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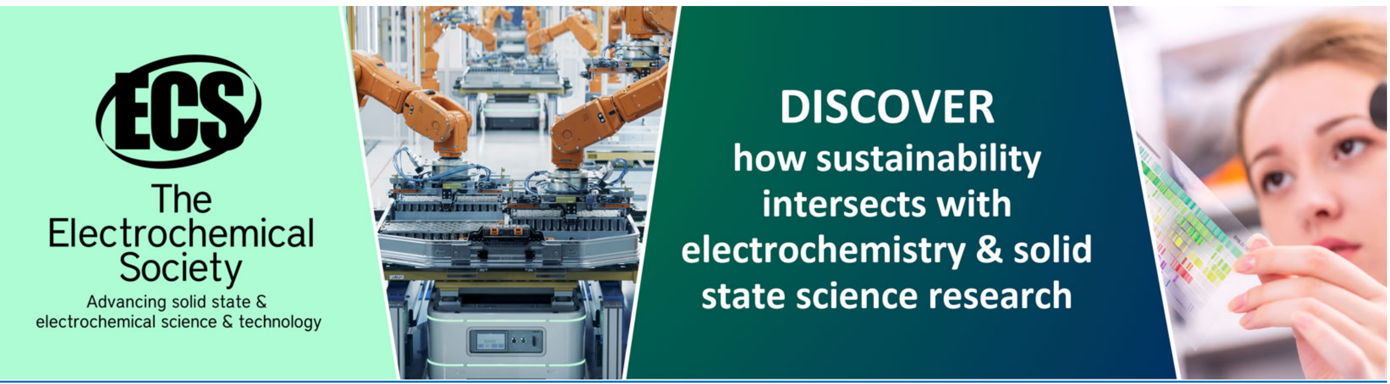

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Geoelectric Sounding for Identification of Aquifer Layer in East Turatea Village South Sulawesi Province

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Abstract. East Turatea Village farmers still depend on rainwater for irrigating their rice fields. This study aims to identify groundwater aquifers in the village of East Turatea which can be used as water sources in irrigating rice fields. The method used is the correlation of well data and Vertical Electric Sounding (VES). Well data is result of water table mapping at three measuring stations. Measure the resistivity of rock using a resistivity meter with a length of 200 m with two Vertical Electric Sounding (VES) points. The measurement results are then processed using Progress software to produce a Vertical Electric Sounding (VES) with a resistivity variation to depth. The result this study found that East Turatea Village's groundwater system in the form of shallow groundwater aquifer has a resistivity value of 0.84 - 5.5 Ohm.m at a depth of 6.04-31.88 m. Meanwhile, deep groundwater aquifers are at a depth of more than 53.8 m with a resistivity value of 1.94 - 2.75 Ohm.m. East Turatea Village groundwater aquifer is estimated to consist of permeable layer such as sand which is in a saturated zone.

1. Introduction

East Turatea Village is one of the developing villages in Tamalatea District where most of the people use PAM water for their daily needs. Some also use pump wells, but these wells are shallow wells that depend on the season. During the dry season, well water decreases and even experiences drought so that it can no longer be used by the community either for daily needs or for agriculture. The area of East Turatea Village's rice fields is 95 ha, of which 93 ha of the rice fields are rainfed [1].

In drilling wells, information regarding the availability of groundwater aquifers is needed. This is related to the placement of groundwater extraction wells. To obtain information on the structure of the rock layers below the surface, geoelectric measurements need to be carried out in order to obtain a description of the presence of the water-bearing layer (aquifer), depth, thickness, potential and aquifer distribution.

This geoelectric method, in principle, injects an electric current on the surface of the earth through a pair of current electrodes and then measures the voltage between the two electrodes using a

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pair of potential electrodes connected to a voltmeter. From the results of these measurements produce data on the strength of electric currents flowing in rocks and electric potential. Based on this data, the resistivity of the rock can be calculated. Geoelectric measurements are carried out at ground level, while groundwater is located below the surface of the ground so that the presence of groundwater cannot be directly observed. This geoelectric measurement is a first step that can provide an overview of subsurface geological conditions related to the groundwater availability.

Geoelectric methods are best used to identify groundwater aquifers. Several applications of the geoelectric method include those used for groundwater investigations in Southeast Iran [2]; investigations of aquifer characteristics and groundwater potential in Kwale, Nigeria [3]; Determination of groundwater potential in Obiaruku and Environs [4]; Determination of shallow aquifers in the Okitipupa Region of Southwest Nigeria [5]; Identification of the Pallantikang Aquifer in Jeneponto Regency [6]; Identification of aquifer layers for determining the depth of dug wells [7]. Geoelectric measurements are intended to obtain a subsurface geological picture where groundwater may be present at a certain depth.

