Groundwater Potential Investigation Using Geoelectric Method with Schlumberger Electrode Configuration in Catur Rahayu Village, Dendang District, Tanjung Jabung Timur Regency, Jambi Province

Tri Rahajoeningroem1*, Bagus Indrajana2
1,2 Department of Electrical Engineering, Universitas Komputer Indonesia, Indonesia

Email : *tri.rahajoeningroem@email.unikom.ac.id,

Abstract. The planning of making boreholes for groundwater exploitation on investigations location is necessary to investigate using the geoelectric method. This method is applied with Schlumberger electrode configuration to obtain information about the coating of subsurface rocks before drilling, where detection target to a depth of about 50 m. The information that will be obtained from the results of this geoelectric measurement is in the form of log geoelectrical sounding with the resistivity price of each rock layer that reflects the form of rock layers below the surface. Furthermore, from the rock resistivity value classification, it can be estimated the type / lithology of each rock layer. From the investigation result using geoelectric method obtained the illustration that the cover layer consists of soil and peat with resistivity values of 60.42 to 245.84 ohms-m. The second layer is in the form of a peat layer with a relatively high resistivity value of 116.78 to 212.58 ohms-m. The third layer is estimated to be a layer dominated by clay, with a relatively low resistivity value of 11.31 to 26.53 ohms-m. Finally, the fourth layer is estimated to be a layer dominated by sand, where the resistivity value is 41.99 to 59.50 ohm-m. This sand layer is expected to be an aquifer layer because it has high water passing characteristic. After the results of groundwater drilling are compared with the results of geoelectric research, it can be concluded that the results of geoelectric research can be used as a guide when conducting groundwater drilling activities.

1. Introduction
The plan to make a wellbore for groundwater exploitation in the requested location requires to obtain supporting data on subsurface bedding, especially the aquifer protective layer. The basic principle of the investigation using the geoelectric method is by injecting an electric current into the earth through a pair of current electrode, then measuring the potential difference through a pair of potential electrons. This method is applied with Schlumberger electrode configuration. The information that will be obtained from the results of the measurement is in the form of a log geoelectrical resistivity with the resistivity value of each rock layer that reflects the shape of the rock layers below the surface. From the rock resistivity value classification, it can be estimated the type of each rock layer. In advance, Geoelectric methods have been successfully used in groundwater exploration, since it is relatively cheap and a quantitative evaluation technique [1].
In addition to its use in groundwater exploration, it is an efficient and economical method for determining the degree of soil corrosivity and the distribution of a contaminant whose salinity varies from that of existing groundwater. In the past study, geophysical method is used to obtain information about the physical properties of the surface. This method is commonly used but need more time for the investigate the groundwater [2]. In some cases using geophysical method the aquifer is not well protected because of too little aquifer protective capacity parameters in the station [3]. On other study, the peat thickness and depth of aquifers is predicted using the geoelectrical resistivity surveys [4]. This survey determined the possibility of groundwater [5]. Therefore, it is necessary to investigate using the geoelectric method to obtain information about the bottom surface coating before drilling [6].

The purpose of this investigation is to determine the parameters of the rock surface subsurface, including the resistivity value of rock bed layer, depth of rock layer from the ground surface and thickness of each rock layer. The results of geoelectric sounding showed that the area of study is dominated by a type of KH-curve that consists of top soil, clay/weathered layer, broken basement and fresh basement. Results from both the Schlumberger and Wenner array data were compared with the static water level measurement; higher correlation value was found in the Schlumberger array than in the Wenner array [7]. While the purpose of this investigation is to provide information regarding the existence of the aquifer layer and its depth.

