ISSN: 2579-5821 (Print)
ISSN: 2579-5546 (Online)
URL address: http://journal.unhas.ac.id/index.php/geocelebes
DOI: 10.20956/geocelebes.v7i1.23654

Jurnal Geocelebes Vol. 7 No. 1, April 2023, 77–88

Identification of Slip Area in Makale Selatan District Using the Geoelectric Method

Bergita Gela M. Saka[1]*, Reni Oktaviani Tarru[2], Enos Lolang[1], Alexander Pakiding[1]

[1]Pendidikan Fisika, Universitas Kristen Indonesia Toraja, Tana Toraja, Indonesia.
[2]Teknik Sipil, Universitas Kristen Indonesia Toraja, Tana Toraja, Indonesia.

*Corresponding author. Email: bergitagelasukumusaka@gmail.com

Manuscript received: 22 October 2023; Received in revised form: 6 February 2023; Accepted: 30 April 2023

Abstract

Landslides are most common in steep areas with heavy rainfall. Aside from rainfall, there are numerous other factors that contribute to landslides. The presence of slip fields in the subsurface layer is one of the primary causative factors. South Makale is one of the sub-districts in Tana Toraja Regency that is located in the mountains, where landslides frequently occur, claiming lives. The purpose of this study was to determine the slip area of potential landslides in three sub-districts, which are Sandabilik, Tiromanda, and Randan batu villages. The geoelectric method with the Wenner-Sclumberger configuration type was used. The measurement data is in the form of rock resistivity values, which are then interpreted based on the rock layer type. The findings revealed that the Sandabilik and Randan Batu villages were landslide risk areas. Sandabilik Village has a slip area in the form of lava rock at a depth of 6.5 - 19.8 meters on line 1 and 1.5 - 16 meters on line 2. Rocks of the same type can also be found in Randan Batu Village, a landslide point with depths ranging from 2 to 16 meters on line 1 and 5 to 20 meters on line 2.

Keywords: Geoelectric Method; Makale Selatan; Wenner-Sclumberger.

Citation: Saka, B.G.M., Tarru, R.O., Lolang, E. and Pakiding, A. (2023). Identification of Slip Area in Makale Selatan District Using the Geoelectric Method. *Jurnal Geocelebes,* 7(1):77-88, doi: 10.20956/geocelebes.v7i1.23654

Introduction

Landslides cannot be avoided without mitigation measures. Many studies have been conducted on various techniques for estimating an area's vulnerability to potential landslides. Landslide vulnerability is defined as the likelihood of landslides occurring in a specific area in the future, and it can be measured by examining the relationship between certain factors and the distribution of landslides (Yuliana et al., 2017). External causes of landslides, according to Carrión-Mero et al. (2021) and Baldermann et al. (2021), can be classified as weathering (physical, chemical, and biological) and erosion, land subsidence, deposition, vibration, and seismic activity, tephra fall, and water regime changes (Brahmantyo & Yulianto, 2014; Kamur et al., 2020).

Weathering and erosion are heavily influenced by climate. Rainfall, water content (%), and water saturation (Sr, %) are all terms used to describe the climate. The high intensity of rainfall, particularly on steep slopes, is one of the main factors supporting the occurrence of landslides. If the intensity of the rainfall is high, the soil water content will rise, causing the physical condition of the slope body to change. Increased water content weakens the soil's physical-mechanical properties and reduces the slope safety factor (Gusman et al., 2018). Furthermore, landslides are more likely to occur when rocks and slopes are not compacted and easily degraded (Yilmaz & Narman, 2015).

South Makale is one of the sub-districts in Tana Toraja Regency where landslides occur more frequently than in other sub-districts. Landslides in the sub-district buried dozens of houses, cut off the main road, and even resulted in the deaths of landslide victims (Wahyuni et al., 2018). One of the causes of landslides is the presence of a plane that is suspected of being a place for material to move, known as a slip plane (Akmam et al., 2019). Slip plane is also known as the boundary between rock slides and hard rock that serves as a foundation (Zakaria et., 2019).

According to preliminary research, which included creating a map of potential landslide-prone areas in Makale Selatan District, Lembang Randan Batu has a very high potential level of vulnerability, while Tiromanda Village has a low potential level of vulnerability (Saka et al., 2022). In general, an avalanche will move the land/ plane above the sliding plane (Heradian & Arman, 2015; Darsono et al., 2016). The distribution of resistivity values beneath the surface is determined by the rock's ability to conduct electricity. Electric current is the movement of electric charges such as electrons or ions. Ions move in the liquid in the pores of the rock (Sutasoma et al., 2017; Zaenudin & Dani, 2019). It is hoped that the findings of this study will be used to inform mitigation efforts undertaken by the local government and the community in order to reduce losses.

Materials and Methods

Makale Selatan is one of the Tana Toraja district's sub-districts, with the sub-district capital located in the Tiromanda sub-district. South Makale sub-district is located at 3°06'33" S and 119°49'51" E. The geoelectric method was used to conduct research in three sub-districts: Sandabilik, Tiromanda, and Randan Batu. Randan Batu Village is prone to landslides every year. The Wenner Schlumberger configuration was used in this study. The Wenner Sclumberger configuration's characteristics are not very sensitive to horizontal changes (Ramadhan et al., 2015; Hendri et al., 2020). The current penetration, on the other hand, is quite deep. This configuration is commonly used in a variety of measurements, including slip plane, underground river, and geotechnical measurements (Telford et al., 1990; Maharani et al., 2018). The study location is shown in Figure 2.

