SPEKTRA: Jurnal Fisika dan Aplikasinya
Volume 8, Issue 1, April 2023
Homepage: doi.org/10.21009/SPEKTRA

DOI: doi.org/10.21009/SPEKTRA.081.04

A COMBINED METHOD OF 1D AND 2D RESISTIVITY FOR GROUNDWATER LAYER ESTIMATION AT A FARMING AREA IN REJOMULYO VILLAGE

Risky Martin Antosia*, Muhammad Ramdan

Department of Geophysical Engineering, Sumatera Institute of Technology, Jalan Terusan Ryacudu, Way Huwi, Jati Agung, Kabupaten Lampung Selatan, Lampung, Indonesia

*Corresponding Author Email: martin.antosia@tg.itera.ac.id

Received: 13 March 2023
Revised: 18 April 2023
Accepted: 19 April 2023
Online: 29 April 2023
Published: 30 April 2023

SPEKTRA: Jurnal Fisika dan Aplikasinya
p-ISSN: 2541-3384
e-ISSN: 2541-3392

ABSTRACT

The groundwater depends on when it is available, more in the rainy and less in the dry seasons. Fluctuation in water availability is a significant problem in activities continuously requiring large amounts of water, such as agriculture. Hence, it is necessary to increase the number of water resources to meet the community's needs. Therefore, the groundwater layer zone was estimated as an initial study at the dry farmland in Rejomulyo village, Jati Agung district, South Lampung, using a combined method between the 1D resistivity method of the Schlumberger array and the 2D form of the Wenner configuration. Each sounding point and the 2D line have a maximum stretch length of 300 m. The 1D outcome correlates to the 2D data processing result to produce a subsurface lithology model. As a result, the research area has three primary layers with three rock types. The first layer has a resistivity value of less than 20 Ωm and is identified as tuffaceous clay. Then the second layer with a resistivity range of 60-66 Ωm is tuffaceous sand, this rock which is referred to as the groundwater layer with a depth of 11-40 m. The last layer has a high resistivity value of 120-141 Ωm as tuff. Based on the results of 3D visualization, the groundwater layer in the study area spreads to the southeast with a confined aquifer type. This targeted rock layer can be utilized for groundwater production.

Keywords: groundwater layer, resistivity method, Schlumberger, Wenner

INTRODUCTION

South Lampung is currently facing a water crisis due to the widespread use of land in infrastructure development, which causes a decrease in groundwater reserves [1]. In addition, water availability also depends on the time; it is more available in the rainy season and less in the dry season. Instability in water availability is a significant problem in activities requiring continuous water, such as agricultural activities. Groundwater is all water contained in subsurface aquifers, including springs on the surface [2]. In Rejomulyo village, the agriculture sector has emerged as one of the leading economies, and most residents work in the agricultural field. During the dry season, the water availability of several farm locations in the village has declined.

Due to the importance of the groundwater presence, it is necessary to conduct an applied physics method in earth science to investigate the confined aquifer, which cannot be influenced by seasons [3]. The resistivity method is a popular and effective geophysical survey to obtain representations of rock layers below the surface that may contain groundwater. The result is that different materials will have different resistivity values [4-6]. The characteristics of rock formations in the method can be described by the parameters measured, including electrical current and potential. An electrical current injects into the earth's surface and then measured value by an amperemeter. Then a voltmeter measures the potential difference due to the injected current [4,5,7].

The 1D resistivity method is commonly applied for groundwater investigation in various locations [2,3], [8-12]. Although rare, mineral exploration also has another implementation [13]. The 2D application is broader because it can display a cross-section of subsurface profiles, for example, ground structure condition [6,14], mineral prospecting [13,15,16], agricultural soil analysis [17], landslide mitigation [18,19], and volcanology study [20], as well as also for groundwater layer identification [21-23].

Several studies have been conducted in a surrounding area applying 1D and 2D resistivity methods [10] deployed the groundwater layer mapping at a campus of ITERA, implementing the 1D mode with Schlumberger configuration. Then, [9] applied the same approach to identify groundwater potential in a neighboring village in the Jati Agung district. Meanwhile, [22] conducted the Wenner array of the 2D method in groundwater prospecting in Jatimulyo village in the same region. Sometimes if a researcher only relies on one approach, misinterpretation often occurs. Therefore, in this study, the authors will combine the methods to estimate the groundwater layer in the dry farming area in Rejomulyo village to get a better result.

METHOD

A 1D electrical resistivity method analyzes the resistivity values distribution below the surface vertically [4,5,10,13]. The measurement technique is made at a central point with an increasing electrode distance from a small to a larger space FIGURE 1. The Schlumberger array is deployed in this study because it is commonly used [8]. In this configuration, the potential electrode (P_1P_2) distance is kept constant FIGURE 1 (b)-(c). Because the distribution target value is vertical, there should be no change in the resistivity value distribution horizontally. It means the lateral resolution is consistently still. The potential electrode space controls the lateral resolution [24].

