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Application of 2D resistivity from geoelectrical methods with dipole dipole configuration for identification of land slides in Citeko Village, Cisarua, Bogor District, West Java

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Abstract. At present, many methods are used to discussed about landslide problems, especially regarding the slip field from the perspective of a one-disciplinary or multidisciplinary approach. One of the approach is using the 2D resistivity geoelectrical method. This research has been carried out to identify landslide and slip fields in Citeko Village, Cisarua District, Bogor Regency using the dipole-dipole resistivity configuration on geoelectrical method. Measurements were made in three passes with 235 metres in length and 5 metres in electrode distance. Data were processed using Res2dinv software, and the results showed that in the study , area lithology of its subsurface rocks was detected, including alluvium and sand layers, weathered material, up to volcanic rocks. Then, there are also clay layers, silt clay layers, and sandstones. The slip fields could be analyzed like a clay layer with resistivity values ranging from $42.3 \Omega\text{m}^{-1}$ to $155 \Omega\text{m}^{-1}$, and its position was in line 1 and line 2, with a depth of 8.5 metres - 16.4 metres. It also identified in line 3 at the depth of 16.4 metres. Then, based on the interpretation of resistivity 3D modeling with Rockworks software from geoelectric data, it shows that the direction of the landslide tends to be centered towards the Northwest to the West, this is also supported by visual observations in the field.

1. Introduction

Citeko Village, is one of the villages in West Java which is included in Bogor Regency, precisely in Cisarua District. Citeko Village is geographically located at an altitude of 952 metres above sea level, and seen from the topography, this area is composed of sloping hills to high. The Bogor area, especially in mountainous and hilly areas, often rains because of the high humidity level and causes the level of erosion in this area to be quite high. Beside that, judging from various geographical and demographic aspects of the West Java region especially Bogor Regency, this is what causes that Bogor Regency could be said as an area with conditions which are prone to landslides, especially in areas that have steep slopes. The slip fields is a fields rock layers located between the groundcover with bedrock. This slip field is water resistant (impermeable), and solid. In the field, the slip fields usually consists of two or more layers of soil / rock with very contrasting differences in resistivity values .[4].

Knowledge of the slip area is needed to estimate the level of vulnerability of an area to the possibility of landslides. Therefore, to minimize this impact, the identification of a sliding plane that acts as a medium for the surface of the landslide shear plane, it becomes very important to carry out as basic research, which namely is identifying the slip fields. [1]. The resistivity geoelectric method is one of the geoelectric methods used to investigate subsurface structures based on differences in the resistivity of rocks. The basic of the resistivity method is Ohm's law, which is by flowing current into the earth through the current electrode and measuring its potential on the earth's surface using the electrode potential. Geoelectricity based on the electrode layout called configuration, is divided into several types of configurations, one of is the Dipole-Dipole configuration. This configuration has the



advantage that it can be used for deeper penetration and a relatively shorter time for electrode changes.[2], [5]

2. Research Methode

The research location is located in the area around the Puncak-Taman Safari alternative road, precisely in Citeko Village, Cisarua District, Bogor Regency, West Java, located at coordinates $6^{\circ} 41' 41.6''$ West longitude with a research area of $\pm 49,256 \text{ m}^2$ or 4.93 ha. Cisarua sub-district is located in the south of Bogor City with topographical conditions in the highlands, namely hills with an altitude of $\pm 789 \text{ masl}$. The measurement was carried out for 1 day on September 9th 2019. Meanwhile, data processing and reporting is carried out at the Trisakti petroleum and mineral geology Laboratory for 1 months. The geoelectric measurement design is as follows (Figure 1). [3].



Figure 1. Geoelectric Measurement Design, which is there is 3 measurement path

The research method used is research and development methods. The measurement uses a dipole-dipole configuration which consists of 3 measurement paths, each of which is 235 metres long with a space between the electrodes of 5 metres. The main tool used to support this research is the Automatic Resistivity System (ARES). Components or research support tools include 48 electrodes, and multicore cables for 48 pieces electrodes, battery 12V, and switchbox. Data were processed using Res2dinv version 3.53g software. The following are the steps for measuring the resistivity geoelectricity with ARES (Figure 3). [5].

