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Corresponding author:

Godwin Wilco Alfredo
Hehanussa
gdwnwilc@gmail.com

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Identification of slip surface as a potential landslide on the Trans Seram Road using Electrical Resistivity Tomography method

Godwin Wilco Alfredo Hehanussa¹, Warsa², Resti Limehuwey¹, Sitti Hafsa Kotarumalos¹, Warni Multi¹

¹Department of Geophysical Engineering, University of Pattimura, Jln Ir. M. Putuhena Ambon 97233, Maluku, Indonesia

²Department of Geophysical Engineering, Institut Teknologi Bandung, Jln Ganesha 10 Bandung 40132, West Java, Indonesia

Abstract

Research related to the identification of slip surfaces was conducted on the Trans Seram Road section in the Sugiarto area, Kariela Hamlet, Haruru Village, Amahai District, Central Maluku Regency. This area is fairly steep and hilly, so landslides often occur. This can disrupt activities and endanger the community, as this area host several community settlements and serves as an important commodity distribution route in the Central Maluku region. This research aimed to assess for landslide potential by identifying the slip surface using the ERT (Electrical Resistivity Tomography) method. ERT measurements were carried out using the Wenner-Schlumberger configuration at four locations within a narrow area adjacent to a relatively deep ravine. At each location, one survey line was established parallel to the road, spanning 200 meters and with an electrode spacing of 5 meters. The results of the measurements and data processing revealed indications of slip surfaces at each location, with varying depths reaching up to 18 meters. To achieve optimal results, it is necessary to validate drilling data on rock layers below the surface and to conduct further geotechnical research. In addition, the results of the research are expected to have a positive impact on the community and local government in designing future policies related to regional development and can serve as a reference to encourage further research.

1. Introduction

The Trans Seram Road is a government-built road that stretches across and connects three districts on Seram Island: Central Maluku Regency, East Seram Regency, and West Seram Regency. This research focuses on a specific point along the Trans Seram Road, located in the Sugiarto area, Kariela Hamlet, Haruru Village, Amahai District, Central Maluku Regency. This point on the Trans Seram Road serves as the only route connecting local residents to Masohi City, the capital of Central Maluku Regency. Additionally, it is a vital distribution route for nine key commodities in the Central Maluku region, including shallots, curly chilies, cayenne peppers, kale, cucumbers, tomatoes, long beans, spinach, and beans. Furthermore, the area is predominantly used for clove and nutmeg plantations (BPS Maluku Tengah, 2023).

The Sugiarto area, Kariela Hamlet, Haruru Village, Amahai District, which serves as the research site, is situated at a high altitude and is flanked by steep slopes. As a result, several locations in the area have experienced landslides (Figure 1). Additionally, cracks have been observed in several sections of the road (Figure 2), indicating potential ground movement in the surrounding area. It will further increase the potential danger to road users, and the distance between the road and the ravine is quite close at several points along each line.

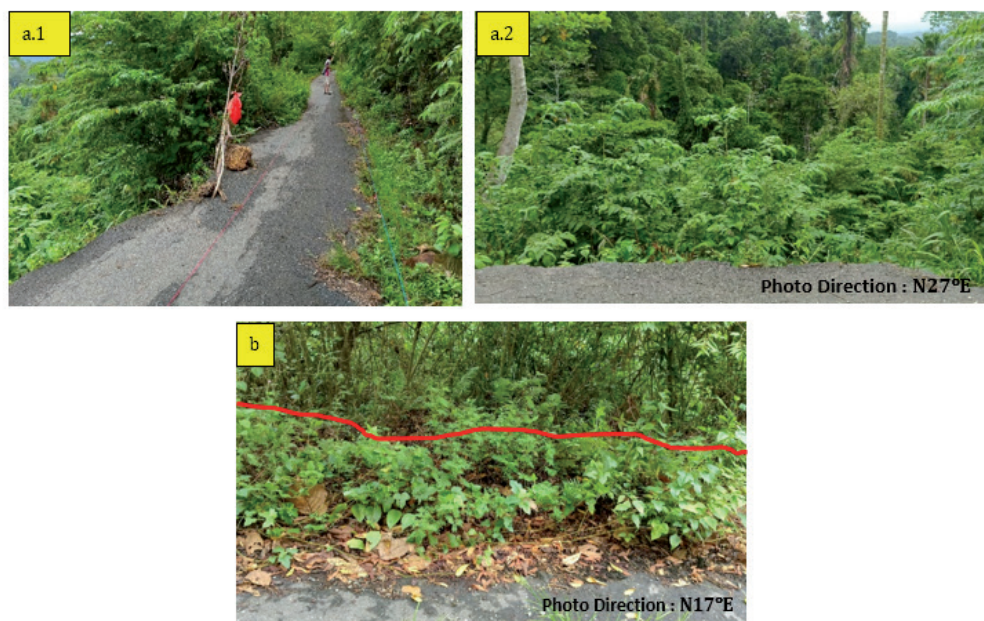


Figure 1. Several landslide points in the Line 4.

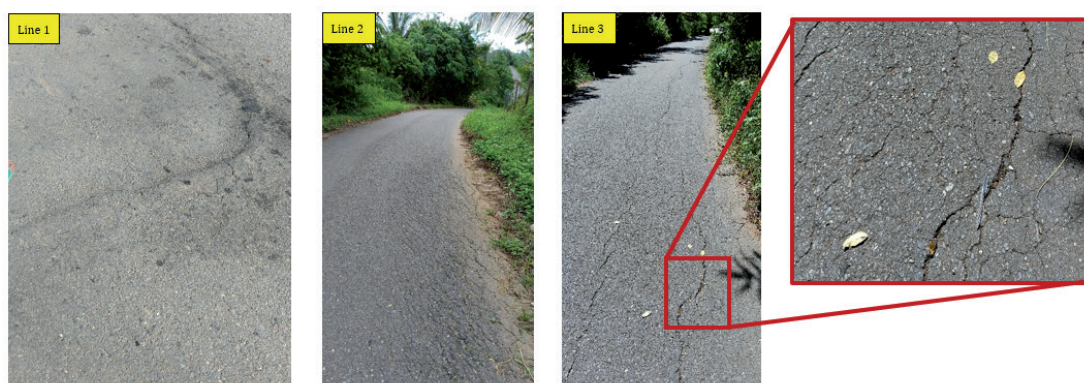


Figure 2. Several road sections in the research area that experienced cracks.

