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Assessment of Groundwater Potential Using Seismic Refraction Method in Secha, Arba Minch, Ethiopia

Jagadeshan G, Gosaye B, Zinabe S and Abeje A
Department of Geology, College of Natural Science, Arba Minch University, Arba Minch, Ethiopia

Abstract: *Recently, there has been increased interest in the use of seismic refraction survey for the exploration of hydrogeological reservoirs. The aim of this study is to identify groundwater potential by means of seismic refraction profiles. Seismic refraction survey was carried out using 12 channel Oyo McSeis seismograph to obtain data in Secha, Arba Minch, Ethiopia. The seismic velocities distribution analysis indicated that, there are three different subsurface lithological zones ranging between (155 -512 m/s), (814-1437 m/s) and (1561-2400m/s). The depth to the groundwater saturated layers ranging from 36 m and 50 m. Gradual increase of seismic velocity indicate changes of lithological layers with vertical depth. This velocity increase may be due to the dense lithological formation which change vertically deep from unconsolidated alluvial and colluvial sediments to dry sand and then to weathered basalts. The seismic refraction profiles results show that the aquifer is a weathered basalt aquifer with average thickness of about 23 m.*

Keywords – *Aquifer, Basalt, Interface, Lithology, Travel time*

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I. Introduction

The seismic refraction survey is considered to be one of effective surface geophysical methods to understand the characteristics of subsurface lithology[5]. Seismic refraction methods have been commonly used for the identification of bed rock physical properties, oil/gas exploration, groundwater exploration, lithology, subsurface structure, folds and fault[6]. The seismic refraction method is based on measurements of the travel time of seismic waves refracted at lithological interfaces between subsurface layers of different velocities[5]. The seismic signal is produced into the subsurface via a shot point using hammer, weight dropped, vibrator and explosives. The seismic energy from the shot returns to the surface of earth by refraction at subsurface lithological interfaces and is recorded at distances much greater than the depth of investigation [7]. The method relies on the tendency of seismic velocities to increase with vertical depth, which sometimes makes it insensitive to low velocity seismic layers in the subsurface of earth. Based on the analysis of the field data, the seismic surveyor draws a profile showing the thickness of the subsurface layers and a good estimate of what geological materials they consist of [5]. Seismic refraction survey uses the process of critical refraction to infer interface depths and layer velocities. The data are usually presented as cross sectional plots representing P-wave path, velocities and depths to various interfaces.

Several studies have been carried out around the world on the seismic refraction method to identify groundwater potential and lithology. United Arab Emirate (Amir et al, 2012), Peru (Thomas et al, 2013), Nigeria (Osumeje and Kudamnya, 2014; Alhassan et al, 2014; Adewoyin et al, 2016; Anomohanran 2012), Israel (Shtivelman, 2002), Malaysia (Andy AB, 2013), India (Venkateshwara et al, 2004; Sundararajan et al, 2004)

II. Study Area

The study area forms a part of Ethiopian rift valley located in a southern nations nationalities and people's' region of Ethiopia. It is situated 12 km southwards from the Arba Minch town (Fig.1).

