American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-4, Issue-8, pp-55-63
www.ajer.org
Research Paper Open Access

Exploitation of Groundwater in Fractured Basement of Ado-Ekiti, Nigeria

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ABSTRACT:*Groundwater is the most efficient resource for meeting water demand in the basement complex areas. Basement complexes worldwide shared common hydrogeological indicators and the situation in the entire Ado Ekiti is not like to be far from that of Afe Babalola University Ado-Ekiti, Ekiti State (ABUAD).This study examined groundwater exploitation in fractured basement of Ado Ekiti and environs. The scope was narrowed to groundwater supply and potential in ABUAD. Seventeen boreholes have been drilled in ABUAD and yet there is a seeming perennial water scarcity in the University. The data generated in this study could provide benchmarks to unravel the prevailing conditions on groundwater potential and exploitation in fractured basement in the whole of Ado Ekiti and environs. The study revealed that most appealing geologic sequence for good groundwater potential is overburden thickness of ≥ 25m and weathered/fractured basement having resistivity range between 20 - 100Ω-m with thickness ranging between 12 – 30m. Present daily water demand for ABUAD stands at 420,000litres/day and in a decade's time the daily projection is expected to be 934200liters/day. If the University is experiencing water scarcity, it means that all the boreholes put altogether is currently producing below 37% efficiency. The problem probably could be attributed to poor borehole completion operation, 'hanging borehole' and incomplete development. Pumping test is very vital for successful borehole completion and benchmark for future operation and maintenance. Efforts should be geared towards the redevelopment of all the boreholes in ABUAD to increase their efficiencies. Pumping test should be carried out to ascertain the true status of the remaining boreholes. Efforts should only be concentrated in areas designated to have good groundwater potential for new borehole schemes. As a long term measures and also to meet up with the decade's forecast on water demand, dam should be constructed for water supply and power generation.*

I. INTRODUCTION

1.1 Background of Study

Exploitation of groundwaterresources involves apart from the location ofsuitable source, the construction of properlydesigned wells. The design and the execution of water supplysystems and their maintenance is also an integralpart of the scheme of exploitation andmanagement. The common groundwater abstracting structures are dug wells and boreholes and are to be designed to get theoptimum quantity of water eco economically from a given geological formation.

Fractured basement complex are good sources for potable water in many part of the world. However, sitting of highly productive wells in these rock units remains a challenging and expensive task because fracture development at regional scale is both **heterogeneous** and **anisotropic (**Manda et al., 2006). Aquifers can be developed either in weathered overburden basement or fractured basement of crystalline rocks of intrusive and/or metamorphic origin which are mainly Precambrian age (Wright, 1992). Sustainable well yields for bedrock, therefore, may strongly depend on the quantity of water stored in materials that can break downwards into bedrock and on periodic replenishment by recharge (Lyford, 2004). The discontinuous nature of the basement aquifer systems makes detailed knowledge and application of geological, hydro-geological and geophysical investigations inevitable (Amudu et al, 2008). In Ado Ekiti or Ekiti State generally, groundwater is found in fractured basement complex as the State is underlain by Precambrian basement rocks. It is also stated that aquifer found in fractured basement in Ado Ekiti and its environs has relatively very low yield, (Gabriel et al, 2014).

1.2 Statement of the Problem

Perennial water scarcity in ABUAD calls for great concern in spite of untiring efforts of the management in providing not less 17 boreholes water sources. The study intends to unravel the root cause of the problem with a view of proffering the solution. EK-RUWASSA, 2014, reported failure rate in previously drilled boreholes in Ekiti State to be around 54%. Reasons advanced for this were probably due to lack of detailed hydrogeological and pre-drilling geophysical investigation or poor understanding of hydro-geological characteristics of the basement complex environment which could probably give rise to improper exploitation framework of groundwater in fractured basement.

1.3 Aim of Study

The aim of this research is to determine sustainable groundwater exploitation in fractured basement complex of Ado-Ekiti.

