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Investigation of Groundwater Aquifer Using Electrical Resistivity Method Wenner-Schlumberger Array Mattoangin Village, Bantimurung District, Maros Regency

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Abstract

Groundwater as a source of clean water which is very important in fulfilling the needs of humans is considered suitable as the main alternative. Layers investigation of soil that is permeable to water (aquifer) in Mattoangin Village, Bantimurung District, Maros Regency aims to obtain 2D model map of the distribution of groundwater below the surface. The presence of groundwater stored in aquifers can be explored by geophysical methods. The Wenner-Schlumberger array has a good resolution so it is deemed suitable for aquifers. The measurement data was processed using Res2DInv software. The exploration resulted in a 2D cross-sectional model of the subsurface resistivity. Based on the results of measurements and data processing, the groundwater aquifer which has the potential to have resistivity values of 9.73-32.7 Ωm on track 1, resistivity values of 6.24-32 Ωm is on track 2 with a depth of 6 - 10 m and resistivity values of 5.68-33, 6 Ωm on track 3 with a depth of 6 - 8 Ωm.

Keywords: Aquifer zone; geo-electrical; resistivity; Wenner-Schlumberger.

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Introduction

Water is a basic need for every living thing. Water is also needed by humans in fulfilling all aspects of life. Humans need clean water, both for daily needs and for drinking (Fadli et al., 2020). However, fulfilling the need for clean water is experiencing problems in several regions of Indonesia. This is due to climate change which causes abnormal natural phenomena, which is the uncertainty of rainy and dry seasons (Larson et al., 2016).

Maros is a part of the Regency in South Sulawesi in Indonesia where many of the population experience access to clean water when the dry season occurs. Maros Regency has a wellspring system as a cave, with a good water system. This can be seen in the Bantimurung Watershed's establishment, which is a clean water source for the surrounding community. As a source of clean water, this problem does not guarantee that it will always fulfill the needs of the community, moreover, in Maros Regency, there has been a drought which has had an impact on the agricultural sector. The need for groundwater in Bantimurung District can be a solution in the long term (Heryani, 2014).

Even though Maros Regency has a good water system, drought often occurs in several areas. One of them occurred in the Lekopancing River Basin Area. In 2017, the Lekopancing River Dam in Maros Regency experienced a drought. The impact of drought has hampered the supply of clean water to the North and East of the City (Wahdaniyah et al., 2017).

Regionally, the Bantimurung District, Maros Regency is dominated by the Tonasa Formation Limestone rock formations which were deposited in the central area, between Maros and Pangkajene, having a thickness of at least 600 m. That limestone was deposited in a shallow marine environment in the form of a stable shelf with dimensions of at least 80 km wide. The deposition of these limestones requires at least a decrease in exposure rate of 3 cm/1000 years (Arsyad et al., 2020).

Groundwater is water that is in the cavities of the deep layers of the soil. Groundwater can also be said to be water below the ground surface. Groundwater generally comes from rainwater that enters the soil through pore spaces (Rizal, 2021).

Groundwater is stored in geological formations called aquifers in the form of porous materials or rocks with the condition that they can store water and has good permeability (Daniswara et al., 2019). The formation of aquifers and their various characteristics is influenced by several factors such as past geomorphological processes, the depositional environment when the rock was formed, the mineral composition of the aquifer, the process and pattern of groundwater movement, and the time the groundwater was trapped in the rock layers (Maria et al., 2018)

Based on its depth, aquifers are divided into 2, which are shallow aquifers and deep aquifers. Shallow aquifers or what can be called phreatic are near the surface of the earth, with a thickness of about 5 – 25 meters. While the aquifer or called arteries is at a depth of 80 meters (Rizal, 2021).

Nowadays, the characterization of bedrock aquifers and their sustainable exploitation is the key to water security in the near term (González et al., 2021). To be able to determine the existence of water sources, it is necessary to detect the presence of aquifer layers in the area. The aquifer layer in the ground cannot be seen directly. The existence of aquifer layers in different places also has different conditions, both in-depth and thickness. There are places where it is difficult to find aquifer layers but there are also places where it is easy to find aquifer layers (Darsono, 2019).

