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Subsurface Interpretation Based on Resistivity Data: A Case Study in Cepoko Village, Indonesia

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Abstract – Semarang continues to experience development which eventually forces peri-urban areas such as Gunungpati District to be converted into residential areas. Cepoko is one of the sub-districts in the Gunungpati District, which is an alternative to build settlements because the land is considered safer than others. Unwise land conversion can trigger landslides, especially in sloping areas such as Cepoko Village. Information on the subsurface structure can be used as a reference for preventing the impact of landslides damage. The study aims to identify the subsurface lithology of Cepoko Village using resistivity data. The subsurface layers can be determined based on the resistivity variation on the subsurface. The study takes secondary geoelectric and drilling data obtained from Selimut Bumi Adhi Cipta Inc. IPI2Win is used for data processing results in a one-dimensional log graph of the resistivity to the depth. The lithology found is clay, sandy clay, loamy sand, gravel sand, and andesite rocks.

Keywords – Geoelectric method, rock resistivity, Schlumberger configuration, subsurface interpretation, Cepoko, Semarang.

I. INTRODUCTION

Semarang continues to experience development which eventually forces peri-urban areas such as Gunungpati District to be converted into residential areas. Unwise land conversion on steep sloping areas can trigger landslides. Cepoko is one of the sub-districts which is used for cultivation, the criticality level of the land is included in the critical-somewhat critical potential category [1] that makes Cepoko an alternative to building settlements.

According to the Regional Hazard Database of Semarang, landslides occurred in Gunungpati District with 18 cases from early 2019 to mid-2020 [2]. The Geographical Information System (GIS) shows that Gunungpati District has a medium-high risk of landslide susceptibility [3]. Cepoko is located in area with slope gradient of 2 % - > 40 %. A steep slope can cause landslides and result in causalities, therefore important to identify subsurface as the landslide prevention.

Subsurface information can be used as a reference for development plans. The subsurface layer can be determined based on the resistivity variation of subsurface layers [4], [5]. The resistivity variation is obtained from the results of current measurements and the potential difference for each electrode spacing. The geoelectric method is sensitive to the water content so that it is suitable for use in landslide-prone areas [6].

This study aims to identify the subsurface lithology in Cepoko. Subsurface investigations through resistivity methods are still quite effective in providing subsurface information in landslides-prone areas [7], [8], [9]. The geoelectric method is quite helpful to identify the subsurface on slopes that are potentially stable and unstable, zones of high water content, and geometries in landslide areas [10].

II. GEOLOGY INFORMATION

The studied area lies in Cepoko Village, situated in Gunungpati District, Semarang City. Semarang as a capital city of Central Java Province with population growth increases in the number of settlements making Cepoko one of the settlement options. The coordinates of the studied area located at 7º4'26"-7 º4'30" S longitudes and 110º21'30"-110º21'32" E latitudes. The slope gradient varies from 2% to 40%. According to Map of Regional Geology of Magelang-Semarang, Central Java Province [11]. Gunungpati District is composed of Damar Formation (Qtd), Kerek Formation (Tmk), Kaligetas Formation (Qpkg), and Kaligesik Volcano Rocks (Qpk), Jongkong Formation (Qpi), Kalibeng Formation (Tmkl). Cepoko is composed of the Kaligetas Formation. This formation consists of breccias and lava with lava inserts and fine to coarse tuff, the lower part of which is claystone containing mollusks and tuff sandstone. Breccias and lahars are dark browns in color with components in the form of andesite, basalt, pumice with a tufa base mass. Tuff is whitish-yellow, fine-coarse, high porosity, brittle. The location of the studied areas is shown in figure 1.

Figure 1. The location of the studied area, BH-1 and BH-2 are the core drilling points, GL-1 and GL-2 are geoelectrical points.

III. METHODOLOGY

This study was carried out based on secondary data which includes geoelectric data and drilling data obtained from Selimut Bumi Adhi Cipta Inc. The drilling data obtained includes two points, the depth of 33 m and 40 m, respectively for BH-1 and BH-2. IPI2win software is used to process geoelectric. The principle of the geoelectric method is injecting an electric current into the earth through the electrodes [12].

