58'54	5º21'21	15.99	75	4.9	6.81	3.5	54	8.80x10-1	7.20x10-1	3.51x10-1	White clay + Fine Sand (Wurno)
30	Dakalo	12º46'21	5º26'30	60.03	10	1.3	1.3	3.5	89	1.22x10°	1.00x10°	3.50x10-1	Fine silty Sand (Wurno)
31	Tudun mai tandu	12º59'34	5º15'20	41.93	39	1.06	5.15	2.5	79	2.51x10-1	2.06x10-1	7.20x10-2	Black Sand & Clay (Wurno)
32	Jurga Rafi	12º49'30	5º18'52	40.40	72	6.7	4.75	3.5	72	1.72x10°	1.41x10°	6.90x10-1	Fine Sand (Wurno)
33	Amanawa	12º48'5	5º19'25	13.44	31	1.3	9.99	3.5	91	1.59x10-1	1.30x10-1	4.54x10-2	Fine Sand (Wurno)
34	Tsafandi Dutse	12º55'9	5º19'51	47.8	27	0.83	8.61	2.5	89	1.18x10-1	9.63x10-2	4.70x10-2	Fine Sand + Clay (Wurno)
35	Kaura miyo	12º50'23	5º06'56	41.96	5.5	0.3	5.78	2.5	72	6.33x10-2	5.20x10-2	2.52x10-2	Sand (Wurno)
36	Lugu	12º55'12	5º06'11	47.30	13	6.7	0.34	4	100	24.04x10°	19.71x10°	6.01x10°	Sand+Shale (Wurno)
37.	Kwalafasa	12º56'45	5º06'59	34.45	16	0.4	4.11	5	54	1.19x10-1	9.73x10-2	2.37x10-2	Clay+Coarse Sand (Wurno)
38.	Jeba	12º49'19	5º05'16	72.42	54	1.9	6.12	4	96	3.80x10-1	3.12x10-1	9.50x10-2	Gray clay + Sand (Wurno)
39.	Abdulsalami	12º48'51	5º07'26	24.28	17.5	0.9	3.56	4	96	3.10x10-1	2.53x10-1	7.71x10-2	Fine Sand (Wurno)
40.	Mazan Gari	12º50'52	5º08'19	39.90	44	2.5	7.87	3.5	90	4.00x10-1	3.18x10-1	1.12x10-1	Fine Sand (Wurno)
41.	Gwarko	12º51'6	5º10'13	48.18	12.5	0.5	0.47	7	54	1.30x10	1.06x10	1.90x10	Coarse Sand (Wurno)