Generally, the resistivity method is only good for shallow exploration with a maximum depth of around 100 meters. If the layer depth is more than this value, the information obtained is less accurate, this is due to the large stretch with the aim of obtaining a penetration depth above 100 m, and the current flowing will be weaker (Minanda et al., 2021). Hence, this paper briefly discusses the application of the electrical resistivity method based on groundwater exploration.

Materials and Methods

Resistivity as a geophysical method basically is observing the symptoms of disorders that occur in normal conditions. The current flows into the earth's layer through two current electrodes in this method (Figure 1). By knowing the value of the potential current, the resistivity value can be determined (Nurfalaq et al., 2021). Electrical resistivity methods are often observed using specific electrode arrays to obtain the resistivity images that show the change in electrical resistivity within the subsurface for the evaluation of basement aquifers (Oyeyemi et al., 2022).

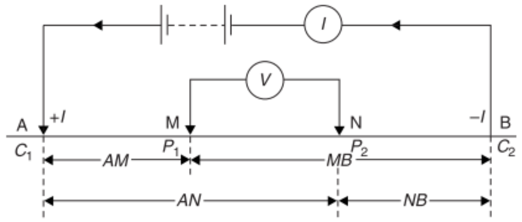

Figure 1. Two current electrodes and two potential electrodes on a homogeneous earth surface (Sunarya et al., 2017).

The geophysical problem is an inversion problem that can estimate model parameters based on observational data.

Problems that can be solved by the inversion method can be represented quantitatively by a physical or mathematical approach. The process of estimating the model and model parameters is based on the data observed on the surface (Miftahurrosyada et al., 2022).

Resistivity is a characteristic of the rock that shows the ability of the rock to conduct electric current (Figure 2). This resistivity value can be determined by connecting the battery with an Ammeter and a current electrode to measure the amount of current flowing into the ground (Jamaluddin & Umar, 2018).

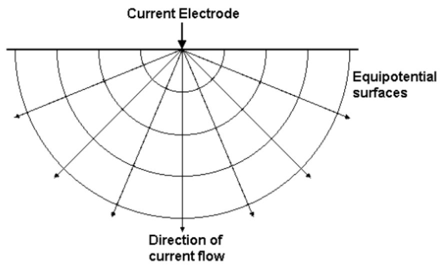

Figure 2. Simplified current flow lines and equipotential from a single current source (Jamaluddin & Umar, 2018).

The application of resistivity method is capable of mapping both low and high resistive formations, and therefore it is a valuable tool for vulnerability studies. With the geometry factor (Jamaluddin & Umar, 2018):

$$k = \pi n(n+1)a \qquad (1)$$

The resistivity data obtained from measurements is the apparent resistivity data. Apparent resistivity data are generally displayed as colored contour maps and interpreted qualitatively (Andriani et al., 2016). The apparent resistivity can be expressed in the form:

$$\rho_a = K\frac{\Delta V}{I} \qquad (2)$$

$$K = \frac{2\pi}{\left(\frac{1}{r_1}-\frac{1}{r_2}\right)-\left(\frac{1}{r_3}-\frac{1}{r_4}\right)} \qquad (3)$$

description:
ρ = Apparent Resistivity (Ωm)
a = Electrode Spacing (m)
I = Electric Current (A)
ΔV = Potential Difference (V)

Where K is geometric factor which is the amount of correction for the location of the two potential electrodes to the location of two current electrodes. The geometric factor depends on the configuration of the current and potential electrodes (Darisma et al., 2020). Geometry values and factors will follow the distribution pattern of the electrodes (Flaño et al., 2018).

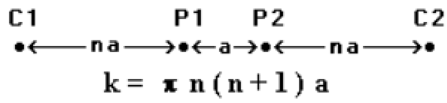

Figure 3. The Setting of Wenner-Schlumberger Array (Jamaluddin & Umar, 2018).

Various arrays are frequently used in the resistivity method. One of them is the Wenner–Schlumberger array (Figure 3). The Wenner–Schlumberger Array is a modification and combination of Wenner and Schlumberger Arrays. Wenner-Schlumberger Array can read data vertically and horizontally better than Wenner Array. Wenner-Schlumberger has good data readability due to how the datum density of this array works. This can be seen from how the datum shape of the array. Datum has maximum data density so that the identified geological model has high accuracy (Bery., 2014).