The geoelectric method was carried out using a Schlumberger configuration with a length of 100 meters at two points in the research location, point GL-1, and GL-2. The earth is composed of heterogeneous rock compositions both horizontally and vertically results in pseudo resistivity values [13]. The apparent resistivity is formulated as follows:

$$\rho_a = K\frac{\Delta V}{I} \quad (1)$$

where K is the geometric factor, ΔV is the potential difference, I is the electric current.

Schlumberger configuration is the sounding system as shown in figure 2. The Schlumberger configuration places the current electrode further than the potential electrode, the electrode spacing is adjusted so that r1 = r4 = (a-1/2 b) and r3 = r2 = (a + 1/2 b), where a is the distance to the center of the current electrode and b is the distance between the two potential electrodes.

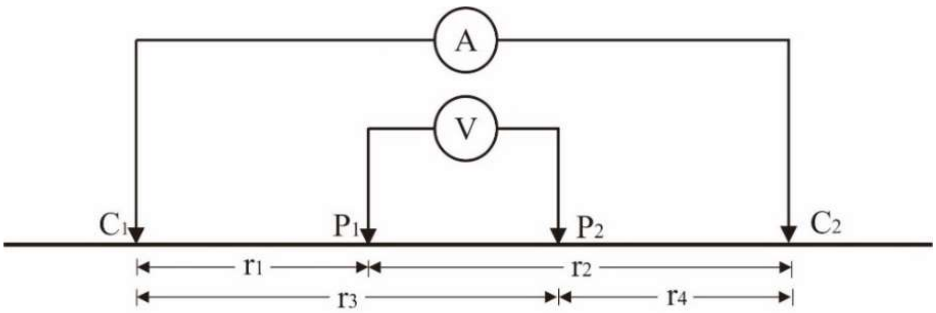


Figure 2. Schlumberger configuration

The Schlumberger geometric factor is formulated as follows:

$$K = \frac{\pi(L^2 - l^2)}{2l} \tag{2}$$

where π is phi, L is half of the spacing of the current electrodes and l is half of the spacing of the potential electrodes. The resistivity measurement of the earth's material is generally determined by charged ions in the fluid pores so that the rock resistivity has different values [14]. The resistivity of various rocks and water types according to Telford et al. (1990) are presented in table 1.

Table 1. The resistivity of various rock and water types (Telford et al., 1990)

Rock	Resistivity (Ωm)	Water	Resistivity (Ωm)
Marls	3-70	Soil water	100
Clay	1-100	Seawater	0.2
Tuff	3×10^3(wet)- 10^5 (dry)	Surface water (ign. rock)	0.1-3000
Oil sands	4-800	Surface water (sediment)	10-100
Andesite	4.5×10^3(wet)- 1.7×10^2 (dry)	Saline water 3%	0.15
Basalt	10- 1.3×10^7 (dry)	Saline water 20%	0.05

The flowchart of the study is shown in figure 3.

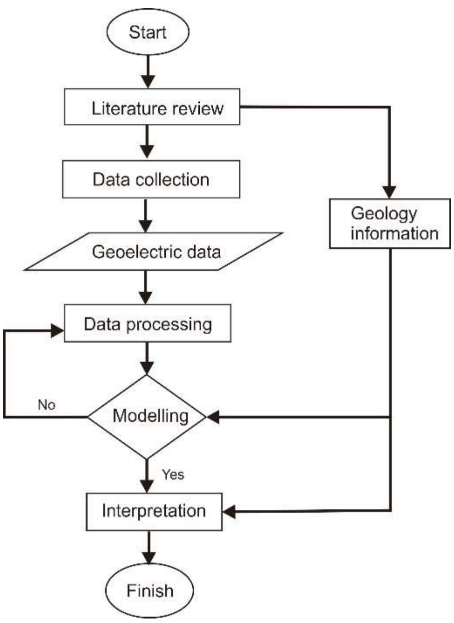


Figure 3. The flowchart of the study

IV. RESULT AND DISCUSSION

Analysis of Geoelectric Data Processing

Geoelectric data provides values of AB / 2, MN / 2, and pseudo resistivity which is then processed in the IPI2win software with a Schlumberger configuration. The result of processing data using IPI2win presents curves and points. The black points are the measurement result, the red curve is the calculation result, the blue curve is the matching curve. The blue curve is used to adjust the red curve to be fitting to the black point curve to find the smallest possible error.

