EVALUATION OF TOTAL GROUNDWATER RESERVES (WATER BUDGET) OF OWERRI AND ENVIRONS, SOUTHEASTERN NIGERIA

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ABSTRACTS

The study had evaluated the inflow-outflow (water balance) of groundwater reserves in Owerri and environs, southeastern Nigeria. This was achieved through detailed study of the hydrogeology and topography of the area, physiography (annual rainfall), aquifer type, boreholes information, populations and growth rate. Owerri has an area of 683.33 km^2, projected population of 538,071 (from 2006 to 2015) with a growth rate of 3.2 %. The annual rainfall depth of Owerri ranges between 60 mm and 4262.2 mm (depending on the time and season) and the thickness of water saturated part of the aquifer range between 20 m and 25 m. The results of the water budget showed that; Total Static Water Resources (tWRs) of Owerri is 4,077,771,775 m^3/a, Total Dynamic Water Resources (tWRd) is 605,465,229.83 m^3/a and Utilizable Dynamic Water Resources (uWRd) is 35,722,448,559.9 m^3/a. At the time of planning, the Projected Water Demand for the people (2015-2065) would be 78,817,598.4519 m^3/a, Projected water demand for industrialization (Iwd) would be 15,763,519.6903 m^3/a, Projected water demand + water demand for industrialization (Pwd+Iwd) would be 94,581,118.1422 m^3/a. However, groundwater available for supply that will meet the current and/or projected demand in Owerri (study area) is adequate, with surplus of 35,627,867,441.8 m^3/a. This study provides account or estimate of calculated water budget and can be employed in forecasting the future water resources surplus/deficit and ways of curbing water resources deficit.

Keywords: Water budget, groundwater, annual rainfall, population growth

1.0 Introduction

Groundwater has been exploited for domestic use, livestock and irrigation since the earliest times. About two billion people (approximately one-third of the world's population) depend on groundwater supplies, withdrawing about 20 percent of global water (600 to 700km^3) annually, much of which is from shallow aquifers (Foster, Garduno, Kemper, Tuinhof and Dumars; *2005*). Groundwater provides a reasonably constant source of water supply that is not likely to dry up under natural conditions.

Offodile (2002) maintained that groundwater is an important resource and it is known to occur more widely than surface water, but its availability is limited by so many factors such as porosity, permeability, storativity etc. Groundwater in storage is made available to man through discharge processes which could be natural or artificial. Discharge without replenishment (recharge) could result to a number of problems, including depletion of groundwater which can lead to well failure or low yield. Groundwater is known to be reasonably safe for domestic use when it occurs at acceptable depths, free of surface contamination and exploited by means of boreholes or any other technically sanitary means (Offodile, 2002).

Owerri is one of the rapidly growing urbanization centers of Nigeria and industrialization has placed an increasing demand for water, many privately-owned boreholes have been sunk into the shallow aquifers hence; regular evaluation of groundwater is of fundamental importance, since about 95 percent of the inhabitants of Owerri rely on groundwater sources for their daily water needs. In this case of the study area, only that aspect of groundwater resources is calculated, adopting Schoeneich's (2007) classification of Total water reserves.

1.1 Location of the Study Area

The study area; Owerri and environs, comprises Owerri Municipal, Owerri-west and Owerri-north Local Government Areas with parts of Mbaitoli and Ikeduru. It lies between latitudes $5^0 20'$ to $5^0 32'$N and longitudes $6^0 51'$ to $7^0 08'$ E (Fig 1).