There is a 2D method to describe the image of the resistivity value below the earth's surface horizontally and vertically. Generally, the measurement line will apply the Wenner array. If the form is compared to the others for the same 2D line, the Wenner configuration is quicker in data acquisition. The illustration of the 2D measurement can be seen in FIGURE 2. The electrode spacing controls the 2D image resolution of the resistivity value distribution. In the same path length, the smaller the electrode distance, the greater the resolution of the resulting image, and vice versa. However, the smaller the electrode distance, the longer the measurement time is required, and vice versa.

According to [4] and [5], the resistivity value (ρ_a) can be obtained from the following equation.

$$\rho_a = k\frac{\Delta V}{I} \tag{1}$$

with k as a geometrical attribute based on the electrode configuration, ΔV is a value of the potential difference between P_1 and P_2, and I is an electrical current that flows from electrode C_1 to C_2 (all units are in the International System). A specific device measures the electrical current and potential; it is a resistivity meter or geolistrik (in Indonesian) [22], while an attribute geometrically is manually measured using the following formula.

$$k = \pi\left(\frac{a^2 - b^2}{2b}\right) \tag{2}$$

and

$$k = 2\pi a \tag{3}$$

where EQUATION (2) is the attribute calculation [10] for the Schlumberger array according to FIGURE 1(a), and EQUATION (3) is the calculation formula for the Wenner configuration [4,24] based on FIGURE 2.

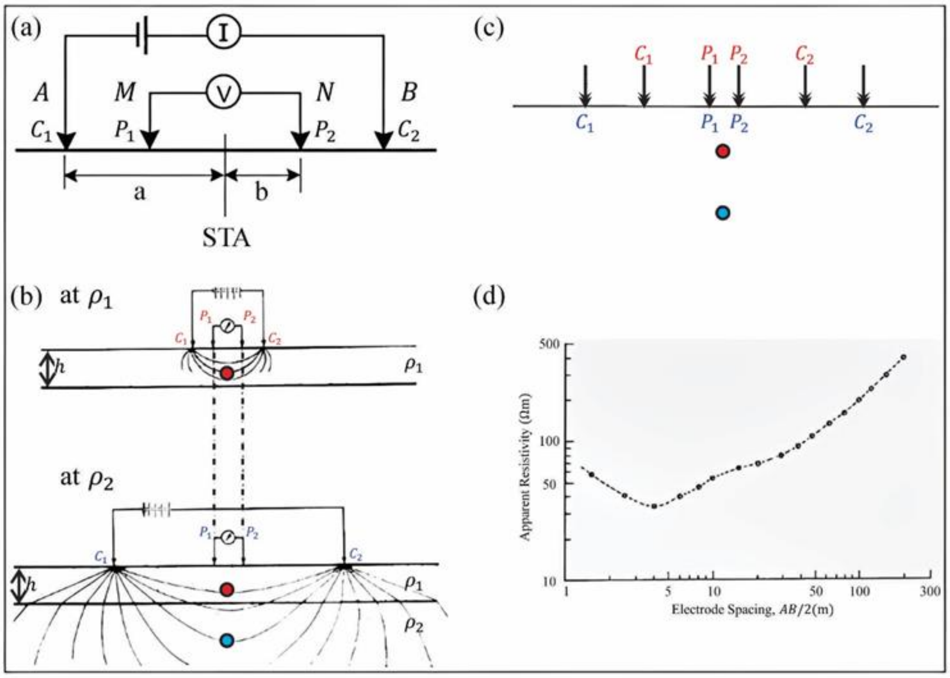


FIGURE 1. The 1D measurement (a) array setting, (b) the electrodes are shifted to the right and left from the central point (STA), (c) depth estimation of the datum point from each shifted electrode, and (d) the datum reconstruction on a chart between resistivity value and half distance "a" or $AB/2$ (modified from [10])

