Depth estimation of the aquifer layer using the geoelectric resistivity method

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Abstract. At present, the distribution of water received by the ITK campus only comes from the PDAM and often experiences interference. Based on this case, a solution is needed to overcome the limitations of water by finding a layer of aquifers around campus area of ITK. The purpose of this study was to estimate the depth of aquifer and subsurface stratigraphy around ITK using the geoelectric resistivity method with schlumberger configuration. The resistivity geoelectric method is used to determine the subsurface structure based on the distribution of rock resistivity values. The results of the interpretation indicate that the subsurface stratigraphy of the study area consists of top soil with resistivity 36.9 Ωm - 558 Ωm, sandy clay with resistivity 16.1 Ωm - 64.9 Ωm, coal insertion with resistivity 637 Ωm, clayey sand with resistivity 133 Ωm - 174 Ωm, and clay with a resistivity of 2.32 Ωm - 8.27 Ωm. The coal and clay seams are aquiklud, the sandy clay layer is aquitar, and the layer that includes aquifers is clay sand layer. The depth of the aquifer at each measurement point on average has a range from a depth of 56.5 m - 72.8 m is medium to productive aquifer

1. Introduction
Groundwater is source of water located in subsurface of earth [1]. On of main source is rainwater that seeps down through the pore hole between rock and soil. According to Sadjab, et al (2012) groundwater is stored in a place called an aquifer. Aquifer is permeable rocks which can contain and transmit groundwater [2]. Along with the development of the Institut Teknologi Kalimantan (ITK) every year which admit new students and build new lecture buildings, so the need for clean water increases. That’s why a method have to find that can be used to identify the aquifer as new water potential resources. According to several studies by Lash Karipour [3], Karunianto [4], Wardani [5] and Muntaha [6] method that can be used to identify aquifer layer is resistivity method. Resistivity method was an active geophysical method using artificial source by injecting electricity through electrode into earth to find the value of subsurface resistivity. Configuration that often used for identify the depth of aquifer was Schlumberger configuration.

2. Numerical Method
Basic concept of resistivity method is Ohm’s Law which was first found by George Simon Ohm. He said that electric current a conductor cable is proportional to the potential difference that passes through cable. This linier relation is expressed by equation [7]:

\[ I = \frac{V}{R} \]
\[ I = \frac{V}{R} \quad (2.1) \]

where \( R \) is conductor resistance.

If a wire is given a resistance proportional to length \( L \) (meter) and inversely proportional to cross-sectional area \( A \) (m\(^2\)) of the conductor, and resistivity \( \rho \) (\( \Omega \text{m} \)), resistance \( R \) can be formulated as:

\[ R = \frac{\rho L}{A} \quad (2.2) \]

In principle, resistivity method works by flowing the electric current into the ground through 2 current electrodes with symbols A and B (C1 and C2) which place into the ground at a certain distance. The longer distance between A and B cause the flow of electric current penetrate the deeper layers.

General description of resistivity method shown in figure 1.

![Electrode configuration on resistivity method](image)

Figure 1. Electrode configuration on resistivity method [9]

In geoelectrical exploration, to measure resistivity in the field using this equation.

\[ \rho_a = k \frac{\Delta V}{I} \quad (2.3) \]

Resistivity method based on assumption that earth is homogenous isotropic. With this assumption, the measure resistivity is true resistivity and not depend on electrode spacing. But in fact, earth is composed of layers with different resistivity, so the measured potential is the influence of these layers. Therefore, the measured resistivity value as if it were the value of resistivity for just one layer. The measured resistivity is actually apparent resistivity [8]. In the Schlumberger configuration, measurements are made by varying the position of the current electrode (AB) and potential electrodes (MN). On the rules of Schlumberger electrodes, current electrode spacing is much greater than potential electrode spacing [7]. Rules of this electrode can be seen in figure 1. In the Schlumberger configuration can be calculated the apparent resistivity value using equation (3) with \( k \) is the geometry factor. \( k \) value for Schlumberger configuration:

\[ k = \pi \left( \frac{l^2 - l_1^2}{2l} \right) \quad (2.4) \]

Rock resistivity was influenced by porosity, water and minerals. Here are some rocks resistivity value based on table 1. Rock resistivity is directly related to rock porosity and rock texture. The relationship between resistivity and porosity was first proposed by Archie (1942) [10]. Resistivity \( (\rho) \) and porosity \( (\phi) \) are expressed in I Archi equations:

\[ \rho = a \rho w \phi^{-m} \quad (2.5) \]

The resistivity relationship in equation (5) is reflected by the large formation factor (F) [11], that is:
With \( \rho \) is the resistivity which is considered as the aquifer layer and \( \rho_w \) as the resistivity of the porous filler water. Formation factors can be used for estimating aquifer zones because they reflect as porosity in sedimentary and igneous rocks that experience fractures. Based on both quantities \( \rho \) and \( \rho_w \) the formation factor value \( F \) can be calculated using equation (6). Some conclusions of formation factor values from several hydrogeological studies were obtained [12] as in table 2 below.

\[
F = \frac{\rho}{\rho_w} = \frac{a}{\phi^{-m}} \tag{2.6}
\]

