E-ISSN 2656-8039

INTERNATIONAL JOURNAL OF
ENVIRONMENT, ENGINEERING & EDUCATION

www.ijeedu.com

Vol. 2, No. 1, 2020

Research Article

Geoelectric Method Implementation in Measuring Area Groundwater Potential: A Case Study in Barru Regency

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Received: *March 11, 2020;* ***Accepted:*** *April 13, 2020;* ***Published:*** *April 15, 2020*

Abstract: Geoelectric measurements to detect the presence of groundwater aquifers in the study area by knowing the type of lithology, distribution, thickness, and depth of rock layers carrying groundwater (aquifer), both vertically and laterally. The research objective is to determine the location for drilling, if later in the study area, the groundwater potential maximally utilized. In this study, the linear symmetry electrode arrangement, the Schlumberger configuration method, is used. Data collection in the field done by using a resistivity meter. The number of geoelectric points is 12 measurement points, but in the article, four geoelectric points will be discussed that can represent all the geoelectric points that contain high aquifers. The results obtained from the geoelectric measurements carried out show a shallow groundwater layer at a depth of 5.0 - 15.0 meters with an aquifer layer in the form of sandy clay (lateral weathering). Freshwater in freshwater at a depth of 25 - 150 meters following the geoelectric point of estimation with layers of sandstone aquifer and tuffaceous clay. Shallow groundwater is fresh with small productivity can be anointed with dug wells at a depth of 5 - 15 meters potential at all geoelectric points with a discharge of 1 liter/second. Then deep groundwater is of average productivity with a well drilled at a depth of 25 – 150 meters, potentially at a specific geoelectric point with a discharge of 1 – 5 liters/second.

Keywords: Aquifer, Electrical Sounding, Freshwater, Resistivity Meter, Schlumberger Configuration.

1. Introduction

Water is one of the natural resources, which is a fundamental necessity of life and is an essential element for all life fairies on earth [1]. Without water, various life processes for animals, plants, and humans would not be able to take place. At present, water has been used not only for consumption, agriculture, and transportation purposes but has expanded to the recreational and industrial sectors. Although water is the most massive composition on earth (around 70%), only 0.70% can use by humans, both in the form of groundwater and surface water. While the remaining 97.20% of the ocean and 2.10% in the form of polar ice [2]. Utilization of water resources for various purposes, on the one hand, continues to increase from year to year because of population growth and development activities. On the other hand, the availability of water resources is increasingly limited and even tends to be increasingly scarce, mainly due to environmental degradation and water quality degradation due to pollution [3]. In this regard, the use of groundwater to meet the needs of clean water and is the main alternative that has widely chosen even though the use of groundwater should be the last choice for the continuity of the existence of the water source itself.

Groundwater is a source of water in nature found in soil or rocks. As one component of the hydrologic cycle, other components of the hydrological cycle will control its formation and movement, namely rainfall, vaporizers sweat, and surface water [4]. Some rainwater that falls to

This Article Citation: *M. D. Falah, "Geoelectric Method Implementation in Measuring Regional Groundwater Potential: A Case Study in Barru Regency," Int. J. Environ. Eng. Educ., vol. 2, no. 1, pp. 1-8, 2020.*

the surface of the ground will seep into the ground and form groundwater. Furthermore, the groundwater that fills the soil or rocks will move through the cavities that exist, heading to places that located lower such as valleys, rivers, and finally to the sea [5]. Based on this theory, the target of interpreting groundwater potential is soil or rock as a medium where groundwater is present, and groundwater as a liquid that fills cavities in soil or rock [6].

In discussing groundwater, in addition to factors above ground level, some factors are no less important in influencing the process of groundwater formation [7]. These factors are geological formations, and therefore it is vital to study their characteristics [8]. Geological formations are rock formations or other materials that function to store large amounts of groundwater in discussing the process of forming groundwater, the geological formation known as an aquifer. Efforts to obtain the composition of the earth's layer, the activity of investigation through the surface of the soil or underground must be made, so that it can be known whether there is a layer of water carriers (aquifers), thickness and depth and to take water samples for water quality analysis. Although groundwater cannot directly observe through the earth's surface, the ground level investigation is an essential preliminary investigation, at least it can provide an overview of the location of groundwater. The determination of groundwater reservoirs can be done by geophysical exploration, one of which is by using the geoelectric method. The principle of the geoelectric method based on the nature of the flow of electricity in the earth and how to detect it on the surface of the earth [9]. This geoelectric method is more effective in determining the depth of bedrock, the search for subsurface water reservoirs [10].

