Landslide Potential Zone Identification Using Electrical Resistivity Tomography Modeling

MB Alghifarry[1], O Dewanto[1], and RC Wibowo[1*]

[1]*Geophysics Engineering, Engineering Faculty, Universitas Lampung, Jl. Sumantri Brojonegoro No.1 Bandar Lampung City, Lampung, Indonesia, 35145*

[*]*Email: rahmat.caturwibowo@eng.unila.ac.id*

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Abstract

The Pidada area, Panjang sub-district, Bandar Lampung City, is located on the physiography of Bukit Barisan and is also influenced by the movement of the Sumatran fault and the Lampung-Panjang fault, so the morphological condition is hilly with steep slopes which cause natural disasters such as landslides. In this study, the knowledge of subsurface rock lithology and slip-slide-prone zones was carried out using the Wenner-Schlumberger geoelectric method. Based on the Wenner-Schlumberger configuration, the top layer consists of weathered rock associated with clay tuff and sandy tuff with a resistivity of 7.2 Ωm - 135 Ωm. Coarse-grained tuff and fine-grained tuff with resistivity values of 135 Ωm - 437 Ωm, and the third layer combines breccia and igneous rock from the Tarahan Formation with resistivity values of more than 437 Ωm. The clay sand layer acts as a slip plane. The type of landslide developed in the research area is a crawling soil landslide.

Keywords: *electrical resistivity tomography, slip surface, hazard mitigation, Pidada.*

I. INTRODUCTION

Environmental problems have now become a global issue, such as natural disasters, often occurring in tropical areas. This is due to the high level of weathering caused by rainfall and exposure to sunlight which is quite high. This is one of the triggers for landslides. Apart from that, slope areas in active fault zones can also trigger landslides because the condition of the slope-forming rocks has been destroyed, resulting in a weak zone. Lampung is one of the provinces in Indonesia on the island of Sumatra, which is prone to natural disasters. Landslides are a natural disaster phenomenon due to the movement of rock or soil particles that fall due to disturbances in soil stability, slip planes, and gravitational forces [1]. A landslide disaster is a natural disaster caused by disrupting the balance, which causes the movement of soil and rock masses from high areas to low areas. Many activities can disrupt the balance of the land, including land use, and space that resists ground movement, such as trees, topographic slopes, and rainfall [2]. One effort to minimize these disasters is by mapping the potential for landslide disasters. So that it can monitor and observe the phenomenon of landslides that occur in an area by providing an overview of the existing conditions of the area based on the factors that cause landslides [3].

Some of the objectives to be achieved in this research are to obtain information on the depth of the slip plane in the Pidada area, precisely on the Suban Bandar Lampung highway, and then interpret the type of layering and subsurface lithology through the results of 2D subsurface cross-section processing in the Pidada area and to determine the type of landslide in the area. Suban Bandar Lampung highway accompanied by prevention efforts.

II. MATERIALS AND METHODS

A. Location

The location of the research area is Jalan Raya Suban, Pidada Village, Panjang District, Bandar Lampung City. Which is administratively located in Bandar Lampung City, in the south of Suka Bumi District, and is located between Merbau Mataram and Bumi Waras Districts, which is accompanied by information based on the geological map sheet of Tanjung Karang (Figure 1). The research area is located at coordinates E 536032.0588 – E 536023.4139 and N 9395970.0261 – N 9395916.2951. With an electrode path length of 115 m with an electrode spacing of 5 m, the research location is shown by the blue line in

(Figure 2).

