Avalanche Mitigation Using the Geoelectrical Resistivity Method of Schlumberger Configuration in Tiromanda Village Makale Selatan District Tana Toraja Regency

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Abstrak. Mitigation of landslides in Tiromanda sub-district, Makale Selatan sub-district, Tana Toraja district using the Schlumberger configuration geoelectrical resistivity method plays an important role in reducing disaster risk. This study aims to determine the distribution of rock lithology in the Tiromanda sub-district, Makale Selatan district, Tana Toraja district. In this study, measurements were made using the geoelectrical resistivity method of the Schlumberger configuration. Measurements were made on 2 tracks with a length of each track is 120 m with the smallest spacing is 1.5 m and the largest spacing is 10 m. The results showed that the lithology in Tiromanda village consisted of three types of rock lithology, namely overburden with a resistivity of 10.7 m – 21.9 m, shale with a resistivity of 157 m – 1955 m, and sediment containing water with a resistivity of 0.484 m – 15.5 m. Based on the results of the analysis of the data indicated as a slip plane at coordinates S 2˚57'13.0" E 119˚55'21.3" with a depth of 5.76 m and the constituent material is shale in fresh condition. Mitigation that can be done is structural mitigation.

Keywords: *Landslide, Geoelectrical, Resistivity, Schlumberger.*

1. Pendahuluan

Regionally, Tana Toraja is included in the regional geological map of the Majene sheet and the western part of Palopo published by the Bandung Geological Research and Development Center. Administratively located at the coordinates 119^{O}19'05" – 120^{O}09'16" BT and 02^{O}36'03" – 03^{O}24'13" LS (Badan Koordinasi Survei dan Pemetaan Nasional, 2000). Tana Toraja is a highland surrounded by mountains with steep slopes, namely the average slope is above 25% and is dominated by limestone, volcanic rock in the form of basalt which causes frequent landslides. One of the efforts in mitigating natural disasters that can be done is geophysical surveys (Fandi, 2020).

Tiromanda Village, Makale Selatan Subdistrict, Tana Toraja Regency with an area of 37.84 km^2 and an area height of about 1500 meters above sea level. It is an area with a hilly sub-district topography, making it one of the areas with great potential for landslides. Soils in the area are of two types: hydromorphic soils in wetlands and iron-bearing soils characterized by the presence of hardpans on tops and hillsides (Claude et al. 2014). Land management is not carried out in a conservation way, so it can be estimated that the Tiromanda sub-district of South Makale sub-district will have a great potential for landslides.

The purpose of this study was to determine the distribution of rock lithology and to find out how to mitigate landslide areas in the Tiromanda village, Makale Selatan district, Tana Toraja district using the geoelectrical method of the Schlumberger configuration.

2. Metode

One of the geophysical methods that can be used in determining the type of rock layer that acts as the slip plane and its depth from the earth's surface is the two-dimensional (2D) resistivity geoelectrical method. The 2D resistivity geoelectrical method can produce a two-dimensional image of the subsurface rock layers based on the resistivity value of the rock that composes the layer (Telford, 1990).

In the resistivity geoelectrical method there are 2 kinds of methods in data collection, namely: the geoelectrical resistivity mapping method and the geoelectrical resistivity sounding method. The resistivity mapping method is a resistivity method that aims to study variations in the resistivity of the subsurface soil layer horizontally. While the geoelectrical resistivity sounding method aims to study variations in the resistivity of rocks in the earth's surface vertically (Effendy, 2012).

Geoelectrical resistivity provides an overview of the distribution of subsurface resistivity. To convert the resistivity form into geological form, knowledge of the typical resistivity values for each type of material and geological structure of the study area is required (Effendy, 2012).

Geoelectrical resistivity survey is to determine the resistivity of the subsurface of the earth by taking measurements on the earth's surface. Earth's resistivity is related to minerals, fluid content and the degree of water saturation in rocks (Todd, 1980). The geoelectrical method is used for shallow exploration because the soil and rock layers are filled with water so that it is very easy to conduct electric current or is conductive (Sultan, 2008).

The soil layer (conductive) has a certain resistivity value, by knowing the resistivity value of the subsurface layer, it is possible to predict the potential layers of soil or rock that are saturated with water (aquifer layer) (Sultan, 2008).

The presence of water in the soil layer on the slope will cause instability on the slope (Akpan et al. 2015). The presence of liquid (solution) or water in the fracture system or the space between grains can reduce the value of the rock type resistance. Types of igneous, altered (metamorphic), or compressed sedimentary rocks generally have high resistivity, on the other hand, loose rock types such as sand, gravel, when saturated with fresh water will have medium resistivity, the resistivity will be even lower if the water is brackish or salt water in it (Soebagyo, 2001).

Claystone that contains water and a solution of various ions in it has a low specific resistance. Hard, dense and dry rock will show a high resistivity value, while soft rock has a high porosity and a lower resistivity value (Soebagyo, 2001).