Generally, the primary factor causing landslides is the presence of slip surfaces within the subsurface soil structure (Colangelo et al., 2008). Therefore, this research aims to assess the landslide potential by identifying the slip surface using the ERT (Electrical Resistivity Tomography) geoelectric method.

2. Geologic setting

The research area is located in the southern part of Seram Island. The geological composition of the area is illustrated in Figure 3. The area primarily consists of two geological units: coral limestone (Ql) and the Tehoru Complex (PTRt). Based on field observations, the rock formations in the research area are predominantly composed of limestone (Figure 4). Limestone generally retains water but cannot transmit it. This condition will allow water to be stored in the limestone, making the rock slippery and reducing its shear strength (Dona et al., 2015). Reduced shear strength will impact slope stability.

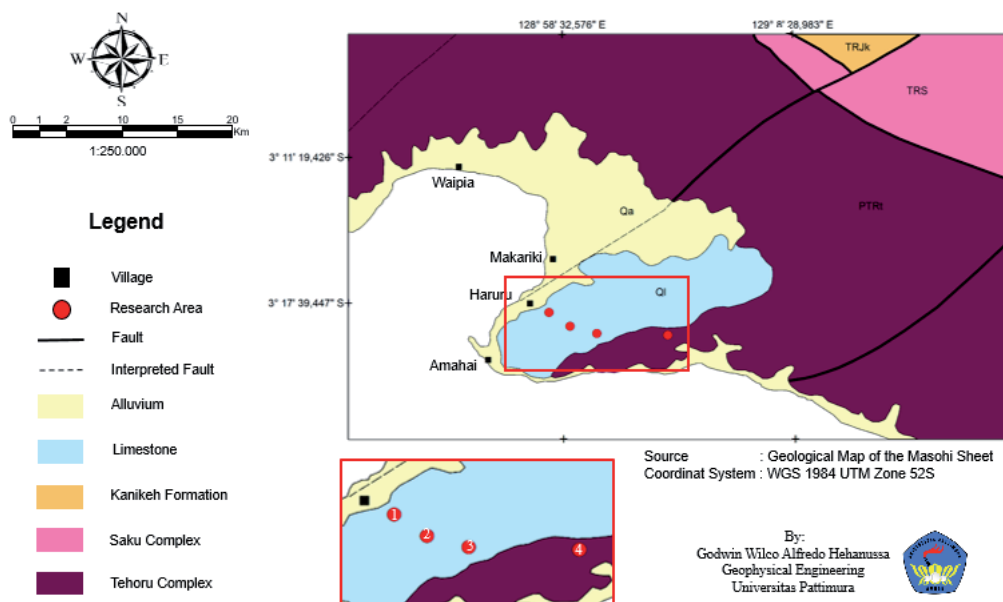


Figure 3. Geological map of the research area with research locations marked with a number code.

The research area consists of four points (Figure 3). In each research area, limestone outcrops were found, as seen in Figure 4.

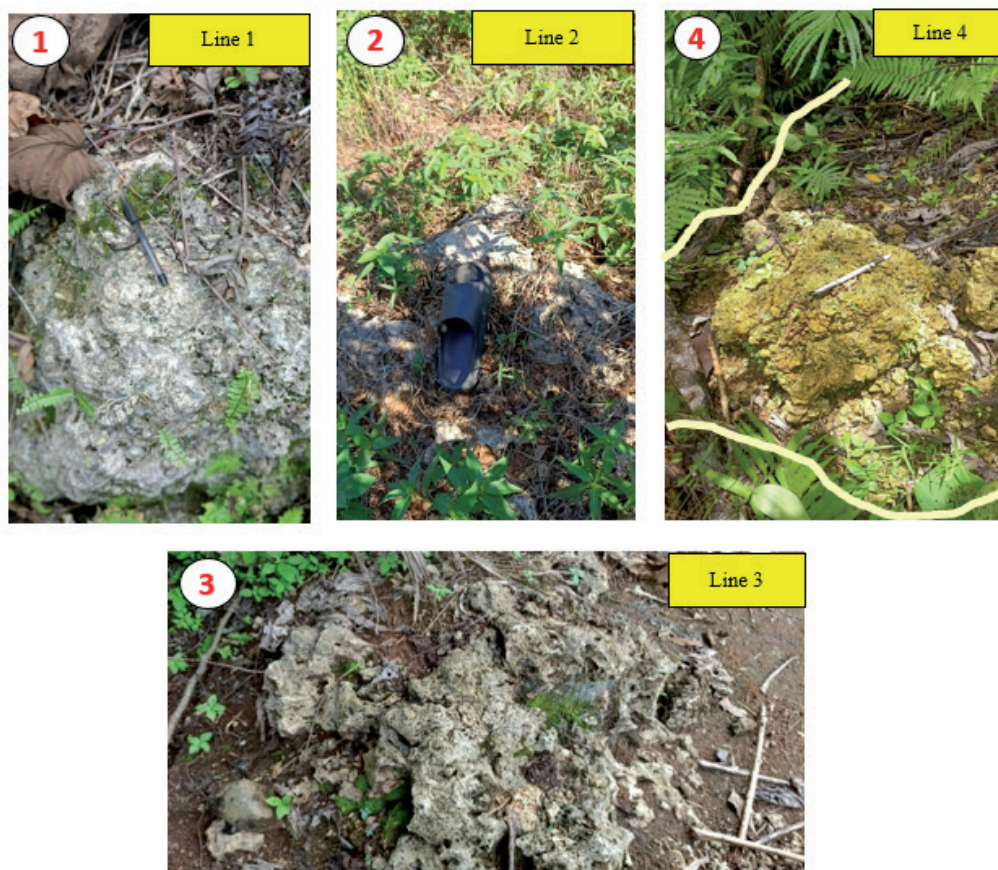


Figure 4. Rocks at the research location.