There are several kinds of rules for estimating subsurface with this geoelectric, including Wenner's rules, Schlumberger's rules, ½ Wenner's rules, ½ Schlumberger's rules, dipole-dipoles. The measurement procedure for each configuration depends on the variation of resistivity to depth in the vertical direction (sounding) or lateral direction (mapping) [11]. The resistivity method with Schlumberger configuration done by conditioning the spacing between potential electrodes fixed while the spacing between current electrodes changes gradually [12]. Measurement of resistivity in the vertical direction or Vertical Electrical Sounding (VES) is one of the resistivity geoelectric methods to determine changes in soil resistivity to a depth that aims to study the variation of rock resistivity below the earth's surface vertically [13]. This method is done by moving the electrodes with a certain distance then the price of the type of resistivity at a depth corresponding to the distance of the electrode will be obtained [14]. The price of type resistivity from the calculation results then plotted against the depth (electrode distance) on the 'log-log' paper, which is the field curve. Furthermore, the field curve translated into rock types and their depth [15].

The resistivity method uses to solve more groundwater problems in alluvium, karstic, and other hard aquifer formations as an inexpensive and useful method. Some uses of this method in groundwater are the determination of depth, thickness, and boundaries of aquifers [16], determination of interface saltwater and freshwater [17], [18], aquifer porosity [19], [20], aquifer hydraulic conductivity [21]–[23], aquifer continuity and specific aquifer results [16], [24], [25], hydrogeological mapping in karst fields [26], [27], groundwater contamination [28], [29]. Contamination from the soil can usually reduce the electrical resistivity of pore water due to increased ion concentration [10], [30]. The electrical resistivity of rocks and minerals varies depending on rock quality, degree of density, and moisture conditions. In general, granules can conduct electricity because they isolated by pores that contain water, and the levels of salt dissolved in them. The electrical resistance of a rock formation depends on the resistance of the electrolyte content and is inversely proportional to the porosity and solubility level of a rock formation. In principle, the type of resistance of rock will be low, if porous, fragmented, distorted water. Specific resistance will be even lower if the rock has a high salt content.

The purpose of this geoelectric measurement is to detect the presence of groundwater aquifers in the study area by knowing the type of lithology, distribution, thickness, and depth of rock layers carrying groundwater (aquifers), both vertically and laterally. While the research aims to determine the location for drilling, if later in the study area, the groundwater potential is used more optimally, the resistivity survey will give an overview of the subsurface resistivity distribution. Specific resistivity prices will be associated with certain geological conditions. To convert the resistivity value into geological form, knowledge is needed about typical resistivity prices for each type of material and structure of the survey area. The price of resistivity of rocks, minerals, soil, and chemical elements, in general, has been obtained through various measurements and can be used as a reference for the conversion process. The actual resistivity value can be done by matching or by the inversion method.

2. Research Methods

2.1. Research Approach

The approach used in this research is to do geoelectric measurements (primary data collection) in the field to obtain current data and potential differences that will later be used to determine the price of resistivity. Based on the price range of these types of resistors, it can be known variations in lithology, thickness, and depth of the layers and their distribution, including the presence or absence of groundwater aquifers. In interpreting, of course, it will not be separated from surface geology data, such as observations of morphology, lithology, and geological structure.

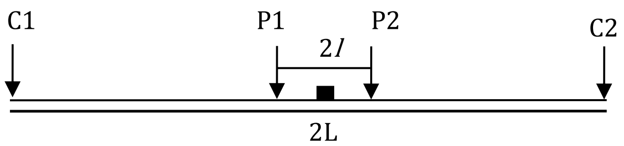

Figure 1. Schlumberger Configuration Linear Configuration Symmetry Arrangement

Information:

C1 and C2	=	Current Electrodes
P1 and P2	=	Potential Electrodes

In this study, the linear symmetry electrode arrangement, the Schlumberger configuration method, is used. This method of setting aims to record the intensity of the electric field by using a pair of electrodes that closely spaced. For this configuration, the L/*l* ratio made very wide so that the intensity of the electric field at the point of estimation is the same as the L/*l*. Therefore, this arrangement is called the gradient arrangement. Based on experience, L length is more excellent than 5*l*. The following is a Schlumberger configuration image.

