Identification of Aquifer using Geoelectrical Resistivity Method with Schlumberger Array in Koto Panjang Area, Nagari Tigo Jangko, Lintau Buo Sub-District, Tanah Datar Regency

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Abstract. Water is one of the most important aspects of life, because all living things need water to sustain their lives. In fact, the availability of water decreases especially in the dry season, one area that are experiencing this situation is Koto Panjang area, Nagari Tigo Jangko, Lintau Buo Sub-district, Tanah Datar Regency, West Sumatera Province. During the dry season, the people in Koto Panjang is difficult to obtain clean water. This problem can be solved by identifying the aquifer layer, both in position and depth. One method that can be used to identifying these aquifer layers is the geoelectrical resistivity method. This method utilizes electric current to measure rock resistivity beneath the earth's surface. There are various configurations of these geoelectrical methods, the schlumberger array gives good results vertically. The measurement area is approximately 20 hectares with 10 acquisition points. Aquifer layers identified at 50-70 meters of depth with three potential drilling points.

1. Introduction

Water is one of the most important aspects of life, it happens all over the world. In particular, water is greatly reduced especially in the dry season, many regions of the world, including Indonesia, drought and difficulty getting water [1]. As in the area of Koto Panjang, during the dry season the population finds it difficult to obtain clean water. Koto Panjang is an area located in Nagari Tigo Jangko, Lintau Buo District, Tanah Datar District, West Sumatra Province.

Along with the increasing population and development of the region, the need for water is increasing, both for the purposes of human life, animal farm and farming. The absence of Regional Water Company into the area is also the cause of the community's difficulties in meeting the needs of clean water. Based on the acknowledgment of one of the residents in this area, one of the efforts to fulfill the need of clean water is usually done by the community by making the well of the ring which reaches 15 meters deep, but will collapse, so that the depth of the well becomes 10 meters and the well will experience drought in the season drought, while for cultivating residents only rely on irrigation from rain water.
The limited knowledge of the community regarding the distribution of groundwater and the lack of research on the distribution of ground water in this area became the author's interest in doing this research. Groundwater is the water beneath the surface of the soil stored in the geological formation of rocks.

Geolectric method is one of the geophysical methods that study the nature of the flow of electricity below the earth's surface and how to detect it on the surface of the earth. By displaying the subsurface resistivity section of the geolectric measurement results, it can be known and predicted layers of rocks or layers of groundwater (aquifer), thickness and depth. Geolectric research is intended to know the arrangement of subsurface geological layers, so it can be known there is a layer of groundwater or aquifers that exist [2].

2. Ground Water
Ground water is one form of water that is around our earth and is in the ground. Groundwater is generally present in soil layers either from close to the surface of the soil up to far off the ground [3]. Groundwater is groundwater that moves below ground in a saturation zone where the hydrostatic pressure is equal to or greater than atmospheric pressure. According [3] Ground water is found in a layer of soil containing water called an aquifer. The depth of groundwater in an area is not the same as the other region, depending on the thickness of the cover layer and the position of the aquifer. Groundwater content of an area can be affected by climate/season, water recharge, geomorphological conditions, geological conditions, human activities and vegetation.

According to [4], based on the ability to pass water from the constrictor, the aquifer can be divided into two: the confined aquifer (confined aquifer) and the aquifer free (unconfined aquifer). A distorted aquifer is a water-carrier layer between two layers of waterproof rock that has a fixed discharge, whereas a free aquifer is a water-bearing layer that is limited to the top by a groundwater surface and below it is limited by an impermeable layer.

3. Electrical Resistivity of Rocks
Rocks are composed of various minerals and have electrical properties. Some rocks are composed of only one type of mineral, a few more formed by a combination of minerals, and organic materials and volcanic materials. The nature of the rock is the characteristic of the rock in conducting the electric current. Rocks can be considered as electrical medium as in electrical conductor wire, so it has a resistivity. Electrical properties is the characteristic of the rock when flowed on the rock [5]. According to [6] rocks have their own characteristics including the electrical properties present in the rock itself. Differences in electrical properties in each rock provide different responses to the currents provided through the method of vertical electrical sounding. This response difference can later be used as reference data to determine the subsurface layers and approach the subsurface condition through the resistivity value obtained.

According to [7] each different rock will have different types of resistance values. This depends on several factors, including rock age, electrolyte content, rock density, the amount of minerals it contains, porosity, permeability and so on.