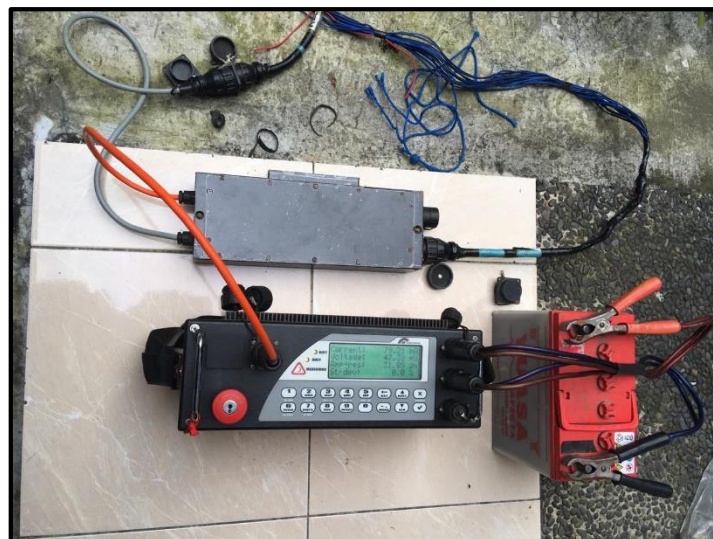


Figure 2. Ares circuit and its main components

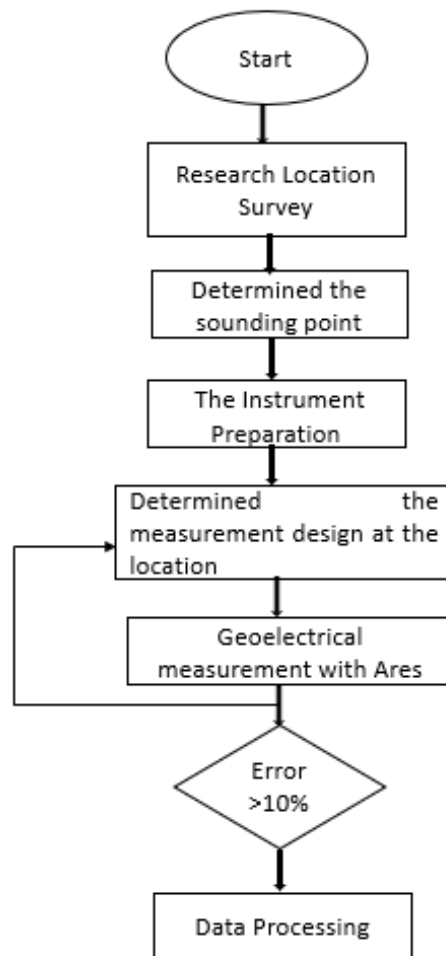


Figure 3. Steps of measurement work

In this resistivity geoelectric method, an electric current is injected into the earth through two current electrodes. Then the potential difference that occurs is measured through two potential electrodes. From the measurement results of current and potential difference for each different electrode distance, the variation in the value of the resistance type for each layer below the sounding point can be derived. [2].



Figure 4. Geoelectric measurement, which is electrodes are injected into the ground, with a different variation of electrode distance

After the measurement is complete, the next step is to process the data. The initial stage of processing 2D data using Res2dinv software, the steps are as follows:

1. Download the measurement data from the ARES tool, then perform calculations to get the apparent resistivity value for each datum point.
2. After the apparent resistivity value is obtained, the value is made in a format that matches the input data format of the software that will be used for data processing, namely Notepad.
3. In the notepad, enter the topographic value obtained from measurements by GPS, this is so that after being inverted using Res2dinv it will produce a resistivity section that has undergone topographic correction.
4. Process data on Res2dinv by running the File menu >> Read data file. Then, edit the data by selecting the Edit >> Exterminate bad datum points option, this is done to remove the datum points that are not good enough, resulting in an inversion section with the lowest possible error value. The following is one of the data edits with the option to exterminate bad datum points (Figure 5). The datum point value circled in red is a bad value, so it is necessary to do the option to exterminate bad datum points. The datum point value circled in red is a bad value, so it is necessary to do the option to exterminate bad datum points.