The results of the data processing are in the one-dimensional log graph with the y-axis as a resistivity (Ωm) and the x-axis is a depth (m). The error table provides information about the graph in the form of the resistivity value of each rock layer (ρ), the depth of each layer (h), the depth of the rock layer from the surface (d), and the depth of the VES point (altitude). Point GL-1 is 15 m east of point BH-1. The GL-1 has a total length of 100 m, the depth of penetration is 30 m. The results of data processing at the GL-1 point are shown in figure 4.

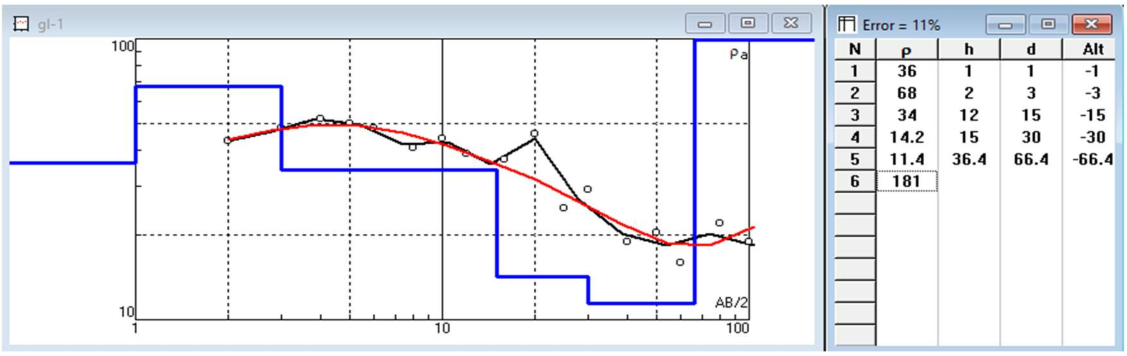


Figure 4. The results of the IPI2win processing for GL-1 point, the black point is the measurement result, the red curve is the calculation result, and the blue curve is the matching curve.

Based on the resistivity curve to depth, it was found that the top layer with a depth of 0 m - 1 m is a clay layer with a resistivity of 36 Ωm. Sandy clay is found in the next layer to a depth of 3 m with a resistivity of 68 Ωm. The loamy sand is found at a depth of 3 m - 15 m with a resistivity of 34 Ωm. The gravel sand is found at a depth of 15 m - 30 m with a resistivity of 14.2 Ωm. Andesite rock is thought to be at a depth of more than 30 m with a resistivity of 181 Ωm. The GL-2 results are shown in figure 5.

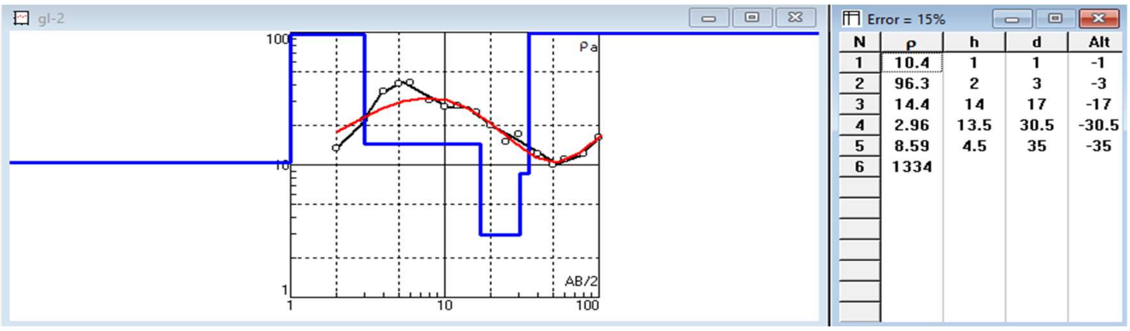


Figure 5. The results of the IPI2win processing for GL-2 point, the black point is the measurement result, the red curve is the calculation result, and the blue curve is the matching curve.

Based on figure 5 shows that the GL-2 result is similar to the GL-1 result. The top layer is clay with a depth of 0 m - 1 m with a resistivity of 10.4 Ωm. Sandy clay is found in the next layer to a depth of 3 m with a resistivity of 96.3 Ωm. The loamy sand is found at a depth of 3 m - 17 m with a resistivity of 14.4 Ωm. The gravel sand is found at a depth of 17 m - 30.5 m with a resistivity of 2.96 Ωm. Andesite rock is thought to be at a depth of more than 30.5 m with a resistivity of 1334 Ωm. The results of geoelectric processing show an error between (11-15) %. The error value shows that the data is still useable, if the error has reached 20%, the data cannot be used.

