

Aquifer layer in Muara Batu and Dewantara Sub-district based on resistivity cross-sectional model

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Abstract. This study aims to determine the depth of the aquifer layer in the Muara Batu and Dewantara sub-district as a source of groundwater that can be used continuously. The identification of this aquifer layer is based on the results of the resistivity values of subsurface rocks measured using the electrical resistivity method of the Schlumberger array. Data acquisition was carried out on 3 lines (MB1, MB3, and MB4) with a length of 330 m each. The variations in the resistivity values of the rocks obtained were modeled in the form of a 2D cross-section using the Res2DInv software, thus providing an overview of the subsurface for groundwater exploitation. The cross-sectional model obtained shows that the shallow aquifer layer is at a depth of 20-52 m (2-12 Ω m) on the MB1 and a depth of >60 m on MB3 and MB4. The low resistivity value <12 Ω m on the MB1 indicates that the subsurface is generally composed of water-saturated rock layers.

Keywords: aquifer, Dewantara, electrical resistivity, Muara Batu

INTRODUCTION

Water is a natural resource that is an absolute necessity for humans and other living things. As time goes by, contamination of groundwater near the surface is increasing due to population growth, industrial activities that produce hazardous waste, using fertilizers, pest poisons, and so on. Limited availability of clean water can affect the quality of public health. The difficulty of providing clean water for public facilities such as mosques, Islamic boarding schools, public schools, and health centers is still present in two of the 27 sub-districts in North Aceh Regency, namely in Muara Batu and Dewantara Sub-district. Generally, the groundwater is not clear and calcareous so it is not suitable for consumption. As a result, to get clean groundwater, people dig drilled wells randomly without any exploration related to the drilling location first. Whereas groundwater exploration activities are very important to determine the exact location of groundwater and the depth of rock layers containing groundwater.

Groundwater can be associated with sandy layers (aquifers) or fractures [1]. An aquifer is a

geological formation that contains water and is significantly capable of draining water through its natural state. An aquifer is also defined as a groundwater reservoir, or as a water-carrying layer.

Groundwater quality conditions tend to change depending on the environment it passes through and the length of time the water flows through the rock layers [2]. Groundwater conditions in Muara Batu and Dewantara sub-district are closely related to subsurface conditions. To find out more clearly the subsurface conditions, distribution, and depth of the aquifer, one of the geophysical methods is the geoelectric method. The geoelectric method can determine the characteristics of subsurface rock layers to a depth of hundreds of meters, this is very useful for determining the possibility of an aquifer layer [3], [4].

Groundwater exploration activities also often combine several measurements using existing geophysical methods to obtain other physical parameters. Some of them are a combination of geoelectric methods with Induced Polarized (IP), boreholes [5], [6], and so on. The more physical parameters of minerals or rocks there are, the identification of subsurface layers becomes easier and more accurate.

Measurements using the electrical resistivity method with the Schlumberger array can provide data on the vertical and horizontal distribution of rock resistivity values. Rock can be an electric medium as in a conducting wire,

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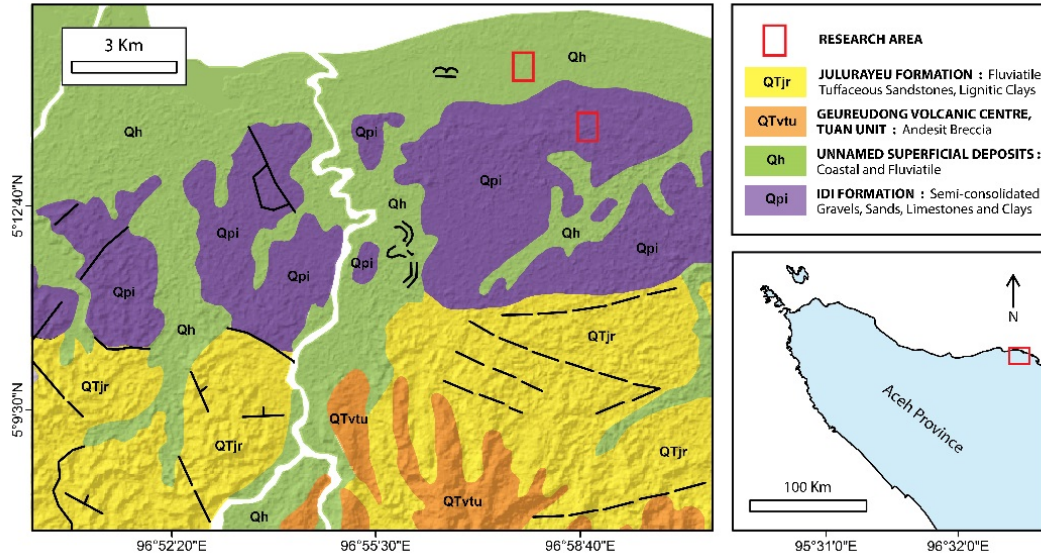