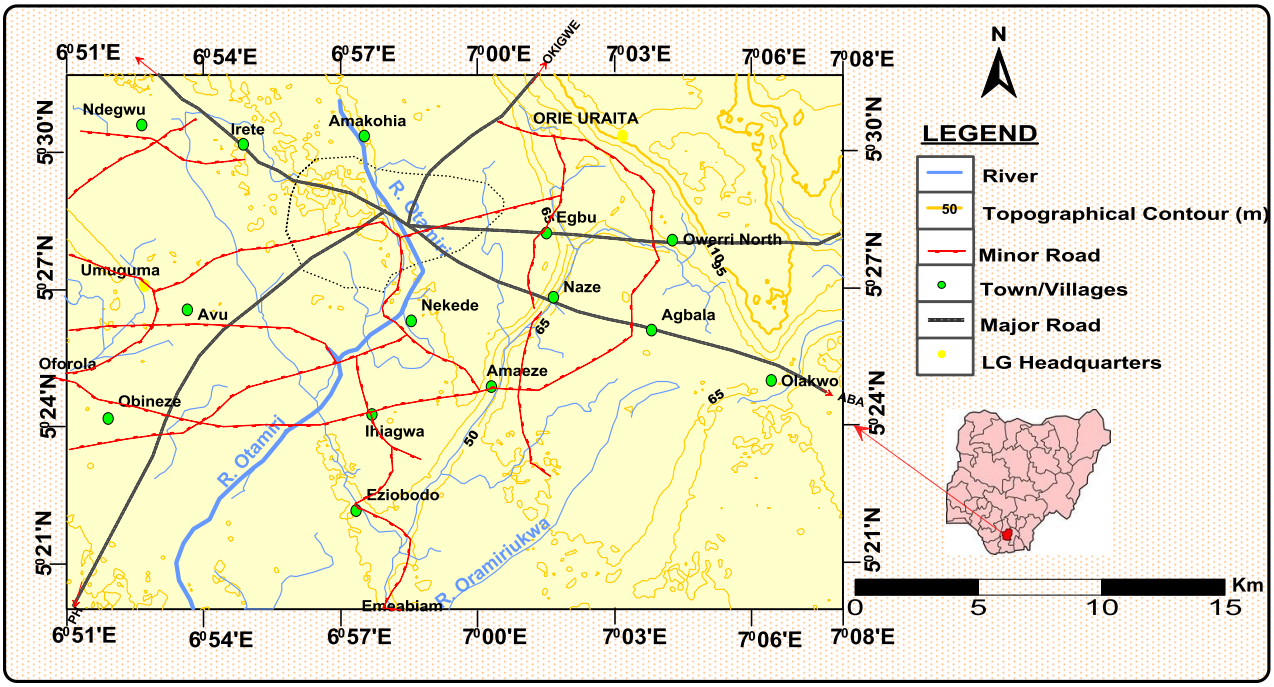

Fig. 1: Location Map of the Study Area (Carved from Department of Lands, Survey and Urban Development, Owerri, 1984)

2.0 Geology of the Study Area

The study area is underlain by the Benin Formation (Fig 2). It consists mainly of friable sands, conglomerates, very coarse sandstone and isolated gravel units and intercalation of shale/clay lenses of Pliocene to Miocene age (Horton, 1965; Short and Stauble, 1967; Ananaba, Onu and Iwuagwu., 1993). The sands and sandstones are coarse to fine-grained partly unconsolidated with thickness ranging from 0 to 2100meters (Avbovbo, 1978). The sediments represent upper deltaic plain deposits and the environment of deposition is partly lagoonal and fluvio-lacustrine/deltaic (Rayment, 1965). The formation which dips south-westward starts as a thin edge layer at its contact with Ogwashi-Asaba Formation in the northern part of the area (Rayment, 1965). The sandy unit which constitutes about 95% of the rock in the area is composed of over 96% of quartz (Onyeagocha, 1980). In many places within the area, the formation is overlain by a considerable thickness of earth (laterite) composed of iron-stained regolith formed by the weathering and subsequent ferruginization of the weathered materials. The Benin Formation within the Imo River Basin consists of unconsolidated yellow and white coastal plain sands with gravel beds, occasionally pebbly with grey sandy clay lenses (Nwachukwu, Feng and Ophori, 2010). The Benin Formation comprises of a thick sequence of poorly consolidated to unconsolidated sandstones that are friable with sorting ranging from poorly to fairly sorted (Onyeagocha, 1980). The Benin Formation has lithologies consisting of sands, silt, gravel and clayey intercalations (Asseez, 1989).

The Benin Formation covers all the area of study, making it a one aquifer system. It is covered with a thick freshwater bearing aquifer in almost all the location, though screened aquifer thicknesses as measured ranges from 20 to 25 m below sea level. The yield of the aquifer in Owerri and environs as determined from pumping test obtained from Anambra-Imo River Basin

Development Authority ranges between 432 m^3/day and 840 m^3/day, drawdown between 1.5 and 3 m. Offodile (2002) reported that Benin Formation gives copious yields up to 1080 m^3/day and that borehole data in Benin Formation area revealed the same sequence of continuous sandy pebbly formation. Offodile (2002) also described the aquifer transmissivity in Benin Formation ranging from 880 to 30,000 m^2/day.

