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Estimation of groundwater potential using the electrical resistivity method - Wenner Array

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Estimation of groundwater potential using the electrical resistivity method - Wenner Array

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Abstract. Groundwater as a water resource has now become a complex national issue. Therefore, due to excessive groundwater abstraction, it is necessary to minimize the negative impact. This research aims to estimate groundwater level distribution and its possible use at the Faculty of Engineering of the University of Jember. A total path length of 392 meters was investigated. Field data was collected using a resistivity meter with the Wenner configuration method. In addition, the data obtained from the measurements were processed using RES2DINV software. The results showed that the distribution of groundwater lies at depths between 25.3-39.7 meters. Meanwhile, the potential use for aquifers is classified as moderate. This is based on the classification of groundwater potential, which indicated that the layers of soil at the site contain alluvium plains and coarse-grained to medium gravel and sand, with the addition of clay.

Keywords: groundwater, resistivity, Wenner configuration

1. Introduction

Groundwater is one of the sources of water that is used to meet the needs of living things, for which the supply is required to be of good quality, cheap, and of sufficient availability. In an effort to obtain the potential of groundwater, investigation activities must be carried out through the surface or subsurface of the soil in order to find out whether or not the aquifer layer exists, as well as its thickness and depth. One of the investigation methods that can be used is the electrical resistivity method. The electrical resistivity method adheres to the basic principle that each rock layer has a different resistivity value. The resistivity value of each layer of rock is determined by the factors of constituent material type, water content in the rock, chemical properties of water, and porosity of the rock [1].

University of Jember, located in the centre of Jember Regency, is a campus with an increasing number of students each year. In addition to this increase, the need for clean water in the campus area will also increase. To compensate, it is necessary to increase the amount of water available in the campus area. One effort that can be taken is to make boreholes in the campus area. However, determining the borehole points is not easy, and they cannot be at any place. A test is needed to determine the points that contain water and at what depth good groundwater is located.

Groundwater estimation methods for groundwater exploration can utilize the Schlumberger or Wenner configuration for the electrical resistivity method. The advantage of the Schlumberger configuration is that data collection in the field is faster and more efficient, and therefore does not require significant costs. This method is also able to provide information about vertical soil layers with deeper reading results compared to other electrical resistivity methods, up to a depth of AB/2, where AB is the length of the measurement line/track [2]. However, the disadvantage is that the electrodes must be moved, which makes the method vulnerable for reading the horizontal scale. As for the Wenner configuration, the advantages are that it can provide soil information horizontally and can also provide soil information for depths of over 100 meters, as long as the track distance is sufficiently long. Another advantage of the Wenner configuration is the large potential electrode spacing width, which does not require sensitive equipment [3].

A previous researcher who used electrical resistivity to estimate groundwater is Mohamaden [4], who researched the desert areas in Egypt. The results led to the discovery of aquifer layers at certain depths and finding fractures in rocks in the study area. Another researcher is Halik [5] who conducted a research on determining groundwater potential at the Faculty of Engineering, University of Jember using the Schlumberger configuration for the electrical resistivity method; the results showed that geologically, the rocks at the study area are dominated by young volcanic deposits consisting of tuffs, breccia, and andesite lava to basalt lava. Hydrogeologically, the aquifer flows through gaps and spaces between grains. This aquifer is moderate with a large distribution. Electrical resistivity estimation results showed that most of the rocks are hard rock layers that have high resistivity values (above 500 Ωm). This layer lacks the properties of aquifer layers. Based on the success of previous researchers, this study estimates the potential of groundwater level using the electrical resistivity method with a Wenner array and the resistivity mapping method, which means applying a different method from previous researchers with the aim to find out how aquifer layers are distributed and the size of the potential use of its groundwater.