3. Data and methods

This research uses one of the geophysical methods: Electrical Resistivity Tomography (ERT). The fundamental concept of the geoelectric method is based on Ohm’s Law. Ohm’s Law, formulated by George Simon Ohm through experiments, establishes the relationship between voltage (V) and current (I) in a conductor (Equation 1).

$$V = I \times R \tag{1}$$

In the geoelectric method, two types of electrodes are used (Figure 5):

- a) Current electrodes, consisting of C_1 and C_2 .
- b) Voltage electrodes, consisting of P_1 and P_2 .

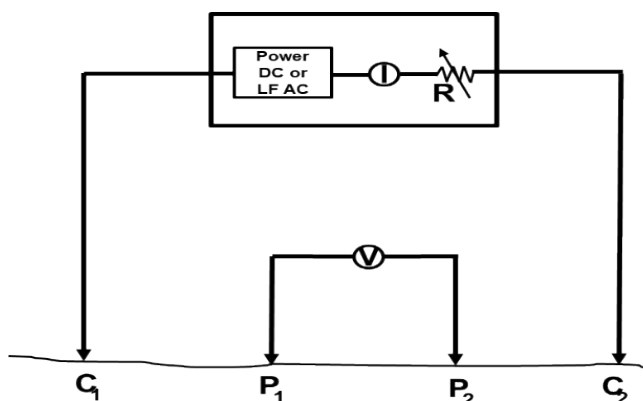


Figure 5. Scheme of current electrode and potential electrode (Modification from Telford et al., 1990).

From the results of the geoelectric method measurements, the apparent resistivity value (ρ_a) will be obtained. The apparent resistivity is calculated by entering the current (I), voltage (V), and geometric factor (K) for the electrode configuration used in the measurement into Equation II. The resistivity values for various natural materials are provided in Table 1.

$$\rho_a = K \frac{\Delta V}{I} \rho_a = K \frac{\Delta V}{I} \tag{2}$$

In general, slip surface identification is best performed using the ERT geoelectric method (Bichler et al., 2004; Sugito et al., 2010; Sutasoma et al., 2017; Santoso et al., 2020; Susilo et al., 2020), because the method can map the presence of water-saturated and unsaturated rock layers without the need for drilling, making it inexpensive and relatively easy to use. The boundary between the water-saturated and unsaturated rock layers usually has contrasting resistivity values. The resistivity value contrast seen in the resistivity cross-section, then identified as the slip surface area. In addition, this method can also be used in landslide evaluation, monitoring, mechanism identification, and mitigation (Perrone et al., 2012; Perrone et al., 2014; Wilkinson et al., 2016; Holmes et al., 2020; Wang et al., 2022; Wicki and Hauck 2022; Olabode et al., 2022).

Table 1. Resistivity values for several materials in nature (Modification from Telford et al., 1990).

NO	Ingredients in Nature	Resistivity Values of Some Materials (Ωm) <i>Telford et al (1990)</i>
1	Limestone	50 - 10 ⁷
3	Sandstone	1-6.4x10 ⁸
4	Clay	1 - 100
5	Slate	6x10 ² -4x10 ⁷

Geoelectric measurements in this research were conducted along four lines using a Naniura NRD resistivity meter; current and potential electrodes with cables, a GPS unit, a hammer, an accumulator, a measuring tape, and a laptop. Each line was 200 meters long, with an electrode spacing of 5 meters. The selection of line length and electrode spacing was based on the conditions of the research area condition, the target depth, and the research duration, to produce a good resistivity cross-section. Furthermore, the electrode configuration used in this research was the Wenner-Schlumberger configuration. The Wenner-Schlumberger configuration is a hybrid of the Wenner and Schlumberger configurations. The Wenner configuration is quite effective in mapping lateral contrasts in a resistivity cross-section,

while the Schlumberger configuration has excellent depth penetration (Loke, 1999; Everett, 2013). This combination will produce good resistivity cross-sections both horizontally and vertically, making the Wenner-Schlumberger configuration suitable for use in mapping slip surfaces. In this configuration, the distance between the current electrode C_1 and the potential electrode P_1 is na , and similarly, the distance between the current electrode C_2 and the potential electrode P_2 is na , while the distance between the two potential electrodes P_1 and P_2 is a (Figure 6).

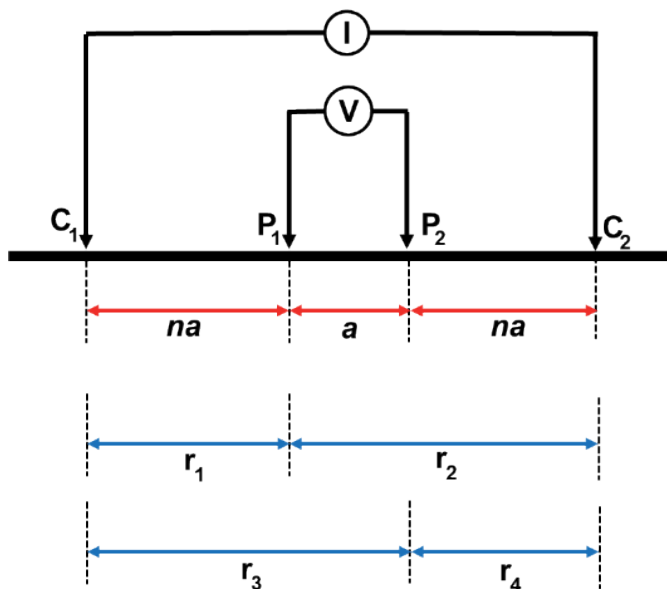


Figure 6. Wenner-Schlumberger configuration (Modification from Loke, 1999; Everett, 2013; Syukri, 2020).