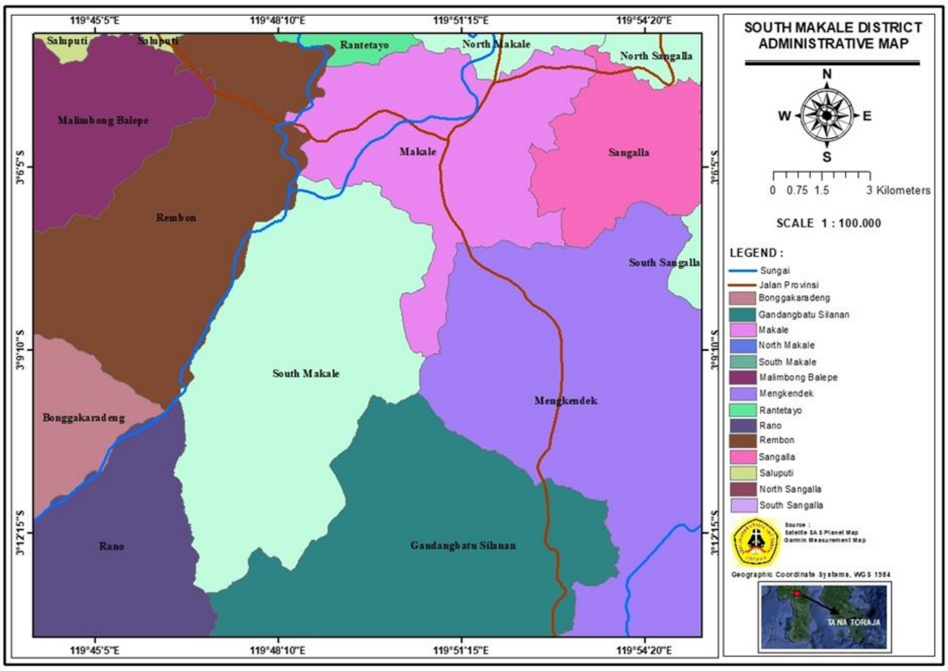

Figure 1. Makale Selatan district administrative map.

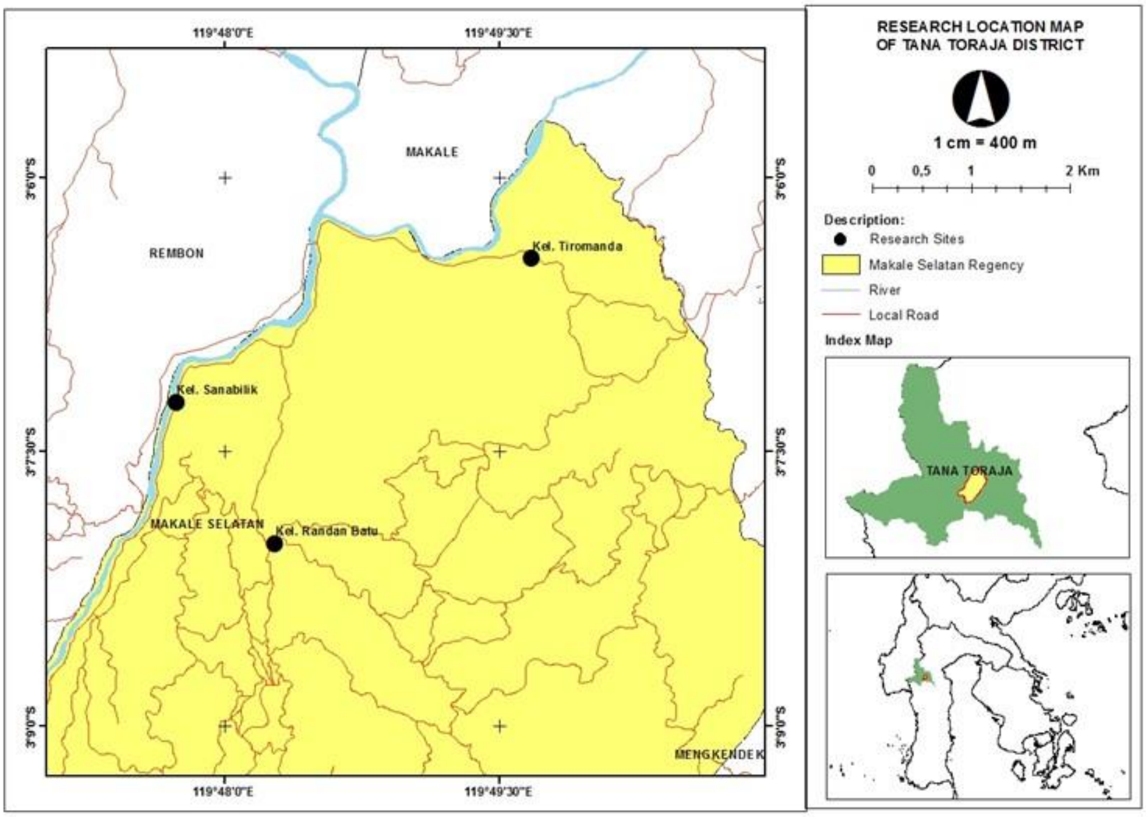

Figure 2. Data collection location.

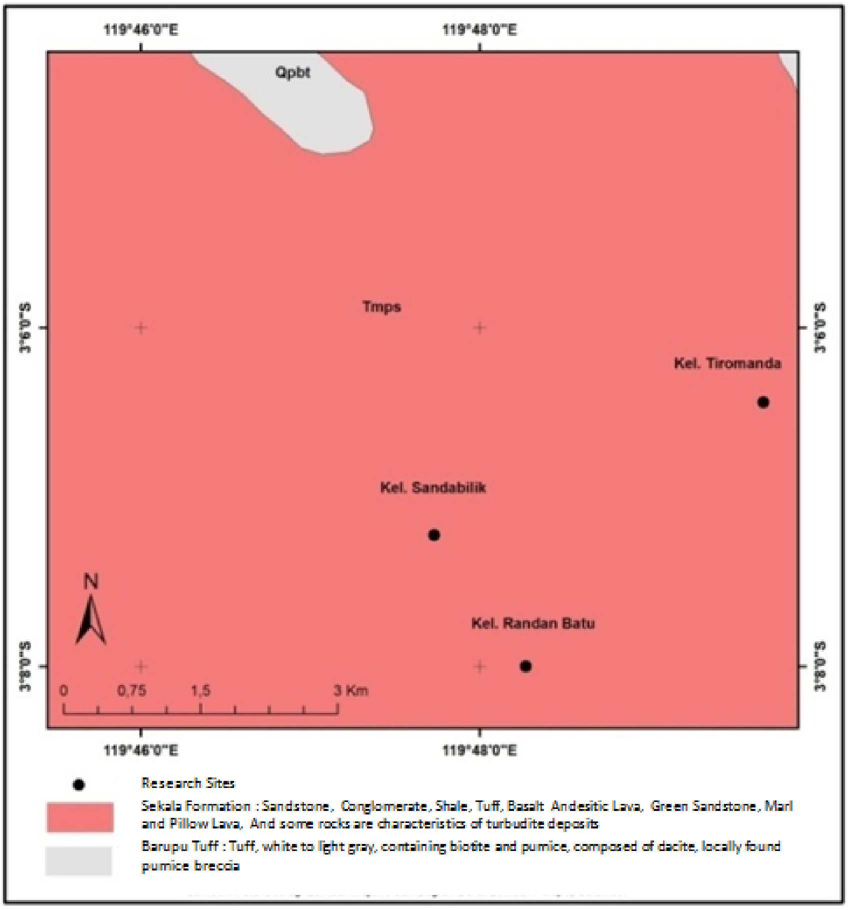

Figure 3. Toraja geological formations (modified from Puslitbang Geologi, 1999).