Rocks in South Sulawesi can be divided into 8 units, namely: malih sandstone units (Late Cretaceous), shale rock units (Early Eocene-Oligocene), limestone units (Eocene), limestone sandstones units (Oligocene-Middle Miocene), limestone units layered (Oligocene-Middle Miocene), volcanic clastic unit (Late Miocene), reef limestone unit (Early Pliocene) and conglomerate unit (Pliocene). The geological structure that develops in the study area consists of upward faults, horizontal faults, normal faults and folds whose formation is related to the regional tectonics of Sulawesi and its surroundings [8].

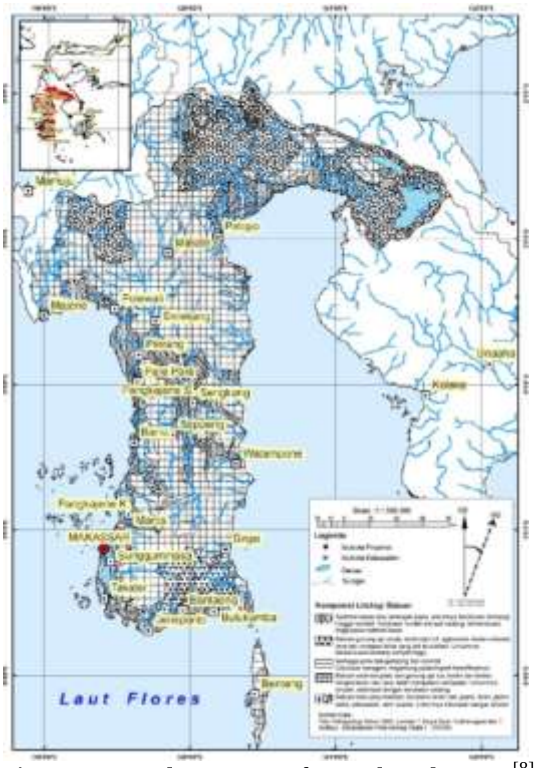

Figure 1. Geology map of South Sulawesi [8]

Figure 1 is a geological map of South Sulawesi. According to [8] based on its lithological composition, rocks in South Sulawesi can be grouped into five (5), namely (1) loose or semi-solid sediments, generally clay to crust in size. Low to moderate graduation, high pass on rough materials. (2) Young volcanic rocks, consisting of tuffs, agglomerates, volcanic breccias, lava, and indecipherable lava deposits. Generally, the graduates are medium to high. (3) Different Types of

Limestone and Dolomite, the graduation varies, depending on the level of karstification. (4) Integrated Sedimentary Rocks and Old Volcano, consisting of breccias, conglomerates, and lava, have experienced multiples. Generally low graduation, local with medium pass. (5) Igneous or Malihan rock, mainly consisting of granite, diorite, gabbro, schist, slab stone, and quartzite. Generally graduation is very low.

Based on the rock group, groundwater in South Sulawesi is in rocks which can act as a water-carrying layer (aquifer). The existing aquifer system can be grouped into four (4), namely (1) Aquifers with water flowing through the space between grains, are found in areas composed of loose or semi-solid sedimentary rock groups. (2) Aquifers with water flowing through the space between grains and fissures, is in an area composed of rock groups young volcanoes, solid sediment rocks and old volcanoes. (3) Aquifer with water flow through fissures and fractures there are areas composed of rock groups frozen and poor. (4) Aquifers with water flowing through fissures, fractures and channels There are areas composed of groups of various types of limestone and dolomite [8].

In general, a simple approach to discussing the earth's electrical phenomena is to consider the earth as a homogeneous medium (same type of lithology) and isotropic (measured from various directions will give the same value). With this treatment the electric field from a point source inside the earth is spherical symmetry. The principle of the geoelectric method is to inject current through a pair of current electrodes C_1 and C_2 which are plugged into the earth. Then another pair of electrodes P_1 and P_2 are used to measure the potential generated by the injection of the current which is also placed on the earth's surface. By knowing the magnitude of the injected current and the potential generated, the resistivity of subsurface rock can be known [9].

