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Subsurface mapping of University Diponegoro Tembalang campus based on resistivity data

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Abstract. Subsurface mapping using the geoelectric method has been carried out in the area of Undip Campus, Tembalang to determine the distribution of subsurface layers resistivity. This study employs the Wenner configuration geoelectric method. Data were collected at seven points with a track length of 100 meters and a distance among electrodes of 5 meters. Data processing is carried out using RES2DINV software packages that produce rock resistivity values and depth estimates, then the interpretation of each track is carried out in detail by taking into account the geological information available in the Undip campus, Tembalang. The results of the interpretation show that the study area is dominated by breccias which are Kaligetas formations. The breccia rocks themselves are claystone which tends to be water-resistant and there is also sandstone. Nearly every data collection point has the same cross-section. Claystone with resistivity ranges from 3.05 Ωm to 26.5 Ωm . Sandstones with resistivity range from 20.0 Ωm to 135 Ωm . The rest found alluvium and sand with a resistivity of almost more than 100 μm .

1. Introduction

Diponegoro University was located in Tembalang District, Semarang is one of the best public universities in Indonesia. Construction of infrastructure facilities on campus is continuously carried out to support the learning process and the progress of Diponegoro University. Development activities include the construction of: reservoirs, parking buildings, lecture buildings, sports facilities, irrigation, final disposal, etc. The development requires the preparation of land and carrying capacity of the region. Integrated mapping is needed not only on the surface but also on the subsurface is very important. So in this study, we focus on mapping the subsurface conditions based on the distribution of resistivity values using resistivity geoelectric method. The principle of resistivity geoelectrical method is injection the current through the subsurface to obtain the potential value of the rocks and to get resistance value [1][2][3]. Wenner configuration selection is preferred for mapping with shallow depth. Furthermore, Sudarsono 1984, revealed the need to study the characteristics of the land and its functions so that they could predict what to do when loading occurred on the land.

The results of the mapping are expected to provide information about soil conditions including soil layers, soil structure, soil conditions, bedrock depth, stability. The information obtained will be used as a reference for the next infrastructure work.



Not only the structure of the building that needs to be known but also the location and condition of the underground where the building will be built. From the type of soil and the depth of bedrock where the rock has not experienced weathering in an area, the planning of the foundation model and the strength of the foundation can be determined [4].

2. Geology Information

Diponegoro University campus in the Tembalang area is in the Kaligetas Formation in the form of breccia rocks with rock characteristics formed from various rock blocks/fragments, angular/tapered lump form, which are mixed with smaller sized material/matrix. This type of rock is a rock that is very sturdy, compact, dense, as well as inclined towards impermeable rocks. The Breccia rocks are exposed on several river slopes around the Faculty of Animal and Agricultural Science campus to around the campus mosque. Breccias are also found in the northern part of the campus which is adjacent to the Permata Hijau housing complex and Bukit Diponegoro. On the north side outside the campus area, found rocks that are different from breccia rocks, namely in the form of claystone and are estimated to still belong to the Kaligetas Formation (in the form of inserts), brownish-yellow [5]. The geological map of the study area is shown in Figure 1.

