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IDENTIFICATION OF LANDSLIDE PRONE ZONE SLIDE PLANE USING 2D RESISTIVITY GEOELECTRIC METHOD IN SAMBOJA REGION EAST KALIMANTAN

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Abstract. This study aims to investigate subsurface conditions to identify ground movement and landslide potential in Samboja District, Kutai Kartanegara Regency, East Kalimantan. To delineate slip surfaces in landslide-prone areas, the research employs the 2D electrical resistivity method using a dipole-dipole electrode configuration. Geoelectrical measurements were conducted along four survey lines based on resistivity values to determine subsurface characteristics indicative of potential slip surfaces. The results show that each survey line has distinct soil and rock properties, influencing the type of landslide that may occur. SBJ01 was measured on an outcrop and used as calibration data for other lines. SBJ02 is susceptible to soil creep, SBJ03 is at risk of translational landslides, while SBJ10 indicates debris flow. The primary factors contributing to landslides in the study area include rainfall infiltration, which increases pore water pressure, and lithological conditions that form weak slip surfaces. This study confirms that the 2D electrical resistivity method is effective in identifying slip surfaces in landslide-prone areas and serves as a valuable reference for disaster mitigation efforts.

Keywords: Geoelectrical, dipole-dipole configuration, slip surface, landslide

Abstrak. *Penelitian ini bertujuan untuk menyelidiki kondisi bawah permukaan untuk mengidentifikasi gerakan tanah dan potensi tanah longsor di Kecamatan Samboja, KabupatenKutai Kartanegara, Kalimantan Timur. Untuk mendelineasi bidang gelincir di daerah rawan longsor, penelitian ini menggunakan metode resistivitas listrik 2D dengan konfigurasi elektroda dipole-dipole. Pengukuran geolistrik dilakukan di sepanjang empat lintasan survei berdasarkan nilai resistivitas untuk mengetahui karakteristik bawah permukaan yang mengindikasikan adanya potensi bidang gelincir. Hasilnya menunjukkan bahwa setiap jalur survei memiliki sifat tanah dan batuan yang berbeda, yang mempengaruhi jenis tanah longsor yang mungkin terjadi. SBJ01 diukur pada singkapan dan digunakan sebagai data kalibrasi untuk jalur lainnya. SBJ02 rentan terhadap rangkak tanah, SBJ03 beresiko mengalami longsor translasi, sedangkan SBJ10 mengindikasikan adanya aliran debris. Faktor utama yang berkontribusi terhadap longsor di daerah penelitian termasuk*

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infiltrasi curah hujan, yang meningkatkan tekanan air pori, dan kondisi litologi yang membentuk permukaan gelincir yang lemah. Penelitian ini menegaskan bahwa metode resistivitas listrik 2D efektif dalam mengidentifikasi bidang gelincir di daerah rawan longsor dan menjadi referensi yang berharga untuk upaya mitigasi bencana.

***Kata kunci**: Geolistrik, konfigurasi dipol-dipol, permukaan gelincir, tanah longsor*

1. Introduction

Based on the Landslide Vulnerability Map of Kutai Kartanegara Regency, the Samboja area, Kutai Regency, East Kalimantan, is a landslide-prone area. Factors that influence landslide events include topography, high rainfall, soil and rock types, slope, and geological conditions composed of clay and sand rock formations. Landslides often cause material losses, casualties, and significant damage to the environment [1]. Therefore, effective mitigation efforts are needed to identify and map potential landslide zones so as to minimize the impact of the disaster. To identify potential landslides, geophysical methods, especially geoelectric methods, can be used.

Two-dimensional (2D) resistivity geo-electrical method is one of the efficient geophysical methods in identifying slide planes in landslide-prone zones. This method allows the detection of subsurface resistivity variations related to the physical properties and lithology of rocks [2]. A sliding plane is formed due to the difference in layers between the overburden or top and the underlying layers. The uppermost layer of a slope is usually composed of water-permeable soil, allowing infiltration of rainwater into the slope. However, water infiltration is often hindered by the presence of impermeable layers that form a sliding plane. Low resistivity generally indicates the presence of a clay layer or water-saturated material, which has the potential to become a sliding plane [3]. By using the two-dimensional (2D) resistivity geoelectric method, subsurface structures can be visualized in more detail, thus providing more valid and accurate information to support slope stability analysis. This research aims to identify the sliding plane in the landslide-prone zone in Samboja area, East Kalimantan, with the hope that the results can be the basis for landslide mitigation planning in the area as well as contributing to the development of geophysical methods for geological disaster analysis.

