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Borehole Drilling, Usage, Maintenance and Sustainability in Ado- Ekiti, Nigeria

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Abstract: *Boreholes are an effective way of tapping into the water bearing aquifer below the ground and pumping the water to the surface. Boreholes for extracting water consist essentially of a vertically drilled shaft, a strong lining (casing) to prevent collapse of the walls, which includes a means of allowing clean water to enter the borehole space (screen), surface protection, and a means of extracting water. This study examines the common drilling techniques, usage, maintenance and sustainability of water boreholes in Ado-Ekiti. Pumping tests were carried on several boreholes in Ado-Ekiti to acquire a general idea of the yield of boreholes in order to proffer viable solution. Hydro geological maps of the area are studied to help in the understanding of the sub surface formation of the region. Questionnaires were also developed and administered in the assessment of borehole usage and maintenance. The study area is characterized by crystalline basement complex rock of low porosity and permeability. Boreholes have to be properly designed, professionally constructed and carefully drilled. It has been discovered that the area generally has low groundwater potential and that there is a high dependence on groundwater as a source for potable water.*

I. Introduction

With rising utility costs and water bills, installing a borehole is fast becoming a viable way to obtain 'cheaper' water for many people. Depending on water usage, boreholes are capable of generating a rapid investment payback, often cutting costs by up to 80% over a metered mains supply. A borehole is basically a narrow vertical shaft bored in the ground. A borehole may be constructed for many different purposes, including the extraction of water or other liquids such as natural petroleum or gases such as natural gas. This brings us to the aim of this study, which is to analyse borehole drilling techniques, borehole maintenance, problems encountered while drilling, borehole usage and sustainability in ado Ekiti. The exploitation of ground water is a complicated process which involves sinking a narrow shaft into the ground to reach the aquifer by using a drilling rig. Failure is sometimes experienced when carrying out borehole drilling operations or when using installed borehole systems. These failures are caused by several complications which may arise from poor maintenance and rehabilitation of boreholes, lack of expertise poor choice of technology, and poor supervision of the drilling project In order to prevent these complications, the following measures must be taken: proper maintenance and rehabilitation of bore hole, proper pump installation and maintenance, proper supervision of borehole projects, the use of appropriate drilling technology and the standardization of borehole design and drilling process. Water is a regional resource and it is not always readily available. This has led to shortage of potable water in some parts of the world. Water shortage is becoming a global issue due to increasing population, economic growth and climate change. Development of new sources of new water sources together with conservation measures should be an important component of any country's national water plan.

The construction of a well, using manual and mechanical drilling techniques is a complicated process. Before drilling starts a good drilling site has to be selected, where experience suggests that there will be an adequate quantity of good quality groundwater. During the drilling process there are a lot of different aspects which require attention to prevent things from going wrong. Besides the practical drilling skills which are executed at ground level, at the same time attention has to be paid to important processes which are happening below ground level during drilling. Water used in drilling (working water) could flow away or worse; the borehole could collapse, burying part of the drilling equipment. And finally, once the hole has been drilled, the well casing, screen and sanitary seals have to be installed at the right depth, preventing contaminated water from entering, and ensuring a sufficient yield. In many countries manual drilling teams experience problems with site selection, loss of working water, soil determination, logging, well installation, well development, water quality and well yield (flow rate of the well). These problems may occur when the drilling process is not completely understood and important steps are missed. Figure 1and 2 shows the map and Hydro geological map of Ekiti state. With the information provided we will be able to understand what takes place beneath the surface during drilling. This will enable us to construct high quality water wells.

