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RESEARCH ARTICLE

GROUNDWATER INVESTIGATION FOR SMALL SCALE IRRIGATION PURPOSE MERAB ABAYA WOREDA, GAMO GOFA ZONE, SOUTHERN ETHIOPIA

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ABSTRACT

Presently the problem of the global warming is becoming the main issue of the world as well as the country which results increase in temperature and decrease in rainfall both in amount and distribution. This unreliable rainfall and desertification in turn reduce the production return from the existing limited natural resource. This problem is becoming the main constraint for development and increasing agricultural production. Besides increase in population is another constraint which needs special mechanism to facilitate food availability for the rapid increasing population. To enhance agricultural production and escape out from the rain feed cultivation, groundwater is paramount important. This groundwater investigation is used different methods such as geological, geomorphological and vertical electrical sounding. When to consider groundwater availability we have to know the geology and topographic setting of the area. Geology of the area is characterized as low laid flat land is covered by unconsolidated sediments; mountains, ridges and domes are covered by ignimbrite, rhyolite and basalts. These rocks covered in upland areas are characterized not as such weathered and there are no penetrative fractures. Most of mountain ridges and domes which composed of ignimbrite and rhyolite are considered as recharge area rather than discharge area. The location of VES points were on unconsolidated sediments covered on the flat land of the study area. A number of VES point indicate that the thickness of unconsolidated sediment is ranges between 40-70m. The main aquifer of the area is below 45m over laid by clay soil. The total thickness of the main aquifer is 200m expected from VES data.

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INTRODUCTION

Most of Ethiopians living in rural area and their life depends on agricultural products. The greatest number of these farmers using traditional agricultural system i. e based on seasonal conditions. The main reason why the farmers do not use technological agricultural system is technology, economy, topography, geology and awareness. In Ethiopia the most irrigable land and surface water/ rivers are not matched that means if there is surface water there is no suitable land for irrigation or if there is suitable land for irrigation there is no surface water. As we know Ethiopia is a country of great topographical diversity and geological complexity. High rugged mountains, flat-topped plateaus, deep gorges, incised rivers and rolling plains are the pre dominant physiographical features. Since the country is located in the tropics, the physical conditions and variations in altitude have resulted in a great diversity of climate, soil and vegetation.

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The highlands on each side give way to vast semi-arid lowland areas the east and west and south. These lowlands contain a plenty of the ground water potential of the country which is shaped by different complex phenomena of geological formation and the diversity of the topography, climate and soil. There were several studies and ground water potential assessments indicate the rechargeable or replenishable ground water potential of the country is in the order of 2.6 billion cubic meters (BCM) (Semu Moges, 2012). More recent emerging studies and implementations like that of Addis Ababa, Kobo and Raya well field indicate the potential is far greater. Estimations of the ground water require a good understanding of the regional geology, hydrology, hydrogeology, hydraulics of ground water flow. The investigation and development of groundwater needs more budget than equivalent surface water, and it is not visible so that most of people do not believe on usability of groundwater. The study area is identified as a big challenge on agricultural productivity due to shortage of agricultural water. Farmers in the area usually cultivate by using rain water/flood harvesting and rain fall but they are facing serious problem due to short rainfall and access to irrigable water.

Therefore the irrigable water sources (both surface and ground water) should be studied and this potential has to be unlocked to enhance agricultural productivity in the areas. Unless, the cumulative impact of such failures in agricultural production and productivity could lead to failure of the local community to be self-sufficient in food production.

Statement of the problem

Government of Ethiopia planned in GTP II most of farmers have to use small and medium sachem irrigation to escape out rain fed agricultural system. As we know 85 percent of the total pupations of Ethiopia are grouped under agrarian. To bring the holistic development in agricultural improvement by changing rain fed agricultural to small scaled irrigation system. Especially this policy more focused on small private based agriculture on every rural farmers farming land. To support this governmental policy different sector bureaus and universities have mandate to apply and appreciate this issue. Irrigation is not simple task to apply directly on the ground because it depends on different factors. Some of the staple factors are topographical setting, accessibility of water, lack of specialized professionals and economic capacity of the country. Although there are different problems which limit the application and water supply for irrigation cases, this project work going to solve those problems from specific area by suggesting alternative options. The first option is surface water but in the area there is no sufficient surface water, therefore the second alternative is groundwater. One of basic problem which will be alleviated during this project work is geological mapping of the study area. Because to know groundwater occurrence and its movement we have to know the horizontal and vertical distribution/succession of lithology and the geological structures that dissecting this lithology is very important. The area has also no hydrogeological map which consists of groundwater occurrence; movement, quality and aquifer thickness which are the most important parameters to exploit subsurface water. The area consists of different rivers and streams some of which are intermittent and a few of them are perennial such as keme, Raya, Shafe etc. Furthermore, land use and land cover map is important to reveal the potential zone for small and large irrigation site to rural home garden and investment area is so far not mapped. When we think of to use water for different purpose, we have to know the accessibility, availability and the quality of water. Therefore, this project work produces different maps which indicating the accessibility and availability.

Location, accessibility and drainage

The study area is located in North of Arba-Minch town, about 60km at middle of Arba Minch to Sodo asphalted road which is 0357000mE to 0361700mE and 0698000mN to 0710000mN and the altitude ranges from 1310 to 1394m. The study area covers about three rural kebeles which cover 60km^2. The area is found western side of Abaya lake catchment and bounded between West Gamo Mountain, east Lake Abaya, south Merab Abaya town and north Wajifo village. The area was controlled (governed) by different mountains that are like Lomene at south East, Gonga at south, Tirga at east, Derke Ridge at south, kola Barena and Yayke at west. Topographically the area is characterized plain land and hill side of Gamo mountain ridge. Its accessibility from Arba Minch to Sodo asphalt road, Merab Abaya to Dega Birbir through gravel road to Fetele kebele. Also there are all weathered road to Doshe and Yayke kebeles. And many different foot roads are in the studied area. A drainage map is a plan of all streams or river systems in drainage of study area. It presents some characteristics of drainage basins through drainage pattern and drainage texture. It is possible to deduce the geology of the basin, the strike and dip of depositional rocks, existence of faults and other information about geological structure from drainage patterns. Drainage texture reflects climate, permeability of rocks, vegetation, and relief ratio, etc. Howard (1967) related drainage patterns to geological information. A dendritic pattern is most common in the study area. This pattern is formed in a drainage basin composed of fairly homogeneous rock with control of the underlying geologic structure. The longer the time of formation of a drainage basin is, the more easily the dendritic pattern is formed. The streams/rivers in the valley originate from the Gamo mountains which flow to the Abaya Lake. Those rivers are Udula, Shope, Daronjiikere, gelakere, daga, Dashe and Solko streams drain in to the valley. The sub-Abaya-basin is drained by those all streams. There is high drainage density in the western highlands and, low lands as well as both in the valley floor and eastern highlands. All rivers and streams carry large volumes of sediments from the mountains in the rainy seasons and deposit on the valley plain.

Climate of the Study Area

Climatic conditions of the area are mostly characterized under ‘kola’ weather condition. The main feature of rainfall in the area is seasonal, poor distribution and variable from year to year. Rainfall distribution over the valley is in monthly distribution is bimodal even if there is different in different area. The average lowest monthly rainfall registered during the month of January at Merab Abaya is 19.9mm. Whereas the average monthly maximum rainfall is 90.7 mm observed during the month of April. About 24 years rainfall data of the area imply that most of months are dry which are getting rainfall below 50 mm. Temperature from November to February hot and dry weather is predominant. From the long-term temperature data obtained from National Metrological Agency (NMSA), the mean maximum temperature of Merab Abaya is 32.7^{o}C. As indicated in Figure (1.4) except three months the mean temperature is greater than 30 ^{o}C the area is getting high temperature.

Research Questions

This project concept note work to give the solution for the problem which justified in the introduction part. The following interdependent questions should be addressed while addressing the rationale of this project.

- Where groundwater is and what is its depth?
- What is the nature of the interconnections between the groundwater and surface water systems?