2. Research Methods

2.1 Research Location

Data collection was conducted in Samboja Sub-district on November 15, 2022 until November 22, 2022. This research is located in Samboja District, Kutai Kartanegara Regency, East Kalimantan Province. Based on data from the Central Bureau of Statistics of Kutai Kartanegara Regency, Samboja District has an area of 1,045.90 km^2. Geographically, this sub-district is located in the coastal area of Kutai Kartanegara Regency, East Kalimantan Province, with a position between 0°52' South latitude to 1°08' South latitude and 116°50' East longitude to 117°14' East longitude. It is bordered by Loa Janan and Muara Jawa sub-districts to the north, Sepaku sub-district to the south, Makassar Strait to the west, and Sanga-Sanga and Muara Jawa sub-districts to the east. Samboja sub-district consists of 21 villages and has a population of around 66,617 people in 2020. The geological map of the research location can be seen in Figure 1.

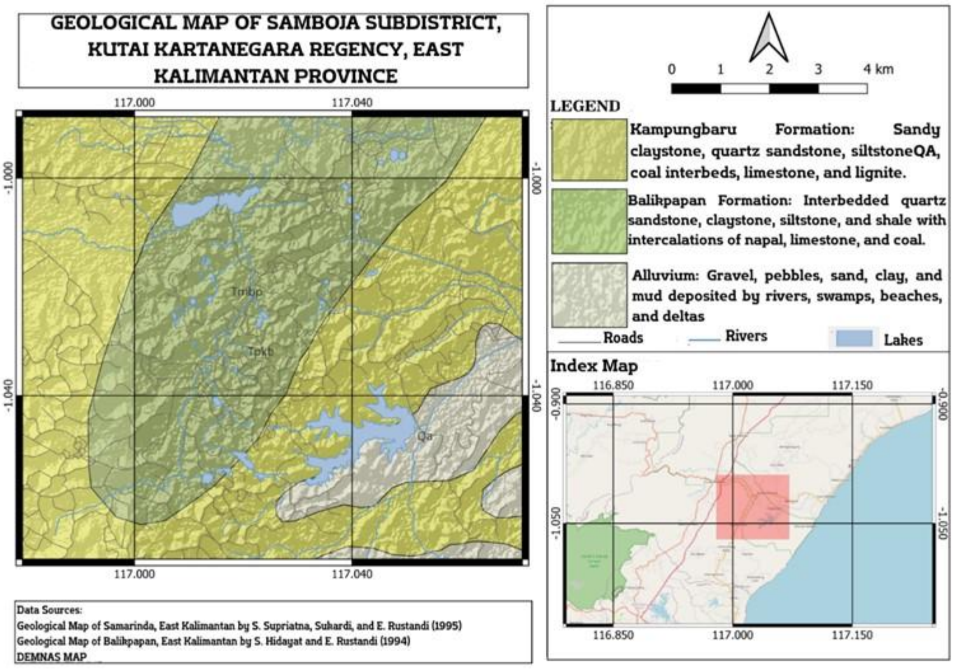

Figure 1. Regional Geologic Map of the Research Location (Modification of Geologic Map of Samarinda and Balikpapan Sheet)

2.2 Research Methods

Data acquisition in this study used 2D resistivity geoelectric method. The 2D Resistivity (Mapping) method aims to determine the variation of rock resistivity under the earth's surface laterally or horizontally. During the measurement, the electrode spacing (current and potential) is made the same for all points on the earth's surface. The results of this measurement can be used as a contour map in the form of a distribution of resistivity values. Under the condition that the subsurface medium is not homogeneous, there is a notion of resistivity (ρ) whose value is influenced by the installation of current and potential electrodes or the geometry factor (k), in addition to the voltage read (V) and the current delivered (I).
General equation of apparent resistivity:

$$\rho = k \, \Delta V / I \qquad (1)$$

Where ρ is the electrical resistivity (Ωm), k is the geometric factor (m), ΔV is the potential difference (V), and I is the electric current (A).