Figure 3 depicts the geological conditions at the study site. The study site is in the Tmps formation unit (Sekala Formation), which contains lithology types such as sandstones, conglomerates, shales, tuffs, and basaltic andesitic lava inserts (Massinai, 2018).

The Barupu Tuff Unit formed independently of the Talaya Volcano Rock Unit and the Latimojong Formation. Tuff, lapilli tuff, and Pleistocene lava breccias make up this unit. Located primarily to the south and east of the study area (Mangala et al., 2017).

The Toraja Formation unconformably overlaps the Latimojong Formation and is unconformably overlain by Lamasi Volcano Rocks (Toml), which are composed of OligoMiocene or Late Oligocene - Early Miocene volcanic rocks, volcanic sediments, and limestones. The Limestone Member (Tomc) of this volcanic rock is aligned with the Riu Formation (Tmr), which is composed of limestone and marl. The Riu Formation is Early Miocene to Middle Miocene in age, and it is unconformably overlain by the Talaya Volcanic Rocks (Tmtv) (Massinai, 2018).

The Schlumberger configuration was used to retrieve geoelectrical resistivity data. This measurement was carried out in Sandabilik Village, Tiromanda Village, and Randan Batu Village, all of which are in the South Makale District of Tana Toraja Regency. A single channel geoelectrical resistivity meter was used in this study. During the geoelectric measurement activities at each research site, two lines with a line length of 75-105 m were taken to obtain a 2D subsurface cross-section.

Results and Discussion

Sandabilik Village

Figure 4 depicts the results of the measurements taken in Sandabilik Village. The first line coordinates are 3°7'15.50" S and 119°47'43.40" E, while the second one coordinates are 3°7'19.20" S and 119°47'42.50" E.

After measuring and processing geoelectrical data on line 1, the subsurface cross-section has a resistivity value ranging from 1,64 to 714 m .

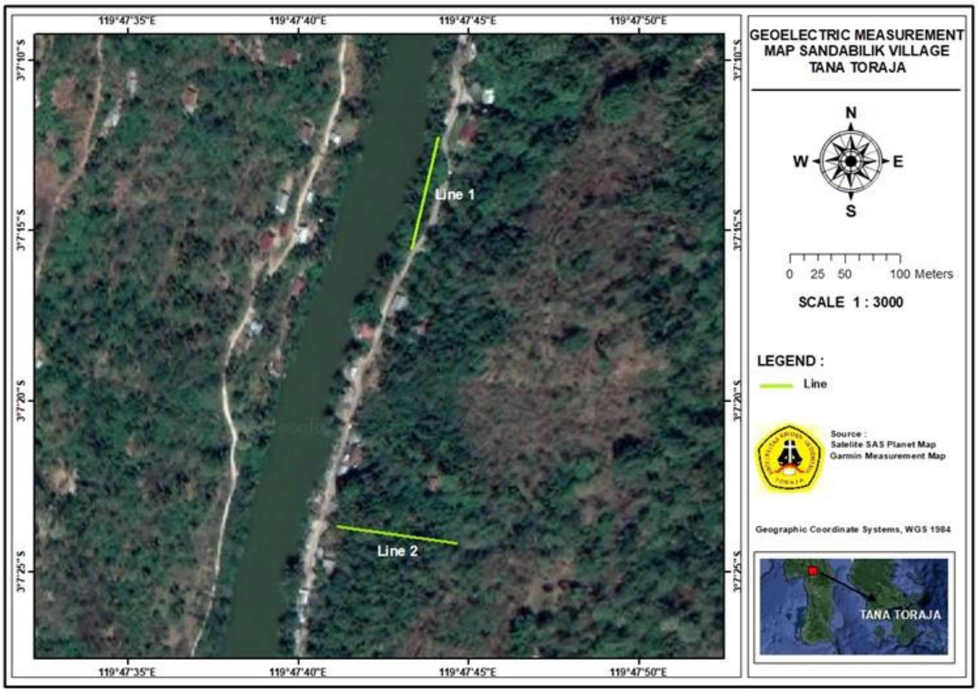

Figure 4. Sandabilik Village measurement locations.

Table 1. The resistivity values for Line 1 in Sandabilik Village.

No	Resistivity Value (Ωm)	Depth (m)	Interpretation
1.	22.1 – 52.8	0 – 20	Soil
2.	1.64 – 9.29	1.5 – 16	Water-interspersed soil
3.	126 – 714	6.5 – 19.8	Lava is a type of compact rock layer

The resistivity section in Figure 5 is divided into three layers based on the resistivity value, the first of which is a soil layer with a thickness ranging from 0 to 20 m and a resistivity value of 22.1 – 52.8 Ωm. The second layer is a layer of soil that has been saturated with water, resulting in a relatively low resistivity value because water is a good current conductor. The layer with the resistivity value 126 – 714 Ωm can be identified as a compact layer with a lithology type of lava at depths ranging from 6,5 to 19,8 m.

The subsurface section below shows the results of geoelectrical measurements on Line 2 of Sandabilik Village, which has a line length of 75 m:

Table 2. The resistivity values for Line 2 in Sandabilik Village.

No	Resistivity Value (Ωm)	Depth (m)	Interpretation
1.	40.4 – 101	0 – 16	The soil layer
2.	2.55 – 16.1	2 – 16	Water-interspersed soil layer
3.	254 – 1601	1.5 – 16	Igneous rock layers in the lava

The second line in Sandabilik village is suspected to have several types of subsurface layers (Figure 6), the first of which has a resistivity value of 40.4 – 101 Ωm and is presumably a soil layer. Soil layers that have a resistivity value of 2.55 – 16.1 Ωm are thought to be saturated with water. Meanwhile, at a resistivity of 254 - 1601 Ωm, the igneous rock layer is thought to be a compact lava layer.