General objective

The general objective is to investigate groundwater potential site for deep well drilling

Specific objectives

- To map topography of the area for the aid of the flow direction of groundwater;

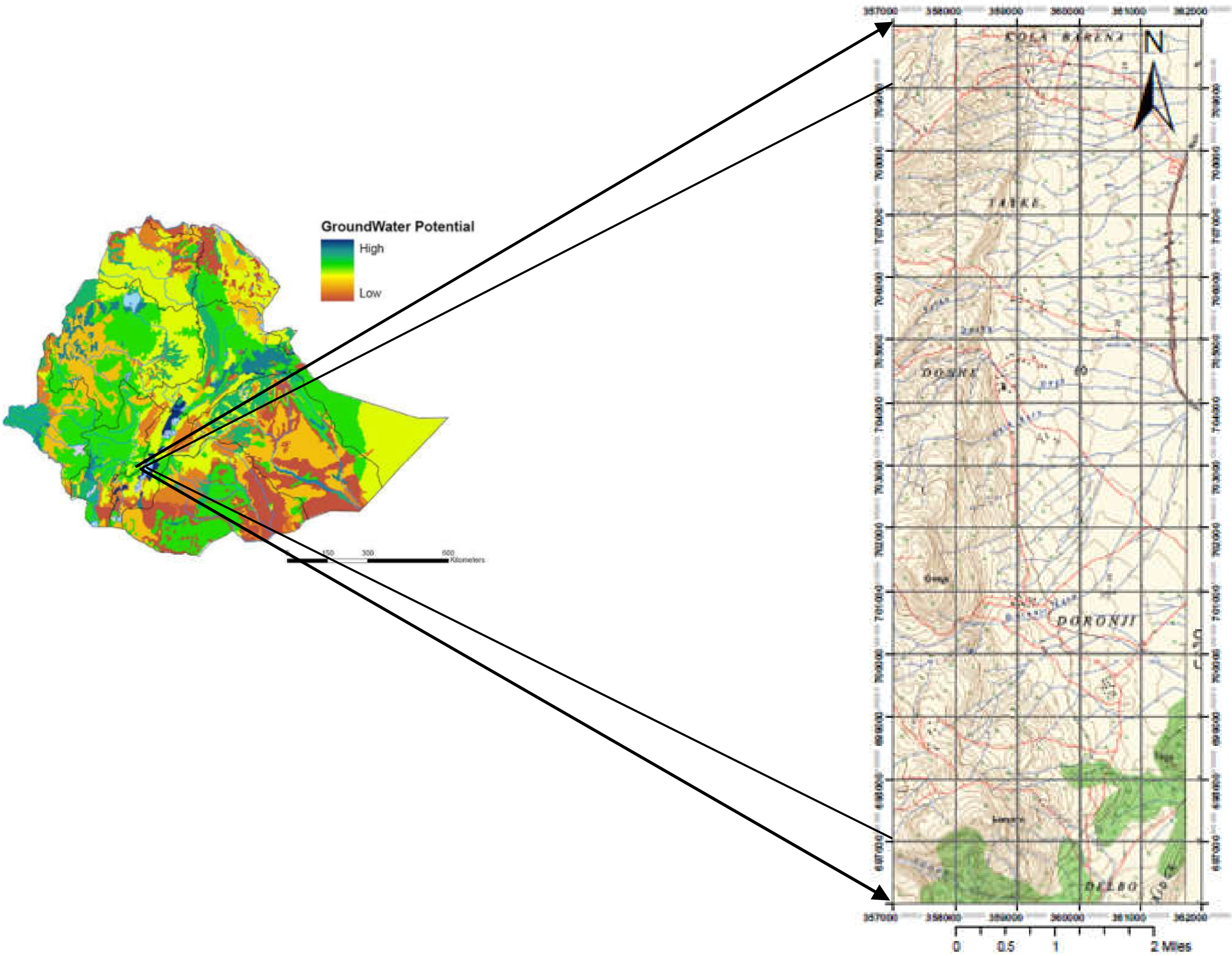


Figure 1.1 Location map of the area

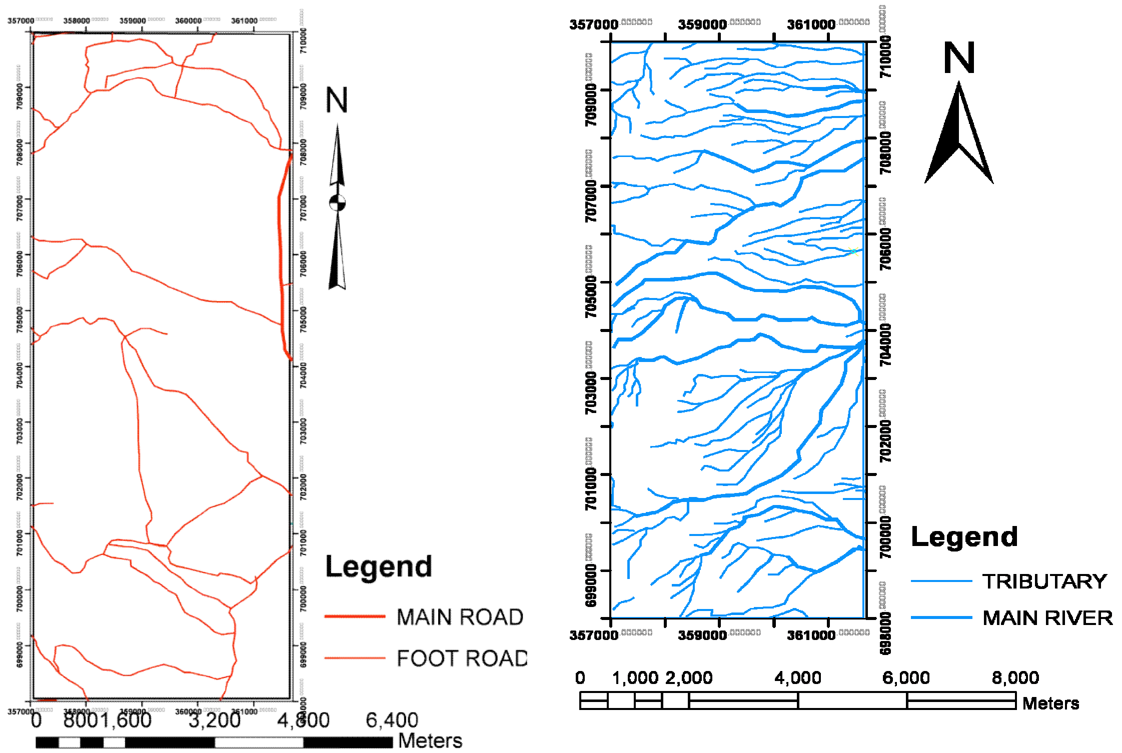


Fig 1.2 Accessibility (a) and drainage map of the study area

- To map lithology and geological structures towards indicate the controlling factor of groundwater flow direction and occurrence;
- To measure the thickness of aquifer and other layers by using geophysical methods (VES);
- Identify the spatial and temporal occurrence and distribution of the ground water resources and ensure its utilization for the different water uses; and
- Implementation of appropriate technologies for the exploitation of ground water in water deficient areas in order to mitigate water scarcity problems.

Expected output

The expected outputs of this research work are

- The detailed geological map of the study area will be produced;
- This investigation also will provide comprehensive information for the development of groundwater;
- The produced hydrogeological map consists of location/pinpoints of hand dug well, shallow well and deep well drilling; and
- This investigation expected to indicate that at what depth groundwater presents and its seasonal fluctuation may be possible.

Beneficiaries

The beneficiaries are:

- The scientific community can use for further studies;
- Gamo-Gofa water and mine Bureau; Merab Abaya woreda
- Non-governmental Organizations which are planned to accesses water for rural peoples; and
- There is also Minster of water and energy; and Regional water Bureau will use this research work to access water for rural peoples.

Limitation

At the very binging the research needed to have 2D or 3D imaging geophysical instrument, but it was not available. As alternatively the research used vertical electrical sounding (VES) method. Electrical resistivity method depends on other related works to interpret the collected data but there is no sufficient data. The geology of any area varies vertically and horizontally within a few distance or depth. If there is no detail outcrop or the drilled vertical geological section, it is difficult to interpret. Therefore, this research used to interpret the collected data by using the borehole data from nearby area about 100-1000m. Some of the area is covered by bushes and shrubs due this to be difficult to pass through this area carrying electrical cable. To solve this problem the local people are cleaning the area to measure vertical electrical sounding. This activity takes most of the researchers working time. Difficulty of the accessibility is of the study area to brining instrument to all the targeted point. Instrument Terrameter has different accessory material such as external battery, AB cables, electrodes, MN cables, hammers and the main instrument which are hard to mobilize by man power. The time which the instrument was rented was for 25 day to measure geological resistivity in different places. Because to measure one vertical electrical sounding needs from both sides of the target point 500m to 1000m. To measure a vertical electrical sounding with the distance mentioned range is spent nearly one day. There is no borehole with geological long present nearby each area due to this to interpret the collected data used boreholes fare away from VES points 5-7km. This makes some difficult on accuracy of interpretation.

MATERIALS AND METHODOLOGY

Materials

1.Topographic maps

- To map horizontal and vertical distribution of the lithology;
- To put geological structure on it;
- To use the map as input for groundwater modeling; and
- To analyze topographic features.

2.GPS

- To locate the coordinate position on the map;
- To indicate the geological structures on the map; and
- To put out the select borehole location on the map.

3.Arc GIS 10.1 soft wares and Erdus imagining

- To map geological, geo-hydrological and physical boundaries; and
- To model groundwater occurrence.

4.Geophysical equipment (Terrametter)

- To predict the depth of groundwater;
- To identify the types of aquifer; and
- To know the thickness and extent of the aquifer.

5.Burtons compass

- To measure the orientation of geological structures; and
- To point out the relative location of the borehole points and geological structures.

6.Measuring Tape

- To measure groundwater depth on the existing shallow wells; and
- To measure the horizontal extent of geological structures.

Methods

To achieve the above objectives of the research the following methods and procedures were used.

Office work

For different scientific research works have different activities and methods to achieve the sited objectives. The collecting existing site information is the starting point for all the following activities and methods. Gathering existing data from different governmental and non-governmental offices prior to reconnaissance field survey.

