AQUIFER CHARACTERISTICS IN PARTS OF OBIO AKPOR LOCAL GOVERNMENT AREA, RIVERS STATE, NIGERIA

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ABSTRACT

A geoelectrical survey of Rumuola pumping station in Port Harcourt, Rivers State, was conducted, aimed at evaluating the Aquifer Characteristics of the station covering a total area of about 250,000 square metres. The station is the hub of water supply to the entire Port Harcourt metropolis and environs. Aquifer pumping tests and eight Vertical Electrical Sounding (VES) were conducted to evaluate the aquifer hydraulic conductivity, transmissivity, storage capacity and discharge of the station. A computer program, IP12win software was used for the one-dimensional inversion of field data processing and interpretation. Results obtained revealed four distinct geoelectric layers overlying a conductive geoelectric basement. The aquifer was characterised by a medium to coarse grained sands with thicknesses ranging from 14.5 - 84.0m and resistivities of 86.3 - 4723Ωm. Based on the model obtained from the pumping test, the average aquifer hydraulic conductivity of 12m/day and transmissivity of 435.025m^2/day was evaluated, depicting a high prolific aquifer yield. The average water level distribution in the area was 11.3m. The area obviously is endowed with very high groundwater potential.

INTRODUCTION

Rumuola pumping station is the headquarter of Port Harcourt Water Corporation (PHWC) located at Rumuola in Obia/Akpor Local Government area of Rivers State. PHWC is the water utility responsible for the provision of urban water supply and wastewater management services in Port-Harcourt and Obio/Akpor LGA of Rivers State, Nigeria. The station supplies water to the entire Port Harcourt LGA and at least 80% coverage for Obio/Akpor LGA. The Port Harcourt and Obio/Akpor LGA water Supply Scheme comprises 13 water pumping stations viz; Diobu, Moscow road, Borokiri, Rumukwurushi, Elelenwo, Trans Amadi, Omerelu street, Eagle Island, Ogbogoro, Olumeni, Ernest Ikoli, Worji and Rumuola pumping stations. The facilities at Rumuola pumping station and the various substations comprises; boreholes, treatment processes and works, booster stations, ground reservoirs, elevated tanks, transmission lines, distribution networks, power supply.

Geophysical survey was conducted in the area to evaluate groundwater potentials of the station. Eight vertical electrical sounding was carried out in the study area. In addition, aquifer pumping test was also carried out in some of the existing boreholes in the area. Computer aided software IP12 Win was used for the data analysis. The determination of aquifer characteristics of the hydraulic conductivity and transmissivity were best made on the basis of data obtained from well pumping test results. These properties are very important in determining the natural flow of water through an aquifer and its response to fluid extraction. From the report of this study and available data, Rumuola pumping station can comfortably accommodate additional number of fifty boreholes drilled at varying depths.

LOCATION AND GEOGRAPHY OF THE AREA

The pumping station is located in Obio-Akpor. It is between latitudes 4°50'18.97"N and 4°50'11.09"'N and longitudes 7°00'12.97"E and 7°00'30.18"E, (Figure 1). The area features a tropical wet climate with lengthy and heavy rainy seasons and very short dry seasons. Only the months of December and January truly qualifies as dry season months in the city. The harmattan, which climatically influences many cities in West Africa is less pronounced in the area. The heaviest precipitation occurs during September with an average of 2500 mm of rain. December on the average is the driest month of the year, with an average rainfall of 2000 mm. Temperatures throughout the year in the city is relatively constant, showing little variation throughout the course of the year. Average temperatures are typically between 25 °C - 28 °C in the city.

