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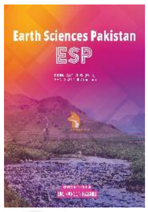

RESEARCH ARTICLE

AQUIFER DELINEATION USING SEISMIC REFRACTION METHOD IN RUMUOHIA COMMUNITY, EMOHUA L.GA, RIVERS STATE, NIGERIA

Minaibim Ellerton Abbey*, Iyeneomie Tamunoberetonari and Opiriyabo Ibim Horsfall

Department of Physics, Rivers State University, Port Harcourt 500001, Nigeria.
****Corresponding Author Email : abbeyminaibim@gmail.com***

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ABSTRACT

Groundwater is a major source of water supply throughout the world. Its dependence is at the increase, so is highly necessary to ensure that there is a significant supply of potable water with high quality. On the verge of seeing these problems, we investigated shallow aquifer in Rumuohia community in Emohua local government area, Rivers State, Nigeria which aimed at utilizing seismic refraction method to delineate depth to shallow aquifer and geological structure of the terrain at five selected locations. The analysis of the result shows two layers with the presence of sand-gravel and clay lithologies. Layer 1 in all five locations is made up of clay with an average velocity of 274.83m/s with a thickness range of 4.88m to 9.98m at an average of 7m. Layer 2 in two locations is made up of sandy clay. In one location, it is clay while in the remaining two locations they are sand with gravel (dry), which infers a potential aquifer with an average velocity of 422.63m/s. The sand being present indicates a good aquifer, and clay serves as a stopper for the sand since it tends to go through compaction by overburden pressure. The study area is generally a good site for a borehole with a high tendency for potable water supply.

KEYWORDS

Groundwater, Aquifer, Seismic refraction, Lithologies

1. INTRODUCTION

The problem of potable water for human consumption has become more severe within developing countries, like Nigeria. A very small percentage of the rural communities in Nigeria are supplied with pipe-borne water. A great number of them rely heavily on the water from streams, ponds, and some hand-dug wells, which may be harmful and disease-prone. The rural dwellers are prone to water-borne diseases such as typhoid, cholera, diarrhea, hepatitis, gastrointestinal problems, etc. More so, exposure to these diseases has socio-economic effects on the people (ASTM, 2000). They spend so much on their health and loss so much time in the pursuit of their economic activities. For loss of time for real economic activities, the cost of living in the areas tends to be high. Upon these, giving the rural communities quality pipe-borne water becomes imperative. Amidst such rural communities is the Rumuohia community, in Emohua Local Government Area of Rivers State in Nigeria.

This is our study area. In time past, some bore-holes were drilled in the Rumuohia community. Some dried up with time; some never yielded water. It is, therefore, necessary to delineate the aquifers in the area to drill sustaining bore-holes. Several geophysical approaches are employed in delineating aquifers in an area. Amongst these are resistivity, up-hole and down-hole, seismic reflection, and refraction methods. In this study, we are adopting the seismic refraction approach to delineate aquifers in the community. Seismic refraction is a geophysical technique for determining the thickness of fundamental geologic layers, water table depth, bedrock surfaces, engineering site characterisation, petroleum and mineral deposits. To characterize the route and velocity of the elastic disturbance in the ground, the subsurface is analyzed by generating arrival time and offset distance information. A hammer, explosives, weight drop (thumper truck), and seismic vibrator are used to create wave disruption in the subsurface.

The first arrival time from the energy source is measured by detectors (geophones) spaced at regular intervals. The velocities and depths of the distinct strata can be estimated using the recorded signals (data) presented on time-distance graphs. This is plausible since the wave disturbance's rays (continuum points on the growing wavefront) follow a direct path and are the first energy to arrive at the close-in geophones. These rays are refracted at subsurface boundary layers where the elastic and density characteristics of the subsurface differ. The critically refracted beam follows the layer interface at the lower layer's velocity and continually "feeds" energy back to the surface, allowing the line of geophones to detect it (Haeni, 1986). According to a seismic wave's travel duration is determined by the medium it passes through; velocities are greatest in solid igneous rocks and lowest in unconsolidated materials (clay, silt, sand, and gravel) (Todd, 1959).