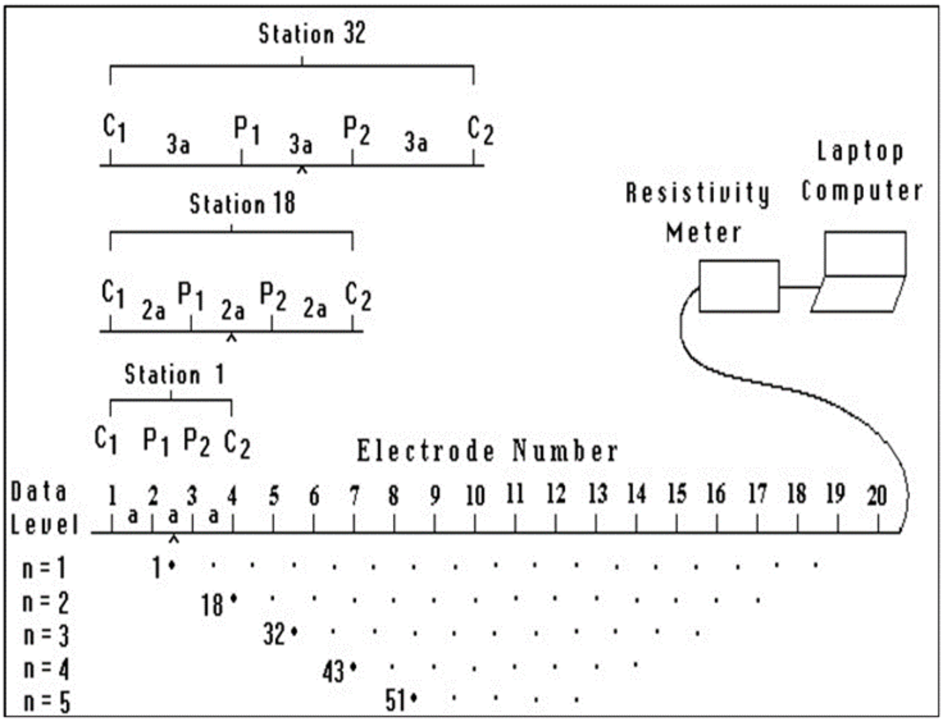


FIGURE 2. The 2D resistivity measurement scheme of the Wenner array with "a" as the electrode interval and "dot" point as the datum representation [24]

FIGURE 3 shows the measurement scheme in the study area in one of the farming regions in Rejomulyo village. Two sounding points for 1D and three lines for 2D measurements are deployed in the area. Each stretch has a maximum length of 300 m with a distance between the electrodes of 15 m (2D method only). Each position of the VES 1 and VES 2 points is precisely on lines 1 and 2. Determining the stretch length comes after the maximum depth target of about 60 m (the enumeration refers to [24]).

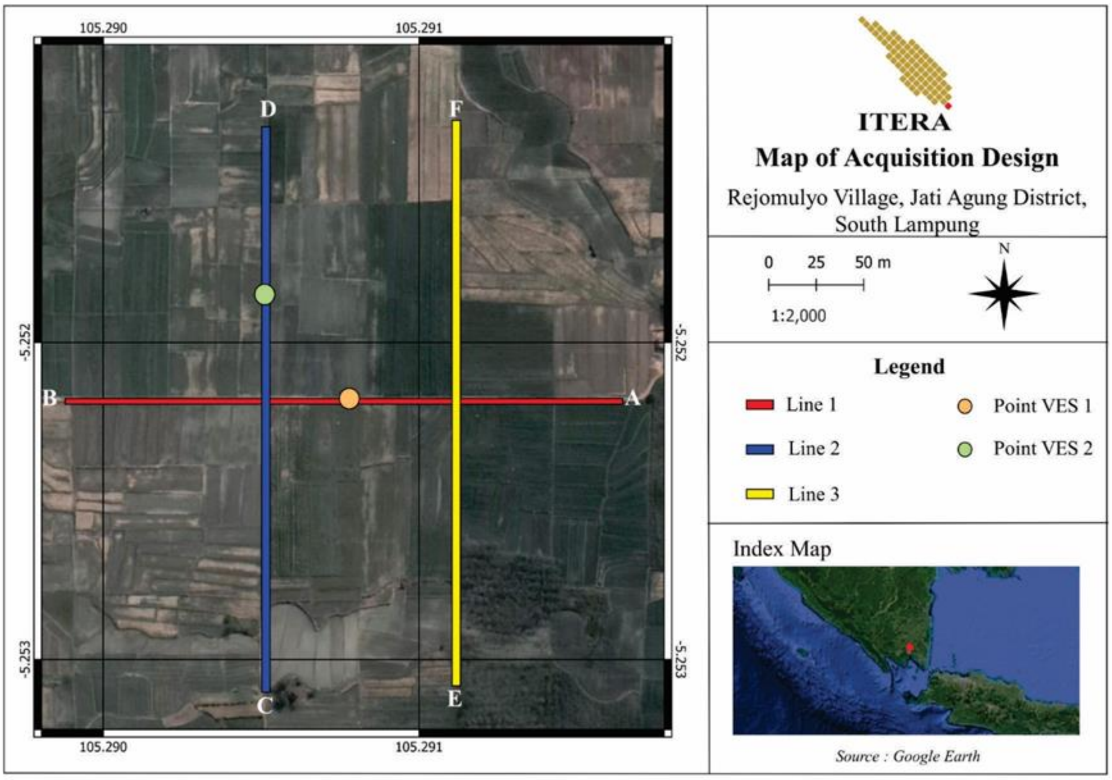


FIGURE 3. Survey design map

Next, each measurement data is computed to attain the observed resistivity value by applying EQUATION (1) and (2) for the 1D method, and the other one uses EQUATION (1) and (3). Then each technique utilizes a specified software to process the observed value to generate the distribution of estimated actual resistivity values. Then the results are associated with the related references to identify the groundwater layer, and the first technique product is correlated to the outcome of the second one. Finally, 3D modeling is generated to predict the radial pattern of the layer in the study area.