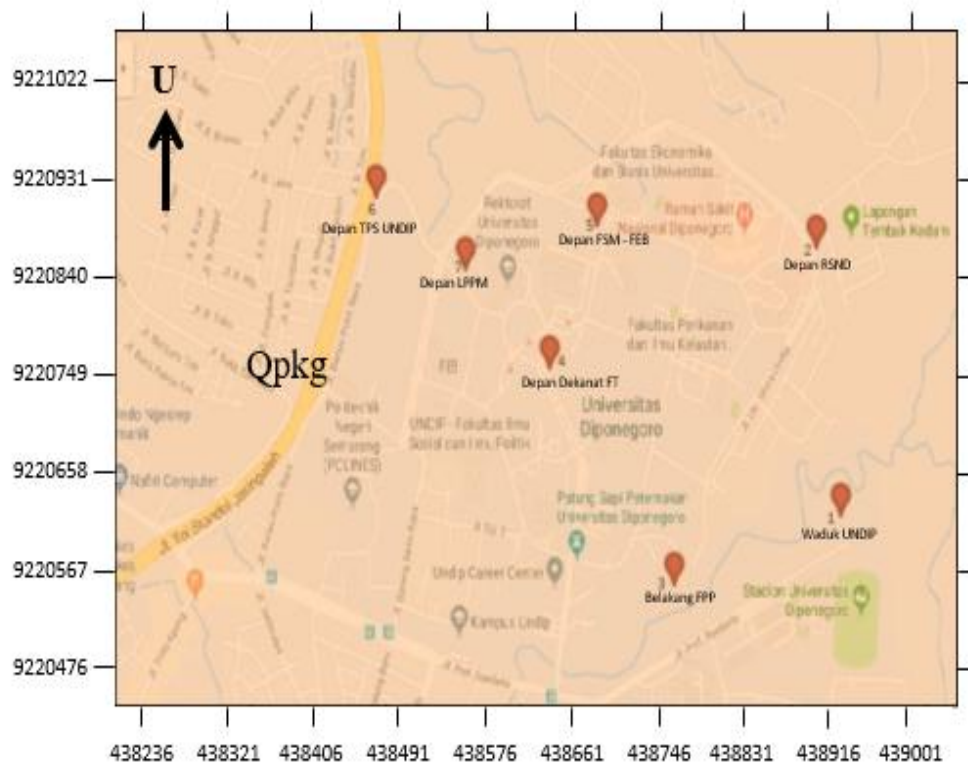


Figure 1. Geological map of the study area

3. Electrical characteristics of rocks

The electrical characteristic of the rock is a characteristic of rocks when an electric current has flowed into them. This electric current can come from nature itself due to an imbalance or an electric current that is deliberately inserted into it [6]. The composition of each different rock will certainly produce a different resistivity value. The value of rock resistivity classifies rock types which greatly varies. The rock resistivity values are presented in Table 1 [7].

Table 1 The resistivity value of rock 1 (Telford, 1990)

Material	Resistance (Ωm)
Air	0
Clay	1-100
Slit	10-200
Marls	3-70
Quartz	$10-2 \times 10^8$
Sandstone	50-500
Limestone	100-500
Lava	$100-5 \times 10^4$
Groundwater	0,5-300
Seawater	0,2
Breccias	75-200
Andesite	100-200
Volcanic Tuff	$2 \times 10^3-10^4$
Copper	1,7
Magnesium	4,2
Iron	10,1
Alluvium	10 – 800

4. Resistivity geoelectrical method – wenner configurations

A geoelectric method is one of the geophysical methods to study the nature of electricity in the earth and how to detect it [7]. This method aims to determine the subsurface conditions based on the electrical conductivity value of rocks. Injection of currents into the ground is carried out in this method through two electrodes which are also connected to the power supply. The response given by the earth is in the form of a potential difference value that is received through two potential electrodes, so we get the resistivity value of subsurface rock. The working principle of the geoelectric method is to inject an electric current into the ground using a pair of electrodes and measure the potential difference using another pair of electrodes. If an electric current is injected into the medium and its potential difference value is known, the resistance value of the medium can be known.

Pseudo resistivity is the total resistivity value of several measured layers which are considered as one homogeneous layer. The measured layer is an inhomogeneous layer at depth h_1 with resistivity value is ρ_1 at layer one, and depth h_2 with resistivity value is ρ_2 at layer two. In the measured conditions, the two layers are considered to be one homogeneous layer so that a pseudo resistivity value is obtained which is then processed by the data so that the resistivity value is obtained for each non-homogeneous layer.

Wenner configuration is a method of mapping and sounding. The measuring point of the Wenner configuration lies between the first potential electrode and the second potential electrode. The spacing between the electrodes is the same, that is, as far as a . C1 and C2 are current electrodes, P1 and P2 are potential electrodes, the arrangement of current and potential electrodes as shown in Figure 2.

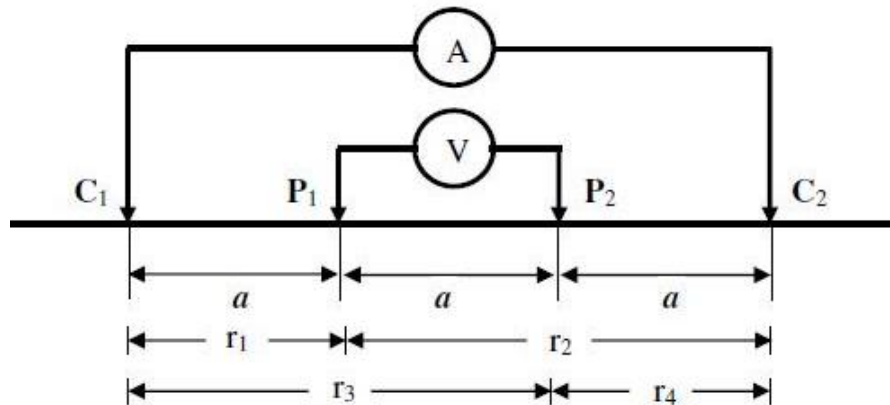


Figure 2. Wenner configuration (Loke and Barker, 1999)