The more the formations and their borders can be determined, the more changes in seismic wave velocities are dictated by changes in elastic characteristics. The structure and geologic history of sedimentary rocks are more important than mineral composition. Wave velocity is reduced by porosity but increased by water content. Seismic refraction methods have been used in a number of investigations across the world to determine groundwater potential and lithology (Burwell, 1940; Sjogren and Wagner, 1969; Galfi and Palos, 1970; Followill, 1971; Shtivelman, 2002; Sundararajan et al., 2004; Venkateshwara et al., 2004; Alhassan et al., 2010; Amir et al., 2012; Anomohanran, 2012; Bery, 2013; Thomas et al., 2013; Osumeje and Kudamnya, 2014; Adewoyin et al., 2016). Importantly, some researchers established that seismic refraction techniques may reliably detect the depth of water in sandy environments (Galfi and Palos, 1970).

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They used a single-channel seismograph, a sledgehammer as the sound source, and 3.3-foot geophone spacing in their experiment. They calculated a depth to the water table of 13.3 feet, which matched the well log data of 13.1 feet. Furthermore, the up/downhole shooting technique has also been used to establish the weathering layer depth, thickness, and velocities in some parts of Niger Delta, Nigeria (Nwachukwu, 2001; Nwankwo et al., 2009; Adeoti et al., 2013; Anomohanran, 2014). More specifically, investigated up-hole/down-hole thickness in the Southwestern Niger Delta and discovered that the thickness of the low velocity weathered layer in the area ranges from 3.6 to 46.2 meters, with an average of 24.0 meters (Osagie, 2009). A group researcher conducted seismic refraction and resistivity studies in Igbogbo Township, South-West Nigeria, where they identified three layers: the first layer, which has a velocity of 150m/s to 336m/s and a thickness of 1.0m to 3.3m; the second layer, made up of lateritic clay and has a thickness of 4.5m to 10.5m and has a velocity of 578 to 878m/s (Ayolabi et al., 2009).

Igboekwe and Ohaegbuchu investigated the thickness and velocity of the weathering layer using the seismic refraction method, concluding that the findings are crucial in determining the time delays required for static adjustments during seismic reflection data processing (Igboekwe and Ohaegbuchu, 2011). In addition, some researchers investigated groundwater potential in portions of Rivers State, Nigeria, using the seismic refraction method (Nwankwo et al., 2013). Their findings revealed a three-layer subsurface model, with the aquifer layer having an average velocity of 500 meters per second and depths ranging from 12.52 meters to 26.56 meters. The refraction results were highly associated with the area's resistivity measurements, which revealed an aquifer depth range of 14.48m to 53.68m.

Nwosu and Emujakporue investigated the thickness and velocity of the weathered layer in Emohua town using the seismic refraction method and discovered two layers: the weathered layer and the sub-weathered layer (Nwosu and Emujakporue, 2016). The velocity and thickness of the weathered layer range from 255.55m/s to 312m/s and 1.60m to 1.89m, respectively. At an unknown thickness, the sub-weathered layer has a velocity varying from 346.94m/s to 368m/s. They concluded that their findings can be used in both groundwater exploration and site characterization in civil engineering. This study is aimed at utilizing the seismic refraction method to delineate depth to shallow aquifer and geological structure of the terrain in Rumuohia Community in Emohua local government area.

2. Location and Geology of The Study Area

Emohua Town is the headquarters of the Emohua Local Government Area in Rivers State, Nigeria. It consists of eight sub-communities, namely: Elibrada, Isiodu, Mbu-eto, Mbuitanwo, Oduoha, Rumuakunde, Rumuohia, and Rumuche. They are usually written with the suffix -Emohua attached to them such as Rumuohia-Emohua. Our selected area of study is Rumuohia-Emohua. It is located in the Niger Delta Sedimentary basin of Nigeria, with an area of 831km^2 (321 sq mi) and a population of 201,901 according to the 2006 census. It is located at Latitude 4°53'2" North and Longitude 6°51'39" East (Figure 1). On the West African continental margin, the Niger Delta sedimentary basin covers an area of around 200,000 square kilometers. The Akata, Agbada, and Benin Formations are the three stratigraphic units that make up this formation. The Akata Formation is a marine shale unit that is under-compacted in most areas and may contain lenses of exceptionally high-pressured siltstone or fine-grained sandstone. It is the face of the pro-Delta faction.

