http://journal.uir.ac.id/index.php/JGEET

E-ISSN : 2541-5794
P-ISSN : 2503-216X

Journal of Geoscience,
Engineering, Environment, and Technology
Vol 10 No 3 2025

RESEARCH ARTICLE

Subsurface Interpretation for Groundwater Potential Mapping Using Electrical Resistivity Tomography (ERT) in Mon Ikeun Village, Aceh Besar, Indonesia

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Received: May 23, 2025; Accepted: Jul 24, 2025.
DOI: 10.25299/jgeet.2025.10.3.22580

Abstract

The Mon Ikeun Village area in Aceh Besar is experiencing a clean water crisis due to a prolonged drought, which has significantly impacted human needs and necessitates identifying alternative water sources. This study aims to determine groundwater potential in the area using the Electrical Resistivity Tomography method. Data acquisition was conducted along three survey lines, each 420 m long. The Wenner-Schlumberger configuration was employed, using 22 electrodes with a spacing of 20 m. Data processing was done using ResIPy software to generate 2D resistivity cross-sections representing the subsurface structure. The resistivity sections were interpreted by correlating them with regional geological data and secondary data from wells located near the study area. The results indicate that two different lithologies dominate the subsurface structure of the study area. The first is a conductive zone with resistivity values of ≤316.23 Ω.m, interpreted as alluvium composed of clay, sand, and gravel. The second is a resistive zone with resistivity values of ≥562.34 Ω.m, interpreted as bedrock composed of limestone. Based on the subsurface lithology, zones with groundwater potential are found in conductive areas with resistivity values ranging from 3.16 to 56.23 Ω.m, which are associated with water-saturated alluvial layers, particularly those dominated by clay and sand. From the 2D resistivity cross-sections analysis, line 3 shows the highest potential for groundwater exploration, with water-saturated layers occurring at both shallow and deeper depths, reaching up to 0–40 m. This study provides valuable information for water resource management in Mon Ikeun Village, especially in addressing future clean water shortages.

Keywords: Groundwater, Clean Water Crisis, Mon Ikeun Village, Resistivity, Geophysics.

1. Introduction

Water is essential for sustaining life and is a fundamental requirement for all living organisms (Fadli et al., 2020). Despite its importance, access to clean water remains a persistent challenge in several regions of Indonesia. Climate change has intensified this issue by causing irregular weather patterns, including unpredictable rainy and dry seasons (Larson et al., 2016). In response, groundwater has emerged as a critical alternative source for meeting the demand for clean water (Triadi and Indra, 2009). Groundwater is part of the hydrological cycle in the water-saturated zone below the ground surface (Singh et al., 2019). Groundwater character is store and drain water, called aquifers, whinch consist of porous materialas or rocks that are able to store and have high permeability (Brindha and Elango, 2012).

One area severely affected by water scarcity is Mon Ikeun Village, located in Lhoknga Subdistrict, Aceh Besar. In recent years, declining groundwater levels have caused numerous wells in the village to run dry, including previously reliable sources (Pemerintah Aceh.id, 2024). By the end of July 2024, more than three million liters of clean water had been delivered to drought-stricken communities in Lhoknga, including Mon Ikeun (Serambinews, 2024). To address this crisis, the Aceh Government, in partnership with the regional water utility PDAM Tirta Montala, has implemented regular water distribution efforts (Pemerintah Aceh.id, 2024). The region's geological characteristics play a significant role in groundwater availability. Based on the geological map in Fig. 1. Mon Ikeun Village is located on a rock formation of lenient alluvium (Qh) and in reef member (Murlr). The young alluvium (Qh) is comosed of sand, gravel, clay, and silt. Meanwhile, the reef member (Murlr) is a carbonate sedimentary structure in the form of limestone (Bennet el al., 1981).