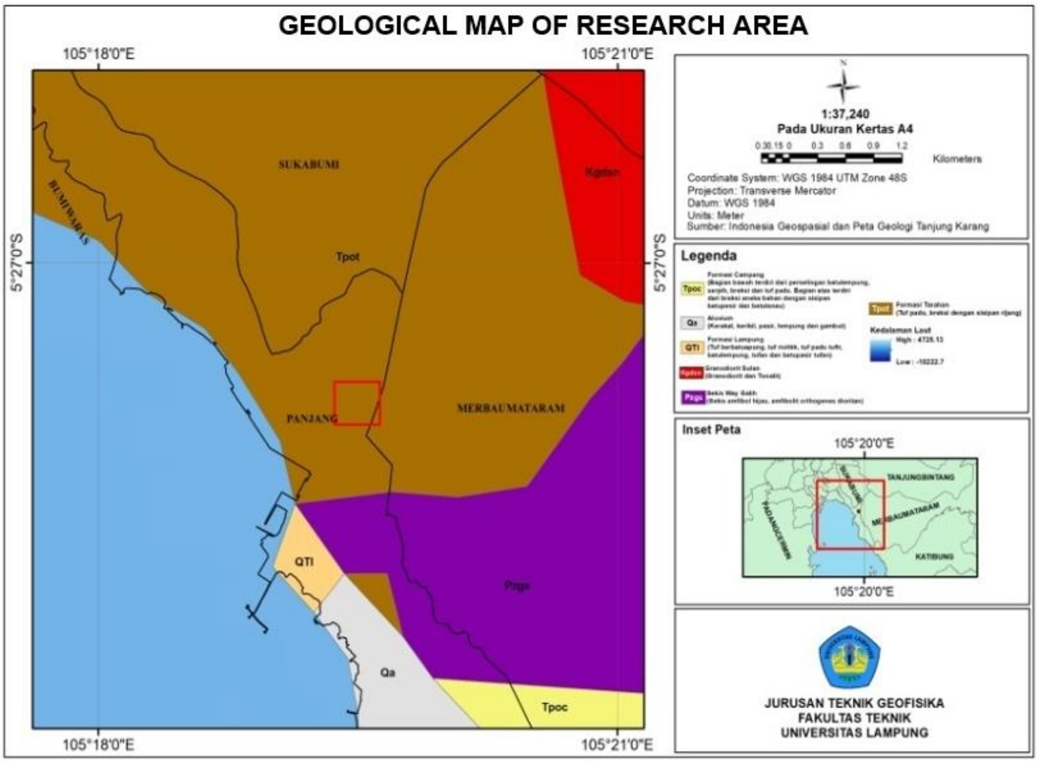

Figure 1. Geological map of the research area

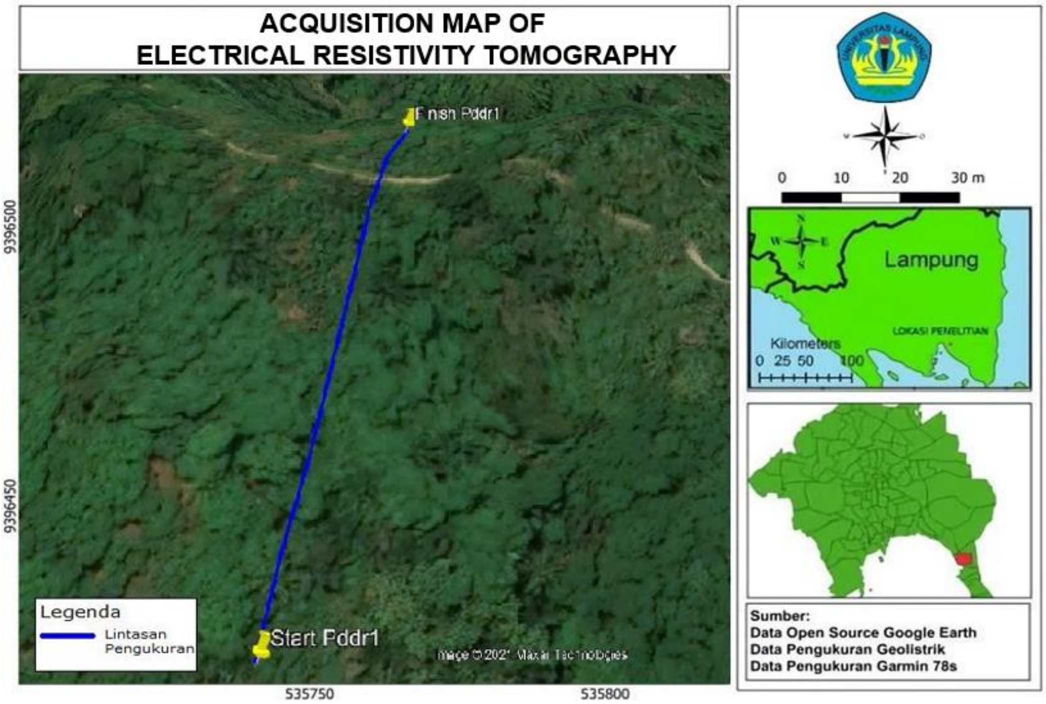

Figure 2. Measurement Trajectory Map

B. Regional Geology

Tanjung Karang has three stratigraphic sequences: pre-Tertiary, Tertiary, and Quaternary. The Tanjung Karang Sheet covers parts of the South Sumatra basin in the back-arc belt and the Barisan mountains in the magma arc belt, namely the Palembang Line and the Barisan Line, which are between pre-carbon - Quaternary ages [4]. Geological map of the research area, which is still located in the geology of Tanjung Karang (Figure 1).

The stratigraphy of the research area is based on the Geological Map Sheet of Tanjung Karang, including volcanic product rocks from the Tarahan Formation (Tpot), namely in the form of solid tuff, breccia with chert inserts, the lower part of the Lampung Formation (QTI) consisting of interbedded claystone, shale and solid tuff, the upper part consisting of breccia of various materials with inserts of sandstone and siltstone and Way Galih Schist (Pzgs) which consists of green amphibolite schist, orthogenic diorite amphibolite (Figure 3).

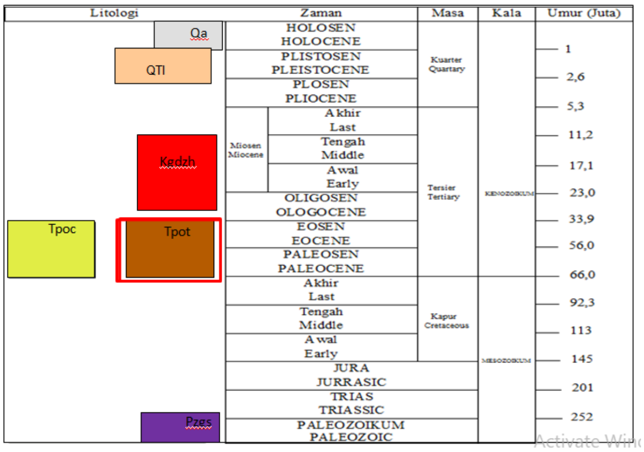

Figure 3. Stratigraphy of the Tanjungkarang Geological Sheet [4]

Based on Figure 3, the stratigraphic components of the Tanjungkarang area can be explained as follows:

1. Tarahan Formation (Tpot)