Homogeneity of rocks should be considered especially on rocks that are close to the surface because it will affect the results of the measurement of potential differences in the geoelectric method. The unevenness of the rock layers is because other rock fragments are not uniformly inserted. The geometry factor is a correction that arises due to the displacement pattern and layout of the potential electrode and current electrode whose magnitude can be obtained by equation 1 through equation 5.

$$K = 2\pi \left[\left(\frac{1}{r_1} - \frac{1}{r_2} \right) - \left(\frac{1}{r_3} - \frac{1}{r_4} \right) \right]^{-1} \quad (1)$$

$$K = 2\pi \left[\left(\frac{1}{a} - \frac{1}{2a} \right) - \left(\frac{1}{2a} - \frac{1}{a} \right) \right]^{-1} \quad (2)$$

$$K = 2\pi \left[\left(\frac{2-1}{2a} \right) - \left(\frac{1-2}{2a} \right) \right]^{-1} \quad (3)$$

$$K = 2\pi \left[\left(\frac{1}{2a} \right) + \left(\frac{1}{2a} \right) \right]^{-1} \quad (4)$$

$$K = 2\pi a \quad (5)$$

where K is the geometry factor, 2π is constant, r_1 dan r_3 is the distance between the first current electrode and the first potential electrode (m), r_2 dan r_4 is the distance between the first current electrode and the second potential electrode (m) [8].

5. Method

Data acquisition was carried out in the campus area of Diponegoro University, Tembalang Semarang from April to May 2019.

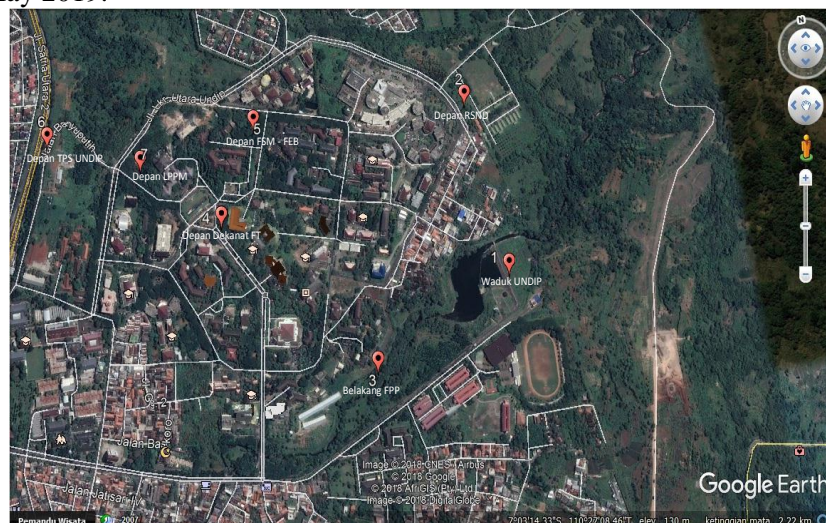


Figure 3. Research areas

The tools used in this study are a set of resistivity meters, Garmin GPS, meters, electrode rods, and hammers. The software used to process data is RES2DINV.

The data acquisition process is carried out to obtain a potential difference value which will then be processed and get a pseudo resistivity value. The apparent resistivity value will then be reprocessed using RES2DINV software so that it will immediately get the rock resistivity value in the study area. The length of the track is 100 meters with the distance among the electrodes is 5 meters and $n = 5$.

Field data obtained in the form of coordinate measurement points, current values (I) and potential (V). Furthermore, using Ms. Excel, the potential value and the current will be processed using the Wenner configuration geometry factor equation to produce an apparent resistivity value (ρ_a). This apparent resistivity value will be processed again using RES2DINV which will eventually obtain rock resistivity and subsurface cross-sectional values of the study area. RES2DINV is a computer program package that will automatically determine subsurface two-dimensional (2D) resistivity models from data obtained through geoelectric surveys. The results of modeling using RES2DINV are interpreted by synchronizing the rock resistivity table with the geology of the study area so that the subsurface structure of the study area is expected to be obtained.

