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Identification of the Aquifer Layer using the Geoelectrical Method in Teupin Batee Village, Aceh Besar

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ABSTRACT

The need for clean water around the world is related to the increasing population, especially in Teupin Batee Village, Aceh Besar District. In addition to surface water, groundwater is one of the potentials that can be utilized by the community, particularly for household needs. The purpose of this study is to identify the aquifer layer using the geoelectric method. One of the geophysical methods that can be used to map groundwater potential is the geoelectrical method based on the resistivity value of subsurface rocks. This study uses the Wenner-Schlumberger array because it can map subsurface structures both vertically and horizontally. From the results of the study, it was found that there are four different layers in this research area including, the top soil layer, hard rock, tuffaceous sand and sand layer as aquifer layer. The top soil layer is mixed with tuff, sand and volcanic breccia to a depth of 8 m with a resistivity value of 5-25 Ωm. The Hard rock layer is at a depth of 8 m – 30 m with a resistivity value of 45-220 Ωm. The tuffaceous sand layer has a resistivity value ranging from 25-55 Ωm. While the sand layer or aquifer is at a depth of 10 m – 60 m with a resistivity value of <10 Ωm which is separated by a layer of tuffaceous sand between the two aquifer layers.

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1. INTRODUCTION

Groundwater is one of the most important human needs related to household, industrial, plantation and livestock needs. Groundwater is generally found in a saturated layer that has a hydrostatic pressure equal to or greater than atmospheric pressure. The capacity of groundwater stored below the surface depends on the nature of the aquifer (a layer of subsurface rock that contains water) which is usually homogeneous [1].

For exploitation of groundwater sought is the deep aquifer layer. Usually, the presence of abundant groundwater is found in layers of sedimentary rock that have high porosity such as sand. We know that one of the physical properties of the aquifer layer is that it has a high conductivity value or a low resistivity value.

One method that can be used in the search for clean water sources is the geoelectrical method. This method can determine the resistivity of rock based on the ability of the aid to deliver electric current that is injected from the surface. The basic principle of this method is to measure the potential difference of an area based on an electric current that is injected into the ground through a current electrode [2]. The current and potential electrodes are generally made of stainless steel, therefore measurements using the geoelectrical method need to be careful not to choose an electrode during the measurement process [3]. As it is known that water has excellent conductivity properties in delivering electricity. Therefore, if the pores of the rock contain air, the resistivity value will be low in the cross-section of the resistivity section model obtained.

The array used in this study is a combination of the Wenner and Schlumberger arrays which is called the Wenner-Schlumberger array. The reason for choosing this array is because of its excellent ability to image subsurface images both vertically and horizontally.

The geoelectrical method has been widely used for the investigation of groundwater layers. For example, Mohamaden (2016) conducted a geoelectric survey at Egypt's Dakhla Oasis to delineate groundwater aquifers and subsurface structures [4]. Geoelectrical methods can also be used to determine aquifer parameters in combination with pumping test data [5], [6], [7]. Even the geoelectrical method can also be combined with other methods such as Self Potential (SP) and Ground Penetrating Radar (GPR) [8], [9]. In addition, resistivity data obtained from measurements using the geoelectrical method are also often integrated with borehole data to obtain a better subsurface image [10], [11].

This research was conducted in Teupin Batee Village, Aceh Besar District. Teupin Batee Village is administratively located in Aceh Besar District, Aceh Province. Morphologically this area is located in a flat area surrounded by hills <500 masl filled with sedimentary rocks of Tertiary age while the west coast area is a highland with an elevation of about 900 masl filled with layered sedimentary rocks of Tertiary age. A series of Plio-Pleistocene volcanoes with an altitude between 500-800 masl occupy the northern coast to the western part of the Sigli area. The highest peak forms the cone of Mount Seulawah Agam with an altitude of 1810 masl [12].

In this area, apart from housing residents, there are also plantations and small farms owned by residents. The increasing need for water due to the increasing population and other activities that require water around Teupin Batee Village are the main reasons for the need for this research. The purpose of this study is to map the aquifer layers in Teupin Batee Village based on the resistivity of subsurface rocks. It is hoped that the results of this study can be used by the surrounding community for the existence of location points and the depth of clean water sources in the area.

