Journal of the Nigerian Association of Mathematical Physics
Volume 52 (*July & Sept., 2019 Issue*), **pp281 – 284**
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SHALLOW SEISMIC REFRACTION METHOD FOR GROUNDWATER STUDIES IN OFUSU, EDO STATE

Edward O. Osagie

Benson Idahosa University, Faculty of Science, Department of Physical Science, Benin City – Edo State

Abstract

A shallow seismic refraction survey was conducted in a sedimentary environment to determine the suitability of the method for groundwater studies in Ofusu, Edo State. An interpretation of the data using the time-intercept method showed that the velocity of sound wave in the aquifer was 1.50 km/s. The thickness of this unit is about 25m. The depth to the water table was found to be about 22m. The velocity of the sound wave in the bedrock was 4.25 km/s while the velocity in the alluvium was 0.33 km/s with a thickness that varied from 0 to about 3m. The seismic refraction method was found to be useful in defining the geometry of the aquifer.

1.0 Introduction

Seismic refraction methods have been used extensively in petroleum, mineral and engineering investigations and to some extent for hydrogeophysical applications. Recent advances in equipment, sound sources and computer interpretation techniques make seismic refraction methods highly effective and economical for obtaining data for groundwater studies. The importance of water for the most basic human needs cannot be over-estimated. Many countries suffer from a lack of fresh surface water. Therefore, it is necessary to exploit groundwater reserves.

Shallow seismic refraction survey was conducted in a sedimentary environment in Ofusu, Edo State. The aim was to determine (i) the depth of the underlying bedrock, (2) the depth of the water table and (3) the saturated thickness of the aquifer.

2.0 Geology of the Area

The study area is approximately located by the geographical coordinates of Latitude 5.32^0 and Longitude 5.15^0. The area is directly underlain by the Benin Formation which consists largely of sands/sandstone with lenses of shale and clays [1].

3.0 Theory of Seismic Refraction

The foundation of seismic refraction theory is Snell's law. It governs the refraction of a sound wave or light ray across the boundary between layers of different physical properties. As sound waves travel from a medium of low seismic velocity into a medium of higher seismic velocity , some are refracted toward the lower velocity medium and some are reflected back into the first medium. As the angle of incidence of the sound ray grazes the surface of the contact between the two media, most of the compressional energy is transmitted along the surface of the second layerat the velocity of sound in the second layer. As this energy propagates along the surface, it generates new sound waves in the upper medium.

This is referred to as Huygens's principle. It states that every point on an advancing wavefront can be required as the source of a new sound wave. This in turn propagates back to the surface at the critical angle and at the seismic velocity of layer one. Therefore, for seismic refraction to work, the velocity of sound in each deeper layer must be greater than in the layer above it. When condition is met, the refracted wave arrives at the earth's surface where it can be detected by a geophone which generates an electrical signal and sends the signal to a seismograph. From a series of geophones placed on the ground, the seismic arrival time versus the shot-to-detector distances can be plotted to give a time-distance curve. [2 ─ 4]

4.0 Field Equipment

The MCSEIS 160 field equipment is a portable 12 or 24 channel seismograph which provides (1) recording and sensitive digital stacking of data, (2) high resolution display of field data and recording parameter on CRT screen, (3) high resolution thermal printer for 24 channels seismic data and record, (4) a standard interface for attaching an IBM compatible personal computer, allowing external storage of all seismic record and a transfer of these records back to the MCSEIS 160.

Corresponding Author**:** Edward O.O., Email: eosagiee@yahoo.com, Tel: +2348083402968

Function keys and keyboard on the front panel with related interface circuitry provides the operator control of data acquisition module. The microprocessor or controlled functions from the front panel responds to touch control soft key operation, no rotary switches are used. Software menus and selected parameters are displayed on the CRT for system set up and operation. The light weight seismograph operates from an external 12-volt battery. The battery voltage was constantly monitored on the display unit. Energy source was a sledgehammer and a striker for a sound source in the seismic refraction survey.

Figure 1: Mc SEIS-SX Seismograph Equipment

5.0 Data Acquisition and Analysis

For this survey, 12 geophones ware used. The shot offset was 15m from the first geophone station. The geophones were fixed at 15m perpendicular to the firing line which consist of the 12 channel terminals to the geophones. The last geophone (number 12) was 180m from the shot offset. The trigger switch was also fixed to the seismograph through the connector and placed under a flat plate. When the system's CRT was displaying or at status, a heavy metal weighing about 5kg was dropped on the metal plate in order to send an artificial seismic wave to the ground through the triggered switch and a record was displayed on the CRT at the display module. The same procedure was carried out for the reverse shooting by taking the shot point to the other end of the firing line. Figure 1 shows the McSEIS – SX seismograph field equipment.

The record of Figure 3 is a photograph of an actual field record printed in clipped mode. It shows discernible first arrival. In Figure 2, the first five geophones form a line that has an inverse slope of approximately 1.5km/s. This velocity is characteristic of the speed of sound wave in saturated, unconsolidated sediments which in this area is the sandy aquifer. The thickness of this unit is about 22m. The geophones 6 through 12 form a line that has an inverse slope value of 4.25 km/s , which in this environment is the bedrock.

A special layout of the geophones was made to determine the velocity of the unsaturated alluvium. At distances, less than the crossover distance, the sound wave travels directly from the sound source to the detectors. Because this compressional wave has traveled a known distance in a known time, the velocity of this layer can be calculated. This velocity was found to be about 0.3 km/s. The thickness of this unit varies from 0 to about 3 km. Figure 4 shows line $A – A^1$, along the axis of the aquifer and was used to determine the saturated thickness of the aquifer.