Figure 1. Geological map of the research area. In the Idi Formation of the Lhokseumawe area, the most common rock outcrops are reefal limestones, gravels, sandstones, calcareous, and mudstone [9]

so it has a certain resistance. Rock resistivity is rock resistance to electric current. Rock resistivity is influenced by porosity, water content, and minerals [7]. The resistivity value is large when a rock and mineral can conduct a small current, whereas the resistivity value is small when the rock and mineral can conduct a large current [8].

This study was conducted to identify the presence of groundwater and the depth of the aquifer in the Muara Batu and Dewantara sub-district using the electrical resistivity method. The results of this study are very useful for related parties or agencies in development planning in Muara Batu and Dewantara. Information from the distribution and depth of the aquifer layer is also very useful in planning groundwater drilling points, where the need for groundwater (clean water) for consumption, agriculture, and public facilities continues to increase along with population growth.

METHODOLOGY

Goelectric data measurements were carried out in 3 lines with a length of 330 m each using the Schlumberger array electrical resistivity method. Administratively, the measurement lines are in two locations. Where the MB1 is in Paloh Awe Village, Dewantara Sub-district and the MB3 and MB4 are in Reuleut Village, Muara Batu Sub-district. More accurate positional coordinates of these tree points are given in Table 2.

The data acquisition process uses a SuperSting R8/IP resistivity meter and Res2DInv software to get an overview of the aquifer layer in the Muara Batu district based on the resistivity cross-sectional model. Each line consists of 455 datum point measurements. The datum points measurement simulation made using the AGISSA Admin software is shown in Figure 2.

Table 1. Resistivities of various rocks, sediments, and minerals [11]

Rock Type	Resistivity Range (Ωm)
Marls	1-70
Clays	1-100
Unconsolidated wet clay	20
Sandstones	$1-6.4 \times 10^8$
Limestone	$50-10^7$
Surface waters (sediments)	10-100
Surface waters (igneous rocks)	$0.1-3 \times 10^3$
Natural waters (sediments)	1-100
Natural waters (igneous rocks)	0.-150
Sea water	0.2

Table 2. The location of the line's geoelectric measurement

No. Line	Latitude/Longitude		Location
	0 m	330 m	
1 MB1	5°14'58.49"N/ 96°57'47.05"E	5°14'48.00"N/ 96°57'44.68"E	Paloh Awee
3 MB3	5°14'3.32"N/ 96°58'46.68"E	5°13'52.68"N/ 96°58'47.98"E	Reuleut
4 MB4	5°14'1.05"N/ 96°58'47.69"E	5°13'50.31"N/ 96°58'48.89"E	Reuleut