2. RESEARCH METHOD

The geoelectrical method is a method that can determine the physical properties of rocks in the form of resistivity. Rock resistivity values can describe the state or nature of the rock itself. Generally, different rocks and minerals have different resistivity values. However, sometimes the resistivity of one rock is in the same range of values. The high and low resistivity values of subsurface rocks are influenced by many factors. Factors that cause low resistivity values include high clay content, high salinity levels and high porosity which is saturated with water. Conversely, if the porosity is high but filled with air, the resistivity value will be high [2].

Table 1. Resistivities of rocks and sediments [2][13]

Rock	**Resistivity range (Ωm)**
Lavas	$10^2 – 5 \times 10^4$
Tuffs	2×10^3 (wet) – 10^5 (dry)
Dacite	2×10^4 (wet)
Andecite	4.5×10^4 (wet)
Basalt	$10 – 1.3 \times 10^7$ (dry)
Gabbro	$10^3 – 10^6$
Sandstones	$1 – 6.4 \times 10^8$
Clays	$1\text{-}10^2$
Alluvium	$1 – 10^3$
Gravel	$10^2 - 10^4$

Table 2. Resistivities of minerals [2]

Minerals	Resistivity (Ωm) Range	Resistivity (Ωm) Average
Fire clay		30
Meteoric waters	$30 – 10^3$	
Surface water (igneous rocks)	$0.1 – 3 \times 10^3$	
Surface water (sediments)	10 – 100	
Soil water		100
Natural water (igneous rocks)	0.5 - 150	9
Natural water (sediments)	1 – 100	3
Sea water		0.2
Saline water, 3%		0.15
Saline water, 20%		0.05

In this method, the rock resistivity value obtained after the measurement is not the actual rock resistivity but the apparent resistivity (ρ_a). The equation to get the apparent resistivity is given by,

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

where k is the geometric factor, V is the potential difference and I is the current. The arrangement of electrode placement arrangements in the geoelectrical method is called the electrode array. The array used causes the geometry factor of each array to be different. The geometry factor is the magnitude of the correction of the potential electrode array and the current electrode. In this study the array used is the Wenner-Schlumberger array (Figure 1).

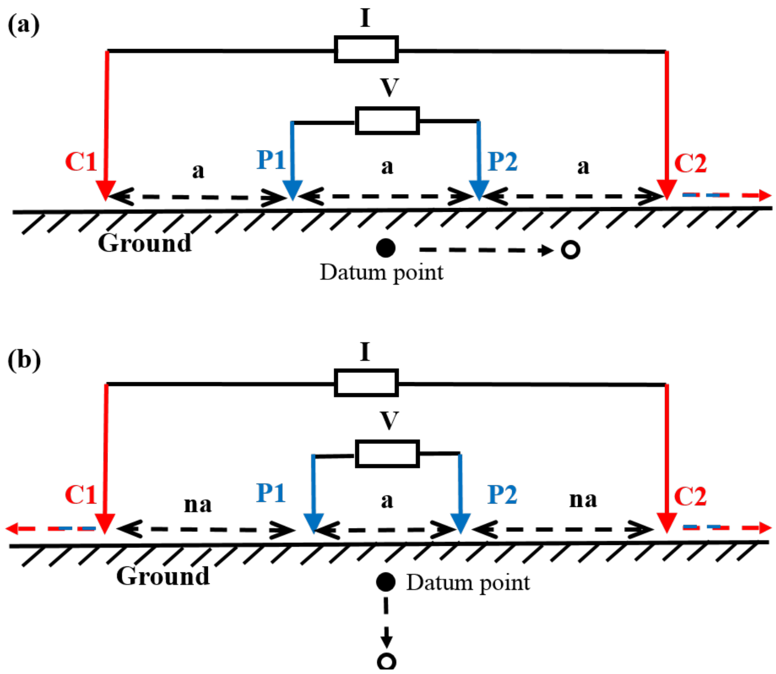

Figure 1. Arrangement of current and potential electrodes, (a) Wenner array, (b) Schlumberger array [2]

The arrangement of electrodes in geoelectrical measurements has its own advantages and disadvantages with regard to depth of investigation, resolution of horizontal and vertical [14]. For example, to see the change in resistivity horizontally, the Wenner array is better than the Schlumberger array. However, for changes in resistivity vertically, the measurement using the Schlumberger array is better than the Wenner array. The Wenner-Schlumberger array is a combination of the Wenner and Schlumberger arrays [8]. In this array the distance between the electrodes P1 and P2 is a and the distance between C1P1 = P2C2 is na. The result of the combination of Wenner and Schlumberger causes the geometric factor k value to also change, namely:ü

$$k = \pi n\,(n+1)a \tag{2}$$

Wenner-Schlumberger array command file was created using AGISSAAdmin software for 56 electrodes with total of 455 datum points. Next, the command file that has been is transferred to the the resistivitimeter device via a data transfer cable by clicking send new command in the command files menu.

