
Determination of Aquifer Parameters of Hand Dug Well For Uunguwar Galadima Sabo, Kaduna

By

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ABSTRACT

A hand dug well was subjected to a number of pumping tests: step drawdown, constant discharge and recovery tests to provide some preliminary estimation of hydraulic parameters for the study area. The objectives of this study is to evaluate the yield of the wells, to determine the transmissivity of the well and the specific capacity of the wells. Some hand dug wells were selected for measurement of daily transmissivity. The parameter studied from the well includes: water yield; water recovery test was carried out and the transmissivity assessed. The results indicate that transmissivity T , and specific capacity SC , were $31.55 \times 10^{-5} \text{m}^3/\text{s}$, $16.7 \times 10^{-3} \text{m}^2/\text{s}$. respectively. Mean static water level (SWL), and well depths were 2.92m, 7.1m, respectively. It can be concluded that aquifers are of moderate potential from the recovery test.

Key Words: Pumping tests, unconfined aquifer, hydraulic parameters.

INTRODUCTION

Groundwater is described as that water which is obtained from the unconsolidated soil or rock formations (Anomohanran, 2013a). Formations, which are capable of providing water in large quantities, are known as aquifers (Oseji *et al.*, 2005). When an aquifer is located below a low permeability layer, the water in the aquifer is said to be confined. The pumping of water from an aquifer through a well over a long period of time, results in the drop of the water level in that aquifer. This drop in water level causes the water around the well to flow toward the well. Researchers and groundwater providers have employed different geophysical procedures in

determining the flow properties of groundwater aquifer. These procedures include electrical resistivity techniques, geophysical well logging and pumping test.

(Moench & Ogata, 1984) claims that the number of water wells has increased exponentially in the past 50 years.

One rare set of studies on well productivity in hard-rock aquifers is reported by (Herbert *et al.*, 1992). Their work at the British Geological Society has focused on performing aquifer tests in hand-dug wells to determine transmissivity and storativity values.

Herbert *et al.* (1992) present several techniques for interpreting pumping tests in hand-dug wells in hard rock aquifers, two of

which require computer analysis and two of which do not.

A confined aquifer is an aquifer which is between two impervious strata (or aquicludes). The water in confined aquifer is under pressure. If a well is drilled into a confined aquifer, the water level rises up to the piezometric surface.

Ochuko and Ruth (2014). Determined the aquifer parameters in Erho, Nigeria. The data obtained were subjected to graphical and analytical evaluation using the Cooper-Jacob method. The values also agreed with the results of similar surveys

carried out in Delta Central District of Nigeria, Igun, Eku and Oria to evaluate their aquifer characteristics. This claim is also in agreement with the work of Rajasekharet *al.* (2014) who used the pumping test method to derive the transmissivity of confined aquifer and obtained it as 0.065 m²/min.

The computed values revealed that the storage coefficients of the aquifer are 0.0011, 0.0010, and 0.0007 for wells 1, 2 and 3 respectively. The mean value of the storage coefficient was computed as 0.00093. These values correspond to the storage coefficient of a confined aquifer (Anomohanran, 2014b)