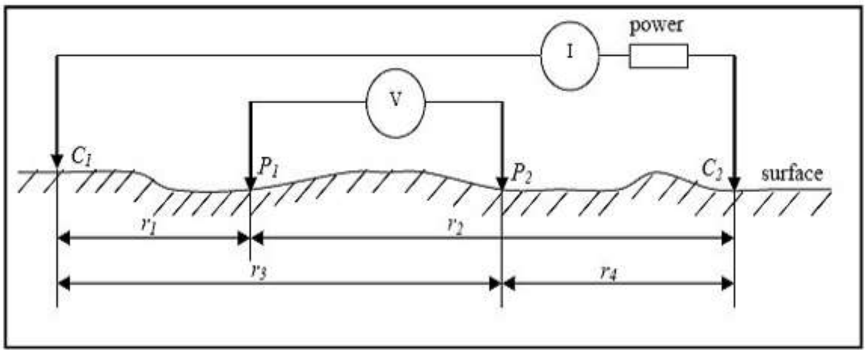

Figure 2. Model of two current electrode and two potential electrode [10]

By deriving the equation mathematically, we get the equation for resistivity:

$$\rho_a = K\frac{\Delta V}{\Delta I} \tag{1}$$

where K is the geometry correction factor denoted by

$$K = 2\pi\left[\left(\frac{1}{r_1}-\frac{1}{r_2}\right)-\left(\frac{1}{r_3}-\frac{1}{r_4}\right)\right]^{-1} \tag{2}$$

Figure 2 shows the electrode arrangement in the Schlumberger configuration which uses four electrodes, namely two inner current electrodes (C_1, C_2) and two potential electrodes (P_1, P_2). In the Schlumberger configuration, ideally, the distance of C_1C_2 is made as small, so that the theoretical C_1C_2 distance does not change. However, due to the limited sensitivity of the measuring instrument, when the P_1P_2 distance is relatively large, the C_1C_2 distance should be changed. The change in the C_1C_2 distance should not be greater than 1/5 the P_1P_2 distance. The geometric factor of this configuration is given by equation 3 where $L = P_1P_2/2$ and $l = C_1C_2/2$.

$$K = \pi\frac{(L^2-l^2)}{2l} \tag{3}$$

In interpreting geoelectric data, a good understanding of geology is needed and interpreting the appearance of the subsurface images into lithology or rock structures. Each rock layer has unique resistivity properties which have their respective resistivity values as shown in Table 1.

Table 1. The resistivity value of various rocks

Materials	**Resistivity (Ohm.m)**
Igneous and Metamorphic Rock	
Granite	$5x10^3$ - 10^6
Basalt	$10^3 – 10^6$
Slate	$6x10^2$ – 4x107
Marble	10^2 – $2{,}5x10^8$
Quartzite	102 – $2x10^8$
Sedimetary Rock	
Sandstone	8 – $4x10^3$
Shale	20 – $2x10^3$
Limestone	50 – $4x10^2$
Soils and wate	
Clay	1 – 100
Alluvium	10 – 800
Groundwater	10 – 100
Sea water	0,2

(Source: [11])

From equations (1) and (3) an equation is obtained for calculating apparent resistivity:

$$\rho_a = K \frac{\Delta V}{\Delta I} \tag{4}$$

$$\rho_a = \pi \frac{(L^2 - l^2)}{2l} \frac{\Delta V}{I} \tag{5}$$

Ground water is water that moves in the soil which is contained in the spaces between the soil grains that seep into the soil and form a layer of groundwater called an aquifer [12]. Groundwater flow in rocks is largely determined by the permeability of these rocks. Permeability is the ability of a fluid to flow through a porous medium. Permeability is a function of the level of spatial relationships between rock pores. Determination of the permeability coefficient can be done by using a constant high or falling head [13]. Another variable that plays a major role in groundwater flow is porosity. Porosity is a measure of empty spaces in a rock. Porosity definitively is the ratio between the volume of space contained in the rock in the form of pores to the volume of the rock as a whole, usually expressed in fractions. The size of the porosity of a rock will determine the fluid storage capacity [14].

The simplest hydrological configuration of the saturated and unsaturated states is the unsaturated zone at the surface and the saturation zone at depth. The boundary between these two zones is called the water table. the ground water level is generally not horizontal like sea level or lake, but more or less follows the topography of the earth above it. At the bottom of the hill higher and down towards the valley. The difference in elevation between the parts of the water level is called the hydraulic head. In swampy areas, the ground water level is equal to the surface, while the river and lake flows are lower. Groundwater levels that do not follow these laws of physics are caused by the very slow groundwater flow (percolation). If there is no rain, the water level under the hill will gradually decrease until it is parallel to the valley. But this never happened, because the rain will recharge again [15].