1.4 Objectives of Study

The specific objectives are:

(i) To re-appraise geophysical investigations carried out in all the boreholes in ABUAD.
(ii) To determine if the boreholes were drilled and constructed in accordance with the result of the investigation.
(iii) To determine aquifer characteristics, draw down, yield, specific capacity, recovery, efficiency of the borehole, pump sizing, etc.
(iv) To determine if all the boreholes in ABUAD put together can guarantee the expected water demands under a given pumping duration per day.
(v) To determine if the boreholes are sited in a way to avoid interference during pumping.
(vi) To determine the estimation of borehole efficiency or variation of in performance with a discharge rate;
(vii) Determine the measurement of transmissivity, storativity and hydraulic conductivity;

1.5 Justification of Study

It is hoped that this study would reveal the level of groundwater exploitation in fractured basement complex in Ado-Ekiti and highlight areas of concern. The research is also intended in a way to improve the analysis and decision support on groundwater exploitation in fractured basement complex in Ado-Ekiti. This research would undoubtedly be the most in-depth studies on the exploitation of groundwater in fractured basement complex in ABUAD in particular and Ado-Ekiti in general.

1.6Scope of Study.

In this study only boreholes data in Afe Babalola University, Ado Ekiti (ABUAD) will be considered in coming up with a generalized sustainable groundwater exploitation in fractured basement of Ado Ekiti. This phenomenon more or less calls for in-depth hydrogeological and geophysical studies to evaluate these conditions.

1.7 Study Area

Ado-Ekiti is located between latitude 7^{0}31 and 7^{0}491 north of the equator and longitude 5^{0}71 and 5^{0}71 east of the Greenwich Meridian. Afe Babalola University is located in Ado-Ekiti along Ijan road, opposite The Federal Polytechnics. The study college is located at the north-western part of the University campus opposite Alfa Belgore Hall and adjacent female hall of residence. It lies at longitudes 5°18'25.87"E and latitudes 7°36' 23.82"N. The terrain in the study area is gently undulating, with topographic elevation ranging from 350m to 370m above sea level. ABUADis located on 130 hectares at an altitude of 1,500ft above sea level which *ipso facto* provides a cool and ideal climate for learning, sporting activities and commercial agriculture (Oyegoke and Oyebode, 2014).

1.7.1Population and Demography of study area

Ado-Ekiti is inhabited by the Yoruba of South Western Nigeria.According to 2006 census the population is about 308,621 inhabitants (Ekiti State Government Portfolio);the increase has made people in the town to depend on sub-surfacewater to compliment the pipe borne water which is always neversufficient.

1.7.2Hydrogeology of Ado-Ekiti

The major surface waters in the study area are rivers Ogbese, Osun, Oni, Osse and Ero. Others are the small tributaries joining the major rivers. It has been observed that wells dug close to the river normally contained water at shallow depths Shemang, (1990). Within the weathered zone, discontinuous water table occurs and water level shows marked seasonal fluctuations Dan-Hassan (1993). As shown in plate 1, The highest groundwater yield in basement terrains is found in areas where thick overburden overlies fractured zones OlorunniwoandOlorunfemi (1987); Olorunfemi sand Fasuyi (1993).

