Application of geoelectrical methods for estimating the availability of shallow aquifer layers

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Abstract. Kalimantan Institute of Technology (ITK) is the only institute of technology in Kalimantan with an area of ±300 Ha. Most of the area of ITK is not built yet. The increasing of interests of people to study in ITK causing the institute to build more lecture facilities to fulfil the people’s interests. Along with its development, it needs an independent clean water resource. The main source of clean water is groundwater. The potential of groundwater in its unbuilt area can be known by using geoelectrical method measurement. Geoelectrical method could give an early representation of the earth’s subsurface condition based on the resistivity parameter. This research produced a 1D cross section of the earth’s subsurface resistivity. Based on the result, it is known that the land cover is a red-yellow podzolic and clayey sand with the resistivity value of 300 – 570 Ωm and 2 – 4 meters of thickness. The second layer is a layer of water-saturated clay associated with low resistivity values of 15 – 44 Ωm with 20 meters of thickness. The third layer is a clayey sand layer which is estimated as aquifer layer in the depth of 9 – 24 meters. There is also an anomaly of coal inserts at VES_1 measurement point in the depth of 17 meters with a resistivity value of 962 Ωm.

1. Introduction

Kalimantan Institute of Technology (ITK) is a developing institute of technology in Balikpapan City, Kalimantan Island. ITK has an area of ±300 hectares which mainly consists of secondary forest and plantations. The high interest of the people of Balikpapan City and surroundings to study in ITK is the main factor its development, especially in the field of lecture facilities. Nowadays, the number of students of ITK is about 3000 students, and will keep increasing for every year. One of the main needs for ITK to be prepared is the source of clean water. The supply of clean water now depends on the local waterworks. The wavy ground of ITK area causes the local waterworks supply to become unreliable. The need of clean water is increasing every year, causing ITK to find an independent water source immediately.

Groundwater is the main source of clean water which can be put to good use [1]. Groundwater is a water source that has the best quality and is easy to be directly used [2]. Groundwater is underground water which is stored in rock layers [3]. The rock layer that can store and drain water properly is called the aquifer layer [4]. Aquifer layer is permeable and has a high porosity. Rock layers that act as aquifer layers are gravel, silt and sand [5]. The number stored water in the aquifer layer will affect the characteristics of the rock layer. Characteristics of rocks that are influenced by water are related to the electrical properties of rocks [6].
Identification of the presence of aquifer layers must be done to determine the potential for groundwater in the area of ITK. The results of this identification can be used as a reference in drilling to explore groundwater as a source of clean water of ITK. One method that is widely used in the identification of aquifer layers is the geoelectrical method. Geoelectric methods have been tested and are widely applied in groundwater mapping [7]. Geoelectrical method is an excellent and precise geophysical method for groundwater exploration [8]. The parameter of the electrical properties used in the geoelectric method is the resistivity value of the rock. The high contrast of resistivity values provides boundary information between rock layers [9]. The rock resistivity measured by the geoelectric method can be used to determine the characteristics of the subsurface layer [10]. Based on the characteristics of the subsurface layer, the presence of aquifer layer can be determined to provide sources of clean water. This research was conducted to determine the stratigraphic conditions and the depth of the aquifer layer in the research location.

2. Research location
The research is located at the area of ITK in Balikpapan City. The research is focused on campus land that has not been constructed. Geoelectrical method measurements are conducted at four measurement points in the land of ITK. The measurements take place in the land of ITK. The condition of the research location is shown in the following Figure 1.

![Figure 1. Research location](image)

The topsoil is water-saturated, making it difficult for rainwater to seep under the surface. The topsoil layer of the measurement location is podzolic soil sediments yang which has a low fertility rate. Most of the topsoil layer can be easily deformed by water flow and surrounding human activities (Figure 2).
The topographic condition of the research location is wavy because of the presence of anticlinal and synclinal axis. Geologically, the research is located on Kampung Baru formation, which has been sedimented since late miocene - pliocene. The sedimentation of Kampung Baru formation consists of sandy clay rocks, quartz sand, silt, marl, coal inserts, limestone and lignite. The sedimentation of Kampung Baru formation is sedimented in deltas and shallow sea environment. The Kampung Baru formation is out of alignment above the Balikpapan formation. Coal and lignite are located in the depth of 2-4 meters with a thickness of 3 meters. Based on preliminary information by deep drilling for groundwater exploitation, the aquifer layer is a sand layer which contains clay.