The research location and resistivity data acquisition are in the Mattoanging Village area, Maros Regency, South Sulawesi Sulawesi (Figure 4). Measurements were observed on 3 tracks with each length of 150 meters with 5 meters of electrodes.

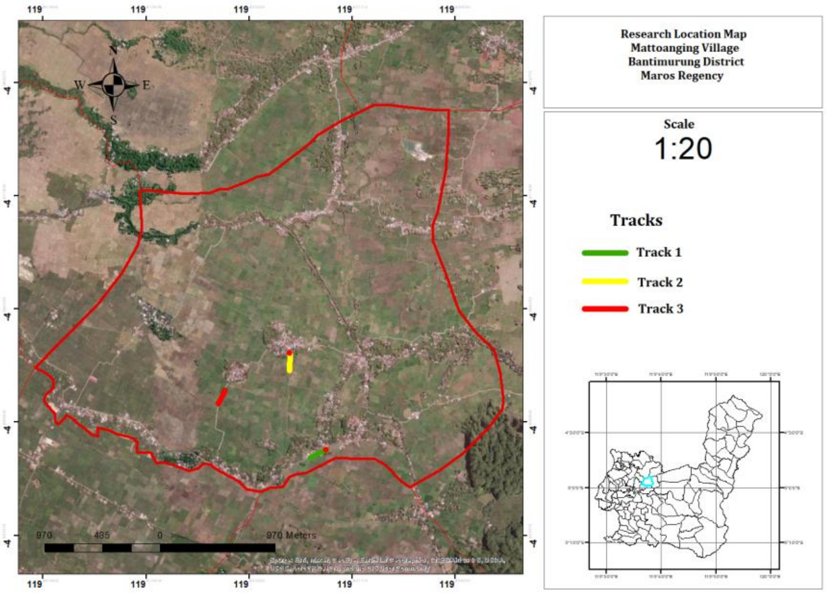

Figure 4. Research Location Map and Data Acquisition (Google Earth, 2022 & BIG, 2022)..

The tools used in this study were a set of Geomative Multi-Channel geoelectric tools, electrodes (stainless steel), cables, meter rolls, geological hammers, GPS (Global Positioning System), batteries, compasses, field safety tools, and software such as Res2DInv, Surfer, Google EarthPro, and Microsoft Excel.

Subsurface resistivity modeling was carried out using the inversion finite difference method for each path to obtain a cross-section of the electrical resistivity layering model of the subsurface soil or rock layer. The condition of water saturation is based on the cross-sections obtained in each layer, so that the condition of subsurface groundwater along the measurement path can be identified. (Bakri, 2015).

In obtaining the apparent resistivity value, data processing is carried out by entering current, voltage, and geometry factor values into Microsoft Excel. The data is combined with topographical data and the format is adjusted in a Notepad file so that it can be processed in Res2DInv software with the least square inversion tool to obtain a resistivity cross-section.

So, the scale on resistivity value and the value of apparent resistivity is entered into Golden Surfer software and will get a display of lithology data.

Table 1. Rock resistivity values (Sunarya et al., 2017).

Material	Resistivity (Ωm)
Natural Waters	0.5 – 150
Clays	1 – 100
Sand	1 – 1000
Andesite	100 – 200
Alluvium	10 – 800
Breccias	75 – 200
Gravel	100 – 600
Sandstone	200 – 8000
Limestone	50 – (1 x 10^7)
Granite	5 x 10^3 – 10^6
Basalt	10^3 – 10^6
Slate	6 x 10^2 – 4 x 10^7
Sandstones	8 – 4 x 10^3
Shale	20 – 2 x 10^3
Limestones	5 – 4 x 10^2
Vulcanic Tuff	20 – 100
Lavas	100 – 5 x 10^4
Conglomerates	6 x 10^3 – 2 x 10^4

The iteration process is carried out 5 times iteration. Iteration is aimed to reduce the RMS error data value. The results obtained are in the form of a resistivity section below the 2D surface. By providing a reference to the resistivity values of rock types as in

Table 1, it will be known what is contained in the subsurface layer of the soil.