Paleocene–early Eocene age consisting of tuff and breccia dominated by chert inserts with a thickness of 500 meters-1000 meters. Scattered around Betung Bay, Mount Balu to Tarahan, type section on the Tarahan River 10 kilometers southeast of Tanjungkarang. Deposited in a continental environment, possibly a volcanic arc.

2. Lampung Formation (QTI)

Which consists of rhyolite-dacite and tuffaceous volcaniclastics, Pleistocene age, widespread throughout the coral cape sheet. Deposited in brackish water terrestrial-fluvial environments. Unconformably overlapping older rocks.

3. Campang Formation (Tpoc)

This formation consists of interbedded claystone, shale, and solid tuff. The upper part consists of breccia of various materials with inserts of sandstone and siltstone.

4. Granodiorite as white (Kgds)

This deposit is dominated by granodiorite with layers of Cretaceous age

5. Schist Way Galih (Pzqs)

Consisting of green amphibole schist, diorite orthogenesis amphibolite.

6. Alluvium (Qa)

Alluvium consists of gravel, gravel, sand, clay, and peat originating from surface deposits of the Holocene age.

C. Rock Resistivity

Resistivity is a parameter that depends on the properties of the conducting material. Apart from that, resistivity is the ability of a material to inhibit electric current. Rock resistivity is the resistance of rocks to the flow of electricity [5].