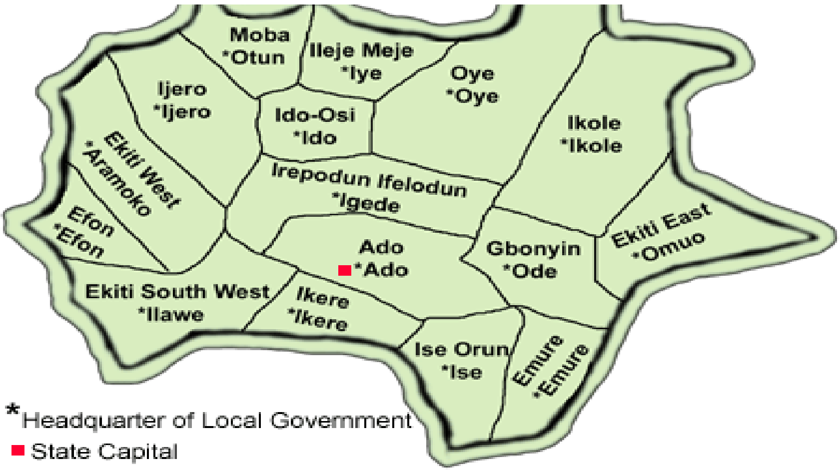

Figure 1: Map of Ekiti State

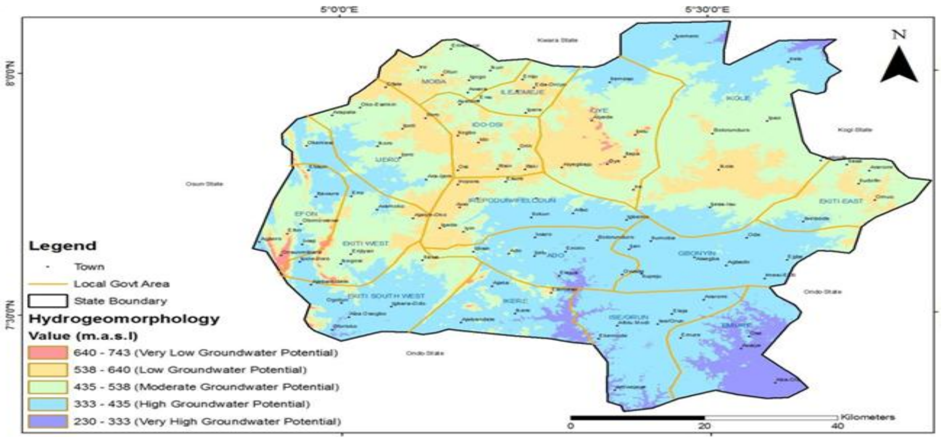

Figure 2: Hydro geological map of Ekiti state

II. Methodology

Project activities

Table 1: Project activities

S/N	Work done	Contribution to knowledge
1.	Development of questionnaire	To evaluate the usage and maintenance of boreholes in ado Ekiti
2.	Survey of the population of ado Ekiti	To determine water demand of ado Ekiti
3.	Conduct pumping tests on various boreholes in the study area	To determine the rate of discharge, rate of recharge, transmissivity, storativity and permeability of the aquifer.
4.	Study geophysical investigations carried out on the groundwater potential of ado Ekiti	This will enable me have a better understanding of the characteristics of the sub surface layers beneath the study area.
5.	Observe and help in the planning and construction of boreholes in ado Ekiti	This will help me acquire information on the common drilling methods used and problems encountered before, during and after the drilling of boreholes.

2.1 Population of area

The population of Ado-Ekiti has increased tremendously in the last decade. This is due to its new status of being the capital of Ekiti-State, carved out of the old Ondo State in 1996. As a result of this, there has also been corresponding increase in demand for potable water by the inhabitants for both domestic and industrial usages. However, public water supply has been inadequate in spite of efforts of government and the water corporation. The shortfall in water demand has been partly met by groundwater development through hand dug wells, springs and the available boreholes. According to Ekiti State Rural Water Supply and Sanitation Agency, the failure rate in the previously drilled boreholes in the State is around 54%. This is probably due to lack of detailed hydro geological and pre-drilling geophysical investigation or poor understanding of the hydro geological characteristics of the Basement complex environment. The study area is underlain by Precambrian basement complex rocks. These rocks are characterized by low porosity and near negligible permeability. The highest groundwater yield in basement terrains is found in areas where thick overburden overlies fractured zones. These zones are often characterized by relatively low resistivity values. (Olorunfemi and Fasuyi, 1993).

2.2 Cost analysis for a borehole

The cost of a borehole is largely dependent upon the depth and amount of casing that the borehole will require. Geology (the type of rock formations) that has to be drill through does have some influence as do the actual ground conditions. Many people expect the easiest drilling to be into soft and loose geologies; however the opposite is generally true. One of the main difficulties with drilling is keeping the borehole open during the drilling process; this is made more difficult if the hole is collapsing owing to the ground being loose and unstable. Many methods could be employed to prevent this from happening, including the use of drilling additives and fluids and the installation of temporary steel casing. All these factors affect the cost of a borehole.