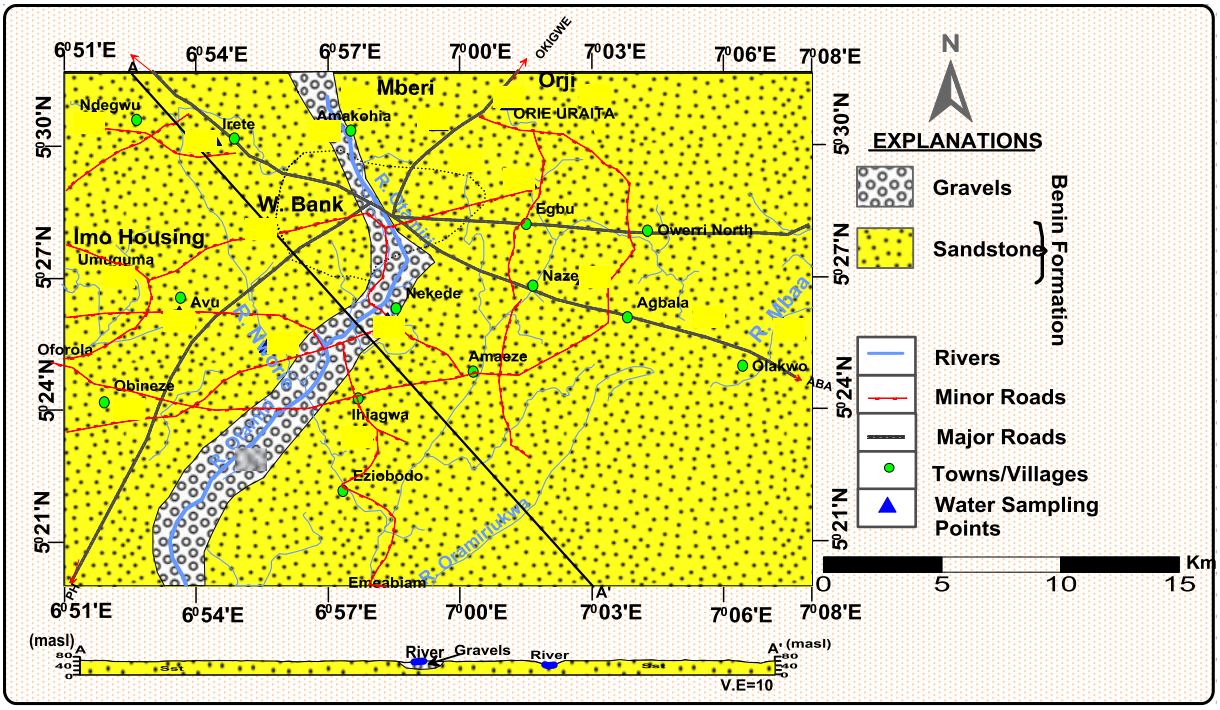

Fig 2: Geological Map of the Study Area (Source: Nwanya, 2016)

3.0 Materials and Methods

The method adopted in calculating the water budget of the study area was Schoeneich's (2007) classification of total water reserve (Table 1).

Table 1: Classification of total water reserve (Source: Schoeneich, 2007).

	TOTAL WATER RESOURCES (tWR)	
	Utilisable Water Resources (uWR)	Non-Utilisable Water Resources (nWR)
Total Static Water Resources (tWRs)	Utilisable Static Water Resources (uWRs)	Non-Utilisable Static Water Resources (nWRs)
Total Dynamic Water Resources (tWRd)	Utilisable Dynamic Water Resources	Non-Utilisable Dynamic Water Resources (nWRd)

Total Static Groundwater Resources in the Study Area (tWRs) is calculated as stated in equation 1:

$gWRs = A \times T \times V$ (1)

Where

"A" = area of aquifer (groundwater deposit),

"T" = mean weighted thickness of water saturation part of the aquifer (as deduced from boreholes information in figures 4 and 5), and

"V" = coefficient of voidity (dimensionless), as expressed by Fetter's (1994) range of gravel and sand; expressed as decimal fraction.