Wenner Configuration

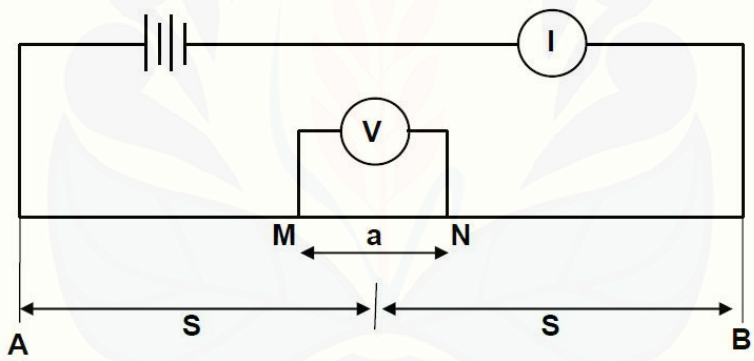

Figure 1. Wenner Configuration [6]

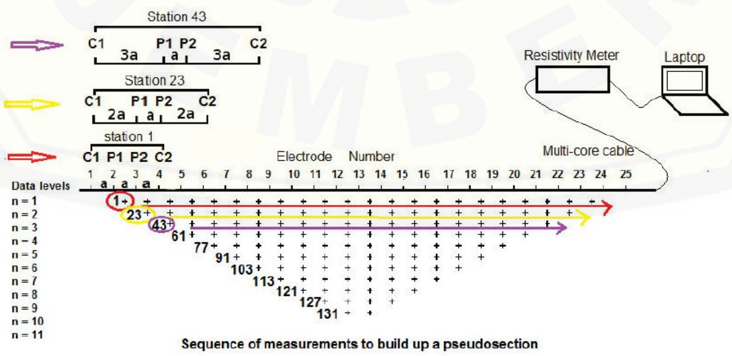

Figure 2. Electrode Sequence for the Wenner Configuration [7]

Figures 1 and 2 are the diagrams of the working principles of the Wenner configuration for resistivity mapping; four configuration electrodes (C1, P1, P2, and C2) with the same spacing are moved together with a fixed distance. The spacing depends on the depth of the layer that will be mapped.

2. Materials and Methods

The study was conducted at the Faculty of Engineering of University of Jember, which is geographically located at coordinates 8°9'43" - 8°9'38" SL and 113°43'24" - 113°43'12" EL. The research location is shown in Figure 3 below:

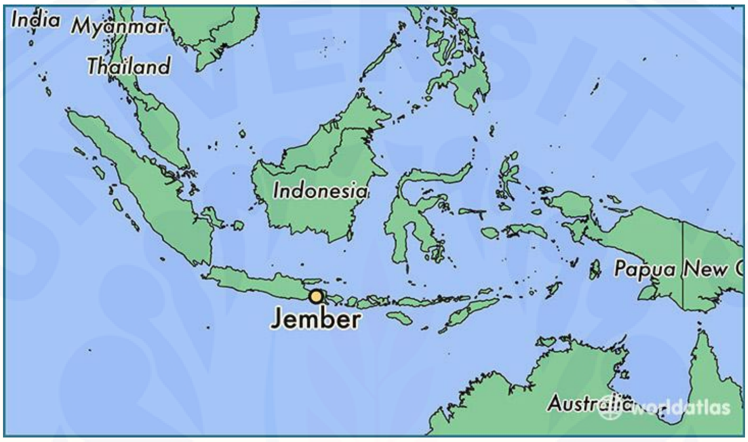

Figure 3. Research Location [8]

The electrical resistivity measurement applied in this study is the Wenner (mapping) configuration. The measurement was performed at one location and along one track with a length of ± 392 meters. Electrode spacing (α) is the differing variable, with lengths of α = 4 metres, α = 8 metres, and α = 12 metres. The intent is to show that with different electrode spacing, a greater spacing means a deeper obtained target depth.

From the data collection in the field, data was obtained in the form of the soil resistance values. This value was multiplied by the Wenner configuration geometry factor to produce apparent resistivity values. Then, the data was used as input data in the RES2DINV software. This software produces sections of subsurface resistivity distributions, which are shown in different colours according to the resistivity values of each rock.