2. Method
2.1 Schlumberger Electrode Configuration
The basic principle of the investigation using the geoelectric method is by injecting an electric current into the earth through a pair of current electrodes A and B, then measuring the potential difference through a pair of potential electrons M and N. If the earth is considered a homogeneous isotropic medium, then the measured resistivity is the actual resistivity, but by the influence of layers with different resistivity, the measured resistivity is not actual resistivity but is apparent price, or so-called pseudo resistivity ($\rho_a$). In rock layers, the difference in resistivity such as causing current from A to B does not flow along a circular arc as in a homogeneous medium, but experiences distortion when it reaches the boundary layer and then takes a easier path. The potential difference that is read on deeper current penetration will experience two kinds of resistance. The potential difference measured at M and N will experience two kinds of resistance due to the difference in resistivity of the two layers, so the measured resistivity is pseudo resistivity (pa). In general, the pseudo/apparent resistivity equation is as follows:

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

$$K = \frac{2\pi}{\left(\frac{1}{\pi} - \frac{1}{\pi^2}\right) - \left(\frac{1}{\pi} - 1\right)} \tag{2}$$

$$K = \pi \left(\frac{s^2 - b^2}{2b}\right) \tag{3}$$

Note: $\rho_a =$ pseudo/apparent resistivity
$K =$ geometric factor
$\Delta V =$ potential difference between M and N
$I =$ the current injected through A and B
$s =$ half distance between current electrodes (AB / 2)
$b =$ half distance between potential electrodes (MN / 2)

The value of apparent resistivity is very dependent on geometric factors, or in other words depends on the configuration / arrangement of the electrodes used. In the Schlumberger electrode configuration, the four electrodes are located in a straight line. A pair of current electrodes is placed on the outside, while a pair of potential electrodes is on the inside, as shown in Figure 1. The apparent resistivity equation on field for the Schlumberger electrode configuration based on equation (1), equation (2) and equation (3) are:
\[ \rho_{as} = \pi \left( \frac{s^2}{2b} \right) \frac{\Delta V}{I} \]  \hspace{1cm} (4)

Whereas the theoretical apparent resistivity equation for the Schlumberger electrode configuration based on the Johansen formulation is as follows:

\[ \rho_{as}(i\Delta y) = \sum_{j = j_{\text{min}}}^{j_{\text{max}}} T(i \Delta y + x)C(j\Delta y - x) \]  \hspace{1cm} (5)

Note:
- \( T \) = resistivity transformation function
- \( i\Delta y \) = the space from Schlumberger (AB / 2) electrode to i
- \( \Delta y \) = sampling interval = Ln(10)/10
- \( C \) = koefisien filter Johansen
- \( x \) = -1.7239458
- \( j_{\text{min}} \) and \( j_{\text{max}} \) = upper limit / lower limit of Johansen's filter coefficient

2.2 Electrical Properties of Materials

Of all the geophysical characteristic of rocks, rock resistivity has the highest value. The resistivity value of a rock can range up to 10 times as possible, or even more. Figure 2 shows a general description of the resistivity values of several rock groups (See Figure 1) [8].

Soil and rocks consist mostly of silicate minerals which are basically insulators. The most common exceptions include magnetite, specular hematite, carbon, graphite, pyrite and pyrite. Therefore, conduction of most electrolytes, and conductivity mainly depends on porosity, hydraulic permeability, water content, dissolved electrolyte concentration, temperature and phase of pore fluid, amount and composition of
colloids (clay content / clay). Figure 2 shows the variation in resistivity values of some rocks, soil, and minerals [9-11].

![Figure 2](image.png)

2.3 Method
In this investigation, a geoelectric method with a Schlumberger electrode configuration is applied, where the detection target is up to a depth of about 50 m. Therefore the maximum current electrode stretch is set at 200 m or half the maximum current electrode range (AB / 2) of 100 m. The information that will be obtained from the results of this geoelectric measurement is in the form of a log geoelectrical resistivity with the resistivity value of each rock layer that reflects the shape of the rock layers below the surface. Furthermore, from the rock resistivity value classification, it can be estimated the type / lithology of each rock layer. Equipment used in measurement is:

- Resistivity-meter, 2 unit
- Power Supply / Accu 12 V, 2 unit
- Electrode stainless steel, 8 pieces
- Current cable with length measurement, 4 rolls
- Potential cable with length measurement, 4 rolls
- Hammer, 8 pieces
- Handy Talky (HT), 8 pieces
- GPS (Global Positioning System), 2 pieces
- Geological Compass, 2 pieces