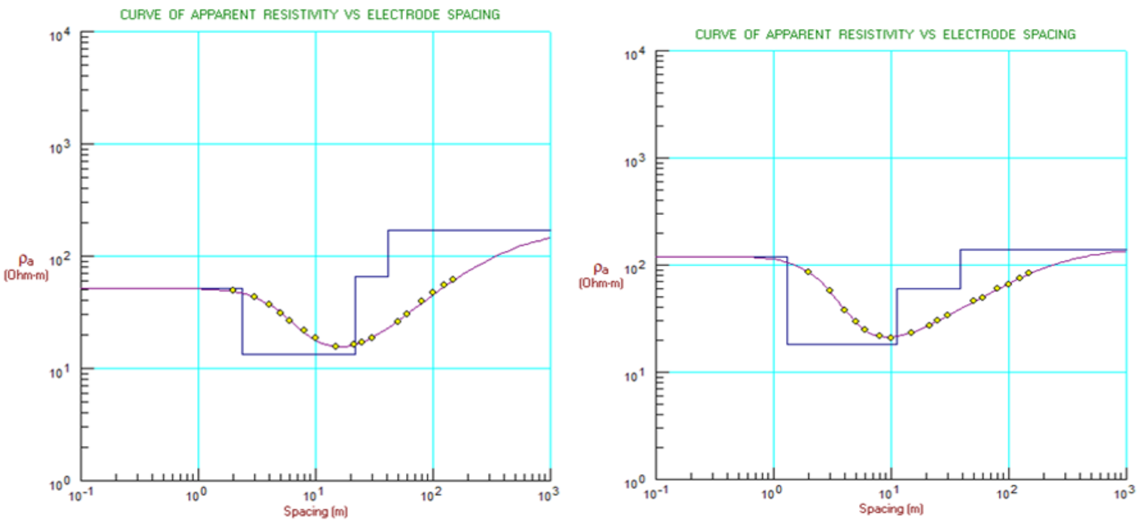
RESULT AND DISCUSSION

According to the geological map of Tanjungkarang [25], the area is in the Lampung Formation. The rock formation is dominated by tuff because of the volcanic activity. Many studies have been conducted in Lampung using the 1D resistivity method, especially in neighboring areas. The 1D data interpretation only refers to [10] because they implemented additional techniques (log resistivity and core sample) to support the results. FIGURE 4 views the 1D data processing result. The "dot" point represents the 1D observed resistivity data, the curve line is the calculated data, and the square curve shows the model parameter. The model can be considered appropriate if the observed and computed data are fitted well [8]. The curve forms of VES 1 and VES 2 are identical, as do each inverted model.

The model in FIGURE 4 describes the estimated value of true resistivity and the layer thickness, which consists of four layers from each sounding point (

TABLE **1**). By referring to [10], the geological rock information in the area is attained (

TABLE **1**). The first layer has a value of about 51-121 Ωm and is described as topsoil. Then the subsequent layers are the primary approximate lithologies: tuffaceous clay (13-18 Ωm), tuffaceous sand (60-66 Ωm), and tuff (120-141 Ωm). [10] explained that the groundwater layer usually is in the lithology of tuffaceous sand with the type of confined aquifer. It means the groundwater layer is flanked by two impermeable zones at the top and bottom. In this case, the top zone is tuffaceous clay, and the other is tuff. Hence, this result is as expected that the groundwater layer should be a confined one.



(a) (b)

FIGURE 4. The 1D resistivity curves (a) VES 1 and (b) VES 2

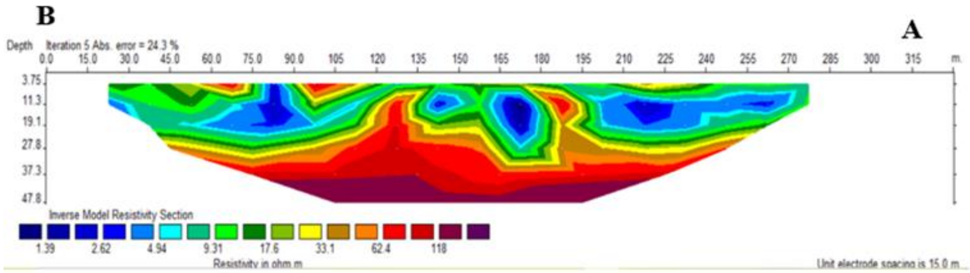
TABLE 1. The 1D resistivity results

	Sounding point of VES 1				Sounding point of VES 2			
Layer(s)	Resistivity (Ωm)	Thickness (m)	Depth (m)	Lithology estimation	Resistivity (Ωm)	Thickness (m)	Depth (m)	Lithology estimation
1	51.4	2.39	0-2.39	Topsoil	120.67	1.30	0-1.30	Topsoil
2	13.38	19.12	2.39-21.51	Tuffaceous clay	18.27	9.92	1.30-11.22	Tuffaceous clay
3	66.38	20.45	21.51-40.96	Tuffaceous sand	60.01	27.06	11.22-38.28	Tuffaceous sand
4	150	-	>40.96	Tuff	140.71	-	>38.28	Tuff

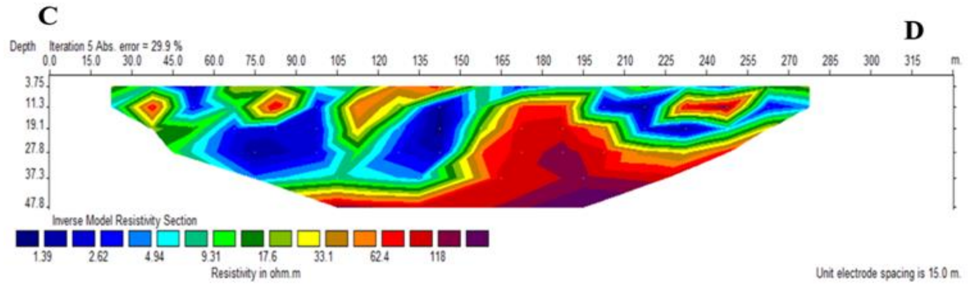
Then the 2D processing outcome of three lines is viewed in FIGURE 5. It shows that the image of the three lines has a similar pattern. There is a value contrast between the middle bottom and the middle top of the 2D cross-section. The high resistivity value is displayed at the middle bottom of the 2D pseudo-section. Meanwhile, at the center top, there is a low resistivity value.