Table 1. Rock Resistivity Values [5]

Resistivity (Ωm)	Matter
0,5 – 300	Groundwater
10 - 800	Alluvium
$1{,}7x10^2 – 45x10^4$	Andesite
200 – 100000	Basal
10 – 8000	Sandstone
75 – 200	Breccia
50 – 1000	Limestone
200 – 10000	Granite
$1x10^{12} – 1x10^3$	Calsite
100 – 600	Granule
$2x10^3 – 10^4$	Conglomerate
500 – 80000	Quartz
$100 – 5x10^4$	Lava
1 – 100	Mud
3 – 70	Marl
1 – 1000	Sand
0.01 – 100	Pyrite
20 – 2000	Shale
20 – 400	Tuff

D. Slope Classification

According to van Zuidam [6], to make it easier to explain differences in relief curves (topography), slope classes were created, namely:

Table 2. Slope Classification [6]

Degree of Slope (Percentage of Slope)	Slope Classification
$0^o – 2^o$ (0 - 2%)	Plain
$2^o – 4^o$ (2 - 7%)	Gentle Slope
$4^o – 8^o$ (7 - 15%)	Wavy Slope
$8^o – 16^o$ (15 - 30%)	Moderate

16 ° – 35 ° (30 - 70%)	Moderately Steep
35 ° – 55 ° (70 - 140%)	Steep
>55 ° (>140%)	Very Steep

III. Results and Discussions

In this research, the Wenner-Schlumberger configuration geoelectric method is used (Figure 2). Data from field measurements are in the form of data files. The data is then inverted using Res2Dinv software to obtain 2D cross-sections. The 2D cross-section resulting from the inversion provides information regarding the distribution of resistivity values of the rock below the surface at each measurement path. The results of the interpretation of the Wenner-Schlumberger configuration were obtained by changing the iteration several times until an interpretation was obtained close to the actual field conditions [7]. This trajectory was carried out up to the 5th iteration with a root mean square (RMS) error value of 5.8%. The maximum depth measured based on the inversion results is 21.5 m. The following is a 2D view of the inversion data without topography and using topography in the Res2DInv software [8].

Figure 4a is the result of resistivity data interpretation obtained from field data collection, Figure 4b is the process of calculating apparent resistivity from acquisition data. Meanwhile, Figure 4c results from an inverse modeling interpretation [9]. The results of this interpretation are modeling which is the opposite of forward modeling. This type of modeling is often called data fitting or data matching because the process involves looking for model parameters that produce responses that match the observed data [10]. It is hoped that the model response and observational data will have a high agreement, producing a fit model [11].