The interpretation of geoelectric data is carried out to determine subsurface structures based on the resistivity value of rocks obtained. One way of interpreting geoelectric data is by matching the resistivity value of the rocks of field survey data processing results with reference sources. Based on the apparent resistivity pseudo section, interpretation and classification of the difference of resistivity values can be done to determine the type of geological material from each layer vertically or horizontally. The result of this classification is subsurface lithology. Based on the subsurface lithology condition which is a classification of the difference in resistivity values in the apparent resistivity pseudo section, it can be interpreted to determine the rock type of each layer vertically or horizontally [9].

6. Result and discussion

Point 1

Data is collected near the UNDIP reservoir with very hard soil conditions. The apparent resistivity at point 1 is shown in figure 4. It is obtained this model with a depth of 0.94 meters to 16.1 meters with resistivity values between 9.73 Ωm to 56.1 Ωm . According to the modeling results, the first layer with a depth of 0.94 meters to 5.07 meters is dominated by silt or clay with resistivity values of 20.6 Ωm to 26.5 Ωm . The second layer with a depth of 5.07 meters to 13.0 meters is dominated by tuff with resistivity values of 12.5 Ωm to 20.6 Ωm . The third layer with a depth of 13.0 meters to 16.1 meters is found again silt layer with a thickness of approximately two meters, but among them found sandstone tuff with resistivity 34.0 Ωm to 56.1 Ωm .

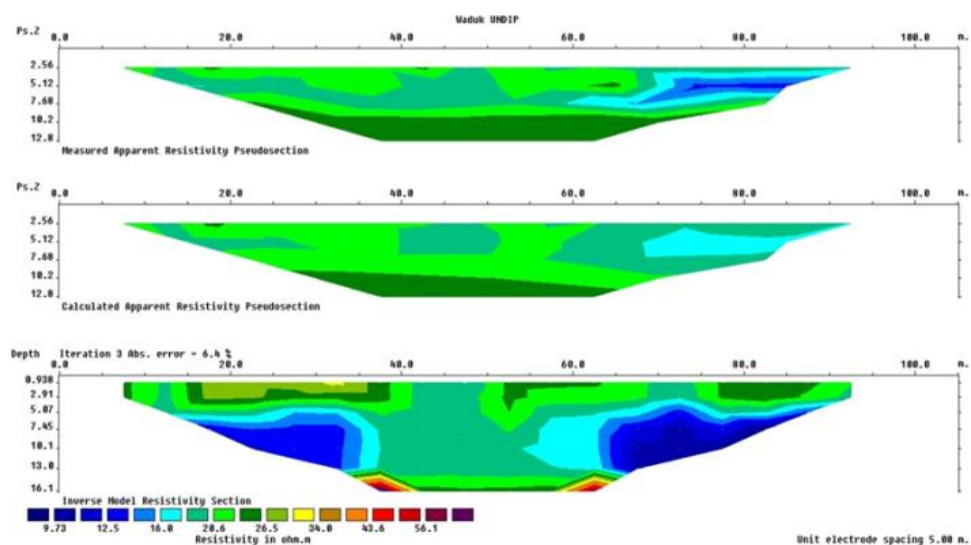


Figure 4. The apparent resistivity point 1

Point 2

Data is collected in front of Diponegoro National Hospital with very loose land conditions. The apparent resistivity at point 2 is shown in figure 5. It is obtained the model with a depth of 0.938 meters to 16.1 meters with resistivity values between 3.95 Ωm to 217 Ωm . According to the modeling results, the first layer with a depth of 0.938 meters to 5.07 meters is dominated by silt or clay with resistivity values of 3.95 Ωm to 22.0 Ωm . The second layer with a depth of 5.07 meters to 10.1 meters is dominated by sandstones with resistivity values of 22.0 Ωm to 69.1 Ωm . The third layer with a depth of 10.1 meters to 16.1 meters is found alluvium and sand layers with the resistivity of 123 Ωm to 217 Ωm .