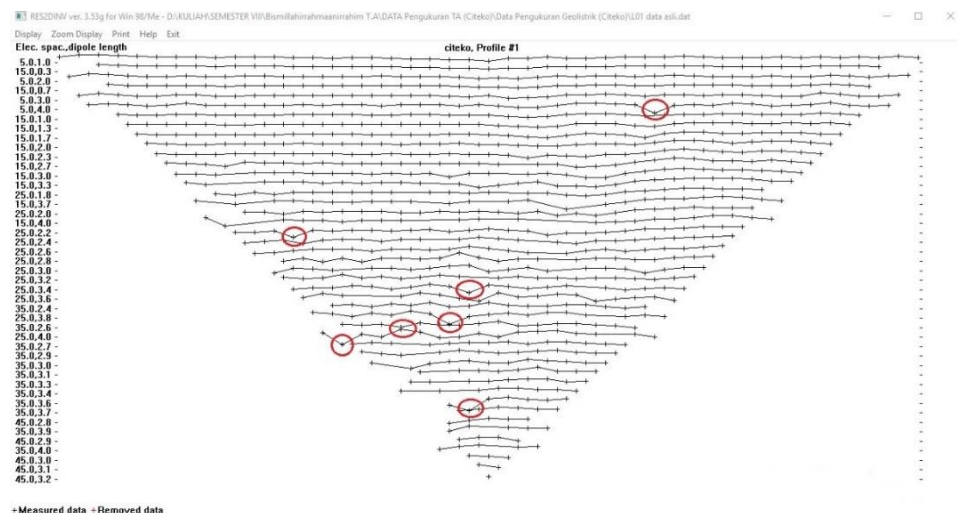


Figure 5. Data editing process on executing bad datum point

5. The next step is inversion, this process is a process of analyzing field data by matching mathematical models and field data. Inversion on Res2dinv is by selecting the inversion menu and selecting Least squares inversion. The result is a resistivity cross section. This resistivity cross section contains information about the resistivity value, the number of electrodes and the measurement depth measurement.
6. After the resistivity section appears, then select the Display >> Show inversion result menu, then select the Display section >> Include topography in model display menu.
7. The results of the resistivity section with the topographic data that have appeared, then the next step is to save the data in XYZ format by selecting the File >> Save data in XYZ format (.xyz) menu. This data will be used for the next stage, namely 3D geoelectric data processing with Rockworks15 software.

2.1. Data analysis

After all data processing has been carried out, the next step is data analysis regarding the results of both 2D and 3D data processing. This data analysis includes interpretation to explain the values in geophysical parametress visualized in 2D and 3D sections into geological language related to subsurface conditions. Analysis of the resistivity value of the rock is by comparing the color image and the magnitude of its value against the rock resistivity value table that refers to the literature that comes from, then determining the type of lithology / rock under the surface of the study area. The contrast

difference between the large resistivity value and the small resistivity value indicates an estimate of the landslide slip plane, from the cross section it can be seen whether or not the slip plane is present and the depth it detects. A slip plane that has the potential to endanger the occurrence of landslides / landslides when the slip plane is at a certain depth is in the second layer after the layers that tend to be not compact are above it. To determine the analysis of the potential direction of land / landslide movement in the study area, interpretation can be carried out by processing the geoelectric data in 3D on the Rockworks15 software.