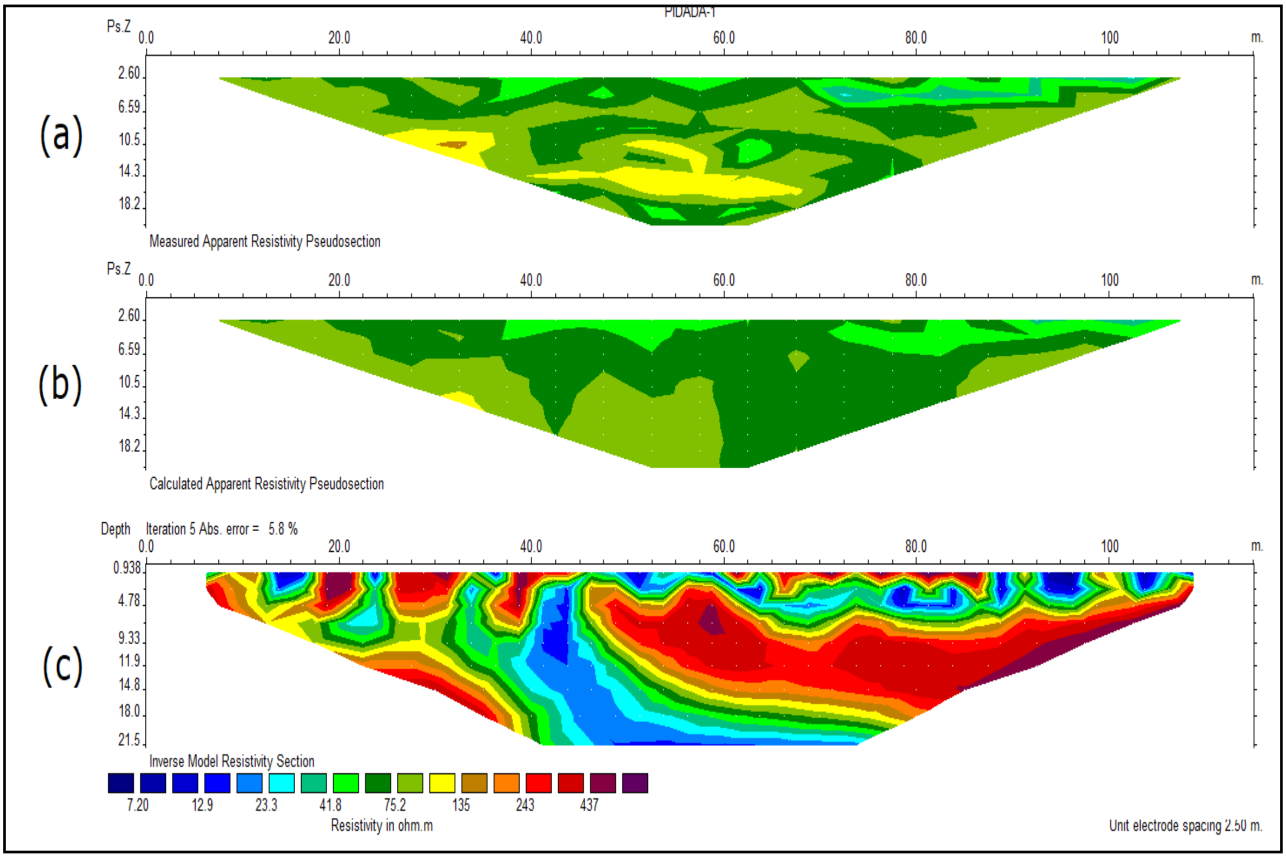

Figure 4. 2D Cross-section of Wenner-Schlumberger Inversion Configuration Without Topography

Based on the results of data processing from the geoelectric acquisition process using the Wenner-Schlumberger configuration, the classification of resistivity values in the layers in the research area can be seen as shown by (Table 3) Classification of resistivity values for the Wenner-Schlumberger configuration [12].

In geoelectricity, slip areas are characterized by contrast in resistivity between two adjacent rocks, where the waterproof layer has a large resistivity value, which is between layers with a smaller resistivity value [13]. Clay sand is impermeable/watertight. If there is water in this layer, the clay sand will become slippery and turn into a sliding surface that will slide all the material above it, causing landslides and subsidence. The slip area on the measurement track (marked by the red dotted line) is indicated to be between layers of tuff sediment and clayey sand at a depth of 4 m to 19 m from the ground surface with a thickness of 13.5 m at a distance of 45 m to 109 m (Figure 5).

Table 3. Classification and interpretation of rock resistivity values

Resistivity Value	Color Indicator	Layer Type based on Telford et al. [5]	Distance (m)	Layer Thickness (m)
7.2 – 135 Ω(Ohm/m)	Dark blue - Yellow	Sandstone and tuff rocks clay tuff	7 – 17 32 – 37 45 – 60 87 – 108	4,06 14,6 20 4,06
135 – 437 Ω(Ohm/m)	Brown – Dark red	Coarse-grained tuff rocks and fine-grained tuff rocks	26 – 33 50 – 105	4 8
>437 Ω(Ohm/m)	Purple - Dark purple	A combination of Breccia and other igneous rocks	20 48 57 93 – 109	2 1.5 5 13