2.2. Location Study

Figure 2. Location Gattareng Village Area.

The research area administratively located in the Gattareng Village area, Pujananting Sub-District. Geographically the area is in positions 40° 42' 00"- 40° 44' 00" South Latitude and 119° 46' 00"-119° 49' 15" East Longitude. Pictured on the topographic map, the area located 45 km southeast of Barru Regency, South Sulawesi Province.

Based on the terrain and topography, groundwater exploration activities intensified in an area of 2,400 ha, located in the central part of Gattareng Village. The research area can reach from the city of Barru to Gattareng Village by motorized vehicles through provincial roads that paved along 18 km and regional roads that paved along 32 km with a travel time of 2 hours motorized vehicles. To reach the research area from the regional road axis can be reached on foot.

2.3. Data Collection

The technique used to collect data is geological data observation and geoelectric data acquisition in the field using multi-channel geoelectric resistivity meter type EDAK-EXG-3. Geoelectric data obtained from measurements in the field in the form of potential difference data (ΔV) and electric current (I). Resistivity variation (ρ) derived from the measurement of potential difference (ΔV). The data is then processed using IP2WIN software. The geoelectric survey results in an actual resistivity cross-section. The resistivity cross-section is made based on a depth table and the resistivity values obtained from data analysis using IP2WIN software. Geomagnetic and geoelectric anomalies cross-section combined to produce a conceptual model subsurface. The output form is shown by the number of layers of type resistors, the actual value of resistors, thickness of each layer, depth of each layer, and elevation of the contact boundary between layers.

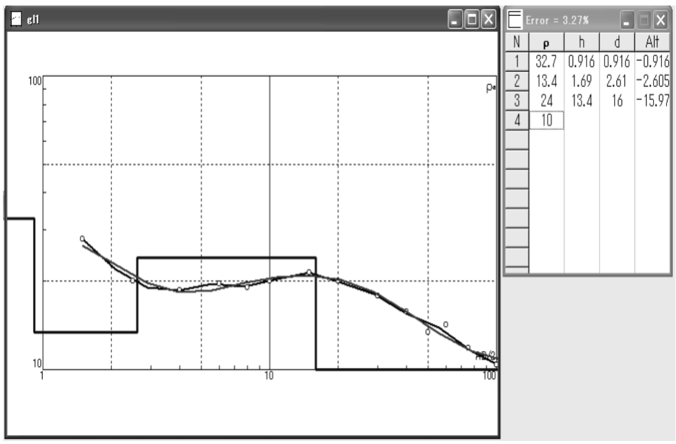

Figure 3. Depth and Resistivity Value of the analysis using IP2WIN.

Smaller resistors of 10 ohm-m interpreted as clay layers. Prisoners of 10 - 100 ohm-m interpreted as layers of sandstones and tuffaceous clay rocks of the Camba Volcano, productivity of small-medium aquifers with fresh groundwater, well discharge (1- 5) l/sec. Prisoners of greater than 100 ohm-m interpreted as andesitic and basaltic breccias, compact and hard, which do not contain groundwater.

2.4. Data Processing

Field data processing is done by calculating the Schlumberger type resistivity using the following formula:

$$Ra = K\frac{V}{i} \quad \text{.......} \quad (1)$$

Information:

Ra	=	Resistivity (ohm-m)
I	=	Strong current (mA)
V	=	The potential difference between two potential electrodes (mV)
K	=	Geometric factor, depending on the configuration of the current electrode and potential electrode

The Schlumberger L/l electrode configuration is greater than 5. for the Schlumberger configuration, the geometric factor (K), given by the formula:

$$K = \frac{\pi}{2l}(L^2 - l^2) \quad \text{.......} \quad (2)$$

So, the resistivity:

$$Rs = \frac{\pi}{2l}(L^2 - l^2)\frac{\Delta V}{2l} \quad \text{.......} \quad (3)$$