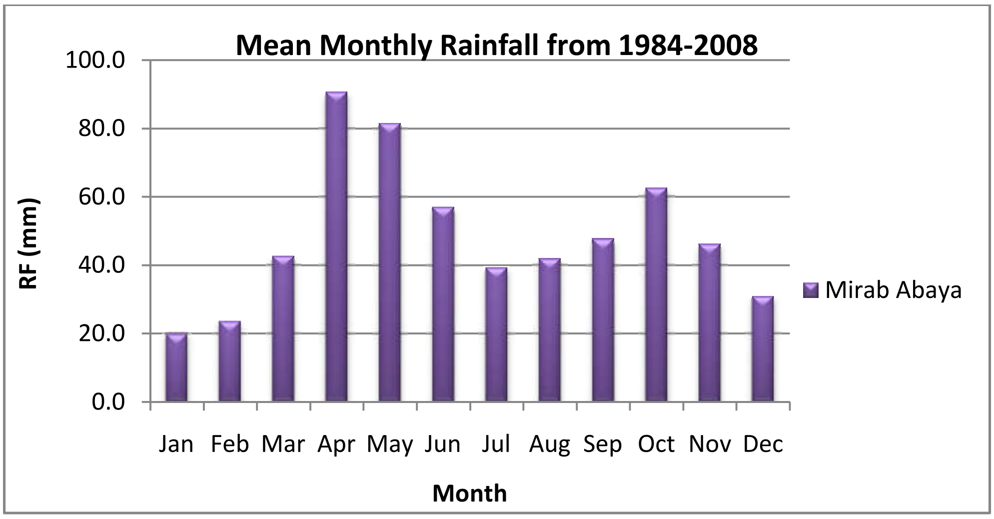


Figure: 1.3 Mean monthly rainfall

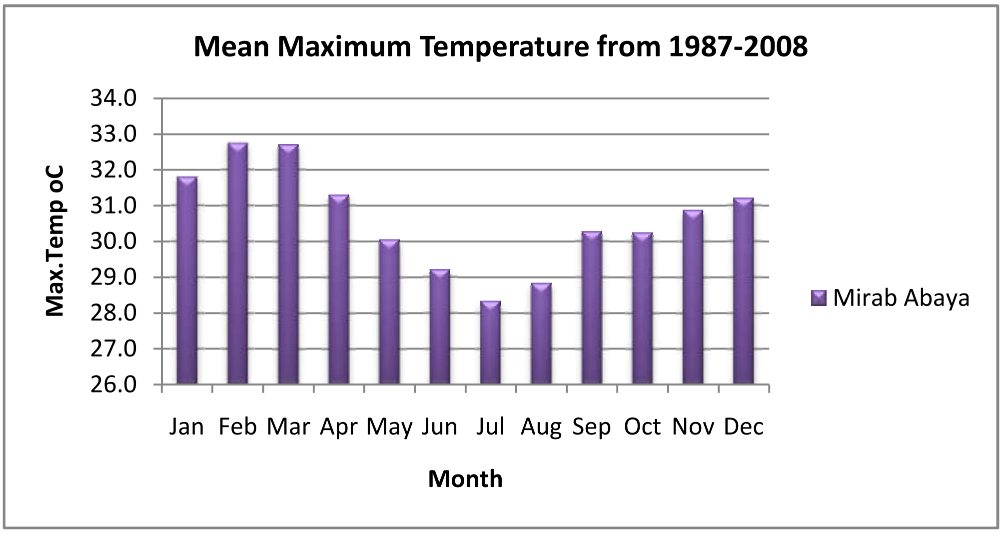


Figure: 1.4 Mean monthly temperature

Figure: 2.1 Geopyhsical matterial (Instrument)

The main idea of this office work is to handle the exact gap which might be filled this research work. Analyzing and interpreting of top map and aerial photos for the preparation of base map.

Reconnaissance field survey

During reconnaissance survey by using base map which was prepared through office work to verify different topographical setting and geological lineament reviewed in office works. Not only these but also to identify the current accessibility of the study area. Furthermore the major lithologies and geological structures were identified. The specific area for vertical electrical sounding was selected base on the geological setting of the area.

Detail field study

Geological methods

This method is very important especially developing countries like Ethiopia because geophysical instrument is too costy to use every where everybody. It depends mostly geological background and work experience. The groundwater occurrence and movement mainly depend on the geology of the area. Geological studies are very much essential. The type of terrain, rock formations, lithological units, geological structures like lineament, fold, fault, joints and fracture system have to be studied in depth. Based on this method researchers climbing up to mountain and visualize the geological setting of the area. Only after the geological investigations, the type of geophysical method to be conducted may be decided.

Geomorphological methods

After a thorough study of the satellite imagery and topographic map, a field check is highly necessary to know the geomorphological features to assess the ground water potential. The geomorphic units like pediments, flood plains, drainage pattern, soil types, lineaments which primarily control the occurrence, movement and potential of ground water have to be investigated in detail.

Hydrogeological methods

The ground water potential of an area mainly depends upon the hydrogeological set up, for which a detailed & systematic hydrogeological survey is a prerequisite. Well inventory study is very important in any ground water exploration programme. Especially in hard rock terrain is groundwater confines to the weathered mantle, joints and fractures. The weathering thickness, joint & fracture system of the area ought to be studied in depth. Water level measurements, water level fluctuation studies are the important factors in the assessment of ground water potential. Only by a systematic hydrogeological study, the ground water abstracting structures like open well, bore well, tube well have to be finalized. The recharge and discharge areas ought to be identified. The fluvial hydrological studies like the river & stream flows, whether it is perennial etc details are important in quantifying the potential.

Electrical Resistivity Method

Under this method the research work used to investigate groundwater was vertical electrical sounding (VES). Resistivity sounding is the study of resistivity variation with depth for fixed center i.e. vertical investigations of subsurface geological layers. This method gives the information about depth and thickness of various subsurface layers and their potential for groundwater exploitation. Since the fraction of total current flows at a depth varies with the current electrodes separations, the field procedure is to use a fixed center with an expanding spread. The Schlumberger array is particularly suited to this technique, because Schlumberger array has some specific advantages. There are always some naturally developing potential (self-potential, SP) in the ground, which have to be eliminated and nullified. Thus, in such electrode configuration, the potential difference for a selected value of AB/2 is measured and in turn, the resistivities are obtained. The resistivities are plotted against AB/2 on a double log graph. A log-log plot of the apparent resistivity versus current electrode spacing (AB/2) is commonly referred to as the "sounding curve". Resistivity data is generally interpreted using the "modeling" process. A hypothetical model of the earth and its resistivity structure (geoelectric section) is generated. The theoretical electrical resistivity response over that model is then calculated and compared with the observed field response. The differences between the observed and the calculated are then adjusted to create a response, which very closely fits the observed data. When this iterative process is automated, it is referred to as *"iterative inversion"* or *"optimization"*. The product from a D.C resistivity survey or VES is generally a "geoelectric" cross section showing thickness and resistivities of all the geoelectric units or layers. If borehole data or a conceptual geologic model is available, then a geologic identity can be assigned to the geoelectric units. A two dimensional geoelectric section may be made up of a series of one-dimensional soundings joined together, which yield the required subsurface information.

Data presentation and interpretation

The apparent resistivity data obtained from the VES survey were presented as depth sounding curves by plotting the apparent resistivities along the ordinate axis and the half current electrode spacing (AB/2) along the abscissa. This plot was made on bi-log paper. The resistivity depth sounding curves were classified based on layer resistivity combinations. For a three (3) layer case, there are four type curves, the H, K, A, and Q type curves. Any type curve can be derived from any combination of these type curves. The curves obtained in the study area were HK (VES one, two, three, five and six), HKH (VES four) and KHAK (VES seven) from Fetele site. The curves obtain from second site (Doshe) were HK (VES two), QHKH (VES one) and QHK (VES three).

The Depth sounding curves were interpreted both qualitatively and quantitatively.

Qualitative Interpretation

Qualitative interpretations of the depth sounding curves involve:

- Classification or grouping of depth sounding curves based on distinctive geo-electric characteristics and determination of percentage of each group.
- Lithological identification aided by lithologic logs where available. On the basis of this, the VES curves were interpreted in terms of lithologies.

Quantitative Interpretation

The quantitative interpretation of the depth sounding curves was carried out by adopting the partial curve matching technique (Bhattacharya and Patra, 1968). In order to do this, the VES data were plotted on a transparent overlay. The partial curve matching technique involved the use of a standard two (2) layer master curve and four (4) auxiliary type curves (H, K, A, and Q).This procedure required segment-by-segment curve matching starting from the position with shorter electrode spacing and moving towards those with longer spacing. The results of the VES curves obtained from the partial curve matching were then used to constrain the interpretation by the computer using iteration software known as IPI2win+Ip. This invariably reduces overestimation of depths.