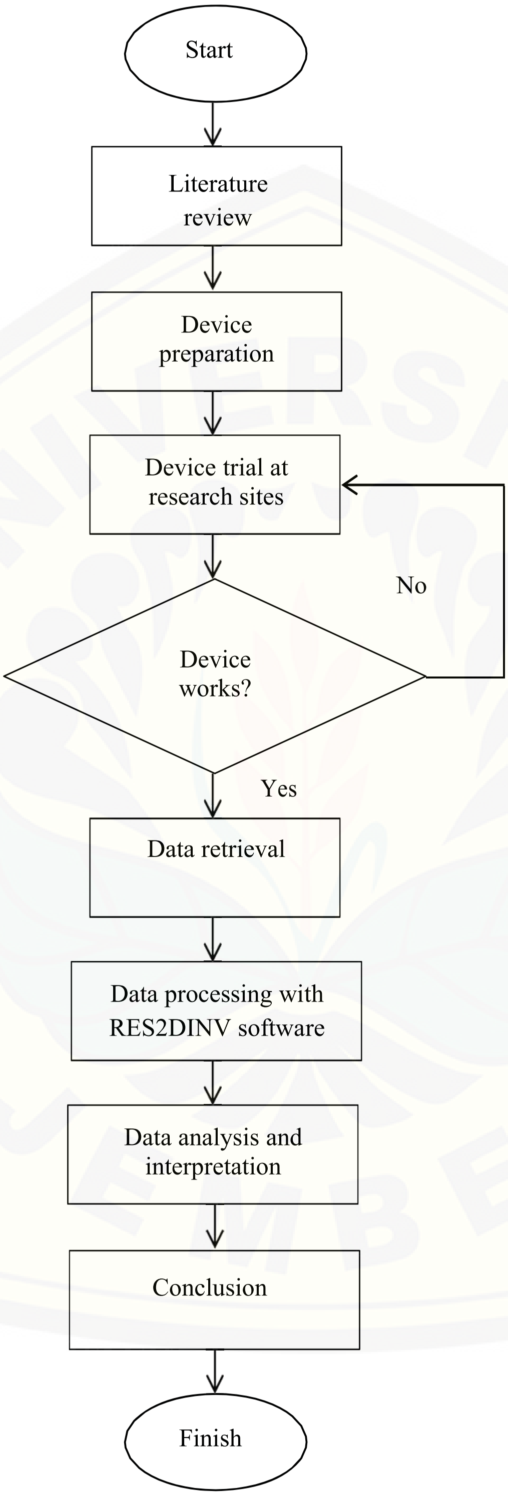

Figure 4. Research Flowchart

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3. Results and Discussion

The measurements were performed three times on the same track. Figure 4 shows the results of the RES2DINV code analysis. The figure provides information about the classification of sub-surface structures described by the apparent resistivity values, which were then used to measure the presence of sub-surface rock layers. The image colours show the resistivity value of each layer in order to identify them.

From the results of measurements with a spacing distance of 4 metres between the electrodes, the section image of sub-surface apparent resistivity with differences in sub-surface rock layers varying from 1.19 Ωm to 308 Ωm and reaching a depth of 13.2 meters was obtained. The layer that includes aquifers is shown in dark blue with resistivity values ranging from 1.19 Ωm to 5.83 Ωm located at a depth of 0.75 m to 13.2 m, ranging from 40 to 360 m. The aquifer is quite extensive, but the results showed that the aquifer layer is at a shallow depth. In this test, the aquifer layer is also surrounded by rocks in the form of gravel and dry gravel, pictured in green and yellow, with ranges of rock resistivity from 32.4 Ωm to 101 Ωm. The image parts in red show that this aquifer is also surrounded by alluvium with a resistivity range from 63.8 Ωm to 139 Ωm.

The resulting section image for 8-metre electrode spacing showed sections of resistivity with a range from 91 Ωm to 702 Ωm and resulted in a 26.5-meter aquifer depth. This aquifer layer is shown by resistivity values from 2.91 Ωm to 13.9 Ωm, which are represented in blue at depths between 1.50 m and 26.5 m. The aquifer layer is also surrounded by rocks in the form of gravel and dry gravel, shown in the image in green and yellow, with a rock resistivity range between 30.5 Ωm and 146 Ωm. The image parts in red show that this aquifer is also surrounded by alluvium with a range of resistivity from 320 Ωm to 720 Ωm. The aquifer is also shallow groundwater in this experiment, because it is less than 100 meters away.