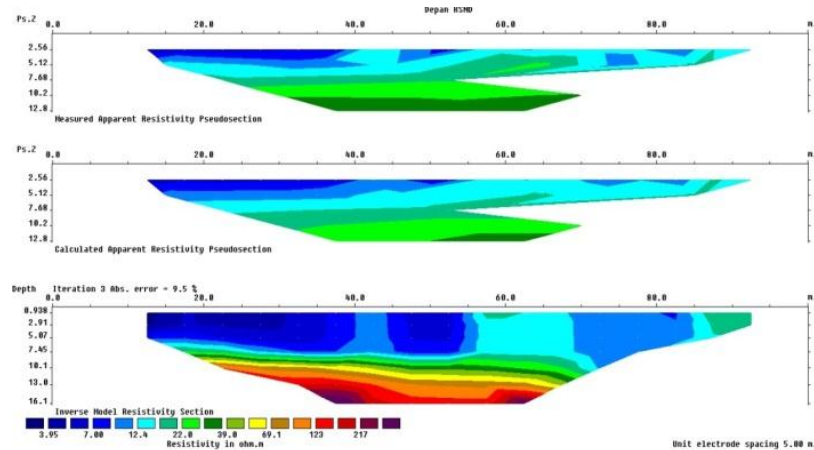


Figure 5. The apparent resistivity point 2

Point 3

Data is collected behind the Faculty of Animal and Agriculture Science with rocky soil conditions. The apparent resistivity at point 3 is shown in figure 6. It is obtained the model with a depth of 0.938 meters to 16.1 meters with resistivity values between 6.41 Ωm to 44.9 Ωm . According to the modeling results, the first layer with a depth of 0.938 meters to 7.45 meters shows several layers of rock ranging from silt with the resistivity of 14.8 Ωm to 19.5 Ωm . Still, in the same layer, a layer of sandstone is seen with a resistivity of 6.41 Ωm to 14.8 Ωm . The second layer with a depth of 7.45 meters to 10.1 meters is found silt rock layers with resistivity values of 14.8 Ωm to 25.7 Ωm , and there are also sandstones with resistivity values of 8.46 Ωm to 11.2 Ωm . The third layer with a depth of 10.1 meters to 16.1 meters is found a little layer of sandstone back with a resistivity value of 8.46 Ωm to 11.2 Ωm . A small amount of silt is also found in this layer with resistivity values of 14.8 Ωm to 25.7 Ωm . Also found layers of sandstone tuff with the resistivity of 25.7 Ωm to 44.9 Ωm . The soil at this point is dominated by very hard rock and very dry soil.

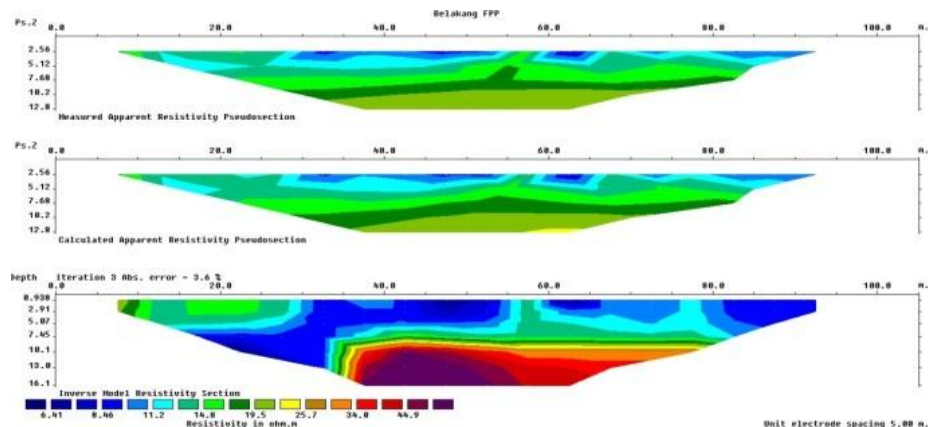


Figure 6. The apparent resistivity point 3

Point 4

Data is collected in front of the Dean Building of the Faculty of Engineering with loose and slightly rocky soil conditions. The apparent resistivity at point 4 is shown in figure 7. It is obtained the model with a depth of 0.938 meters to 16.1 meters with resistivity values between 3.05 Ωm to 248 Ωm . According to the modeling results, the first layer with a depth of 0.938 meters to 7.45 meters is dominated by silt or clay with resistivity values of 3.05 Ωm to 10.7 Ωm . The second layer with a depth of 7.45 meters to 13.0 meters is dominated by sandstones with resistivity values of 20.1 Ωm to 70.5 Ωm . The third layer with a depth of 13.0 meters to 16.1 meters is found alluvium and sand layers with resistivity 132 Ωm to 248 Ωm .