2.2. Theoretical basis about definition of land slides

Landslide is a type of mass movement of soil or rock, or a mixture of the two, down or out of the slope as a result of disturbing the stability of the soil or rock forming the slope. In other words, landslide is a process of mass transfer of soil / rock in an oblique direction from its original position, so that it is separated from a steady mass, due to the influence of gravity, with the type of movement in the form of rotation and translation. Slope-forming material in the form of rock, scrap material, soil, or loose material, moves towards the foot of the slope or exits the slope. [1]. Geologically, it can be interpreted as a geological event where soil movement occurs such as the fall of soil or rock or large lumps of both. Landslides occur when soil material slides along an area that has a certain slope, especially during the rainy season which can cause loads on the inner surface of the soil pores due to water seeping into the soil and increasing the weight of the soil mass which can trigger the displacement due to instability of gravity. This gravitational instability can occur in an area that has a sliding fields, and under certain conditions the slip fields can change into a discontinuous fields. The factors that cause landslide prone slopes include internal factors (factors originating from the slope body) and external factors (factors originating outside the slope), including: seismicity, climate (rainfall), vegetation, morphology, rock / soil and the situation. An area, the level of soil moisture (moisture), the presence of seepage, and geological activities such as fractures (especially those that are still active), and fractures. [6]. In theory, rock layers prone to landslides are generally characterized by the presence of rock layers containing clay and / or water material. If the layer has high permeability properties to pass and store water, then under certain circumstances (high rainfall) it will be saturated and affected by gravity so that it experiences stability disturbances, the possibility of the layer moving above the sliding plane is very large. Apart from the factors mentioned above, there are other factors that can cause landslides, such as controlling factors and triggering factors for landslides. Controlling factors can be in the form of slope slope (slope elevation related to the height of the slope), condition and composition of soil or rock slopes, in this case generally unconsolidated sediments, and groundwater point conditions. Meanwhile, trigger factors can be in the form of an increase in water content due to rainwater seepage, the presence of water sources at the foot of the slope, vibrations or earthquakes, cutting of slope legs, and land use that violates regulations.[1]

2.3. Definition of slip fields

The slip fields is a field between rock layers located between the overburden and bedrock. This slip field is water resistant (impermeable), solid. In the field, the slip field usually consists of two or more layers of soil / rock with very contrasting differences in resistivity values. The slip fields can also be interpreted as a connecting area between cracked / unstable rocks and strong rocks, the boundary area between permeable and impermeable rocks, and the boundary area between rocks / soft soil. [6]. Based on the type of shape, the landslide slip area can be divided into:

- Translation slip field. This type of slip fields occurs when the mass of soil, rock or landslide material moves on the sliding fields which is flat or gently wavy.
- Rotation Slip Field. Rotational slip fields can occur when the mass of soil, rock or landslide material moves in the slip plane in a concave or semicircular pattern. [6].

2.4. Definition of dipole - dipole configuration

Dipole-dipole configuration (Dounle dipole) is a configuration where the distance between electrode A and electrode B is the same as the distance between electrode C and electrode D. The distance between electrode A and electrode D is $(L + a)$ while the distance between electrode C and electrode B is equal to (La) where L is the length of the midpoint of the current electrode and the midpoint of the potential electrode. [5].

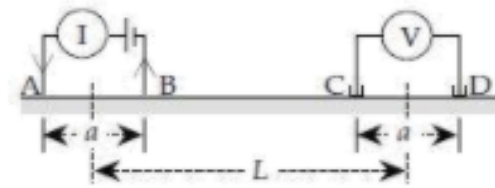


Figure 6. Dipole dipole configuration

The geoelectric method equation for dipole dipole configuration is as follows :

$$r_{AC} = L ; r_{AD} = L + a \dots \dots \dots (1.1)$$

$$r_{CB} = L - a ; r_{DB} = L \dots \dots \dots (1.2)$$

$$\rho = \pi \frac{V}{I} \frac{L(L^2 - a^2)}{a^2} \dots \dots \dots (1.3)$$

where 'a' is the distance between electrodes whose the values changes depending on the desired stretch, and ρ is the resistivity value (ohm/m).

