Gravity: Jurnal Ilmiah Penelitian dan Pembelajaran Fisika

http://jurnal.untirta.ac.id/index.php/Gravity

ISSN: 244-515x; e-ISSN: 2528-1976

Vol. 10, No. 2, August 2024, Page 61 – 73

Identification of sliding fields using the geoelectric resistivity method as an effort to mitigate landslides (case study: Payan, Punten Village, Batu City)

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(Received: 24 January 2024; Accepted: 20 August 2024; Published: 30 August 2024)

ABSTRAK

A sliding plane is a layer below the surface that is impermeable. The sliding plane becomes a place where the soil mass experiences movement so that the weathered layer above it experiences landslides following the slope. Payan Hamlet, located in Punten Village, Batu City, which is the research area, is included in a landslide-prone village as evidenced by the recapitulation of BPBD disaster data for Batu City during 2022, 6 landslides occurred. The geoelectric method used in this study is the Wenner configuration. It was used to identify the subsurface condition and interpret the slide plane and direction of the landslide. There are 5 trajectories in this study with 5 m electrode spacing. Based on the results of 2D data processing, the distribution of resistivity values in the research area is diverse. The resistivity value is divided into 3 (three) categories. The low resistivity category with a value of 13 - 51 Ωm is interpreted as a clay layer, the medium resistivity category with a value of 70 - 100 Ωm is interpreted as a tuff layer, and the high resistivity category with a value of 100 - 200 Ωm is interpreted as volcanic breccia. The interpretation of the layer that becomes the sliding field in the research area is the tuff layer with a depth of ± 3.8 - 4m. Based on the results of 2D data processing and calculation of the degree of slope, it can be analysed that the direction of the landslide leads to the southeast side of the research area. Installation of evacuation route signs around the research area is considered as a disaster mitigation effort that can be done.

Keywords: Geoelectric, landslide, slide field, slope.

DOI: 10.30870/gravity.v10i2.24135

INTRODUCTION

Landslides are a common natural disaster in Indonesia. Besides being caused by rainfall and bare slopes, landslides can occur due to earthquakes or volcanic activities (Badan Nasional Penanggulangan Bencana, 2020). The presence of Arjuno - Welirang volcanic activity in the study area results in morphological conditions in the form of slope in the area that can affect the level of slope stability that can cause landslides to occur (Balai Besar Litbang Sumberdaya Lahan Pertanian (BBSDLP), 2013; Rahma & Zulfian, 2020). In addition, the high rainfall throughout the year in Batu City can trigger landslides (Jalaludin, 2023; Luthfin, 2023; Suyanto, 2013). The higher degree of slope and high rainfall, the greater the potential for landslides to occure (BPBD Kota Batu, 2022; Fazri et al., 2022; Leluno et al., 2020) . BPBD Batu City released data on rainfall values for 2022. Based on the data, in 2022 a value of 2238.73 mm was obtained, and Punten Village is in an area with moderate to high rainfall. The recapitulation of rainfall values can be correlated with data on disasters that occurred throughout 2022. There were a total of 7 out of 8 landslide disasters occurring throughout 2022 in Punten Village with a time span of October to December. This data shows that the majority of landslide disasters occur during the rainy season (BPBD Kota Batu, 2022; Eka Putri et al., 2023).

Based on several previous landslide events that occurred in Batu City, especially Punten Village, the Early Warning System for landslides installed at the location, as well as previous studies on Landslide Zone Investigation using Resistivity Method and Slope Stability Analysis for Landslide Disaster Mitigation (Sutasoma et al., 2017), this research must be conducted in order to provide information on the subsurface and sliding plane conditions at the research location to be used as data in efforts to prepare a landslide disaster mitigation plan in the research area, especially Punten Village, Batu City (Naryanto, 2011; Sutasoma et al., 2017).

Previous research similar to this research is a journal entitled "Landslide Zone Investigation with Resistivity Method and Slope Stability Analysis for Landslide Disaster Mitigation" by Muwardi Sutasoma, Adi Susilo and Eko Andi Suryo, in 2017. This research uses dipole-dipole geoelectric method and slope stability analysis, with a track length of 100 m - 300 m as many as 5 passes. The result of this research is that the factor of safety value of the research area is obtained so that it can be concluded that the research area is very prone to landslides and the direction of landslides in the area can also be determined (Maryati, 2018; Nia & Mahdavi, 2020; Pratiwi et al., 2022a).