2.3 Field Measurement Method

The tool used when measuring resistivity is Syscal Pro Resistivitymeter. The electrode arrangement used in field data acquisition is the Dipole-Dipole configuration. Lines SBJ01, SBJ02, and SBJ03 use a spacing of 3 meters between electrodes with a total of 72 electrodes. While the SBJ10 line has an inter-electrode spacing of 1 meter with a total of 36 electrodes. The SBJ01 line is a line measured above the outcrop and the data results will be used as calibration material for other lines. The use of Dipole-Dipole configuration is because the configuration is more capable of describing good resistivity distribution patterns with high resolution laterally and vertically, so that the data obtained will be more accurate. The electrode arrangement is as shown in Figure 2, where a is the spacing distance between current electrodes and the spacing between potential electrodes. While the software used in data processing is Prosys II, Res2Dinv and some supporting software, including: QGIS and MsExcel.

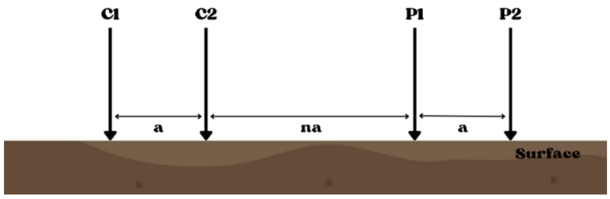

Figure 2. Dipole-dipole Electrode Conguration

2.4 Research Phase

Data processing begins with raw geoelectric data exported from Syscal Jr. Resistivity meter. Then enter the exported data into the Prosys II software then edit the data to remove outliers or data errors in the software. Then export it back into the .dat file so that it can be processed by Res2dinv. Processing and analysis of apparent resistivity data obtained from field measurements using the Res2dinv program is carried out using the inversion method with least squares based on quasi-Newton optimization techniques (Least square inversion). The inversion method is one of the modeling methods to reconstruct the earth layer model based on measurement data. In the results, the condition of the subsurface layer is described in the form of rectangular blocks that explain the condition of the apparent resistivity distribution. The results of data analysis are integrated with the study of regional geological and stratigraphic conditions to interpret the field data conditions. Flowchart can be seen in Figure 3.

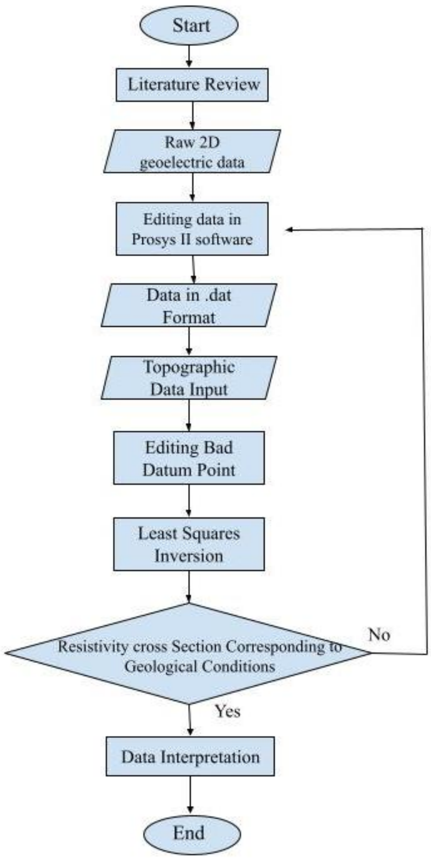

Figure 3. Flow Chart

3. Result and Discussion

Data acquisition using the Dipole-Dipole configuration resistivity method, carried out as many as four passes with the length of each line 216 meters and 36 meters. After processing using Res2DInv software, the results are obtained in the form of subsurface resistivity cross sections on each line, then interpretation is carried out to determine the type of rock and indications of the presence of a sliding field. The measurement line map of samboja sub-district can be seen in Figure 4.