3. Results and Discussion
3.1 Location of Measurement Points
From the geological map of the Muara Bungo Sheet and the Jambi Sheet, the geological information from the investigation area was obtained that the study location was in the area of Catur Rahayu Village. In the
western part of this location is above the Kasai Formation which consists of alternation between tuff and sandstone claystone, while in the eastern location is above Aluvium which consists of grit, gravel, silt, and clay. Geoelectric measurements in the field were made in 21 measurement points (sounding) with the position of geoelectric measurement points as shown in Figure 3 and Figure 4.

3.2 Data processing
Data from geoelectric measurements (entirety) obtained good quality field data. This can be seen from field data showing changes in pseudo resistivity values that are relatively smooth and do not contain much noise (interference). The software used in processing geoelectric data with Schlumberger electrode configuration is PROGRESS Ver. 3.0. From the results of geoelectric data processing obtained rock parameters for each measurement point at each location. From the resistivity value of the rock layers can then be estimated rock types based on Figure 3 and Figure 4 as well as the geological information of the investigation area. Estimation results of rock types can be seen in Table 1.

Figure 3. Location Map of the Study Area [12]

Figure 4. Map of Geoelectric Measurement Points
Table 1. Estimated Rock Type based on Resistivity Value

| No. | Village      | Layer | Color     | Resistivity (Ohm-m) | Rock Type Estimation |
|-----|--------------|-------|-----------|---------------------|----------------------|
| 1   | Catur Rahayu | Layer-1 | grey      | 60.42 - 245.84     | cover layer          |
|     |              | Layer-2 | Light green | 116.78 - 212.58   | peat                 |
|     |              | Layer-3 | Light yellow | 11.31 - 26.53   | clay                 |
|     |              | Layer-4 | Light blue  | 41.99 - 59.5     | sand (aquifer)       |

The depth of the aquifer layer for each geoelectric measurement point can be seen in Table 2. To provide a clearer picture of subsurface conditions at the investigation site, then from several measurement points in the same direction, several geoelectric cross sections are made.

Table 2. The Depth of the Aquifer Layer at Geoelectric Measurement Points

| No. | Village      | Point | UTM coordinates (zone = 48 M) | Geographical coordinates | Depth of Aquifer Layer (m) |
|-----|--------------|-------|-------------------------------|--------------------------|---------------------------|
|     |              |       | X | Y | Longitude | Latitude | Depth |
| 1   | Catur Rahayu | CR-01 | 377873  | 9860666 | 103.902279 | -1.260364 | 29.43 |
| 2   | Catur Rahayu | CR-02 | 378077  | 9860678 | 103.904113 | -1.260256 | 28.53 |
| 3   | Catur Rahayu | CR-03 | 378279  | 9860676 | 103.905928 | -1.26027 | 27.04 |
| 4   | Catur Rahayu | CR-04 | 377674  | 9860274 | 103.904899 | -1.263909 | 26.81 |
| 5   | Catur Rahayu | CR-05 | 377874  | 9860287 | 103.902287 | -1.263792 | 26.96 |
| 6   | Catur Rahayu | CR-06 | 378076  | 9860286 | 103.904102 | -1.263802 | 28.92 |
| 7   | Catur Rahayu | CR-07 | 379474  | 9860074 | 103.916666 | -1.265725 | 31.93 |
| 8   | Catur Rahayu | CR-08 | 379674  | 9860074 | 103.918481 | -1.265725 | 29.27 |
| 9   | Catur Rahayu | CR-09 | 379873  | 9860072 | 103.920252 | -1.265744 | 28.86 |
| 10  | Catur Rahayu | CR-10 | 380071  | 9860074 | 103.920311 | -1.265727 | 32.23 |
| 11  | Catur Rahayu | CR-11 | 380072  | 9860274 | 103.922041 | -1.263918 | 34.45 |
| 12  | Catur Rahayu | CR-12 | 380072  | 9860472 | 103.922042 | -1.262127 | 33.04 |
| 13  | Catur Rahayu | CR-13 | 379274  | 9859674 | 103.914867 | -1.269342 | 34.69 |
| 14  | Catur Rahayu | CR-14 | 379475  | 9859679 | 103.916673 | -1.269298 | 35.11 |
| 15  | Catur Rahayu | CR-15 | 379677  | 9859677 | 103.918489 | -1.269317 | 32.18 |
| 16  | Catur Rahayu | CR-16 | 379874  | 9859677 | 103.920259 | -1.269317 | 33.12 |
| 17  | Catur Rahayu | CR-17 | 380070  | 9859673 | 103.922021 | -1.269354 | 31.26 |
| 18  | Catur Rahayu | CR-18 | 379077  | 9859079 | 103.913094 | -1.274724 | 33.11 |
| 19  | Catur Rahayu | CR-19 | 379274  | 9859075 | 103.914864 | -1.274764 | 31.6 |
| 20  | Catur Rahayu | CR-20 | 379470  | 9859075 | 103.916626 | -1.274761 | 30.27 |