L> 10 l the Geometric factor (K) becomes:

$$K = \frac{\pi}{2l}L^2 \quad \text{.......} \quad (4)$$

So, the resistivity for L> 10 l becomes:

$$Rs = \frac{\pi}{2l}L^2\frac{\Delta V}{I} \quad \text{.......} \quad (5)$$

Information:

2L	=	Electrode current separation distance (C1-C2)
2l	=	Potential electrode separation distance (P1-P2)

The apparent resistivity value of the measurement results plotted on double logarithmic graph paper with a modulus of 62.5 mm. The apparent resistivity price (Ra) is ordinate, and L is abscissa. The curve obtained from the field is called the apparent resistivity curve in the field. The graph then changes the actual resistivity price. The way to calculate the apparent resistivity price of the rock layer model and the resistivity price matched with the measurement results (curve matching), by matching the apparent resistivity curve with the theoretical resistivity curve. The curve of the curve will reflect the state of the arrangement of the rock layers with a specific resistivity value, and depth below the estimated point measured. The measurement results continued using the Progress VER.3.0 program. Based on this interpretation, layer parameters can be obtained, namely the magnitude of the actual resistivity and thickness of each rock.

3. Result and Discussions

Field data from measurements in the study area have analyzed using curve matching and the Progress VER.3.0 program to obtain the right resistivity price, rock layer thickness, and the possibility of a groundwater carrier layer (aquifer). Based on the results of the geoelectric estimation, several cross-sections of type and hydrogeological prisoners can be made in the area, as follows:

4.1. Cross-section Type and Hydrogeological Resistance GT-02

Location coordinates 04° 42' 42.2" South Latitude and 119° 48' 24.1" East Longitude of Greenwich in a bumpy area, which is a residential and plantation population, its constituent rock consists of the Camba Volcano Rock. Expectation point cable is directed northwest-southeast with a maximum electrode current separation distance of 500 meters.

Based on the results of geoelectric estimation with the correlation of geological and hydrogeological data of the local area, an analysis of the cross-section of rock and hydrogeology resistors can find; namely, Depth 0.0 - 1.3 meter, prisoners of type 47.0 ohm-m, which is a cover soil layer is a brownish-gray laterite soil. Depth 1.3 - 4.0 meters, resistivity type 19.6 Ohm-m, interpreted as a layer of clay laterite soil. Depth 4.0 - 13.8 meters, resistivity of 10.6 Ohm-m, interpreted as a layer of tuffaceous clay rock containing free, fresh, low-productivity groundwater, deposited with dug wells. Depth 13.8 - 53.7 meters, resistivity type 31.6 Ohm-m, interpreted as a layer of tuff sandstone, containing freshwater (aquifer layer), small-medium productivity, can pot with boreholes. The depth 53.7 - 108 meters, resistance of 1,234 ohm-m, interpreted as a compact and hard basalt rock layer, a non-aquifer layer. Depth of more than 108 meters, resistivity type 370.0 Ohm-m, interpreted as a maritime limestone layer, compact and hard, non-aquifer layer.

Underground water development in the study area can be done by drilling and dug wells. Dug wells can carry out in free groundwater to a depth of 13.8 meters. Based on this, the planning of underground water exploitation can be carried out according to the direction of the measurement results of the resistivity of each type of rock layer, as follows: Drilling can be carried out to a depth of 53.7 meters, aquifer layer, and filter installation at a depth 15 - 50 meters the bottom is covered with hubcaps, the wellbore discharge is suspected 1-2 liters/sec. Casing and grouting installation at a depth 0-15 meters to prevent surface water seepage directly from entering the well.