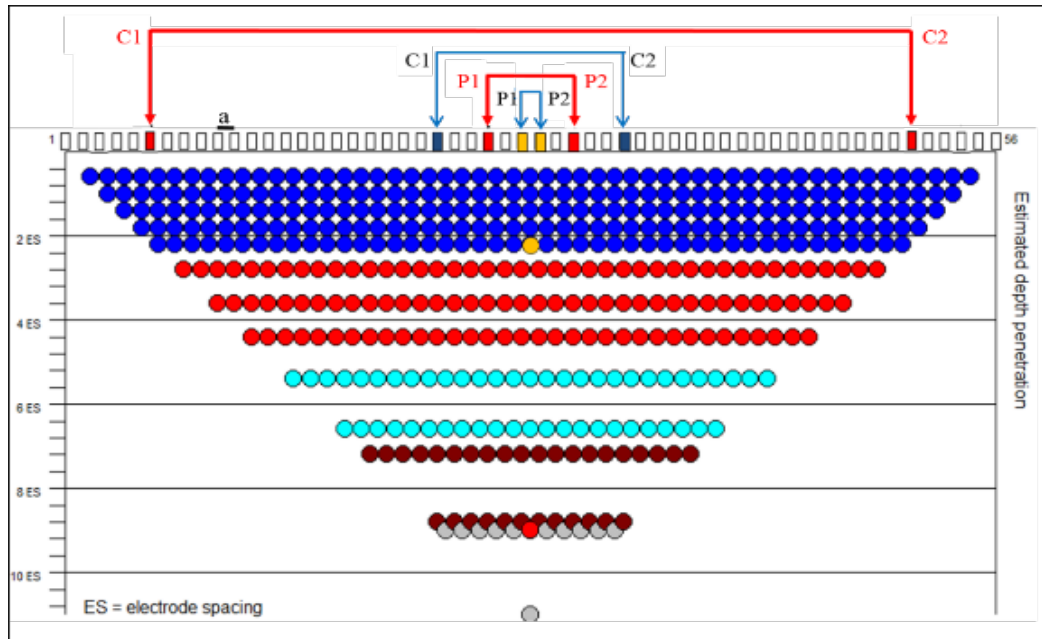


Figure 2. Illustration datum point measurement using Schlumberger array with 56 electrodes.

RESULTS AND DISCUSSION

The geology of the study area based on the geology of the Lhokseumawe quadrangle [9] is included in the Idi formation and unnamed surface deposits. The Idi Formation consists of semi-consolidated gravels, sands, limestones, and clays. While the unnamed superficial deposits consist of coastal and fluvial deposits. The measurement line locations included in the Idi formation are MB3, and MB4, and those included in the unnamed superficial deposit are MB1.

The morphology of the MB1 measurement location (Figure 3) is a lowland area and has a distance of 1.3 km from the sea (north side). The resistivity cross-sectional model on the MB1 line obtained a low resistivity value range of 0.2-12 Ω m. The image of the MB1 resistivity cross-section shows that it consists of 4 layers. The boundaries of this layer are depicted by dashed black lines. This layer is the first layer which is at an altitude of 4 m above sea level (asl) to a depth of 14 m with resistivity values ranging from 4 – 12 Ω m. This layer consists of clay and silt. The second layer is from a depth of 4 to 25 m with a resistivity value of <2 Ω m.

High conductivity indicates that this layer contains brackish water and is a weak layer consisting of silty clay (dominant), silt, and sand. Areas with subsurface conditions like this are very vulnerable to liquefaction. Then the third layer from a depth variation of 20 to 52 m with a resistivity value of 2-12 Ω m is a layer consisting of silt and sand. This layer is indicated as a shallow aquifer layer and can provide sufficient water for exploration. The fourth layer is from a depth of 52 to 60 m with a resistivity value of <4 Ω m. This layer is also indicated as the aquifer layer. However, the groundwater in this layer is not better than the layer above it based on the resistivity value obtained. As for the KEK Arun Lhokseumawe area which has the same geological condition as the MB1 location, the presence of an aquifer layer is indicated at a depth of ± 60 m with a resistivity value of <30 Ω m [10]. Overall, the low resistivity values (>12 m) on the MB1 indicate that the subsurface is a water-saturated layer.

MB3 (Figure 4) is a line whose measurements are in hilly areas and adjacent and parallel to MB4 (Figure 5). The resistivity cross-sectional model of the MB3 is generally obtained with a