Aquifer is a geological formation where the formation contains water and under conditions commonly found in the field allow water to pass through the formation (permeable). These formations are generally unconsolidated such as sand or silt layers. Aquiclude (aquiclude) is a geological formation that cannot be passed through a significant amount of water, although the formation also contains water. Generally, aquiclude is a limiting layer above or below the confined aquifer layer. Examples of aquiclude are layers of clay or loam rock. Often for practical purposes the aquiclude is considered a waterproof or impervious layer. Aquitard (aquitard) is a layer or geological formation that is less impermeable to water than aquiclide, but can still transmit or pass water even in small amounts. This layer is often not very thick and in practice can or is often referred to as the semipervious layer or leaky formation. Rainwater that seeps into the ground becomes part of the groundwater, slowly flows into the sea, or flows directly into the ground or on the surface and joins river water. The amount of water that seeps into the ground depends on, besides time and space, it is also influenced by the steepness of the slopes. Soil surface material condition and the type and amount of vegetation and of course rainfall. Even though the rainfall is large but the slopes are steep, covered with impermeable minerals, the percentage of water flowing on the surface (run off) is more than on gentle slopes and the surface is permeable, the percentage of water that is absorbed is more. Some of the infiltrated water does not move far because it is held by molecular attraction as a layer on the soil grains. Some of it evaporates back into the atmosphere and the rest is a reserve for plants as long as there is no rain. Water that is not held near the surface breaks down into a zone where all open spaces in the sediment or rock fill with water (water saturation). Water in the zone of saturation is called groundwater. This zone boundary is called the water table. The layer of soil, sediment or rock above which is not saturated with water is called the zone of aeration as shown in Figure 3 [15].

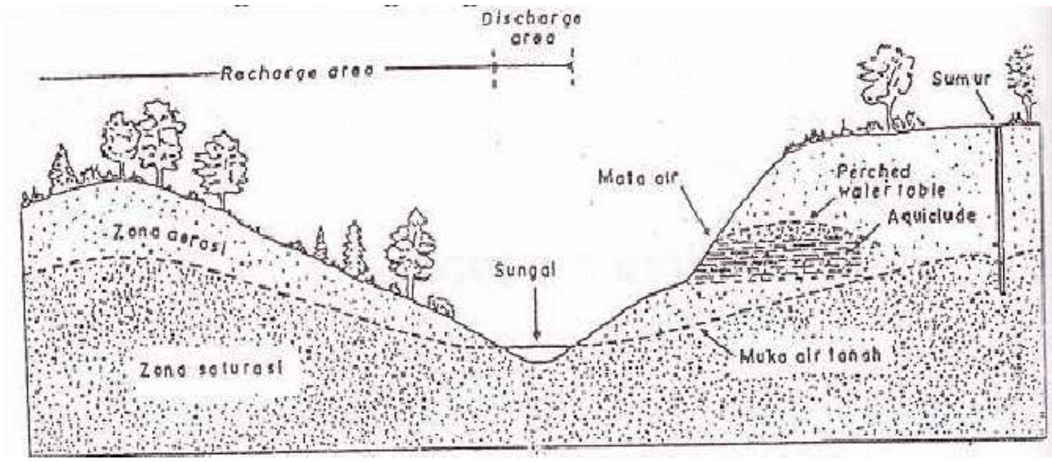

Figure 3. Relative positions of some terms related to subsurface water [15].

The groundwater level is generally not horizontal, but tends to follow the topography of the surface above it. The difference in elevation between parts of the groundwater level is called the hydraulic head. This groundwater level that does not follow the laws of physics is caused by the very slow flow of groundwater (percolation). The area where the rainwater seeps down (precipitation) to the saturation zone is called a recharge area. The area where groundwater comes out is called the discharge area [15].

2. Methodology

This research was conducted in East Turatea Village, Tamalatea District, Jeneponto Regency. Astronomically, the research location is located between 119°40’45”E – 119°42’50”E and 5°38’55”S – 5°40’57”S (Figure 4). This research consists of two activities, namely observation of wells to determine the groundwater level of the research location and geoelectric measurements to determine the value of rock resistivity in the study area. Measurement and observation stations can be seen in Figure 4.