In determining the estimated layer, there are reliable references, which is the Indonesian National Standard (SNI) 2818 of 2012, regarding the Schlumberger measurement of groundwater and SNI 2528 of 2012 regarding the measurement of Wenner groundwater. SNI 2818 and SNI 2528 attach area conditions, water types, and types of sediment layers based on the measured resistivity scale (Table 2–4).

Table 2. Land detention with resistivity scale (SNI, 2012).

Land detention	Resistivity (Ωm)
Wet Area	50 – 200
Dry Area	100 – 500
Very Dry Are	200 - 1000

Table 3. Water type with resistivity scale (SNI, 2012)

Water type	Resistivity (Ωm)
Ground Water	1 – 100
Rainwater	30 – 1000
Sea Water	< 0.2
Ice	105 - 108

Table 4. Rock type with resistivity scale (SNI, 2012)

Rock type	Resistivity (Ωm)
Igneous and Metamorphic rocks	100 - 10000
Consolidated Sediment	10 – 100
Unconsolidated Sediment	1 -100

Results and Discussion

Geoelectrical measurements on track 1 are 145 meters long with an electrode spacing of 5 m that is oriented west-east. Using the Wenner-Schlumberger array resulted in 196 data datums. Geoelectrical data inversion on line 1 resulted in a resistivity cross-section as shown in the Figure 5 with an RMS error value of 1.4. the lowest resistivity value is 9.73 Ωm and the largest is 110.01 Ωm.

Based on information from wells around the measurement track, it can be known that the groundwater level is 1 meter, with a layer of sandy loam down to the bottom of the well as deep as 3 meters. From the drilled well it is known that the bedrock is in the form of limestone 6 meters deep.

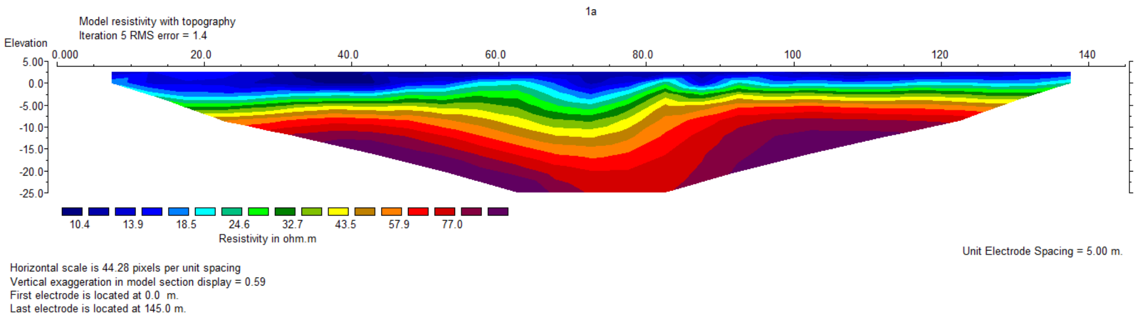

Figure 5. Track 1 and Coordinate (791558,9447740).

Based on information from wells data and resistivity cross-sections, it can be concluded that the cross-section of line 1 contains 2 layers, which are (Figure 6):

1. The first layer with a low resistivity value with a resistivity value range of 9.73 – 32.7 Ωm is interpreted as a layer of sandy clay with a thickness varying from 6 – 10 meters. This layer is a shallow aquifer layer.
2. The second layer with a high resistivity value with a resistivity value range of 32.7 – 110 Ωm is interpreted as a layer of limestone up to the end of the data as deep as 30 meters.

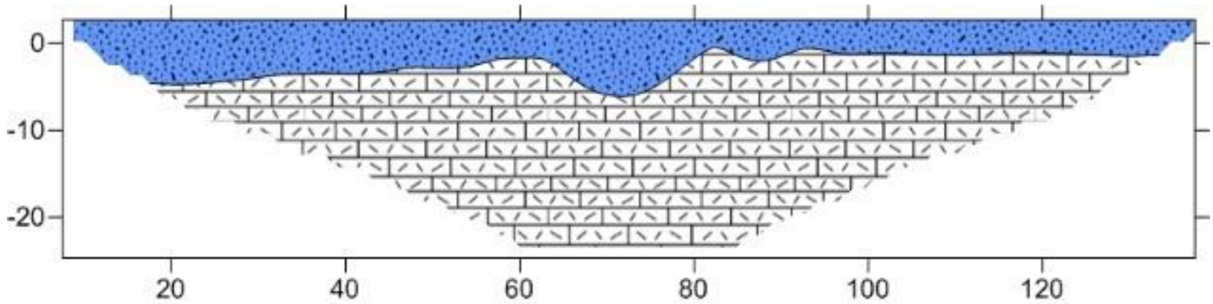

Figure 6. Lithology of layer 1.

