IDENTIFICATION OF HARD LAYER USING WENNER CONFIGURATION RESISTIVITY METHOD (CASE STUDY: JALAN SAMBOJA – SEPAKU)

Febrian Dedi Sastrawan[*1], Liliana Rossa[1], Rahmania[1], Meidi Arisalwadi[1], Adrian Rahmat Nur[2]

[1]*Department of Physics, Institut Teknologi Kalimantan*
Jl. Soekarno-Hatta Km 15, Balikpapan, 65144, Indonesia
[2]*Department of Physics, Haluleo University, Kendari, Southeast Sulawesi, Indonesia*

Received: 11th August 2022 ; Revised:25th November 2022 ; Accepted: 4th April 2023

ABSTRACT

Samboja – Sepaku road is a land transportation route that can be used from Balikpapan and Samarinda to the new capital city. There is a problem with this road. Namely, cracks appear on several roads due to subsidence. This is because the soil layer supporting this road is thick and has young sediment. The hilly topography and steep ravines that dominate this road area also contributed to the subsidence. Efforts that can be made to deal with the occurrence of land subsidence are geotechnical engineering, such as making siring. In the construction process, the siring foundation must be planted in a dense layer of soil that is not easily shifted or unstable, also known as a hard layer. The hard layer's position can be determined by identifying the subsurface stratigraphy using the resistivity method. The results of the subsurface lithology depiction obtained two types of soil layers that dominate the roadside area, namely clay layers with resistivity values of 2.31 Ωm – 15.1 Ωm and sandy clays with resistivity values of 38.7 – 253 Ωm. The clay layer is recommended as a hard layer at a depth of 15-20 meters..

Keywords: Hard layer; subsurface; lithology; resistivity; stratigraphy

Introduction

Samboja - Sepaku Road is one of the traffic access areas in East Kalimantan Province with a reasonably high level of mobility. As a result, the road is subjected to a relatively large load, and it is necessary to pay attention to the road's carrying capacity based on the subsurface layer's structure. Based on the geological map sheet of Samarinda, this road area is dominated by a thick layer of sediment with easily released characteristics, such as clay. The clay layer has swelling and shrinkage properties, where if the clay is saturated with water, the clay will expand, and if it is dry, the clay will shrink.[1] As a result of the properties of clay, it causes problems in the body of Jalan Samboja – Sepaku, namely cracks arise. This indicates that this road has the potential for landslides such as subsidence. Mitigation efforts can be made to overcome the threat of subsidence on this road are to making siring or retaining walls.[2] In the construction process, the piles of the siring must be planted to reach a hard layer that can become a good carrying capacity for the siring in holding and continuing the load it will receive.[3]

One way that can be done to determine the position of the hard layer is to identify the composition of the subsurface layer. The method that can be used to determine the distribution of the composition of the subsurface layer is by using the geophysical method. Geophysics is the study of the dynamics of the earth with the rules or principles of physics.[4] Many principles of physics can be used according to the type of method to apply. Examples are seismic methods, gravity methods, magnetic methods, electromagnetic methods, and resistivity methods.[5] One of the geophysical methods that can be applied to determine the structure of the surface layer is the resistivity method.[6]

*Corresponding author.
E-Mail: febrian.dedi@lecturer.itk.ac.id

The working principle of the resistivity method is the utilization of the electrical properties of rocks, namely the ability to withstand electric currents through them, which is called resistivity.[7] This method utilizes the resistivity (specific resistance) properties of the subsurface layer of the earth. This resistivity value is obtained from the relationship between electric current and voltage. The relationship between these three is the principle of applying Ohm's Law. Mathematically written as follows[8]:

$$R = \frac{V}{I} \quad (1)$$

The resistivity method works by injecting an electric current into a medium that carries a D.C. (Direct Current) electric current with a high voltage into the ground. [9-10] The result of the current injection will be measured by the potential distribution through the potential electrode. The resistivity value of the subsurface layer is obtained from the amount of current emitted through the current electrode and measures the response in the form of potential at a potential electrode due to an electric current injected into the earth.[11] If you want to get the results as a picture of the arrangement of the deep subsurface layers, then the distance between each electrode, current and potential, gradually increases. The greater the distance between the electrodes, the deeper the current penetration into the subsurface layer.[12]