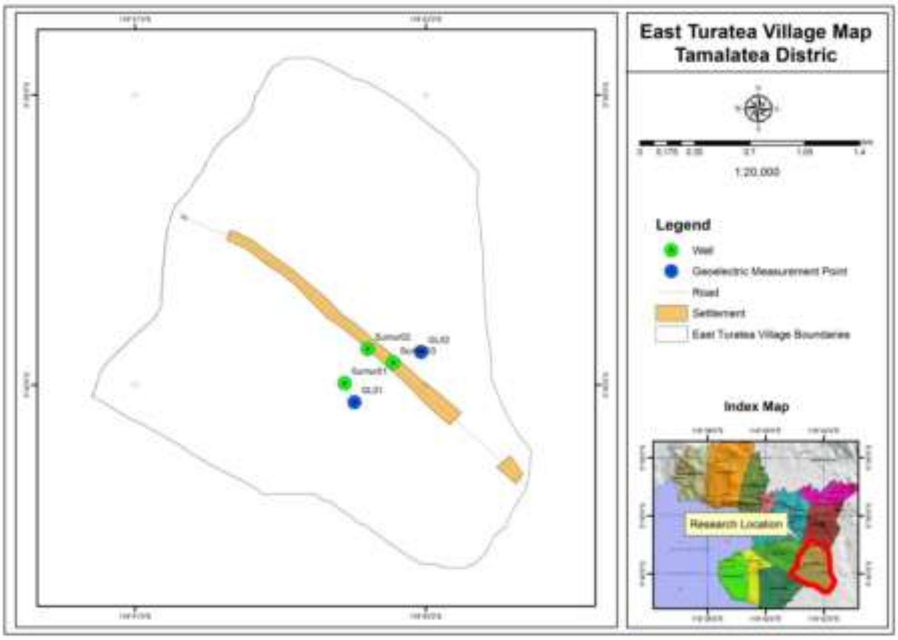

Figure 4. Map of research area

The equipment used in the field research includes the Global Positioning System (GPS), a set of resistivity meter type Naniura model NRD 300 HF, digital camera, writing tool, meter with 50 m and 30 m length respectively and laptop (netbook).

2.1 Data collection

Data collection consists of literature studies, field research. Literature studies in the form of reviewing references, results of previous research that are relevant to the research topic, while field research is carried out to obtain field data which includes measuring the water level in observation wells and estimating subsurface rocks. with the resistivity approach

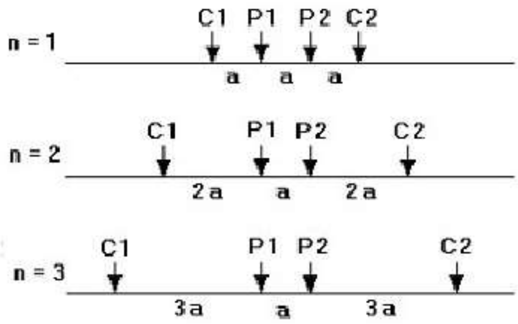

Figure 5. The electrode arrangement of the Schlumberger configuration [11]

The geoelectric method is carried out using the Schlumberger configuration. In this configuration, current (I) is injected into the ground through two current electrodes (C_1C_2) and the potential difference (V) will be recorded by two potential electrodes (P_1P_2). The arrangement of the electrodes is arranged so that the position of the current electrode (C_1C_2) is outside of the potential electrode (P_1P_2) which is on the inside which lies in a straight line (Figure 5). The data obtained is then recorded in the measurement table. From the geoelectric data, the resistivity value of the rock is calculated using Equation (4) which is then processed with Progress software to obtain a resistivity section of the subsurface rock layer. The geoelectric method is carried out using the Schlumberger configuration. In this configuration, current (*I*) is injected into the ground through two current electrodes (C_1C_2) and the potential difference (*V*) will be recorded by two potential electrodes (P_1P_2). The arrangement of the electrodes is arranged so that the position of the current electrode (C_1C_2) is outside of the potential electrode (P_1P_2) which is on the inside which lies in a straight line (Figure 5). The data obtained is then recorded in the measurement table. From the geoelectric data, the resistivity value of the rock is calculated using Equation (4) which is then processed with Progress software to obtain a resistivity section of the subsurface rock layer.

2.2 Processing and Data Analysis
From the results of data collection, then an analysis of the results of geoelectric measurements is carried out according to the field conditions in order to obtain accurate results. Data from measurement results in observation wells are in the form of water level data (water table). Then this data is further processed using mapping software to produce a water level map of East Turatea Village. This data is used as supporting data in interpreting geoelectric data. Calculation and processing of resistivity geoelectric data is carried out using a data processing application and Progress to obtain a 1D model describing the variation of resistivity for each measurement point. Then do a subsection of the rock surface. The results of this data processing are then interpreted by comparing the results of data processing with rock resistivity tables and other supporting data (water level data).