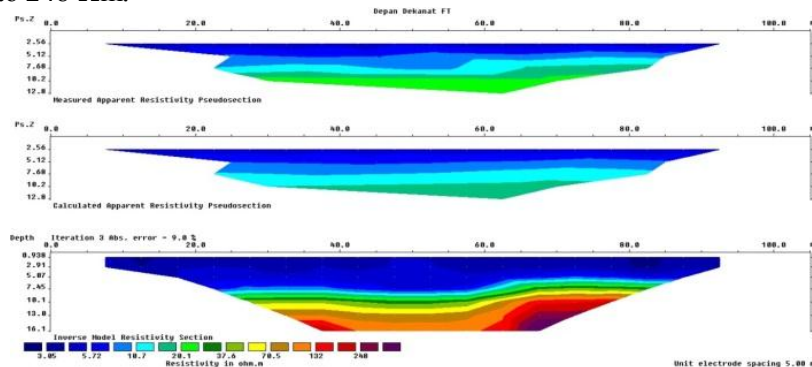


Figure 7. The apparent resistivity point 4

Point 5

Data is collected in front of the area of the Faculty of Science and Mathematics and the Faculty of Economics and Business with very loose soil conditions such as clay and slightly rocky. The apparent resistivity at point 5 is shown in figure 8. It is obtained the model with a depth of 0.938 meters to 16.1 meters with resistivity values between 3.89 Ωm to 177 Ωm . According to the modeling results, the first layer with a depth of 0.938 meters to 7.45 meters is dominated by silt or clay with resistivity values of 3.05 Ωm to 11.6 Ωm . The second layer with a depth of 7.45 meters to 10.1 meters is dominated by sandstones with resistivity values of 20.0 Ωm to 59.5 Ωm . The third layer with a depth of 10.1 meters to 16.1 meters is found alluvium and sand layers with resistivity 103 Ωm to 177 Ωm .

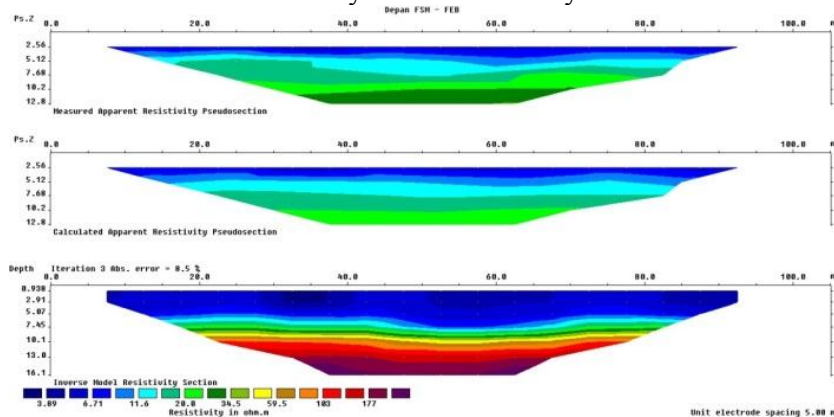


Figure 8. The apparent resistivity point 5

Point 6

Data is collected in front of the UNDIP Waste Disposal area with very loose soil conditions such as clay and slightly rocky. The apparent resistivity at point 6 is shown in figure 9. It is obtained the model with a depth of 0.938 meters to 16.1 meters with resistivity values between 3.44 Ωm to 352 Ωm . According to the modeling results, the first layer with a depth of 0.938 meters to 7.45 meters is dominated by silt or clay with resistivity values of 3.44 Ωm to 12.9 Ωm . The second layer with a depth of 7.45 meters to 13.0 meters is dominated by sandstones with resistivity values of 25.0 Ωm to 93.9 Ωm .

Ωm . The third layer with a depth of 13.0 meters to 16.1 meters is found alluvium and sand layers with resistivity 182 Ωm to 352 Ωm .