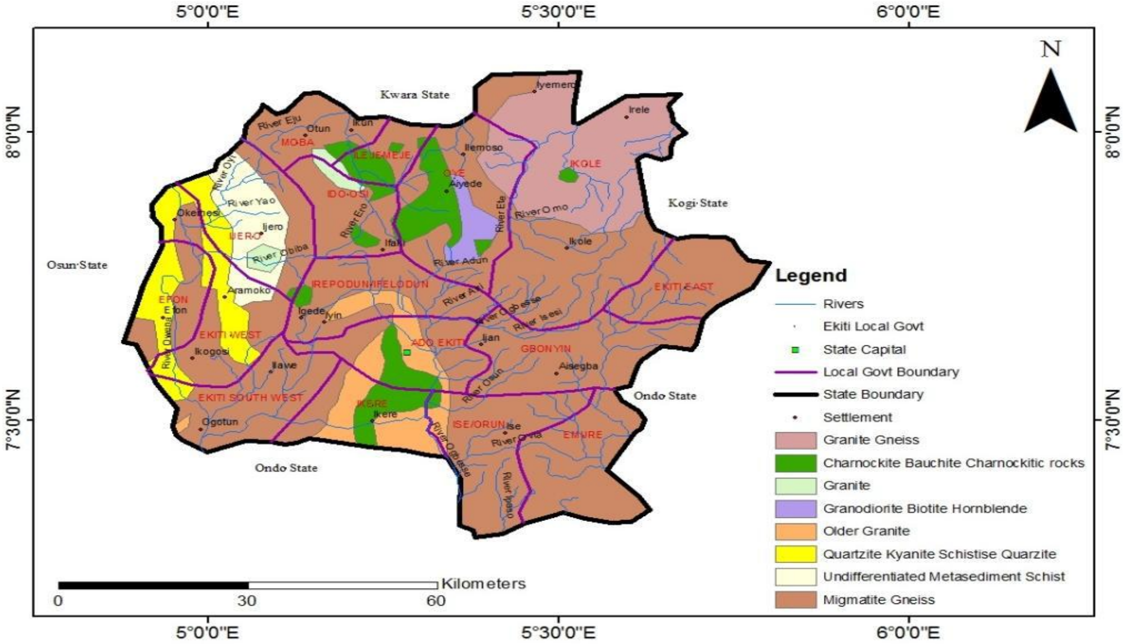

Plate 1: Hydrogeology of Ado-Ekiti

II. METHODOLOGY

The research methods adopted for the study against the backdrop of the research aim and objectives are Water demand determination, Reappraisal of Geophysical Survey, Pumping Test, Recovery Test, Constant Rate Test and Analysis.

2.1 Water Demand (WD) Determination

From the reviews it is observed that per capita and population method is favoured in developing countries like Nigeria in the computation of WD. NWSSP (2000) gives credence to this method hence this work will adopt the method in computing water demand for ABUAD.

In computing the water demand for ABUAD, it will be assumed that University falls within semi settlement and according to NWSSP (2000), water per capita for urban areas of Nigeria is put at 60litres. Under this method of per capita and population, it therefore means that water per capita (Wpc) value will be multiplied with the projected population (Pp) of ABUAD to forecast its water demand using the empirical equation below: $WD = Wpc \times Pp$

The result will thereafter be evaluated against the total water supply output of the University. The essence is to see if the total water supply output is more or less than the water demand of the University.

2.2 Reappraisal of Geophysical Survey

Under this method, the research adopted groundwater potential map compiled by Oladimeji et al (2013) to reappraise geophysical survey of boreholes in ABUAD. Seventy one survey stations were conducted across nooks and crannies of ABUAD. From the survey major electrolyteunits were delineated and it included overburden rocks (clayey lateritic rocks), weathered basement/fractured basement and fresh basement. Using Wright (1992) groundwater potential classification scheme, groundwater potential zones were classified. The scheme was used in reappraising the 17 boreholes in the University.

2.3Pumping Tests

Pumping test was conducted in four out of seventeen boreholes strategically located in the University and based groundwater potential zones. The whole idea was to have a benchmark of groundwater hydraulics in each zone for easy generalization and computation. Borehole in ABUAD Inn and that of Talent Discovery Centre were selected to represent boreholes in moderate groundwater potential zone while borehole at the back of College of Engineering and that of Old Staff Quarters were selected to represent that of poor groundwater potential zone. The borehole at the back of Female Hall of Residence 2 located within the good groundwater potential zone could not be selected because it was not productive at the time of the test.