Agbada Formation is the for formation which directly lies on top of the Akata Formation, and it consists of a sequence of sand and sandstone bodies intercalated with shale. Local transgressions and regressions give rise to the intercalation of sands, sandstone, and shale. Agbada Formation ranges in age from Eocene to Holocene with about 3000 meters thick (Ugwu and Nwankwo, 2013; Weli and Ogbanna, 2015). The Benin Formation is the topmost unit of the Niger Delta. The formation is predominantly sandy containing over ninety percent grains of sand and sandstones, with a few shale intercalations which become more abundant towards the base. The formation generally exceeds 2000 meters in thickness and ranges in age from Miocene to Recent. The total thickness of sediments in the Niger Delta may be as much as 12,000 meters (Osumeje and Kudamnya, 2014).

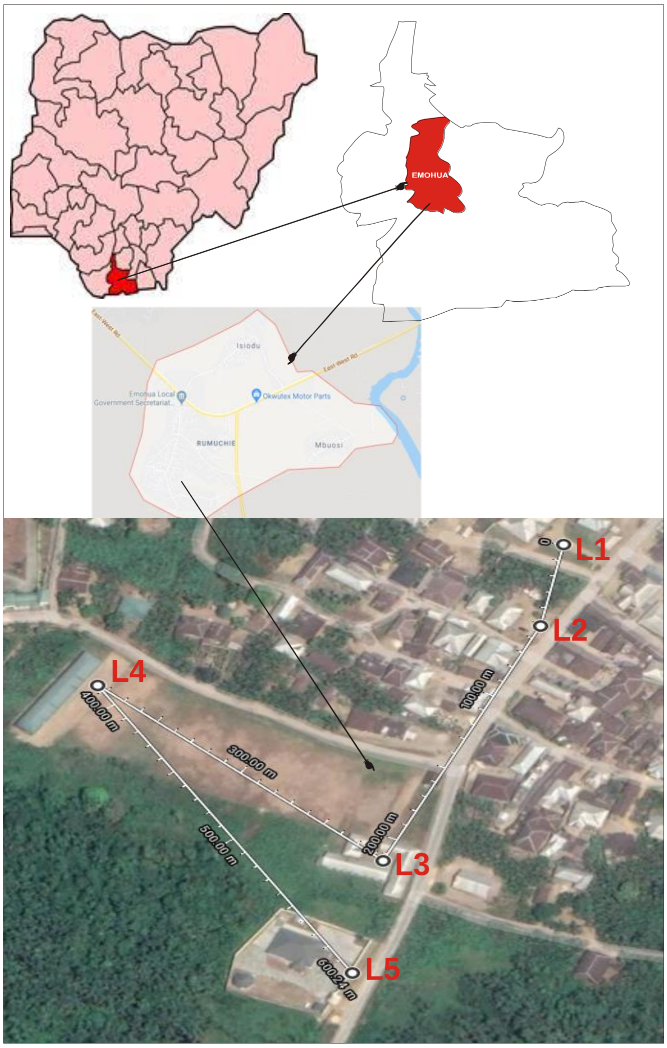

Figure 1: Map of the Study Area showing site locations of as L1, L2, L3, L4 and L5.

3. Methodology

3.1 Materials

The following materials were used: energy sources, geophones (sensor or detector), seismograph (recording device), a global positioning system (GPS), measuring tape, peg sticks, and 12 volts D.C battery.

3.2 Data Acquisition

A 12-channel seismograph (ABEM Terraloc Mark 6) was used with an energy source of a 16kg sledgehammer striking a steel plate. A total of five (5) in-line profiles at continuous profiling of 120metres were used. The technique consisted of laying out twelve (12) geophones at an interval distance of 10metres which is marked with tape and pegged in a straight line and recording arrival times from shot points produced by striking a 16kg sledgehammer onto a steel plate at the end of the geophone spread. The signals received by the geophones as obtained on the recording unit were displayed on the screen as traces and three strikes were made for sharp peaks and better troughs. The GPS and the compass were used to know the elevations and the bearing of the location under observation to the North Pole. The seismograph has an option for picking of arrival time automatically and the recording unit had digital incoming signals, thus random background noise caused by the ground vibrations can be minimized in the final record.