3. Results and discussions
East Turatea Village groundwater level data was obtained from observation wells. This observation source is a source of groundwater used by the community in the village. The observation wells used are three wells scattered in the village of East Turatea. The depth of the ground water level observed in the observation wells varies from a depth of 3.44 - 8 m. The results of the mapping of the groundwater level of the East Turatea Village showed that Kallongerasa Hamlet had the deepest groundwater level (purple) with a depth of 6 - 8 m. However, in general, the groundwater level in East Turatea Village has a shallower water level (blue), namely 4-6 m which is spread almost all over the East Turatea Village which is the research location.

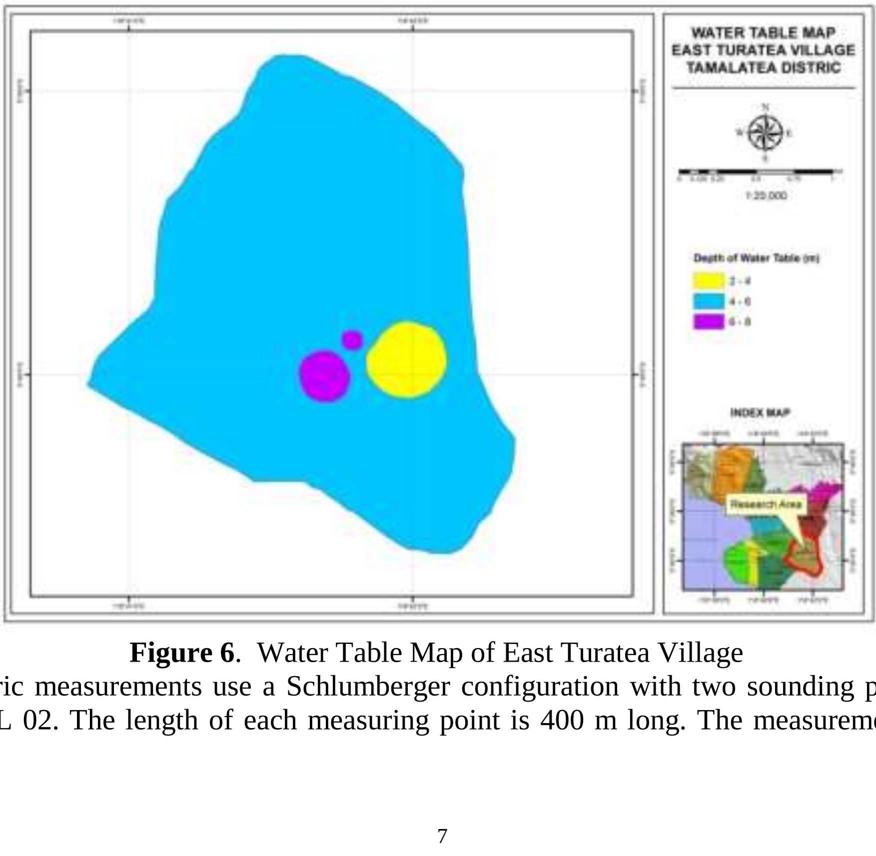

Figure 6. Water Table Map of East Turatea Village

Geoelectric measurements use a Schlumberger configuration with two sounding points, namely GL 01 and GL 02. The length of each measuring point is 400 m long. The measurement results for each stretch are in the form of sounding points that describe the variation of rock resistivity to depth then the data is processed into the Progress software. Figure 7 and Figure 8 are the results of the Progress Software. In this figure, there are three curves, namely the observation data (yellow point), the calculated curve (purple line) and the parameter curve (blue line). The working principle of this software is to match the observed data curve with a calculated curve and respond to the model parameter curve that describes the number of layers, thickness and resistivity value of the rock. The resistivity value obtained is then compared or matched with a predetermined resistivity table.

GL 01 measuring point is in Kallongerasa Hamlet at the coordinates 119^{o}41'44,726 "E and 5^{o}40'4,491"S. Figure 7 illustrates the number of layers at the measurement point, thickness and resistivity values of rock. The resistivity values obtained ranged from 0.84 to 18.47 Ohm.m. with a depth of up to 53.8 `m. The thickness of the rock layers varies from 0.61 to 23.71 m.