The application of this method has a configuration or arrangement of electrodes used in the data collection process depending on what is to be achieved or the purpose of the application. The configuration used in this study is the Wenner configuration because the purpose of this study is a horizontal mapping to get an overview of the distribution of the identified layers. This configuration is composed of the distance between the electrodes, both the current and potential electrodes, of the same length. This configuration is suitable for mapping because the coverage of the horizontal direction is excellent.[13]

The resistivity method also has the advantage that it can see the structure of the subsurface layer laterally and in 2 dimensions. From the 2-dimensional model obtained, it is hoped that it can describe the structure of the subsurface layer so that conclusions can be drawn regarding the layers that make up the subsurface on the measurement trajectory.[14] In addition, the resistivity method is also environmentally friendly because it does not damage the structure of the soil layer. This method is also suitable for shallow exploration and relatively faster for data collection.[15]

Methods

The research area is on Jalan Samboja – Sepaku, which connects Kutai Kartanegara Regency and North Penajam Paser Regency. Based on the Geological Map of Samarinda Sheet, the research area is located in the Pulau Balang Formation and the Balikpapan Formation. This study measured five measurement paths using the Wenner configuration resistivity method. The length of the measuring track is 150 meters.

Measurements are made by injecting current under the earth's surface through current electrodes. As a result, the current entering the ground will cause the value of the measured potential difference through the potential electrode. The electrode arrangement used in the Wenner configuration consists of two current electrodes and two potential electrodes with an equal distance between the electrodes. The electrode used is connected to a resistivity meter.

The measurement results from the field obtained the value of the injected current and potential difference. These two values are used to obtain the apparent resistivity value of the detected subsurface layer using a geometry factor. The apparent resistivity value is then processed with RES2DInV software to obtain a 2D modeling of the subsurface layer. The resulting 2D cross-section is then interpreted based on the distribution of resistivity values supported by regional and local geological data in the study area.

Result and Discussion

The distribution of the resistivity value of the subsurface layer of the earth is influenced by the fluid content, porosity, and metal mineral content.

The interpretation results on measurement path one is composed of a layer of clay with a resistivity value of 2.31 – 15.1 Ωm and sandy clay with a resistivity value of 38.7 – 253 Ωm. The maximum achievable depth based on a 2D cross-section is 30 meters. The clay layer spreads at a distance of ±20 – 65 m and gets thicker as it gets deeper. The sandy clay layer spreads from the surface to a depth of 30 meters and thickens as the distance between the electrodes increases. The sandy clay layer that inserts on the surface has a higher resistivity value than the other layers due to the less water content due to the dry soil conditions. The hard layers identified in this measurement path are clay layers at a distance of ±20 – 60 m and sandy clay at a distance of ±65 – 130 m with a depth of 25 – 30 m. The properties of clay begin to solidify and harden with dry conditions and are plastic in moderate water conditions. The sandy clay layer has a sand content that, although the bearing capacity is low, can increase the shear strength value in the layer