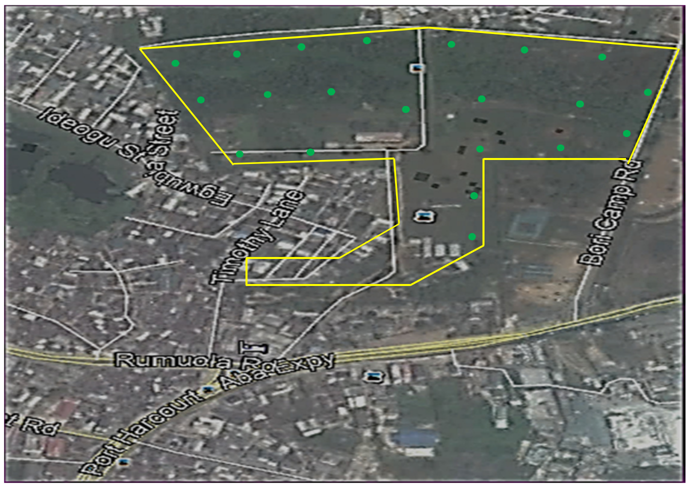

Figure 1: Rumuola Pumping Station

PHYSIOGRAPHY - HYDROLOGY AND HYDROGEOLOGY

The Rumuola pumping station is generally a lowland area with average elevation below 30 metres above sea level. Its geology comprises basically alluvial sedimentary basin and basement complex. The thick mangrove forest, raffia palms and light rainforest are the major types of vegetation. Due to high rainfall, the soil in the area is usually sandy or sandy loam. It is always leached, underlain by a layer of impervious pan. Basically, the area consists of medium coarse to unconsolidated sands with groundwater at the water table atmospheric pressure. The top sediments are aerated unconsolidated and highly variable thickness throughout the area, Onuoha and Mbazi (1988), Amechi and Horsfall (2015). The subsurface geology of the Niger Delta consists of three lithostratigraphic units; Benin, Agbada and Akata Formations, which are in turn overlain by quaternary sediments. The Benin formation is about 2100m thick and is made up of over 90% massive, porous and coarse sands, Allen (1965). The high permeability of Benin formation, the overlying lateritic red sand and weathered top of the formation provide the hydrologic condition favouring aquifer formation in the area. Groundwater potentials are very high due to the high permeability, high recharge potential and considerable aquifer thickness. The water in most of the area has high iron content and water table varying between 1.0m to 15.0m inland. The aquifer here is usually unconfined and is encountered at varying depths. Locally, a multi-storey aquifer is formed by the localized fine sands and clay which separate the coastal plain sands. The high rainfall ensures adequate groundwater recharge.

The groundwater potential of Port Harcourt area is mainly from the upper section of the Benin Formation. Most boreholes penetrating Benin Formation reveals few meters thick of silt clay, often becoming shale to a thickness of 10m to 200m, (Offodile, 1984). These shale lenses create several sub-aquifers in the formation. The upper sub-aquifer to a depth of some 10m is unconfined, while the deeper sub-aquifers are leaky, confined sub-aquifers and isolated from the ground surface.

Data from previous studies show that only about 200m to 300m of the Benin Formation is currently being exploited for groundwater. (Mbonu, *et al,* 1991). The first 100m is the dominant layer penetrated by most of the existing boreholes of the River State Water Board, private operators and owners. The three main aquiferous zones identified up to maximum depth of 300m: the Upper unconfined sub-aquifer with thickness from 50m to 100m, the Middle semi-confined Sub-Aquifer which consists of thick medium to coarse grained sands, inter-fingering with thin clay lenses and fine clayey sands. This section extends from about 100m to 200m depth and the Lower confined sub-aquifer which extends from about 200m to 300m depth, and consists of coarse grained sands and gravels with some clay intercalates. This is characterized by well high yields.

GEOELECTRIC MODEL PARAMETERS FOR AQUIFER CHARACTERISATION

Considering a unit square of cross sectional area of a group of n-layers of infinite lateral extent. From Darcy's law the quantity of water (Q) discharged in unit time is given as

$$Q = K\,A\,I \qquad (1)$$

where K is Hydraulic conductivity, I is Hydraulic gradient and A the cross sectional area through which water percolates. Here Q is a scalar quantity, similarly, the differential equation for current flow according as in Ohm's law is given as

$$J = \sigma E \qquad (2)$$

where J is current density E is electric field intensity, σ is the electrical conductivity.
The total transverse unit resistance R is given by

$$R = \sum_{i=1}^{n} h_i \rho_i \qquad (3)$$

where h_i and ρ_i are layer thickness and resistivity of i[th] layer in the section, respectively.
The total longitudinal Conductance 'S' for the unit square can be shown as