It looks like only two rock layers, so the 1D result will be applied to clarify the lithology's differentiation from the cross-section.

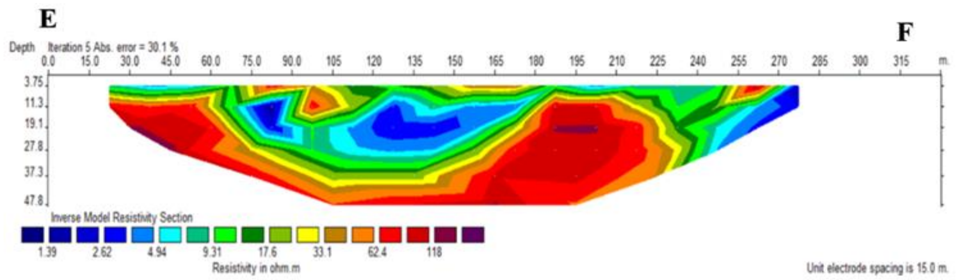
Consequently, the boundary of the rock type information from the correlation can be obtained for the 2D profiles (FIGURE 6). The depth of each rock layer from the 1D product (to simplify the correlation, it is changed to a log view) is fitted well with the 2D shapes for the primary rock types, except for the topsoil. In the cross-section profile, the upper layer (from the ground surface) cannot be displayed because of the processing routine on the software and depending on the electrode spacing. The electrode interval of 15 m is implemented, so according to [24], the upper layer can be presented in this outcome approximately from 3 m to the bottom view (see FIGURE 5 or FIGURE 6). Thus, the profile only delineates three lithologies in the 2D cross-section. Then, the third line interpretation will follow the rapport results. The 2D shapes represent that the rocks' distribution horizontally is changed drastically in depth. It might be like that from a geological point of view. The lithology distribution also provides information on the direction of the groundwater layer in the study area. The layer depth varied around 11-40 m. The arrangement of the 2D shapes in FIGURE 7 provides a more explicit illustration of the order of rock distribution. Then the 3D modeling in FIGURE 8 is carried out to depict the estimation of groundwater layer spreading. In the area, the tuffaceous sand is centered in the middle of three lines but also has the potential to outspread in the southeast direction. It means that positions are possible for groundwater production.



(a)

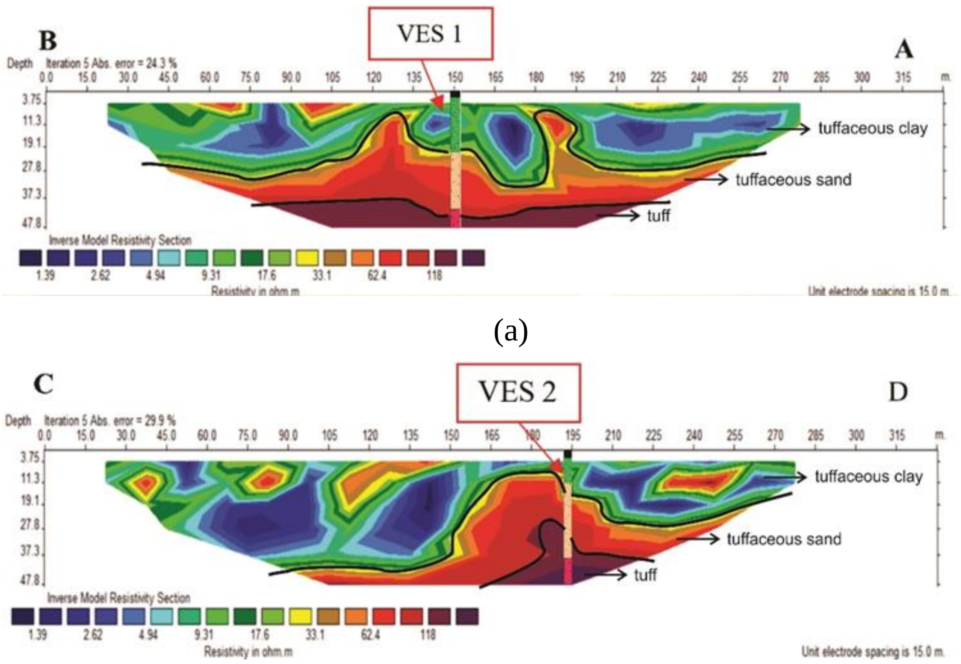


(b)



(c)

FIGURE 5. The 2D resistivity profiles (a) line 1, (b) line 2, and (c) line 3



(a)

(b)