Groundwater is often accessed through drilling. However, drilling without a proper scientific approach can lead to failure. To increase the success rate, it is essential to conduct thorough investigations beforehand. One effective approach is the use of geophysical methods. Various geophysical techniques are available to assess groundwater potential, including electrical resistivity, seismic refraction, magnetic, gravity, and electromagnetic methods (Adagunodo et al., 2013; Adaguodo et al., 2014; Joel et al., 2016; Oyoyemi et al., 2017). Among these, the Electrical Resistivity Tomography (ERT) method has proven highly effective, offering accurate and high-resolution information for identifying groundwater zones (Mohamaden and Ehab, 2017; Nigm, et al., 2008; Kayode et al., 2016; Mogaji and Omobude, 2017; Attwa and Zamzam, 2020). ERT injects electrical current into the ground and measures the resulting potential differences (Telford et al., 1990). This method is capable of recording hundreads of data points in the subsurface and produces a two-dimensional (2D) view of the earth showing the distribution of rock resistivity variation both horizontally and vertically (Tabbagh et al., 2000). Compared to the one-dimensional (1D) Vertical Electrical Sounding (VES) technique, ERT produces a more representative subsurface geologic model that is closer to the actual subsurface geology (Loke and baker, 1996; Loke, 2000). Resistivity is a key parameter that reflects subsurface physical properties, such as rock type, mineral content, and the degree of water saturation. The resistivity of water-bearing rocks is influenced by several factors, including porosity, salinity, temperature, rock conductivity, and thermal conditions (Telford et al., 1990). In general, rocks with high resistivity conduct little current, while rocks with low resistivity conduct more current (Wahyuni et al., 2021). Several electrode configurations can be used in resistivity surveys. Among them, the Wenner-Schlumberger configuration is particularly effective, as it provides high sensitivity for detecting both vertical and horizontal variations in the subsurface (Darmawan et al., 2014). This study aims to assess the groundwater potential in Mon Ikeun Village by analyzing 2D resistivity cross-sections and correlating the results with secondary data from nearby wells. The findings are expected to support local government and community efforts by providing essential information on groundwater availability. This information can be used to guide sustainable groundwater management and ensure reliable access to clean water, especially during dry seasons.

This research is limited to the interpretation of ground water potential based on 2D electrical resistivity data obtained from the Wenner-Schlumberger configuration in study area. The analysis does nos inclued direct maesurements of water quality or quantity, and only considers subsurface conditions within the depth range achievable by the method. Correlations are made with existing well data without conducting driling or pumping tests.

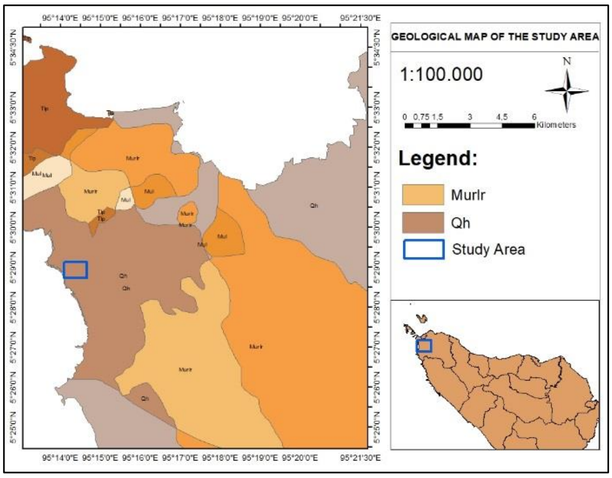

Fig. 1. Geological map of the study area (modified from Bennet et al., 1981).