$$S = \sum \frac{h_i}{\rho_i} \qquad (4)$$

But the longitudinal layer conductance, S_i can also be represented by

$$S_i = \sigma_i h_i \qquad (5)$$

where σ_i is the layer conductivity, which in this case is analogous to the layer transmissivity, T_{ri} used in groundwater hydrology. The aquifer transmissivity is the product of aquifer thickness (h) and hydraulic conductivity (K) expressed as

$$T_{ri} = K_i h_i \qquad (6)$$

where K_i is the hydraulic conductivity of the i[th] layer of thickness h_i, R and S of above equations called Dar Zarrouk parameters which have been shown as powerful interpretational aids in groundwater studies, (Parasnis, 1986). The analytical relationship between aquifer transmissivity T and Transverse resistance R on one hand, and between the transmissivity and aquifer longitudinal conductance S on the other, (Niwas and Singhal, 1981)

$$T_{ri} = K\sigma R = \frac{KS}{\sigma} = Kh \qquad (7)$$

In ground water resources management, the product Kσ remains fairly constant, Niwas and Singhal (1981), Onuoha and Mbazi (1988). In this case knowing the values of K from the existing boreholes and σ from the sounding interpretation around the boreholes, one can estimate the transmissivity and its variation from place to place from determination of R or S for the aquifer.

METHODOLOGY

Eight Vertical Electrical Sounding were carried out at the study area pumping station using the Schlumberger array along some designated areas of the station. The ABEM SAS log 300B Terrameter was used with a maximum electrode spacing ($\frac{AB}{2}$) of 100 – 300m. At every VES point, the apparent resistivity (ρ_a) was automatically displayed on the monitor of the Terrameter and the corresponding electrode spacing ($\frac{AB}{2}$) and ($\frac{AM}{2}$) were recorded. The Schlumberger configuration was used because it is capable of isolating successive hydrogeologic layers beneath the surface by comparing their resistivity contrast, (Dobrin, 1976). The depth probed was limited by the space available in the premises to a maximum of AB = 600m. The field parameter obtained from the resistivity meter was resistance R(Ω) which was then multiplied by its corresponding Geometric Factor (G) to obtain the resistivity needed for the interpretation. The existing downhole and strata logs and pumping test data were all assessed in the Corporation for the study. The field results of the surveys are presented in Tables 1, 2 and 3.

RESULTS AND DISCUSSION

The summary of computer results and inferred lithology of the Vertical Electrical Soundings (VES) data are presented in Table 1 and Figure 3 respectively, while the plotted results of apparent resistivity against its corresponding current electrode spacing (AB/2) are presented in Figure 2. One-dimensional invasion software IP12Win was used for the VES data analysis and interpretation. The VES data showed a four layer case in the area with thickness 0.4 – 67.3m and resistivity of 86.3 - 4732Ωm. The total depth encountered at the vicinity of VES was 84.8m, which is in agreement with the existing borehole depth at the station. Further analysis revealed the geoelectric section. The top layers consist of dry sandy soil (lateritic sand) as depicted by strata log of the existing borehole. The second and third layers consist of fine grained sands with intercalation of sandy clay. The fourth layer consists of medium to coarse sands. This layer constitutes the water – bearing zone with considerable thickness. This is confirmed by the existing strata log showing medium to coarse sand at depths varying from 15m to 84m, though this was restricted by space for deeper probe. The producing aquifer extends from sandy layer beyond the present probe depths, (Figure 3). This layer, though not completely resolved due to limited space, may represent another water saturated zone since there is no saline water proximity.

The aquifer characteristics of the area as depicted in wells 4 and 8 are displayed in Table 2. Based on the geology of the area, lithologic inferences were made from the interpreted data. High transmissivity (> 400m^2/day) values recorded over most parts of the area agreed with the geology of the Benin formation (coastal plain sands) consisting of fine-medium-coarse grained sands. Again, the relatively low electrical conductivities confirms borehole's high yield experienced in the area with yield as high as 436.8m^3/hr. With the hydraulic conductivity values obtained from the pumping test analysis of the existing boreholes within the area, electrical conductivity and transverse résistance obtained from the sounding result, we can estimate the transmissivity of the aquiferous zone and its variation from place to place.

