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Groundwater Exploration for Water Well Site Locations Using Geophysical Survey Methods

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Abstract: *Groundwater can be encountered in various modes of occurrence. Groundwater exploration is the investigation of underground formations to understand the hydrologic cycle, know the groundwater quality, and identify the nature, number and type of aquifers. There are different groundwater exploration methods. One of the surface geophysical methods is therefore the vertical electrical sounding method. Vertical electrical sounding (VES) is one to provide valuable information regarding the vertical successions of subsurface geo-materials in terms of their individual thicknesses and corresponding resistivity values. The objective of this study was therefore to locate two well site locations using surface geophysical methods for water supply purposes.The wellpoints are installed by jetting them into the ground.*

Key Words: **Groundwater exploration; Geophysical survey; Water well; Haramaya University; Lake Haramaya watershed.**

Introduction:

Water is an essence food and basic component of life. The need for water is strongly ascending and has a diversified function, which is not only important for drinking purposes but is also vital for any developmental activities. Nowadays, the use and sustainability of water is getting more complex due to population growth, urbanization and industrialization. Any development is related either directly or indirectly with water utilization.

For any developmental activity, both surface and groundwater sources are the main components depending on their quality and availability. In an area where surface water is not feasible for the desired activity, groundwater is the second alternative, if it has the anticipated amount and quality. Therefore, site investigation/ exploration, sometimes called a pre-construction evaluation, has to be performed primarily for an effective and sustainable utilization of groundwater resources

Groundwater has become immensely important for the different water supply purposes in urban and rural areas of both the developed and developing countries . However, groundwater exploration in hard rock terrain is a very challenging and difficult task, if the promising groundwater zones are associated with fractured and fissured media . In such an environment, the groundwater potentiality depends mainly on the thickness of the weathered/ fractured layer overlying the basement.

Groundwater can be explored using different methods. The four major groundwater exploration methods are the areal method, surface method, subsurface method and esoteric methods. Among these methods, esoteric method is not based on science, mostly based on traditional

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indicators. Each of the above listed groundwater exploration methods have different sub-methods under them. Geophysical survey is therefore one of the sub-methods under the surface method of groundwater exploration . This method is very important for both groundwater resource mapping and water quality evaluations . Its application for groundwater exploration purposes has increased over the last few years due to the rapid advances in computer packages and associated numerical modeling solutions .

Material and Methods:

Description of study area:

Haramaya University is located in the Lake Haramaya watershed. Lake Haramaya Watershed is situated in the Eastern Ethiopia, found in Haramaya and partly in Kombolcha districts, Eastern Hararghe Zone, Oromia Regional State at 505 km East of Addis Abeba and 20 km north-west of Harar town. The university is therefore found in the Haramaya district. It lies at 9°22'03"-9°27'12" North and 41°58'14"- 42°05'26" East.

The average annual rainfall in the watershed is 801 mm. The dry period (less than 30 mm per month) extends from October to January; while, the wettest month is August with an average rainfall of 144 mm. According to Shimelis , the annual average effective rainfall of Lake Haramaya watershed is about 673 mm

The study was conducted integrating both the desk study and field work activities. The desk study in this project involves evaluation of regional and sub-regional hydrogeological maps and evaluation of the previously developed Geological and hydrogeological maps of the watershed. Furthermore, it also involves investigations based on the enhanced Thematic Mapper satellite images at a resolution of 15 × 15 meters and evaluation of Geological and Hydrogeological map of Ethiopia (1:2,000,000).

Physiographically, the study area is part of the Harar Plateau areas, which is the upper part of Wabi-Shebele Basin . It is characterized by three major stratigraphic units including the Precambrian crystalline basement (mainly granite), Mesozoic sedimentary rocks (sandstone and limestone) and Quaternary sediments from old to young . The Precambrian basement complex includes the high grade metamorphic gneisses and migmatites, and the intrusive granites [8]. The sandstone rock unit outcrops on the eastern and western side overlying by limestone that is dipping towards west and underlined by the basement rocks . The quaternary sediment is covering the low lying area that comprises lacustrine sediments, alluvial and eluvial sediment