2. Methodology

This study was coducted in Mon Ikeun Village, Aceh Besar Regrency, using the Electrical Resistivity Tomography method. ERT is a non-invasive geophysical technique commonly uded to investigate subsurface structures ang groundwater potential. Resistivity data data acquisition was done using the ARES Resistivity Meter across three survey lines. Line 1 was oriented southwest–northeast, line 2 south–north, and Line 3 west–east. The layout of the survey lines is shown in Fig. 2. Each line was 420 m long and utilized 22 electrodes spaced 20 m apart. Data acquisition employed the Wenner-Schlumberger electrode configuration. The measurements obtained during the resistivity survey represent apparent resistivity values. These apparent resistivity values do not directly reflect the true resistivity distribution of the subsurface; instead, they represent the response of a hypothetical homogeneous medium. The apparent resistivity data from each line were initially presented as pseudosections. To accurately represent the true subsurface structure, further processing was required. This was achieved through inversion using ResIPy software, which produced 2D resistivity cross-sections that illustrate both lateral and vertical variations in the subsurface resistivity.

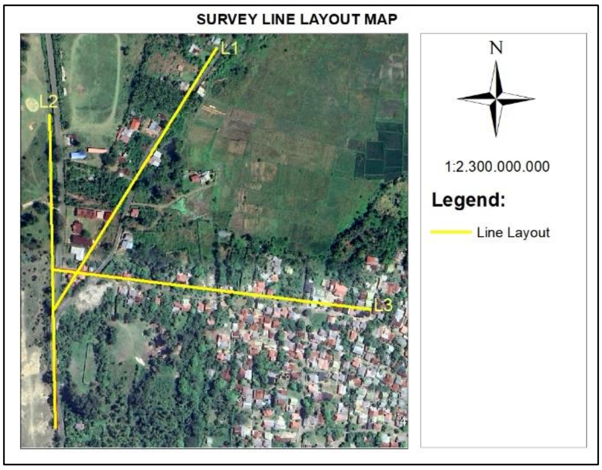

Fig. 2. Survey line layout map.

3. Result and Discussion

Inversion modeling using ResIPy software in Mon Ikeun Village produced 2D resistivity cross-section for all three lines, as shown in Fig.3. The inversion process involves 10 iteration, resulting in low RMS misfit values: 1.83% for line 1 (Fig. 3a), 2.01% for line 2 (Fig. 3b), and 1.62% for line (Fig. 3c). These low RMS misfit values indicated that the inversion models accurately represent the field data.

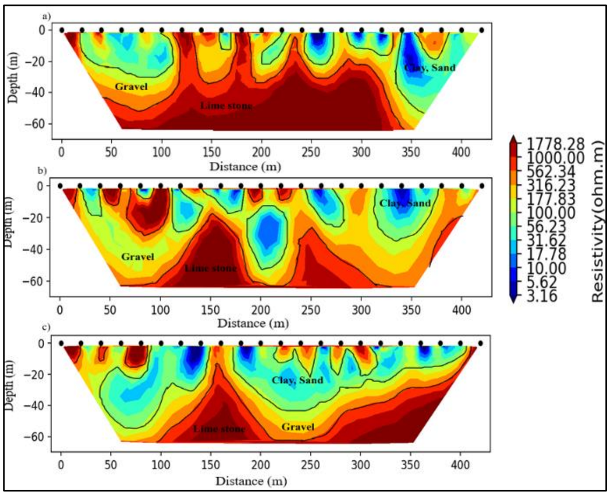

Fig. 3. Interpretation of subsurface structures based on 2D resistivity section: a) line 1, b) line 2, c) line 3.

As shown in Fig.3, the interpreted subsurface structure reveals distinct stratigraphic layers. The colors in the model represent the resistivity values of the subsurface materials in each layer. All three profiles display similar lithological characteristics : a conductive zone with resistivity values of

≤316.23 Ω.m, interpreted as alluvium consisting of clay, sand, and gravel; and a resistive zone with resistivity values of ≤316.23 Ω.m, interpreted as a hard layer (bedrock) composed of limestone. These interpretations are consistent with the regional geological setting shown in Fig.1. The geology of Mon Ikeun Village comprises young alluvium (Qh)