3.3 Data Processing

ReflexW version 3.0 was used to handle and interpret the seismic refraction data. The data collected from the field was subjected to different stages of processing to enhance the signal-to-noise ratio. The signal quality was improved by applying a bandpass filter (ranging from150Hz and 50Hz). Manually pick the first arrival times and the ray-tracing method is used to calculate the ray paths. The layers' velocities can be computed by taking the reciprocal of the slopes obtained by plotting the travel time against offset distance (Figure 2).

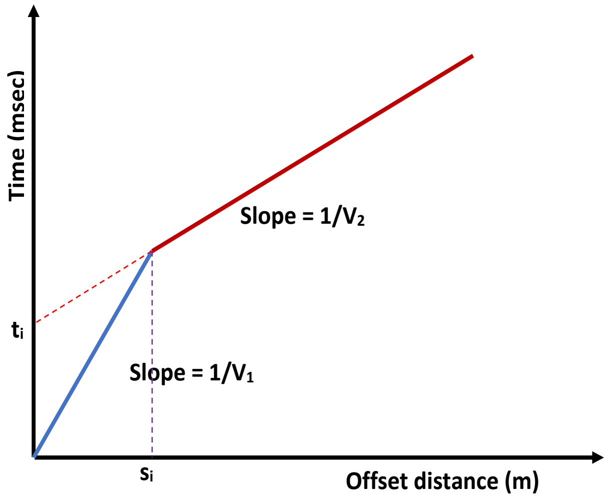

Figure 2: Travel-time graph for two-layered subsurface

Figure 2 above shows two layers model with velocities V_1 and V_2 and the depth (Z) to reflectors (boundaries) is estimated by using equation 1 or 2.

$$Z = \frac{1}{2} t_i \frac{V_2 V_1}{\sqrt{V_2^2 - V_1^2}} \tag{1}$$

$$Z = \frac{s}{2} \sqrt{\frac{V_2 - V_1}{V_2 + V_1}} \tag{2}$$

where V_1 is the velocity of the first layer; V_2 is the velocity of the second layer, s is the crossover distance and t_i is the intercept time from Figure 2.

4. Geological Interpretation/Results

Since it is a shallow subsurface survey, and the study areas are overlain by cretaceous and tertiary sediment. From standard data for P-wave propagation as shown in Table 1, we make inferences on the lithology.

Table 1: Established Standard P-Wave Velocity (Ugwu, 2010)

Rock Type	Standard P-Wave Velocities (m/s)
Granite	5520 – 5640
Sandstone	1400 – 4300
Limestone	1700 – 4200
Clay	110 – 2500
Loose Sand	1800
Coarse Sand (wet)	1150 – 1670
Sand with gravel (wet)	690 – 1150
Sand with gravel (dry)	430 – 690
Sand clay	360 – 430

The summary of results of the seismic refraction surveys carried out at five (5) locations in the Rumuohia community is presented in both tables and figures.

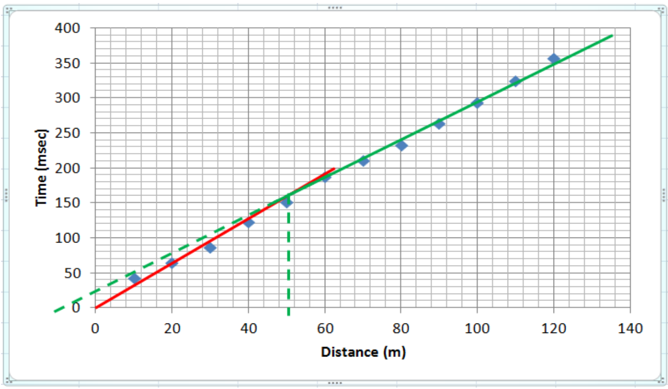

Figure 3: Travel time Vs Offset distance of Church (DLBC)