The research was conducted in several stages, beginning with a literature review and field survey to identify suitable locations for data collection. Based on the field survey results, four measurement locations were selected, with one survey line established at each location. The selection and distribution of these lines were guided by the presence of steep and narrow road sections, as well as areas where landslides had previously occurred along the road edges. The next stage involved data collection and processing. During this stage, several software tools were utilized, including:

1. Microsoft Excel, used for recording and performing calculations on field-measured data.
2. RES2DINV, used to model geoelectric measurement data, produces a subsurface cross-section of the research area based on variations in resistivity values.

The final stage consisted of analyzing and interpreting the processed data obtained from the RES2DINV software.

4. Results

Geoelectric measurements were conducted along five survey lines at four different locations. Based on the processing results from the RES2DINV software, an initial interpretation was carried out using the resistivity values observed in the resistivity cross-section. In the resistivity cross-section, there are areas with low and high resistivity values. Areas with low resistivity values usually represent groundwater or water-saturated rock layers, while areas with high resistivity values are usually hard or impermeable rock layers (Perrone et al., 2012; Everett, 2013; Perrone et al., 2014; Dona et al., 2015; Sugiyanto et al., 2018). These two areas play a role in the landslide process, and the initial interpretation of the resistivity cross-section obtained indicates landslides on each line. The results of this initial interpretation will then be combined with the geological conditions at the research location, which will be discussed in the discussion section.

1. Line 1

The resistivity cross-section of line 1 (Figure 7) shows the lowest resistivity value of 1.62 Ωm and the highest resistivity value of 3094 Ωm with an error percentage of 13.6%.

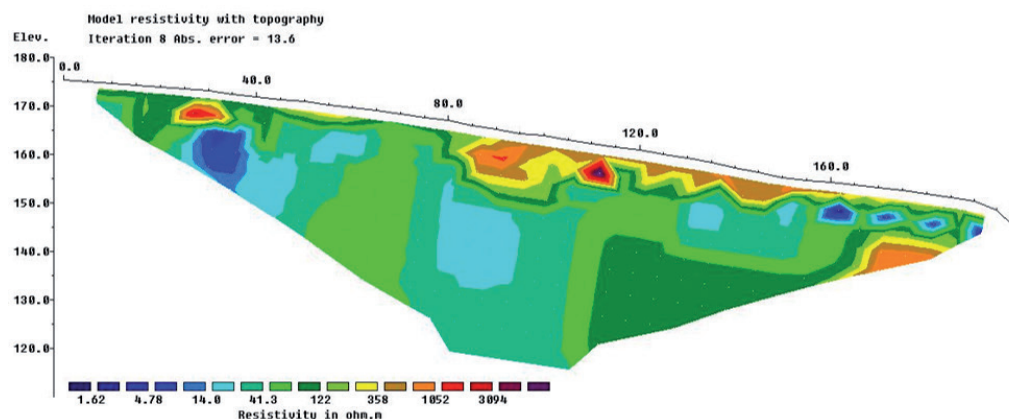


Figure 7. Cross section of line 1 resistivity with topography.

2. Line 2

From the processing results for line 2, a resistivity cross-section with an error percentage of 14.6% was obtained (Figure 8). In the cross-section, the resistivity varies from 1.62 Ωm to 3094 Ωm.

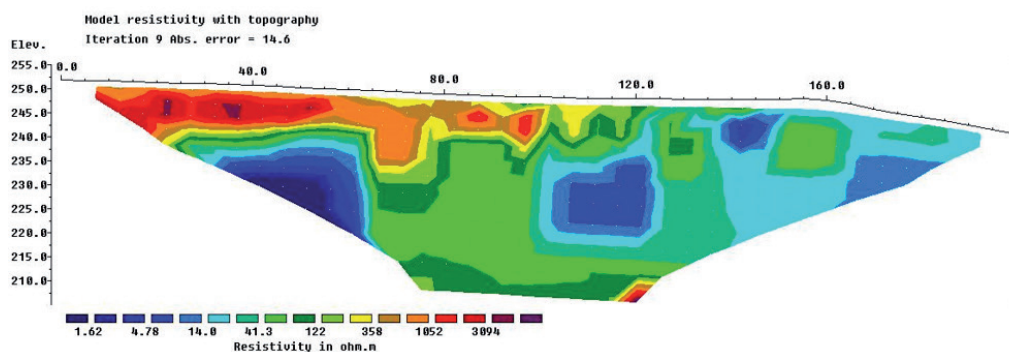


Figure 8. Cross section of line 2 resistivity with topography.

3. Line 3

Figure 9 shows the resistivity cross-section of line 3 with a distribution of various resistivity values with an error of 8.5%. On line 3, resistivity values range from 4.78 Ωm to 3094 Ωm.

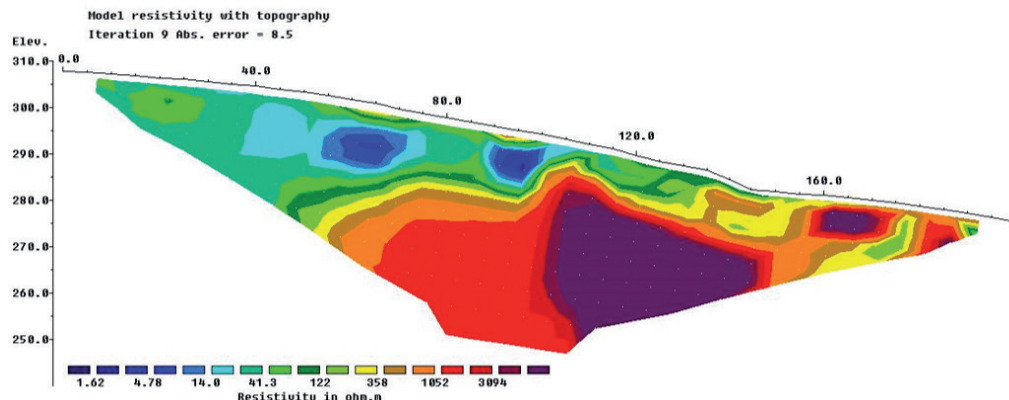


Figure 9. Cross section of line 3 resistivity with topography.