Geoelectric measurements on track 2 are 145 meters long with 5 m electrode spacing oriented west-east. Using the Wenner-Schlumberger array produces 196 data datums. Geoelectrical data inversion line 2 results in a resistivity cross-section as shown in the Figure 7 with an RMS error value of 2. The lowest resistivity value is 6.24 Ωm and the largest is 566.71 Ωm.

Based on information from wells around the measurement line, it can be known that the groundwater level is 1 meter, with a layer of sandy loam down to the bottom of the well as deep as 3 meters. From the drilled well it is known that the bedrock is in the form of limestone 7 meters deep.

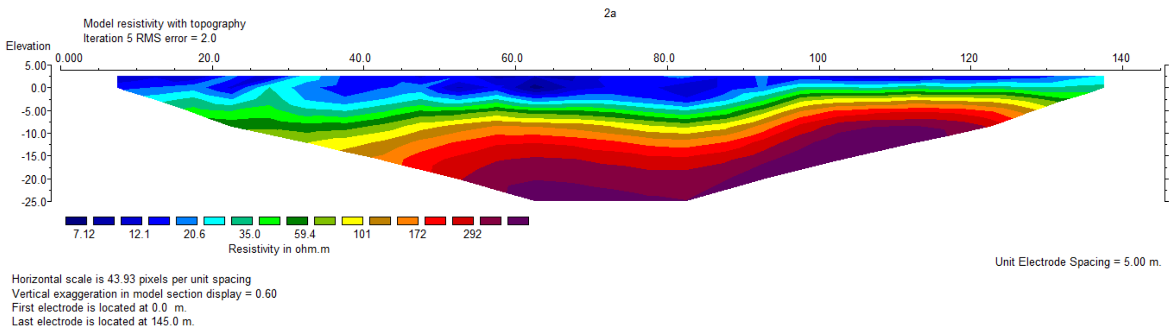

Figure 7. Track 2 and Coordinate (791255,9448551).

Based on information from wells data and resistivity cross-sections, it can be concluded that the cross-section of line 2 contains 2 layers, which are (Figure 8):

1. The first layer with a low resistivity. Resistivity value range of 6.24 – 35 Ωm interpreted as a layer of sandy clay with a thickness varies from 6 – 10 meters. This layer is a shallow aquifer layer.
2. The second layer with a high resistivity value with a resistivity value range of 35 – 566.71 Ωm is interpreted as a layer of limestone up to the end of the data as deep as 30 meters.

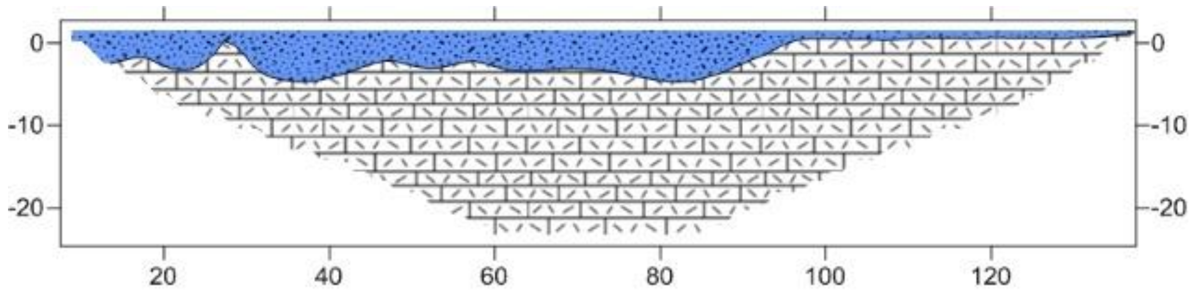

Figure 8. Lithology of Layer 2.