3. Method
Geoelectrical method could give subsurface information based on the rock’s resistivity characteristics. Geoelectrical method measurement is done by applying electric current into the earth’s subsurface using two electrodes. The amount of electric current (I) along with the potential difference between two certain points (ΔV) give a resistance parameter (R) based on Ohm’s equation:

\[ R = \frac{\Delta V}{I} \quad (1) \]

The value of resistivity could be obtained by adding a geometry factor parameter to the equation (///) as a compensation to the current electrode and potential electrode [11]. The amount of geometry factor value depends on the electrode configuration type used. The geoelectrical method measurement used in this research is a Schlumberger configuration type with the value of geometry factor as follows:

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

L is the distance between current electrode to the central measurement point and l is the distance between potential electrode and the central measurement point. Based on both equations, the equation to calculate the apparent resistivity value is:

\[ \rho_a = k \frac{\Delta V}{I} \quad (3) \]

4. Result and discussion
The data processing of the geoelectrical method measurement with Schlumberger configuration resulted 1D cross section of the subsurface resistivity. The resistivity value in this result is related to
The characteristic of the subsurface rocks layer. The relation between resistivity value with the rocks layer could give information about stratigraphy and subsurface rocks type. This information could be used to determine the presence of aquifer layer.

Based on the 1D cross section, the subsurface resistivity of VES_01 shows a piece of interesting information that there is a soft coal insert with a high resistivity value of 962 Ωm in the depth of 17 m under the surface. The topsoil layer with a resistivity value of 570 Ωm is a podzolic soil and sandy clay with a thickness of 2 m. The second layer is estimated as a water-saturated clay layer with a low resistivity value of 15 Ωm and thickness of 6 m. The next layer is estimated as a clayey sand layer with a resistivity value of 341 Ωm.

The stratigraphy of the VES_02 measurement point consists of topsoil layer with resistivity value of 396 Ωm. The topsoil layer has the same thickness of the topsoil in VES_01 measurement point. Under the topsoil, there is a clay layer in the depth of 2 – 19 m below surface with a resistivity value of 44 Ωm. The bottom layer based on the 1D cross-section of subsurface resistivity is estimated as a clayey sand layer with a resistivity value of 112 Ωm.

Generally, the subsurface layer condition of VES_03 and VES_04 measurement points have similar characteristics. They consist of topsoil layer on the surface, water-saturated clay layer below, and clayey sand layer at the bottom. The known differences are only for the thickness, depth and the range of resistivity value of every measurement point. The characteristic similarity for those measurement points is caused by the location of the measurement points which located on the same geological formation. Low resistivity value is associated by clay layer while high resistivity value is associated by clayey sand layer.

The sandy clay layer of the research location is evenly distributed. It is estimated as an aquifer layer with intermediate production potential. The amount of clay in the aquifer layer lows the productivity of the layer. The aquifer layer of the VES_01 measurement point is a semi-confined aquifer which located in the depth of 9 – 17 m. The characteristic of a semi-confined aquifer is the placement of the aquifer which is between two permeable layers, specifically soft coal layer below and clay layer above. The soft
coal layer has fractures, causing leakage to the aquifer layer. The clay layer above acts as a cap rock layer. The aquifer layers of the VES_02, VES_03 and VES_04 measurement points are estimated to be located in the depth of 15 m, 19 m and 23 m below the surface, respectively. The aquifer layers are identified as shallow type aquifer with intermediate production potential. These shallow aquifer layers could be used as a clean water source to fulfil the ITK needs.

The other important information obtained from this research is the founding of shallow clay layer in the depth of 2 m dan 4 m. This information can be used as supporting data to decide the depth needed for building foundation. Special treatment is needed to make the ground for being able to withstand building load.

5. Conclusion
The data shows that there is a potential of the shallow aquifer in the location for being used to fulfil the need of clean water of ITK. The subsurface layers of the research location consist of topsoil layer, water-saturated clay layer, clayey sand layer and soft coal insert. The clayey sand layer acts as a shallow aquifer with resistivity value of 112 – 341 Ωm. Information about clay layer can be used as supporting data for building process of ITK.

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