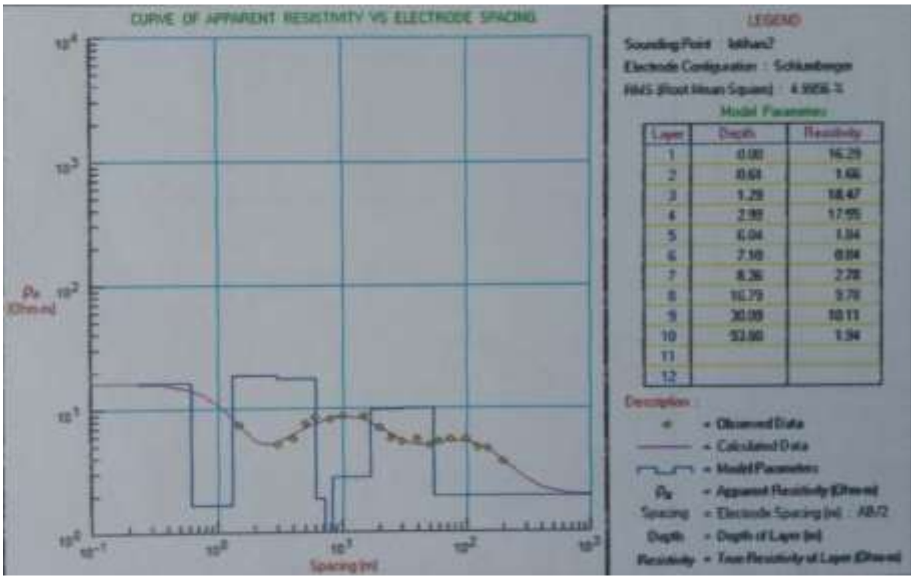

Figure 7. Vertical Electric Sounding GL 01

To convert the resistivity values into rock types, an interpretation process is carried out. Data interpretation needs to be supported by additional data such as well data (water level), resistivity table and geological conditions of the study area.

Table 2. Interpretation of GL 01 subsurface rocks

Layer	Resistivity values (Ohm.m)	Depth (m)	Material
1	1,66-18,47	0-6,04	Zone of Aeration
2	0,84-2,78	6,04-16,79	Shallow groundwater (freatic)
3	9,78-10,11	16,79-53,8	Impermeable layer
4	1,94	53,8>	Depth groundwater (artesian)

GL02 measurement point is in Manrumpa Hamlet at the coordinates 119^{o}41'58,706”E and 5^{o}39'53,595"S. Figure 8 illustrates the number of layers at the measurement point, thickness and resistivity values of the rock. The resistivity values obtained ranged from 2.75 to 38.03 Ohm.m. with a depth of up to 88 m. The thickness of the rock layers varies from 0.94 to 56.39 m.

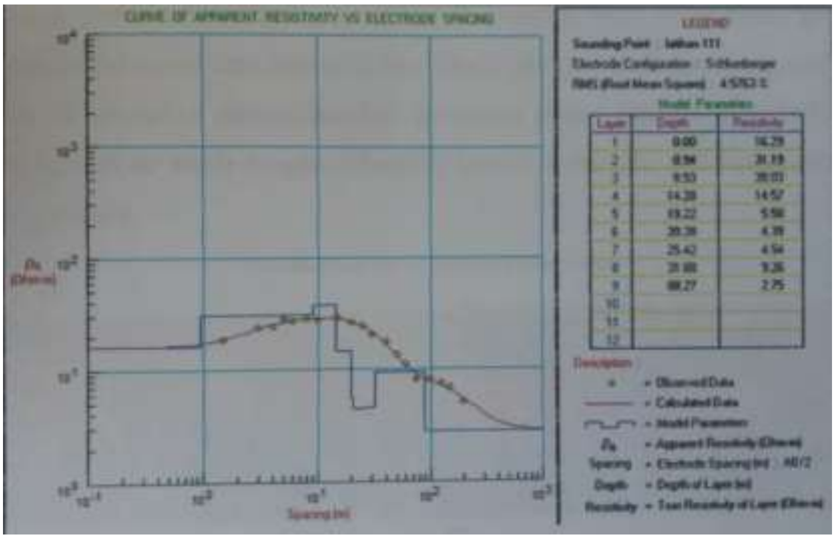

Figure 8. Vertical Electric Sounding GL 02

Table 3. Interpretation of GL 02 subsurface rocks

Layer	Resistivity Values (Ohm.m)	Depth (m)	Material
1	14,57-38,03	0-19,22	Zone of aeration
2	4,39-5,5	19,22-31,88	Shallow groundwater (freatic)
3	9,26	31,88-88,27	Impermeable layer
4	2,75	88,27>	Depth groundwater (artesian)

Aquifer is a layer of rock that carries or stores ground water. Rocks that can function as aquifers usually have pores so they can store water. In addition, these rocks have good permeability, which is the ability to pass water (permeable). These rocks are generally not as consolidated as sand beds.
In identifying subsurface rocks, it is done by comparing the resistivity value of the rock as measured by a predetermined rock resistivity table (table 1) 10-100 Ohm.m [11]. In addition, supporting data is also required such as regional geological data of the research area and water level data that has been obtained in the field. Based on the interpretation of the two geoelectric measurement data, the rock resistivity value is 0.84-38.03 Ohm.m. In the resistive range these rocks are classified into four layers, namely the unsaturated layer, the shallow groundwater layer (phreatic), the impermeable layer, and the deep groundwater layer (artesian).