FIGURE 6. The correlation of 1D results and 2D resistivity profiles (a) VES 1-line one and (b) VES 2-line two

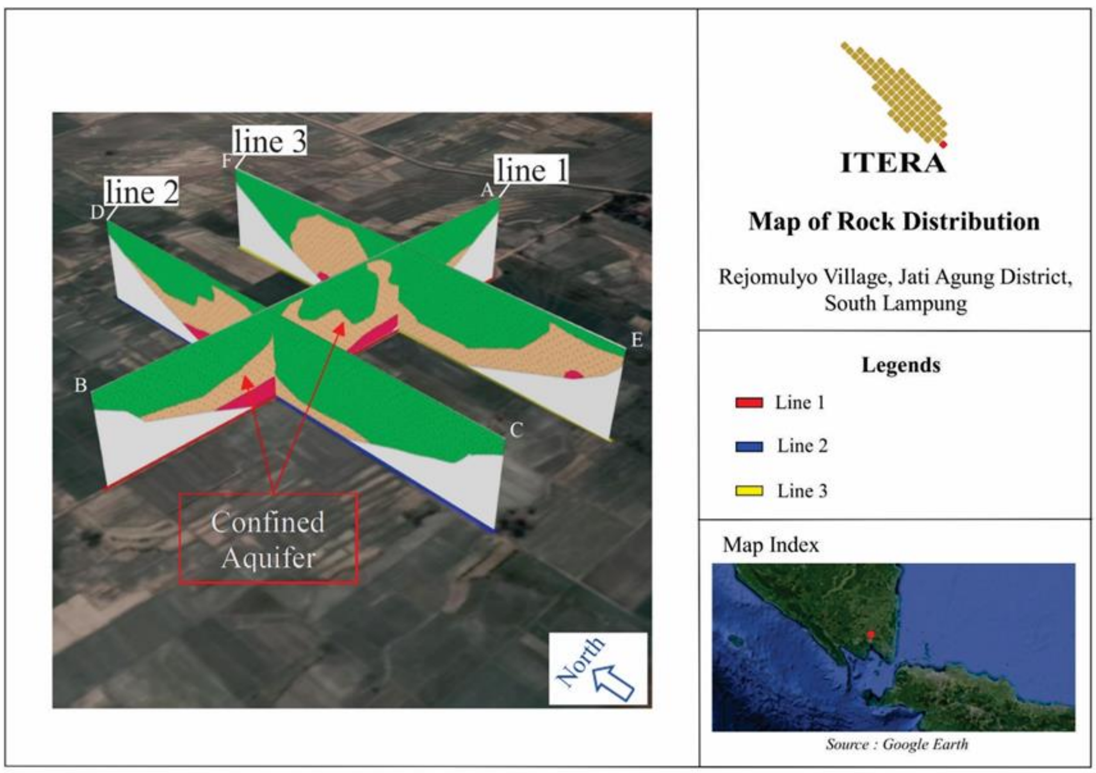


FIGURE 7. The arrangement of the 2D lines is according to their positions on the map