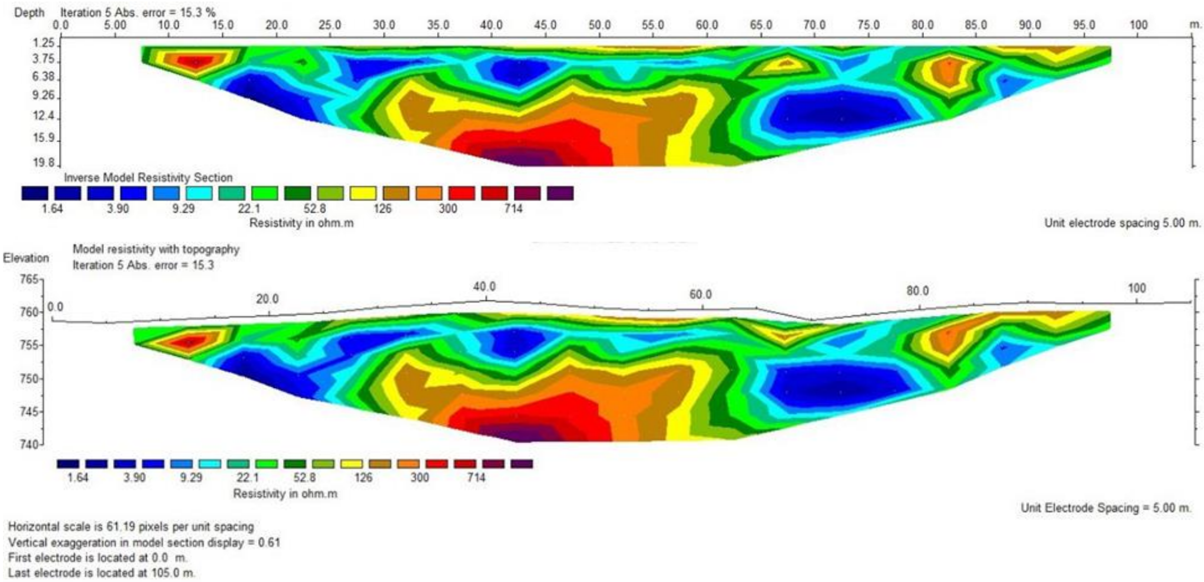

Figure 5. (above) Line 1 subsurface cross-section; (below) Line 1 subsurface cross-section with topography in the Sandabilik sub-district.

Tiromanda Village

The geoelectric method was used to conduct research in Kel. Tiromanda Kec. Makale Selatan, which is located at coordinates 3°6'26.40" S 119°49'40.60" E, as shown in Figure 7.

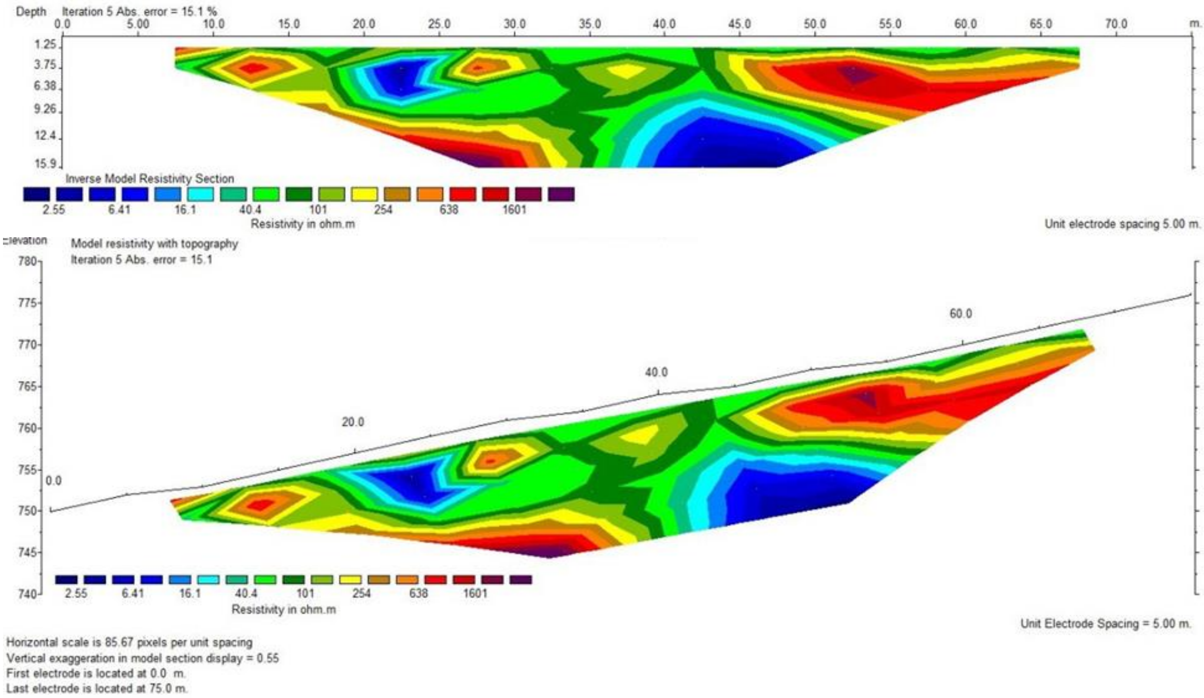

Figure 6. (above) Line 2 subsurface cross-section (b) Line 2 subsurface cross-section with topography in Sandabilik Village.