That is,

$$v = \frac{\Delta x}{\Delta t}$$

where v is the velocity of sound inlayer one
Δx is the change in distance
and Δ t is the change in time.

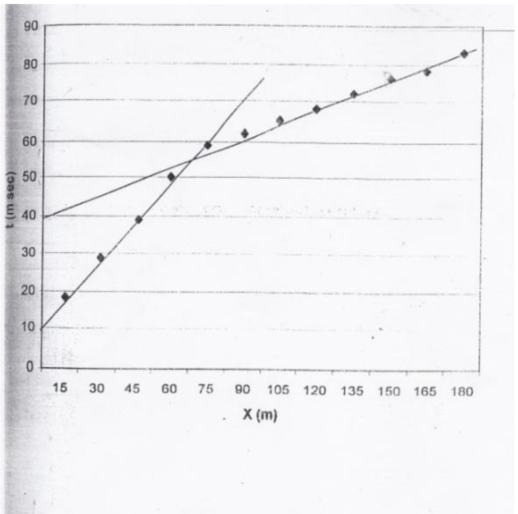

Figure 2: Time Distance curves for refraction survey

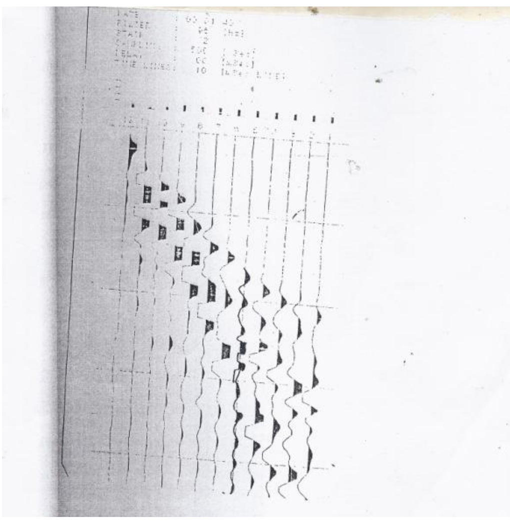

Figure 3: Reverse shooting field record on thermal paper

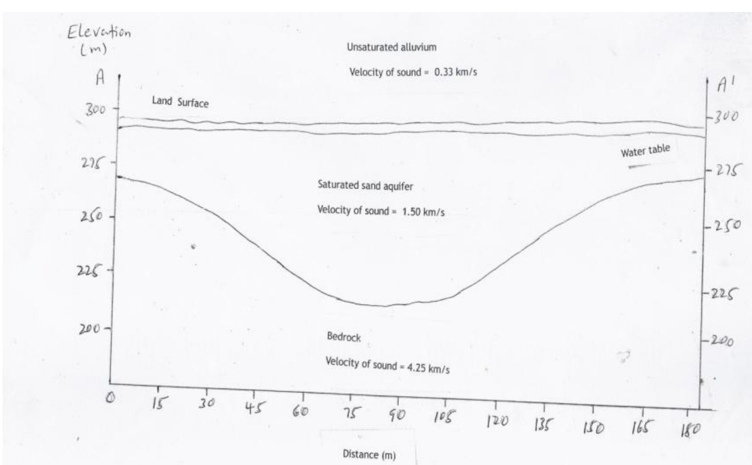

Figure 4**:** Seismic refraction profile, Ofusu

6.0 Discussion

The vertical electric sounding (VES) method is a very well established technique for groundwater exploration in Nigeria. Obiora and Onwaka [6] used the method for groundwater exploration in Ikorodu, Lagos State. Ikorodu is directly underlain by the Benin Formation similar to Ofusu in Edo State. They found using the VES method that the depth to the water table in Ikorodu was about 18 m. This is comparable to the depth of 22 m to the water table found in this study at Ofusu using the shallow seismic refraction method.

Otutu and Ujuanbi [7] carried out a study of the groundwater potential in Emu Kingdom in Ndokwa Land in Delta State using the VES method. Emu Kingdom lies on the sedimentary basin similar to Ofusu in Edo State. They found the depth to the water table to be about 15 m. This result is also comparable to the depth of 22 m to the water table found in this study at Ofusu using the shallow seismic refraction method.

Okolie, Osemeikhain and Asokhia [8] carried out a survey to estimate the groundwater potential in parts of the Niger Delta area using the geoelectric method. They found the depth to the water table to be about 30 m in Asaba. This is comparable to the depth to the water table of 22 m found in this study in Ofusu. These results substantiate the fact that shallow seismic refraction method can be effectively used for groundwater exploration in Nigeria.

7.0 Conclusion

Seismic refraction method which have long been used in exploration of minerals and petroleum can be effectively used in groundwater exploration. The technique was able to define the geometry of the aquifer in this study. It is an economical method to obtain data for groundwater studies. The data are relatively accurate. Depths to individual refractors are normally within 10 percent of the actual depths. [5] A comparison of the results from the shallow seismic refraction used in this study and the more established vertical electric sounding (VES) method which has been used for a long time in Nigeria shows that the results are comparable. Therefore, shallow seismic refraction technique is a valuable tool for conducting groundwater investigations in Ofusu and other geologically similar areas.

Acknowledgements

The author extends his appreciation to the Editor-in-Chief Prof. Idiodi and the anonymous reviewers for their constructive suggestions and comments which have improved the quality of the manuscript.

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