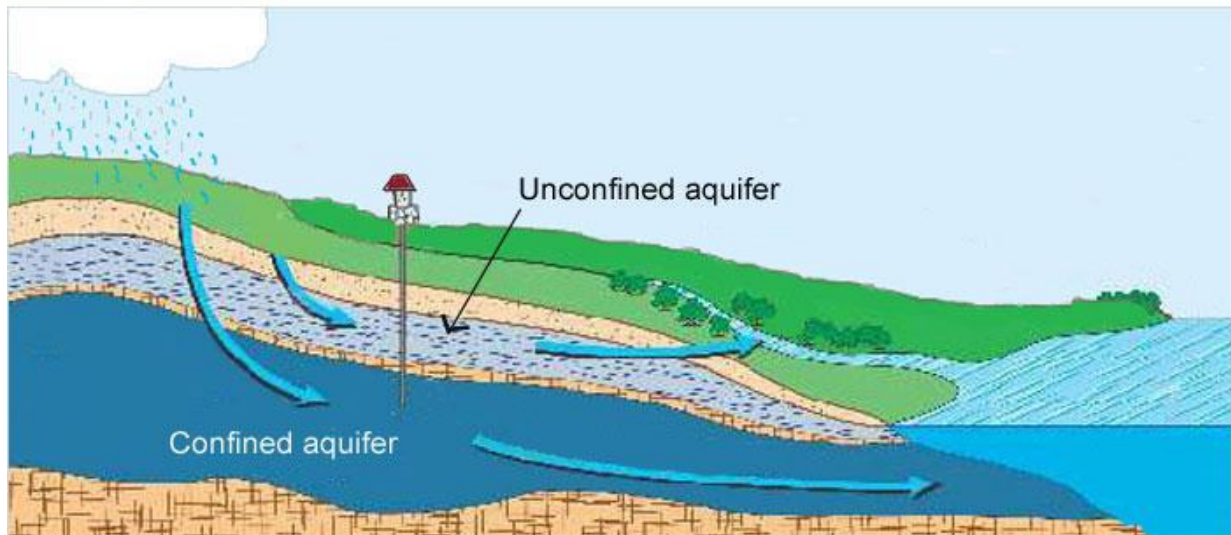


Figure 1: Confined and Unconfined aquifer.

An unconfined aquifer is the one in which a free surface (water table) exists. The unconfined aquifer extends from the ground surface up to the impervious stratum. The productivity of an aquifer can be expressed in terms of its storage coefficient. Transmissivity (T), is the rate at which water passes through a unit width of a saturated thickness of an aquifer under a

unit hydraulic gradient. The Hydraulic conductivity (K) and Transmissivity (T) are related by the expression $T = Kb$ where

$T =$ in m³ per day, $K =$ in m per day and, $b =$ in m, the drawdown, s is given by the equation,

$s = 2.3Q/4\Delta T \log 2.25Tt/r_2$ (Cooper and Jacob 1946).

$T=2.3Q/4\Delta s$ as previously outlined Q being the constant pumping rate in m^3 per day.

Storativity is also referred to as storage coefficient (S) is the volume of water an aquifer releases from or takes into storage per unit surface area per unit change in head. $S = 2.25T \ t_0/r^2$.

Furthermore there are energy losses as water rushes into wellbore so that the head in the aquifer is larger than the water level in pumping well (Edet, 1993). However, the values of S are usually about 0.2 for water table aquifers and 10⁻⁵ and 10⁻³ for confined aquifers (Lohman 1972).

Specific Capacity (Sc) is the discharge rate per drawdown. Mathematically specific capacity (SC) $SC = Q/s$ where Q is the discharge rate in m^3/d . And s =drawdown in m the productivity of a well is often expressed in terms of its specific capacity (Bradbury & Rothschild, 1985).

Hydraulic Conductivity (K) is the quantitative measurement of permeability that is the ease in which water can pass through a unit thickness of an aquifer. $T = Kb$. Thus, $K = T / b$ where b = saturated thickness of the aquifer

Table 1: hydraulic conductivity for various unconsolidated sedimentary materials

unconsolidated sedimentary materials	
Materials	Hydraulic conductivity (m/s)
Gravel	3×10^{-4} to 3×10^{-2}
Coarse sand	9×10^{-7} to 6×10^{-3}
Medium sand	9×10^{-7} to 5×10^{-4}
Fine sand	2×10^{-7} to 2×10^{-4}
Silt, loess	1×10^{-9} to 2×10^{-5}
Till	1×10^{-12} to 2×10^{-6}
Clay	1×10^{-11} to 4.7×10^{-9}
Unweathered marine clay	8×10^{-13} to 2×10^{-9}

Papadopoulos and Cooper (1967) developed an analytical solution and type curves in and around a large diameter well in a homogeneous and isotropic non-leaky confined aquifer. Water well as an excavation or structure created in the ground by digging, driving, boring, or drilling to access groundwater in underground aquifers.

Two broad classes of well are shallow or unconfined wells completed within the

uppermost saturated aquifer at that location, and deep or confined wells, sunk through an impermeable stratum into an aquifer beneath.



Figure 2: View into a hand-dug well cased with concrete rings



Figure 3: A dug well in a village in Kerala, India.

Driven wells may be very simply created in unconsolidated material with a *well hole structure*, which consists of a hardened drive point and a screen (perforated pipe).

From the Johnson Drillers Journal, (1975) they accessed that Many people assumed that the doubling of the diameter of a well doubles its yield, and concluded that it was far from true.

Q varies as $\frac{K}{\log R/r}$ where K represents

all the constant terms.