3. Result and Discussion

After measuring and processing data, the following analysis results are obtained :

Line 1



Figure 7. Slip Field Area on line 1

Measurements on this line are at an altitude of 944 - 963 masl. The length of line 1 is 235

metress with a distance between the electrodes of 5 metress, the direction of the track is Northwest - Southeast. The maximum penetration measurement depth reaches 47 metress below the surface. From the results of data processing, the 2D geoelectric cross section is obtained as follows :

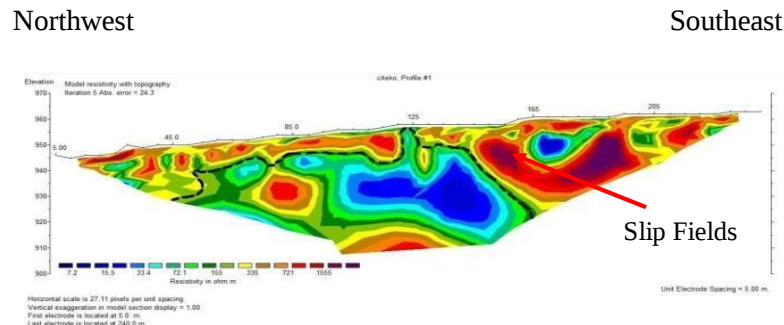


Figure 8. Cross sectional image of Slip Field on line 1 from res2div data processing

By grouping the resistivity values and the type of rock lithology as follows :

Table 1. The results of resistivity calculations and rock type analysis from the cross-section of the image on line 1

No	Resistivity (Ohm Metres ⁻¹)	Type of Soil/Rocks
1.	7,2 – 33,4	Silt clay to sandstone
2.	72,1 – 155	Clay/ Dry clay
3.	355 – 1555	Alluvium and sandstone, until weathered material which derives from volcanic rock.

The slip fields on line 1 is detected at depths ranging from 8.50 to 31.2 metress from the surface which is included in the shallow-medium slip fields with a resistivity value of 72.1 Ω m - 155 Ω m which is interpreted as a layer of clay. The width of this slip fields layer extends from electrode number 50 to 160 with a direction tending more to the Northwest.

Line 2

Line 2 is parallel to line 1, to be precise on the slope body, with an elevation range between 938 - 954 masl, the direction of the northwest - southeast trajectory with a maximum depth of penetration that can be achieved, namely $\pm$ 47 metress below the surface. Geoelectric data processing produces a 2D cross section as below.



Figure 9. Slip Field Area on line 2

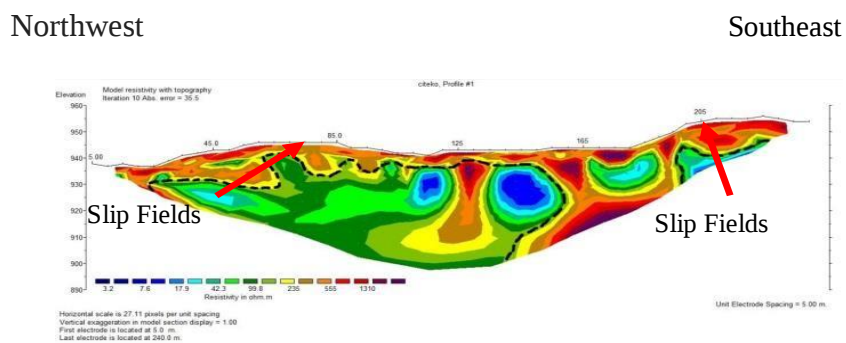


Figure 10. Cross sectional image of Slip Field on line 2 from res2div data processing

The interpretation of rock type grouping based on the distribution of their resistivity values is shown in the table below :

Table 2. Resistivity and rock type and soil on line 2

No	Resistivity (Ohm Metres ⁻¹)	Type of Soil/Rocks
1.	3,2 – 17,9	Silt clay to sandstone
2.	42,3 – 99,8	Clay
3.	235 – 1310	Alluvium and sandstone, until weathered material which derives from volcanic rock

Figure 10. shows that there are 2 landslide slip fields detected in the Southeast, from the electrode number 195 to the electrode number 225 at an elevation of 956 masl with depth <8.50 metres to 16.4 metres below the surface. The slip fields on the other side is detected in the Northwest direction detected at electrode number 25 to electrode number 160 at an elevation of 952 masl with a depth of <8.50 metres to 31, 2 metres below the surface, with a resistivity variation of the two slip fields ranging from $42.3 \Omega \text{ m}$ - $99.8 \Omega \text{ m}$ which is interpreted as a layer of clay which has impermeable properties, so that this layer is unable to pass water.