2.3.1 Recovery Test

The primary aim of recovery test was used in evaluating borehole performance rather than the aquifer performance by measuring the borehole performance. From field experience and as a **"Rule of Thumb",** an inefficient well isthe onethatif the pump is shut off after one hour of pumping and 90% or more of the drawdown is recovered after five minutes, the well is concluded to be unacceptably inefficient.

2.3.2 Constant Rate Test and Analysis

The constant rate test provides data which can be interpreted by comparison with the behaviour of type aquifers. The intent of the test is:

- To assess the borehole performance;
- To obtain values of the aquifer transmissivity and storativity;
- To obtain that values that could be used to predict long-term aquifer and borehole performance; and
- To obtain the specific capacity of the borehole which give the basis for selecting pump size and pump size and pump setting for the borehole in long term production.

The analyses of the pumping test data will be based on information obtained from the pumped borehole itself since there will be no observation borehole.

The constant rate-pumping test will be conducted with a discharged rate. Some hydrological data parameters could be calculated from the field data so generated and analysed. Basic assumptions in computing well hydraulics derived from constant rate test include the following:

- The aquifer is semi to unconfined
- Thickness of the aquifer is about 12m minimum, that is 12 m will be used for the computation and analysis
- Length of screen is 12m
- Radius of screen is 0.0625m

2.4.2.1 Transmissivity:

Transmissivity (T) could be calculated from the general equation: $T = 0.183Q/\Delta Sw$

Where T= Transmissivity (m^2/d), Q= Discharge Rate (m^3/d), ΔSw = difference in drawdown during one log cycle; between 10m and 10m since pumping started which is the slope of time drawdown graph.

Table 1: Classification of Transmissivity

S/N	Magnitude	Class	Designation	Specific Capacity ($m^{2/}$day)	Groundwater Supply Potential	Expected Q if S=5m
1.	> 1000	I	Very high	> 864	Regional importance	> 4320
2	100-1000	II	High	86.4 – 864	Lesser regional Importance	432 – 4320
3	10-100	III	Intermediate	8.64 – 86.4	Local water Supply	43.2 – 432
4.	1-10	IV	Low	0.864 – 8.64	Private Consumption	4.32 – 43.2
5.	0.1-1	V	Very low	0.0864 – 0.864	Limited Consumption	0.423 – 4.32
6.	<0.1	VI	Imperceptible	< 0.0864	Very difficult to utilize for local water supply	< 0.432

Source: Driscoll, F.G (1986)

2.3.2.2 Storativity:

With no observation borehole, the storativity would be estimated through the coefficient of permeability (K) derived from BABUSKIN'S Equation: $K = (0.306Q/ls) \times (\log 1.321/r)$; Where; K – coefficient of permeability (m/d), Q – Discharge rate employed in test, l – Length of screen assumed to be equivalent to thickness of aquifer. S – Maximum drawdown at end of test, r – Radius of screen.

The BABUSKIN'S equation assumes stabilization of the dynamic water level (DWL) under unconfined condition and BEICINKI's equation relates specific yield and coefficient of permeability (K) through; u = 0.117 x 7√K where u = specific Yield ratio and K = coefficient of permeability (m/d). Under unconfined condition, specific yield is equivalent to storativity.

2.3.2.3 Specific Capacity:

Specific Capacity q = Q/s; q = specific capacity in m³/h/m, Q = Discharge Rate in m³/h, s = Drawdown at end of test in m

2.3.2.4 Entrance Velocity through Screens:

Entrance Velocity at envisaged pumping rate could be calculated from the general equation:
V = Q/πRLP; V= entrance velocity in m/s, Q = envisage discharge rate in m³/s, R= radius of screen, L = length of screen, P = percentage of opening in screen

2.3.2.5 Range of Cone of Depression:

The range of cone of depression for the pumping rate is calculated from SICHARDI'S formula: R = 10s x √K; R = Range of cone of depression, S = Maximum drawdown at stabilization, K = Permeability coefficient.The value of R will indicate whether the borehole within the field will have mutual interference during pumping activity.