In this work, mean average range of 20 % to 35 % (27.5 % or 0.275) was used to calculate the total static groundwater resource of the study area.

The Dynamic Groundwater Resources (WRd) of Owerri is calculated as stated in equation 2.

$WRd = A \times D = Pv$ (Volume of rainfall) (2)

Where,

A = area,

D = depth of rainfall,

Pv = volume of rainfall

The Utilizable Dynamic Water Resources of Owerri (study area) was found based on the following assumptions: out of the total dynamic water resources of the study area, 11 % is set aside for losses due to dry season and 30 % is set aside for unaccountable water loss due to wastages and environmental degradation. Therefore Utilizable Dynamic Water Resources will be 59 % of the Total Dynamic Water Resources (tWRd) of the study area.

4.1 Water Demand and Consumption

4.1.1 Population of Water Consumers in Owerri (Study Area)

This was calculated using the population of people living in Owerri and the growth rate as stated by bureau for statistics' (2006) population census. The population of Owerri was projected from 2006 to 2015; thereafter, from 2015 to 2065 (50years) using equation 3.

P $e^{r\,n}$ (Kpedekpo, 1982) (3)

Where,

P = present population,

e = exponential,

r = population growth rate, and

n = the projected year.

This is because the population of Nigeria is expected to stabilize by the year 2050. For a viable water resources management plan of an area, the planning horizon should be at least 30 year.

5.0 Results

The groundwater budget of Owerri is summarized in Table 2. The results showed that Owerri has enough groundwater resources to meet the present and future water demand of the people, with a large water resources surplus of 35,722,448,559.9 m^3/a in 50 years' time.

Table 2: Summary of Water Budget for Owerri (Study Area)

Water Resources	**Total volume (m^3/a)**
Total Static Water Resources (tWRs)	4,077,771,775 m^3/a.
Total Dynamic Water Resources (tWRd)	605,465,229.83 m^3/a
Utilizable Dynamic Water Resources (uWRd)	35,722,448,559.9 m^3/a
Projected Water Demand for the people (2015-2065)	78,817,598.4519 m^3/a
Projected water demand for industrialization (Iwd)	15,763,519.6903 m^3/a
Projected water demand + water demand for industrialization (Pwd+Iwd)	94,581,118.1422 m^3/a
Result = uWRd – (Pwd + Ir)	35,627,867,441.8 m^3/a
Surplus	35,627,867,441.8 m^3/a

6.0 Discussion

Total static water resources in the study area (tWRs) are divided into surface water static water resources and groundwater static water resources (gWRs). In the case of the study area, only that aspect of groundwater static resources (gWRs) is calculated (gWRs = A×T×V), which is 4,077,771,775 m^3/a. According to Schoeneich's (2007) water budget for River Basin Development Authorities in Nigeria and which the study area is inclusive; static water resources of Anambra-Imo River Basin Authority is 607 km^3. The groundwater static resources of the study area represent about 0.67 % of the static water resources of Anambra-Imo River Basin Authority.

Total dynamic water resources of the study area (tWRd) are equal to the volume of water flowing in a unit of time through a water deposit (surface body or aquifer) and are normally expressed in cubic meters per year (m^3/ year) (Schoeneich, 2007). Total dynamic water resources of the study area (tWRd); tWRd = A×D = Pv (volume of rainfall) are 605,465,229.83 m^3/a and were calculated from Figure 3, using coefficient of base flow corresponding to 2,161.1 mm/a depth of rainfall in Owerri (Pv) (volume of rainfall × coefficient of base flow corresponding to 2,161.1 mm/a depth of rainfall).