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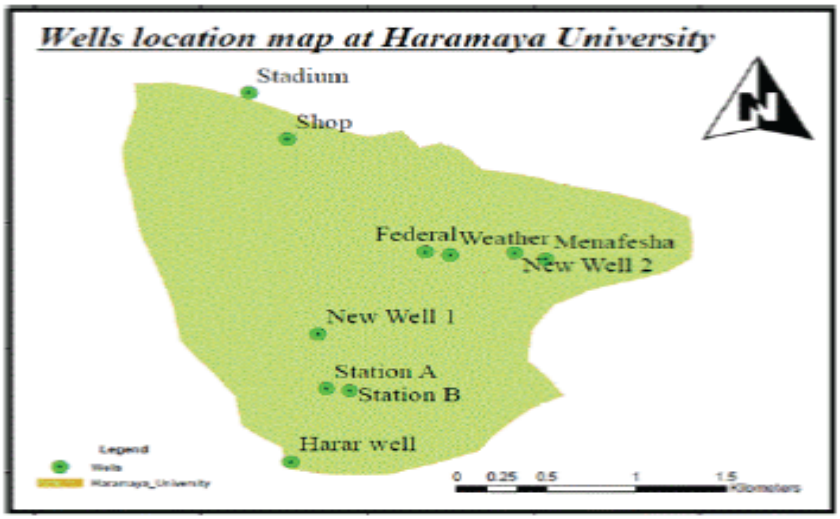

Groundwater occurrence, circulation and storage properties of the area are determined greatly by the type of geology, geological contacts, geomorphology and rainfall patterns. The main aquifer system in the area is the unconsolidated material composed of loose coarse grained sand, pebbles and rock fragments, silt and clay materials, which is characterized by high-moderate to low productivities

The basement (granite) unit has low permeability and productivity ; while, the sandstone and limestone units are characterized by moderate range of permeability and productivity [10]. The subsurface boundary condition of this porous, single-unconfined aquifer system is the replica of surface topography except on the North boundary.

Hydrogeological and geophysical investigation:

Groundwater potential evaluation for a given area/basin requires integrated approach. Detailed quantification of the amount of groundwater demand a detailed water balance study and defining the boundary conditions, establishment of the lateral and vertical extent of aquifers and confining beds. In the absence of detailed hydro meteorological and hydrogeological data, groundwater potential evaluation tends to be more semi-quantitative mainly based on geophysical investigation.

The method followed in this study, for the most part, was depending on the short-term field hydrogeological investigation and surface geophysical surveying. Both approaches provide information on the availability of groundwater in a semi-quantitative sense

Geophysics provides no information on the exact amount of groundwater available in the subsurface. The amount can only be estimated when the geophysical survey is supported by the local hydrogeological features such as recharge potential, availability of permeable rocks, catchments areas, etc.

All the interpretations shown in the geophysical part of this study are made semi-quantitatively by integrating the hydrogeological field observations with the geophysical signature obtained

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from the VES data. The recommendations of the likely depth of drilling are made on the basis of the VES data and the nearby well data. The supervisor/ hydro geologist can recommend the accurate drilling depth during the drilling operation. For instance in some sites where geophysics does not give conclusive answers on the total depth of the aquifers, yield of the well can be defined by using provisional tests with the compressor of the drilling machine.

Conclusion:

The main goal of the study was to select potential well locations for water supply purposes. Among the several disciplines the preconstruction study, i.e., site investigation, which includes geological, Hydrogeological and Geophysical investigations need special attention that helps to minimize the project cost and increase quality and quantity of water.

Accordingly, the work has resulted in the identification of two shallow well development sites (VES-4 and VES-7), where new well 2 and new well 1 were drilled in, respectively. As indicated above, the work is mainly based on the geophysical investigations conducted in the study area, the conventional hydrogeological investigations and remote sensing (satellite imagery), and limited previous works in similar areas. The geophysical signature indicates that the recommended groundwater drilling depth is for shallow wells. For these wells the maximum depth of drilling may reach up to 60 m. However, as it was done in VES 4 and 7 (locations of new well 2 and new well 1), this figure may be changed based on the available water obtained during drilling and it is to be checked with provisional tests with the compressor. This is to be decided by the supervisor/field Hydro geologist.

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