Cost of mobilization to and from site: This is the cost of getting all drilling equipment from the storage yard to home or site of the client. The cost is usually depends on whether the equipment is wheeled or tracked and on the distance travelled to reach the site.

Cost of drilling: The cost for drilling is determined per meter for different diameters. The borehole usually starts at a larger diameter of about 203mm and this is drilled into the solid rock to allow for the casing to be installed through the soft upper portions and prevent collapse. The bore is then continued at a diameter of165mm through the solid rock to the target depth or the saturated region. Most rock types are drilled at the same rate, however quartzite which is very abrasive is charged at a higher price because it wears the drill bit down quickly. Typical costs for drilling in ado-Ekiti are between N5, 000–N8, 000 per meter.

Cost for casing and gravel packing of borehole: This is the cost per meter for the supply and installation of casing. Most boreholes only require steel casing through the soft weathered overburden (12-24m) to secure the upper parts of the borehole from collapse, however some boreholes are drilled into highly weathered rock which extends a lot deeper down than usual. These types of boreholes require the installation of screens and casing from surface to the end of the hole. We use PVC casing and screens in these. A gravel filter pack is placed around the outside of the screens to keep sand out of the well and allow the water through. Typically costs for casing are around N7, 000 per meter for PVC casing and screens.

Cost of installation of well head: The well head is installed over the head of the borehole to allow access to the borehole and protect it from contamination. The well head should be made of reinforced concrete so as to withstand load. The cost of installation is around N22,000.

Cost of developing and flushing of the borehole: Developing and flushing of borehole is one of the most important procedures undertaken once the borehole has been drilled. This procedure helps remove rock fragments which could get caught up in the aquifer cracks and thereby blocking water from entering the borehole. All boreholes that reach water should be developed until they are sand free. The cost of developing a borehole is around N25, 000.

Cost of cleaning up the site: Borehole drilling can be messy. All the soil, mud and rock fragments which come out of the hole accumulate on the surface making a huge mess. The drill cuttings should be cleaned up and taken away from the site. The final clean up happens when the rig moves off the borehole. Cleaning of the site is usually the obligation of the drillers.

Water analysis: If the water is to be used in the home then it recommended that a potable water analysis of the borehole be undertaken by a registered water lab. It is important that the water sample be taken after some time of pumping and that the sample gets to the lab and is analysed for pathogens within 6 hours of sampling. This test costs about N65, 000.

Cost of pumping system: The cost for the supply, installation and commissioning of a pumping system largely depends on the depth of the borehole, piping, amount of water to be pumped and the pressure requirements of the system. Typical costs for an average home water supply pump range from N850, 000 – 1,085,000.

Table 2: Cost Analysis for a Borehole

S/N	TASKS	COST
1.	mobilization to and from site	Depends on distance
2.	Drilling operation	N5, 000 to 8, 000 per meter
3.	installation casing and gravel packing of borehole	About N7, 000 per meter
4.	installation of well head	About N22,000
5.	Developing and flushing of the borehole	About N25,000
6.	Cleaning up of site	Depends on the volume of materials removed from well
7.	Water analysis	Around N65,000
8.	Supply, installation and commissioning of pumping system	N850,000 – N1,085,000
9.	Payment for service (workmanship)	Depends on negotiation between client and company

2.3 Site investigation

In order to carry out this project successfully, Investigations were carried out on five boreholes in the following regions of Ado Ekiti; Ado Ekiti North, Ado Ekiti South, Ado Ekiti West, Ado Ekiti East and Ado Ekiti Central. The geophysical survey was carried out on the borehole construction site beside Afe Babalola University, Ado-Ekiti in order to determine the ground water potential of the area. The method used in geophysical survey for the proposed water boreholes was the electrical resistivity sounding. The electrical resistivity sounding method is the most common method used to carry out geophysical surveys in the state.

The site selection strategy is to maximize the probability of successfully completing the borehole, at a site with favorable geological, hydro geological, and geochemical conditions, within budgetary and schedule constraints.

Site Description

The survey site is Afe Babalola secondary school proposed site ado-Ekiti. There are no structures on the site. The compound is well fenced and the topography is relatively level. The area is characterized by short dry season and long wet season and has high rainfall of about 160mm and peak rainfall between August and September. The area has high temperature ranging between with relatively high humidity during the wet season and low humidity during the dry season.