An electrode spacing of 12 metres was used in the third test. The obtained resistivity values of the entire variety of rock layers were from 5.86 Ωm to 317 Ωm, reaching a depth of 39.7 meters. From this test, it can be seen that the aquifer layer is more distributed than with the two previous tests with a smaller area. The detected aquifer layer is quite deep, from a depth of 25.3 metres to 39.7 metres, with a range of distances from 66 metres to 300 metres. The apparent resistivity values indicated that the aquifer in this test is in the range from 5.86 Ωm to 18.3 Ωm. Similar to the previous test, this layer is affected by gravel and dry gravel, as shown in the image in green and yellow, with rock resistivity that ranges from 32.4 Ωm to 101Ωm.

From the three performed tests, it can be seen that the aquifer distribution in each test is interconnected. This is because the test was performed at the same location and with the same track or line, with only the spacing between electrodes being different. The results of the third test with a spacing of 12 metres between electrodes showed a quite large aquifer potential among the three tests, but the location of aquifer is shallow, because the obtained depth was only up to 39.7 meters. The estimation of the area that contains groundwater can be made from the second test with the following calculation:

Area = p x t
= 162 m – 66 m) x (39.7 m – 20 m)
= 1891.2 m^2
Volume = p x t x l
= 1891.2 m^2 x 1 m
= 1891.2 m^3

(Assuming the width of the well to be dug is 1 metre)

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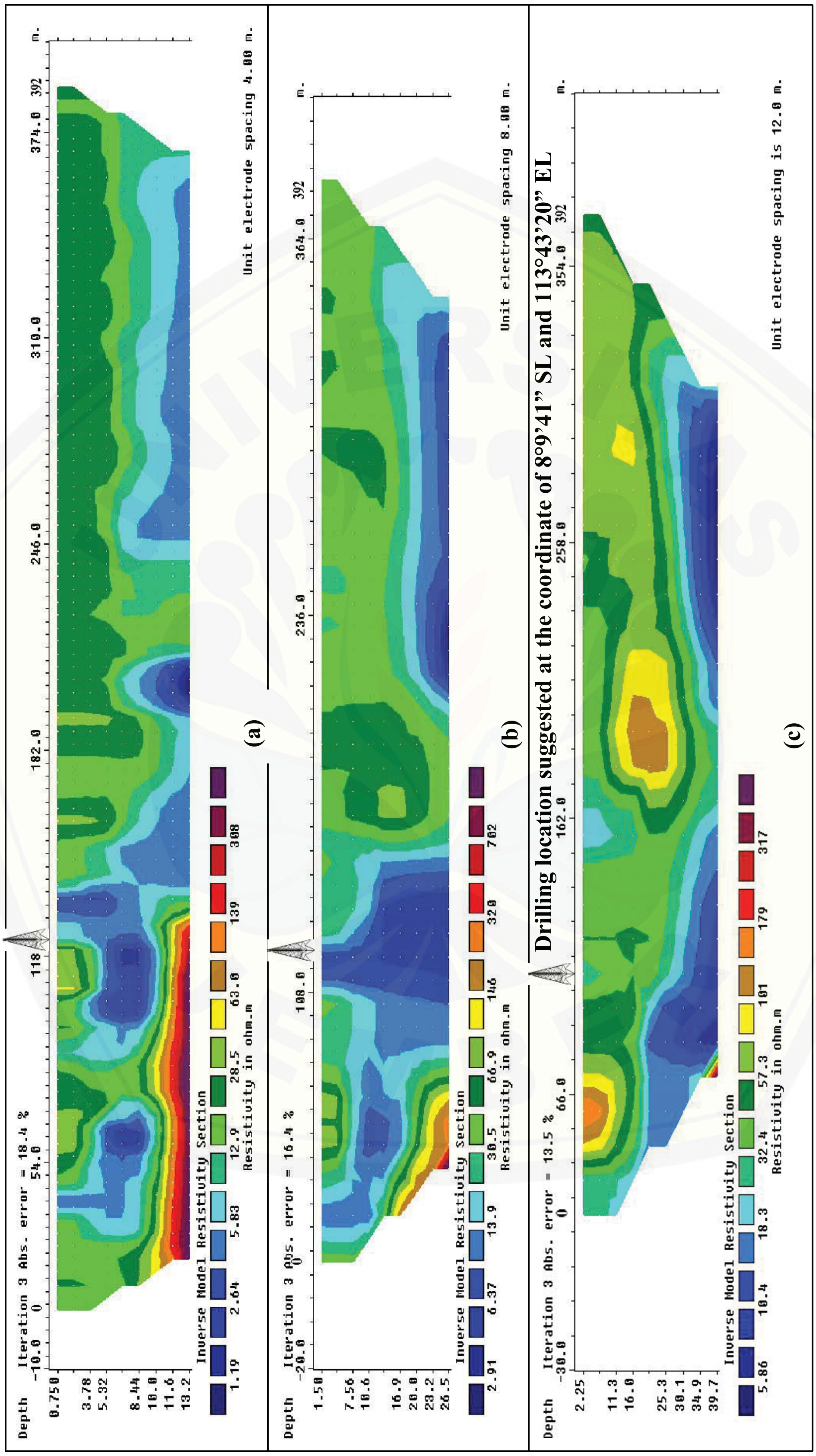