42.	Kwaciya Lalle	12º52'13	5º13'10	50.72	53	1.02	11.21	3.5	73	1.11x10-1	9.10x10-2	3.17x10-2	Fine Sand (Wurno)
43.	Zanzoro	12º53'34	5º13'43	22.03	21	6.7	0.22	2.5	78	37.20x10	30.50x10	14.90x10	Sand (Wurno)
44.	Badau	12º46'49	5º08'43	42.07	8	0.6	5.63	2.5	78	1.30x10-1	1.07x10-1	5.20x10-2	Gray clay (Wurno)
45.	Tauma	12º49'51	5º09'34	36.90	43	2.3	7.88	3.5	90	3.60x10-1	3.00x10-1	1.02x10-1	Sand (Wurno)
46.	Kaura Danmalle	12º47'41	5º08'4	16.84	23	6.7	0.32	3.5	72	25.54x10	21.00x10	7.30x10	Coarse Sand (Wurno)
47.	Gwastu	12º48'7	5º10'17	43.42	33	1.5	7.84	2.5	60	2,33x10-1	2.00x10-1	9.34x10-2	Fine Sand (Gwandu)
48.	Karaje	12º47'34	5º13'16	41.85	75	6.7	0.85	2.5	72	9.62x10	8.00x10	3.85x10	Medium Sand (Gwandu)
49.	Shiyar Ajiya	12º46'28	5º014'32	50.55	65	4	7.2	3.5	79	6.80x10-1	5.60x10-1	2.00x10-1	Coarse Sand (Wurno)
50.	Karazuntu	12º52'24	5º14'29	51.56	36	5	1.34	2.5	77	4.60x10	3.73x10	1.82x10	Sand+Clay (Wurno)
51.	Bagarune danajiwe	12º56'10	5º10'30	43.12	72	2.3	4.35	3.5	66	6.50x10-1	5.30x10-1	1.80x10-1	Sand+Clay (Wurno)
52.	Kulodo	12º58'37	5º1158	28.61	36	1.3	3.53	3.5	54	4.50x10-1	3.70x10-1	1.30x10-1	Sand (Wurno)
53.	Runbu	12º50'55	5º08'16	47.45	62	2.9	3.53	3.5	96	1.00x10	8.22x10-1	3.00x10-1	Coarse Sand with Clay (Wurno)
54	Chofi	12º35'7	5º14'41	29.60	67	6.7	0.85	3.5	103	9.62x10	8.00x10	2.75x10	Coarse Sand (Wurno)
55	Kyaluje	12º39'16	5º19'44	33.58	15	6.7	0.94	3.5	91	8.70x10	7.13x10	2.50x10	Clayey sandstone (Wurno)
56	Dabagin lafiya	12º43'39	5º27'17	57.83	7	0.3	7.38	3.5	84	5.00x10-1	4.10x10-2	1.42x10-2	Coarse Sand (Taloka)
57	Tsamiya Gari	12º35'2	5º23'54	11.50	75	6.7	1.49	2.5	40	5.50x10	4.50x10	2.20x10	Coarse Sand (Taloka)
58	Tsamiya	12º35'4	5º23'56	5.83	75	6.7	2.47	2.5	33	3.31x10	2.7x10	1.32x10	Coarse Sand(Taloka)
59.	Bangi	12º44'5	5º16'0	74.15	9	0.53	1.82	3.5	91	3.60x10-1	3.00x10-1	1.02x10-1	Fine Sand(Wurno)
60.	Bangi	12º44'6	5º15'42	44.48	9	0.23	2.78	3.5	90	1.01x10-1	8.30x10-2	3.00x10-2	Fine + clay(Wurno)
61.	Dandin Make	12º43'22	5º07'8	48.2	47	6.7	0.8	3.5	91	10.22x10	8.40x10	3.00x10	Fine Sand + grey clay(Wurno)
62.	Kwamtsi	12º41'51	5º10'52	49.5	39	5.1	6	3.5	121	1.04x10-1	8.50x10-1	3.00x10-1	Black fine Sand(Wurno)

63.	Lugge	12º43'41	5º11'59	26.1	68	6.7	2.9	2.5	91	2.82x10	2.31x10	1.13x10	Coarse to fine Sand (Wurno)
64.	Kwantsi Danchadi	12º45'1	5º08'0	49.4	26	1.08	23.7	2.5	138.5	5.60x10-2	4.00x10-2	2.22x10-2	Fine sand(Wurno)
65.	Kwantsi Danchadi	12º43'49	5º13'50	23.4	72	6.7	5.3	2.5	88	1.26x10	1.54x10	6.17x10-1	Fine Sand with clay (Wurno)
66.	Siri Modi	12º44'55	5º08'20	33.4	77	6.7	1.7	3.5	72.5	4.81	4.00x10	1.37x10	Fine Sand(Taloka)
67.	Da Kalo	12º44'36	5º12'45	32.5	54	6.7	5.5	2.5	103	1.50	1.22x10	6.00x10-1	Fine Sand(Wurno)

CONCLUSION

The Bodinga area and environs has abundant groundwater resources with higher yield mostly occurring in the thicker Sandy layers and solution openings in the limestone units. Generally the water comes from the Kalambaina, Wurno, Taloka, and Gwandu formations. The clayey layers of these formations are thicker than the sandy units with depth increase; the presence of these finer clayey and Silty materials within the Aquiferous layers reduces the performance and efficiency of this unit as water storing and producing unit. However, this can be improved through longer duration of pumping, proper well development and construction.

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