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SUSTAINABLE MANAGEMENT OF BOREHOLE YIELDS IN BASEMENT COMPLEX AQUIFERS

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ABSTRACT

Groundwater development in some basement complex areas found in places like Katsina and other parts of northern Nigeria is a major challenge because the terrain is generally underlain by rocks of low permeability. This paper evaluated the sustainable management of borehole yields in such an environment directed at assisting people with the knowledge for assessing portable groundwater supply, using Katsina as a case study. Pumping tests were carried out for six boreholes to determine their yields using constant rate test approach. The depths of the boreholes ranged from 60 to 101 m, installed with five inches (127mm) PVC casings. The pump used for the pumping test was 1.5 horsepower because of the depths. It was discovered that one of the borehole had very high yield of 1.4 l/s and one proved abortive, while five boreholes had relatively low to moderate yield from 0.42 to 1.0 l/s for every 7 to 30 minutes pumping with 5 to 30 minutes lag intervals. The yield from the last borehole was 0.42 l/s for every 7m with 30 minutes lag interval. The low yield boreholes were located in areas of aquifers of low extent. Based on the findings, sustainable management of the borehole yields was suggested by recommending daily four hour cycle of pumping that could yield 42,762 litres/4 hr cycle instead of abandoning the relatively low/moderate yield boreholes. It is recommended that this approach be replicated in other areas with basement complex formations with low yields.

Keywords: Groundwater development, basement complex, sustainable management, pumping test

1.0 INTRODUCTION

A borehole supplies a sustainable yield if the volume of water required by the population reliant on it is available throughout the dry season and over periods of below average rainfall (Madonald, *et. al.,* 1959). Groundwater occurs in basement complex (igneous and metamorphic rocks) and sedimentary environment in Nigeria. Groundwater exploitation is done by drilling boreholes or constructing wells through ground formation in order to access underground aquifers. Groundwater is readily available in sedimentary environment and the yields are mostly sustainable, though at great depth in most cases. However, groundwater availability in most basement complexes poses a challenge because the aquifers have relatively low storage and limited extent. Besides, the pores in weathered basement might be relatively small to allow appreciable transmission of groundwater in significant quantity unless there is presence of large fractures. As a result, borehole yields from some basement complexes especially, in northern part of Nigeria might not be sustainable unless some strategies are put in place (Madonald *et al.,* 1959; Hamidu *et al*., 2014; Adeeko and Ojo, 2015; Tajudeen *et al.,* 2019 and Afuwai *et al*., 2014).

Borehole yield is determined by carrying out pumping test for the drilled boreholes or wells. A pumping test is an exercise in which a borehole is pumped at a controlled rate and water level is measured in one or more surrounding observation wells and optionally in the pumped well itself. The data obtained from pumping tests are used to estimate borehole performance and aquifer properties (Subramanian, 2017). In other words, pumping tests may be performed to determine the hydraulic characteristics of aquifers (aquifer tests) or to provide information about the yield and drawdown of a borehole (i.e. well or borehole tests). It is worth mentioning that the former requires observatory wells in addition to the test well, while the former does not require observatory wells.

Consequently, information about the borehole is gathered by measuring the static water level after the borehole is pumped at a maximum rate until the discharge rate attains a steady state. The drawdown in the borehole is the difference between the initial static water level before pumping and final water level after pumping at steady state. The specific capacity of the borehole/well is determined as discharge drawdown ratio. At steady state, the discharge from a borehole is termed the yield of the borehole (Balasubramanian, 2017; AQTESOLV, 2019 and Bruin and Hudson, 1961) Hence, possible information obtained from borehole tests are specific capacity and yield. As stated before, the borehole yields from basement complex might not be sustainable unless some strategic measures are put in place for effective management and operation of such borehole facilities.

Hence, this study aimed at investigating borehole yields in the basement complex area of Katsina, Katsina state, Nigeria, with a view to using the information gathered for sustainable management and operation of the boreholes so that the water needs of the community can be met.