Geology and hydrogeology

The study area, Merab Abaya woreda is situated under the western escarpment of main rift margin and at the margin of western lowland. The main lithologic units of the Woreda are volcanic rocks of both acidic and basic in composition and unconsolidated deposits in lowland areas especially eastern and central part of the area. Most of the areas around Yayke kebele and its vicinity are covered by basic rocks mainly trap basaltic rock with inter bedded of tuff. The flow basalts are highly weathered & fractured near the surface and less influenced by defects when depth increases. During field investigations the site geology thoroughly completed early in the project to identify and evaluate features such as those listed below that which offer an insight into the geology and hydrology of the site. Those features are; Bedrock outcrop properties, Open fractures and joints, springs, Seeps, Disappearing streams and Dry valleys. Bedrock outcrops should be examined to determine the stratigraphic position of seeps, springs, zones of solution, and zones of fracturing – both horizontal and vertical. Minor, structural features such as anticlines, synclines, monoclines and domes may alter the local dip of the nearly flat-lying bedrock formations. Such subtle features, particularly in areas of locally high permeability and low gradients can radically alter flow directions. The orientation of joint sets, particularly the largest and most systematic joints are equally important. Such structural information is rarely shown on published geologic maps, and hence evaluation of these is important during the site investigation. In the absence of any suitable outcrops, some of this information can be obtained from drilled boreholes. Those lithologic units are basalt, rhyolite, and ignimbrite are described as follow.

Figure:3.1 Basalt

Basalt

Basalt is an extrusive igneous rock which formed from the rapid cooling of basaltic lava. It is characterized by dark fresh color, and dark gray weathered color. It is compositionally mafic. These basalts are mainly covered ridges, mountains and some of flat area. They are mostly exposed around road cuts, river cuts and at hill sides. These basalts characterized fractured and weathered i.e. there are a good condition to hold groundwater.

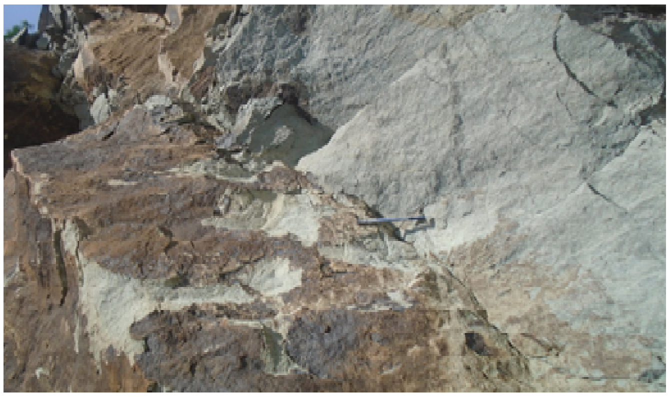


Figure: 3.2 Rhyolite

Rhyolite

It is a type of extrusive volcanic igneous rock formed on the surface of the earth by cooling of magma. It is an extrusive equivalent of plutonic rock granite. This type of rock unit characterized by felsic in composition, fine grain size and it has grey fresh colour and light grey weathered colour. It covered central and western part of the study area. It is also weathered and fractured at mountain area; and massive at plate land.

Figure 3.3 Ignimbrite

Ignimbrite

Ignimbrite is classified into two according to its hardness. These are welded ignimbrite and poorly welded ignimbrite. But the ignimbrite appeared in our study area is poorly welded ignimbrite. It is exposed along gentle to flat surface and characterized by different colour. The fresh sample has grey light and light green colour and weathered sample has grey colour. It has very low degree of welding and aphanitic in texture. It has felsic in composition.

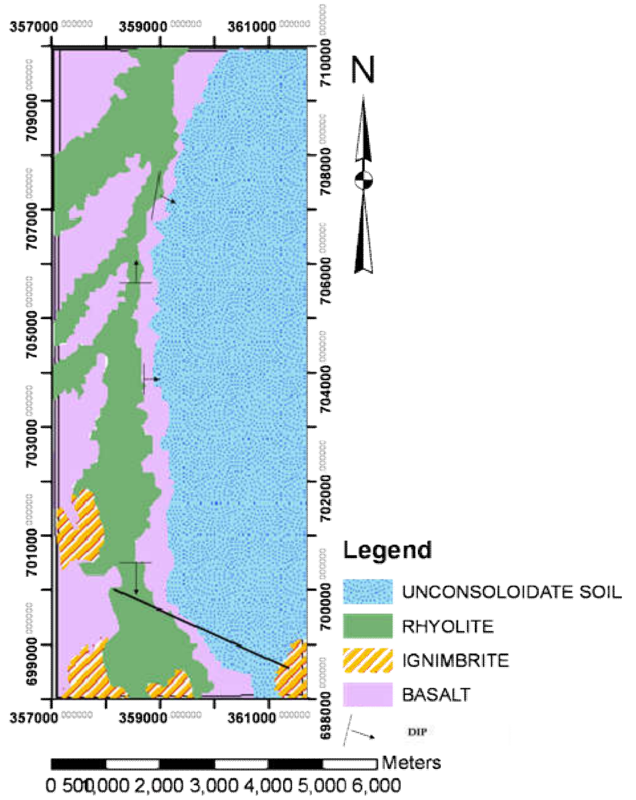
Geological structures

The study area is found within western escarpment of Ethiopia main rift system. The area is dominantly affected by rift faults which are north east to south west orientations. A plenty of springs that people have been using are along these fault zone. The faults are interpreted from air photographs (verified in the field), while the other structures are observed and some measurements were taken in the field. The study revealed N-S and NNE-SSW with minor E-W striking faults (Fig.3.4). Joints are other structures common in the study area. The strikes of the joints are generally parallel to the faults of the area and seldom perpendicular. Most of the joints are vertical and some are horizontal, parallel to lava flow bedding planes in volcanic rocks. Two major joint sets are observed (NNE & WNW trending) with some minor sets (NE & NW strike, Fig. 3.4). There is also unevenly distributed different fractures are characterized in the area. These joints mainly observed on basalt. Local people use groundwater as spring on surface through these joints.

Figure: 4.4 Major Joint in Rhyolite unit

Unconsolidated sediments

These sediments consist of alluvial, colluvial deposits and residual soils. In the study area, alluvial soils cover at the flat lands on the foot of mountain, banks of rivers and gullies and hill sides. The alluvial deposit ranges in grain-size from fine grain soil to granular soils such as sand, gravel and boulders. Fine grain soils (silt and clay) widely observed around the center of flat lands. Granular soils are widely observed along streams and near to the foot of mountains. These soils are mostly dark and some places gray in color, loose to stiff and in places stratified. Colluvial deposits are common along foot of steep slopes of Gamo mountain ridge. The rivers/streams in the basin mostly display a wide range of flow (Maximum-Minimum flow) and come to the flat land as flash/distributed flows. The flashy/distributed nature of flow resulted in high sediment load in flat land that is one opportunity to get unconsolidated sediment aquifers in the valley. Its thickness ranges from 3 to 10m when measured on out crop. But measured in existing borehole and interoperated from electrical resistivity data the thickness of unconsolidated is averaged 70m. Generally the thicknesses of these unconsolidated deposits are uneven because of the depositional environment and undulating topography of under laying rocks. The weathering condition of rock is not uniform due to different mineralogical composition and erodability of rocks this undulating topography is formed beneath unconsolidated sediments.



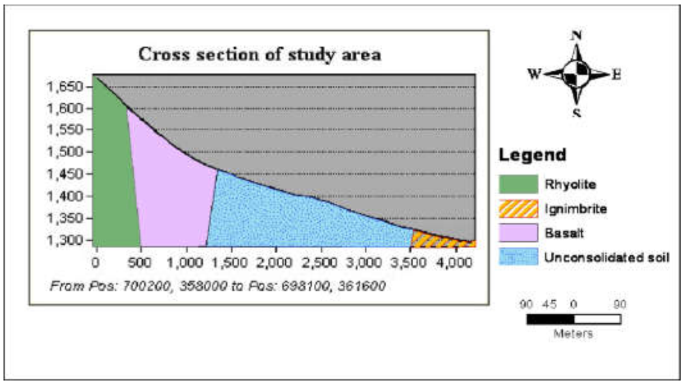
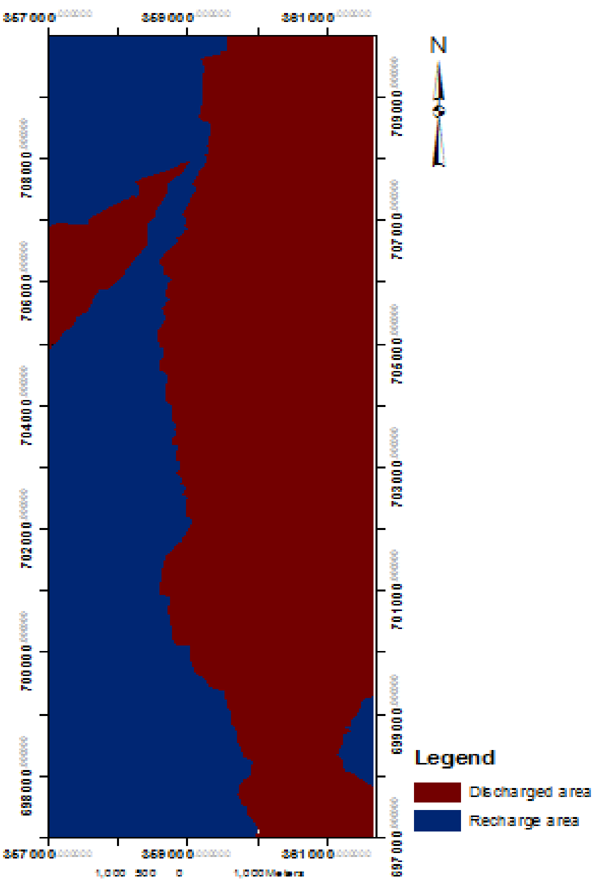