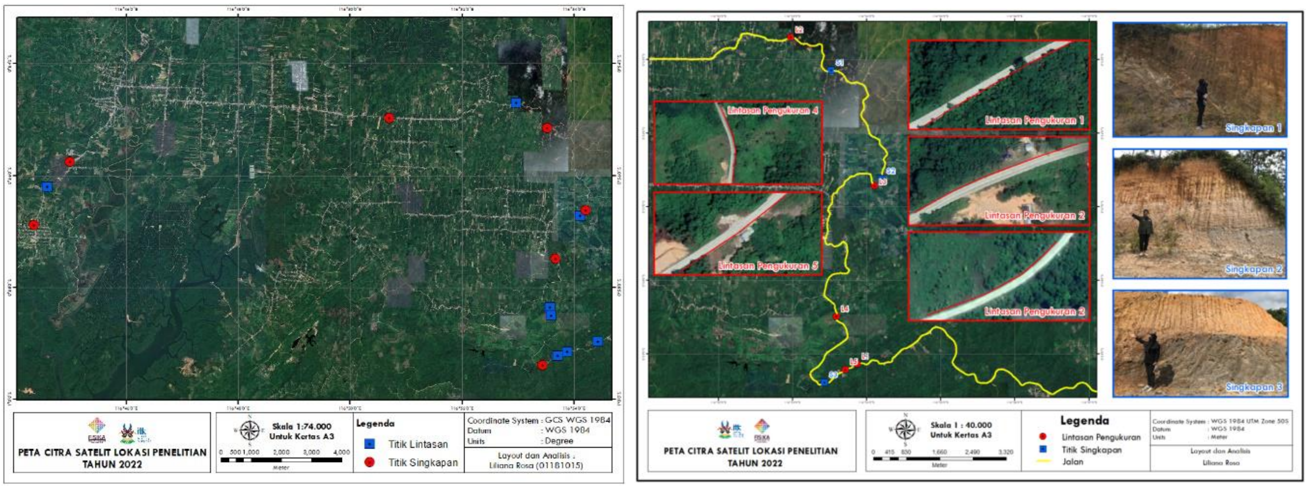

Figure 1. Map of the Research Area with Measurements and Outcrops

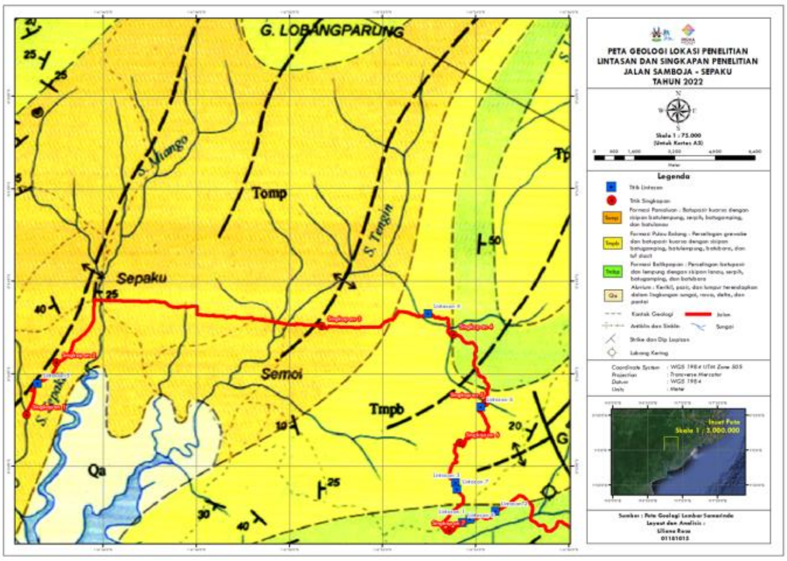

Figure 2. Geological Regional Map Sheet Samarinda

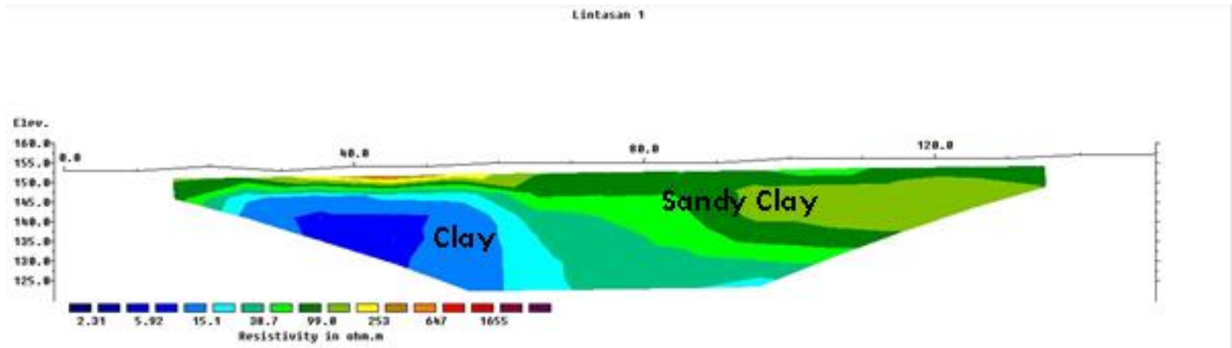

Figure 3. 2D Cross-Section Inversion Results of Measurement Path 1

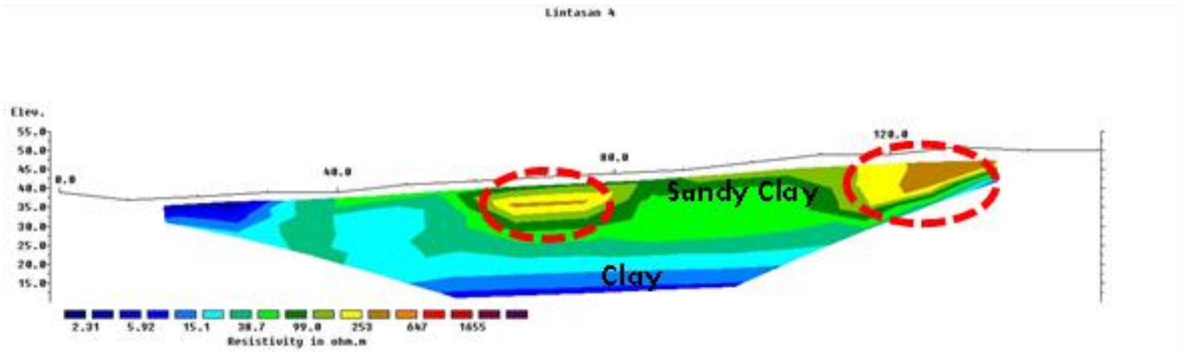

Figure 4. 2D Cross-Section Inversion Results of Measurement Path 2

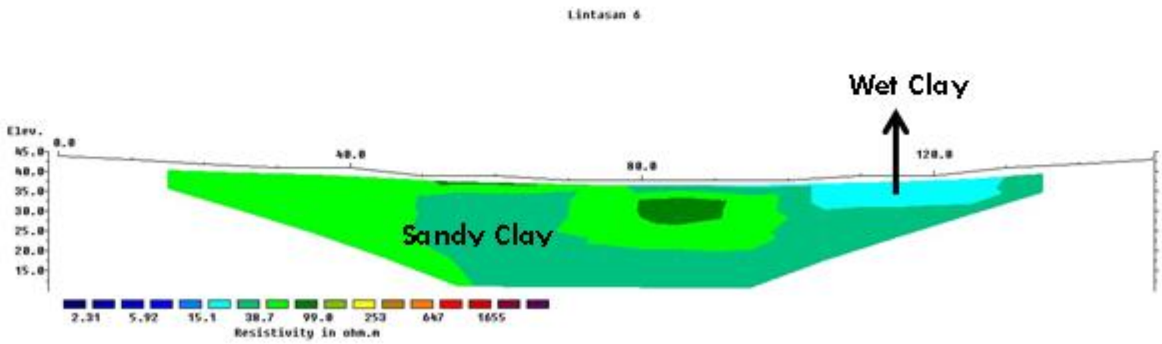

Figure 5. 2D Cross-Section Inversion Results of Measurement Path 3

The interpretation results on measurement path two are composed of a sandy clay layer with a resistivity value of 38.7 – 253 Ωm and a clay layer with a resistivity value of 2.31 – 15.1 Ωm. The maximum achievable depth based on a 2D cross-section is 25 meters. There is a difference in water content in the sandy clay layer, which can be seen from the color gradation of the modeling results in this layer. Layers with lighter colors have higher resistivity values due to the low fluid content. A dry layer will make the cavities between pores larger so that the current that passes through them is held back more. The clay layer has a lower resistivity value because of the large water content contained in this layer. The nature of water that efficiently conducts electricity makes the resistance of the clay layer low. The hard layer identified in this measurement path is a layer of clay at a depth of 20 – 25 meters at a distance of ± 50 – 100 meters. Increasing shear strength in clays with deeper depths tends to be faster than at the surface or with fewer depths.