Geoelectric measurements on track 3 are 145 meters long with 5 m electrode spacing oriented west-east. Using the Wenner-Schlumberger array produces 196 data datums. Geoelectrical data inversion line 3 results in a resistivity cross-section as shown in the Figure 9 with an RMS error value of 1.6. The lowest resistivity value is 5.68 Ωm and the largest is 130.75 Ωm.

Based on information from wells around the measurement line, it can be known that the groundwater level is 1 meter, with a layer of sandy loam down to the bottom of the well as deep as 3 meters. From the drilled well it is known that the bedrock is in the form of limestone on 7 meters deep.

Based on information from wells data and resistivity cross-sections, it can be concluded that the cross-section of line 3 contains 2 layers, which are (Figure 10):

1. The first layer with a low resistivity value range 5.68 – 33.6 Ωm interpreted as a layer of sandy clay with a thickness that varies from 6 – 8 meters. This layer is a shallow aquifer layer.
2. The second layer with a high resistivity value with a resistivity value range of 33.6 – 130.75 Ωm is interpreted as a layer of limestone up to the end of the data as deep as 30 meters.

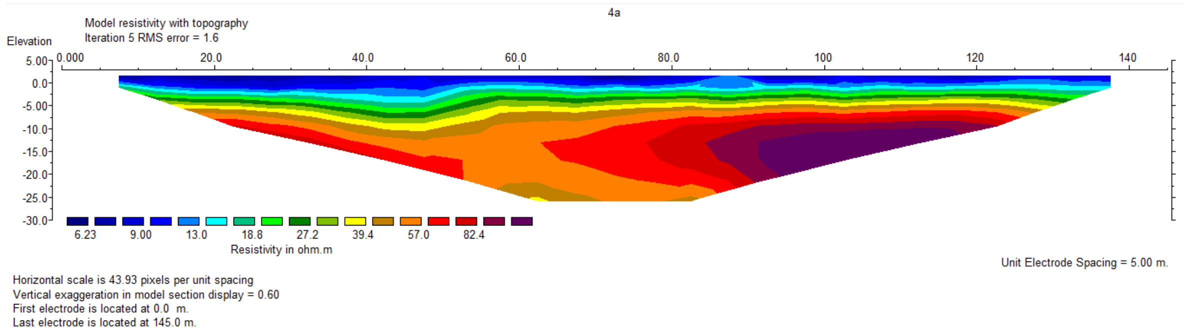

Figure 9. Track 3 and Coordinate (790652,9448132).

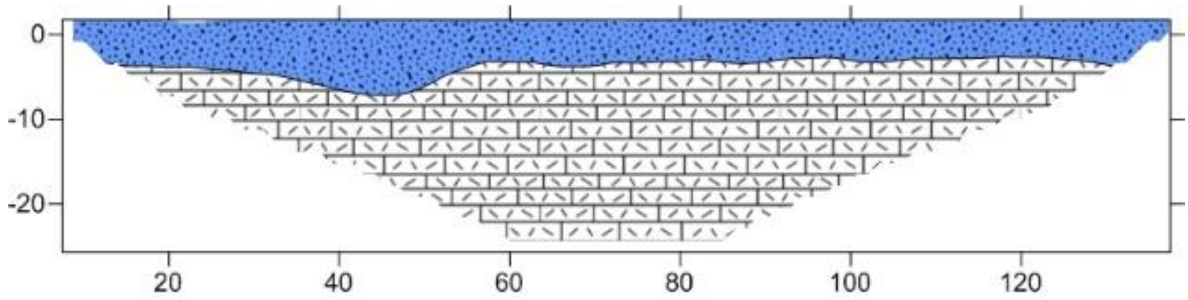

Figure 10. Lithology of Layer 3.

Conclusion

Based on the result study presented, it shows that the application of electrical resistivity method successfully identifies the aquifer as a groundwater source. The information from well data and resistivity cross-sections can be concluded that there are 2 layers in the cross-section of track 3: The first layer shows low resistivity values with range values 5.68 – 33.6 Ωm interpreted as sandy clay with various thicknesses 6 – 8 meters. This is a shallow aquifer. The second layer shows high resistivity with range values 33.6-130.75 Ωm interpreted as a limestone layer to the end of the data limit as deep as 30 meters.