Fig 3.5 Geological Map of the area

Hydrogeology of different lithologies

As it was observed in the shallow and deep wells, the average thickness of the weathered and fractured zones basalt rocks are about below 40 m from surface. Secondary porosity due to fracturing is significant in this unit. This in turn indicates its capacity for water transmission and provides good site for water supply. Existing borehole was that the depth of 103m with good permeability that is 5.5 l/s. However, in some parts, it has massive rock which reduces its water bearing capacity and productivity. Indicated VES1 in Yayke Kebele the depth of massive basalt rock is about 92m, therefore, this massive rock limited groundwater occurrence. In general this formation can be considered highly potential aquifer in the flat land of the study area due to its secondary porosity and permeability. But ignimbrite and rhyolite covered mountains, hill sides and dome shaped topography act as a conduit rather than an aquifer. Therefore, these mountains, hills and domes considered as recharge area to the flat lands. Along different fractures from hill sides some small spring flow to flat land this shows the recharge of the area is not only from rain fall. Unconsolidated deposits averagely 40m thickness measured in different shallow and deep wells. This unit is overlying three stated litho-units in the northeastern, eastern, southeastern and central parts of the study area particularly along the margins of the major and minor streams. It comprises of clay, silt, sand and gravel sized particles in different proportion as identified in the field. In the central and eastern parts of the study area, these deposits can be considered as potential water bearing formation due to their primary porosity and location whereas due to their location in the northwestern, southwestern and southern parts of the study area the unconsolidated deposits act as a conduit rather than being an aquifer.



Recharge and discharge area map

RESULTS AND DISCUSSION

In the study area the flat land is covered by unconsolidated geological materials. Groundwater recharged to this flat land from eastern part of Gamo mountain dew springs, streams and runoff high lands. In the area there were one bore hole and shallow well with the depth of 103 and 55 respectively. In nearby and in the compound of study area there are also different bore holes and shallows wells which this research used to interpreted the discharge capacity and groundwater levels. Based on existing bore hydrogeological logs and logs from different outcrops the VES data were interpreted. According to the data indicates the above table VES 1 has four geoelectrical resistivity layers. The first layer is dry clay soil which is the thickness of 3.12m and the second layer is moist clay with the layer thickness of 7.17m. The third layer is fractured basalt with moist water and fourth layer is the expected aquifer with the thickness of infinitive. The curve type is HK i.e. the resistivity of first layers is less than the second layer, then the resistivity of third layer is greater than the second layer as well as fourth layer. The aquifer type of the area is confided that is over laid by aquitard. After third layer or at fourth layer resistivity became low that is 0.496 Ωm the resistivity of geological materials. In case of volume it suggested as high amount of groundwater at fourth layer. Generally VES no 1, 2, 3, 5 and 6 are characterized in same manner although there are each layer thickness is differences. As the above table 1 indicates that the VES 2, 3, 5 and 6 are HK type curve and the upper most layers is clay soil. The three sites are favourable for deep groundwater drilling because they have enough aquifer thickness. VES 4shows the upper two layers are clay dominated soil type. The thickness of first layer and resistivity respectively are 5.52m and 4.53 Ώm. The second layer is thickness about 4.44m and resistivity of 1.41 Ώm. In this vertical electrical is characterized as weathered and fractured basalt which contaion water moisture. It is not confined layeyer because if the the rock is intact the resistivity of this layer is greater than the acutual resistivity point on the table 1 above. The potential layer in this VES poin is layer four even if its thickness is less than the required thickness of deep groundwater well for irrigation purpose. The last layer commanly call aquifuge i.e the massive rock and it is not water bearing geological formation mostly massive basalt. The curve type of VES 7 is KHAK this curve characterized the geological material with six layers. The layer 1 and 2 are clay soil with little moisture containt, and the thickness and resistivity are 1.35 and 1.8m and 14.1 and 22.9 Ώm.

The first VES indicates six layers in which one single layer has its own description as it point toward from its resistivity. The first and second layers show soil with shallow thickness of 0.75m to 5.72m with the depth of 6.47m. The layers which are from third to fifth are indicate a good groundwater aquifers and their resistivity is low with the sufficient thickness of aquifers that is between 55.1m to 99.9m with the depth of 70m to 225m. The sixth layers is resistivity point out as it is basement rock or bade rock of the groundwater aquifer with the error of RMS=4.71%. On the second VES data it indicates as it has four layers. On this VES data the groundwater aquifer is shallow because of its depth is shallow with only 11.8m and its thickness is from 2.94m to 5.37m but the fourth layers indicates a good groundwater aquifers with the depth of below 12m and its thickness also high its resistivity is 7.28ohmm. The error is shows RMS= 4.54%. Descriptions of this VES data indicate five layers with difference property and different layers. The first layer to third layers are indicates the saturation of soil with low resistivity, low thickness and low depth from 3.13m to18.1m which is the depth of plant root. At the fourth and fifth VES layers has shows groundwater aquifer with the resistivity of 43.9ohm to 7.32ohmm and its thickness is 8.77m its depths is 26.9m. The error of this layer is RMS=6.71%. From the above table (3) the thickness and resistivity date show a good groundwater bearing formations with the sufficient thickness which is bordered by very high resistivity rock. The resistive of this rock is 691ΩM with the total depth of above 92m up to sixth layer; but the expected aquifer thickness is around 70m. With this depth if the aquifer has high potential to yield water it is favorable otherwise the VES 1 will not use for borehole for irrigation. The second VES data indicate different estimation than the first data.

Table 1. Layer resistivity and their corresponding thickness (Fetele Kebele)

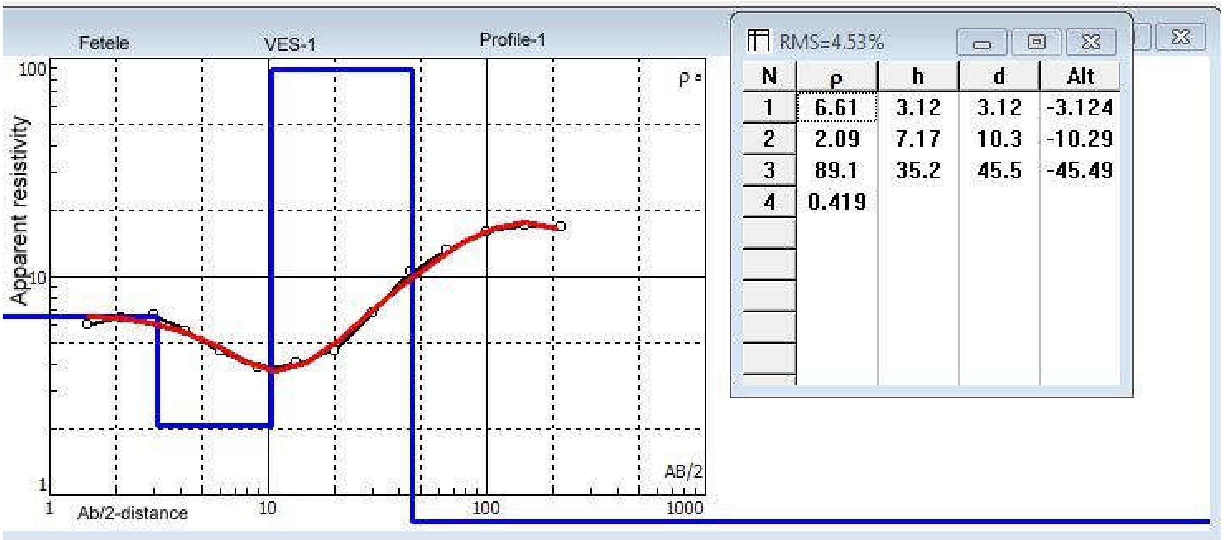
VES	Curve type	ρ1 Ωm	ρ2 Ωm	ρ3 Ωm	ρ4 Ωm	ρ5 Ωm	ρ6 Ωm	H1 (m)	H2 (m)	H3 (m)	H4 (m)	H5 (m)	RMS %
1	HK	6.61	2.09	89.1	0.419	--		3.12	7.17	35.2	∞		4.53
2	HK	8.96	6.22	59.6	8.7	….		1.8	23	34.5	∞		4.77
3	HK	11.2	5.77	76.8	13.9	…..		2.71	9.7	33.4	∞		4.45
4	HKH	4.53	1.41	97.2	1.17	1513		5.52	4.44	14.7	50.2		10.1
5	HK	8.88	2.78	37.5	0.13	…..		8.08	8.16	177	∞		4.46
6	HK	4.09	0.547	221	13.5	….		4.73	3.03	13.5	∞		18.8
7	KHAK	11.4	22.9	1.68	7.7	58.6	9.84	1.35	1.8	1.96	42.3	37.4	6.91