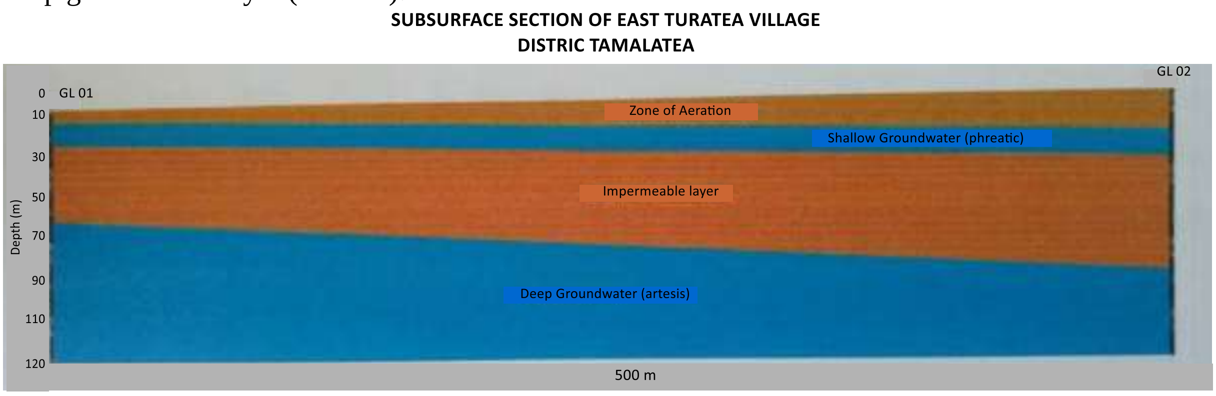

Figure 9. Subsurfac section of East Turatea Village

The uppermost layer of the research location is an alluvial deposit which has a resistivity value of 1.66 - 38.03 Ohm.m. Alluvial deposits constitute a water-unsaturated zone layer at a depth of 0 - 19.22

m. The aquifer layer in East Turatea Village is at a depth of 6.04-31.88 m with a resistivity value of 0.84-5.5 Ohm.m. This aquifer layer is thought to consist of permeable layers such as sand. This material is a water-saturated zone, where the pores of the rock have been filled with water. The third layer is a watertight layer like clay at a depth of 16.79-88.27 m. This watertight rock has a resistivity value of 9.26-10.11 Ohm.m. The lowest layer is a layer of deep groundwater aquifers (artesian) which has a resistivity value of 1.94-2.75 Ohm.m at a depth of more than 53.8 m.

East Turatea Village has quite a lot of groundwater potential. The potential for groundwater is spread throughout the village of East Turatea. The depth of groundwater obtained based on the results of geoelectric measurements is 3-8 m. Shallow groundwater in East Turatea Village can be found at a depth of 6.04 - 31.88 m. Meanwhile, deep groundwater is estimated at a depth of 53.8 m. The results of water level and well depth measurements also show that groundwater can be found at a depth of 3-8 m. The results of the study [16] also confirmed that the presence of groundwater in Turatea Village was at a depth of 6 m. Groundwater that is used by the community through wells is shallow (phreatic) groundwater. The community of East Turatea Village has exploited this large potential for groundwater. The people of East Turatea Village make use of this ground water by making wells, both conventional and bore wells. Based on data [1], people who utilize groundwater use 64 pumps, 494 pump wells, and 609 wells. This ground water is used for various purposes, from household to agriculture.

4. Conclusion

From the results of data analysis and discussion that has been carried out, several conclusions can be drawn as follows: East Turatea Village groundwater system in the form of shallow groundwater aquifer has a resistivity value of 0.84 - 5.5 Ohm.m at a depth of 6.04-31.88 m. Meanwhile, deep groundwater aquifers are at a depth of more than 53.8 m with a resistivity value of 1.94 - 2.75 Ohm.m. East Turatea Village groundwater aquifer is estimated to consist of permeable layer such as sand which is in a saturated zone.

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