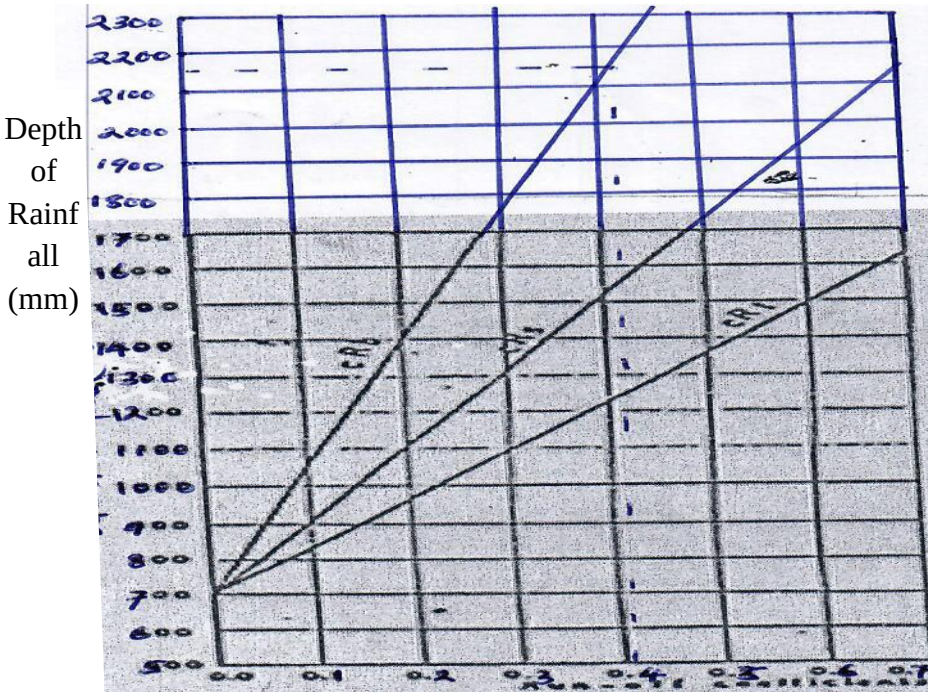

Figure 3: Correlation between depth of rainfall and runoff coefficient in drainage basins (Adapted after, Schoeneich, 2007).

Legend: cRt = total runoff coefficient; cRs = surface runoff coefficient; cRb = base flow coefficient.

The Utilizable Dynamic Water Resources (uWRd) of Owerri (study area) are 35,722,448,559.9 m^3/a. It forms this part of the total dynamic water resources, which can be abstracted from a surface or groundwater deposit at joint cost, technical and social cost – not exceeding the local value of the abstracted water (Schoeneich, 2007). They were found based on the following assumptions: the total dynamic water resources of the study area as calculated above are 605,465,229.83 m^3/a, 11 % is set aside for losses due to dry season and 30 % is set aside for unaccountable water loss due to wastages and environmental degradation. Therefore Utilizable Dynamic Water Resources will be 59 % of the Total Dynamic Water Resources (tWRd) of the study area, which is uWRd = 605,465,229.83 m^3/a× 59 % = 35,722,448,559.9 m^3/a. The Utilizable Dynamic Water Resources of Anambra-Imo River Basin Authority, according to Schoeneich's (2007) is 28.4 km^3/a, and study area represent 2.1 % of it.

6.1 Water Demand and Consumption

6.1.1 Population of Water Consumers in Owerri (Study Area)

According to 2006 National Population Census which stated the population of each Local Government Area as Owerri municipal 125,337, Owerri north 176,334 and Owerri west 101,754 summed at 403,425 populations of the people living in Owerri (Table 3). According to the bureau for statistics, the population growth rate of Owerri in 2006 population census is 3.2% (0.032 %). The study area falls within the residential water consumption category. The projected population of Owerri (projected from 2006 to 2015) was used to calculate the population projection in Owerri from 2015 to 2065 (50 years) using Equation 3.

Table 3: 2006 Population Census of Owerri by Local Governments (Source: National Population Commission, Owerri).

Name	**Status**	**Population Census 26-11-1991**	**Population Census 21-3-2006**
Owerri Municipal	L.G.A	---	125,337
Owerri North	L.G.A	---	176,334
Owerri West	L.G.A	---	101,754
Total			403,425

6.1.2 Water Demand in Owerri

Therefore Owerri population (as projected from 2006 to 2015, 9years) using Equation 3, is 403,425 people (2006) $e^{0.032 \times 9}$ = 403,425 $e^{0.288}$ = 538,071 projected population of people of Owerri in 2015. Therefore, the projected population by 2065 (50years) is 538,071 people (2015) $e^{0.032 \times 65}$ = 538,071 $e^{2.08}$ = 4,306,972.593 people in 2065. Water consumption in Owerri by the people is mainly urban residential. The 50 lpcd including wastages is considered for urban dwellers in this work, in line with Schoeneich's (2007) 50 lpcd, in his work on water resources management in Nigeria. Therefore, the present water demand in Owerri is = 50 lpcd or 0.05 m^3/d × 538,071 people = 26,903.55 m^3/d or 9,846,699.3m^3/a.