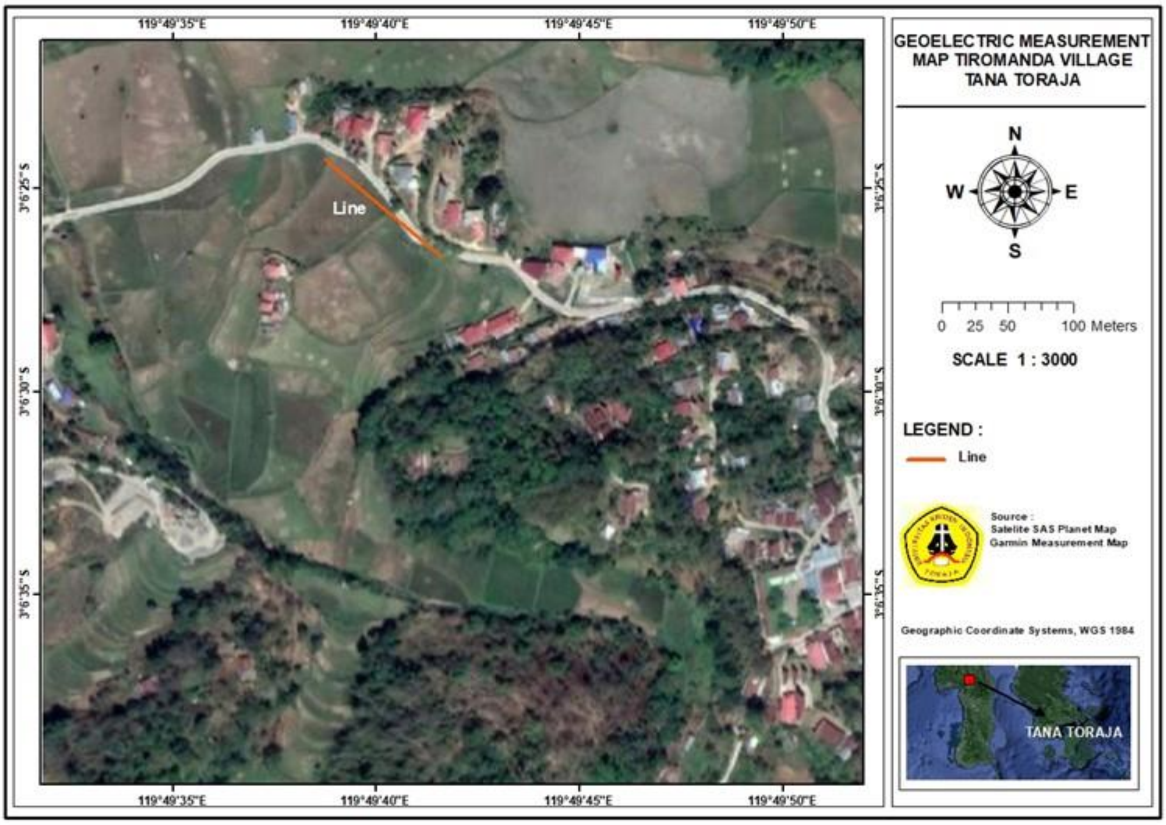

Figure 7. Tiromanda Village Measurement Locations.

Table 3. The resistivity values for Line 1 in Tiromanda Village.

No	Resistivity Value (Ωm)	Depth (m)	Interpretation
1.	13.8 – 46.8	0 – 16	The soil layer
2.	0.646 – 7.46	3 – 15.9	A sandstone layer that has been saturated with water

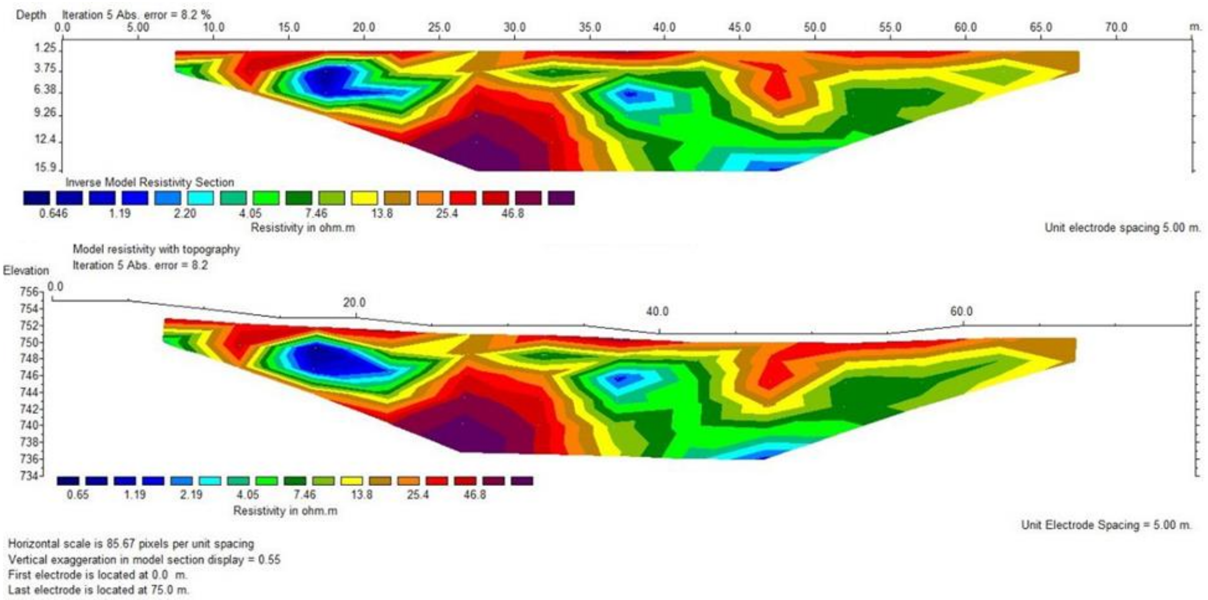

Figure 8. (above) Line 1 subsurface cross-section; (below) Line 1 subsurface cross-section with topography in the Tiromanda sub-district.

The results of geoelectric measurement data processing in Tiromanda Village has two layers. There are two types of layers: a soil layer with a resistivity value of 13.8 – 46.8 Ωm at a depth of 0 – 16 m, and a layer with a resistivity value of 0.646 – 7.46 Ωm at a depth of 3 – 15.9 m, which can be assumed to be sedimentary rock as sandstone interspersed with water (Table 3 and Figure 8).

Randan Batu Village

The Lembang Randan Batu contains a landslide point. Every year, landslides occur in this valley, killing many people. The coordinates of Line 1 are 3°8'52.90" S 119°48'16.40" E and Line 2's are 3°8'53.70" S 119°48'16.96" E, as shown in Figure 9.

Line 1 has completed a 75-meter-long line. Data processing can be seen at Table 4 and Figure 10. The first is a layer of previously weathered rock soil with a resistivity value of 35 – 21.2 Ωm that is saturated with water at a depth of 0 – 16 m. Layers with resistivity values ranging from 36.7 – 110 Ωm are thought to be at depths ranging from 2 to 16 m.

The depth 20 m is obtained from interpreted as layers of sandstone and lava in the second line measurement with a line length of 105 m (Table 5 and Figure 11). Layers with resistivity values ranging from 6.13 – 969.9 Ωm are thought to be sandstone interspersed with water at depths ranging from 0 to 20 m. Layers 5 – 20 m are interpreted as lava with resistivity values of 193 – 768 Ωm.

Table 4. The resistivity values for Line 1 in Randan Batu Village.

No	Resistivity Value (Ωm)	Depth (m)	Interpretation
1.	2.35 – 21.2	0 – 16	Water-saturated soil layer
2.	36.7 – 110	2 – 16	Lava

Table 5. The resistivity values for Line 2 in Randan Batu Village.