### Table 1. Resistivity rocks

| Material                  | Resistivity (Ωm) |
|---------------------------|-------------------|
| Pirit (Pyrite)            | 0.01-100          |
| Kwarsa (Quartz)           | 500-800000        |
| Kalsit (Calcite)          | \(1 \times 10^{12} - 1 \times 10^{13}\) |
| Garam Batu (Rock salt)    | 30 - 1 \times 10^{13} |
| Granit (Granite)          | 200 - 10000       |
| Andesit (Andesite)        | 1.7 \times 10^{2} - 45 \times 10^{4} |
| Basal (Basalt)            | 200 - 10.0000     |
| Gamping (Limestone)       | 300 - 10000       |
| Batu pasir (Sandstone)    | 200 - 8000        |
| Batu tulis (Shales)       | 20 - 2000         |
| Pasir (Sand)              | 1 - 1000          |
| Lempung (Clay)            | 1 - 100           |
| Air tanah (Ground water)  | 0.5 - 300         |
| Air asin (Sea water)      | 0.2               |
| Magnetit (Magnetite)      | 0.01 - 1000       |
| Kerikil kering (Dry gravel) | 600 - 10000   |
| Aluvium (Alluvium)        | 10 - 800          |
| Kerikil (Gravel)          | 100 - 600         |
| Batu Bara (Coal)          | 0.6- 100000       |

This research was done for two days, on January 20 and January 25, 2019 which located around the ITK campus. The measurement points are determined first by using Google Earth, then the coordinates of the measurement points obtained are entered into the Global Positioning System (GPS) device to make it easier on the way to the location. The coordinate system used in GPS is the Universal Transverse Mercator (UTM) coordinate system which is only divided into two coordinates namely latitude (X) and longitude (Y). In figure 2 is the location of the measurement points in the study area.
Data obtained from each measurement point is data that explains the electrical properties of subsurface rocks, namely the potential difference value (ΔV) generated and the value of current (I) given. Large data of current value (I) and potential difference (ΔV) can be obtained through resistivity meter display screen, then data is recorded into data table with Schlumberger configuration in which there is already a geometry factor value (k) and current electrode position (AB/2) and the position of the potential electrode (MN/2). Data acquisition at each measurement point is repeated three times, this aims to get good and maximum data. From these data, it can be calculated the apparent resistivity value at each measurement point, then processed using an inversion program. Data obtained from processing with inversion program in the form of rock coating based on the value of resistivity, layer thickness, depth of layer and the amount of error (error) generated. Based on the results of inversion, it can be interpreted by making subsurface stratigraphic modeling from each measurement point.

Figure 2. Measurement points at research area

3. Result and Discussion
The results of the analysis and the interpretation of the one-dimensional cross section in figure 3 obtained at the first measurement point, the estimated resistivity value of the aquifer layer is the third layer with a thickness of 15.3 m and a depth of 58.3 m - 73.5 m above ground has a value of 165 Ωm with formation factor is 3. This type of aquifer can be categorized as a leaky aquifer because it is under the aquitard layer [13]. This layer is thought to be a layer of clay sand. Based on the factor value of the formation obtained this layer is medium to productive aquifer [12].

Furthermore, the results of the analysis and results of one-dimensional cross section in figure 4 obtained at the second measurement point, the resistivity value that is assumed to be aquifer layer, namely the third layer with a thickness of 43.4 m, and a depth of 72.8 m - 116 m above ground level has a value of 133 Ωm with formation factor 2. The type of aquifer at the second measurement point is a leaky aquifer because it is coated by an aquitard layer at the top [13]. This layer is thought to be a layer of clay sand. Based on the formation factor values obtained this layer is poor aquifer medium [12].

Then the results of the analysis and results of one-dimensional cross section in figure 4 obtained at the third measurement point, the resistivity value that is assumed to be aquifer layer is the fifth layer
with a thickness of 78.3 m, and a depth of 115 m from the ground surface has a value of 174 Ωm with a formation factor 3. The type of aquifer at the first measurement point is a leaky aquifer because the upper part is covered by layers of aquitard [13]. This layer is thought to be a layer of clay sand. Based on the factor value of the formation obtained this layer is medium to productive aquifer [12].

![Dimensional cross section at first measurement point](image1)

![Dimensional cross section at second measurement point](image2)

![Dimensional cross section at third measurement point](image3)

**Figure 3.** (a.) dimensional cross section at first measurement point, (b.) dimensional cross section at second measurement point, (c.) dimensional cross section at third measurement point.

Based on the three measurement points, the types of rock detected were clay layers, clay sand layers, sandy clays, coal insertion and Top Soil in the form of embankment soil (a mixture of soil, sand and clay). The rock layers which are not aquifer layers are in the form of clay, coal and Top Soil, while the aquifer layer is a layer of clay sand. Based on the three measurement points used to identify the presence of aquifers, the three detected points have the potential to have aquifers.

The results obtained from the qualitative data processing process found that the depth of the average aquifer layer at each measurement point is from 56.5 m - 72.8 m. Based on these results it can be concluded that the aquifer layer can still be identified at depths of more than 40 m. The three aquifers
at each measurement point are deep aquifers because they are below a depth of 20 meters above the ground. The three layers of groundwater aquifer at each research point are estimated to be composed of clay sandstone. The resistivity value in the groundwater aquifer layer at each measurement point has a value range of 133 $\Omega m$ - 174 $\Omega m$.

4. Conclusion

Based on the research that has been done it can be concluded that subsurface stratigraphy based on the value of resistivity variation at each measurement point on average consists of the type of top soil layer with resistivity of 36.9 $\Omega m$ - 558 $\Omega m$, sandy clay with resistivity of 16.1 $\Omega m$ - 64.9 $\Omega m$, coal with resistivity 637 $\Omega m$, clay sand with resistivity of 133 $\Omega m$ - 174 $\Omega m$, and clay with resistivity of 2.32 $\Omega m$ - 8.27 $\Omega m$. The depth of aquifer at each measurement point has an average range from 56.5 m - 72.8 m with the type of clay sand layer and is medium to productive aquifer.

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