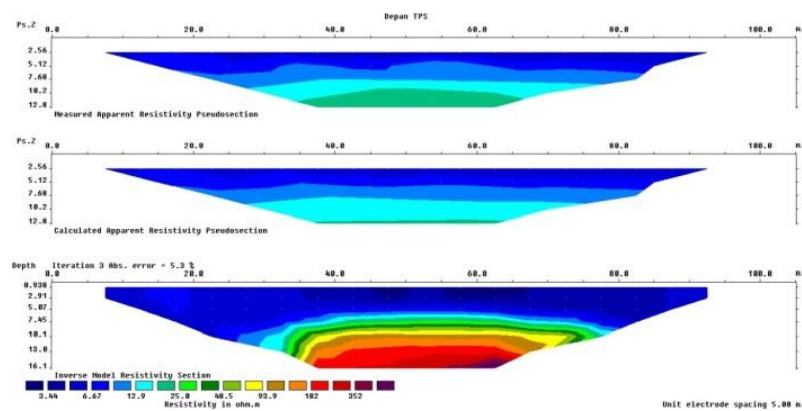


Figure 9. The apparent resistivity point 6

Point 7

Data is collected in front of the LPPM Building (next to the FISIP building) with rocky soil conditions. The apparent resistivity at point 7 is shown in figure 10. It is obtained the model with a depth of 0.938 meters to 16.1 meters with resistivity values between 4.57 Ωm to 237 Ωm . According to the modeling results, the first layer with a depth of 0.938 meters to 7.45 meters is dominated by silt or clay with resistivity values of 4.57 Ωm to 14.1 Ωm . The second layer with a depth of 7.45 meters to 13.0 meters is dominated by sandstones with resistivity values of 24.8 Ωm to 135 Ωm . The third layer with a depth of 13.0 meters to 16.1 meters is found alluvium and sand layers with resistivity 135 Ωm to 237 Ωm .

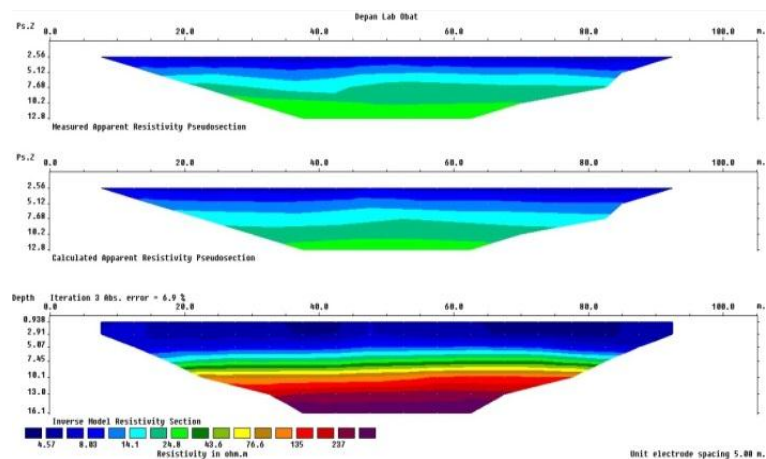


Figure 10. Cross-section of Resistivity Point 7

Based on research that has been done and the image of the resistivity of the earth's surface shown in the previous sub-chapter, it can be interpreted that the research area is generally clay and sand, for alluvium itself is included in clay, this can be proven by the geological map in the area that the research area is located in the Kaligetas Formation, wherein the formation there are also sandstones and claystone containing mollusks. Breccia rocks are also found in the study area. With the characteristics of breccia rocks which are waterproof and found along rivers in the study area, it can also be said that clay rock still dominates the study area.

In the results of the apparent resistivity of the subsurface, there are five data collection locations with the same subsurface estimation, because the results obtained are close to the same resistivity value. When viewed from the condition of the land where the data collected is more or less the same, that is very loose and slightly rocky soil. Loose soil can be interpreted as land that stores a lot of water

content. The water content can be obtained by rainwater entering the ground, or because the nature of the soil is clay which tends to be always wet and loose.

7. Conclusions

Based on the research conducted, it can be concluded that the study area is dominated by breccias which are part of the Kaligetas Formation, according to the geology of the study area. The breccia rocks themselves are claystone which tends to be waterproof and sandstone. Claystone with resistivity ranges from 3.05 Ωm to 26.5 Ωm . Sandstone with resistivity ranges from 20.0 Ωm to 135 Ωm . The rest is found alluvium and sand with the resistivity of almost more than 100 Ωm . Furthermore, for infrastructure work on the Undip campus, Tembalang, it is better to pay more attention and adjust water-resistant soil conditions, so the building that stands on it will be sturdy and durable.

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