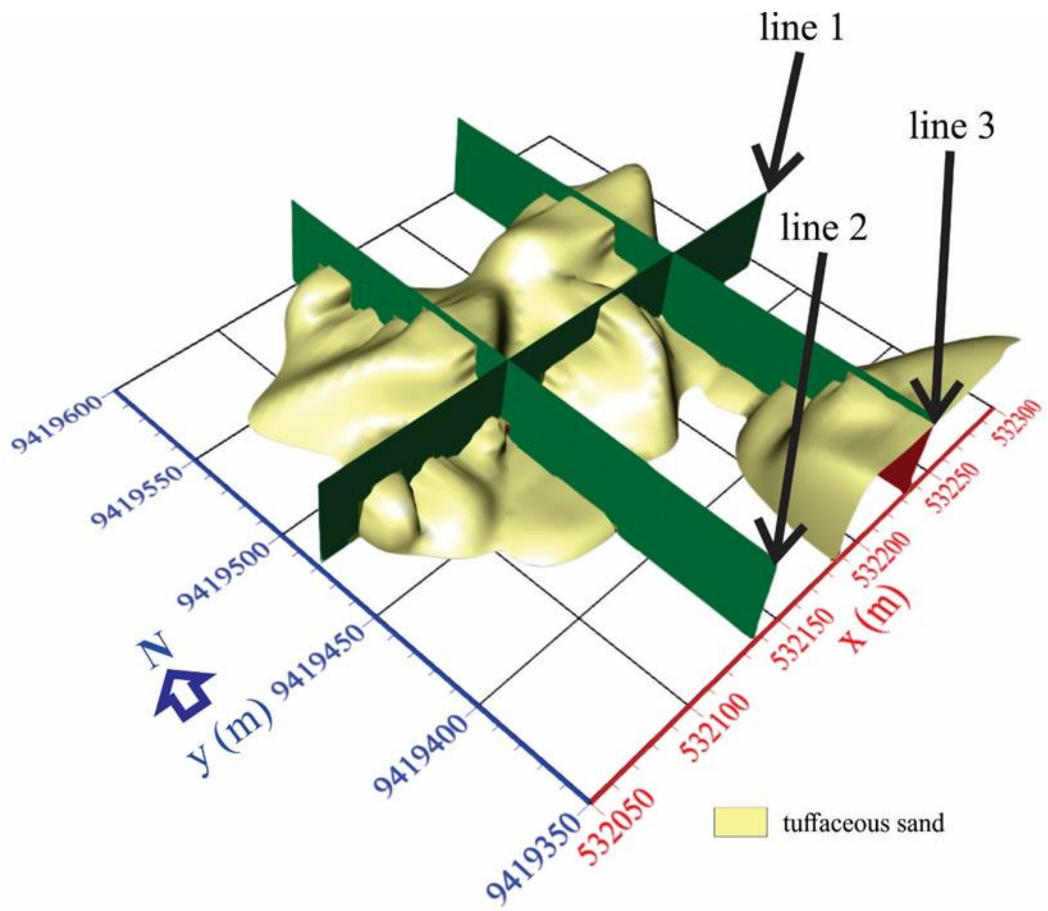


FIGURE 8. The 3D modeling of the groundwater layer

These methods can delineate a better interpretation of subsurface rock estimation. A vertical resistivity distribution from the 1D technique can confirm and improve the anomaly ambiguity of the 2D profiles vertically (FIGURE 6). And then, the horizontal value distribution from the 2D form can also be depicted well. Accordingly, this combined method can reference other studies regarding applied earth physics using the resistivity method. Moreover, this study can also be added as one of the literature for other regions geologically in groundwater layer identification, particularly in Lampung formation.

CONCLUSION

The resistivity measurement of 1D and 2D methods was conducted in the Rejomulyo village, Jati Agung district, South Lampung. The groundwater lithology is tuffaceous sand with resistivity values ranging from 60 Ωm to 66 Ωm. This combined method can effectively delineate the layered rocks in the subsurface. Thus, the lateral and vertical resistivity distribution can be described better. Its outcome presents that the groundwater layer is located around the middle of the study area and is likely to outspread to the southeast direction. It has a depth of about 11-40 m with the confined aquifer type and has a possibility for groundwater production. However, forecasting the groundwater layer in the surrounding study area needs more data acquisition for better resolution and coverage. Also, a time-lapse investigation is required to see whether any influences of the season change on the groundwater substance within the aquifer.

ACKNOWLEDGEMENT

The authors would like to thank Geophysical Engineering students for assisting in the data acquisition of this study.

REFERENCES

[1] T. K. Nufutomo, F. C. Alam and A. H. Kiranaratri, "Kualitas Air Embung untuk Irigasi di Margodadi, Lampung Selatan," *Media Ilmiah Teknik Lingkungan*, vol. 5, no. 2, pp. 101-107, 2020, doi: 10.33084/mitl.v5i2.1640.

[2] D. Sedana, A. As'ari and A. Tanauma, "Pemetaan Akuifer Air Tanah di Jalan Ringroad Kelurahan Malendeng dengan Menggunakan Metode Geolistrik Tahanan Jenis," *Jurnal Ilmiah Sains*, vol. 15, no. 1, p. 33, 2015, doi: 10.35799/jis.15.1.2015.6778.

[3] R. M. Antosia *et al.*, "Peninjauan Ulang Kedalaman Akuifer Menggunakan Metode Resistivitas 1D di Desa Gayau, Kabupaten Pesawaran," *Jurnal Abdi Masyarakat Indonesia*, vol. 2, no. 2, pp. 651-660, 2022, doi: 10.54082/jamsi.309.

[4] J. M. Reynolds, "An Introduction to Applied and Environmental Geophysics," John Wiley & Sons, 2011, [Online], Available: www.wiley.com/go/reynolds/introduction2e.

[5] W. M. Telford, L. P. Geldart and R. E. Sheriff, "Applied Geophysics," Cambridge University Press, 1990.

[6] A. S. Wijaya, "Aplikasi Metode Geolistrik Resistivitas Konfigurasi Wenner Untuk Menentukan Struktur Tanah di Halaman Belakang SCC ITS Surabaya," *Jurnal Fisika Indonesia*, vol. 19, no. 55, pp. 1-5, 2015, doi: 10.22146/jfi.24363.

[7] R. M. Antosia, "Voltmeter Design Based on ADS1115 and Arduino Uno for DC Resistivity Measurement," *JTERA (Jurnal Teknologi Rekayasa)*, vol. 5, no. 1, pp. 73-80, 2020, doi: 10.31544/jtera.v5.i1.2019.73-80.

[8] A. Farduwin *et al.*, "Inversi Data Geolistrik Menggunakan Particle Swarm Optimization: Studi Kasus Desa Gayau," *JGE (Jurnal Geofisika Eksplorasi)*, vol. 7, no. 2, pp. 88-99, 2021, doi: 10.23960/jge.v7i2.118.

[9] A. Y. Paembonan *et al.*, "Investigasi Air Tanah Berdasarkan Nilai Resistivitas di Dusun Jatisari, Kabupaten Lampung Selatan," *JGE (Jurnal Geofisika Eksplorasi)*, vol. 7, no. 2, pp. 100-110, 2021, doi: 10.23960/jge.v7i2.117.