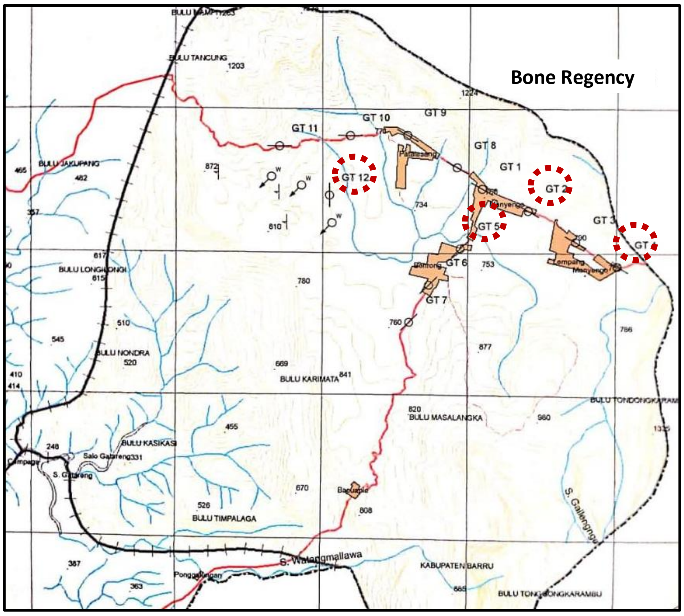

Figure 4. Location Map of Geoelectric Measurement Research Points

4.2. Cross-section Type and Hydrogeological Resistance GT-04

Location coordinates 04° 43' 5.4" South Latitude and 119° 49' 0.2" East Longitude of Greenwich in a bumpy area, which is a residential and plantation population, the constituent rocks consisting of the Camba Volcano Rock. Expectation point cable directed northwest-southeast with a maximum electrode current separation distance of 500 meters.

Based on the geoelectric estimation results with the correlation of geological and hydrogeological data of the local area, an analysis of the cross-section of rock and hydrogeological resistivity types can found, namely depth of 0.0 - 0.7 meters, resistivity of type 236.1 ohm-m, constituting a cover soil layer which is brownish-gray soil laterite. The depth (0.7 - 2.7) m, the resistivity of 55.9 Ohm-m, interpreted laterally by layers of basalt rock. A depth of 2.7 - 23.5 meters, resistivity of 18.3 Ohm-m type, interpreted as a layer of tuffaceous clay rock containing free, freshwater, small productivity, can be pitted with dug wells. Depth of 23.5 - 83.7 meters, prisoners of 27.6 Ohm-m type, interpreted as a layer of tuffaceous sandstone, containing freshwater (aquifer layer), average productivity, can pave with bore wells. Depth of more than 83.7 meters, resistivity 18,690.0 Ohm-m, interpreted as a basal layer, compact, hard, non-aquifer layer.

Underground water development in the study area can be done by drilling and dug wells. Dug wells can carry out in free groundwater to a depth of 23.5 meters. Based on this, the planning of underground water exploitation can be carried out according to the direction of the measurement of the type of resistivity of each rock layer, as follows: Drilling can be carried out to a depth of 83.7 meters, aquifer layer, and filter installation at a depth of 15 - 80 meters below closed with hubcaps, the wellbore discharge is estimated to be 1-5 liters/second. Installation of casing and grouting at a depth of 0-15 meters to prevent surface water seepage directly from entering the well.

4.3. Cross-section Type and Hydrogeological Resistance GT-05

Location coordinates 04° 42' 58.1" South Latitude and 119° 47' 56.6" East Longitude of Greenwich in a bumpy area, which is a residential and plantation population, its constituent rock consists of the Camba Volcano Rock. Expanding point cable northeast-southwest direction with a maximum current separation distance of 500 meters.

Based on the geoelectric estimation results with the correlation of geological and hydrogeological data of the local area, an analysis of the cross-section of rock and hydrogeological resistivity types can found, namely Depth of 0.0 - 0.7 meters, resistivity of 54.1 Ohm-m type, a cover soil layer which is brownish-gray soil laterite. Depth of 0.7 - 2.0 meters, prisoner type 795.0 Ohm-m, interpreted laterite soil layers with lumps of basalt rock. Depth of 2.0 - 25.3 meters, resistivity of 14.9 Ohm-m, interpreted as a layer of tuff sandstone containing free groundwater, fresh, small productivity, can pot with dug wells. Depth 25.3 - 47.6 meters, resistivity 3.5 Ohm-m, interpreted as a layer of clay tuff, soft, non-aquifer layer. Depth of more than 47.6 meters, prisoner type 1854.0 Ohm-m, interpreted as a basal layer, compact, hard, non-aquifer layer.