From the results of the investigation using the geoelectric method, subsurface bedding features are obtained. The discussion including the type of subsurface bedding in Catur Rahayu Village. There are:

a. **Cover Layer**

Cover layer consisting of soil and peat [13]. This layer has a resistivity value that varies between 60.42 to 245.84 ohms-m. The cover at the investigation site is more dominated by peat.
b. **Peat**: The second layer is a layer of peat. This layer has a relatively high resistivity price between 116.78 to 212.58 ohms-m. In this peat layer there is surface water, but when the dry season, the presence of water in the peat layer can be reduced and even dry [14].

c. **Clay**: The third layer is estimated to be a layer dominated by clay, with a relatively low resistivity value of between 11.31 to 26.53 ohms-m. In this layer the possibility of groundwater density is relatively small due to clay rock which has low water passing characteristic [15].

d. **Sand (aquifer)**: The fourth layer is estimated to be a layer dominated by sand, where the resistivity value is between 41.99 to 59.5 ohms-m. This sand layer is thought to be an aquifer layer because it has high water passing properties [16].

In general, the results of geoelectric investigations at the location of Catur Rahayu Village can be seen in Table 3.

| No. | Layer Type        | Value Range | Average         |
|-----|-------------------|-------------|-----------------|
|     |                   | Depth (m)   | Thickness (m)   | Resistivity (Ohm-m) | Depth (m) | Thickness (m) | Resistivity (Ohm-m) |
| 1   | Cover layer       | 0.00 - 0.00 | 0.45 - 1.99     | 60.42 - 245.84      | 0.00      | 0.99          | 128.75               |
| 2   | Peat              | 0.45 - 1.06 | 3.39 - 8.10     | 116.78 - 212.58     | 0.59      | 3.35          | 113.92               |
| 3   | Clay              | 0.64 - 9.10 | 23.8 - 30.6     | 11.31 - 26.53       | 4.34      | 26.54         | 18.23                |
| 4   | Sand (aquifer)    | 26.8 - 35.1 | 41.99 - 59.50   | 41.99 - 50.19       | 30.88     | 50.19         |                      |

4. **Conclusion**

From the results of the investigation using the geoelectric method, it was concluded that each layer has specific resistivity values that can determine the characteristics. The cover layer consists of soil and peat with resistivity values of 60.42 to 245.84 ohms-m. The second layer is in the form of a peat layer with a relatively high resistivity value of 116.78 to 212.58 ohms-m. The third layer is estimated to be a layer dominated by clay, with a relatively low resistivity value of 11.31 to 26.53 ohms-m. Finally, the fourth layer is estimated to be a layer dominated by sand, where the resistivity value is 41.99 to 59.50 ohm-m. This sand layer is thought to be an aquifer layer because it has high water passing characteristic. After the results of groundwater drilling are compared with the results of geoelectric research, it can be concluded that the results of geoelectric research can be used as a guide when conducting groundwater drilling activities.

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