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Author Contribution

Conceptualization, Syafnur, A. and Jibran, H.; methodology, Jibran H. and Sae, A.; software, Nurdin, N.H.; validation, Tonapa, W.D.; format analysis, Syafnur, A. and Sae, A.; investigation, Tonapa, W.D.; data curation, Sae, A.; visualization, Nurdin, N.H.; supervision, Syafnur, A. and Nudin, N.H.; funding acquisition, Syafnur, A. All authors have read and agreed to the published version of the manuscript.

Conflict of Interest

The authors declare no conflict of interest.

References

Andriani, F. D., Suwandi, E. A., Dhani, H. S., Firmansyah., Faranie, S. (2016). Pemodelan Kedepan Geolistrik Resistivitas Berdasarkan Metode Beda Hingga (Kasus 2D: Model Lapisan yang Homogen). *Prosiding Seminar Nasional Fisika, 5*, 73-78. https://doi.org /10.21009/0305020414

Arsyad, M., Ihsan, N., & Tiwow, V. A. (2020). Analysis of mineral sediment characteristics of Bantimurung Bulusaraung National Park in the Karst Maros Region. *Journal of Physics: Conference Series*, 1572(012007), 1–7. https://doi.org/10.1088/1742-6596/1572/1/012007

Bakri, H., Husain, J. R., & Firdaus. (2015). Pendugaan Air Tanah Dengan Metode Geolistrik Tahanan Jenis Di Desa Tellumpanua Kec.Tanete Rilau Kab. Barru Sulawesi-Selatan. *Jurnal Geomine*, 3(1), 165–169. https://doi.org/10.33536/jg.v3i1.19

Bery, A. A. (2014). Depth analysis for sensitivity pattern section in the electrical resistivity using the 2D computerized modeling method. *Electronic Journal of Geotechnical Engineering*, 19, 9389–9400. http://eprints.usm.my/36685/1/Depth_Analysis_19%28Z%29_2014%5B1%5D.pdf

BIG. (2020). Peta Rupa Bumi Indonesia (RBI) dan Peta Kontur. Badan Informasi Geospasial. https://tanahair.indonesia.go.id/portal-web

Darisma, D., Fernanda, F., & Syukri, M. (2020). Investigation of Groundwater Potential using Electrical Resistivity Method and Hydraulic Parameters in Lam Apeng, Aceh Besar, Indonesia. *Journal of Geoscience, Engineering, Environment, and Technology*, 5(4), 185–190. https://doi.org/10.25299/jgeet.2020.5.4.5501

Darsono, D., & Darmanto, D. (2019). Identifikasi Keberadaan Lapisan Akuifer Tertekan (Confined Aquifer) Berdasarkan Data Geolistrik (Studi Kasus: Desa Sambirejo Kecamatan Plupuh Kabupaten Sragen). *Indonesian Journal of Applied Physics*, 9(01), 46–53. https://doi.org/10.13057/ijap.v9i01.30122

Daniswara, A., Dahrin, D., & Setianingsih, S. (2019). Analysis and Modelling of Geoelectric Data Modeling for The Identication of Groundwater Aquifer at Cisarua Area, West Bandung. *Jurnal Geofisika*, 17(2), 22–25. http://dx.doi.org/10.36435/jgf.v17i2.416.

Fadli, A. I., Yuwanto, S. H., & Bahar, H. (2020). Hidrogeologi dan Kualitas Air Tanah Desa Sumber Banteng, Kecamatan Kejayan, Kabupaten Pasuruan, Jawa Timur. *Jurnal Sumberdaya Bumi Berkelanjutan (SEMITAN)*, 2(1), 367–379. http://ejurnal.itats.ac.id/semitan/article/view/1030

Flaño, O., Ayesta, I., Izquierdo, B., Sánchez, J. A., & Ramos, J. M. (2018). Experimental study on the influence of electrode geometry and electrode path on wear pattern in EDM. *Procedia*

CIRP, 68, 405–410. https://doi.org/10.1016/j.procir.2017.12.103

González, J. A. M., Comte, J. C., Legchenko, A., Ofterdinger, U., & Healy, D. (2021). Quantification of groundwater storage heterogeneity in weathered/fractured basement rock aquifers using electrical resistivity tomography: Sensitivity and uncertainty associated with petrophysical modelling. *Journal of Hydrology*, 593, 125637. https://doi.org/10.1016/j.jhydrol.2020.125637

Google Earth. (2022). *Explore, Search and Discover*. http://www.earthgoogle.com.