The dipole-dipole configuration geoelectric method is one alternative in identifying subsurface soil layers (Reynolds, 1997; Syukri, 2020). However, there are many other methods of geoelectric methods that can be used, the most common of which is the wenner configuration (Badan Nasional Penanggulangan Bencana, 2023; Nugraheni et al., 2022; Susilo, Sunaryo, Isdarmadi, et al., 2017). This configuration will get more subsurface profiles in mapping with a certain depth (Irjan, 2012; Susilo et al., 2018). For the case in Punten Village, Wenner configuration of the Geoelectric method would be suitable for use because the target is the sliding plane of the study area and only at a shallow depth (Sirait & Ihwan, 2015; Susilo et al., 2009).

RESEARCH METHODS

Data collection was carried out in Payan Hamlet, Punten Village, Batu City. Data acquisition was carried out in stages, from a total of 5 tracks starting from track 5 with a track length of 90 metres (m), then track 4 with a track length of 90m, track 3 with a track length of 100m, track 2 with a track length of 90m, and track 1 along 80m as the survey design made and seen in Figure 1.

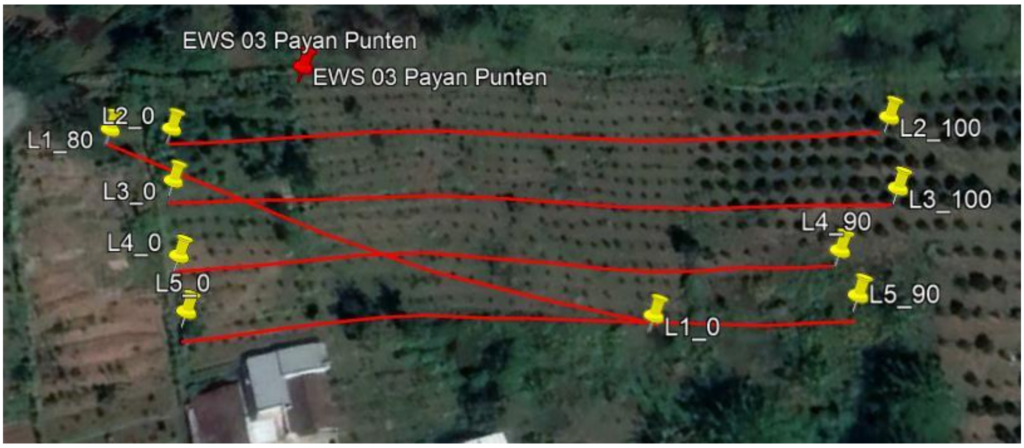

Figure 1. Research survey design

The Equipment used in this study was a Voltbraton brand resistivity meter, 2 current electrodes, 2 potential electrodes, 4 elektrode cables, a 50 m long rollmeter, a 12 Volt accumeter, 3 handytalkies, 3 hammers, GPS and Stationery. Data acquisition began by stretching the rollmeter from the designated point 0 at the end of the track to the centre point marked by the location of the resistivity meter. Then the current electrodes and potential electrodes were stuck at the points that had been determined on the data logsheet, and connected to each cable. After all electrodes have been plugged in and connected to the cable, the resistivitymeter is turned on by connecting the cable with the accumeter and the cable that has been connected to the electrode is connected to the resistivitymeter according to the cable name label, for the potential electrodes labelled P1 and P2 are connected to the cable plug labelled M and N on the resistivitymeter, and the current electrodes labelled C1 and C2 are connected to the cable plug labelled A and B on the resistivitymeter. Furthermore, the current is injected by pressing the measure button until the current value reading is stable and then pressing the hold button. The voltage and current values read were recorded on the data logsheet, these steps were repeated four times for each measurement point (Junaidy et al., 2019; Pratiwi et al., 2022; Rosyida et al., 2019).

The value of the specific resistance or resistivity of a material can be said to be a parameter of a material to be able to inhibit the flow of electric current. The resistivity method in geophysical exploration is used to determine the state of the earth's subsurface structure by measuring the difference in rock resistivity values. The resistivity value can be measured by injecting electric current through electrodes stuck in the ground. The amount of resistivity of a material is not the same value but varies. Variations in resistivity values are based on differences in rock type, mineral content, porosity level, and temperature (Susilo, Sunaryo, Fathur, et al., 2017).