Table XIII shows that if a 6-inch well was yield 100gpm with a certain drawn down, a 12-inch well-constructed at the same spot was yield 110gpm with the same drawdown; an 18-inch well was yield 137gpm, or 37percent more water at the same draw down. (Davis, 1996)

Table 2: The table shows Well Diameter Vs Yield Ratio

Well Diameters						
6"	12"	18"	24"	30"	36"	48"
100	110	117	122	127	131	137
-	100	106	111	116	119	125
-	-	100	104	108	112	117
-	-	-	100	104	107	112
-	-	-	-	100	103	108
-	-	-	-	-	100	105

These ratios apply both to specific capacity and total yield. For example, if a 12-inch well is producing 20gpm per ft of drawdown,

then a 24-inch well in the same location would produce 111 percent as much or a 22.2gpm per ft of drawdown. So the table

shows doubling the diameter of a water table was increase the yield by 11 per cent.

$$Q = \frac{Pm(H-h)}{52.8 \log R/r} \quad (1)$$

Where

m=thickness of the aquifer, in ft,
H=static head at bottom of aquifer in ft,
h=depth of water in the well while pumping, P=permeability of water-bearing sand in gpm per sqft, R=radius of the cone of depression in ft, r=radius of the well in ft

The objectives of this study is to evaluate the yield of the wells, to determine the transmissivity of the well and the specific capacity of the wells.

MATERIALS AND METHODS

Materials used on site

A standby generator is a back-up electrical system that operates automatically. Automatic standby generator is required here to ensure a constant power supply for the pump to be continuously on.

Water Level Meters use corrosion proof stainless steel probes attached to permanently marked flat tape, fitted on a well-balanced reel. A sensitivity control allows the buzzer to be turned off while in cascading water, and ensures a clear signal in both high and low conductivity conditions.

Stopwatch is a handheld timepiece designed to measure the amount of time elapsed from a particular time when it is activated to the time when the piece is deactivated



Figure 4: A typical mechanical analog stopwatch.

The stopwatch function is also present as an additional function of many digital wristwatches, cell phones, portable music players, and computers.

Field Technique

This pumping test technique was carried on a large diameter hand dug well in three sequential stages: The step draw down test, the constant rate test, and Recovery test.

Method

The first data taken was the water level of the well at site. The depth of the well was also determined on site. The well was pumped at a constant rate (18.05m³/s). Recording of the pumping water level started at 1minute, and data collected at an interval of 1minute for the first 10minutes. The next data collected for the pumping water level was collected for 10mins, after which there was an interval of 5minutes from 20 to about 30minutes to commencement of pumping. At exactly 30minutes the pumping test was ended and the recovery test begins immediately.

A single hole pumping test was employed in this residential area because observation well was not used. At 30 minutes the water would have not increased, as it was at the same level. A minute later, the water was expected to

increase and the recovery level was then be taken for the 32nd minute. This sequence of 2 minute interval was continue for about 10mintues after which the next interval was taken to 5minute, then 10mintues interval then finally 20 minutes till the well was fully recovered back to its initial water level (the water level that was taken before the pump was switched on). The data collected was used to determine

Transmissivity (T), Conductivity (k), Specific Capacity (SC) and, Draw down which was calculated.

The difference in the elevation of the water level before and after pumping was plotted against time of pumping on a semi-logarithmic graph sheet for the location considered. The graphs was used to determine the drawdown per log cycle of time (ΔL) and the time intercept (t_0). These two values were then substituted into the Cooper-Jacob equations to evaluate the storage coefficient, transmissivity and specific capacity of the aquifer.