The area is characterized by dense ever green forest. The basement complex rocks are crystalline rocks of low porosity and permeability. In this geologic environment groundwater accumulation depends on:

1. Degree of weathering and thickness of the overburden
2. Degree and nature of fracturing of the rocks
3. The presence and absence of clays above the weathered zone and its effect on rate of infiltration of water into the aquifer
4. The hydrological continuity (permeability) of the weathered zone.

Source of recharge in the area include stream and precipitation, cracks, fractures bedrock depression and weathered basement. The sources of recharge mentioned above are the geologic subsurface structure in basement terrain that can favour groundwater accumulation. Porosity, permeability and transmissivity are the parameters of an aquifer. A good aquifer must have high porosity, high permeability and transmissivity.

Electrical resistivity soundings

The electrical resistivity test was started by putting two iron pins (called 'current electrodes') into the ground.

1. The current electrodes were then subjected to electricity. The electricity flows through the ground from one current electrode to the other, in a half circle (see below).
2. The resistance that the electricity finds on its way is measured by two other electrodes, the 'potential electrodes'. The resistance depends on the distance between the two current electrodes, the soil formation through which the current flows and the humidity in this formation.
3. The electrical Resistivity sounding is used to determine the resistivity at different depths in the underground.
4. The current electrodes are placed each time further apart from each other in the ground and each time the resistance is measured. The further the current electrodes are placed apart, the deeper the electricity flow will reach. This way of working is often used when a suitable location for one borehole needs to be determined.

5. In case information is required over a larger area of which the approximate depth of the aquifer is known, electrical resistivity soundings are done at different points, each time at the same depth. In that way the resistivity is measured at a certain depth at different locations in an area. This is done by having for each measurement a fixed distance between the current electrodes while repeating the measurements along a number of traverses over an area in a grid pattern.
6. The outcome will make it possible to plot the resistivity values on a map, indicating zones of high and low resistivity (meaning zones of different groundwater potential) at a certain depth in the underground.
7. All the information obtained is entered into a computer that analyses the measurements with special software.

The idea is that if there is water underground the electricity will flow more easily through it because the resistance in wet ground against a flow of electricity is lower than such resistance in dry ground. Therefore the computer can predict based on the measurements where water will probably be. However, good skills are required to interpret the outcome of the computer program. The resistance measured also depends on the type of soil, which makes it difficult to interpret the outcome properly. In other words, the software cannot tell you just like that whether there is water in the underground formation and how deep it is. It requires someone who knows how to interpret the outcome of the computer analysis to predict this by analysing the outcome of the computer program along with knowledge about the soil and soil layers in the underground formation, information about other boreholes in the area.

2.4 Causes of Borehole Failures

According to Ekiti State Rural Water Supply and Sanitation Agency, the failure rate in the previously drilled boreholes in the State is around 54%. This is probably due to lack of detailed hydro geological and pre-drilling geophysical investigation or poor understanding of the hydro geological characteristics of the Basement complex environment. Borehole failure is defined as a situation when a borehole which was recorded as successful, or productive immediately after drilling, subsequently fails to deliver a sufficient yield of safe as follows:

- Drilling of crooked boreholes which affect installation of casing, screens and pumps
- Poor collection of samples, and essential data like penetration rate log, lithological log during drilling operation. This can lead to poor design and subsequently well failure.
- Use of drilling fluid in such proportion that will lead to sealing of the intake portion of the well with mud cake or cause excessive mud invasion into the aquifer system
- Use of substandard casings and screens in an attempt to save cost. This can result into causing an incursion of soil or formational materials into the well
- Use of inappropriate gravel packs materials like rock chippings
- Lack of placement of sanitary seal or grout.

  Borehole failure is defined as a situation when a borehole which was recorded as successful, or productive immediately after drilling, subsequently fails to deliver a sufficient yield of safe water throughout the year. Problems associated with water well drilling result from many causes including equipment failure, depletion of the aquifer, corrosive qualities of the water and improper welldesign and construction.

3.0 Borehole drilling

Once the water requirements are known and an assessment either by a hydrogeologist or an examination of geological maps has been undertaken, the borehole can be drilled according to the information found. Typically, a borehole used as a water well is completed by installing a vertical pipe (casing) and well screen to keep the borehole from caving in. Drilled wells are typically created using either top-head rotary style, table rotary, or cable tool drilling machines, all of which use drilling stems that are turned to create a cutting action in the formation, hence the term 'drilling'. Boreholes can vary in depth and design depending upon the level of the water table, quantity of water stored in the ground and the requirements of the customer but typically are between 60-120 vertical metres. Normally the inner pipe is at least 4" in diameter to accommodate a 3” or 4” borehole pump and must be surrounded by gravel to prevent dirt clogging up the plastic pipe then sealed near the surface using a special grout. This grout usually goes down as far as the impermeable layer and is designed to prevent contamination from surface water entering the borehole. The outer metal casing pipe is usually at least 6" diameter to accommodate all this.