2.0 MATERIALS AND METHODS

Study Area

The study area is situated in Batagarawa, Katsina, Katsina State, Nigeria. The coordinate of the boreholes investigated are shown in Table 1. Katsina State is known to be underlain by rocks of Basement Complex of pre-Cambrian age, the Katsina-Daura Sediments of Cretaceous age and the Chad formation of Quaternary age. The locations of the boreholes are shown in Figure 1 while the distances between the boreholes are shown in Figure 2

Borehole	Coordinate Longitude	Latitude
B1	12 52.675 N	007 33.547 E
B2	12 53.204 N	007 34.071 E
B3	12 52.753 N	007 33.405 E
B4	12 52.689 N	007 33.374 E
B5	12 52.655 N	007 33.490 E
B6	12 53.288 N	007 33.916 E
B7	12 52.630 N	007 35.024 E

The coordinates of the boreholes are located on a terrain underlain by rocks of Basement Complex of pre-Cambrian age.

Table 1: Coordinates of Boreholes drilled in Batagarawa Katsina State

Borehole	Coordinate Longitude	Latitude
B1	12 52.675 N	007 33.547 E
B2	12 53.204 N	007 34.071 E
B3	12 52.753 N	007 33.405 E
B4	12 52.689 N	007 33.374 E
B5	12 52.655 N	007 33.490 E
B6	12 53.288 N	007 33.916 E
B7	12 52.630 N	007 35.024 E

in which groundwater is generally available in small quantities from joints and fractures due to low permeability of crystalline rocks, as reflected