In general, the exploration of resistivity geoelectric method uses four electrodes, two electrodes as current sources (A and B) and two other electrodes as potential difference gauges (M and N). The Wenner configuration is one of the electrode configurations that can be used when taking resistivity geoelectric data. This configuration is commonly used in mapping data collection. When taking geoelectric data using this configuration, the land required is relatively larger than the use of other configurations. There are 4 electrodes arranged in this configuration. The electrodes include two current electrodes and two potential electrodes. The potential electrode arrangement is inside the current electrode. The distance between electrodes or the space between electrodes can be called a. The arrangement of electrodes contained in the Wenner configuration can be seen as in Figure 2.

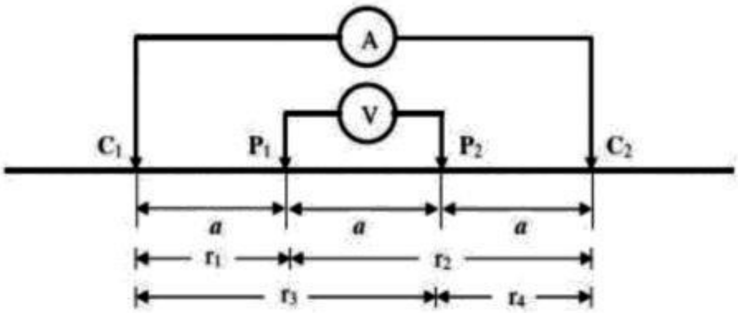

Figure 2. Electrode arrangement in Wenner configuration[4]

Data from data acquisition results in the form of apparent resistivity value data in each track. The data is then processed using several software including Microsoft Excel, Notepad, RES2DINV, and RockWorks. Based on this processing, the results are obtained in the form of a 2-dimensional model of the Geoelectric cross section used to interpret the presence of a sliding field (Badan Standarisasi Nasional, 2005).

RESULTS AND DISCUSSION

The geo-electrical data obtained are 5 trajectories with details of 4 trajectories stretching horizontally southeast - northwest, and 1 trajectory stretching diagonally across 4 other trajectories (can be seen in Figure 1). In the data collection process, track 1 stretches from west to east to cut the other four tracks vertically, but it cannot be done because the stretch length only covers 75 m due to terrain conditions that are too steep. So after re-orientation of the terrain, this track was made slightly inclined in the direction of southwest to northeast with a length of 80 m and descending from a higher slope.

The other four traverses run parallel to each other. Tracks 2 and 3 extend 100 m from southeast to northwest, tracks 4 and 5 extend 90 m in the same direction. Soil conditions at the time of data collection tend to be looser due to rain that occurred a few days before data collection. The data acquisition process was carried out for 7 days due to frequent rains in Batu City, especially the research location, so there was a break between track 1 and others. However, this situation does not affect the geoelectric data obtained.

Traverse 1 runs in a south-west to northeast direction. Traverse 1 in the survey design is used as a tie point for the other four traverses. The author interprets it as a geological outcrop or some kind of large rock buried in the ground. The resistivity value of 13 - 51 Ωm is interpreted as clay, tuff lithology is interpreted with a resistivity value of 70 - 100 Ωm. Then volcanic breccia is interpreted with a resistivity value of 100 - 200 Ωm.

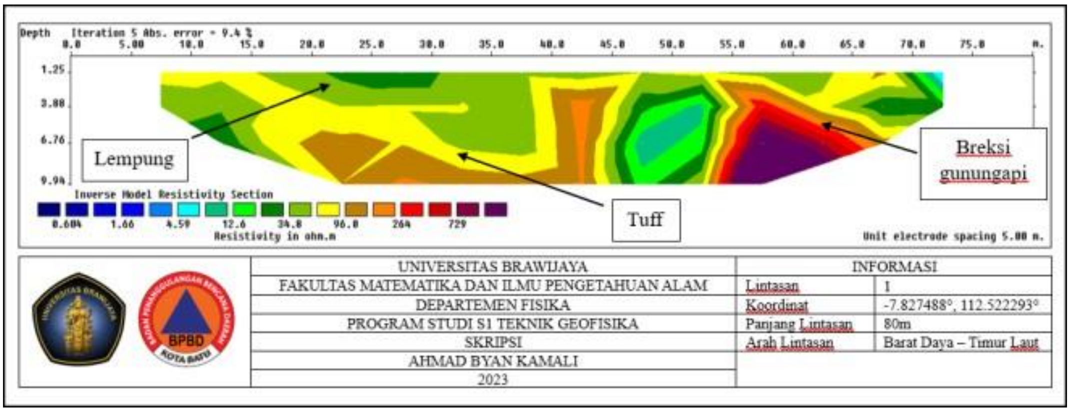

Figure 3. 2D cross-section results of track 1

The sliding plane as the boundary layer between the impermeable layer and the weathered layer above it in track 1 is interpreted to be at a depth of ± 3.8 - 4 m. The layer that acts as a sliding plane in this track is tuff that borders the clay above it. The layer that acts as a sliding plane on this track is tuff bordering the clay above it. Tuff becomes the slide plane and clay will be the dominant layer of the landslide.