4. Line 4

The distribution of resistivity values range from 4.78 Ωm to 122 Ωm (Figure 10). The resistivity cross-section of line 4 was generated by performing eight iterations and an error of 7.9%.

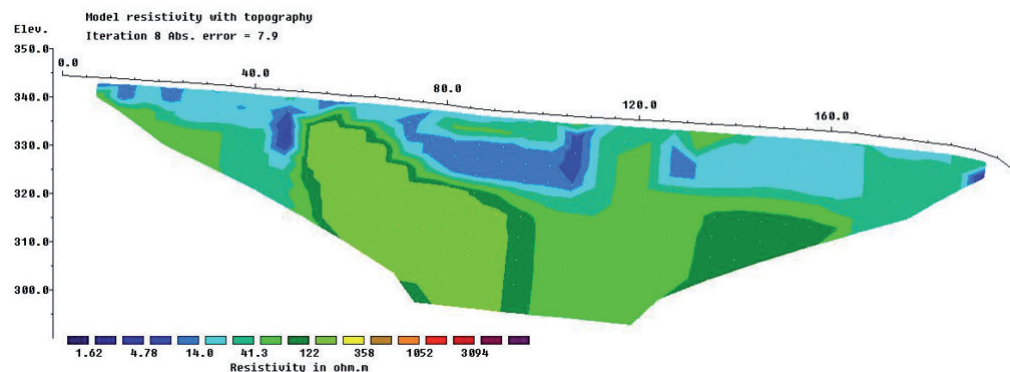


Figure 10. Cross section of line 4 resistivity with topography.

5. Discussion

Initial interpretation of the resistivity cross-section in the previous section showed the presence of water-saturated and unsaturated areas on each line. Further interpretation was carried out to determine the slip surface on each line. Further interpretation was carried out by comparing the geological conditions at the research location. The rock type at the research location was alluvium (sand, silt, clay), and several limestone outcrops were also observed. This was then compared with the previously obtained resistivity cross-section. The results showed that areas with high resistivity values were limestone areas. Characteristically, alluvium is a layer of rock that is saturated with water, while limestone is a layer of rock that is impermeable. Limestone, which is a waterproof layer, can store water but cannot pass water. It can make this layer slippery and act as a slip surface during the rainy season. This is shown in the contrast of resistivity values between the two (water-saturated layer and unsaturated layer), where the boundary of resistivity values between high resistivity and low resistivity will generally act as a slip surface (Sri et al., 2011; Perrone et al., 2012; Perrone et al., 2014; Dona et al., 2015; Sutasoma et al., 2017; Multi et al., 2024).

1. Line 1

In Line 1 (Figure 11), the resistivity values ranging from 14 Ωm to 122 Ωm are classified as an alluvium layer; while values ranging from 358 Ωm to 3094 Ωm are interpreted as a limestone layer. Additionally, the resistivity value of 1.62 Ωm on this line indicates the presence of groundwater. Field observations confirm the existence of a limestone outcrop at a distance of 30 meters (Figure 11). Furthermore, field observations indicate that this area has a high potential for landslides, as the the road surface subsides at several points (Figure 2b). This area is also characterized by its narrow topography, with a distance of 4 meters between the road and the ravine on the left side and 11 meters on the right side (Figure 11). Based on the resistivity cross-section in Figure 11, the slip surface in Line 1 is estimated to be at a depth range of 1.25 meters to 12 meters, as indicated by the resistivity contrast (Sri et al., 2011; Perrone et al., 2012; Perrone et al., 2014; Dona et al., 2015; Sutasoma et al., 2017; Multi et al., 2024).

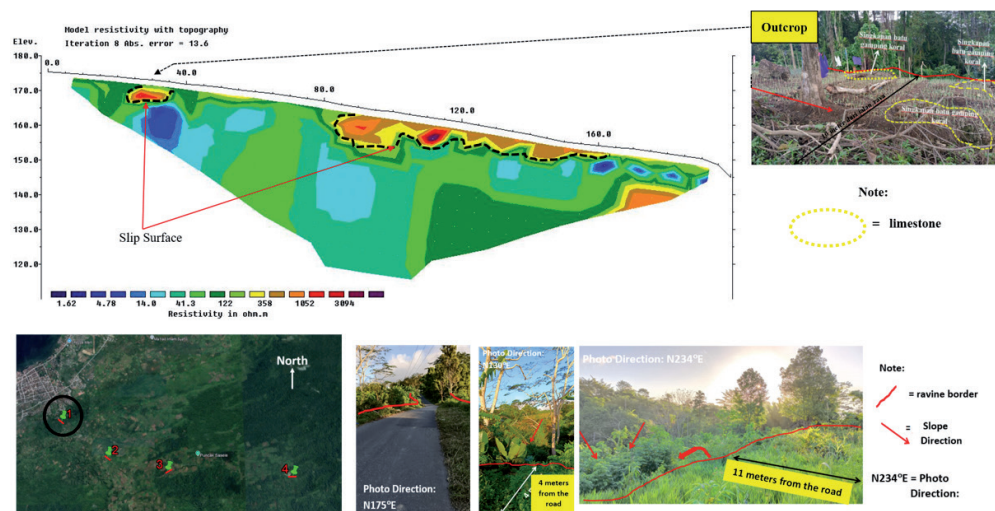


Figure 11. Resistivity cross section of line 1: dashed black line as an indication of the slip surface.