Figure 3: Typical borehole drilling showing water flow

Ado Ekiti east (Afe Babalola university talent discovery centre)Boreholes 1

S/N	Depth (m)	Lithology
1.	0.00 – 1.00	Rusty red lateritic sand, coarse
2.	1.00 – 2.00	Rusty red lateritic gravel
3.	2.00 – 3.00	Rusty lateritic mud, coarse sand, gravel
4.	3.00 – 4.00	Mud greyish brown, gravel
5.	4.00 – 6.00	Light greyish brown weathered base complex
6.	6.00 – 8.00	Greyish granite base complex
7.	8.00 – 35.00	Dark- grey – greenish horn blends
8.	35.00 – 40.00	Dark grey mica schist – gneissic basement complex
9.	40.00 – 46.00	Dark grey granite basement complex
10.	46.00 – 50.00	Dark grey granite basement complex
11.	50.00 – 70.00	Dark grey mica schist

Ado Ekiti north (EKSU campus)Borehole

S/N	DEPTH (m)	LITHOLOGY
1.	0.00 – 6.00	Weathered basement
2.	6.00 – 89.00	Fresh fractured basement

Ado Ekiti west (better life) borehole

S/N	DEPTH (m)	LITHOLOGY
1.	0.00 – 3.50	Top soil
2.	3.50 – 70.00	Granite basement

Ado Ekiti central (Christ school) Borehole

S/N	DEPTH (m)	LITHOLOGY
1.	0.00 – 1.00	Rusty yellow mud, very coarse sand
2.	1.00 – 4.00	Yellowish grey micaceous coarse sand
3.	4.00 – 6.00	Grey micaceous, very coarse sand gravel
4.	6.00 – 9.00	White – yellow, large gravel, very coarse
5.	9.00 – 11.00	Shale dark grey, whitish gravel, sand
6.	11.00 – 12.00	Sand brown coarse, gravel silty shale
7.	12.00 – 14.00	Dark grey, grey silty sand, gravel
8.	14.00 – 17.00	Grey granitic base complex
9.	17.00 – 20.00	Grey gneissic base complex
10.	20.00 – 27.00	Greyish – black micascist base
11.	27.00 – 56.00	Black – grey hornblende / micashist
12.	56.00 – 68.00	Black – grey hornblende / micashist base complex

Ado Ekiti south (Mary Assumption Hospital) Borehole

S/N	DEPTH (m)	LITHOLOGY
1.	0.00 – 1.00	Dark brownish top sandy soil, fine grain
2.	1.00 – 2.00	Poorly sorted, angular, brownish coarse grained sand
3.	2.00 – 7.00	Moderately sorted fine to medium grained, yellowish to brownish sand, light brown lay.
4.	7.00 – 8.00	Light brown clay
5.	8.00 – 9.00	Moderate well sorted light gneissic base complex.

III. TESTING, RESULTS AND DISCUSSION OF RESULTS

Total water demand for Ekiti state
Assuming water requirement/head/day = 100liters
Total population of state from table = 2,384,212
Total water demand = total population × water requirement/head/day
=2,384,212 × 100liters
=238,421,200liters/day
=238,421.2 m^3/day

Total water demand for ado Ekiti
Assuming water requirement/head/day = 100liters
Total population of Ado Ekiti from table = 308,621
Total water demand = total population × water requirement/head/day
=308,621× 100liters
=30,862,100liters/day
=30,862.1 m^3/day

Pump test analysis
The purpose of the following pump test analysis is to determine the aquifer characteristics for various boreholes in ado Ekiti thereby assessing the viability and possible use of groundwater in conjunction with supply based on the assumptions of pumping tests (Kruseman and ridder, 1970)

Assumptions
1. Flow into well is radial and there are no entrance losses
2. Instantaneous release of water from storage upon lowering of the draw-down curve (no lag) when pumping.
3. There is no seepage or leakage from or to the aquifer
4. Prior to pumping the piezometric surface is horizontal
5. There is complete penetration of the aquifer by well.
6. Aquifer is homogenous, isotropic, uniform and of infinite areal extent.
7. Well radius is infinitesimal and pumping rate is constant.