Table 2. Layer resistivity and their corresponding thickness (Doshe Kebele)

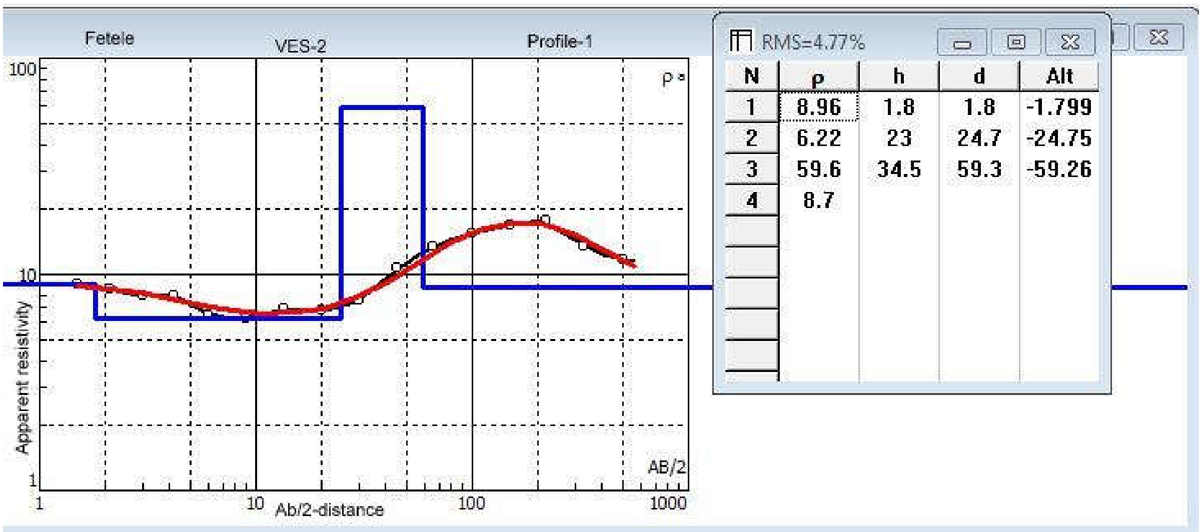
VES	Curve type	ρ1 Ωm	ρ2 Ωm	ρ3 Ωm	ρ4 Ωm	ρ5 Ωm	ρ6 Ωm	H1 (m)	H2 (m)	H3 (m)	H4 (m)	H5 (m)	RMS %
1	QHKH	34.8	19.4	6.14	21.3	2.08	988	0.75	5.72	63.5	55.1	99.9	4.71
2	HK	31.2	8.02	46.9	8.63			2.94	3.51	5.37	∞		4.54
3	QHK	52.3	8.73	1.73	35.1	5.85		3.13	6.11	8.86	8.77	∞	6.71

Table 3. Layer resistivity and their corresponding thickness (Yayke Kebele)

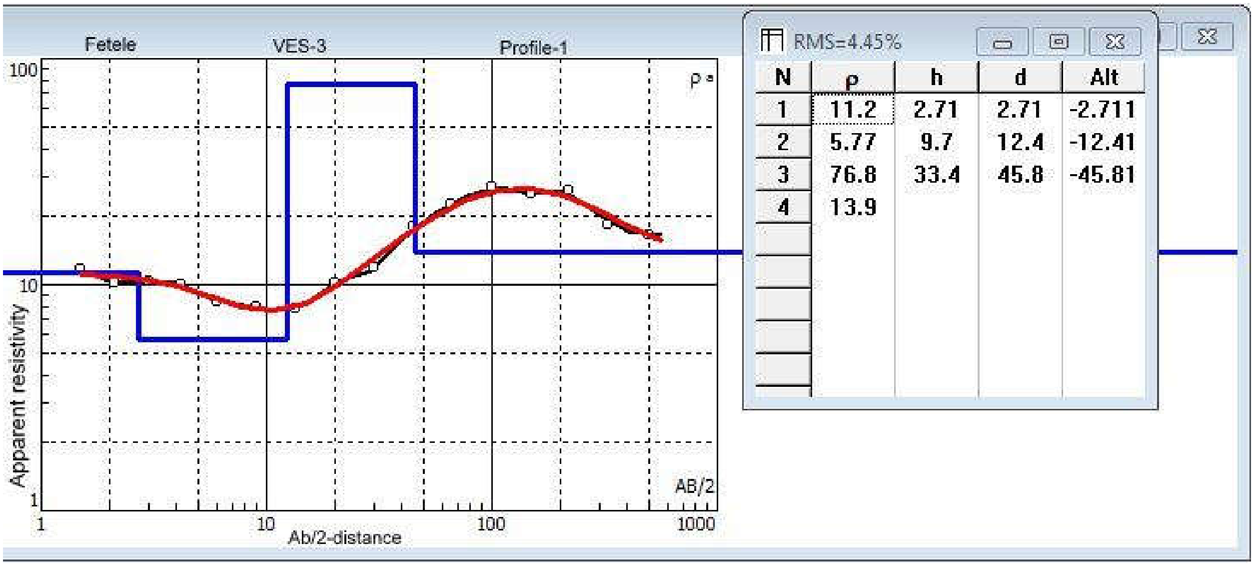
VES	Curve type	ρ1 Ωm	ρ2 Ωm	ρ3 Ωm	ρ4 Ωm	ρ5 Ωm	ρ6 Ωm	ρ7 Ωm	H1	H2	H3	H4	H5	H6
1	HKHKHH	24	1.62	29.3	1.93	18.4	1.08	9.93	0.75	0.402	1.39	3.1	11.1	14.3
2	AHKH	25.4	10.5	1.71	26.5	0.72	691		1.03	11.3	8.24	21.8	49.9	∞