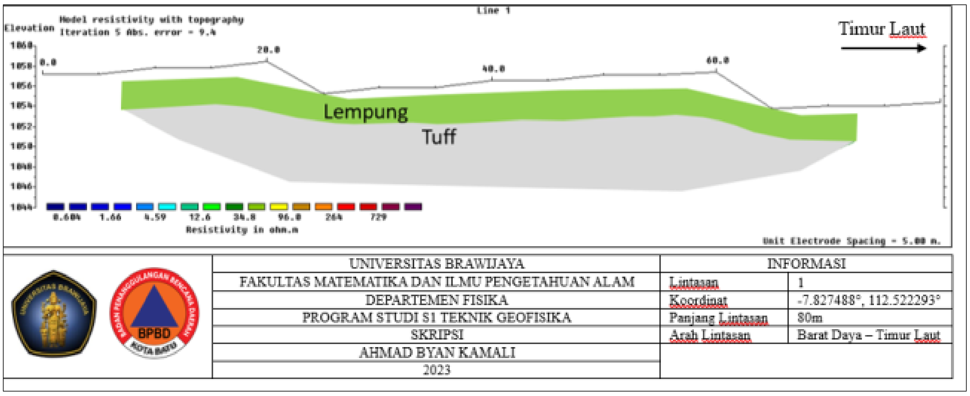

Figure 4. Interpretation of track 1 slide plane

Track 2 stretches vertically from the southeast to the northwest with a line length of 100m, and the highest elevation value on this track is 1070m, which can be seen in Figure 4. Environmental conditions along track 2 are found in the form of sapling plantations. The soil conditions on this track can be said to be fertile soil because the cabbage plants can grow well. Interpretation based on the distribution of resistivity values, the presence of clay is seen from the distribution of resistivity values in the range of 13 - 51 Ωm which is marked with green to dark green colour. Meanwhile, the presence of tuff is seen from the distribution of resistivity values in the range of 70 - 100 Ωm. While volcanic breccia is interpreted to be present in the resistivity value in the range of 100 - 200 Ωm.