No	Resistivity Value (Ωm)	Depth (m)	Interpretation
1.	6.13 – 96.9	0 – 20	Water-filled sandstone
2.	193 – 768	5 – 20	Lava

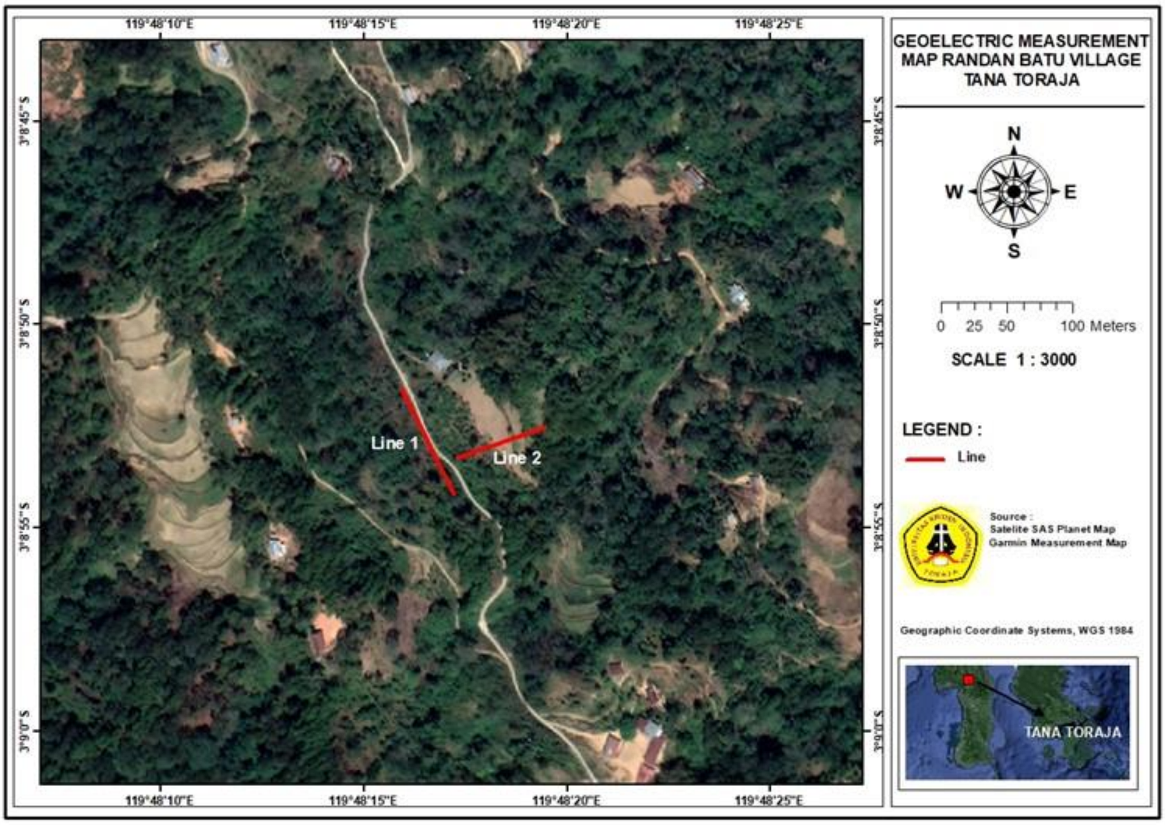

Figure 9. Locations of Measurement in Lembang Randan Batu.

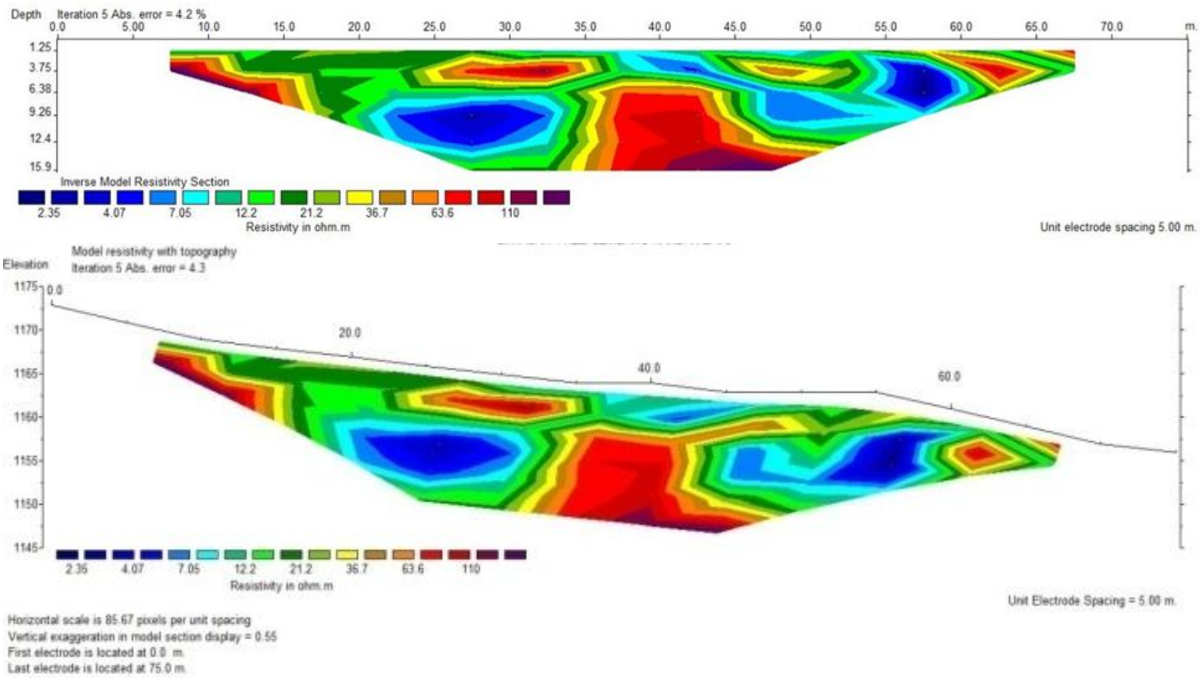

Figure 10. (above) Line 1 subsurface resistivity cross-section (below) Line 1 resistivity cross-section with topography at Lembang Randan Batu.

According to the interpretation of the results of geoelectrical measurements, the South Makale District has the potential for landslides. This is evident from measurements taken in the Tiromanda. Lava rocks can be found at depths ranging from 6,5 to 19,8 meters on line 1 and 1,5 to 16 meters on line 2. The same thing can be found in Lembang Randan Batu, a landslide points with depths ranging from 2 to 16 meters on line 1 and 5 to 20 meters on line 2. Both areas have water-saturated soil above a layer of lava rock.