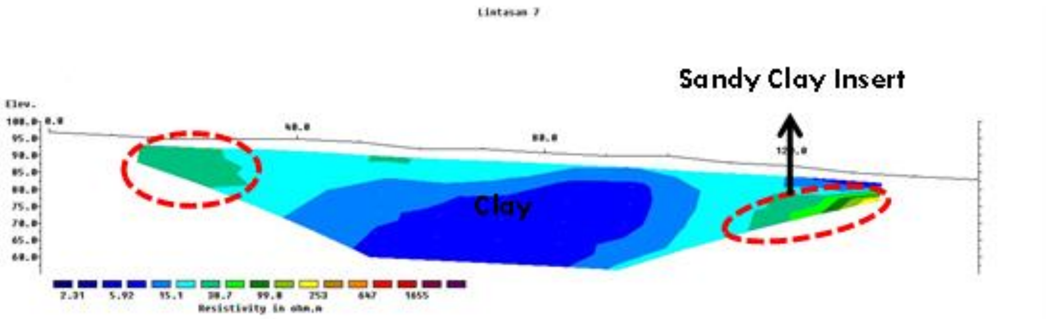

Figure 6. 2D Cross-Section Inversion Results of Measurement Path 4

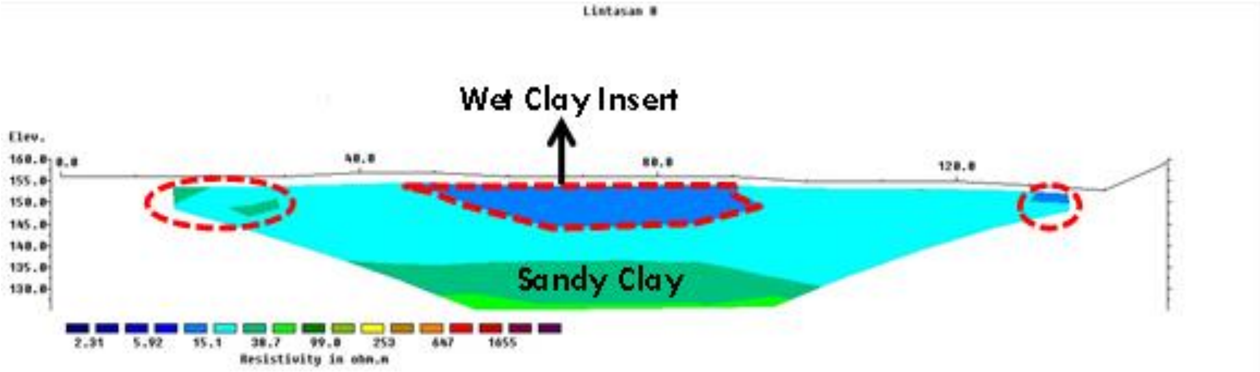

Figure 7. 2D Cross-Section Inversion Results of Measurement Path 5

The interpretation results on measurement path three are composed of a sandy clay layer with a resistivity value of 38.7 – 99.0 Ωm and a clay layer with a resistivity value of 15.1 Ωm. The maximum achievable depth based on a 2D cross-section is 32.5 meters. Based on the cross-sectional image of the 2D inversion, the sandy clay layer with a green color of Tosca has a lower resistivity value than other sandy clay layers. This is because the clay content that composes this layer is more. More clay content can trap water entering the larger layer. The amount of water trapped in this layer makes the resistivity value low. In the bright green sandy clay layer are chunks of dark green sandy clay with a high resistivity value scale. Sandy clay chunks have a high resistivity value due to the low water content in this layer. The layer begins to undergo a petrification process, so the current will be blocked more when electrified. The clay layer inserts on the surface at a distance of ±112 – 130 m from the surface to a depth of 10 m with a low resistivity scale characterized by light blue color. Due to its position on the surface, the clay is in direct contact with the outside environment, so rainwater enters this layer first. It is supported by the nature of the clay that can trap water, making the resistivity value low. If siring will build on track 3, it is recommended to put the piles in the sandy clay layer at a distance of ±50 – 100 m at a depth of 15 – 30 m. Sandy clay layers with less water and deeper depths will be more compact due to geological processes, namely higher compaction. Supported by a large amount of sand content, this layer can withstand heavy loads and has a reasonably low shear rate.

The interpretation results on measurement path four are composed of a clay layer with a resistivity value of 5.92 – 15.1 Ωm and a sandy clay layer with a resistivity value of 38.7 – 253 Ωm. The maximum achievable depth based on a 2D cross-section is 30 meters. Clay layers with low resistivity values form subsurface intrusions at a distance of ±40 – 115 m at a depth of 5 – 30 m. This layer causes cracks in the road body due to the shrinkage nature of the road. The more water content due to the large surface area, this layer expands and causes the layer above it to crack. A light blue characterizes the clay layer with a higher resistivity value because it has less water content. A layer of sandy clay with a moderate to high resistivity value is inserted into the light blue clay layer reaching a depth of 15 meters. This layer