Based on research that has been done by [8] value of resistance types for some types of rocks are as follows:

| Resistivity (Ωm) | Interpretation     |
|-----------------|--------------------|
| 0               | Water              |
| 200-8,000       | Sandstones         |
| 1-1,000         | Sand               |
| 1-100           | Clay               |
| 0.5-300         | Groundwater        |
Table 2. Specific resistivity value of rocks [10]

| Resistivity ($\Omega$m) | Interpretation         |
|------------------------|------------------------|
| 80 – 200               | Water Income           |
| 30 – 100               | Groundwater            |
| 10 – 200               | Silt-Clay              |
| 100 – 600              | Sand                   |
| 100 – 1000             | Sand and Gravel        |
| 20 – 200               | Mud Rocks              |
| 50 – 500               | Sandstone              |
| 100 – 500              | Conglomerate           |
| 20 – 200               | Tufa                   |
| 100 – 2000             | Andesite Group         |
| 1000 - 10000           | Granite Group          |
|                        | Chert Group, Slate     |

4. Geoelectric Method

Geoelectric method is one of the geophysical methods that studies the nature of the flow of electricity in the earth and how to detect it on the surface of the earth [11]. The response is based on the measurement of potential field and current on the surface that occur either naturally or due to the injection of the current into the earth. Some of geoelectrical method are: self potential method (SP), Telluric currents, magnetotelluric, electromagnetic, induced polarization (IP) and resistivity method [12]. Principle of resistivity method is making use of it contrast of target rock resistivity to its environment [13].

The basic principle used in geoelectric estimation is by way of electric current flowing into the earth so that the electric field appears around the two current electrodes A and B. This geoelectric investigation includes the detection of the magnitude of the potential field, the electromagnetic field and the electric current flowing in the earth both naturally (passive method) and by injection of current into the earth (active method) from the surface.

If the conditions on the surface of the earth are homogeneous, isotropic, the same voltage will appear in all places, but because the conditions below the surface of the earth are in fact not homogeneous, the stresses are different in each place. These voltage or potential differences are measured on the ground surface through two potential M and N electrodes, these two electrodes connected by the receiver.

5. Schlumberger Array

The Schlumberger array is a configuration with a constant system of spacing rules with the note of the "n" multiplier factor for this array is the ratio of the distance between the AM electrode and the distance between MN. If the distance between the potential electrode of MN is a then the distance between the current electrode (A and B) is 2na + a. It can be seen in Figure 1.
The Schlumberger array factor (k) can be found using the formula:

\[ k = \frac{\pi a^2}{b} \left[ 1 - \frac{b^2}{4a^2} \right], a \geq b \]  

(1)

![Schlumberger Array Diagram](image)

**Figure 1.** Schlumberger array

6. Method

6.1. Design

Geoelectric data retrieval technique used in this research is vertical electrical sounding method also called 1 dimension detection method. Vertical Electrical Sounding (VES) is a method invented by the Schlumberger brothers in the 1920s. This method produces 1D resistivity data. In the use of this method, the midpoint of a measurement remains at a point, but the space between the electrodes is added to obtain information on the deeper subsurface layer [14]. In this method the distance between the electrode C1 to the midpoint and the C2 electrode to the midpoint is equal. Similarly, the distance of P1 electrode and P2 electrode. While the results of data processing method 1-D can be seen in Figure 2.

![1-D Resistance Method Diagram](image)

**Figure 2.** The measurement technique of the 1-D resistance method [15]

The location of data collection is three jorong in Koto Baru subdistrict lintau Buo district flat ground that is jorong Abdul Rahman, Thousand and Cendrawasih. Geoelectric data collection spread over 10 coordinate points. Deployment point of location of data taking can be seen in Figure 3 and Table 3.
Figure 3. The measurement technique of the 1-D resistance method

Table 3. Spreading point locations geoelectric data retrieval

| Location | Coordinate (UTM) |
|----------|------------------|
| VES 01   | 47 M 702382 9942151 |
| VES 02   | 47 M 701907 9942669 |
| VES 03   | 47 M 701061 9943649 |
| VES 04   | 47 M 700386 9943987 |
| VES 05   | 47 M 700812 9944440 |
| VES 06   | 47 M 700204 9944526 |
| VES 07   | 47 M 700619 9944719 |
| VES 08   | 47 M 699931 9945069 |
| VES 09   | 47 M 699621 9945099 |
| VES 10   | 47 M 699719 9945659 |