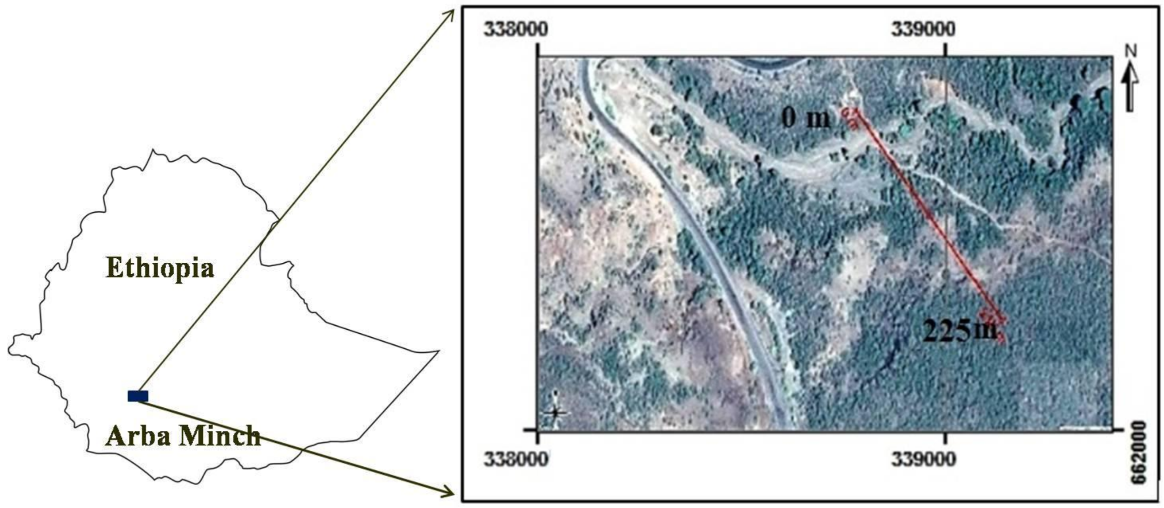

Fig. 1 Location of the study area

Study area characterized by semi arid and arid climate with temperature ranges from 18°C and 42°C and March is the warmest month of the year. The study area experiences warm and dry climate during summer from December to February and cold climate during winter from July to September. In winter, there is much less rainfall compared than in summer season.The annual average rainfall is about 818 mm, which is mainly received during the main wet season April to June and second wet season is September to October. Maize is the major crop and other crops such as, cotton, potato, sweet potato, corn, beans, mango and some other fruits and vegetable are also cultivated in the area. Topographically, the area is characterised by several hills forming undulating terrain. The altitude ranges between 1220-1311 m above sea level. The surface runoff has resulted into the development of dendritic drainage pattern in this area. The region comprises of rocks such as basalt, quaternary sediment, and quaternary alluvial and colluvial deposits. The Occurrence of groundwater in the study area is associated mainly by the basaltic rocks and minor alluvial aquifers.

III. Methodology

Seismic refraction survey was carried out in the study area, two profiles were surveyed using a 24-channel Oyo McSeis seismograph. The seismic data were acquired along a 225 m long profile at the foot scarp of the East African Rift. The continuous profiling, in-line shot seismic refraction method was used. The technique consisted of laying out 24 geophones in a straight line and recording arrival times from shot points produced by striking a 10kg sledge hammer into a steel plate at the end of the geophone spread. In order to reduce the noise level and enhance the quality of the seismic signal, the steel plate was strike four times and the acquisition was done in an area free of unwanted seismic signal and traffic noise. Twenty-four geophones were spaced 5meters apart to form a continuous profiling. The shoting point of the first profiles were 2.5, 27.5, 57.5, 92.5, 112.5 and 125 m. The shoting point of the second profiles were 125, 142.5, 167.5, 202.5, 222.5 and 225 m. Two profiles were overlaping to ensure continuity of data. Seismic refraction data were processed by pickwin and plotrefa software.

IV. Data Processing And Interpretation

The first step in processing Pickwin package was first used to select the first arrival breaks (Fig. 2a and Fig. 2b). After picking the first breaks for all the seismic events (Fig. 3a and Fig3b). A plot is then made showing the arrival times against distance between the shot and geophone positions. This is called a time-distance graph (Fig. 3). The Plotrefa package was used for the second stage of this interpretation. This package was used to carry out the time term inversion in order to generate the seismic tomography section of the surveyed area (Fig. 4). This inversion employs a combination of linear least square and delay time analysis to invert the first arrival for a velocity section. This process enabled us to assign the number of subsurface layers as depicted by the distance-time graph. After the layers were assigned, a tomography image of the profile was produced showing the number of lithological layers and the primary wave velocities of each layer. The information produced by the seismic tomography image is used to obtain other geologicall information as they relate to the study area region.