III. DATA ANALYSIS AND DISCUSSION

This chapter focuses on the analysis of the data collected using the methods as described in chapter 3. Determination of water demand, borehole development, sitting of borehole and reappraisal of geophysical reports and pumping test in ABUAD will be analyzed and discussed.

3.1 Determination of Water Demand

3.1.1 Water Quantity Estimation

The daily water demand of as calculated based on per capita demand of NWSSP (2000) for ABUAD is420000 liters/day

3.1.2 Population Forecast of Water Demand

Using the arithmetical progression method of estimation is 934200 litres/day

3.2 Reappraisal of Geophysical Report andBorehole Construction

Table 2 showed geophysical report reappraisal of 17 boreholes in ABUAD in line with groundwater potential map parameters recommended byOladimeji et al (2013) adopted to have a firsthand knowledge of the probable production potential level of the boreholes. These parameters are thickness of overburden and weathered/fractured basement lithounits including resistivity of weathered/fractured basement.

Table 2: Analysis of Geophysical Report Based on Groundwater Potential Map of ABUAD

S/N	Name	UTM		OBT (m)	RWF (Ω-m)	WFT (m)	GP
		ETX	**NTY**				
1.	Back of College of Social &MgtSc	754896	841587	10 (Ltd groundwater potential	30 (Optimum aquifer potential)	11 (poor ground-water potential)	Poor groundwater potential
2	Left back of Coll. Soc. & Mgt. Sc.	754743	841525	16 (Ltd groundwater potential	55 (Optimum aquifer potential)	14 (Fair ground-water potential)	Moderate groundwater potential
3.	Back of MHS	754925	841525	14 (Ltd groundwater potential	45 (Optimum aquifer potential)	13 (Fair ground-water potential)	moderate groundwater potential
4.	Back of male Hall of	755142	841280	18 (Ltd groundwater potential	40 (Optimum aquifer	10 (poor ground-water	Poor groundwater potential

	Residence .				potential)	potential	
5.	Female Hall of Resc.1	755107	842264	10 (poor groundwater potential	16 (Ltd aquifer potential)	9 (poor ground-water potential	Poor groundwater potential
6.	Back of female hall of Resc. 2	754198	841652	22 (Ltd groundwater potential	75 (Optimum aquifer potential)	17 (Fair ground-water potential)	Good groundwater potential
7.	Female hall of Resc.	754958	84217	10 (Ltd groundwater potential	10 (Ltd aquifer potential)	6 (poor ground-water potential	Poor groundwater potential
8.	Local Kitchen	755355	841617	14 (Ltd groundwater potential)	15 (Ltd aquifer potential)	11 (poor ground-water potential)	Poor groundwater potential
9.	Front of Local Kitchen	754472	841617	10 (Ltd groundwater potential)	60 (Optimum aquifer potential)	13 (poor ground Water potential)	Slightly moderate groundwater potential)
10.	Laundry	755447	841744	14 (Ltd groundwater potential)	15 (Ltd aquifer potential)	10 (poor ground-water potential)	Poor groundwater potential
11.	Back of Water Plant	755538	841836	14 (Ltd groundwater potential)	20 (Ltd aquifer potential)	10 (poor ground-water potential)	Poor groundwater potential
12.	Old Staff Qtrs. (Front of BLK C)	755628	842206	12 (Ltd groundwater potential)	20 (Ltd aquifer potential)	10 (poor ground-water potential)	Poor groundwater potential
13.	Old Staff Qtrs. (Front of BLK E)	755189	842299	14(Ltd groundwater potential)	15 (Ltd aquifer potential)	10 (poor ground-water potential)	Poor groundwater potential
14.	Old Staff Qtrs. (Front of BLK F)	755658	843590	10 (Ltd groundwater potential)	10 (Ltd aquifer potential)	6 (poor ground-water potential)	Poor groundwater potential
15.	ABUAD INN	754008	841183	22 (Ltd groundwater potential)	Optimum aquifer potential	14 (Fair ground-water potential)	Moderate groundwater potential
16.	TDC	754008	841801	22 (Ltd groundwater potential)	60 (Optimum aquifer potential)	14 (Fair ground-water potential)	Moderate groundwater potential
17.	Back of Engr. BLK	754649	841801	14 (Ltd groundwater potential)	30 (Optimum ground-water potential	9 (poor ground-water potential)	Poor groundwater potential