Line 3

Measurements on this line intersect line 2 with an elevation of 962 - 918 masl with the northeast - southwest trajectory. The slopes on this trajectory are around $\pm 30^\circ$ and the maximum depth of penetration achieved is ± 47 metres below the surface.



Figure 11. Slip Field Area on line 3

Measurements on this line intersect line 2 with an elevation of 962 - 918 masl with the northeast - southwest trajectory. The slopes on this trajectory are around $\pm 30^\circ$ and the maximum depth of penetration achieved is ± 47 metres below the surface.

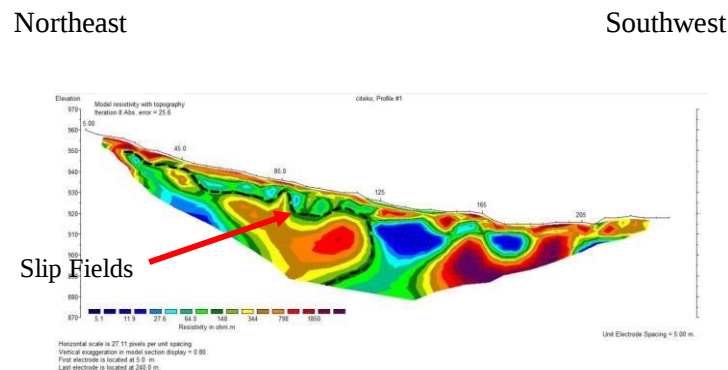


Figure 12. Cross sectional image of Slip Field on line 3 from res2div data processing

Based on the results of geoelectric data processing in Res2div, on line 3 shows subsurface conditions with variations in the resistivity value as shown in the table below.

Tabel 3 Resistivity and rock type/soil on line 3

No	Resistivity (Ohm Metres ⁻¹)	Type of Soil/Rocks
1.	5,1 – 27,6	Silt clay to sandstone
2.	64,0 – 148	Clay/Dry Clay
3.	334 – 1850	Alluvium and Sandstone, Volcanic stone until Volcanic weathered material stone

On line 3 shows a slip field detected at a depth of 16.4 metres below the surface with a resistivity value of 64.0 Ω m - 148 Ω m which is indicated by a green image in the cross section. The suspected slip fields layer detected at electrode number 25 to electrode number 125 was interpreted as a layer of clay to dry clay, which was characterized by a solid characteristic with a poor water absorption. Based on the cross section image, the sliding area on this track is relatively long so it is very possible for landslides to occur and tends to lead to the southwestern part.

3.1. Analyst Results of Geoelectric Data 3D Modeling with Rockworks 15 Software

Geoelectric data modeling with Rockworks software was carried out to determine the overall direction of the potential movement of lands / landslides in the study area. From the 3 measurement paths data, they are stacked together and made a 3D model and produce the output as below :

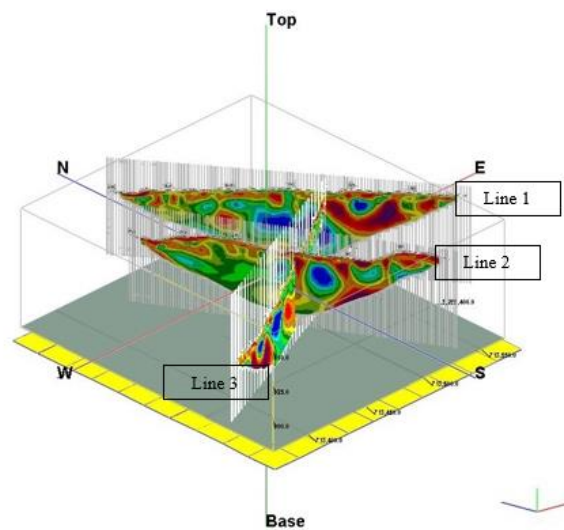


Figure 13. Geoelectric 3D section, N-S direction

The modeling above is a normal position that can be seen from the North-South (North-South) direction, to see the direction of the landslide, interpretation of the three trajectories is carried out in 3D, and the model is rotated and viewed from a different direction, namely the East-West (East-West)) it will be more visible the direction of the potential for landslides, which are as follows :