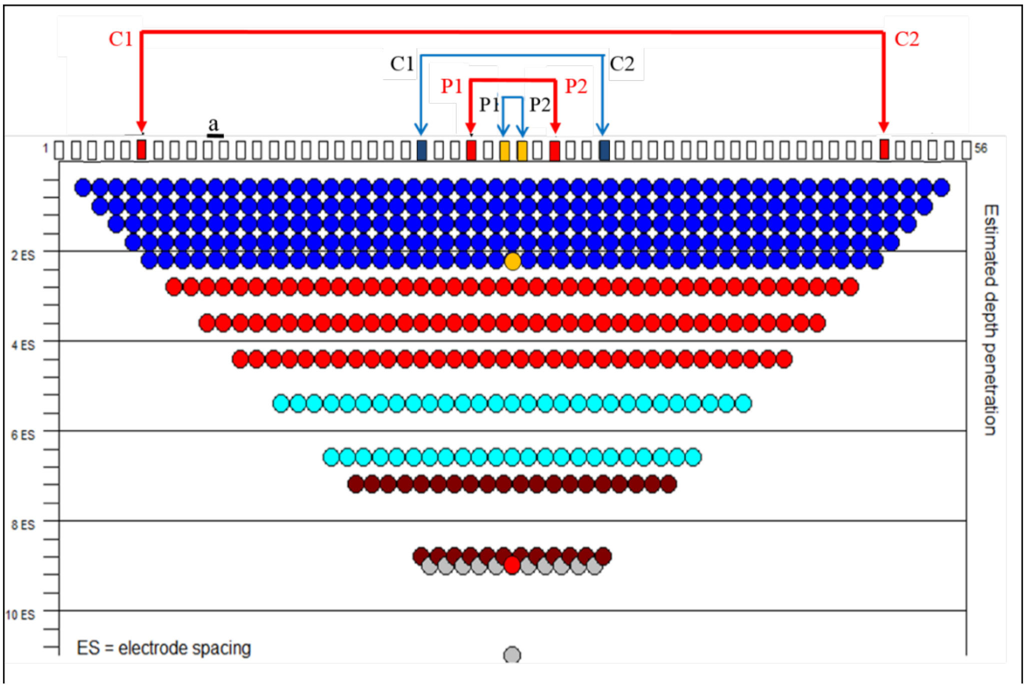

Figure 2. Illustraion of measurement points created using AGISSAAdmin for Wenner-Schlumberger array

This research was conducted in Teupin Batee Village, Aceh Besar District with a line length of 330 m and a distance between electrodes of 6 m (Figure 3). The longer the electrode distance will cause the flow of electric current to penetrate deeper layer of rock. Resistivity data measurements were carried out using a SuperSting R8/IP resistivitymeter (Figure 3). As for the altitude and position data taken at each electrode using GPS. Data processing in this study uses Res2DInv software based on least squares optimization to determine subsurface conditions [15]. This program gives results in the form of pseudo-sections and resistivity inversion results [16].

Figure 3. Resistivitymeter SuperSting R8/IP

3. RESULTS AND DISCUSSION

The geology of this research area is composed of sedimentary rock and volcanic rock (Figure 4), including from young to old, namely alluvium Qh; Qvtl Lava from Lam Teuba Volcano; Lam Teuba Qtvt Volcanic Rocks which are composed of andesite to dacite volcanic rocks, pumice breccia, tuff, agglomerates, and ash flows; the Idi Qpi Formation which is composed of semi-hardened sand and gravel; and the Seulimum QTps Formation which is composed of tuff and calcareous sandstone, conglomerate, and mudstone [12].