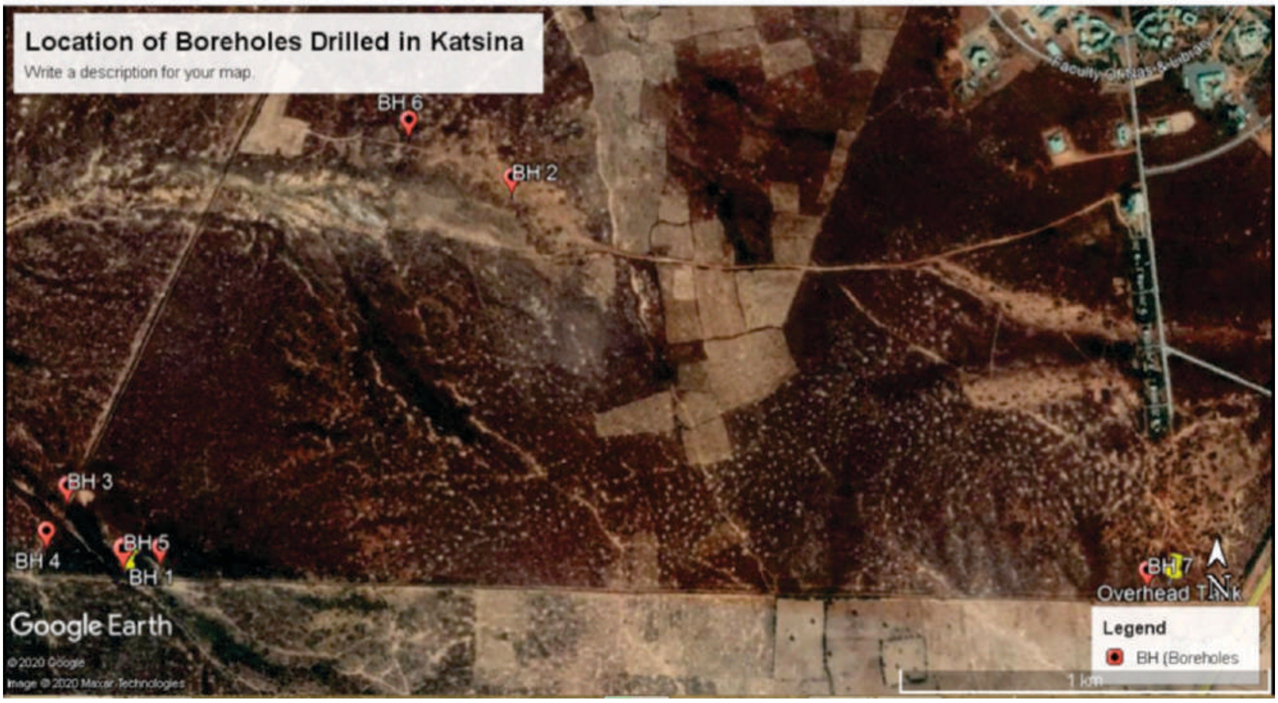

Figure 1: Imagery Locations of boreholes analysed for pumping test in Katsina, Katsina State

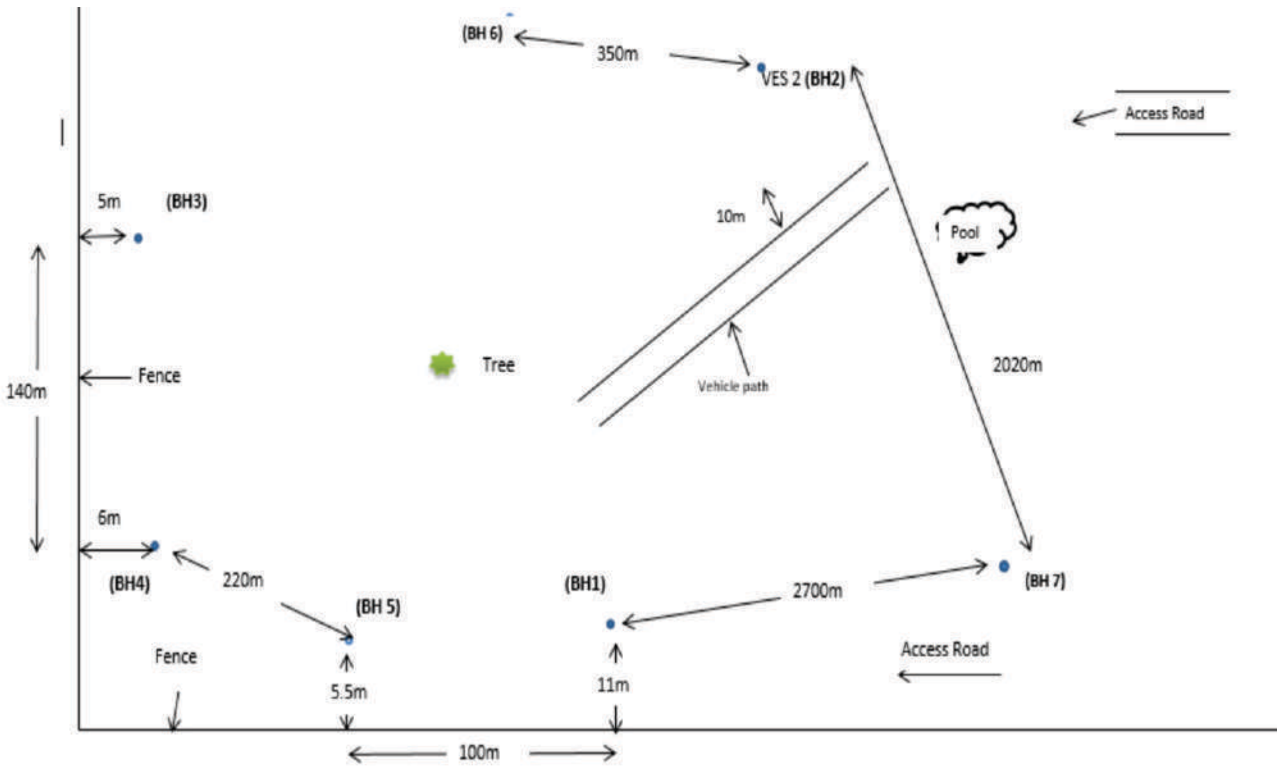

Figure 1:Distances of the boreholes from one another

in Figure 3. As shown in the figure, the basement complex is characterised with low yield of 0.85 l/s as compared to Katsina-Daura Sediments and Chad formation which have appreciable yield of 2.06 l/s and 3.26 l/s respectively, according to Agbede (1997).