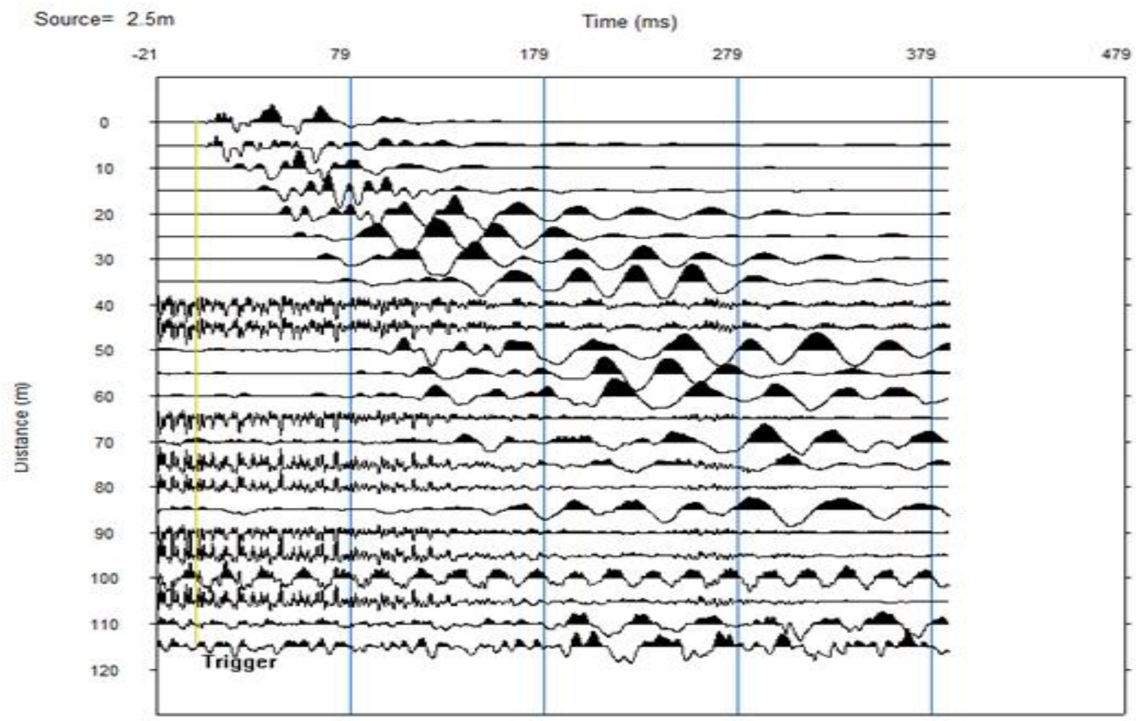

Fig. 2a Time and distance curve for profile 1

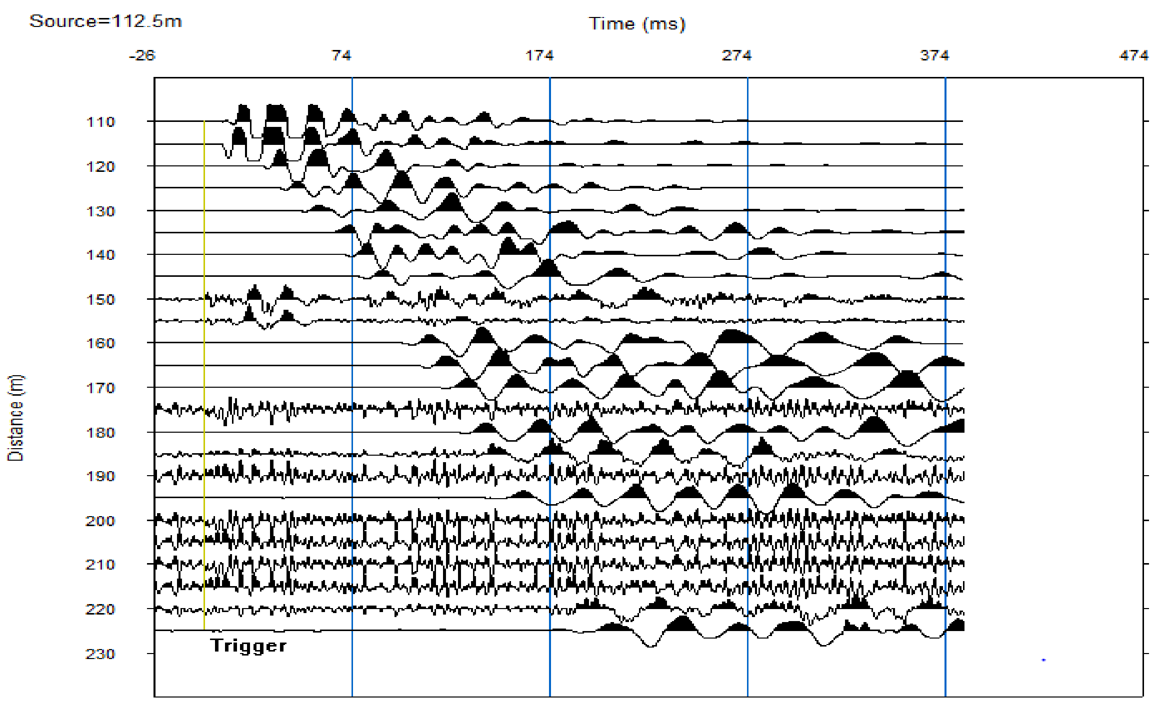

Fig.2b Time and distance curve for profile 2

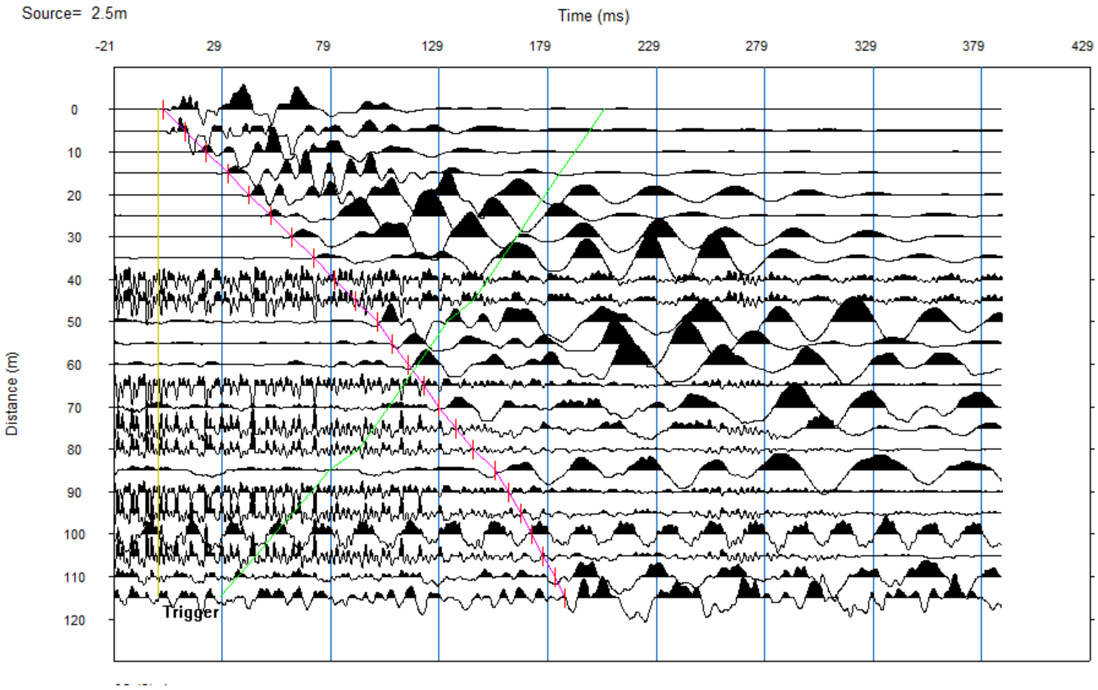

Fig. 3a Select the first pick arrival time for profile 1

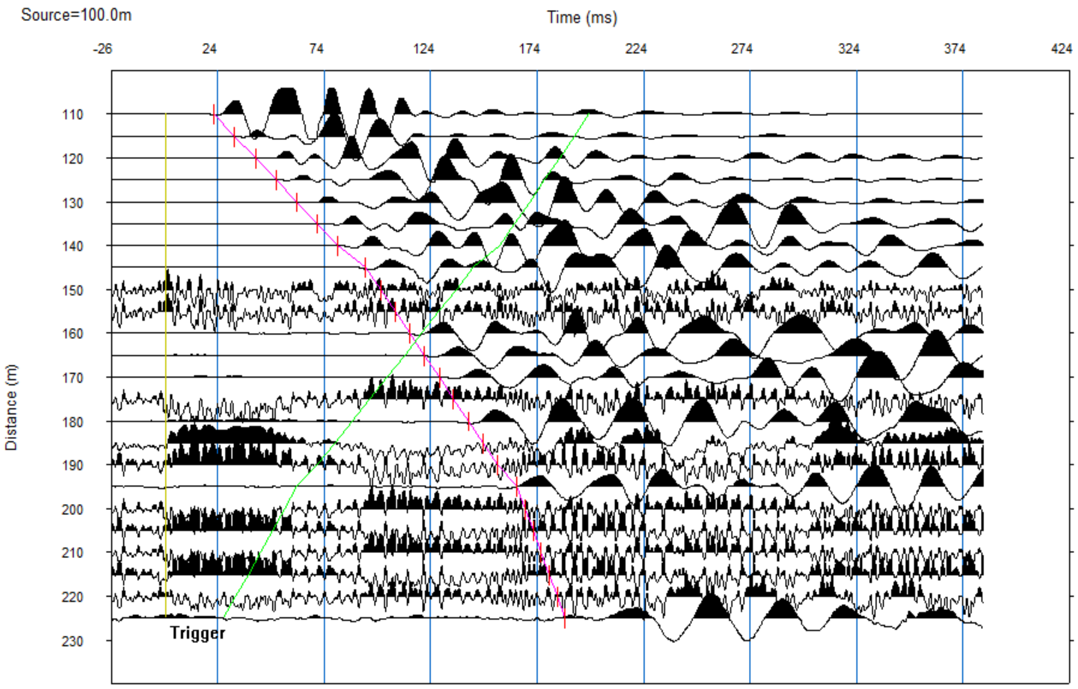