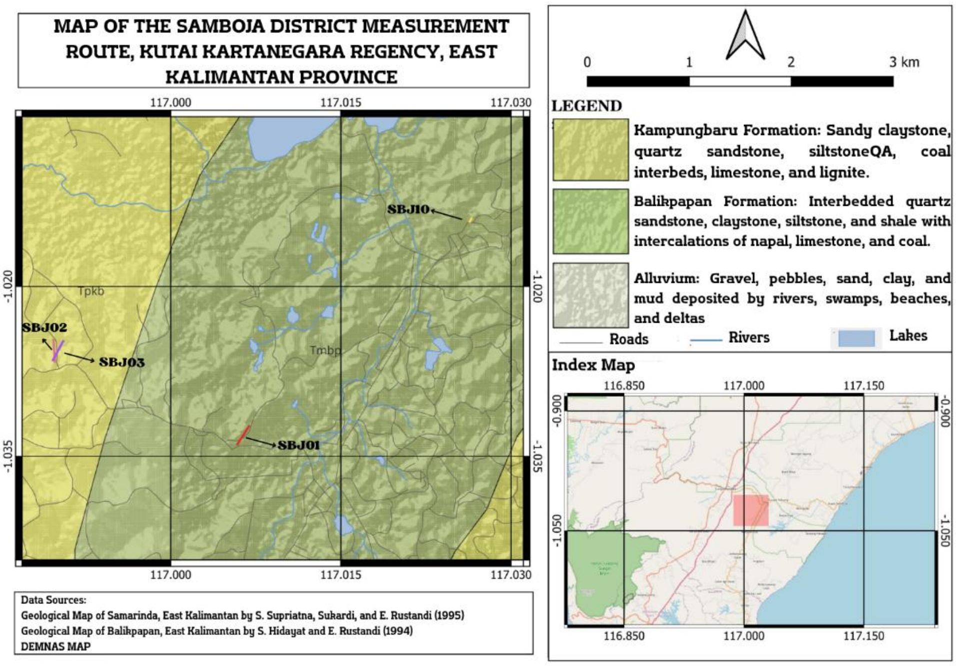

Figure 4. Trajectory Map of Research Location (Modification of Geological Map of Samarinda and Balikpapan Sheet)

3.1 Line SBJ01

The first line with a length of 213 meters in the direction of Southwest - Northeast can be seen in Figure 5.

Figure 5. Outcrop of SBJ01 (Side View)

The measurement line SBJ01 was taken on top of the Balikpapan Formation outcrop as a calibration material for other lines in the research area. The Balikpapan Formation, which consists of quartz sandstone, siltstone, shale, marl insert, limestone, and coal, provides characteristic resistivity variations. The selection of the outcrop as the first measurement location aims to obtain a reference and resistivity foundation from the directly exposed rock types, so that the results of the resistivity distribution can be used to compare and analyze the results of the other cross sections.

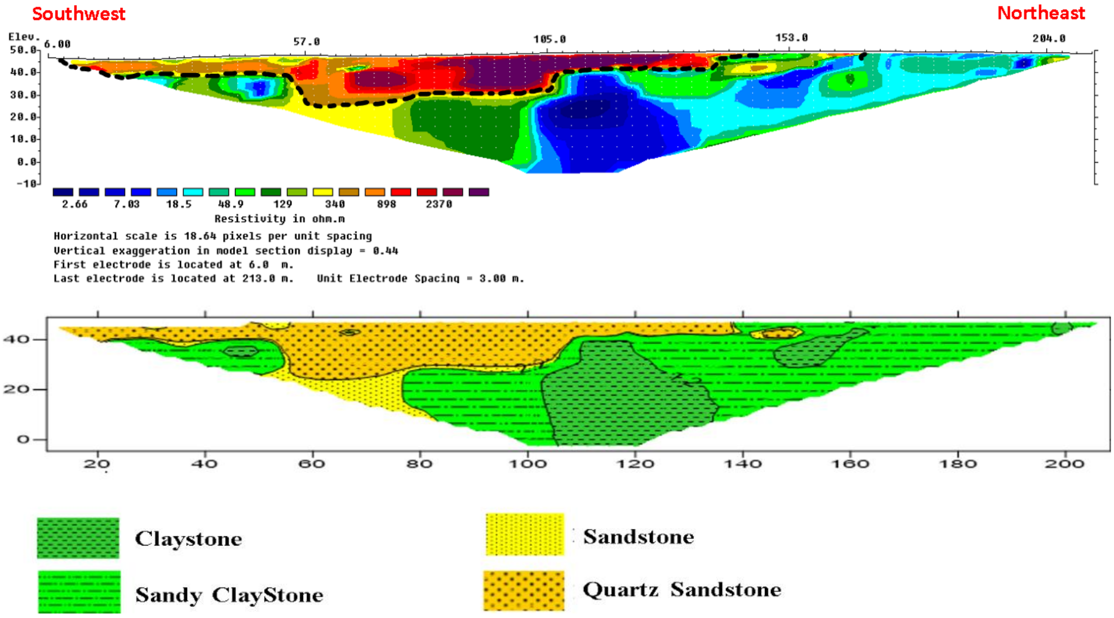

Figure 6. Resistivity Cross Section SBJ01 (a) Resistivity Distribution Cross Section, (b) Cross Section Lithology