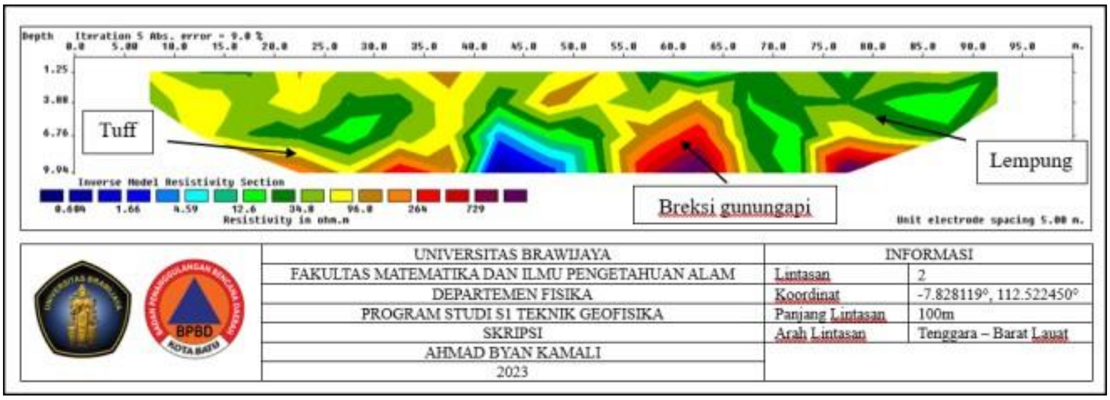

Figure 5. 2D cross-section results of track 2

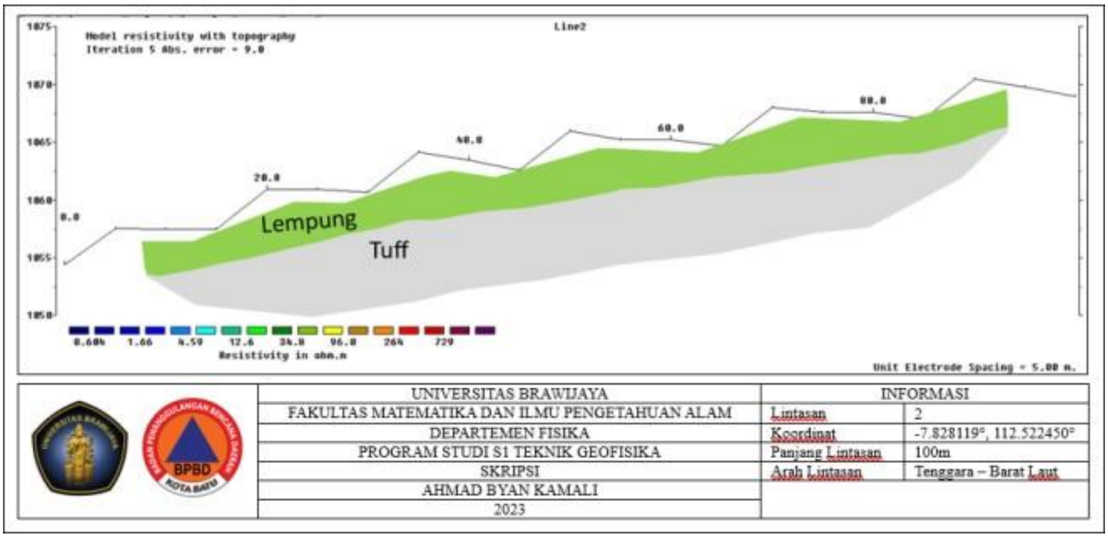

Figure 6. Interpretation of the slide plane of traverse 2

In traverse 2 the sliding plane is interpreted to be at a depth of 3.8 - 4 m. The layer that becomes the sliding plane in this traverse is tuff due to the higher resistivity value compared to clay. The layer that becomes the sliding plane on this track is tuff due to the higher resistivity value compared to clay.

The direction of traverse 3 runs from southeast to northwest horizontally in the survey design of the study area. The length of track 3 is 100m with the highest elevation point of 1066m. The environmental conditions along this track are the same sapling plantations as the other tracks. During the data acquisition process, the conditions on the 80th metre stretch of land were not planted with any plants so that the conditions were more loose soil and easily eroded. Based on the distribution of resistivity values, clay is in the range of low to medium resistivity values with a value of 13 - 51 Ωm, while tuff is interpreted in the range of 70 - 100 Ωm. While volcanic breccia which has the highest resistivity value among the other 2 lithologies is in the range of resistivity values of 100 - 200 Ωm

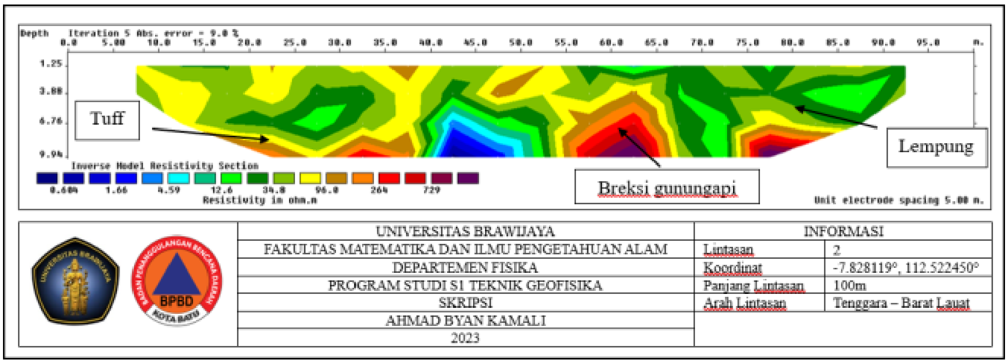

Figure 5. 2D cross-section results of track 3

The sliding plane in traverse 3 is interpreted to be at a depth of 3.8 - 4m. The layer that becomes the sliding plane in this traverse is tuff. The tuff is adjacent to the clay above it which has a lower resistivity value.