6.2. Data Processing
From the measurement value of the geoelectric sounding survey shows that the rock resistivity at the research sites ranges from 0.613-4094 Ohm-m. The following resistivity value of each point location of geoelectric data retrieval based on interpretation results using IP2WIN program.
### Table 4. Resistivity value of measurement results

| Location | From(m) | To(m) | Resistivity |
|----------|---------|-------|-------------|
| VES 1    | 0       | 1     | 245         |
|          | 12.2    | 113.2 | 26.3        |
|          | 113.2~  |       | 0.163       |
|          | 0       | 1     | 349         |
| VES 2    | 1       | 1.804 | 14          |
|          | 1.804   | 6.884 | 512         |
|          | 6.884   | 19.08 | 5.93        |
|          | 19.08~  |       | 6.11        |
|          | 0       | 3.07  | 68.8        |
|          | 3.07    | 7.07  | 479         |
|          | 7.07    | 162.1 | 6.04        |
|          | 162.1~  |       | 554         |
|          | 0       | 1     | 289         |
| VES 3    | 1       | 2.65  | 4154        |
|          | 2.65    | 58.45 | 24          |
|          | 58.45   | 147.1 | 13.1        |
|          | 147.1~  |       | 316         |
|          | 0       | 1     | 118         |
|          | 1       | 2.27  | 18          |
|          | 2.27    | 7.03  | 499         |
|          | 7.03    | 28.03 | 6.58        |
|          | 28.03   | 67.13 | 50.9        |
|          | 67.13~  |       | 0.468       |
|          | 0       | 1     | 47.2        |
|          | 1       | 1.86  | 1301        |
| VES 4    | 1.86    | 17.7  | 125         |
|          | 17.7    | 84.91 | 20          |
|          | 84.91~  |       | 6.03        |
|          | 0       | 1     | 117         |
|          | 1       | 2.671 | 20.9        |
|          | 2.671   | 7.13  | 203         |
|          | 7.13    | 51.56 | 21          |
|          | 51.56~  |       | 12.1        |
|          | 0       | 1     | 593         |
| VES 5    | 2.671   | 7.13  | 203         |
|          | 7.13    | 51.56 | 21          |
|          | 51.56~  |       | 12.1        |
|          | 0       | 1     | 593         |
| VES 6    | 2.671   | 7.13  | 203         |
|          | 7.13    | 51.56 | 21          |
|          | 51.56~  |       | 12.1        |
|          | 0       | 1     | 593         |
| VES 7    | 2.671   | 7.13  | 203         |
|          | 7.13    | 51.56 | 21          |
|          | 51.56~  |       | 12.1        |
|          | 0       | 1     | 593         |
| VES 8    | 2.671   | 7.13  | 203         |
|          | 7.13    | 50.94 | 4.11        |
|          | 50.94~  |       | 4.71        |
|          | 0       | 3.189 | 23.5        |
| VES 9    | 3.189   | 8.237 | 1.12        |
|          | 8.237   | 25.38 | 13          |
|          | 25.38   | 48.87 | 2.15        |
|          | 48.87~  |       | 434         |
|          | 0       | 1     | 29.6        |
|          | 1       | 2.3   | 201         |
| VES 10   | 2.3     | 5.296 | 13.6        |
|          | 5.296   | 19.35 | 110         |
|          | 19.35   | 73.2  | 6.57        |
|          | 73.2~   |       | 1394        |
6.3. Analysis and Result

Based on log resistivity value each of geoelectric sounding done interpretation of depth and thickness of aquifer. According to Todd (1980), rocks that can serve as the best water carrier layers are sand, crust, and gravel. While 90% of the aquifer consists of unconsolidated rocks, especially gravel and sand.

The geoelectric measurements at VES 01 point indicate that the value of the geoelectric resistivity range is 0.163-459 Ohm-meter. Point VES 01 consists of four layers, the first layer has a 245 Ohm-meter resistivity, a second layer of 59 Ohm-meters, a third of 26.3 Ohm-meters and a fourth 0.163 Ohm-meters. Based on the resistivity value of each layer does not show the existence of aquifer coating.

The geoelectric measurement results at VES 02 point indicate that the value of the geoelectric resistivity range is 6.11-349 Ohm-meters. Point VES 02 consists of five layers, the first layer has a 349 Ohm-meter resistivity, second layer 14 Ohm-meters, third 512 Ohm-meters, fourth 5.93 Ohm-meters and fifth 6.11. Based on the resistivity value of each layer shows the finding of aquifer layer at depth of 19.8 meters. The aquifer layer at the point VES 02 in the form of sand material.

The geoelectric measurements at VES 03 indicate that the value of the geoelectric resistivity range is 6.04-554 Ohm-meters. Point VES 03 consists of four layers, the first layer has a 68.8 Ohm-meter resistivity, second layer 479 Ohm-meters, third 6.04Ohm-meters and fourth 554 Ohm-meters. Based on the resistivity value of each layer does not show the existence of aquifer coating.