Fig 3b Select the first pick arrival time for profile 2

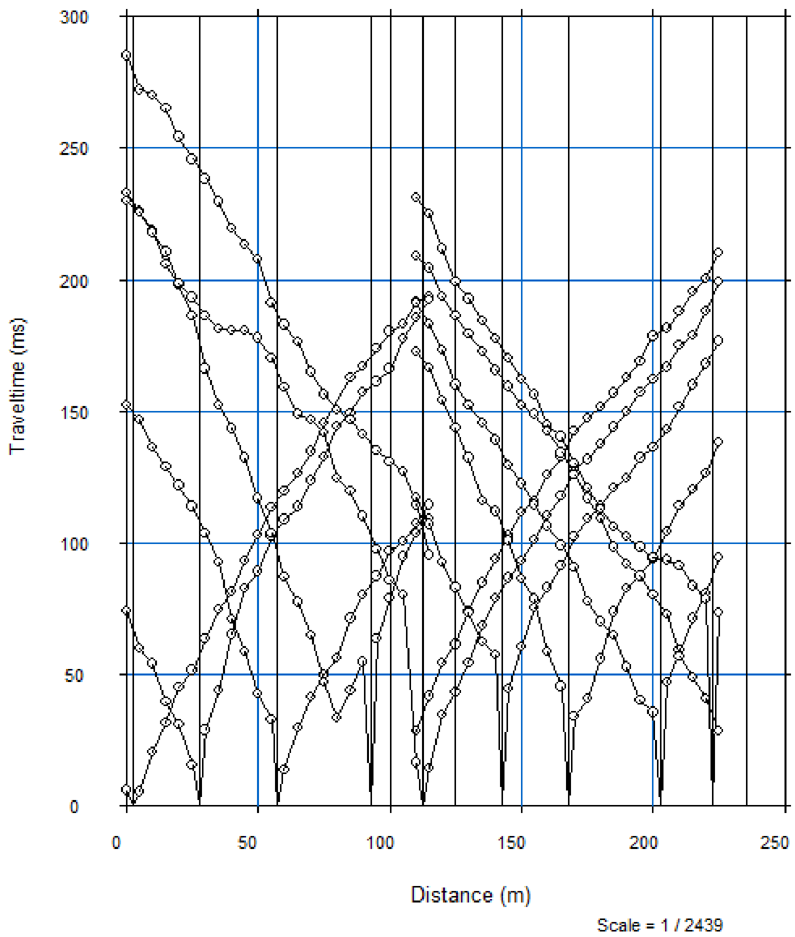

Fig. 4 The picked inversion of travel time curves for integrated profiles.

V. Result And Discussion

The results obtained from the data acquired for the seismic refraction method in the study area revealed this region can be categorized as a three layer system with the velocity of each layer increasing with depth, this may be as a result of the variation in the composition of the subsurface lithology with depth. velocities of sound were determined for the first, second and third layer (Table 1).