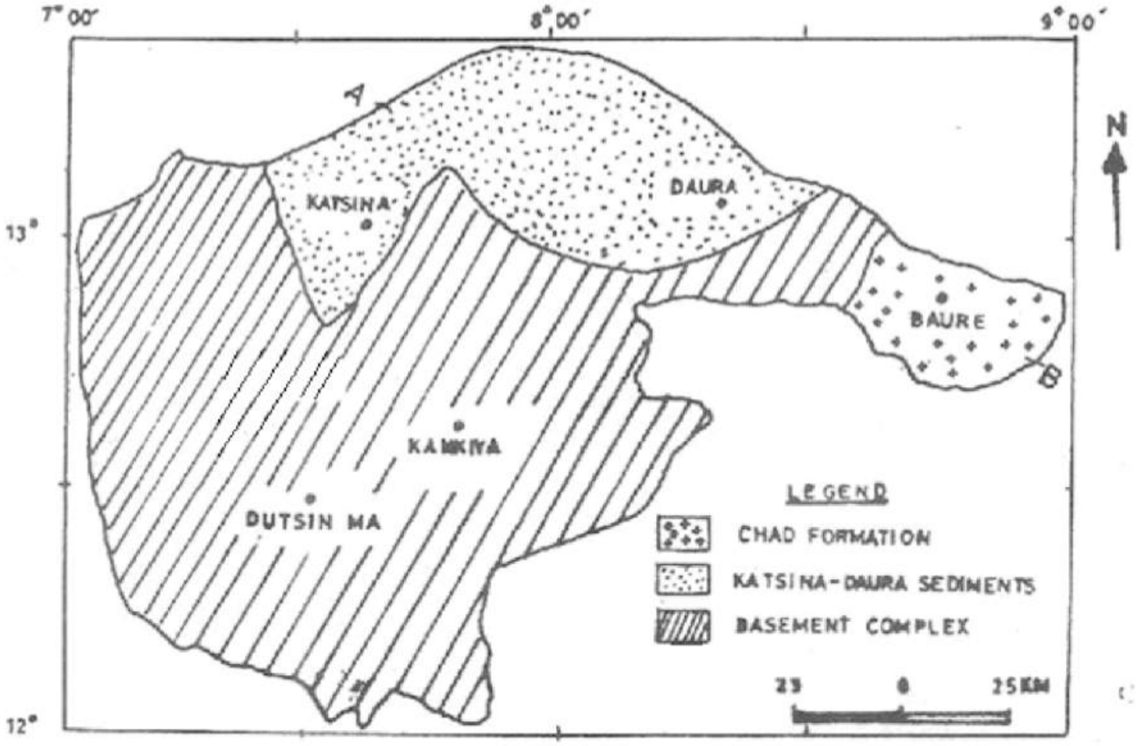

Figure 3:Geology map of Study Area (Source: Agbede, 1997;)

Materials

The equipment used to perform the test operation included:

- A submersible pump powered from a source
- Connected riser pipes inside the borehole and discharge pipes outside of the borehole
- V-notch weir
- Water level sounder
- One bucket for flow rate verification
- Stopwatch (for taking time intervals)

Pumping test

To carry out the pumping test, the submersible pump, 1.5 horsepower, was installed in each of the borehole by lowering the pump, with riser pipers attached, to the installation depth in each of the boreholes.