This can be achieved using analytical relationship between aquifer transmissivity and transverse resistance in one part, and between transmissivity and longitudinal conductance in the other parts (Equations 6 and 7). The isopach contour map of the thickness of the aquiferous zones shows comprehensive geohydrological information about the area, namely the variation in thickness of the alluvial cover. The aquiferous zone appeared thick enough for drilling of a productive borehole over the entire area of study, but the isopach and water level distribution maps constructed from the VES results (Figures 4 and 5), show that this aquifer is highly variable in thickness, being thicker in the Southern part of the study area.

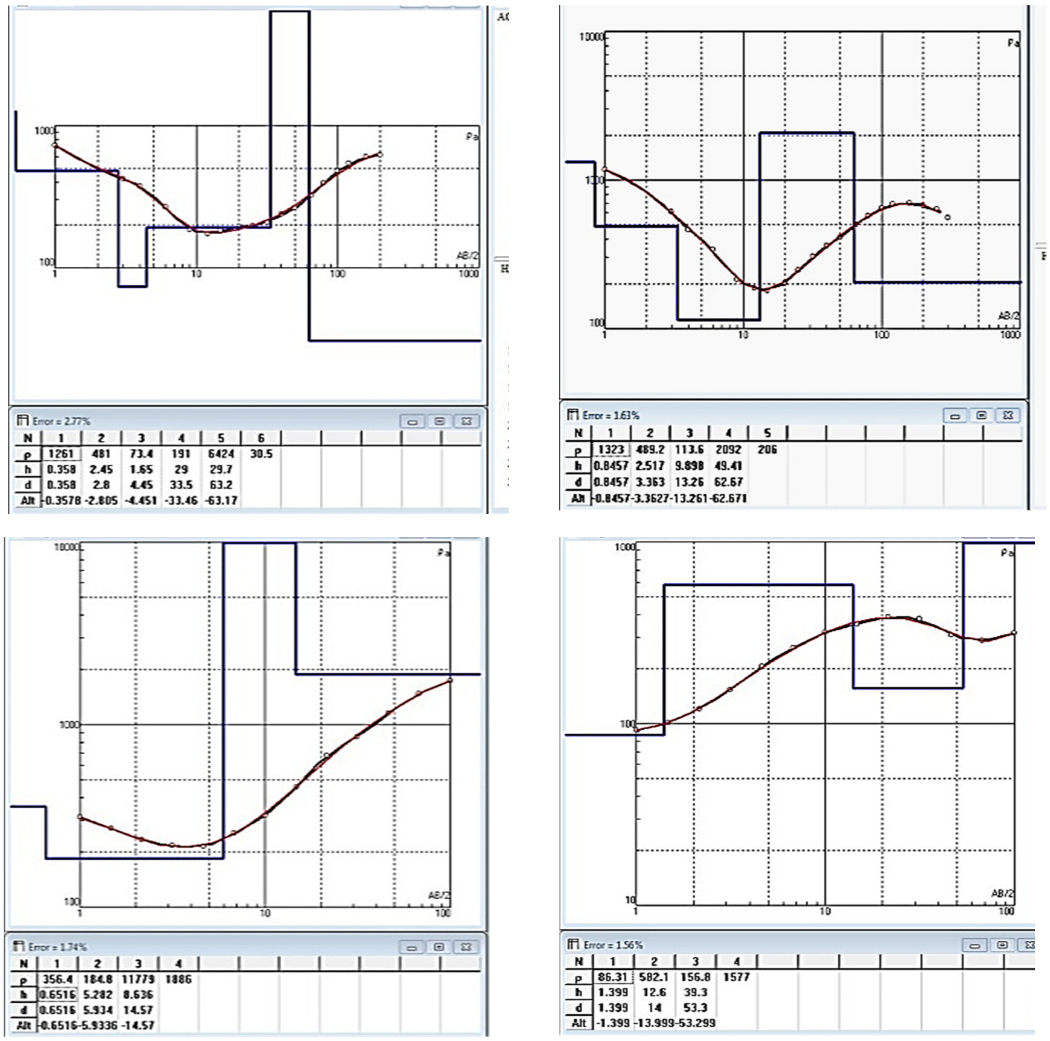

Figure 2. Field sounding curves and interpretative results at Rumuola Pumping station