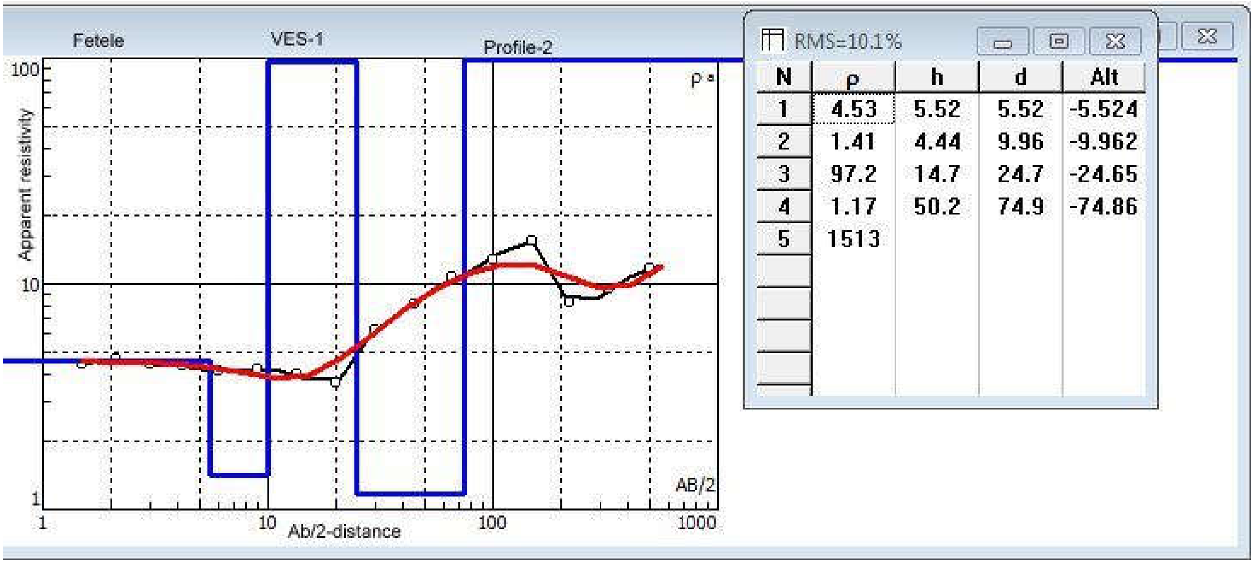
VES 1



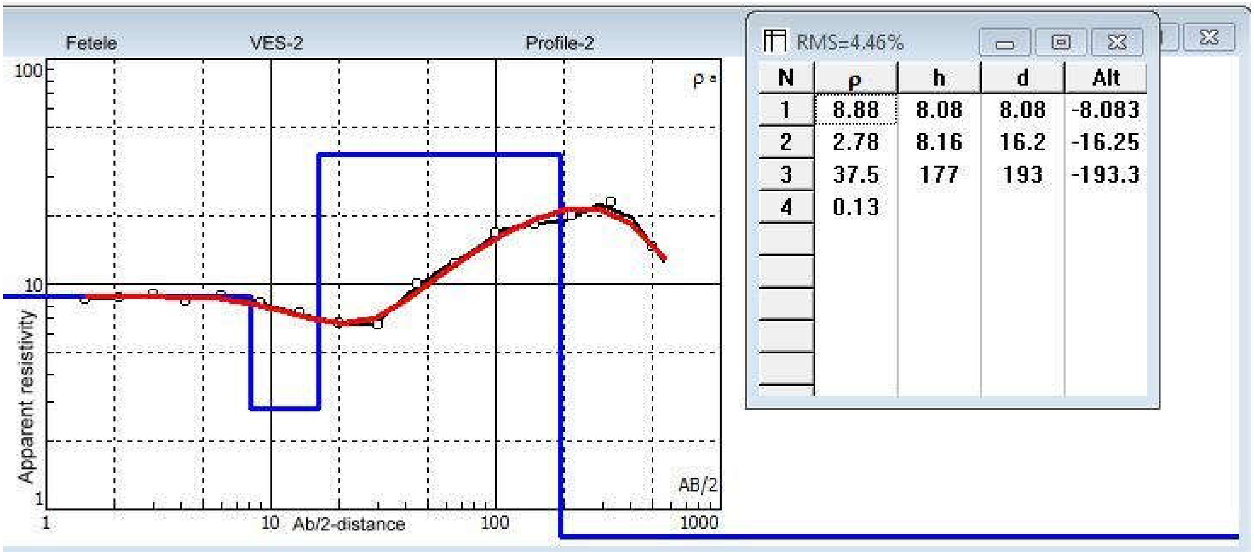
VES 2



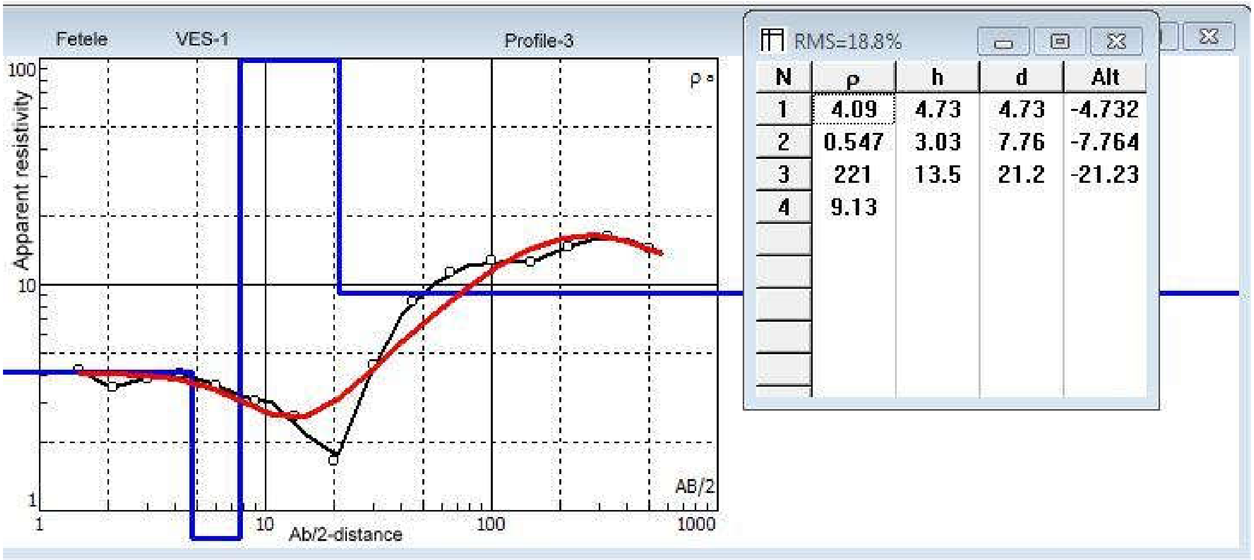
VES 3



VES 4

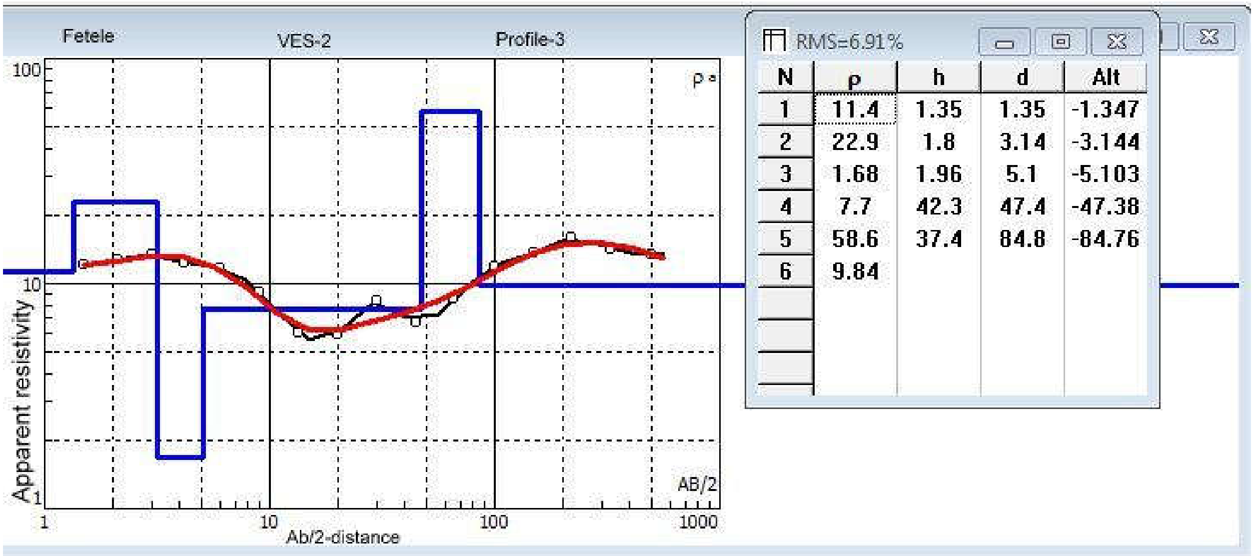


VES 5



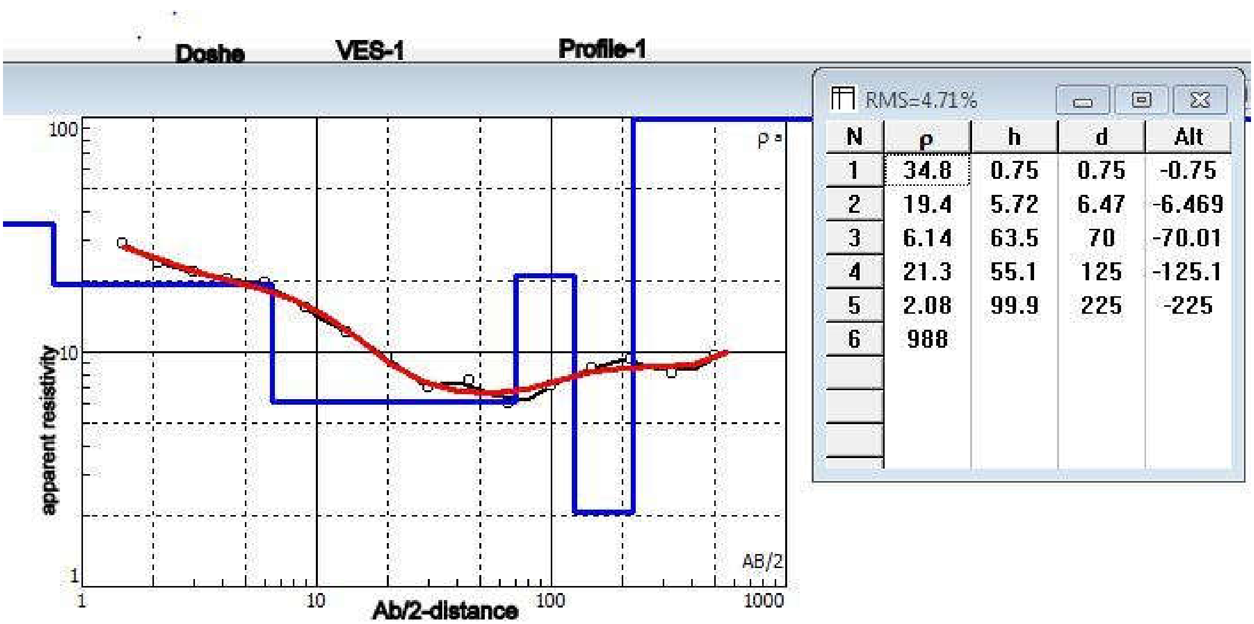
N	ρ	h	d	Alt
1	4.09	4.73	4.73	-4.732
2	0.547	3.03	7.76	-7.764
3	221	13.5	21.2	-21.23
4	9.13			