forms chunks at a distance of ±115 – 135 m at a depth of ±10 – 25 m. The porosity in sandy clay makes it easier for currents to be held in this layer, so the resistivity value is higher than that of clay. The layer identified as a hard layer on measurement path 4 is a clay layer with a moderate resistivity value scale at a depth of 25 m at a distance of ±35 - 115 m. The deeper depth and distance from the surface will make the clay denser, and increasing the shear strength value on the clay tends to be faster. The water content in this clay also supports this is lower than the clay that forms the intrusion.

The interpretation results on measurement path five are composed of a layer of clay with a resistivity value of 15 – 20 Ωm and a sandy clay layer with a resistivity value of 38.7 Ωm. The maximum achievable depth based on a 2D cross-section is 27.5 meters. A layer of clay with a low resistivity value is inserted on the surface to a depth of 12.5 meters between a layer of clay with a moderate resistivity value. Based on the field conditions of measurement path 5, the presence of this layer is evidenced by the presence of puddles on the soil surface around the measuring electrode. The impermeable nature of clay makes water that should have entered the soil layer trapped at the surface. Overall the clay layer formed reaches a depth of ±17.5 m. The difference in the blue color that characterizes the clay layer is due to the difference in water content that fills the layer. Clay has more water content which makes the electrical resistance of clay lower. Based on the color gradation in the inverted cross-section, the sandy clay layer with a turquoise green color has more clay content than the light green one. Layers with more clay content have small spaces between constituent particles, making it easier for current to flow through them. Light green clay has more sand content, so it has a large space between the particles that make up the layer. The layer containing sand also has a low water binding ability because it has large pore spaces and a high permeability level. Planting piles on measurement path, five is recommended at a depth of 17.5 m at a distance of ± 50 - 100 m, with the type of hard layer being a sandy clay layer. The sandy clay layer has undergone a more complex geological process than the clay layer on the surface because the depth of this layer is much deeper, so the water content that fills this layer is also lower. That although there is clay content in the sandy clay layer, the density is better than the clay layer on the surface and is supported by more complex geological processes, so the density is also good. The sand content in this layer can also increase the soil's density and reduce the soil's water content.