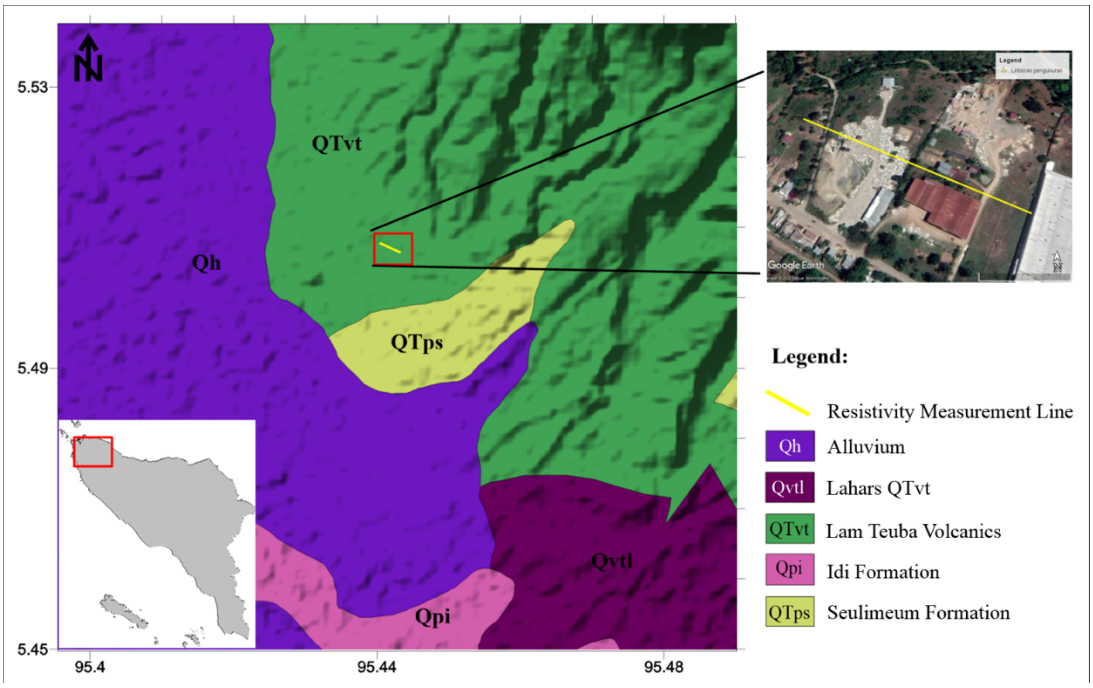

Figure 4. Geological map of the research area and measurement line

Figure 5 which is the measured apparent resistivity pseudo-section, calculated apparent resistivity pseudo-section, and the results of the inversion model. The measured apparent resistivity pseudo-section is the data that is measured in the field, while the calculated apparent resistivity pseudo-section is the calculated model. Apparent resistivity here means the resistivity obtained from an equivalent homogeneous medium based on Equation 1. High resistivity is related to the ability of rocks to conduct electricity which is quite weak. Usually the water content in these rocks is very low. While the resistivity model which has a low value is related to the ability of rocks to conduct electricity which is relatively high. Models with low resistivity can be interpreted as having a high water content. The inversion results in Figure 5 are obtained after 3 iterations with a fairly small error of 7.6%. The more similar the results of the calculated apparent resistivity pseudo-section with the measured apparent resistivity pseudo-section, the smaller the error will be.

The resistivity model in this study was obtained around 4-290 Ωm. The resistivity values obtained are interpreted based on the geology of the study area (figure 4). By direct observation, the measurement line from northwest to southeast is in the Lam Teuba Volcanic Rock formation consisting of tuffaceous sand and volcanic breccias. The influence of topography or the presence of local faults [17] makes the conditions subsurface the volcanic landscape area very complex and complicated. The results of the interpretation of the resistivity model can be seen in Figure 6. There were 4 different layers including top soil, tuffaceous sand layer, hard rock, and sand layer. It was found that up to a depth of 8 m is top soil with resistivity values ranging from 5-25 Ωm. This top soil layer is very complex because it also mixes with tuff, sand and vulcanic breccia. This condition makes the presence of surface water to be found in this layer. However, the presence of water in this layer is strongly influenced by rain. Hard rock layer are on the left side of the model at a depth of 8 m to 30 m from a distance of 0 to 90 m with a resistivity value of 45-290 Ωm. The aquifer layer is predicted to be at a depth of 15 m to 60 m from the left of the model and at a depth of 12 m to 60 m from the right of the model with resistivity values <10 m. The aquifer layer is located on the sand layer which is bounded by the tuffaceous sand layer between the two aquifer layers. This tuffaceous sand layer has resistivity values ranging from 25-55 Ωm. Tuffaceous becomes more conductive because it mixes with sand which has high porosity and contains water.