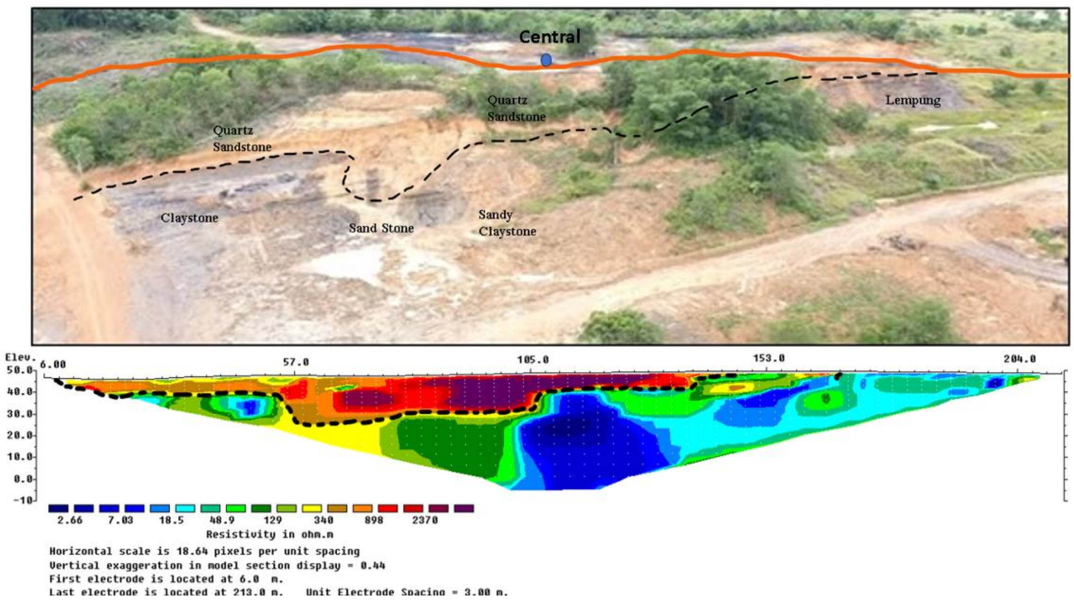

Figure 7. Resistivity Cross Section Calibration Results correlated with Outcrops (Front View)

From Figure 6 and Figure 7 the resistivity cross section of the SBJ01 line shows the presence of a low resistivity zone valued at <20 ohm.m, which is dominated by light blue to dark blue colors. This zone is categorized as claystone, which is impermeable and has a fairly high mechanical weakness. The medium resistivity layer with a value of

20-129 ohm.m likely represents sandy claystone. Resistivity values of 129 - 250 ohm.m shown in dark green to yellow are indicated as sandstone layers. In addition, high resistivity zones with values >250 ohm.m, shown by brown to red colors, indicate quartz sandstone layers, which have better mechanical strength.

As a calibration site, this outcrop exhibits resistivity parameters that can be used to validate interpretations on other passes around the study area. This analysis suggests that the low resistivity zones identified on this traverse have the potential to become slip planes, especially if there is direct contact with layers of medium or high resistivity.

3.2 Line SBJ02

Line SBJ02 has a line length of 213 meters with a North - South direction shown in Figure 8.

Figure 8. SBJ02 Line Location

This 2D resistivity measurement line is located in the Kampungbaru Formation with relatively flat topographic characteristics and insignificant slope. The resistivity cross section shows the presence of a low resistivity zone with a value of <20 ohm.m which is dominated by light blue to dark blue color. This zone is interpreted with claystone or siltstone which is impermeable and has the potential to retain water. The clay layer is an impermeable layer thought to be a sliding field, because rainwater that seeps into the layer will experience saturation and water will flow on the clay layer as a contact area which ultimately functions as a sliding field. The low resistivity zone that is seen extending at a depth of 15 meters, especially between horizontal points 51-147 meters, needs to be a concern as a potential slipsurface.

In Figure 9, a medium resistivity zone of 20-129 ohm.m can be seen, identified as sandy claystone, possibly acting as a transition layer. This layer functions as an underground water flow path, which under high infiltration conditions can increase the load on the layer below. Then the resistivity value of 129 - 250 ohm.m shown in dark green to yellow is indicated as a sandstone layer. Whereas zones of high resistivity rated >250 ohm.m, represented by brown to red colors, indicate quartz sandstone layers. Although this layer is relatively stable, the presence of the layer above the weak zone can be an area of stress accumulation.