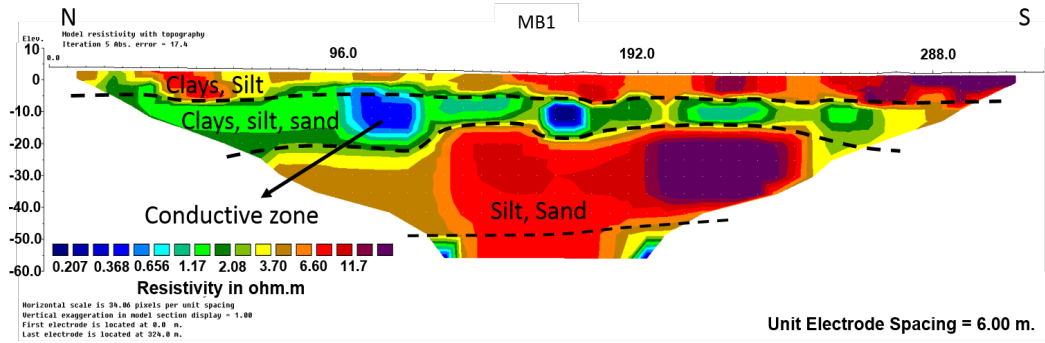


Figure 3. MB1 Resistivity Cross-section

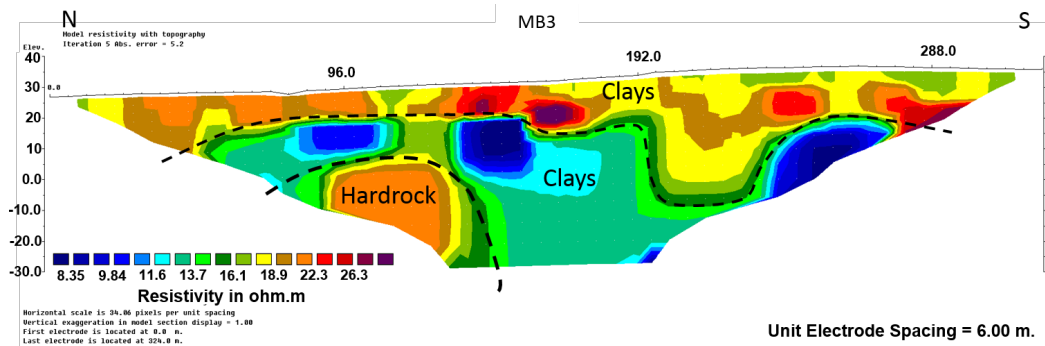


Figure 4. MB3 Resistivity Cross-Section

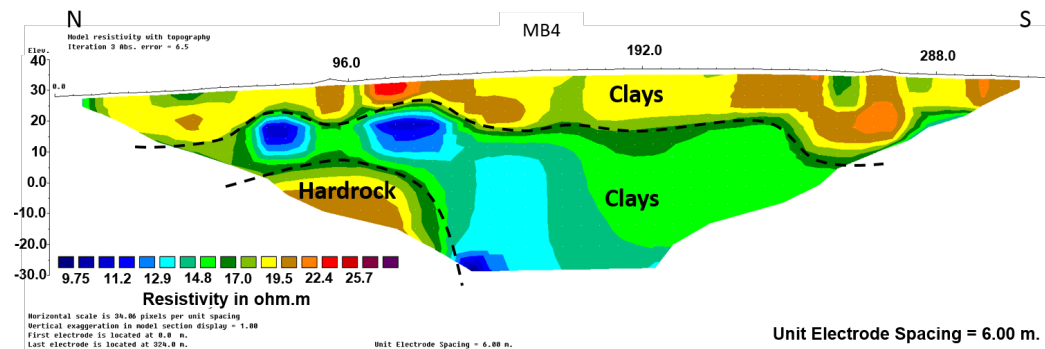


Figure 5. MB4 Resistivity Cross-Section

resistivity value of 8 – 26 Ω m. MB3 consists of a clay layer at the top with a resistivity value of 16 – 26 Ω m and a clay layer with a resistivity value of 8 – 16 Ω m. This clay layer with lower resistivity values (8 – 16 Ω m) indicates that this layer can contain water and from the cross-sectional image model depicting this low resistivity value continuously downwards (imaged in blue–light green), it is very possible at this location point the presence of aquifers can be found at depths >60 m from the surface. Resistivity values that are not so high (19-23 Ω m) are also seen below this line at a distance of 65-130 m at a depth of 32-60 m which are indicated as hard rocks. Geologically this location is in the Idi formation so the hard rock can be indicated as a limestone layer.