The primary wave velocity of topmost layer (Violet colour), where lowest seismic velocities ranging from 155m/s to 512m/s with an average velocity of 314m/s were detected, corresponds to an area within the top soil (overburden) which are mainly unconsolidated dry alluvial and colluvial sediments. The thickness of the first layer ranges between 1m to 10m with an average of 5.5m. The thickness of the first layer varies laterally within the surveyed area**.**

The second layer made up of the yellowish orange colours and seismic velocity ranges from 814m/s to 1437m/s with an average of 1056m/s were detected, corresponds to an area which is mainly unconsolidated residual dry sand. The thickness of the second layer ranges between 18m to 35m with an average of 26.5m. The second layer is characterized by a slightly higher velocity than the first layer**.**

The third layer made up green colour and seismic velocity ranges from 1561m/s to 2400m/s with an average of 1858m/s were detected, corresponds to an area which is mainly weathered basaltic rocks. The natural conditions prevailing in this layer of interest and seismic refraction velocity favour presence of significant amount of groundwater potential due to the presence of weathered zone. The thickness of the third layer ranges from 20m to 26m with an average of 23m. Table 2 shows the summary of results from each profile, with an indication of the potential of the region.

Table 1: Summary of data from tomography model

Layers	Min and Max Velocity (m/sec)	Min and Max Thickness (m)	Average velocity (m/sec)	Average thickness (m)	Formations
Layer 1	155 -512	1-10	314	5.5	Unconsolidated sediments (Alluvium and Colluvium)
Layer 2	814-1437	18-35	1056	26.5	Unconsolidated residual dry Sand
Layer 3	1561-2400	20-26	1858	23	Weathered Basalt (Water Saturation Zone)

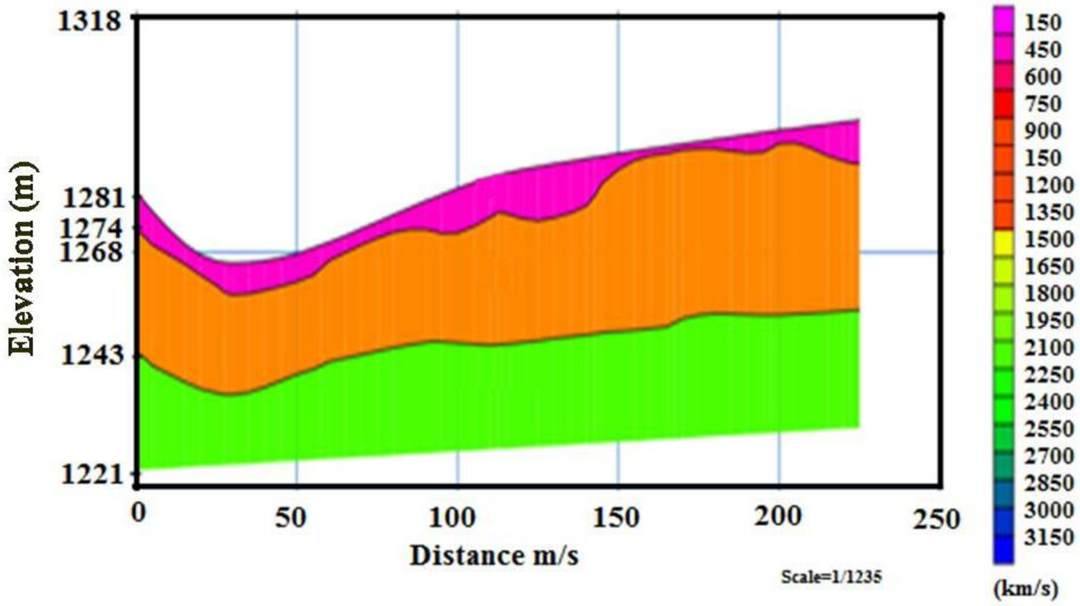

Fig. 5 Tomographic section of subsurface lithology

The survey shows variations in the thickness and velocity of all three subsurface layers. There is a linear increase in velocity with depth within the probed depth. The change in velocity may largely be as a result of the variation in subsurface lithology, texture, structure, grain size, compaction, cementation and the level of groundwater saturation. Thickness of all three layers has gradually increasing from west to eastern part of the study area.

VI. Conclusions

Seismic refraction method delineated the third layer as the most competent layer, having recorded higher values of velocity than the other layers. This most competent layer is between the depth of 38 m and 50 m into the subsurface. The methods have yielded average velocities of 314 m/s for the upper layer, interpreted as unconsolidated sediments (Alluvium and Colluvium) with thickness of 5.5 m. The middle layer has a thickness of 26.5 m and average velocity of 1056 m/s and is interpreted as unconsolidated residual dry Sand. Third layer's average velocity is 1858 m/s and is interpreted as weathered basalts (water saturated) with 23m vertical extension. Thickness of each the layer has increased from west to eastern direction of study area. According to velocity and lithology of third layer which could form good reservoir for groundwater potential were identified.

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