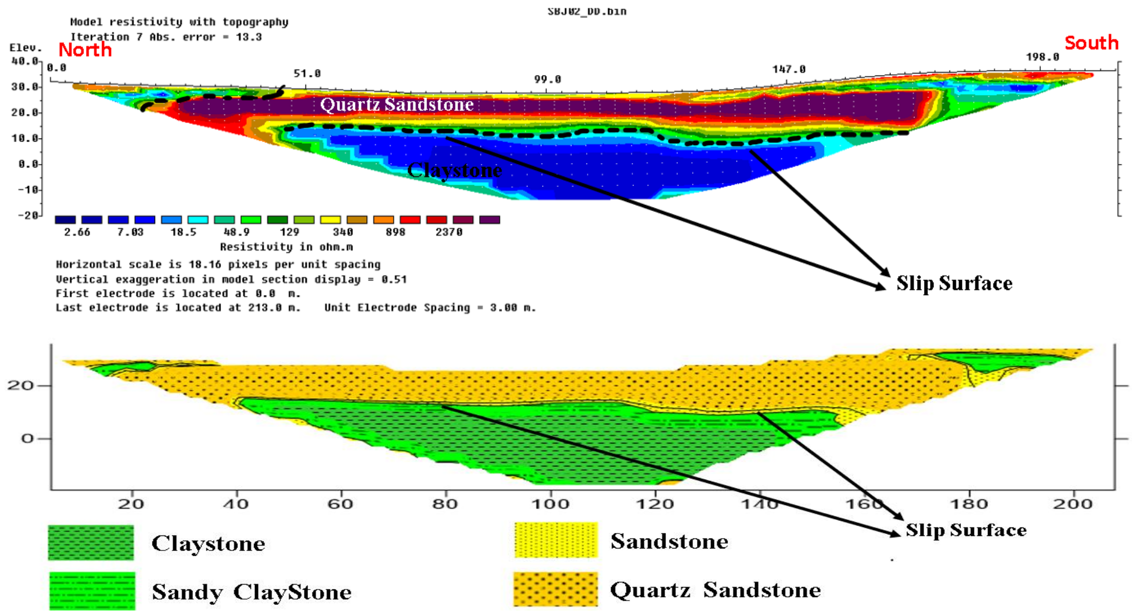

Figure 9. Resistivity Cross Section SBJ02 (a) Resistivity Distribution Cross Section, (b) Lithology Cross Section

Due to the relatively flat topography and the absence of a driving force large enough to trigger a large landslide, these conditions are more likely to allow soil creep to occur. Soil creep is a slow movement of soil that is not immediately visible, but in the long term can cause deformation to buildings or infrastructure on the surface. The presence of water-saturated claystone at the bottom allows for slow ground movement due to increased pore water pressure. For mitigation and risk reduction, the presence of low resistivity zones still requires special attention. Therefore, monitoring of local hydrology such as changes in groundwater levels, is important to maintain site stability.

2.3 Line SBJ03

Line SBJ03 runs from Southwest - Northeast intersecting line SBJ02 with a line length of 213 meters in Figure 10.

Figure 10. SBJ03 Line Location

This line is located in the Kampungbaru Formation, which consists of passive mudstone, quartz sandstone, siltstone, and coal, marl, and limestone inserts.