2. Line 2

Figure 12 shows field observations indicating the presence of limestone outcrops from the starting point of the line up to a distance of 60 meters, as well as cracks on the right side of the road near the ravine. In the resistivity cross-section, the range of 14 Ω m to 122 Ω m corresponds to the alluvium layer, while the range of 358 Ω m to 3094 Ω m corresponds to the limestone layer. The slip surface is estimated to be at depths of 1.25 to 15 meters.

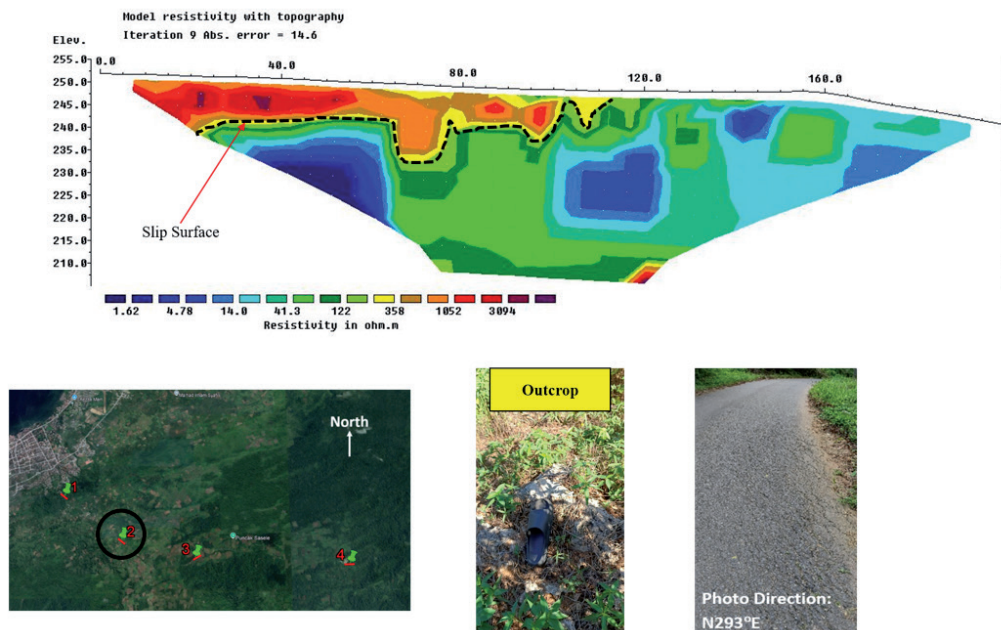


Figure 12. Resistivity cross section of line 2: dashed black line as an indication of the slip surface.

3. Line 3

In Line 3, the resistivity range of 14 Ωm to 122 Ωm corresponds to the alluvium layer, while the range of 358 Ωm to 3094 Ωm corresponds to the limestone layer. A limestone outcrop is observed at a distance of 180 meters in the field. Based on the resistivity contrast in the resistivity cross-section, the slip surface is interpreted to lie within a depth range of 1.25 to 18 meters.

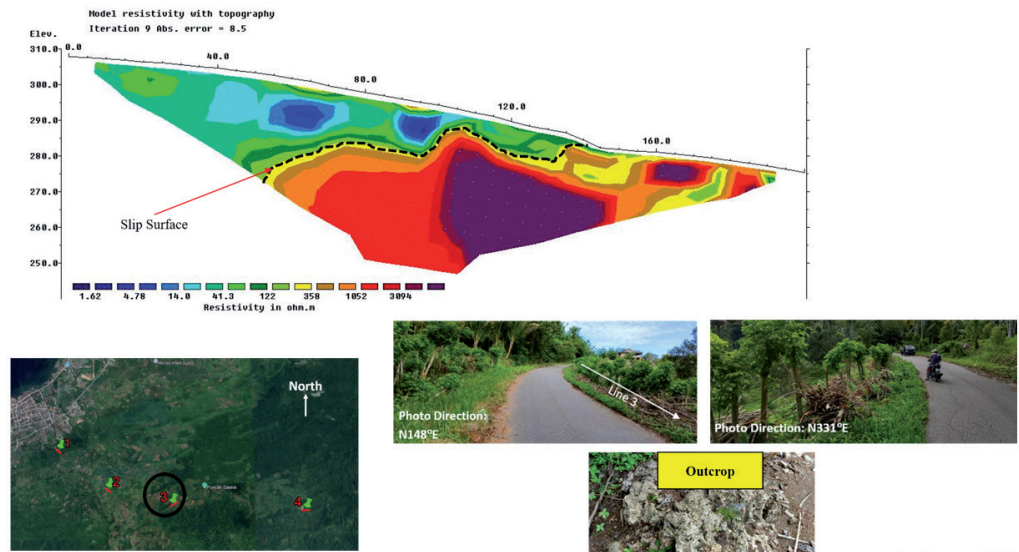


Figure 13. Resistivity cross section of line 3: dashed black line as an indication of the slip surface.

4. Line 4

Field observations indicate that the left side of this area is bordered by a ravine, with several landslide points visible, while the right side features a cliff. The landslide-prone areas are located at distances of 60 to 70 meters and 130 to 160 meters (Figure 14). Additionally, an outcrop of coral limestone is observed at a distance of 135 meters. Based on the results, the resistivity range of 4.78 Ωm to 14 Ωm represents the alluvium layer, while the range of 41.3 Ωm to 122 Ωm is interpreted as the limestone layer. Consequently, the slip surface on Line 5 is estimated to be at a depth range of 1.25 meters to 11 meters (Figure 14).