Underground water development in the study area can be done by drilling and dug wells. Dug wells can carry out in free groundwater to a depth of 15.0 meters. Based on this, the planning of underground water exploitation can be carried out according to the direction of the measurement results of the resistivity of each type of rock layer, as follows: Drilling can be carried out to a depth of

25.3 meters, aquifer layer and installation of filters at a depth of 15-25 meters below it closed with hubcaps, the wellbore discharge estimated to be 1-2 liters/sec. Installation of casing and grouting at a depth of 0-15 meters to prevent surface water seepage directly from entering the well.

4.4. Cross-section Type and Hydrogeological Resistance GT-12

Location coordinates 04° 42' 35.8" South Latitude and 119° 47' 2.5" East Longitude of Greenwich in a bumpy area, which is a rice paddy population, the constituent rock consists of the Camba Volcano Rock. Expanse point cable stretch is east-northeast-southwest southwest with a maximum current separation distance of 500 meters.

Based on the geoelectric estimation results with the correlation of geological and hydrogeological data of the local area, a cross-section analysis of rock and hydrogeological resistivity types can make, namely depth of 0.0 - 2.2 meters, a prisoner of 12.5 Ohm-m type, a cover soil layer which is brownish-gray soil laterite. A depth of 2.2 - 4.9 meters, resistivity of 49.1 Ohm-m, interpreted as a layer of laterite soil with lumps of basalt rock. Depth 4.9-18.4 meters, resistivity type 17.3 Ohm-m, interpreted as a layer of sandstone, containing groundwater (aquifer layer), fresh, medium productivity, can anoint with dug wells and boreholes. Depth 18.4 - 65.0 meters, prisoners 2,240.0 Ohm-m, interpreted as volcanic breccias, compact and hard, non-aquifer layers. Depth of more than 65 meters, prisoners of type 6.4 ohm-m, interpreted as a napal layer, soft, non-aquifer layer.

Underground water development in the study area can be done by drilling and dug wells. Dug wells can carry out in free groundwater to a depth of 10 meters. Based on this, the planning for underground water exploitation can be carried out according to the direction of the measurement results of the resistivity of each rock layer, as follows: Drilling can be carried out to a depth of 18.4 meters, aquifer layer and filter installation at the bottom 10-18 meter depth closed with hubcaps, the wellbore discharge estimated to be 1-2 liters/sec. Installation of casing and grouting at a depth of 0-10 meters to prevent surface water seepage directly from entering the well.

The groundwater of the study area and its surroundings based on aquifer productivity and the way it located can divide into four aquifer areas (groundwater carrier layers), i.e., aquifer areas: high productivity, medium productivity, small local productivity means, and rare groundwater areas. The high productive aquifer region is composed of Tonasa Formation rock consisting of reef limestone, sandstone limestone, slab limestone, and bio-clastic limestone. Low-high rock graduation depends on the number of fractures or fissures. Groundwater flow limited to fracture zones, fissures, and dilution channels. Discharge wells and springs greater than 10 liters / second, deep groundwater level. The shape of the landscape of this area is karst topography, in several places found springs, caves, and underground river flows. Rivers and springs of this area are generally permanent with steep valley slopes.

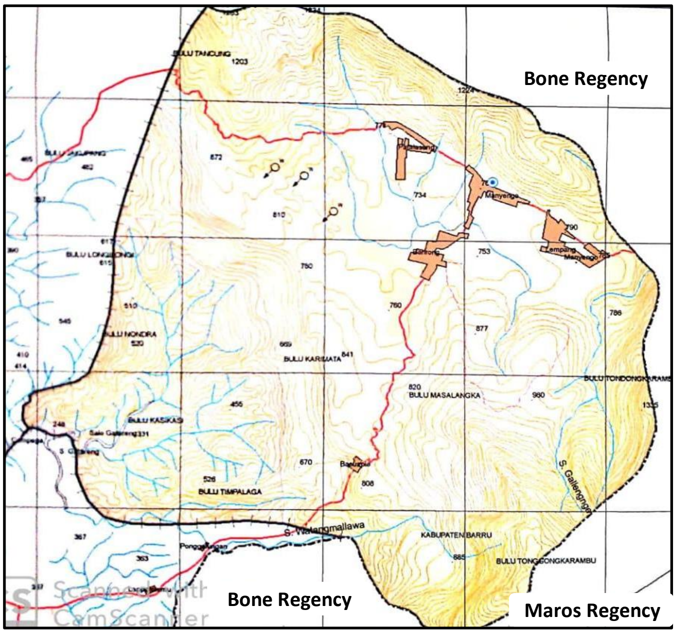

Figure 5. Geological Map of Groundwater Exploration Research Area (Gattareng Village, Barru Regency)