The controlling factor for the occurrence of avalanches is a phenomenon that conditions a slope to have the potential to move, even though at this time the slope is still stable (not moving or not yet landslide). The slope that has the potential to move will only move if there is a disturbance that triggers the movement (Karnawati, 2005).

The resistivity geoelectrical method is used because the method is very sensitive to electrical anomalies including water so that it can be used to describe the location of a saturation point that can cause potential landslides and the resulting data can be used as one of the disaster mitigation efforts (Yulina et al. 2015; Jayadi et al. 2020).

Geoelectrical resistivity with Schlumberger configuration is a geoelectrical method with a certain electrode arrangement that can detect, measure and predict the presence of types of material under the earth. The result of interpretation of the Schlumberger configuration is in the form of rock lithology based on the resistivity value of depth.

Where the system of electrode spacing rules in the Schlumberger configuration is arranged constantly. The process of determining the resistivity uses 4 electrodes placed in a straight line (Utom, Odoh, and Okoro 2012). Dielectric conduction occurs in materials that have low conductivity values or insulators, when there is an influence of an external electric field, so that electrons from atoms can move slightly in the nucleus (Reynolds, 1997). The method commonly used for measuring resistivity in general is by injecting electric current into the earth using two current electrodes, and measuring potential difference using two voltage electrodes (Zubaidah and Kanata, 2008; Mun'im, 2020).

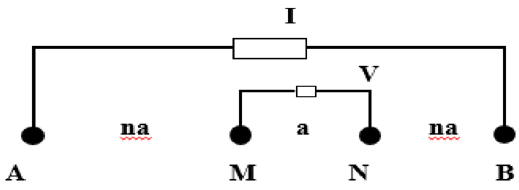

Fig 1. Schlumberger Configuration Electrode Arrangement.

The resistivity value obtained from geoelectrical measurements with the Schlumberger configuration is strongly influenced by the geometry factor. The geometry factor is determined by the distance AB and MN. The geometry factor of the Schlumberger configuration is (Telford, 1990)

$$k = \pi \left[\frac{\left(\frac{AB}{2}\right)^2 - \left(\frac{MN}{2}\right)^2}{2\left(\frac{MN}{a}\right)^2} \right] \quad (1)$$

where k is the geometric factor of the Schlumberger configuration; is the parameter whose value is specified; A and B are current electrodes (Amperes), while M and N are potential electrodes (Volts).

3. Results and Discussion

Geoelectrical resistivity data retrieval or geoelectrical resistivity data acquisition is carried out directly in the field. The number of trajectories in this study is 2 trajectories. The electrode spacing starts from 1.5 m, 2 m, 2.5 m, and so on until the maximum stretch according to the conditions in the field, so that the distance from the midpoint of the measurement to the current electrode is 0.3 m, 3 m, and 10 m.

The way it works is to activate the resistivity meter by pressing the "On" button. Pressing the test button (AB and MN) as the test electrode is connected properly. Press the inject button (until it sounds 3 times) then press the Hold button on the multimeter on the resistivity meter simultaneously. Record the value that is read on the multimeter that is on the resistivity meter. Changing the distance A and B for the next data according to the Schlumberger configuration table and, repeatedly changing the distance M and N activities.

The first stage of data processing is to calculate the apparent resistivity (ρ_a) value by entering the values of ΔV, I, a and K into the Microsoft Excel program. Furthermore, interpretation of rock layers using IP2Win software.

Based on the measurement results to determine the lithology in the study area, it is shown in the following graph.

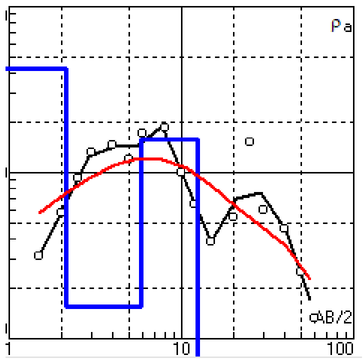

Fig. 2. Results of Data Processing Resistivity to Depth on Sounding 1

Figure 2 shows a logarithmic graph between the distance AB/2 as the x-axis and the apparent resistivity value as the y-axis. The black dots are the apparent resistivity value data points for each different AB/2 value. The black line is a graph of the original data from the field data, while the red line is a graph of the model created by the software. The blue line is the result of the inversion of the software that determines the actual thickness, depth and resistivity values of each layer of the earth's surface.

Table 1. Data Interpretation.

Lithology	Depth (m)	Resistivity (Ωm)
Cover ground (*top soil)*	0.24	10.7
Sandstone, Shale	2.15	423
Sediment contains water	5.82	15.5
Sandstone, Shale	12.4	157

Based on the measurement data obtained by using the Schlumberger configuration using IP2Win software. The results of the first track measurement can be estimated with a resistivity value of 10.7 m with a thickness of 0.24 m as the first layer, namely the overburden. The resistivity value of 423 m with a depth of 2.15 m contains shale, the resistivity of 15.5 m at a depth of 3.67 m is suspected to be sedimentary rock containing water and the resistivity value of 157 with a depth of 6.58 m is shale.