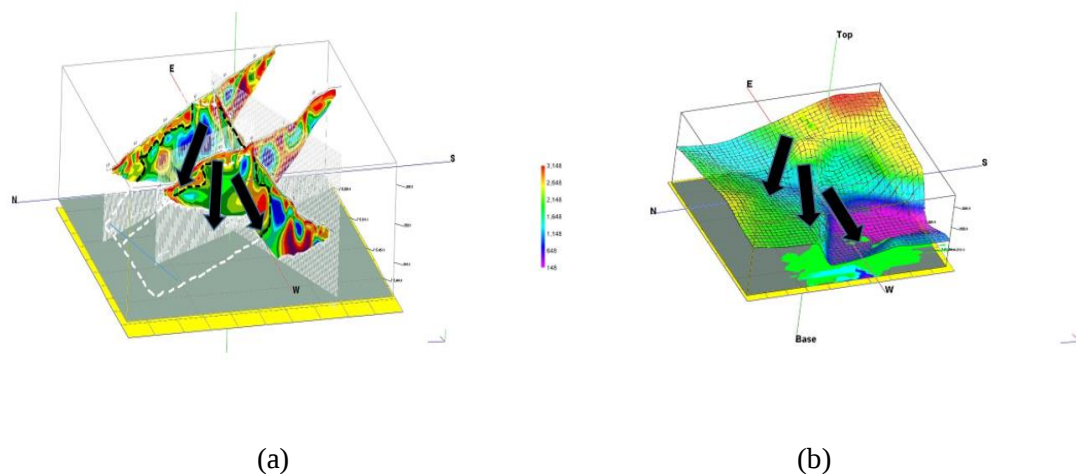


Figure 14. (a). Geoelectric 3D section, N-S direction after rotate and viewed from different direction. (b). Resistivity 3D cross section, E-W direction

Based on the interpretation of resistivity 3D modeling (Figure 14) seen from the East-West (East-West) direction, it shows that the direction of the landslide tends to be centered towards the Northwest to the West, this is also supported by visual observations in the field.

4. Conclusion

Based on data processing and analysis, the rock layers found in the study area, namely Citeko Village, Cisarua District, Bogor Regency, West Java, consist of layers of silt clay to sandstones, clay, alluvium and sand, volcanic rock to weathered volcanic rock. The slip fields on line 1 is located at a depth between > 8.50 metres - 31.2 metres with a variation of the resistivity value of $72.1 \Omega \text{ m}$ - $155 \Omega \text{ m}$ in the northwest direction. The slip fields on line 2 in the southeast is located at an intermediate depth < 8.50 metres - ± 16.4 metres below the surface, while in the Northwest it is detected at a depth of < 8.50

- 31.2 metres below the surface with a variation of the resistivity value of $42.3 \Omega \text{ m}$ - $99.8 \Omega \text{ m}$, and the slip fields on line 3 is located at a depth of 16.4 metres with a resistivity value variation of $64.0 \Omega \text{ m}$ - $148 \Omega \text{ m}$ at the West direction. The slip area at the study area is interpreted as a layer of clay to dry clay.

Based on the interpretation of resistivity 3D modeling with Rockworks software from geoelectric data, it shows that the direction of the landslide tends to be centered towards the Northwest to the West, this is also supported by visual observations in the field.

5. Suggestion

The results from geoelectrical method should be developed by improving the structure of civil engineering on this prospect mining coal area to eliminate the risk of landslides and subsidence.

6. Reference

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