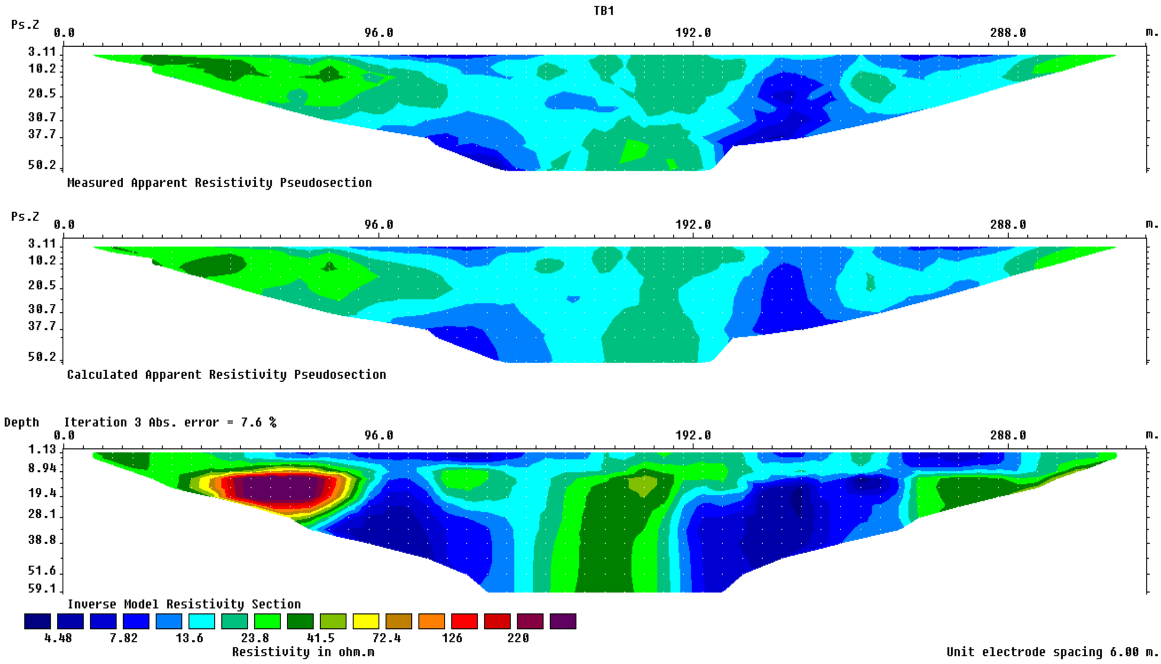

Figure 5. Pseudo-section of measured apparent resistivity, calculated apparent resistivity and inverse model resistivity.

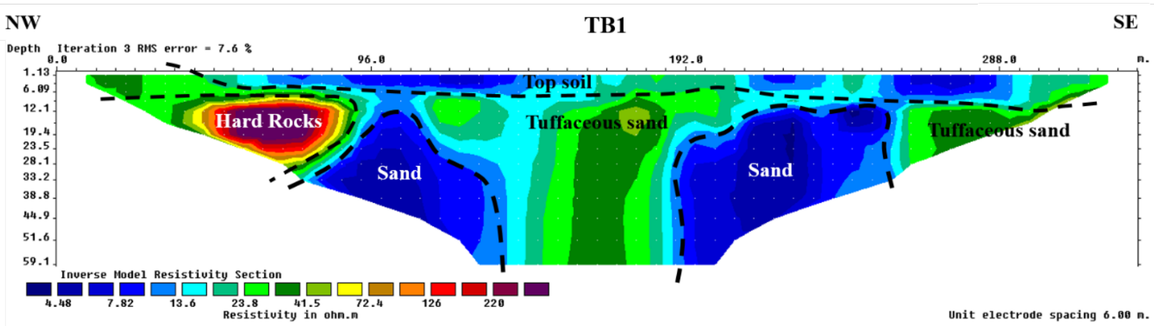

Figure 6. 2D resistivity model resulting from the inversion

4. CONCLUSION

Geoelectrical method has been widely used for the exploration of groundwater potential. From the results of research conducted in Teupin Bate Village, Aceh Besar District, it shows that the geoelectrical method can identify the aquifer layer quite well. The aquifer layer is characterized by a low resistivity value of about <10 Ωm which is in the sand layer. It is estimated that the aquifer layer is at a depth of 10-60 m which is separated by a layer of tuffaceous sand with a resistivity value of 25-55 Ωm. In addition, from the resistivity model, other layers can also be identified, namely top soil and hard rock, each of which has a resistivity value of 5-25 Ωm and 45-290 Ωm.

Drilling for water sources should be carried out at locations where the subsurface layer has a low resistivity value and consists of layers of porous rock such as sand.

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