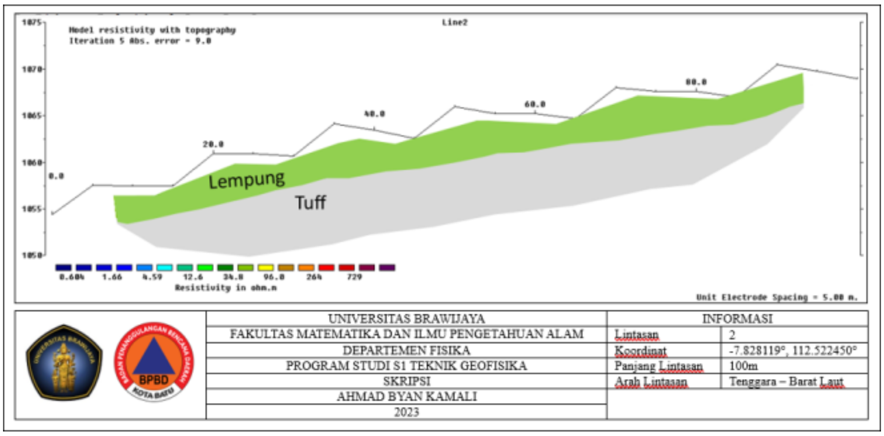

Figure 6. Interpretation of the slide plane of traverse 3

Track 3 has a stretch length of 90 m with the direction of the southeast - northwest stretch can be seen in Figure 7. The highest elevation point on this traverse is 1063m. Lithological interpretation is seen from the difference in contrast of resistivity values displayed on the 2D cross section. On this track, the lithology is found in the form of clay, tuff, and volcanic breccia. Clay is interpreted with a resistivity value range of 13 - 51 Ωm, while a resistivity value of 70 - 100 Ωm is interpreted as tuff. While at a depth of ± 4 - 7 m there is a distribution of resistivity values of 100 - 200 Ωm which is interpreted as volcanic breccia

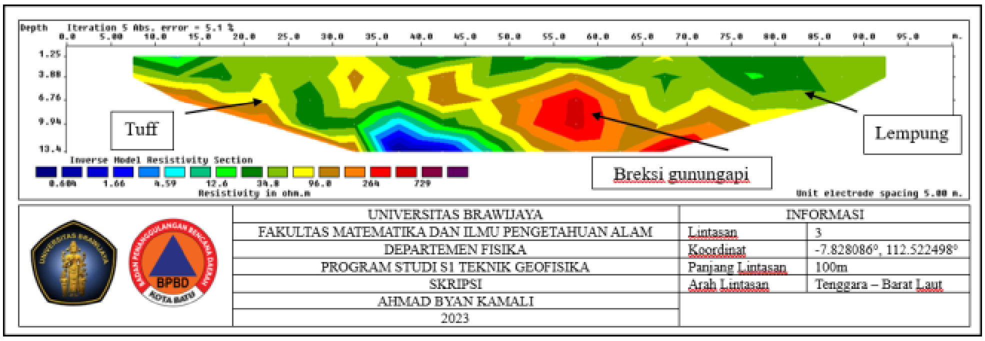

Figure 7. 2D cross-section results of track 3

The sliding plane in traverse 3 is interpreted to be at a depth of 3.8 - 4m. The layer that becomes the sliding plane in this traverse is tuff. The tuff is adjacent to the clay above it which has a lower resistivity value.

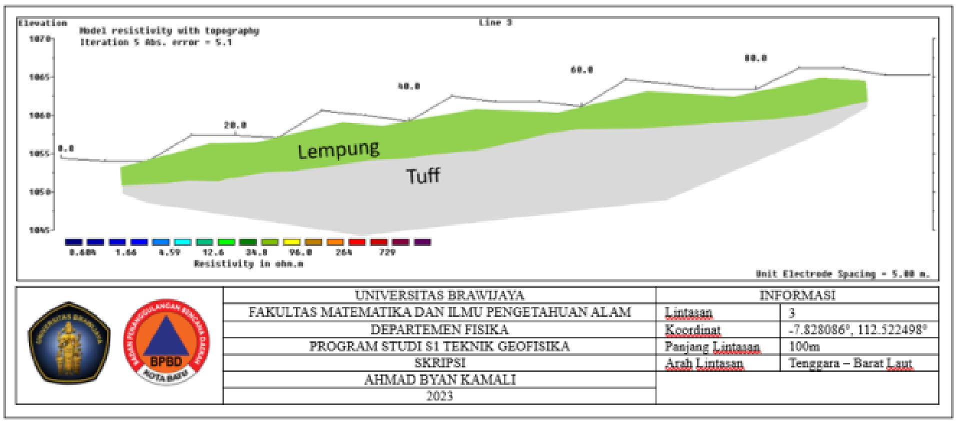

Figure 8. Interpretation of the slide plane of traverse 3

Track 4 has a stretch length of 90 m with the direction of the southeast - northwest stretch can be seen in Figure 11. The highest elevation point on this traverse is 1063m. Lithological interpretation is seen from the difference in contrast of resistivity values displayed on the 2D cross section. On this track, the lithology is found in the form of clay, tuff, and volcanic breccia. Clay is interpreted with a resistivity value range of 13 - 51 Ωm, while a resistivity value of 70 - 100 Ωm is interpreted as tuff. While at a depth of ± 4 - 7 m there is a distribution of resistivity values of 100 - 200 Ωm which is interpreted as volcanic breccia