The test set up entailed connecting the discharge pipe to the riser pipes from the submersible pump in the borehole. The discharge pipe was placed such that it discharged into the first of the three compartments in the V-notch box as shown in Figure 2. The flow from the first compartment attained laminar state as it flowed into the third compartment before being discharged over the weir. The depth of flow at the weir was used to compute the discharge. The pumping continued for a period of time and the discharge was measured with respect to time after which the yield was obtained.

Figure 2: Pumping Test

3.0 RESULT AND DISCUSSION

The pumping test results for borehole (BH1) is presented in Figure 2 which showed a steady drawdown of 4.8 m in about 40 minutes of pumping and attained a steady state discharge of 1.4 l/s. This result implies that the borehole is of high yield. Besides, the short duration of steady drawdown reflected that a pump of higher capacity could be installed at Bh1

Long hours of pumping could not be achieved in the other boreholes because the yields were low and the pump used for the exercise was of higher capacity (1.5 horsepower). Consequently, pumping test of the other boreholes were done intermittently and the findings were reported in Table 2.

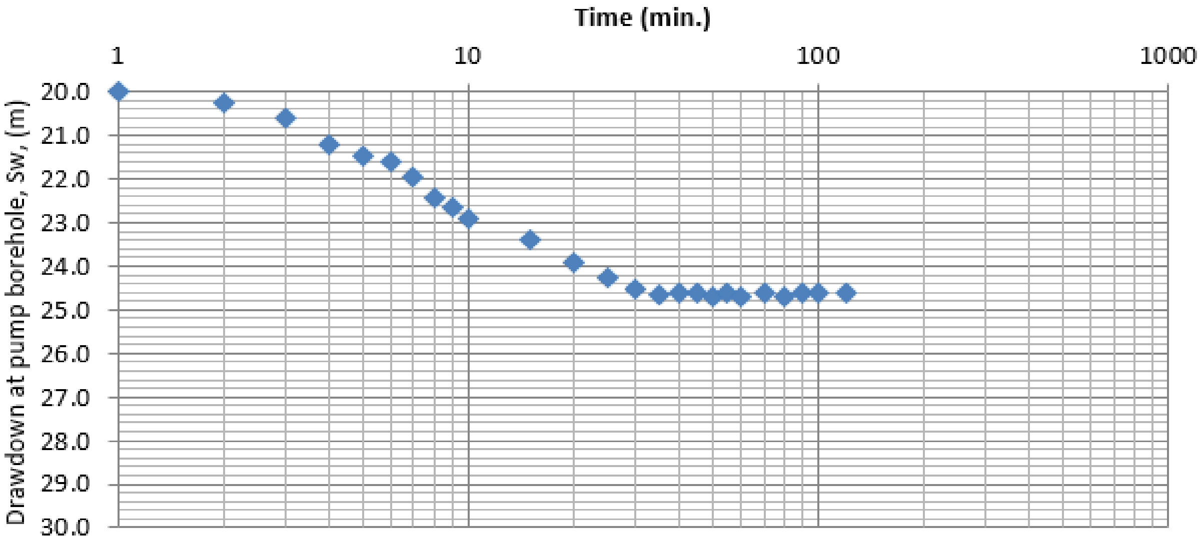

Figure 2: Drawdown at Borehole BH1

Table 2:Borehole Yields

Borehole No	BH Depth (m)	Surface Water Level (m)	Pump Installation Depth (m)	Length of pumping test (min)	Yield (l/s)	Comments
BH1	101	20	70	120	1.4	High yield
BH2	70	3	60	30 repeatedly after 5min interval	1.0	Moderate yield
BH3	90	17	70	7 repeatedly after 5min interval	0.96	Relatively moderate yield
BH4	60	27	55	7 repeatedly after 5min interval	0.93	Relatively moderate yield
BH5	85	30	80	7 repeatedly after 30min interval	0.42	Relatively low yield
BH6	90	Nil	N/A	N/A	N/A	N/A
BH7	85	32	80	120	0.42	Moderate yield