Groundwater development in this region is quite good, because aquifer productivity is high, and the water is suitable for clean water, agriculture, and industry. Its distribution in the central and western parts of the Bulu Karimata area and its surroundings, only its location, which is somewhat far from the settlement, becomes an obstacle in its utilization. The electrical resistivity of rocks and minerals varies depending on rock quality, degree of density, and moisture conditions. In general, granules can conduct electricity because they isolated by pores that contain water, and the levels of salt dissolved in them. The electrical resistance of a rock formation depends on the resistance of the electrolyte content and is inversely proportional to the porosity and solubility level of a rock formation. The principle of resistance of a rock type will be low if porous, fragmented, distorted water. Specific resistance will be even lower if the rock has a high salt content.

The geoelectric method is more effective when it used for relatively shallow exploration. This method rarely provides layers with depth information of more than 300 or 450 meters. Therefore, this method is rarely used for hydrocarbon exploration but is more widely used in the field of engineering geology, such as determining the depth of bedrock, searching for reservoirs of water, geothermal exploration, and environmental geophysics [31], [32].

At the subsurface, groundwater collects in an aquifer or aquifer layer. This aquifer is a formation or rock layer that can hold, store, and drain groundwater. Therefore, the layer must be water-flowing, containing many cavities, cracks, or gaps that are interconnected so that the formation can hold water and limited by a waterproof coating. Water can be added to aquifers naturally as water infiltrates into the soil. Areas, where water infiltrates into aquifers, are known as recharge zones. The free aquifer absorption zone above is generally the area above the aquifer because water can move directly from the surface into the aquifer [33]. However, for cases of a distressed aquifer, the absorption zone may be limited to the range where the impermeable layer reaches the surface. Because water must infiltrate through layers of soil and rock to reach an aquifer, absorption rates can be prolonged and low [34]. Some aquifers formed a long time ago, and they are no longer actively replenished, and some call this type of aquifer fossil water.

Groundwater can move through an aquifer until it reaches an opening to the surface. In absorbing, water reaches the surface over a large area. In spring, water flows from the earth at a small point. Due to the pressure of the water above it, water from aquifers is generally under high pressure and can result in the production of spring artesian. Springs and seeps will only continue to flow if the surface water is higher than they are. Due to the movement of water, the location of the absorption zone may be far from the location of seepage and springs [35].

Water can also be removed from aquifers by human suitable drilling activities. Aquifers have historically been vital for humans who have used water to water livestock, irrigate crops, powering factories, and as city water sources. If the removal rate of water for human use exceeds the prolonged natural rate of absorption, then the total amount of water in the aquifer will decrease, which causes a decrease in the water table (aquifer depletion) [36]. The low water table requires deeper wells, which significantly increases the cost of pumping water from aquifers and subsequently drains water from the already slow, recharge rate [37].

4. Conclusion

To meet the needs of raw water for agriculture and drinking water in areas where surface water is lacking, groundwater is a very reliable alternative. The presence of groundwater is and does not spread evenly, depending on the geological conditions of the underground (water-bearing layer or waterproof layer). To find out the presence of groundwater, it is necessary to conduct a geological investigation of the soil. The presence or absence of groundwater potential many ways can be done, such as hydrogeological map studies and direct investigations in the field. Furthermore, one of the most comfortable but most effective methods of direct investigation in the field for research into groundwater potential is using a geoelectric survey, namely the estimation of resistivity of rock species below the surface of the earth with a capable resistivity meter. To obtain information on subsurface data concerning the geological structure, the information obtained from this geoelectric investigation will be beneficial in determining the steps for further drilling.

Acknowledgments

The Research and Survey funded and fully cooperated by the Mining and Energy Office of Barru Regency, South Sulawesi Province.

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