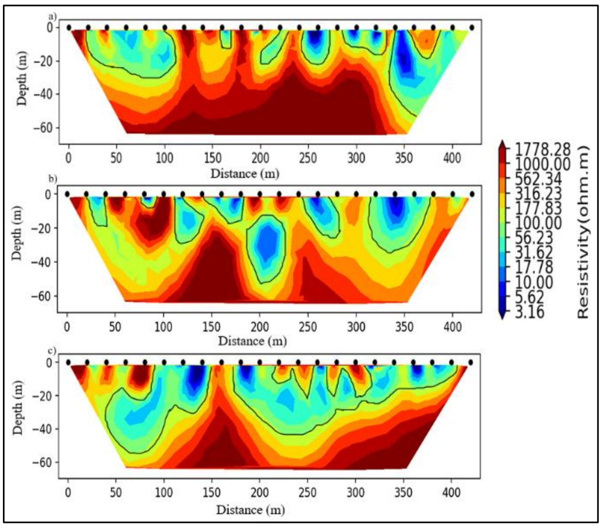

Fig. 4. Interpretation of groundwater potential based on 2D resistivity cross-section: a) line 1, b) line 2, c) line 3.

Fig. 4 shows that gorundwater in the study area is indicated by conductive zones, marked by black otulines. These zones are distributed in several regions with resistivity values ranging from 3.16 to 56.23 Ω·m, and are interpreted as saturated clay and sand layers. This is consistent with findings from previous studies, which suggest that groundwater potential is commonly associated with sandy of fractured layers (Adagunodo et al., 2018; Darisma et al., 2020; Muzakki et al., 2021; Faisal et al., 2022; Bachtiar et al., 2022). In this study, groundwater in clay and sand lithologies, supporting the conclusions of earlier research.

In Fig. 4a (line 1), the conductive zones are found between 20-100 m at depths of 0-25 m, at 220 m at a depth of 0-20 m, between 260-280 m at 0-20 m, between 300-320 m at 0-15 m, and from 340-420 m at depths of 0-45 m. In Fig. 4b (line 2), conductive zones appear between 20-40 m at 0-20 m, at 120 m at 0-25 m, and reef member formations (Murlr). The young alluvium consists of sand, gravel, clay, and silt, while the reef member formation represents carbonate sedimentary rock, primarily (Bennet et al., 1981). Variation in material composition across the profiles may influence the subsurface's permeability and groundwater storage capacity. Groundwater potential is indicated by materials with low resistivity valeus, i.e., conductive zones. The interpretation of groundwater potential based on the 2D resistivity section from all thre lines is presented in Fig.4.

between 140-180 m at 0-20 m, at 200-220 m at 15-45 m, between 240-260 m at 0-20 m, and between 320-380 m at depths of 0-30 m. Compared to line 1, the conductive zones in line 2 are generally shallower. In Fig. 2c (line 3), conductive zones are present betwen 40-80 m at depths of 20-50, between 100-140 m at 0-30 m, between 180-300 m at 0-40 m, and between 320-420 m at 0-20 m.

The interpretation of all three indicates that Mon Ikeun Village has promising groundwater potential. This is evidenced by the presence of conductive zones in each profile, although with varying depths and spatial distributions. Among the three, line 3 shows the most significant potential based on the broader and deeper distribution of conductive zones, making it the ares with the hidhest estimated groundwater availability.

To futher validate the resistivity data interpretation, it was correlated with field information. This was done by comparing the depth of conductive zones on the 2D resistivity cross-section with local well data. Interview eith residents in Mon Ikeun Village revealed that two types of wells are used: dug wells with depths ranging from 6 to 15 m, and drilled wells with depths between 12 to 24 m. This information was used to verify the accuracy of the resistivity interpretation, as presented in Fig. 5 through Fig. 8.