RESULTS

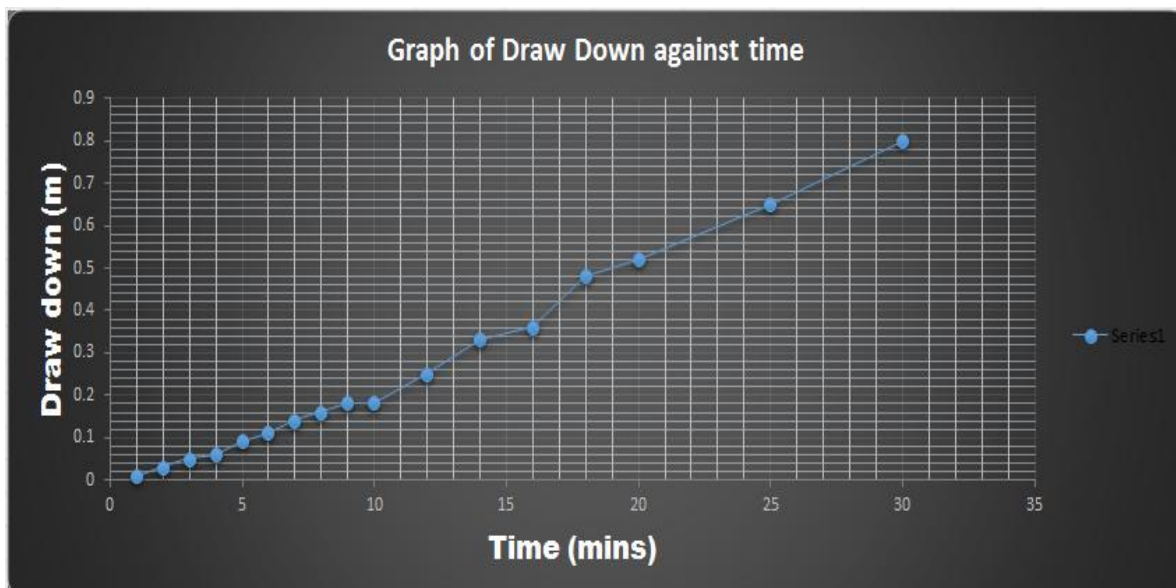


Figure 5: Graph of Drawdown against time

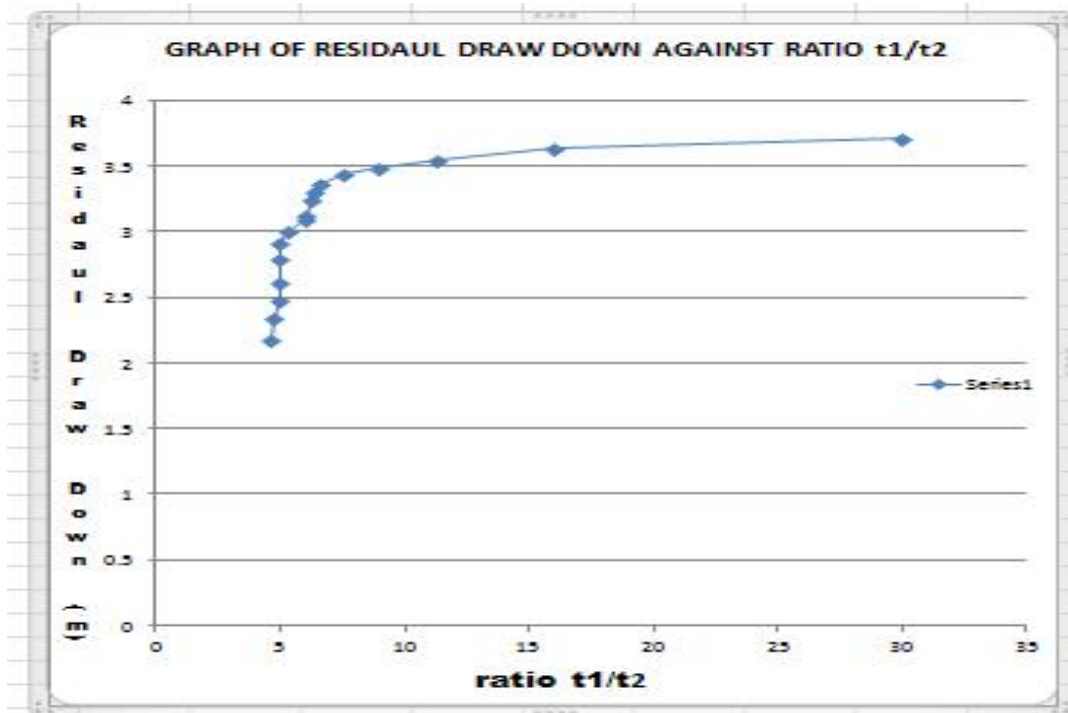


Figure 6: Graph of residual Draw down against ratio t1/t2

The Hydraulic conductivity (K) and Transmissivity (T) are related by the expression $T = Kb$ where

$s = 2.3Q/4\Delta T \log 2.25Tt/r^2$ (Cooper and Jacob 1946).

T is evaluated from the slope of semi- log plot of time- drawdown curves (Figs 4.1 and 4.2) for both constant discharge and recovery aquifer tests using the relation: $T = 2.3Q/4\Delta s$

Q being the constant pumping rate at 26l/m converted to $43.3 \times 10^{-4} \text{m}^3/\text{s}$

Δs is slope from the graph gotten to be 0.79

$$T = \frac{2.3 \times 43.3 \times 10^{-4}}{4 \times 0.79} = 31.55 \times 10^{-5} \text{m}^2/\text{s}$$

The transmissivity for the drawdown is gotten to be $31.55 \times 10^{-5} \text{m}^2/\text{s}$. From the Johnson drillers journals 1975 they suggested that the values of the coefficient of transmissibility range from about 1000 to over 1000000 gpm per ft. they concluded

that an aquifer whose transmissibility of less than 1000 gpm per ft can supply only enough water for domestic wells and the like.