Source: Oladimeji et al (2013)
Where NTY - Northing (Y-Axis), OBT - Overburden thickness, RWF - Resistivity of weathered/fractured layer, WFT - Weathered/fractured layer thickness, GP- Groundwater potential

3.3 Pumping Test

3.3.1 Recovery Test

The research project relied on the recovery test method, which is both time and cost effective, in arriving at a qualitative way of having first-hand information on the borehole efficiency and performance. Any well that is shut off after one hour of pumping and 90% or more recovery is achieved after five minutes is considered to be inefficiently unacceptable. Basically, well efficiency more or less serves as a monitoring tool in which future maintenance of the well could be predicated upon. All the boreholes in question recovered between 45 – 86% on or before the expiration of 5 minutes.

3.3.2 Constant Rate Pumping Test

Refer to appendices 1 – 4 showing graphical analysis of constant rate pumping test.

Table 3: Boreholes Hydraulic Parameters Summary

S/N	NAME	Q (m^3/d)	T(m^2/d)	K	S_O	q (m^2/d)	V (m/sec)	R (m)	Expected Q if S is 5m (m^3/d)
1.	Talent Discovery Centre	108	274.5	0.238	0.057	7.03	$2.7x10^{-3}$	74.93	35.15
2.	ABUAD INN	130	1321.67	1.1206	0.124	33.08	$3.2x10^{-3}$	41.60	165.4
3.	Back Of College of Engr.	64.08	488.61	0.286	0.063	8.454	$1.6x10^{-3}$	40.54	42.27
4.	Front Of Old Staff Quarters	48	109.8	0.153	0.046	4.50	$1.12x10^{-3}$	41.70	22.5

Source: Field Survey (Compiled from Appendices 1, 2, 3, 4, 5, 6a, 7a, 8a and 9a)

Where Q - Discharge Rate, T - Transmissivity, K – Permeability, S– Storativity, Q - Specific Capacity, V- Entrance Velocity, R - Radius of Depression

3.4 Discussion of Findings

The study aims at determining sustainable groundwater exploitation in weathered/fractured basement complex of Ado-Ekiti vis-a-vis ABUAD.

3.4.1 Water Demand

Water demand for the University as computed during the study stands at 42, 0000 litres/day (420m^3/day or 17.5m^3/hr) and 93, 4200 litres/day (934.2m^3/day or 38.93m^3/hr), water quantity estimation and population forecast of water demand methods respectively. The expected daily water production at 100% assumed installed capacity should be 1142.12m^3/day, which is 24hrs pumping. But at 60% operational efficiency, the expected daily output should be 685.3m^3day, which could be adequate to meet the present day water demand of the University. If the present daily consumption is not met, it probably implies that the functionality/operational efficiency of the water schemes is below 37% installed capacity.

3.4.2 Geophysical Survey and Borehole Construction

Findings revealed that lithological sequence of overburden, weathered basement and fractured basement identification is first step in groundwater exploitation in Ado Ekiti and environs. The second step is to establish whether resistivity and thickness of weathered/fractured basement in addition to the thickness of overburden unit. Resistivity range of 20 - 100Ω-m and thickness of 12m to 30m with overburden thickness of ≥ 25m are considered to have good groundwater potential but regrettably none of the boreholes located in ABUAD within this zone. What prevailed in most cases are the resistivity and thickness values of weathered/fractured basement meeting these conditions without overburden unit thickness of ≥ 25m.