The determination of the following parameters below indicates the viability of the aquifer and their pumping.
T= transmissivity (ability of aquifer to permit groundwater)
S_c= storage coefficient (storage capacity of the aquifer)
E = well efficiency
S_p= specific capacity of borehole or well.

II Methodof Analysis
Almost all the aquifers investigated in the study area behave as confined aquifer in which water is present in weathered portions of the basement crystalline complex and the flows fit the non-steady state conditions.
The possible methods of analysis are
1. Theis recovery method
2. Jacob's approximate method
3. Brereton step drawdown pumping test method
4. Eden and hazel method

Equation of drawdown
$S=\frac{Q}{4\pi T}.W(u)$
Brereton's method, based on equal time duration in the steps in pumping, is similar to lewis clark's explanation for computing the total drawdown in step drawdown step tests.
$S_m = a(Q_m logbt + D_m) + CQ^2$...................... (i) Brereton's equation
$S_{wt} = (a + blogt)QLCQ^2$ .... (ii) Lewis Clark's equation
Where

$W(u)$= well function with $u=\frac{r^2 s}{4Tt}$
a = Aquifer coefficient = $\frac{2.30}{4\pi T}$
b = Aquifer coefficient = $\frac{2.25T_t}{rw^2 Sc}$
e = Well loss coefficient
$Q_{m=}$ Pumping rate at the n^{th} step
S_{wt} = Drawdown at start time t
S_m = Drawdown at the end of the n^{th} step

$$D_m = (Q_m - 1log2 + Q_m - 2log\frac{3}{2} + Q_1 log\frac{m}{m-1})$$

The two equations are best suited for short duration step pumping say 90mins each (Brereton1979) and show no immediate movement towards steady state or equilibrium. In any case, they require more than three steps for their effective use.
The recommended and modified theis recovery method is suitable for the state's aquifer analysis. Transmissivity is calculated as
$T = \frac{2.3Q_{av}}{4\pi\Delta s}$ .... (iii)
The maximum storage coefficient of the aquifer is calculated from eden and hazel's expression for the drawdown in a confined aquifer using the step method.
$st = \frac{2.3Q_{av}}{4\pi T}.log_{10}\frac{2.25Tt}{rw^2 Sc}$ … … ...... (v)

Borehole characteristics in ado Ekiti

Well location	Theis (modified)	Logan	Max yield m^3/day	Storage coefficient
Ado ekiti	0.84	1.8	115	4.7×10^{-2}
Ado Ekiti east	4.5	4.1	129.6	2.5×10^{-4}
Ado Ekiti west	3.8	4.8	260	1.6×10^{-2}
Ado central	1.9	1.4	320	2.5×10^{-6}
Ado south	35.7	10.0	288.5	5.2×10^{-10}

Ado Ekiti borehole characteristics (Watson,1999)

Pumping tests
LOCATION: Ado Central (Christ school)
DEPTH OF WELL: 68.00M
WELL DIAMETER: 120mm

Time since pumping stopped. t^l (minutes)	Time since pumping started. $t = t^l + 4320$	$\frac{t}{t^l}$	Residual drawdown S (meters)
1	4321	4321	17.80
2	4322	2161	15.11
5	4325	1442	13.32
10	4330	433	11.62
20	4340	217	10.33
50	4370	87.7	9.35
100	4420	44.2	8.78
200	4520	22.6	8.34
400	4720	11.8	7.72
800	5120	6.40	7.42
1000	5320	5.32	6.58
1200	5520	4.60	6.23

$$TransmissivityT = \frac{2.3}{4\pi\Delta s} = \frac{2.3\times20.75}{4\pi(2)} = 3m^3/day$$

$$S_t = \frac{2.3}{4\pi T}log\frac{2.25T_t}{r_w s_c}$$

$$17.8 = \frac{2.3 \times 20.75}{4\pi \times 1.9} log \frac{2.25 \times 1.9 \times 3}{0.08^2 Sc}$$

$storagecapacityS_c = 2.5 \times 10^{-6}$
Comment: values of $Transmissivityt$ and $storagecapacityS_c$ indicate poor quality of aquifer
Comment: values of T and S_c indicate poor quality of aquifer.