Heryani, N. (2014). Penilaian kesesuaian pembangunan dam parit bertingkat untuk antisipasi kekeringan: studi kasus di Kecamatan Cenrana, Kabupaten Maros, Provinsi Sulawesi Selatan. *Jurnal Sumber Daya Air*, 10(2), 113–124. https://jurnalsda.pusair-pu.go.id/index.php/JSDA/article/view/129

Jamaluddin, & Umar, E. P. (2018). Identification of subsurface layer with Wenner-Schlumberger arrays configuration geoelectrical method. *IOP Conference Series: Earth and Environmental Science*, 118(012006), 1–7. https://doi.org/10.1088/1755-1315/118/1/012006

Larson, S., Kirono, D. G. C., Tjandraatmadja, G., & Barkey, R. (2016). Monitoring and evaluation approaches in water resources project design: experiences from an urban water system climate change adaptation project in Indonesia. *Water Policy*, 18(3), 708–726. https://doi.org/10.2166/wp.2015.144

Maria, R., Rusydi, A. F., Lestiana, H., & Wibawa, S. (2018). Hidrogeologi Dan Potensi Cadangan Airtanah Di Dataran Rendah Indramayu. *Jurnal Riset Geologi dan Pertambangan*, 28(2), 181–192. https://jrisetgeotam.lipi.go.id/index.php/jrisgeotam/article/view/803

Miftahurrosyada., Zakiyyah, A. R., Salsabiila, F., Putrianti, R. A., Wibowo, R. C., & Zaenudin, A. (2022). The Effectiveness of Using the Damped Least Squares Inversion Method on the Schlumberger Configuration Curve in Determining Underground Structures. *Jurnal Ilmu Fisika dan Pembelajarannya (JIFP)*, 6(1), 28–33. https://doi.org/10.19109/jifp.v6i1.10624

Minanda, A., & Ardi, N. D., & Waslaluddin (2021). Uji Sensitivitas Metode Geolistrik Resistivitas Konfigurasi Wenner Alpha Pada Model Silinder. *Prosiding Seminar Nasional Fisika*, 1(1), 385–389. http://proceedings.upi.edu/index.php/sinafi/article/view/1862

Nurfalaq, A., Jumardi, A., Manrulu, R. H., Nawir, A., & Umar, E. M. (2021). Geoelectric Sounding for Identification of Aquifer Layer in East Turatea Village South Sulawesi Province. *Journal of Physics: Conference Series*, 1940(012028), 1–11. https://doi.org/10.1088/1742-6596/1940/1/012028

Oyeyemi, K. D., Aizebeokhai, A. P., Metwaly, M., Omobulejo, O., Sanuade, O. A., & Okon, E. E. (2022). Assessing the suitable electrical resistivity arrays for characterization of basement aquifers using numerical modeling. *Heliyon*, 8(5), e09427. https://doi.org/10.1016/j.heliyon.2022.e09427

Rizal, N. S. (2021) *Teknik Pendugaan & Eksploitasi Air Tanah*. LPPM Unmuh Jember.

SNI. (2012). *SNI 2528:2012 Tata cara pengukuran geolistrik Wenner untuk eksplorasi air tanah*. Badan Standarisasi Nasional.

SNI. (2012) *SNI2818:2012 Tata cara pengukuran geolistrik Schlumberger* *untuk eksplorasi air tanah*. Badan Standarisasi Nasional.

Sunarya, W., Hasanuddin, H., Syamsuddin, S., Maria, M., & Syamsuddin, E. (2017). Identifikasi Bijih Besi (Fe) Menggunakan Metoda Geolistrik Resistivitas Konfigurasi Wenner-Schlumberger di Kabupaten Luwu. *Jurnal Geocelebes*, 1(2), 72–81. https://doi.org/10.20956/geocelebes.v1i2.2793

Wahdaniyah, N., Kartini, K., Rahayu, I. P., Asman, A. I., & Annisa, D. N. (2017). Mitigasi Bencana Kekeringan di Kawasan Daerah Aliran Sungai Maros Kabupaten Maros Provinsi Sulawesi Selatan. *Seminar Nasional Geomatika*, 2, 361–370.