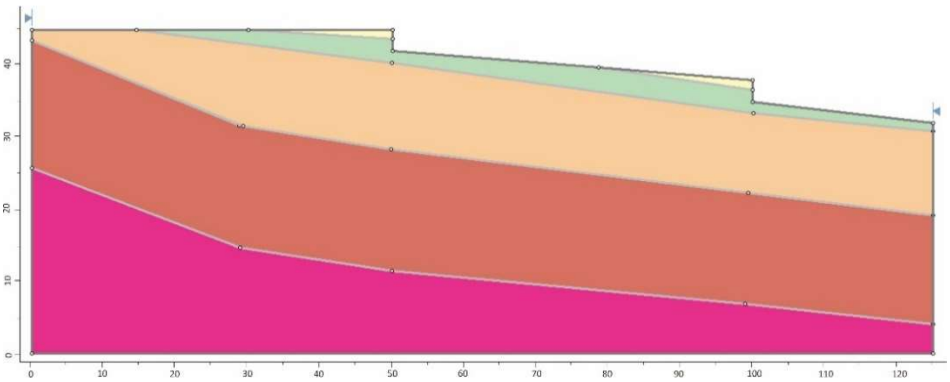
Analysis of Drilling Data

Drilling is carried out at a point that represents local soil/rock conditions. The results of core drilling are presented in table 2.

Table 2. The composition of the BH-1, and BH-2 core drilling soils

Borehole Point	Depth (m)	Soil Description
BH-1	0.00-0.70	Clay, reddish-brown, soft, with pebble gravel
	0.70-2.00	Clay, sandy, brown, soft, with pebble gravel
	2.00-5.00	Clay, brown, soft to stiff, with pebble gravel
	5.00-10.00	Sandy clay, brown, stiff to hard, with pebble gravel
	10.00-14.00	Loamy sand, greyish brown, solid
	14.00-25.00	Sandy clay, brown, hard, with pebble gravel and cobble gravel
	25.00-26.00	Gravel sand, brown, very solid
	26.00-28.00	Sandy clay, brown, very stiff, with pebble gravel
	28.00-33.00	Gravel sand, grey, very solid
BH-2	0.00-2.00	Clay, brown, firm
	2.00-11.50	sandy clay, brown, firm to stiff, with pebble gravel and cobble gravel
	11.50-17.00	Loamy sand, brown, semi-solid, with pebble gravel and cobble gravel
	17.00-21.00	Sandy clay, brown, stiff until very stiff, with pabble gravel and cobble gravel
	21.00-22.00	Gravel sand, grey, very solid
	22.00-24.50	Sandy clay, brown, very stiff
	24.50-26.50	Gravel sand, brown, very solid
	26.50-32.00	Andesite, grey, very strong
	32.00-33.50	Gravel sand, grey, very solid
	33.50-35.00	Andesite, grey, very strong
	35.00-37.00	Sand, grey, very strong
	37.00-40.00	Andesite, grey, very strong

The results of drilling BH-1 and BH-2 indicate that the lithology of the research location is by with the results of geoelectric data processing. The location of the research area is a sloping area with its dimension 125 m of length and 45 m of height. According to the results of geoelectric processing along with drilling data and geometrical conditions in the field, and the interpretation of the soil of the research location can be made as shown in figure 6.



Depth (m)	Material/Name	Color
0 - 1	Clay	
2 - 3	Sandy clay	
4 - 15	Loamy sand	
15 - 30	Gravel sand	
>30	Andesite	

Figure 6. The interpretation of the soil of the research location in Cepoko.

V. Conclusion

Based on the results of the geoelectric processing along with drilling data and geological information of Cepoko Village, Gunungpati District, Semarang, Indonesia, can be concluded that the subsurface in the studied area consists of five layers, there is clay, sandy clay, loamy sand, gravel sand, and andesite. Clays are dominating the soils in Cepoko, so further investigations are needed to prevent the landslide that can occur during the rainy season because the properties of clay can turn into sliding fields in sloping areas.

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