Three boreholes are located in zone with moderate groundwater potential and the rest (14 in number) are located in poor groundwater potential zone. (Table 3) and pumping test result actually confirmed the groundwater potential classification scheme adopted as there was clear demarcation between the pumping rate of the three boreholes situated in moderate groundwater potential zone against those fourteen boreholes situated in the poor groundwater potential zone. Two boreholes situated in the moderate groundwater has a mean discharge rate of 119m^3/day whereas those boreholes (2) situated in poor groundwater potential zone had a mean discharge value of56.08m^3/day.

Very importantly, findings also revealed that construction design of a borehole can impact negatively on the yield of a borehole no matter how appealing the geophysical survey result of the groundwater potential can be as was seen in the significant difference in the performance level between the borehole at the back of College of Engineering and the one located in front of Old Staff Quarters, even though both of them shared to the same zone, poor groundwater potential zone. The borehole at the back of College of Engineering has relatively more promising hydraulic parameter than the one in front of Old Staff Quarters (Block F).

3.4.3 Pumping Test

Although all the boreholes could be accepted with certain measures of efficiency based on application of recovery tool but in terms of specific capacity tool, it is below acceptable standard. As mentioned earlier the specific capacity values in all the boreholes were not in tandem with transmissivity values proposed by Driscol, F.G. (1986). This simply an indication that development was incomplete and boreholes were likely not constructed according to standard best practices. In fact out of four boreholes pumping test was conducted only the borehole at the back of College of Engineering could be said to meet the minimum standard of borehole construction. The remaining three could be tagged in local parlance as **"Hanging Borehole"**

Transmissivity values of all the boreholes pump tested should guarantee adequate yield for industrial, municipal or irrigational purposes under Driscol, F.G (1986) classification scheme as all of the boreholes pump tested except the one in the front of Old Staff Quarters (Block F) had transmissivity values well above 124m^2/day, but the specific capacity of the boreholes would not guarantee this. Even the storativity values of the pump tested boreholes were within the acceptable range of 0.01 and 0.3. The entrance velocity values of the boreholes were within the laminar flow range and all the boreholes were located away from radius of depression of each borehole. The question is where the problem lies. The answer could still be traced to construction/development procedures adopted.

IV. CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

Sustainable groundwater exploitation is achievable in Ado Ekiti and ABUAD in particular if boreholes are located and constructed based on standard best practices. Lithological unit sequence needed for good groundwater yield and sitting of boreholes is overburden unit of thickness $\geq$ 25m and weathered/fractured basement with resistivity ranging from 20 - 100Ω-m and thickness between 12 -30m. More over hydraulic parameters gotten from the pump tested boreholes have revalidated the groundwater potential map of ABUAD proposed by Oladimeji et al (2013).

Judging from the number of boreholes and their assumed production level, the present daily water demand in ABUAD put at 420,000litres/day could be met even if the production level is put at 37% of installed capacity. The focus now should be on how the demand will be met in ten years time considering the fact that projected demand is put at 934,200litres/day. The lingering water scarcity in ABUAD could probably be largely due to the fact that most of the boreholes are functioning far below installed capacity. As noted that most of the boreholes have constructional problems

4.2 Recommendations

In view of the research questions answered coupled with the aim and objectives realized, there are needs for the following recommendations:

1) To improve the efficiency in boreholes in ABUAD, the boreholes need to be re-developed by surging and airlifting method until sand free nature is achieved. This should be done annually considering the manner the boreholes were constructed.
2) Pumping test should be carried out in the remaining boreholes to really confirm their functionality status. This should be planned during long vacation when student population is low because the process will require long time of borehole shut down.
3) Subsequence boreholes should be sited in zone earmarked for good groundwater potential and water piped to central reservoir for re-distribution to areas of needs.
4) National borehole completion format should be used in documenting completed borehole history to enable monitoring, operation and maintenance.

5) Finally, as a long term measures, there should be an urgent plan to dam the nearby river for both water supply and power generation.

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