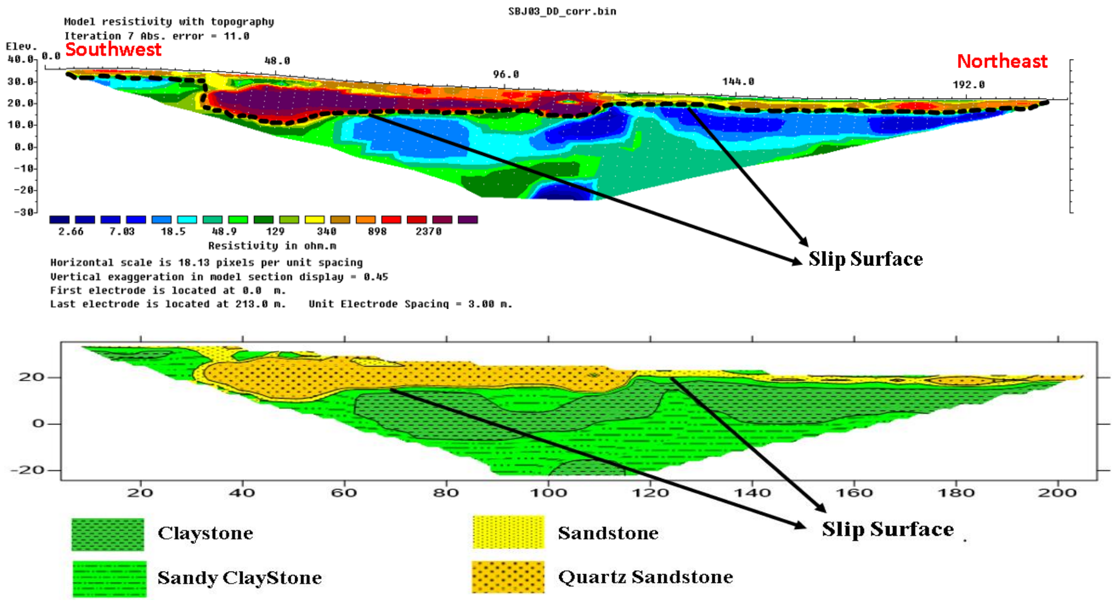

Figure 11. Resistivity Cross Section SBJ03 (a) Resistivity Distribution Cross Section, (b) Lithology Cross Section

Figure 11 is the result of 2D resistivity modeling that shows a zone with a low resistivity value of 20 ohm.m shown in blue. This zone is thought to represent the presence of claystone which has high porosity characteristics and is an impermeable layer. The accumulation of water in this layer may contribute to the weakening of the soil structure, thereby increasing the potential for ground mass movement. Medium resistivity values 20 -129 ohm.m are thought to represent the presence of sandy claystone.

Zones with higher resistivity of 129-250 ohm.m, shown in green to yellow colors, likely represent sandstone. Whereas zones with higher resistivity >250 ohm.m, shown in brown to purple, likely represent quartz sandstone. These layers are generally more compact and may act as mechanical boundaries that inhibit movement of the overlying soil. The significant resistivity contrast between layers with low and high resistivity values at depths of approximately 5-20 meters indicates the potential presence of active slip planes.

The resistivity differences between the clay, sandstone and quartz sandstone layers indicate the presence of slip planes that allow translational avalanches to occur. Translational avalanches occur when the soil mass moves along a flat or slightly inclined slide plane. If water infiltration increases due to heavy rainfall, the soil mass above the slide plane will slide downward slowly or suddenly. This has the potential to cause slope instability, especially in high rainfall conditions. To minimize the risk of landslides, some mitigations that can be done are the construction of retaining walls, installation of effective drainage systems to reduce pore water pressure in the soil, and installation of other reinforcement methods to improve soil cohesion.

2.4 Line SBJ10

The location of line SBJ10 can be seen in Figure 12, stretching for 36 meters with a spacing of 1 meter between electrodes.

Figure 12. SBJ10 Line Location

2D resistivity cross section SBJ10 in Figure 13 is located in Balikpapan Formation showing resistivity variation that represents the lithology characteristics in the area.