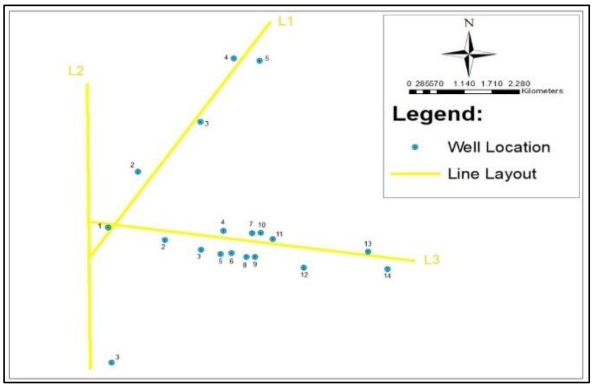

Fig. 5. Well location map.

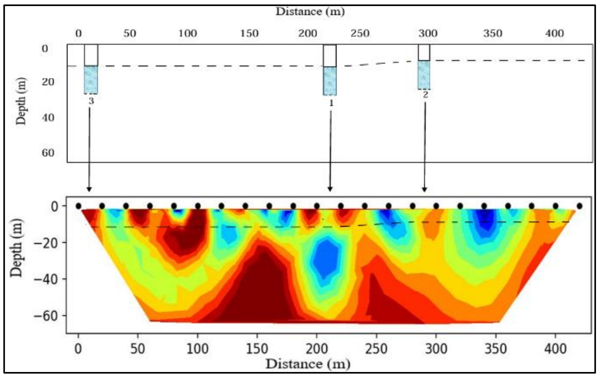

Fig. 7. Correlation between 2D resistivity cross-section and well data log line 2.

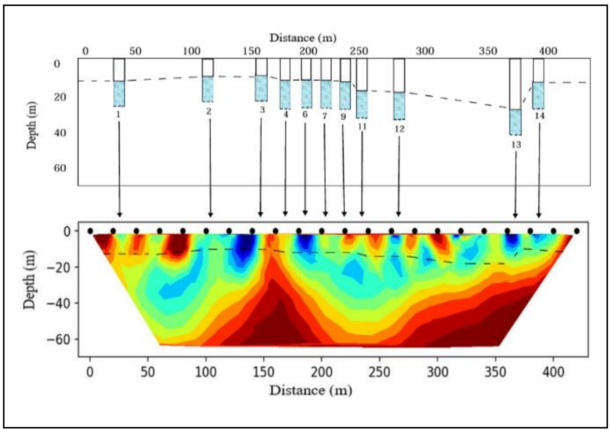

Fig. 8. Correlation between 2D resistivity cross-section and well data log line 3.

The correlation between the 2D resistivity cross-section and well data across all thre survey lines shows that the conductive zones-interpreted as water-saturated layers-generally align with the depth to the groundwater table identified in wells located along the survey profiles. The consistency between the low-resistivity zones in the cross-section and the groundwater depths from the well data indicates that the resistivity modeling accurately represents the actual subsurface conditions.

4. Conclusion

This study successfully identified groundwater potential in Mon Ikeun Village using the Erectical Resistivity Tomography method. Based on the 2D resistivity cross-section, groundwater potential zones were detected in conductive areas with resistivity values ranging from 3.16 to 56.23 Ω.m. These zones are interpreted as water-saturated layers dominated by clay and sand lithology. Among the three surveyed lines, line 3 was the most suitable for gorundwater exploation, with significant conductive zones detected at depths ranging from 0 to 40 m. Therefore , line 3 is recommended as a priority location for exploration well drilling.

Acknowledgment

The authors would like to thank the Ministry of Higher Edducation, Sciencs and Technology, Indonesia for fully supporting the research through the research grant of Penelitian Tesis Magister (PTM) PTNBH Universitas Syiah Kuala (USK) 2025. Furthermore, special gratitude also given to staff and students of Physics Departement, Faculty of Mathematics and Sciences, and Enggineering Geophysics Departement, Faculty of Engineering, Universitas Syiah Kuala for the efforts during data acquisition and analysis.

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