In 50 years from 2015 (2015-2065), the projected water demand for Owerri will be: 4,306,972.593 people × 0.05 m^3/d = 215,348.62965 m^3/d or 78,817,598.4519m^3/a. It is expected that in 50 years from 2015, well advanced industrializations will be established and this perhaps will take or use 20% of the projected water demand in the study area, (Iwd) which is 20% of 78,817,598.4519 m^3/a = 15,763,519.6903 m^3/a. This gives a total of 78,817,598.4519 m^3/a + 15,763,519.6903 m^3/a = 94,581,118.1422 m^3/a (i.e. projected water demand + 20% of the water demand for industrialization). Therefore, at the ultimate planning horizon (50 years from 2015), the estimated water demand that will be allocated to industrialization is = 15,763,598.6903 m^3/a.

Owerri (study area) has a total dynamic groundwater resources of 605,465,229.83 m^3/a, to meet the present and future water demand of people in the area. During the time of planning, the area

will have a large water resources surplus of 35,722,448,559.9 m^3/a - 94,581,118.1422 m^3/a = 35,627,867,441.8 m^3/a (i.e. uWRd – projected water demand).

This study of water budget for Owerri shows that the area will have a water surplus of 35,627,867,441.8 m^3/a, at the projected and planning horizon.

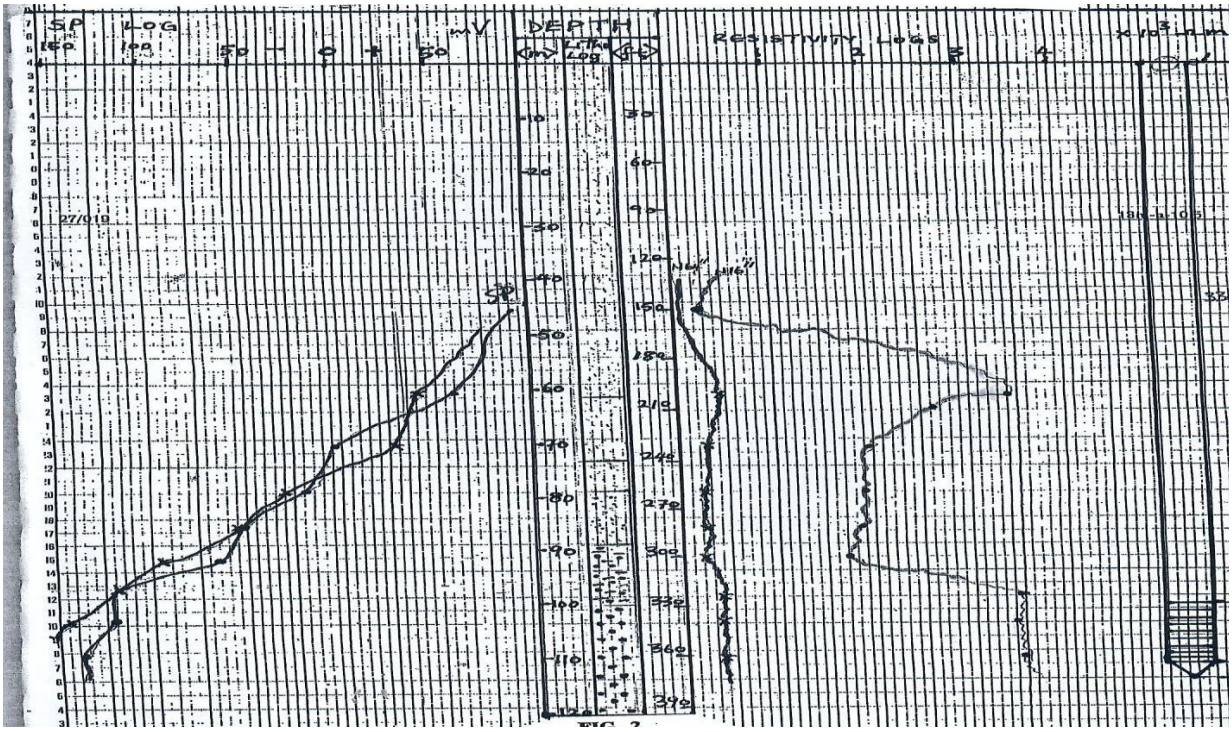

Fig 4: Borehole Logging Details in Benin Formation of the Study Area
(Source: Anambra-Imo River Basin Authority)