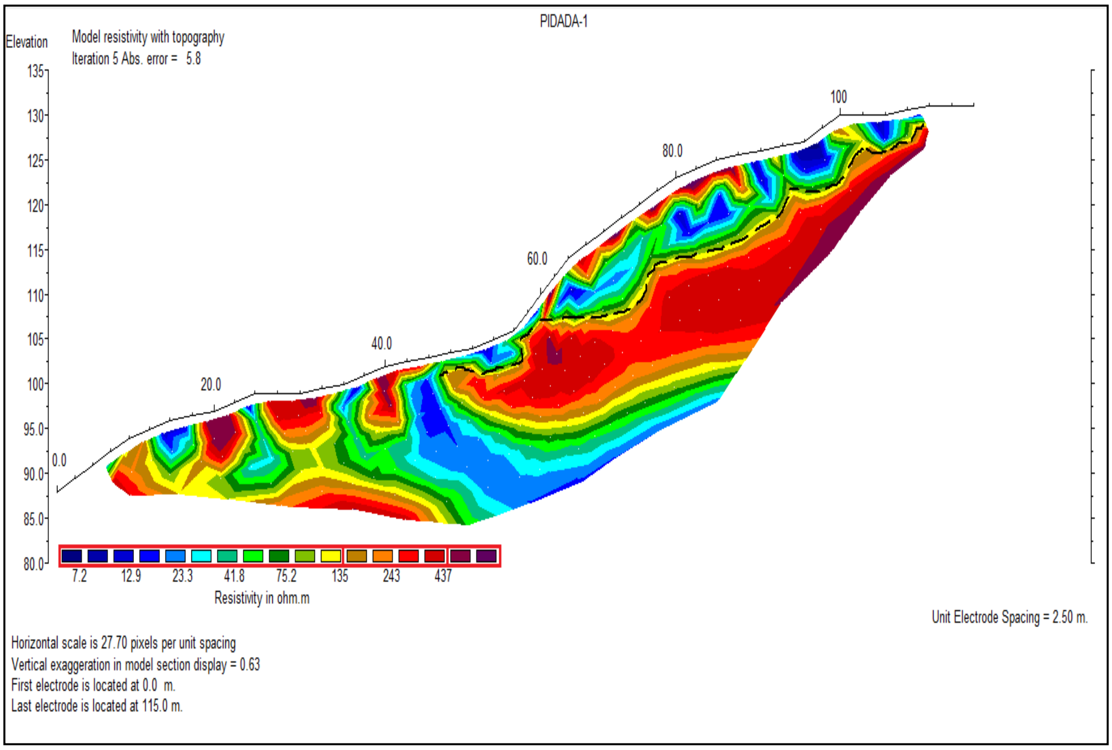

Figure 5. 2D Cross-section of the Wenner-Schlumberger Inversion Configuration with Topography

Based on the shape of the slip plane projected from topographic data (Figure 11), the slope of the study area is around 10º – 30º, which is included in the steep category (Table 2). The type of landslide classification that has the potential to occur is the rotational landslide type. Then look at the 2D cross-section (Figure 4 and Figure 5) for the slip plane at a distance of 45 to 110 meters, with a slip plane length of around 65 meters at a depth ranging from 4 - 19 meters.

The subsurface layers or rocks that make up the research area correlate with the rocks that make up the Tanjung Karang geology sheet (Figure 1), which are composed of dominant variations of tuff rock and breccia rock [14] and XRD data [15].

Supported by data from BPS Lampung in (Table 4), the intensity of rain in Lampung province in the last 3 years is in the medium category, which means it can be identified that the potential for landslides in the study area is medium-low potential.

Table 4. Rainfall in Lampung Province [16]

Month	Total Rainfall (mm)		
	2019	**2020**	**2021**
January	300.50	411.60	330.50
February	360.50	173.10	262.50
March	133.60	194.20	160.10
April	128.00	191.70	165.70
May	331.10	59.80	84.50
June	207.00	47.80	33.40
July	120.90	67.20	84.10
August	180.40	0.00	84.90
September	123.60	0.50	157.20
October	224.80	122.20	127.60
November	273.70	142.40	384.20
December	300.50	157.90	235.80
Average	223.72	130.7	175.88

Meanwhile, to minimize the occurrence of landslides, water drainage has been carried out on the cliffs of Pidada Hill so that rainwater does not accumulate on the cliffs and does not loosen the bonds between the soil, thereby minimizing the occurrence of landslides [17]. Another effort is to reforest the Pidada hill cliffs so that sunlight and rainwater do not easily reach the ground surface directly so that physical weathering is hampered. Then, to inform the public, efforts to socialize landslide zones will help anticipate before a disaster occurs [18].

IV. CONCLUSIONS

Based on resistivity and topography data processing and analysis of rainfall data and slope degrees that have been carried out on the research area data, the conclusion is that the clay sand layer functions as a slip plane located at a depth of 4 m to 19 m from the ground surface and the type of landslide in the Suban Road Bandar Lampung is a rotational type of landslide with medium-low potential and is used to prevent landslides by reforestation and creating water ditches.

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