In the first trajectory, there was no indication of a slip plane. This is because on this trajectory it is not perpendicular to the slope but parallel to the slope. Although there are contrasting differences under the surface and there is also a layer that is easy to pass water (permeable), this material is in the form of soil and also shale that has undergone weathering which is above a layer that is difficult to pass water (impermeable) where this material is in the form of shale in fresh condition. In addition, the impermeable layer tends to be flat so it does not have the potential to attract the layer above it.

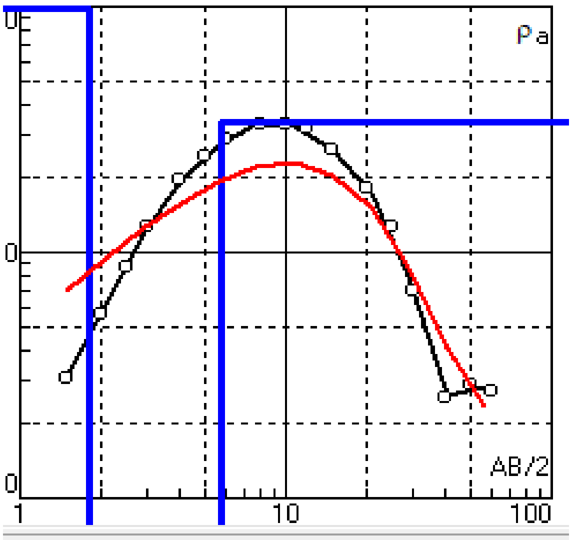

Fig. 3. Results of Data Processing Resistivity to Depth on Sounding 2

Table 2. Data Interpretation.

Lithology	Depth (m)	Resistivity (Ωm)
Cover ground (*top soil)*	0.444	21.9
Sandstone, Shale	1.84	1955
Sediment contains water	2.95	0.484 – 4.91
Sandstone, Shale	5.76	338

On the second track, it is estimated that the resistivity value of 21.9 m with a depth of 0.444 m contains the main layer, namely overburden, the second resistivity is 1955 m with a depth of 1.84 m, there are shale stones in fresh condition, the third and fourth resistivities are 0.484 – 4, At 91 m with a depth of 5.76 m, there are sedimentary rocks containing water, and the last resistivity value of 338 m is shale that has undergone weathering.

In the second trajectory, a layer is found which is indicated as a slip plane. the layer is at a depth of 5.76 m where this layer is shale material in fresh condition with a resistivity value of 1955 m. This is based on the nature of the shale, which is watertight or impermeable. While the layer below is a permeable layer, namely sedimentary material that has been saturated with water and also weathered material with a resistivity value of 0.484 m - 4.91 m. In another study, it was said that geoelectrical the slip plane is characterized by a resistivity contrast between two adjacent rocks where the impermeable layer has a large resistivity value which is right between the layers having the smaller resistivity.

Another thing that supports the estimation of the slip plane on the second track is that the shape of the slip plane tends to be shaped like a basin and follows the slope of the slope.

3.1. Landslide Mitigation

The natural causes of landslides include the morphology of the earth's surface, land use, lithology, geological structure, rainfall, and seismicity. In addition to natural factors, it is also caused by human activity factors that affect a landscape, such as agricultural activities, slope loading, slope cutting, and mining.

In the first trajectory, there was no indication of a slip plane. This is because on this trajectory it is not perpendicular to the slope but parallel to the slope. Although there are contrasting differences under the surface and there is also a layer that is easy to pass water (permeable), this material is in the form of soil and also shale that has undergone weathering which is above a layer that is difficult to pass water (impermeable) where this material is in the form of shale rock in fresh condition. In addition, the impermeable layer tends to be flat so it does not have the potential to attract the layer above it.

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As a mitigation effort before a landslide disaster occurs, the thing to do is plant trees that can absorb a lot of water in the soil, and increase the surrounding vegetation.

4. Conclusion

From the research that has been carried out, it can be concluded as follows, the distribution of rock lithology in the Tiromanda sub-district, Makale Selatan district, Tana Toraja district in the area of the first track there may be overburden, sandstone, shale, and sediment containing water with a rock resistivity range of 10.7 – 423 m to a depth of 12.4 meters above sea level. In the area of the second track there may be overburden, sandstone, shale, limestone, and sediment containing water with a rock resistivity range of 0.484 – 1955 m to a depth of 5.76 meters above sea level.

Based on the data obtained in the first trajectory there is no slip plane because the waterproof layer tends to be flat and does not tilt following the slope. On the second track, it was found that there were river flows as well as multi-storey buildings around the track and an impermeable layer in the form of a basin and following the slope of the slope under a layer of fresh shale where this layer is thought to be a slip plane.

Mitigation that can be done is structural mitigation to minimize disasters through the construction of facilities and infrastructure that involve architects in the planning and development phase as well as increasing vegetation around areas prone to landslides.

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