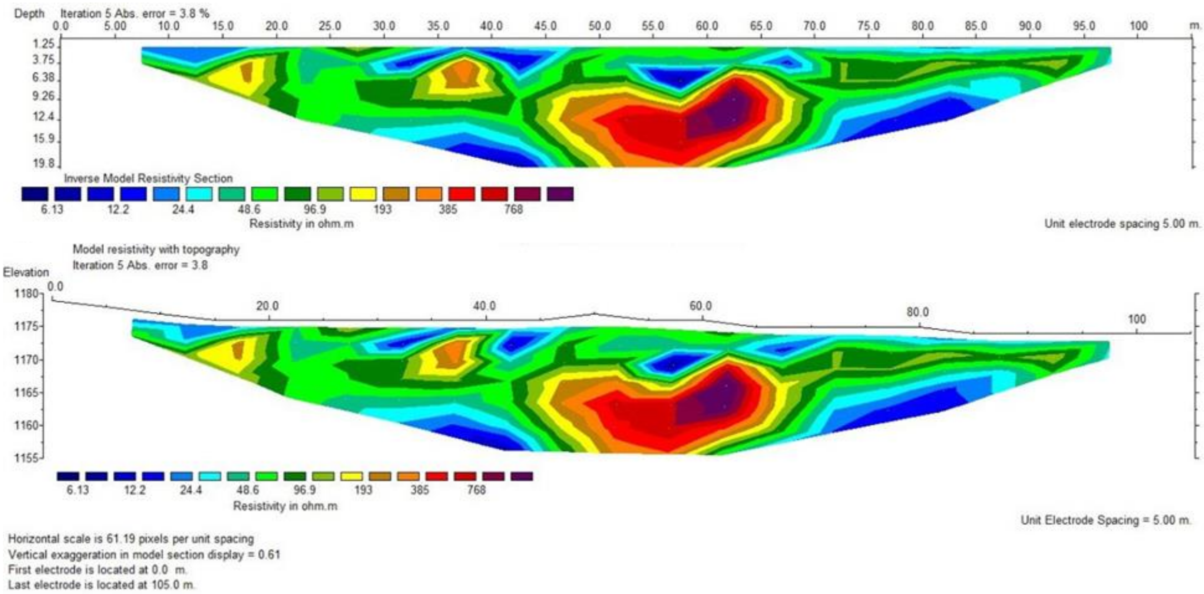

Figure 11. (a) Line 2 subsurface resistivity section (b) Line 2 resistivity section with topography at Lembang Randan Batu.

The lithology of the soil layers in the South Makale sub-district is composed of rocks, specifically sandstone, shale, tuff, and basaltic andesitic lava inserts. Tuff and lava layers can be altered to form clay material, which can act as a slip surface for the movement of the soil/ rock mass above it (Nurhayati et al., 2016). Weathering of lava rock can also contribute to mass movement. This movement can take place in either a straight or curved glide plane.

The slip plane is the material's resistivity contrast plane in the unsaturated and saturated zones. The condition of the water contained in the cavity of the media, which is soil or rock, distinguishes the unsaturated zone from the water-saturated zone. When there is no precipitation (the process of rain) in the unsaturated zone, the cavity conditions in the media will be partially filled with air and partially filled with water, but if precipitation occurs, the cavity conditions in the media can become saturated with water due to the infiltration process (absorption of rainwater by land). Meanwhile, whether good water precipitation occurred in the water-saturated zone, media conditions will always be filled (saturated).

Landslide areas are typically associated with low resistivity and high-water content. In this study, the soil is saturated with water, and the slip plane is typically made of a clay material with a higher resistivity (Yatini and Suyanto, 2018). If there is a lot of rain, especially if it is heavy rain, and it lasts for a long time in the two villages, it is likely that water will accumulate in the saturated layers, causing movement if an avalanche occurs. This occurs because rainwater seeping into the soft clay layer causes the material's volume to change, causing the excess material to become more compact.

Due to the force of gravity, the compact material becomes more slippery and serves as the foundation for slipping weathered material in the form of water-saturated clay down the slope.

The high resistivity value on the results of geoelectrical measurements indicates that the potential for landslides in the Sandabilik and Lembang Randan Batu sub-districts is relatively high.

Based on previous research, Tiromanda Village, which is in an area prone to landslides, is also classified as low. Based on the results of potential landslide mapping with the ArcGIS software (Saka et al., 2022). This also supports the findings of geoelectrical measurements, which show that the layer in Tiromanda Village is soil saturated with water at a depth of 3 – 15.9 meters and has no slip plane.

Conclusion

Based on the results of the two-dimensional interpretation, it is possible to conclude that the two South Makale sub-districts, Sandabilik Sub-District and Randan Batu Sub-District, have the potential for landslide-prone areas. This is supported by measurement results, which show the presence of slip planes in the layers at 6.5 – 19.8 meters on line 1 and 1.5 – 16 meters on line 2 in Sandabilik Village, and at 2 – 16 meters on line 1 and 5 – 20 meters on line 2 in Randan Batu Village.

Acknowledgements

Thank you to Toraja Christian University of Indonesia for funding research through Independent Research Grants with a Basic Research scheme, as well as the Physics Department of UIN Alauddin Makassar and students from the UKI Toraja Physics Education Study Program who helped collect data.

Author Contribution

The authors collaborate to conduct surveys, collect data, and analyze geoelectrical measurements.

Conflict of Interest

The authors declare that they hold no competing interests.

References

Akmam, A., Amir, H., & Putra, A. (2019). Identifikasi Bidang Gelincir Menggunakan Metoda Geolistrik Tahanan Jenis Daerah Rawan Longsor Di Kota Padang Dan Kabupaten Agam Sumatera Barat. *Talenta Conference Series: Science and Technology (ST)*, 2(2), 152–165. https://doi.org/10.32734/st.v2i2.487

Baldermann, A., Dietzel, M., & Reinprecht, V. Chemical weathering and progressing alteration as possible controlling factors for creeping landslides. *Science of The Total Environment*, 778(146300), 1–13. https://doi.org/10.1016/j.scitotenv.2021.146300

Carrión-Mero, P., Montalván-Burbano, N., Morante-Carballo, F., Quesada-Román, A., & Apolo-Masache, B. (2021). Worldwide Research Trends in Landslide Science. *International journal of environmental research and public health*, 18(18), 9445. https://doi.org/10.3390/ijerph18189445

Darsono, D., Nurlaksito, B., & Legowo, B. (2016). Identifikasi Bidang Gelincir Pemicu Bencana Tanah Longsor dengan Metode Resistivitas 2 Dimensi di Desa Pablengan Kecamatan Matesih Kabupaten Karanganyar. *Indonesian Journal of Applied Physics*, 2(02), 51–60. https://jurnal.uns.ac.id/ijap/article/view/1292/1234

Gusman, M., Nazki, A., & Putra, R. R. (2018). The modelling influence of water content to mechanical parameter of soil in analysis of slope stability. Journal of Physics: Conference Series, 1008(1), 012022. https://doi.org/10.1088/1742-6596/1008/1/012022

Hendri, H., Faryuni, I. D., & Zulfian, Z.