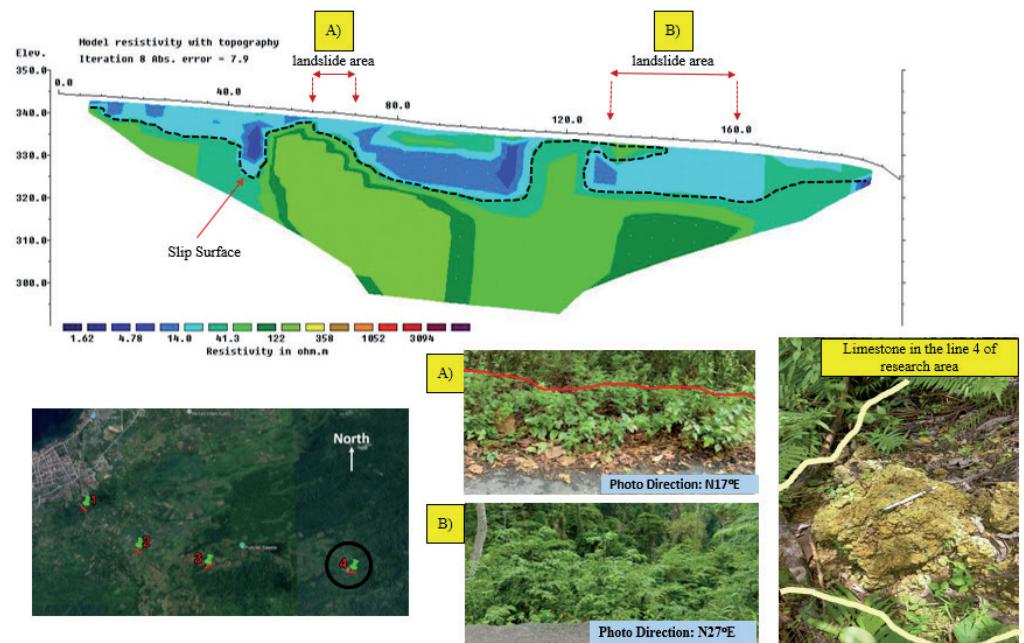


Figure 14. Resistivity cross section of line 5: dashed black line as an indication of the slip surface.

The resistivity of each rock layer along each line is shown in Table 2.

Table 2. Resistivity value of each layer on each line.

Line	Rock Type	Resistivity Values (Ωm)	
1	Aluvium	14	- 122
	Limestone	358	- 3094
2	Aluvium	14	- 122
	Limestone	358	- 3094
3	Aluvium	14	- 122
	Limestone	358	- 3094
4	Aluvium	4.78	- 14
	Limestone	41.3	- 122

Based on Table 2, it can be seen that there is a difference in the range of alluvium and limestone resistivity values in Line 1, Line 2, Line 3, and Line 4. Line 4 shows a lower range of resistivity than Lines 1, 2, and 3. The decrease in resistivity values in Line 4 is thought to be due to an increase in water saturation in the limestone and a more water-saturated alluvium layer filling the limestone pores, thereby reducing the limestone resistivity value in this area. The increase in saturation in this area can also be a major factor in the occurrence of landslides in Line 4.

Field conditions on Line 1, Line 2, Line 3, and Line 4 show limestone outcrops spread almost across the surface on Line 1, Line 2, and Line 3, with limestone outcrops that are fresher and more solid than those on Line 4 (Figure 4). At Line 4, a water-saturated alluvium layer dominates the surface (Figures 15 and 16), and the steep slope conditions create a high landslide potential. This condition can be observed on the section of the road affected by the landslide (Figures 17 and 18), with landslide material visible in the form of an alluvium layer, small limestone fragments, and chunks of asphalt.



Figure 15. Rock layers on the cliff wall at Line 4 at the 15 meter point in the direction of the track: limestone begins to be visible at a depth of 2.5 meters.



Figure 16. The cliff section observed on Line 4.



Figure 17. Rock layer at a depth of 2 meters on Line 4 (landslide area point A).



Figure 18. Rock layer on Line 4 (landslide area point B).

Based on the interpretation results of the resistivity cross-section of each line, it shows that the research area has sufficient potential for landslides with varying depths of the slip surface. It is expected that people active in this area, or those who are building plantations and settlements will pay attention to the risk of this disaster. Furthermore, to get a clearer description, further research can be carried out, such as landslide mapping with a multi-geophysical approach (Bichler et al., 2004), the addition of geoelectric survey lines, different electrode configurations, or the addition of the use of drill data in the research.

6. Conclusions

Based on field observations, each research location is situated close to a ravine, with several cracks and road surface subsidence observed in various sections of the road. These conditions highlight the need to identify slip surfaces as indicators of potential landslides. The slip surface in the research area is the boundary between the alluvium and limestone layers. In Line 1, 2, and 3, the limestone resistivity is 358 Ωm -3094 Ωm , and the alluvium resistivity is 14 Ωm -122 Ωm . Furthermore, in Line 4, the limestone resistivity is 41.3 Ωm -122 Ωm and the alluvium resistivity is 4.78 Ωm -14 Ωm . The results of this research indicate the presence of a slip surface in each research area with varying depths, ranging from 1.25 meters to 18 meters, with an error percentage ranging from 7.9% to 14.6%. To achieve optimal results, it is necessary to validate drilling data on the rock layers below the surface and to conduct further geotechnical research. In addition, the results of this research are expected to provide a positive impact on the community and local government in designing future policies related to regional development and can be a reference to encourage further research.