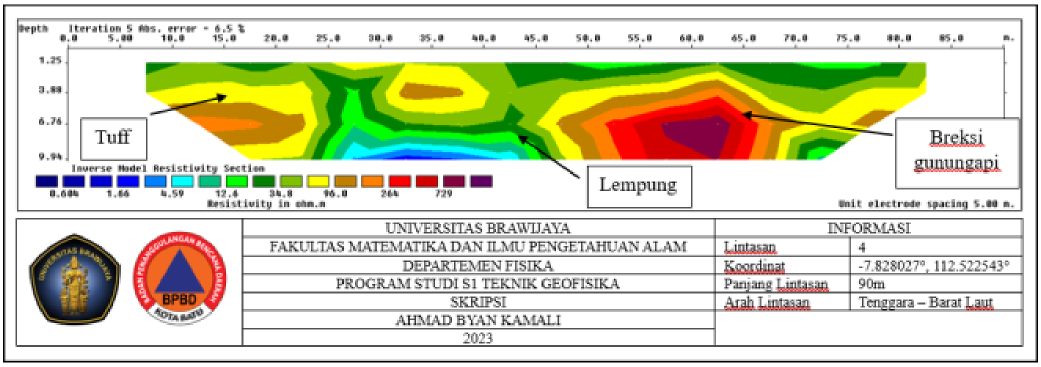

Figure 9. 2D cross-section results of track 4

On track 4, which runs from the southeast to the northwest for 90 m, it is found that the sliding plane is at a depth of 3.8 - 4 m below the surface. The layer that becomes the sliding plane on this track is tuff with a higher resistivity value than the clay above it.

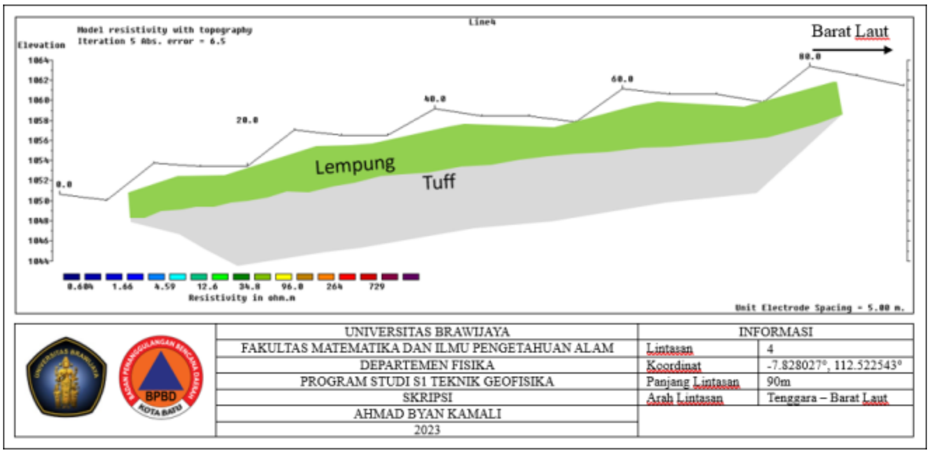

Figure 10. Interpretation of the slide plane of traverse 4

Track 5 has a track length of 90 m with a track direction of southeast - northwest. The highest elevation point on this traverse is 1061m. This track is on the side of the lowest terrace of the survey design in the study area. Lithological interpretations on this track include clay, tuff, and volcanic breccia based on the contrast of resistivity values. The resistivity value interpreted as clay is a low to medium resistivity value in the range of 13 - 51 Ωm, while tuff is interpreted to be at a resistivity value of 70 - 100 Ωm. The third lithology on this track is volcanic breccia which is interpreted at a resistivity value of 100 - 200 Ωm.