LOCATION: ado Ekiti south (Mary assumption hospital)
DEPTH OF WELL: 43.00M **WELL DIAMETER:** 120mm

Time since pumping stopped. t^I (minutes)	Time since pumping started. $t = t^I + 4320$	$\frac{t}{t^I}$	Residual drawdown S (meters)
1	4321	4321	25.87
2	4322	2161	25.06
5	4325	1442	24.44
10	4330	433	22.59
20	4310	217	21.08
50	4370	87.7	18.71
100	4420	44.2	16.60
200	4520	22.6	13.17
400	4720	11.8	8.05
800	5120	6.40	6.43
1000	5320	5.32	4.56
1200	5520	4.60	4.01

$TransmissivityT = \frac{2.3}{4\pi\Delta s} = \frac{2.3 \times 92.2}{4\pi(3.75)} = 4.5\ m^3/day$

$$S_t = \frac{2.3}{4\pi T} log \frac{2.25 T_t}{r_w s_c}$$

$$17.8 = \frac{2.3 \times 92.2}{4\pi \times 4.5} log \frac{2.25 \times 4.5 \times 2}{0.08^2 Sc}$$

$S_c = 2.5 \times 10^{-4}$
Comment: S_c value is too low. Pumping rate is believed to be excessive for this type of aquifer.

LOCATION: Ado West (Better Life)
DEPTH OF WELL: 70.00m
WELL DIAMETER: 115mm

Time since pumping stopped. t^I (minutes)	Time since pumping started. $t = t^I + 4320$	$\frac{t}{t^I}$	Residual drawdown S (meters)
1	4321	4321	37.87
2	4322	2161	36.73
5	4325	1442	33.41
10	4330	433	29.32
20	4340	217	25.56
50	4370	87.7	23.65
100	4420	44.2	21.42
200	4520	22.6	18.07
400	4720	11.8	13.77
800	5120	6.4	8.75
1000	5320	5.32	7.45
1200	5520	4.6	6.43

$$T = \frac{2.3}{4\pi\Delta s} = \frac{2.3 \times 154.1}{4\pi(7.5)} = 3.8\ m^3/day$$

$$S_t = \frac{2.3}{4\pi T} log \frac{2.25 T_t}{r_w s_c}$$

$$17.8 = \frac{2.3 \times 154.1}{4\pi \times 4.5} log \frac{2.25 \times 3.8 \times 3}{0.08^2 Sc}$$

$$S_c = 1.6 \times 10^{-2}$$

LOCATION: Ado East (Afe Babalola university talent discovery)
DEPTH OF WELL: 70.00M
WELL DIAMETER: 125mm

RECOVERY TIME (ELAPSED TIME IN MINUTES)	RECOVERY WL READING FROM TOC (M)	RECOVERY WL (M)	DRAWDOWN OR RESIDUAL (M)	PUMPING RATE/DISCHARGE (M^3/Hr)	
0	27.03	26.12	15.36		
0.5	25.99	25.08	14.32		
1	25.33	24.42	13.66		
1.5	24.81	23.90	13.14		
2	24.63	23.72	12.96		
2.5	24.54	23.63	12.84		
3	23.50	22.59	11.83		
3.5	21.70	20.79	10.03		
4	21.46	20.55	9.79		
4.5	20.76	19.85	9.09		
5	20.09	19.18	8.42		
6	18.93	18.02	7.26		
7	18.11	17.20	6.44		
8	17.44	16.53	5.77		
9	17.35	16.44	5.68		
10	16.62	15.71	4.95		
12	16.22	15.31	4.55		
14	16.04	15.13	4.37		
16	15.73	14.82	4.06		
18	15.52	14.61	3.85		
20	15.32	14.41	3.65		
22	15.13	14.22	3.46		
24	15.00	14.09	3.33		
26	14.91	14.00	3.24		
28	14.85	13.94	3.18		
30	14.76	13.85	3.09		
35	14.58	13.67	2.91		
40	14.45	13.54	2.78		
45	14.31	13.40	2.64		
50	14.15	13.24	2.48		
55	14.00	13.09	2.33		
60	13.91	13.00	2.24		

By 5minutes since pumping was stopped 45% Recovery was achieved.