The geoelectric measurement at VES 04 shows that the value of the geoelectric resistivity range is 13.1-4154 Ohm-meters. Point VES 04 consists of five layers, first layer has a 289 Ohm-meter resistivity, second layer 4154 Ohm-meter, third 24 Ohm-meter, fourth 13.1 Ohm-meter and fifth 316. Based on the resistivity value of each layer indicates the finding of aquifer layer at a depth of 58.45 meters. The aquifer layer at the point VES 04 in the form of sand material.

The result of geoelectric measurement at VES point 05 indicates that the value of the geoelectric resistivity range is 0.468-499 Ohm-meter. Point VES 05 consists of six layers, the first layer has a 118 Ohm-meter resistivity, the second layer is 18 Ohm-meters, third 499 Ohm-meters, the fourth is 6.58 Ohm-meters, the fifth is 50.9 Ohm-meters and the sixth is 0.4468 Ohm-meet. Based on the resistivity value of each layer shows the finding of aquifer layer at a depth of 28.03 meters. The aquifer layer at the point VES 05 in the form of sand material.

The geoelectric measurement at VES 06 shows that the value of the geoelectric resistivity range is 6.03-1301 Ohm-meters. The VES 06 point consists of five layers, the first layer has a 47.2 Ohm-meter resistivity, a second layer of 1301 Ohm-meters, a third 125 Ohm-meters and a fourth 20 Ohm-meters and a fifth of 6.03 Ohm-meters. Based on the resistivity value of each layer does not show the existence of aquifer coating.

The geoelectric measurement at VES 07 shows that the value of the geoelectric resistivity range is 12.1-203 Ohm-meters. Point VES 07 consists of five layers, the first layer has a 117 Ohm-meter resistivity, a second layer of 20.9 Ohm-meters, a third of 203 Ohm-meters, a fourth 21 Ohm-meters and the fifth 12.1 Ohm-meters. Based on the resistivity value of each layer shows the finding of aquifer layer at depth 51.56 meters. The aquifer layer at the point VES 07 in the form of sand material.

The geoelectric measurement at VES 08 shows that the value of the geoelectric resistivity range is 4.11-593 Ohm-meters. Point VES 08 consists of five layers, the first layer has a 593 Ohm-meter resistivity, second layer 82.8 Ohm-meters, third 64 Ohm-meters, fourth 4.11 Ohm-meters and fifth 4.71 Ohm-meters. Based on the resistivity value of each layer shows the discovery of aquifer layer at a depth of 50.94 meters. The aquifer layer at the point VES 08 in the form of sand material.

The geoelectric measurements at VES point 09 indicate that the value of the geoelectric resistivity range is 1.12-434 Ohm-meters. Point VES 09 consists of five layers, the first layer has a resistivity of 23.5 Ohm-meters, second layer 1.12 Ohm-meters, third 13 Ohm-meters, fourth 2.15 Ohm-meters and fifth 434 Ohm-meters. Based on the resistivity value of each layer shows the finding of aquifer layer at depth of 48.87 meters. Aquifer layer at point VES 09 in the form of sand material with gravel.
The geoelectric measurements at VES point 10 indicate that the value of the geoelectric resistivity range is 6.57-1394 Ohm-meters. Point VES 10 consists of six layers, the first layer has a 29.6 Ohm-meter resistivity, a second layer of 201 Ohm-meters, third 13.6 Ohm-meters, fourth 110 Ohm-meters and fifth 6.57 Ohm-meters and sixth 1394 Ohm-meters. Based on the resistivity value of each layer shows the finding of aquifer layer at a depth of 73.2 meters. Aquifer layer at point VES 09 in the form of sand material with gravel.

Based on the interpretation of resistivity values, the depth and thickness of aquifer can be seen in the Table 5.

Table 5. Results of aquifer identification

| No.   | Depth(m) |
|-------|----------|
| VES-01| -        |
| VES-02| 19.8     |
| VES-03| -        |
| VES-04| 58.45    |
| VES-05| 28.03    |
| VES-06| -        |
| VES-07| 51.56    |
| VES-08| 50.94    |
| VES-09| 48.87    |
| VES-10| 73.2     |

The result of identification of aquifer in the study area indicates that the average depth of the aquifer found in the study area is 47.3 meters. Aquifer modeling can be seen in Figure 4.
Figure 4. Aquifer modeling in the research area

7. Conclusions
Based on the results of geoelectric interpretation of the points indicated there is aquifer layer is the point VES 02, VES 04, VES 05, VES 07, VES 08, VES 09 and VES 10 with average depth found aquifer is at depth of 47.3 meters. VES 02, VES 05 and VES 09 are potential drilling points can be drilled groundwater to obtain groundwater source.

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