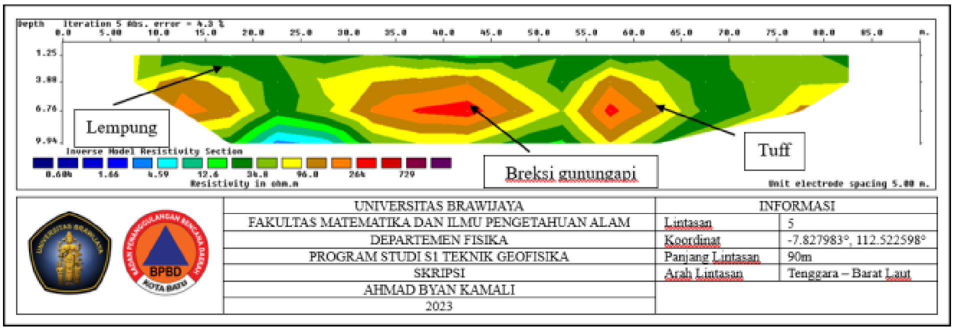

Figure 11. 2D cross-section results of traverse 5

The sliding plane in traverse 5 is interpreted to be at a depth of 3.8 - 4 m below the surface. The layer that becomes the sliding plane on this track is the tuff layer. Tuff has a higher resistivity value than clay. The avalanche on this traverse is to the southeast.

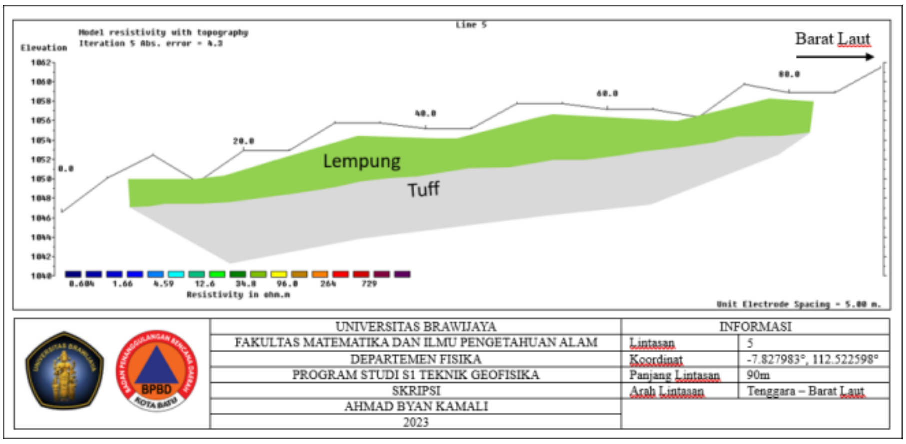

Figure 12. Interpretation of the slide plane of traverse 5

The 2D cross section was generated from data processing using RES2DINV software. The Res2dinv device performs an inversion process to produce 2D cross sections with the data read is the result of processing data in Ms. Excel which is then stored in notepad format (.txt). The resulting cross section illustrates the image of subsurface conditions on the geoelectric track in the study area. This 2D cross section is used to identify the type of rock lithology, the presence of a slide plane, and the landslide that occurred. This 2D cross section also shows some information such as resistivity value, depth, elevation, and electrode spacing used during measurement. Based on the measurement results and data processing, the resistivity value scale can be seen in Table 1.

Table 1. Category division of resistivity value scale

Resistivity Value	Category	Colour scale on the cross section
0.604 - 50 Ωm	Low	Dark blue to dark green
51 - 150 Ωm	Medium	Dark green to brown
>150 Ωm	High	Orange to purple

From the whole track, it is interpreted that the limiting lithology that has the potential as a sliding field is tuff lithology, which has impermeable properties and small pores, making it difficult to pass water. Water will settle and fill the layer above, which is an alluvial clay with a depth of 0 - 3.5 metres. Due to the absence of plant roots or other materials that hold it, if it is continuously exposed to water, then this layer will landslide. This is where the sliding plane of the research area can be identified, which is characterised by a slope that shows a rather steep degree.

CONCLUSIONS

Based on the results of the analysis of the subsurface conditions of the research location using the type resistance geoelectric method, it was found that the research location found 3 rock lithologies. The clay layer dominates and becomes an avalanche layer with a resistivity value of 13 - 51 Ωm, as well as tuff as a boundary layer that has impermeable properties with a resistivity value of 70 - 100 Ωm, and volcanic breccia which has a high resistivity value with a value of 100 - 200 Ωm. Based on the 2D cross-section generated from the processing of resistivity geoelectric data, it can be analysed that the presence of a sliding plane on each geoelectric track is at a depth of 3.8 - 4 m below the surface. Then, the condition of the slope at the research location can be said to be a rather steep slope wavy to steep. Disaster mitigation efforts that can be formulated in this study are by placing evacuation route signs and determining the gathering point as the direction and location of the evacuation of the community around the research location in the event of a disaster.

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