Conclusion

The results showed that the subsurface layer of the five measurement paths consisted of a layer of clay with a resistivity value of 2.31 Ωm – 15.1 Ωm and sandy clay with a resistivity value of 38.7 Ωm – 253 Ωm. The estimated depth of the hard layer ranges from 15 – 20 meters from the soil surface, with most of the layer types being clay. This information regarding the estimated depth of the hard layer can be used as an initial study material if later road repairs are carried out with the construction of siring.

References

1. Putra RH, Haza ZF, Sulistyorini D. Pengaruh Pasir Terhadap Tingkat Kepadatan Tanah lempung Ekspansif. RENOVASI: Rekayasa Dan Inovasi Teknik Sipil. 2018 Aug 19;3(2):21-32.
2. Noor, Djauhari. Stratigrafi Analisis. Bogor: Fakultas Teknik Universitas Pakuan; 2019.
3. Wesley, L. D. Mekanika Tanah untuk Tanah Endapan dan Residu. Yogyakarta: Penerbit Andi; 2010.
4. Dobrin, M.B., dan Savit, C.T. Introduction to Geophysics Prospecting 4th Edition. Newyork: McGraw-Hill Book Company; 1988.
5. Kearey P, Brooks M, Hill I. An Introduction to Geophysical Exploration:

Third Edition. United Kingdom: Blackwell Science Ltd; 2002.
6. Kanyawan., Oktavia Erviana, Zulfian. Identifikasi Struktur Lapisan Bawah Permukaan menggunakan Metode Geolistrik Tahanan Jenis sebagai Informasi Awal Rancang Bangun Pondasi Bangunan. Pontianak : Universitas Tanjungpura; 2020.
7. Fuadi Z, Muhardi M, Yusa M. Identifikasi Lapisan Bawah Permukaan dan Bidang Gelincir Lereng Kelurahan Muara Lembu Metode Geolistrik. Siklus: Jurnal Teknik Sipil. 2020 Mar 30;6(1):56-66.
8. Telford, W.M., Sherif, R. and Keys, D.D. Applied Geophysics First Edition. Cambridge, NY: Cambridge University Press;1976.
9. Setiono., Dedi, dkk. Penyeledikan Zona Akuifer menggunakan Geolistrik Metode Schlumberger di Sekitar Pantai Utara Kecamatan Kramat, Suradadi dan Warureja Kabupaten Tegal, Jawa Tengah. Semarang : Universitas Diponegoro; 2014.
10. Abdullah, Mikrajudin. Fisika Dasar II. Bandung : Institut Teknologi Bandung; 2017.
11. Telford, W.M., Sherif, R.E. and Keys, D.D. Applied Geophysics Second Edition. Cambridge, NY: Cambridge University Press; 1990.
12. Manrulu RH, Nurfalaq A, Hamid ID. Pendugaan sebaran air tanah menggunakan metode geolistrik resistivitas konfigurasi wenner dan schlumberger di kampus 2 universitas cokroaminoto palopo. Jurnal Fisika Flux: Jurnal Ilmiah Fisika FMIPA Universitas Lambung Mangkurat. 2018 Feb;15(1):6-12.
13. Taib, M.I.T. Eksplorasi Geolistrik Diktat Kuliah Metoda Geolistrik. Bandung: Departemen Teknik Geofisika ITB;2004.
14. Afdal A. Penentuan Konfigurasi Elektroda Metode Geolistrik Tahanan Jenis Paling Optimum untuk Survei Air Tanah. Jurnal Ilmu Fisika. 2009 Sep 5;1(2):1-7.
15. Sastrawan FD, Arisalwadi M, Rahmania R. Identifikasi Lapisan Bawah Permukaan Berdasarkan Data Resistivitas 2 Dimensi. JST (Jurnal Sains Terapan). 2020 Sep 30;6(2):99-105.