VES No	Layer 1		Layer 2		Layer 3		Layer 4		Layer 5		Total Depth (m)
	ρ1 (Ωm)	h1 (m)	ρ2 (Ωm)	h2 (m)	ρ3 (Ωm)	h3 (m)	ρ4 (Ωm)	h4 (m)	ρ5 (Ωm)	h5 (m)	
1	1323	0.8	113.6	2.5	2092	9.8	206	49.4			62.7
2	1261.1	0.4	481	2.45	734	1.65	191	29	6424	29.7	63.2
3	86.3	1.4	582.1	12.6	156.8	39.3	1577				53.3
4	356.4	0.6	184.8	5.3	11779	8.6	1886				14.5
5	897	1.7	149	15.9	1303	67.3	220				84.8
6	836	1.3	361	2.0	119	4.2	206	22	1163		29.5
7	536	2.7	55.4	3.2	4732	13.7	283				19.6
8	104	0.5	687	0.7	51	4.1	2361	36	339		41.3

Table 1. Summary of Results from interpreted VES points

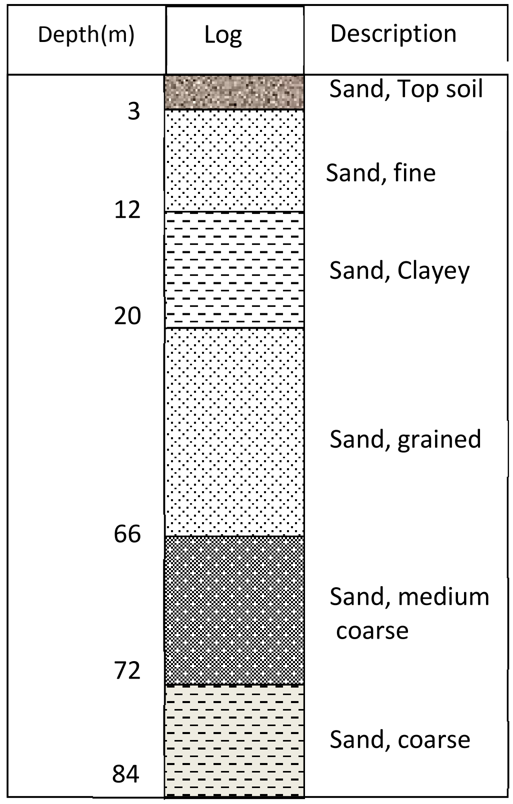

Figure 3. Typical strata log at the study area pumping station.

SN	Parameters	BH 4 VES 3	BH 8 VES 5
1	Pumping test field data of hydraulic conductivity, K (m/day)	14.56	9.44
2	Screen length (m)	15	15
3	Transmissivity of the aquiferous zone (m^2/day).	436.32	433.73
4	Aquifer thickness, h (m)	39.3	67.3
5	Longitudinal conductance (Ω^{-1})	0.0064	0.00077
6	Kσ value.	0.93	0.0073
7	Resistivity of aquiferous zone (Ω-m)	156.8	1303
8	Specific capacity (m^2/hr/m)	20.07	59.52
9	Discharge, Q (m^3/hr)	436.8	434.4
10	Layer conductance, σh.	9×10^{-5}	13.8×10^{-5}
11	Transverse unit resistance, hρ	6162.24	87691.9

Table 2. Aquifer parameters for Wells 4 and 8 at Rumuola pumping station.

S/N	Borehole no	Coordinates		Water level Distribution (m)
		Easting	Northing	
1	BH-5	279009	534939	14.5
2	Old BH-5	278986	535933	14.5
3	BH-6	279123	534981	13.7
4	Old BH-6	279087	534969.9	13.7
5	BH-7	278685	534965	11
6	BH-8	278822	535006	10
7	BH-10	279100	535071	10
8	BH-11	278514	535024	8.5
9	BH-12	278604	535024	10
10	BH-13	278702	535085	10
11	BH-14	278794	535166	10.5
12	BH-15	278900	535186	9.5
13	BH-16	279005	535207	11

Table 3. Borehole coordinates and water level distribution at Rumuola pumping station.