The cross-sectional model of the subsurface resistivity of the MB4 line (Figure 5) generally

shows a resistivity value of 9-26 Ω m. The MB4 also consists of an upper layer of clay (17-26 Ω m) and clay with a lower resistivity value of 9-17 Ω m. The hard rock on the MB4 is visible at a distance of 60-120 m at a depth of 32-60 m with a resistivity value of 17-23 Ω m. The aquifer layer at this location is also indicated to be at a depth >60 m from the surface.

CONCLUSION

Based on the cross-sectional model data obtained, it shows that the location of MB1 is the subsurface layer that is saturated with water. The aquifer layer (sand) is indicated to be at a depth of 20 m below the measurement surface on MB1 with a resistivity value of 12-2 Ω m and at a depth of >60 m on MB3 and MB4.

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REFERENCE

- [1] Adagunodo, T.A.; Akinloye, M. K.; Sunmonu, L. A.; Aizebeokhai, A. P.; Oyeyemi, K. D.; Abodunrin, F. O. 2018 Groundwater exploration in Aaba residential area of Akure, Nigeria, *Front. Earth Sci.* **6** 1–12 DOI: 10.3389/feart.2018.00066.
- [2] Seizarwati, W. 2020. Tipologi dan kualitas sumber-sumber air di Pulau Yamdena dan Selaru, Maluku Tenggara Barat', *J. Sumber Daya Air* **6** 1–16 DOI 10.32679/jsda.v12i1.166.
- [3] Sugiyanto, D.; Rusydy, I.; Marwan, M.; Hidayati, D. M.; Asrillah, A. 2018. A Preliminary study on aquifer identification based on geo-electrical data in Banda Aceh, Indonesia, *J. Nat.* **18** (3) 122–126 DOI: 10.24815/jn.v18i3.11204.
- [4] Aflah, N.; Muchlis, M.; Idris, S.; Ardjakusumah, W. O. 2018. Analysis of shallow subsurface at hydrocarbon potential areas in North Aceh Based on electrical resistivity model. *J. Nat.* **18** (3) 148–151 DOI: 10.24815/jn.v18i3.12170.
- [5] Idris, S.; Syukri, M.; Surbakti, M.S.; Marwan, M.; Muchlis, M.; Rusydy, I.; Aflah, N. 2018. Analysis of shallow subsurface structure at geothermal area of Ie Jue using resistivity method. *J. Nat.* **18** (2) 18–21 DOI: 10.24815/jn.v18i1.9676.
- [6] Rusydy, I.; Setiawan, B.; Zainal, M.; Idris, S.; Basyar, K.; Putra, Y. A. 2020. Integration of borehole and vertical electrical sounding data to characterise the sedimentation process and groundwater in Krueng Aceh basin, Indonesia. *Groundw. Sustain. Dev.* **10**(7) 100372 DOI: 10.1016/j.gsd.2020.100372.
- [7] Loke, M. H. 2015. Tutorial: 2D and 3D Electrical Imaging Surveys, no. October, [Online]. Available: <http://www.geotomosoft.com/coursenotes.zip>.
- [8] Wahyuni, A.; Massinai, M. F. I.; Mun'im, A.; Massinai, M. A. 2021. Resistivity method for characterising subsurface layers of coastal areas in South Sulawesi, Indonesia. *J. Geosci. Eng. Environ. Technol.* **6** (4) 217–225 DOI: 10.25299/jgeet.2021.6.4.6242.
- [9] Keats, W.; Cameron, N.R.; Djunuddin, A.; Ghazali, S.A.; Harahap, H.; Kartawa, W.; Ngabito, H.; Rock, N.M.S.; Thomson, S.J.; Whandoyo, R. 1981 The geology of the Lhokseumawe Quadrangle (Bandung: Pusat Penelitian dan Pengembangan Geology)
- [10] Fadhli, Z.; Syukri, M.; Marwan. 2019 Identification of Aquifer layer based on 2D resistivity data in Lhokseumawe Aceh-Indonesia, *J. Aceh Phys. Soc.* **8**(3) 78–83 DOI: 10.24815/jacps.v8i3.14518.
- [11] Telford, W. M.; Geldart, L. P.; Sheriff, R. E. 1990. *Applied Geophysics Second Edition* (New York: Cambridge University Press).