RECOVERY TIME (ELAPSED TIME IN MINUTES)	RECOVERY WL READING FROM TOC (M)	RECOVERY WL (M)	DRAWDOWN OR RESIDUAL (M)	PUMPING RATE/DISCHARGE (M^3/Hr)	COMMENTS
70	13.68	12.77	2.01		
80	13.50	12.59	1.83		
90	13.00	12.09	1.33		
100	12.50	11.59	O.83		
110	12.33	11.42	0.66		
120	12.25	11.34	0.58		
135	11.67	10.76	0.00		
150	11.67	10.76	0.00		
165	11.67	10.76	0.00		

By 5 minutes since pumping stopped 45% Recovery was achieved.

Transmissivity (T)
$T = 0.183Q/\Delta S_w$
ΔS_w = Slope of Time – Drawdown graph
$\Delta S_w = 0.072$
$T = 0.183 \times 108/0.072$
$= 274.5 m^2/day$

Permeability (K)
K = (0.306Q/LS) x log (1.321/R)
L = Length of screen equivalent to thickness of aquifer = 12m
S = Max. drawdown = 15.36m
R = Radius of screen = 0.062m
K = (0.306 x 108/12 x 15.36) x Log(1.321/0.062)
= 0.238
Storativity (S_o)
$S_o = 0.117\sqrt{K}$
$= 0.117\sqrt{0.238}$
= 0.057
Specific Capacity (q)
q = Q/S
Q = 4.5m^3/hr = 108m^3/day
S = Max. drawdown = 15.36m
= 108/15.36
= 7.03m^2/day
If drawdown (S) is 5m:
Q = Sq
= 5 x 7.03m^3/day
= 35.15m^3/day
Entrance velocity (V)
V = Q/πRLP
Q = 4.5m^{3}hr = 0.00125m$^{3/}$sec
R = 0.062m
L = 12m (Length of screen)
P = % of opening in the screen (0.2)
V = 0.00125/3.14 x 0.062 x 12 x 0.2
= 2.7 x 10^{-3}m/s
Range of cone of depression (R_c)
$R_c = 10S \times \sqrt{k}$
S = 15.36m (max. drawdown)
K = 0.238
$R_c = 10 \times 15.36\sqrt{0.238}$
= 74.93m

Pumping test
LOCATION: ado north (EKSU campus)
DEPTH OF WELL: 89.00M
WELL DIAMETER: 120mm

Time since pumping stopped. t^I (minutes)	Time since pumping started. $t = t^I + 4320$	$\frac{t}{t^I}$	Residual drawdown S (meters)
1	4321	4321	17.80
2	4322	2161	15.11
5	4325	1442	13.32
10	4330	433	11.62
20	4340	217	10.33
50	4370	87.7	9.35
100	4420	44.2	8.78
200	4520	22.6	8.34
400	4720	11.8	7.72
800	5120	6.40	7.42
1000	5320	5.32	6.58
1200	5520	4.60	6.23

$$T = \frac{2.3}{4\pi\Delta s} = \frac{2.3\times 113}{4\pi(26)} = 0.84m^3/day$$

$$S_t = \frac{2.3}{4\pi T} log \frac{2.25T_t}{r_w s_c}$$

$$17.8 = \frac{2.3 \times 113}{4\pi \times 0.84} log \frac{2.25 \times 0.84 \times 2}{0.08^2 Sc}$$
$$S_c = 4.7 \times 10^{-2}$$

IV. CONCLUSION AND RECOMMENDATIONS

Conclusion

In conclusion, the study area is characterized by crystalline basement complex rock of low porosity and permeability. The various pumping tests that were carried out indicate that the area generally has low groundwater potential. This research gives better understanding of the common drilling methods used in drilling water wells in the study area, borehole yields and the problems faced before during and after drilling. I discovered that there is a high dependence on groundwater as a source for potable water. It has also been discovered that in the study area that the practice of borehole maintenance is very poor.

Recommendation

Borehole maintenance should be taken more seriously and borehole owners should develop the habit of carrying out regular maintenance on their borehole wells so as to ensure that they reach their serviceability life. It is necessary that borehole drilling should be monitored by a certified agency and that drilling license be issued to qualified water well drillers so as to reduce the infiltration of inexperienced drillers into the water well drilling sector and to reduce the drilling of sub-standard water wells. Owners of boreholes should consider rehabilitating boreholes instead of abandoning them. Rehabilitation of wells can save money and prevent the sub surface layers from losing stability as a result of excessive well drilling.

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