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References

- BPS Maluku Tengah, 2023. Statistik Pertanian Hortikultura. Badan Pusat Statistik Kabupaten Maluku Tengah.
- Bichler, A., Bobrowsky, P., Best, M., Douma, M., Hunter, J., Calvert, T., Burns, R., 2004. Three-dimensional mapping of a landslide using a multi-geophysical approach: the Quesnel Forks landslide. *Landslides* 1, 29–40. <https://doi.org/10.1007/s10346-003-0008-7>
- Colangelo, G., Lapenna, V., Loperte, A., Perrone, A., Telesca, L., 2008. 2D electrical resistivity tomographies for investigating recent activation landslides in Basilicata Region (Southern Italy). *Annals of Geophysics* 51, 275–285. <https://doi.org/10.4401/ag-3048>
- Dona, I.R., Akmam, Sudiar, N.Y., 2015. Identifikasi Bidang Gelincir Menggunakan Metode Geolistrik Tahanan Jenis Konfigurasi Schlumberger di Bukit Lantiak Kecamatan Padang Selatan. *Pillar Phys.* 5, 1–8.
- Everett, M.E., 2013. Electrical resistivity method, in: *Near-Surface Applied Geophysics*. Cambridge University Press, Cambridge, pp. 70–103. <https://doi.org/10.1017/CBO9781139088435>
- Holmes, J., Chambers, J., Meldrum, P., Wilkinson, P., Boyd, J., Williamson, P., Huntley, D., Sattler, K., Elwood, D., Sivakumar, V., Reeves, H., Donohue, S., 2020. Four-dimensional electrical resistivity tomography for continuous, near-real-time monitoring of a landslide affecting transport infrastructure in British Columbia, Canada. *Near Surf. Geophys.* 18, 337–351. <https://doi.org/10.1002/nsg.12102>
- Loke, M.H., 1999. *Electrical Imaging Surveys for Environmental and Engineering Studies: A Practical Guide to 2D and 3D Surveys (Technical Report)*. Penang, Malaysia.
- Multi, W., Limehuwey, R., Patty, P.J., Kotarumalos, S.H., Ramadhan, A., Sukri, M.R.A., 2024. Identification of potential sliding surface using geoelectric method in the Ambon Region, Maluku. *JGE (Jurnal Geofisika Eksplorasi)* 10, 37–46. <https://doi.org/10.23960/jge.v10i1.351>
- Olabode, O.P., Lim, H.S., Ramli, M.H., 2022. Geophysical and geotechnical evaluation of landslide slip surface in a residual soil for monitoring of slope instability. *Earth Space Sci.* 9, e2022EA002248. <https://doi.org/10.1029/2022EA002248>
- Perrone, A., Lapenna, V., Piscitelli, S., 2012. Electrical Resistivity Tomographies for Landslide Monitoring: a Review. *Berichte Geol. B.-A.* 93, 1–150.
- Perrone, A., Lapenna, V., Piscitelli, S., 2014. Electrical resistivity tomography technique for landslide investigation: A review. *Earth-Sci. Rev.* 135, 65–82. <https://doi.org/10.1016/j.earscirev.2014.04.002>
- Santoso, B., Subagio, Hasanah, M.U., Suwargana, H., 2020. Investigation Estimating of Land Movement Using Methods of Electrical Resistivity Tomography and Self-Potential in Pasanggrahan Baru Area, South Sumedang. *J. Geol. Miner. Resour.* 21, 33–44. <https://doi.org/10.33332/jgsm.geologi.v21i1.497>
- Sri, C.W., Tris, A.H., Pariadi, Putri, H., Resty, F.N., Raisa, K.D., Ori, M., 2011. Aplikasi Metode Tahanan Jenis 2D Untuk Mengidentifikasi Potensi Daerah Rawan Longsor di Gunung Kupang, Banjarbaru. *J. Fis. FLUX* 8, 95–103.
- Sugito, Irayani, Z., Jati, I.P., 2010. Investigasi Bidang Gelincir Tanah Longsor Menggunakan Metode Geolistrik Tahanan Jenis di Desa Kebarongan Kec. Kemranjen Kab. Banyumas. *J. Berk. Fis.* 13, 49–54.
- Sugiyanto, D., Rusydy, I., Marwan, M., Hidayati, D.M., Asrillah, A., 2018. A Preliminary Study on Aquifer Identification based on GeoElectrical Data in Banda Aceh, Indonesia. *J. Nat.* 18, 122–126. <https://doi.org/10.24815/jn.v18i3.11204>
- Susilo, A., Fitriah, F., Sunaryo, Ayu Rachmawati, E.T., Suryo, E.A., 2020. Analysis of landslide area of Tulung subdistrict, Ponorogo, Indonesia in 2017 using resistivity method. *Smart Sustain. Built Environ.* 9, 341–360. <https://doi.org/10.1108/SASBE-06-2019-0082>
- Sutasoma, M., Susilo, A., Suryo, E.A., 2017. Penyelidikan Zona Longsor dengan Metode Resistivitas dan Analisis Lereng untuk Mitigasi Bencana Tanah Longsor. *Indones. J. Appl. Phys.* 7, 39–46. <https://doi.org/10.13057/ijap.v7i1.8784>
- Syukri, M., 2020. *Basics of Geoelectric Methods*. Syiah Kuala University Press, Banda Aceh.
- Telford, W.M., Geldart, L.P., Sheriff, R.E., 1990. *Applied Geophysics*, 2nd ed. Cambridge University Press, Cambridge. <https://doi.org/10.1017/CBO9781139167932>

- Wang, X., Wang, X., Wang, K., Luo, W., Xiao, J., Hu, J., Hu, D., 2022. Research on internal structure and mechanism of landslide based on hydrogeophysical investigation (Quan'an Landslide, Southwest China). *Geofluids* 2022, 7843011. <https://doi.org/10.1155/2022/7843011>
- Wicki, A., Hauck, C., 2022. Monitoring critically saturated conditions for shallow landslide occurrence using electrical resistivity tomography. *Vadose Zone J.* 21, e20204. <https://doi.org/10.1002/vzj2.20204>
- Wilkinson, P., Chambers, J., Uhlemann, S., Meldrum, P., Smith, A., Dixon, N., Loke, M.H., 2016. Reconstruction of landslide movements by inversion of 4-D electrical resistivity tomography monitoring data. *Geophys. Res. Lett.* 43, 1166–1174. <https://doi.org/10.1002/2015GL067494>