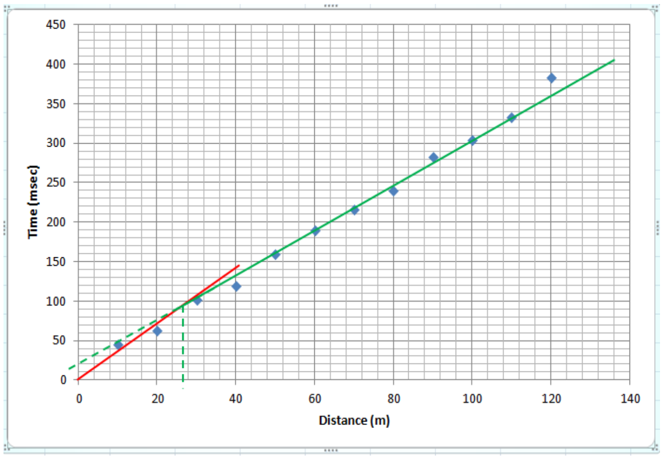

Figure 4: Travel time Vs Offset distance of Townhall/Playground

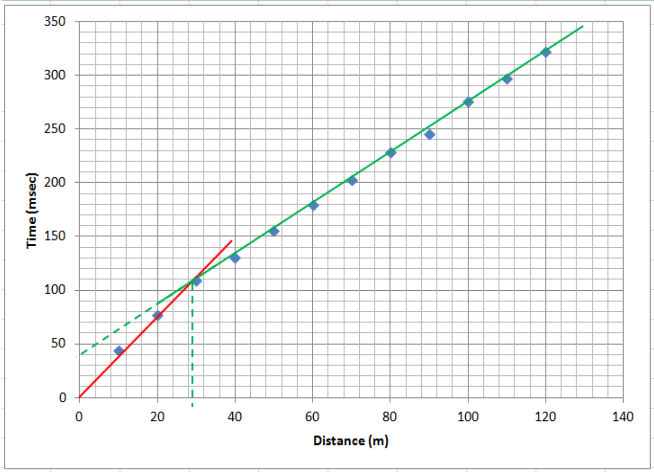

Figure 5: Travel time Vs Offset distance of Primary School

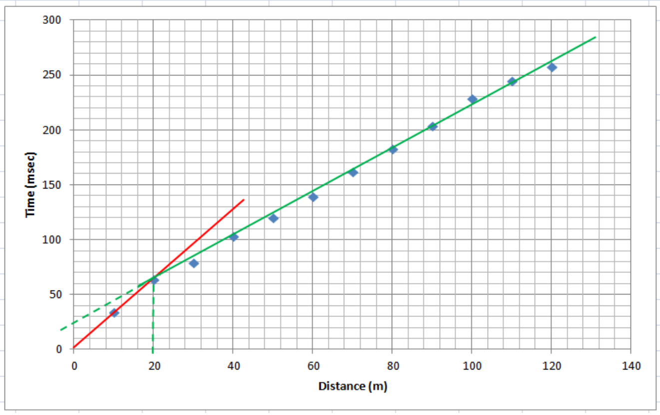

Figure 6: Travel time Vs Offset distance of Secondary School

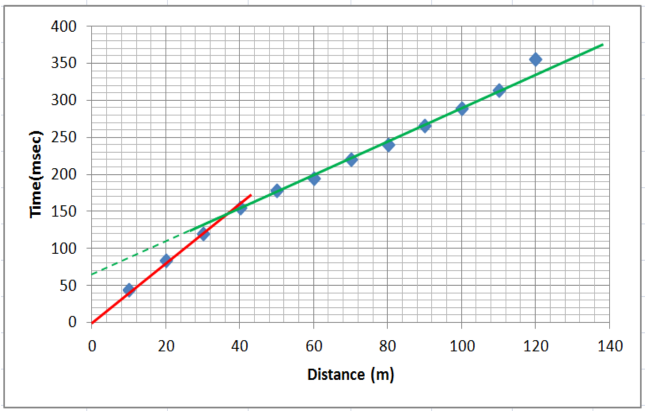

Figure 7: Travel time Vs Offset distance of Big House

Table 2: Results Summary

SN	Location	Coordinates	Layer 1 Velocity V_1 (m/s)	Geologic Implication	Layer 2 Velocity V_2 (m/s)	Geologic Implication	Thickness (m)
1	Church (DLBC)	4.872393N, 6.856478E	315.79	Clay	375.00	Sandy Clay	7.32
2	Town Hall	4.871740N, 6.856473E	240.00	Clay	350.00	Clay	5.83
3	Primary School	4.870024N, 6.855355E	266.67	Clay	428.13	Sandy Clay	6.99
4	Secondary School	4.871051N, 6.854378E	311.69	Clay	506.67	Sand with Gravel (dry)	4.88
5	Big House	4.869314N, 6.855433E	240.00	Clay	453.33	Sand with Gravel (dry)	9.98