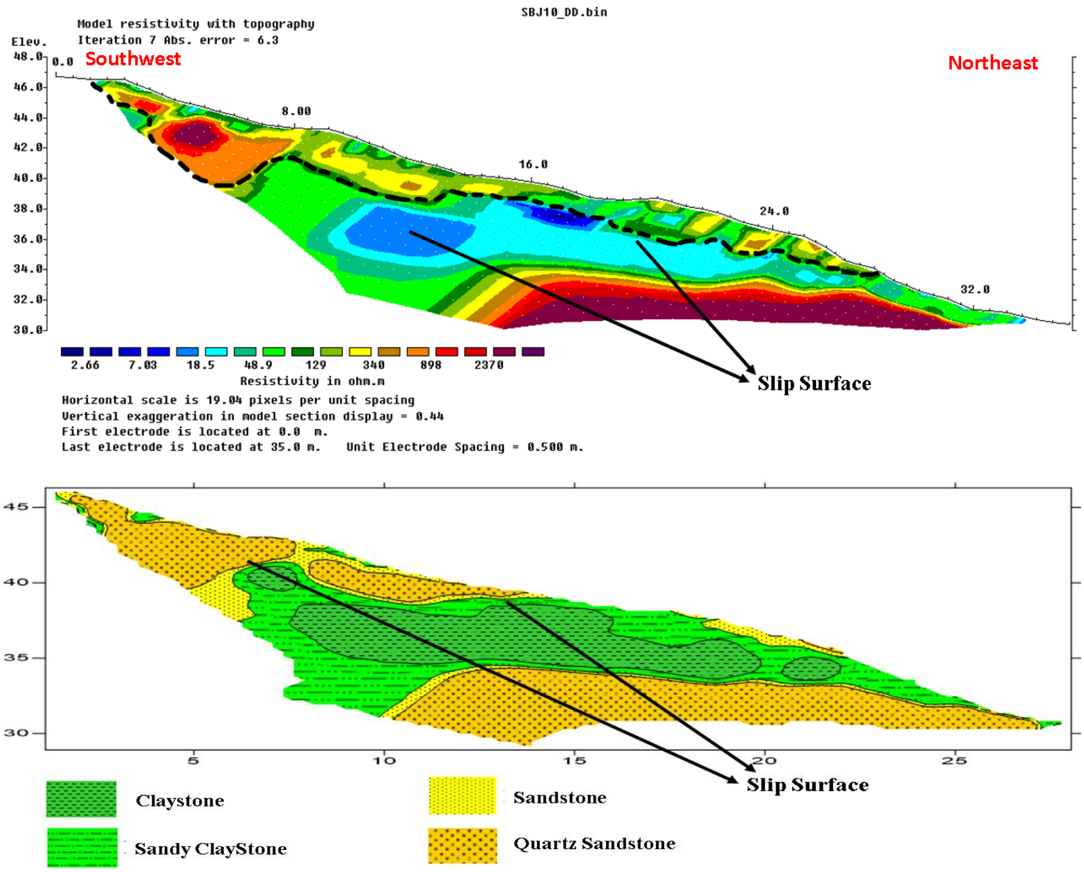

Figure 13. Resistivity Cross Section SBJ03 (a) Resistivity Distribution Cross Section, (b) Cross Section Lithology

Layers with low resistivity values <20 ohm.m, shown in dark blue to light blue are identified at depths up to about 15 meters. This layer is interpreted as claystone which is impermeable and tends to be a weak zone. In the intermediate to surface layer, intermediate resistivity values of 20-129 ohm.m, shown in dark green to light green reflect the presence of more permeable sandy claystone as a transitional layer. Resistivity values of 129 - 250 ohm.m, shown in dark green to yellow indicate the presence of sandstone layers. Whereas high resistivity values > 250 ohm.m, shown in brown to purple, represent a denser and more stable quartz sandstone layer.

The transition between low and medium resistivity layers is observed at a depth of 10-20 meters, which has the potential to be a sliding plane. Impermeable shale and claystone layers can trap water above them, increasing pore water pressure and decreasing the shear strength of the material. This increases the potential for landslides, especially in locations with significant slopes. This situation can trigger debris flows, where the water-saturated silt loam layer becomes unstable during heavy rainfall, allowing the overlying material to move rapidly down the slope in the form of soil or mud flows. If the slope is steep enough, these avalanches can carry large amounts of material over long distances, especially along streams or valleys.

4. Conclusion

This research successfully identified the slide field in Samboja Subdistrict, Kutai Kartanegara Regency, East Kalimantan, using 2D resistivity geoelectric method in dipole-dipole configuration. The analysis results show that each line has different geological characteristics, which affect the type of landslide that may occur. Line SBJ01 shows indications of rotational landslides due to the presence of impermeable clay layers as a sliding plane, while line SBJ02 has the potential to experience soil creep due to the accumulation of water in clay layers in areas with relatively flat topography. In the SBJ03 traverse, a translational landslide potential was found, where rainwater infiltration can cause soil movement along the slide plane. Meanwhile, traverse SBJ10 indicates the flow of debris, especially when heavy rainfall increases pore water pressure.

The results of this study show that the 2D resistivity geoelectric method is effective in identifying slip planes in landslide-prone zones. The information obtained can serve as a basis for disaster mitigation efforts, such as improvement of drainage system to reduce pore water pressure, slope stabilization with retaining wall, and hydrological monitoring to prevent excessive water accumulation in the prone zone. With proper mitigation measures, it is expected that the risk of landslides in the study area can be minimized to reduce the impact on the environment and infrastructure.

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