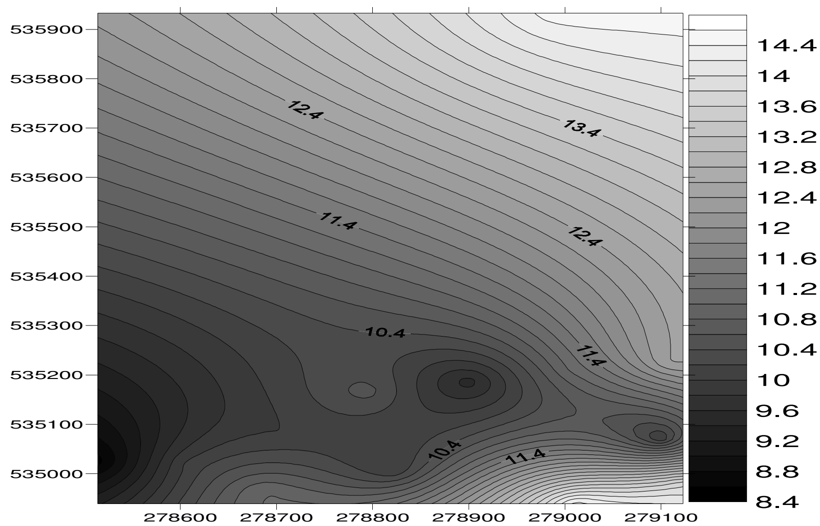

Figure 4. Contour map of the water level distribution pattern

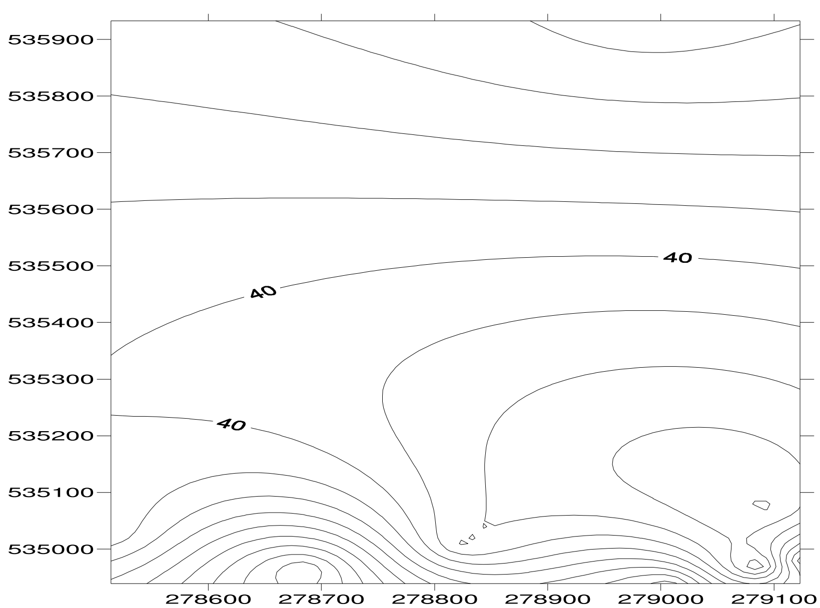

Figure 5. Isopach map of the aquiferous zone.

CONCLUSION

The entire surveyed area is suitable for drilling water boreholes considering the amount of groundwater in the place. Productive well depth in the area is in excess of 100m. The aquifer may extend to about 200m beneath the subsurface and the limit of the aquifer and the layers beneath it could not be ascertained due to limited space for electrode spread. High transmissivity recorded in this survey also agrees with the geology of Benin Formation as well as borehole data of the station. Plain sands consisting of medium – coarse grained sands indicates high prolific yield of aquifer formation. Groundwater potential is very high in the area which is compensated by the high level of groundwater recharge in the region.

However, the close agreement between the values obtained as well as the aquifer hydraulic conductivity from analysis of VES data and those obtained from pumping test analysis, attest to the accuracy of the results of the study.

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