5. Discussion

The graphs (Figure 3, 4, 5, 6, and 7) showed that the model is of two layers namely: layer 1 and layer 2. At the first location: Church, layer 1 has a velocity (V_1) of 315.79m/s at a depth of 7.32m and layer 2 a velocity (V_2) of 375m/s at an unknown depth. In comparism with the standard P-wave velocities, it shows that layer 1 is made up of clay lithology while layer 2 is of sandy clay lithology; see Table 1 and 2. At the second location: Town Hall, layer 1 has a velocity (V_1) of 240m/s at a depth of 5.83m and layer 2 a velocity (V_2) of 350m/s at an unknown depth. In comparism with the standard P-wave velocities, it shows that both layers are made up of clay. At the third location: Primary School, layer 1 has a velocity (V_1) of 266.67m/s at a depth of 6.99m and layer 2 a velocity (V_2) of 428.13m/s at an unknown depth. In comparism with the standard P-wave velocities, it shows that layer 1 is of clay while layer 2 is of sandy clay. At the fourth location: Secondary School, layer 1 has a velocity (V_1) of 311.69m/s at a depth of 4.88m and layer 2 a velocity (V_2) of 506.67m/s at an unknown depth. In comparism with the standard P-wave velocities, it shows that layer 1 is of clay while layer 2 is of sand with gravel (dry).

At the fifth location: Big House, layer 1 has a velocity (V_1) of 240m/s at a depth of 9.98m and layer 2 a velocity (V_2) of 453.33m/s at an unknown depth. In comparison with the standard P-wave velocities, it shows that layer 1 is of clay while layer 2 is of sand with gravel (dry). In summary, layer 1 in all five locations is made up of clay with an average velocity of 274.83m/s. Layer 2 in two locations (Church and Primary School) are made up of sandy clay. In the Townhall location, it is clay while in the remaining two locations (Secondary School and Big House) it is sand with gravel (dry), which infers a potential aquifer with an average velocity of 422.63m/s. The thicknesses of layer 1 in all locations are in the range of 4.88m to 9.98m with an average thickness of 7m while that of layer 2 is infinite or unknown due to the energy source (sledgehammer) which cannot generate a stronger seismic signal when compared to explosives. More so, the above analysis reveals that seismic velocity increases with depth, mainly because of compaction. Some boreholes drilled in the Rumuohia community yielded water for a very short period and stopped because people neglect to delineate the aquifer before drilling. Also, this can be attributed to the fact that some people drill during the wet season when the water table is closed to the surface and during the dry season the well becomes dried up.

6. Conclusion

In this study, we investigated the delineation of shallow aquifers in the Rumuohia community at five selected locations using the seismic refraction method. The analysis of the result shows two layers with the presence of sand-gravel and clay lithologies. The sand present indicates a good aquifer, and clay serves as a seal for the sand since it tends to undergo compaction by overburden pressure. Additionally, it is observed that shallow aquifers (which are the first aquifer units) can be located at depths not less than 7m since the energy source used was minimal/not strong enough to image deeper horizons; the study area is generally a good site for borehole with a high tendency for good water supply for home use. These results agree with existing kinds of literature in this domain of study.

Recommendation

This study is not an end in itself. Upon this we make the following suggestions/recommendations for further studies:

- Increase energy source to delineate more layers.
- The result could be used for further research and also as a guide to scholars for future project works.
- The result can be used as a guide for groundwater studies in the Rumuohia community.
- It is therefore recommended that to drill a shallow water borehole in the Rumuohia community the depth should not be less than 7.00 meters.
- Further studies can be carried out to determine the recharge capacity of the aquifer(s) and production rate.
- Adequate measures can also be put in place not to create septic tanks in proximity with regions marked for groundwater production to avoid pollution.
- Regular testing of water quality should be encouraged to forestall the incidence of water-borne diseases.

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