The low yields result in intermittent groundwater supply such that steady state could not be achieved and the boreholes (BH2, BH3, BH4, BH5 and BH7) were pumped repeatedly at interval of times to get assumed yield for the interval of pumping as presented in Table 2. Borehole BH 6 proved abortive out of the 7 boreholes assessed. Table 3 showed that borehole BH2 had an average yield of 1.0 l/s for 30 minutes of pumping while BH3 reflected an average yield of 0.96 l/s for 7 minutes pumping duration intermittently at a lag duration of 5 minutes each. The lowest yield was observed in borehole BH7 which reflected an average discharge of 0.42l/s in 7 minutes pumping duration and a lag time of 30 minute interval.
The intermittent supply was an indication that the water level in the borehole was below the inlet or suction level of the pump which meant that whole pump was not completely submerged in water, this is supposed to cool the pump because of the temperature generated by its coil.
Further operation of the pump in this condition could burn the coil and damage the pump. This implies that low yield boreholes that cannot discharge continuously should have a lag period of time to recharge before pumping resumes. The lag periods were determined by trials for a number of intermittent pumping and lag periods. A lag period of 5 minutes was observed for borehole BH2, BH3, BH4, while BH5 had a lag time of 30 minutes.

Gathering information on repeated pumping time and lag time for a low yield borehole is essential for effective management of such a borehole, in recommending pumping rate and designing or scheduling of pumping timer, as a component of the pump panel. Based on the findings, suitable pumps, depth of installation and pumping schedule were proposed for the boreholes so that the available groundwater could be tapped economically and reasonably. The recommendations based on these statistics and the expected yields for the boreholes are presented in Table 3. Table 3 showed that the expected yield from BH1 was 20,160 l/s in 4hr/day and the total expected yield from all the boreholes was 42.762 l/s; this indicated an additional 22,602 l/s yield from the low to moderately yield boreholes, which could have been neglected having adjudged the low boreholes as non-productive ones.

Table 3:Recommendations for Pumps Installation and Operation

Borehole No	Rec. Pump Installation Depth (m)	Rec. Pump (hp)	Daily Pumping Cycle (4hr) by the University	Rec. Pumping Rate (l/s)	Expected Yield (L) in 4hr/ day
BH1	50-70m	2	4	1.4	20,160
BH2	60m	0.5	4	0.5 (for every 40min pumping with 5min interval)	6,396
BH3	70m	0.75	4	0.38 (for every 30min pumping with 5min interval)	4,692
BH4	55	0.5	4	0.35 (for every 30min pumping with 5min interval)	4,322
BH5	65m	0.5	4	0.42 (for every 7min pumping with 30min interval)	1,144
BH6	-	-	4	-	-
BH7	65m	0.75	4	0.42	6,048
Total daily yield (L) (4hr cycle)					**42,762**

Low yield boreholes have been abandoned in the past because of lack of knowledge on how to schedule their pumping intermittently and automated using a timer as investigated and reported in this study.

4.0 CONCLUSIONS AND RECOMMENDATIONS

Seven boreholes were drilled in Batagarawa, Katsina State, and their yields were determined.. BH 1 showed very high yield, BH 2 and BH 7 reflected moderate yield, BH 3 and BH 4 indicated relatively moderate yield while BH 5 showed relatively low yield and only borehole BH6 proved abortive. A total yield of 42,762 litres/4 hr cycle is estimated from six of the boreholes. Recommendations were made on the installation of pumps and depth for each of the boreholes.

It is also recommended that 24 hour timers should be fixed for the boreholes to achieve the proposed pumping cycle 4 hours daily. 0.5 horsepower is recommended for BH 5 while 0.5 to 0.75 horsepower pumps are recommended for the other moderate yield boreholes to ensure that the boreholes are pumped as per recommended pumping schedule and 4 hour cycle on daily basis.

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