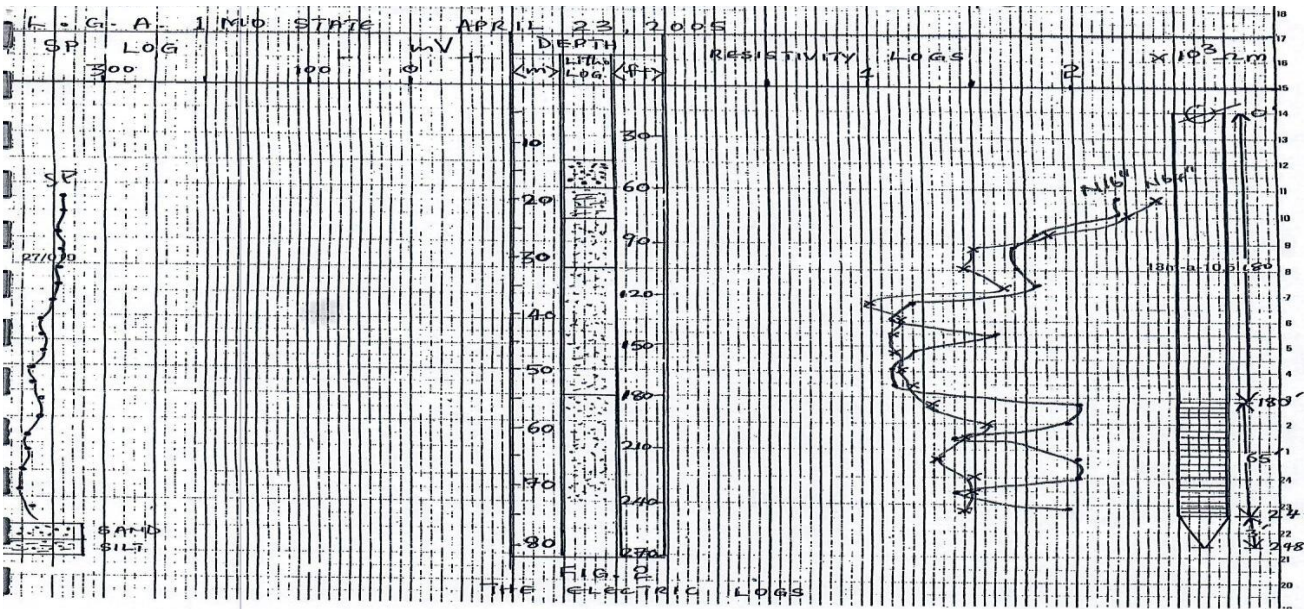

Fig 5: Borehole Logging Details in Benin Formation of the Study Area
(Source: Anambra-Imo River Basin Authority)

7.0 Conclusion

Total dynamic groundwater resources of the area is 4,077,771,775 m^3/a. The current maximum water demand for an estimated population of 538,071 (year 2015) people in the study area is 9,846,699.3 m^3/a. The projected population of 4,306,972.593 people in the next 50 years from 2015 and at the growth rate of 3.2 % in the study area would make water demand for the people to be 78,817,598.4519 m^3/a. The projected water demand for people and industrialization (2015 to 2065) would be 94,581,118.1422 m^3/a. During this time of planning, the study area will have a large water resources surplus of 35,627,441.8 m^3/a, since utilizable dynamic groundwater resources (uWRd) is 35,722,448,559.9 m^3/a, at the projected 50 years (2015 to 2065), including advanced industrialization. However, groundwater available for supply that will meet the current and/or projected demand in Owerri (study area) is adequate, with surplus of 35,627,867,441.8 m^3/a.

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