(2020). Identifikasi Bidang Gelincir dan Tipe Tanah Longsor di Daerah Rawan Longsor Desa Bantai Menggunakan Metode Geolistrik. *Prisma Fisika*, 7(3), 167–174. https://doi.org/10.26418/pf.v7i3.36329

Heradian, E. A., & Arman, Y. (2015). Pendugaan Bidang Gelincir di Desa Aruk Kecamatan Sajingan Besar Kabupaten Sambas dengan Menggunakan Metode Tahanan Jenis. *Prisma Fisika*, III(2), 56–61. https://jurnal.untan.ac.id/index.php/jpfu/article/view/11878/11082

Kamur, S., Awal, S., & Iskandar, A. (2020). Identifikasi Bidang Gelincir Zona Rawan Longsor Menggunakan Metode Geolistrik Di Ruas Jalan Toraja – Mamasa. Majalah Geografi Indonesia, 34(2), 101–107. https://doi.org/10.22146/mgi.48262

Maharani, I., Faresi, T. A. Z., Sari, R. S., & Sugiyanto, D. (2018). Identify Landslide Areas Using Resistivity Methods Wenner-Schlumberger Configuration in Meunasah Krueng Kala Area, Aceh Besar. *Journal of Aceh Physics Society*, 7(3), 139–143. https://jurnal.usk.ac.id/JAcPS/article/view/11242

Mangala, A., Yobel, Y., & Alfadli, M. K. (2017). Pemodelan Struktur Geologi Dan Analisis Sumber Panas Menggunakan Metode Gravitasi, Magnetik Dan Fault Fracture Density (FFD) Pada Daerah Panas Bumi Bittuang, Sulawesi Selatan. *Proceeding Seminar Nasional Kebumian Ke-10*, 1566–1578. https://repository.ugm.ac.id/274243/

Massinai, M. A. (2018). Tektonik dan Pengaruhnya Terhadap Potensi Bencana Kebumian di Wilayah Tana Toraja. *Neutrino Jurnal Pendidikan Fisika*, 1(2), 25–31. https://journals.ukitoraja.ac.id/index.php/neo/article/view/488

Nurhayati, N., & Ardi, N. D. (2016). Identifikasi Zona Bidang Gelincir Daerah Rawan Longsor Cihideung Kabupaten Bandung Barat dengan Menggunakan Metode Resistivitas Konfigurasi Wenner. *PROSIDING SNIPS 2016*, 581–589.

Puslitbang Geologi (1999). *Peta Seismotektonik Daerah Tana Toraja dan sekitarnya. Sulawesi*. ESDM. https://geologi.esdm.go.id/geomap/pages/preview/peta-seismotektonik-daerah-tana-toraja-dan-sekitarnya-sulawesi

Ramadhan, B. T., Rahayu, D. A., Rahmawati, T., Riswandha, Y., Firdaus, M. F., Suprapto, D. J., & Danusaputro, H. (2015). Identification of landslide with resistivity method Wenner-Schlumberger configuration at Bendanduwur Semarang as the first step of landslide disaster mitigation. *Padjadjaran Earth Dialogue: International Symposium on Geophysical Issues*, 8–10.

Saka, B. G. M., Jefriyanto, W., Lolang, E., & Tarru, R. O. (2022). Pemetaan Daerah Potensi Rawan Longsor Kecamatan Makale Selatan Kabupaten Tana Toraja. *Neutrino Jurnal Pendidikan Fisika*, 5(1), 11–14. https://ukitoraja.ac.id/journals/index.php/neo/article/view/1511

Sutasoma, M., Susilo, A., & Suryo, E. A. (2017). Penyelidikan Zona Longsor dengan Metode Resistivitas dan Analisis Stabilitas Lereng untuk Mitigasi Bencana Tanah Longsor. *Indonesian Journal of Applied Physics*, 7(1), 35–45. https://doi.org/10.13057/ijap.v7i1.8784

Telford, W. M., Telford, W. M., Geldart, L. P., & Sheriff, R. E. (1990). *Applied Geophysics*. Cambridge university press.

Wahyuni, A., Saka, B. G. M., & Rahmaniah, R. (2018). Mitigasi Bencana Geologi (Gempabumi Dan Tanah Longsor Di Kabupaten Toraja Utara Dan Tana Toraja Dalam

Mengurangi Risiko Bencana. *Neutrino Jurnal Pendidikan Fisika*, 1(2), 33–38. https://journals.ukitoraja.ac.id/index.php/neo/article/view/512

Yatini, Y., & Suyanto, I. (2018). Identification of slip surface based on geoelectrical dipole-dipole in the landslides hazardous area of Gedangsari District, Gunungkidul Regency, Province of Daerah Istimewa Yogyakarta, Indonesia. *IOP Conference Series: Earth and Environmental Science*, 212(1), 012013. https://doi.org/10.1088/1755-1315/212/1/012013

Yilmaz, S., & Narman, C. (2015). 2-D electrical resistivity imaging for investigating an active landslide along a ridgeway in Burdur region, southern Turkey. *Arabian Journal of Geosciences*, 8, 3343–3349. https://doi.org/10.1007/s12517-014-1412-0

Yuliana, E., Tryono, F. Y., & Minarto, E. (2017). Aplikasi Metode Geolistrik Tahanan Jenis Untuk Identifikasi Zona Bidang Gelincir Tanah Longsor Studi Kasus Desa Nglajo Kec. Cepu Kab. Blora. *Jurnal Sains Dan Seni ITS*, 6(2), B42–B47. https://doi.org/10.12962/j23373520.v6i2.26083

Zaenudin, A., & Dani, I. (2019). Pemodelan 2D Dan 3D Geolistrik Tomografi Untuk Interpretasi Bidang Gelincir Dan Arah Aliran Air Pada Struktur Bawah Permukaan Rel Kereta Api Di Baturaja, Sumatera Selatan. *Wahana Fisika*, 4(2), 104–110. https://doi.org/10.17509/wafi.v4i2.20327

Zakaria, M. F., & Maisarah, S. M. (2019). Identifikasi Bidang Gelincir Pada Daerah Rawan Longsor Desa Srimartani, Yogyakarta. *Jurnal Geofisika Eksplorasi*, 5(3), 55–63. http://dx.doi.org/10.23960/jge.v5i3.36