VES 6



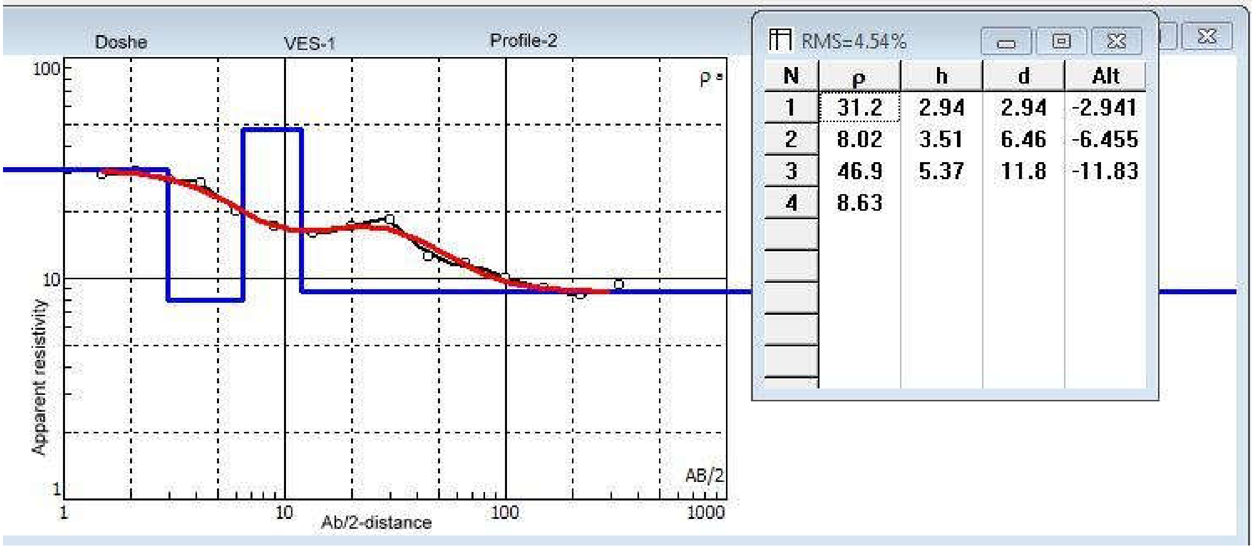
N	ρ	h	d	Alt
1	11.4	1.35	1.35	-1.347
2	22.9	1.8	3.14	-3.144
3	1.68	1.96	5.1	-5.103
4	7.7	42.3	47.4	-47.38
5	58.6	37.4	84.8	-84.76
6	9.84			

VES 7



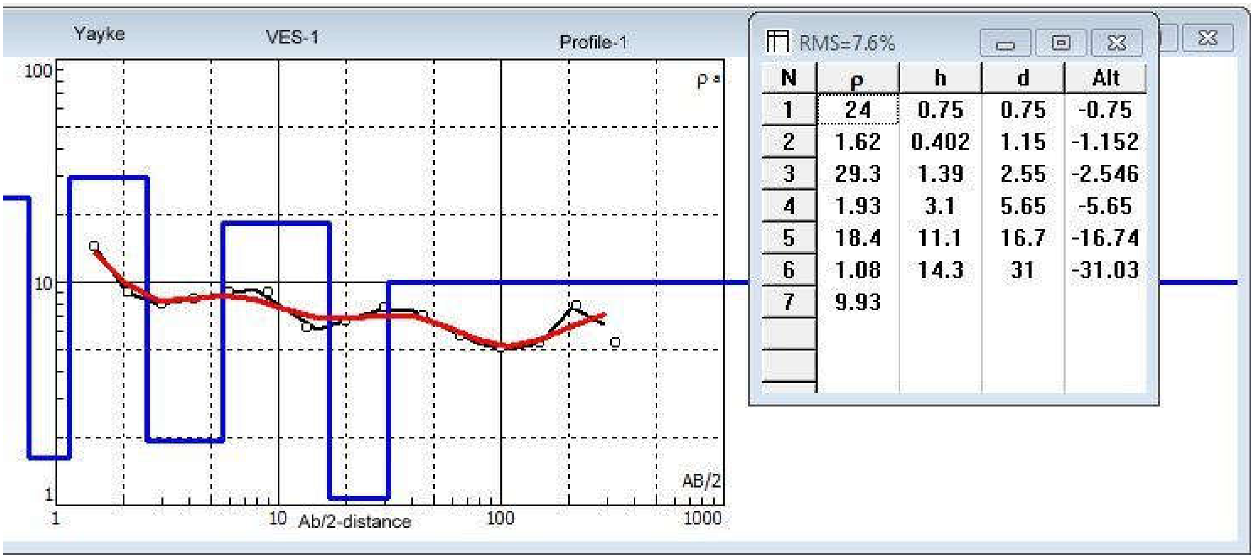
N	ρ	h	d	Alt
1	34.8	0.75	0.75	-0.75
2	19.4	5.72	6.47	-6.469
3	6.14	63.5	70	-70.01
4	21.3	55.1	125	-125.1
5	2.08	99.9	225	-225
6	988			

VES 1

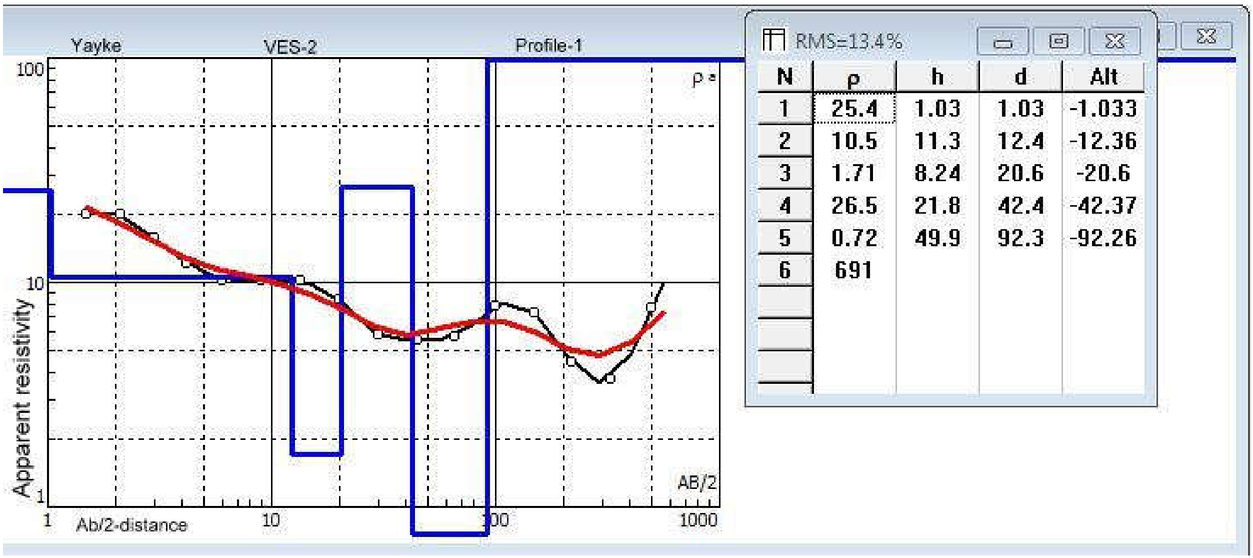


VES 2

VES 3



VES 1



VES 2

This data which has the six layers and it indicate shallow groundwater aquifer with the about 92.3M. Generally the area is categories under two main properties that means the area is categories based aquifer properties that are shallow groundwater aquifer and depth groundwater aquifers that can be use for groundwater investigation for different purpose to the local society shoes purpose can be for irrigation, for house garden, for drinking of people and for drinking of cutely,

Conclusion and Recommendation

- The result of geological and vertical electrical sounding investigation carried out in Merab Abaya woreda shows various subsurface geological conditions. The area is composed of unconsolidated sediments, weathered and fractured rocks and massive rocks. The main aquifer unit recognized is fractured basalt and unconsolidated sediments. Eventhough their thickness and resistivity in different place are different due to different characteristics of rocks.
- In Fetele kebele there were seven VES points, from seven six are screening good aquifer for well drilling. VES 4 is favorable for shallow well because its thickness around 50m. VES 5 is about 200m thickness is water bearing formation or aquifer. Such type of thick aquifer is very important deep well drilling either for domestic or irrigation purpose.
- Doshe kebele the upper soil composition is somewhat different from soil composition in Fetele kebele. The soil characterized Doshe kebele is some layers are characterized as clay, gravel with clay and sand with clay and gravel. Because of this the upper soils in this area is high resistivity than in Fetele kebele. In this site measured three VES points three of them are with sufficient thickness of water bearing formations.
- Yayke kebele is also included under the study; there are two VES points in this spot point. The major aquifer identified from vertical electrical sounding is fractured basalt. Other minor aquifer units include the sandy clay zones in both VES points. In these locations, the expected groundwater yield is so appreciable. Therefore, most of the study area is with sufficient groundwater for irrigation.

Recommendation

- It is recommended that a borehole will be drilled at VES station with thick aquifer, to a depth of about 220 m. The depth of fracture rocks in different traverses and even within traverses have different depth. Especially Fetele VES four is not recommended to drill deep borehole because the thickness of the aquifer is not sufficient.
- The distribution of groundwater is uneven due to lithological variation, geological controlling and weathering degree of the rock. The drilling of bore well is better to not far away from the purposed VES points. When drilling of bore well it should be fully penetrated the thickness of aquifer, to get whole groundwater potential.
- The area was identified during field investigation the upper 3-10m is collapsible soil therefore, it needs surface casing up to 6m. The area better will be drilled by using 12'' bit and casing of 9'' PVC.

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