[10] Rizka and S. Satiawan, "Investigasi Lapisan Akuifer Berdasarkan Data Vertical Electrical Sounding (VES) dan Data Electrical Logging; Studi Kasus Kampus Itera," *Bulletin of Scientific Contribution: Geology*, vol. 17, no. 2, pp. 91-100, 2019, [Online], Available: http://jurnal.unpad.ac.id/bsc.

[11] J. Asfahani, "Review on the role of geoelectrical surveys in characterizing and deriving the constraints and hydrogeological conditions in semi arid Khanasser Valley region in Syria," *Contributions to Geophysics and Geodesy*, vol. 49, no. 1, pp. 37-66, 2019, doi: 10.2478/congeo-2019-0004.

[12] A. C. D. O. Braga, W. M. Filho and J. C. Dourado, "Resistivity (DC) method applied to aquifer protection studies," *Revista Brasileira de Geofisica*, vol. 24, no. 4, pp. 573-581, 2006, doi: 10.1590/s0102-261x2006000400010.

[13] B. Santoso *et al*., "Penentuan Resistivitas Batubara Menggunakan Metode Electrical Resistivity Tomography dan Vertical Electrical Sounding," *Jurnal Material dan Energi Indonesia*, vol. 6, no. 1, 2016.

[14] B. Wijatmoko, B. Santoso and E. Supriyana, "Kajian Struktur Resistivitas Dangkal di Sekitar Sumur Sindu Kecamatan Jatitujuh Kabupaten Majalengka," *Spektra: Jurnal Fisika dan Aplikasinya*, vol. 1, no. 1, pp. 9-16, 2016, doi: 10.21009/SPEKTRA.

[15] R. M. Antosia *et al*., "Andesite prospect at West Sungkai of North Lampung: Its distribution based on electrical resistivity tomography," *in IOP Conference Series: Earth and Environmental Science*, vol. 882, no. 1, p. 012086, 2021, doi: 10.1088/1755-1315/882/1/012086.

[16] A. Farduwin *et al*., "Identification of zeolite using electrical resistivity tomography in Campang Tiga, South Lampung Regency," *in IOP Conference Series: Earth and Environmental Science*, 2021, doi: 10.1088/1755-1315/882/1/012046.

[17] S. Zulaikah *et al*., "Pengukuran Resistivitas dan Dielektrisitas Tanah Perkebunan Apel: Sebuah Langkah Awal dalam Studi Agrogeophysics," *Spektra: Jurnal Fisika dan Aplikasinya*, vol. 16, no. 1, pp. 52-54, 2015.

[18] M. Souisa, L. Hendrajaya and G. Handayani, "Pencitraan Resistivitas Bidang Longsor di Perbukitan Booi dan Erie Kota Ambon Menggunakan Konfigurasi Wenner Schlumberger," *Spektra: Jurnal Fisika dan Aplikasinya*, vol. 16, no. 2, pp. 1-5, 2015.

[19] Mahrizal, A. Fauzi and Akmam, "Teknologi Monitoring Geolistrik Time-Lapse untuk Memantau Daerah Rawan Longsor di Kota Padang," *Spektra: Jurnal Fisika dan Aplikasinya*, vol. 1, no. 2, pp. 103-108, 2016, doi: 10.21009/SPEKTRA.

[20] Rizka *et al*., "The Identification of Krakatoa Tsunami Deposits Based on Comparison of Geological and Electrical Resistivity Tomography Method, in Kunjir, South Lampung," *in IOP Conference Series: Earth and Environmental Science*, IOP Publishing Ltd, vol. 830, no. 1, p. 012026, 2021, doi: 10.1088/1755-1315/830/1/012026.

[21] E. Minarto, N. N. Christy and A. Ruchimat, "Identification of Groundwater Potential Using Wenner Configuration 2D Resistivity Method (Kupang, Nusa Tenggara Timur)," *in Journal of Physics: Conference Series*, vol. 1805, no. 1, p. 012034, 2021, doi: 10.1088/1742-6596/1805/1/012034.

[22] R. M. Antosia *et al*., "Pemanfaatan Metode Geolistrik 2 Dimensi dalam Mengidentifikasi Kemenerusan Lapisan Air Tanah di Dusun IID, Desa Jatimulyo, Kecamatan Jati Agung, Kabupaten Lampung Selatan," *Jurnal Abdi Masyarakat Indonesia*, vol. 2, no. 2, pp. 753-762, 2022, doi: 10.54082/jamsi.324.

[23] S. Uhlemann *et al*., "Electrical resistivity tomography determines the spatial distribution of clay layer thickness and aquifer vulnerability, Kandal Province, Cambodia," *Journal of Asian Earth Sciences*, vol. 147, pp. 402-414, 2017, doi: 10.1016/j.jseaes.2017.07.043.

[24] M. H. Loke, "Tutorial : 2-D and 3-D electrical imaging surveys," pp. 29-31, 2023, [Online], Available: https://www.geotomosoft.com/coursenotes.zip.

[25] S. A. Mangga *et al*., “Peta Geologi Lembar Tanjungkarang, Sumatera,” Bandung: Pusat Survei Geologi, 2010.