Specific capacity is the discharge rate per drawdown. Mathematically specific capacity (SC)

$SC = Q/s$, where Q is the discharge rate in m^3/s . And $s = \text{drawdown in m}$

$$SC = \frac{43.3 \times 10^{-4}}{0.2588} = 16.7 \times 10^{-3} \text{m}^2/\text{s}$$

The productivity of a well is often expressed in terms of its specific capacity (Freeze and Cherry, 1979). The calculated specific capacity of the well is gotten to be $16.7 \times 10^{-3} \text{m}^2/\text{s}$.

It is the quantitative measurement of permeability that is the ease in which water can pass through a unit thickness of an aquifer. Hydraulic conductivity, K and transmissivity T are related by the expression). $T = Kb$. Thus, $K = T/b$ where $b =$

saturated thickness of the aquifer Akwa ObioInwang 2003. In this work the saturated thickness of the aquifer was not determined so the Hydraulic Conductivity.

DISCUSSION

The mean depth of the well is 7.1m, the static water level is 2.92m

$$T = 31.55 \times 10^{-5} \text{m}^2/\text{s},$$

And SC = 69.745m²/s, yield was gotten as 26l/m which is 18.05m³/s

CONCLUSION

Pumping test data was analyzed for a hand dug well in Unguwan galadima area and the following conclusions were determine:

- i. *It can be concluded that aquifers are of moderate potential from the recovery test.*
- ii. A transmissivity (T) which was gotten to be 13.138m²/s, conductivity (K) was not obtained due to the absence of the aquifer thickness, and specific capacity (Sc) which was used to determine as 69.745m³/s/m the efficiency of a hand dug well.
- iii. The test was also used to determine the pumping rate as well as the discharge rate of the well. For a pumping test that lasted for 180 minutes. The depth of the well is 7.1m.

REFERENCES

Anomohanran, O., & Iserhien-Emekeme, R. E. (2014). Estimation of aquifer parameters in Erho, Nigeria using the Cooper-Jacob evaluation method. *American Journal of Environmental Sciences*, 10(5), 500

Anomohanran, (2013a). Geophysical investigation of groundwater potential in Ukelegbe, Nigeria. *J. Applied Sci.*, 13: 119-125. DOI: 10.3923/jas.2013

Anomohanran, O., 2014b. Hydrogeophysical and hydrogeological investigations of groundwater resources in delta central, Nigeria. *J. Taibah Uni. Sci.*, DOI: 10.1016/j.jtusci.2014.06.003

Bradbury, K. R., & Rothschild, E. R. (1985). A computerized technique for estimating the hydraulic conductivity of aquifers from specific capacity data. *Groundwater*, 23(2), 240-246.

Davis, P. N. (1996). Recreational Use of Watercourses. *Mo. Env'tl. L. & Pol'y Rev.*, 4, 71.

Edet, A. (1993). Groundwater quality assessment in parts of Eastern Niger Delta, Nigeria. *Environmental Geology*, 22(1), 41-46.

Herbert, R., Barker, J., & Kitching, R. (1992). New approaches to pumping test interpretation for dug wells constructed on hard rock aquifers. *Geological Society, London, Special Publications*, 66(1), 221-242.

Johnson Drillers Journal, (1975). Ground Water and Wells. Geological survey team U.S.

Lohman, S. W. (1972). Ground-water hydraulics.

Moench, A., & Ogata, A. (1984). Analysis of constant discharge wells by numerical inversion of Laplace transform solutions. *Groundwater Hydraulics*, 146-170.

Ochuko and Ruth. (2014). Estimation of aquifer parameters using the cooper-jacob evaluation method in Erho, Nigeria. Physics Department, Faculty of Science, Delta State University, Abraka.

- Oseji, J., Atakpo, E., & Okolie, E. (2005).
Goelectric investigation of the
aquifer characteristics and
groundwater potential in Kwale,
Delta state, Nigeria.
- Papadopulos and Cooper (1967). Aquifer
parameters determination for large
diameter wells using neural network
approach.
- Rajasekhar, P., K.P. Vimal and M. Mansoor,
2014. Determination of confined
aquifer parameters by Sushil K.
Singh method. *Am. Int. J. Res. Sci.
Technol. Eng. Math.*, 5: 158-163
- Schnellmann, M., Anselmetti, F. S., Giardini,
D., & McKENZIE, J. A. (2005). Mass
movement-induced fold-and-thrust
belt structures in unconsolidated
sediments in Lake Lucerne
(Switzerland). *Sedimentology*, 52(2),
271-289.