(a) 4-metre spacing; (b) 8-metre spacing; (c) 12-metre spacing

Figure 5. RES2DINV Image from the Inversion Results

The classification of groundwater potential at the Faculty of Engineering of University of Jember is as a moderate productive aquifer that passes through a gap, with area distribution and well discharge of generally less than 5 litres/second [9].

In addition, the results of this test also support the theory that a longer spacing between electrodes on the same path or track results in a deeper target depth that is imaged. A comparison of target depths are shown in Table 1 below:

Table 1. Depth Estimation

L (m)	n	a (m)	Ze/a	Depth Target Estimation (m)	RES2DINV Image Results (m)
392	6	4	0.416	9.984	13.2
392	6	8	0.416	19.968	26.5
392	6	12	0.416	29.952	39.7

Based on the identification that had been conducted, the aquifer layer produced using the electrical resistivity method with the Wenner array was indicated to be a perched aquifer layer because the aquifer layer shown by the imagery showed special conditions. The subsurface water in this aquifer is separated from the main subsurface water by layer that is relatively impermeable with limited distribution and is located above the main subsurface water level. This aquifer occurs in the aerial zone that forms an aquifer above the impermeable layer. This type of aquifer cannot be used for groundwater development because it has large variations in surface water and volumes [10]. However, if it is still desired to drill at this location, it can be seen that the recommended location is a distance of 120 meters from the zero point of the investigation, precisely at the coordinate of 8°9'41" SL and 113°43'20" EL. This is because the test results showed resistivity data of 5.86 Ωm to 57.3 Ωm with the layers estimated to contain ground water, silt-clay, mud stone, sandstone, tuff, sandy silt, and fresh water.

Calibration of the results was carried out by comparing them with drilling data carried out around the study site. Drilling results showed that at a depth of 0-16.5 m the type of soil is sandy silt, sand, and sand gravel. This is consistent with the results of this study as in Figures 4(a) and 4(b) which show that the aquifer location is in the range of 0.75-26 m. Based on these results, it can be said that the electrical resistivity method with the Wenner array can be applied to the study location.

4. Conclusion

Based on research that was performed, the following conclusions are obtained:

1. The resistivity value at the study site is between 5.86 Ωm to 57.3 Ωm, with the layers estimated to contain groundwater, silt-clay, mudstone, sandstone, tuff, sandy silt, and fresh water. This distribution is located at a depth of 25.3-39.7 metres. Based on the visible image, the distribution of this aquifer layer is classified as a perched aquifer layer with a quite large formed aquifer, but the position of the aquifer is at a shallow depth.
2. The groundwater potential at the Faculty of Engineering of the University of Jember is classified as a moderate productive aquifer, which passes through a gap with an area distribution and well discharge of generally less than 5 litres/second. This is based on the classification of groundwater potential, which indicated that the soil layer at this location contains plain alluvium deposits and coarse to medium grain gravel and sand, with the addition of clay. This condition is in accordance with the results of the study, which shows that the estimated layers contain groundwater, silt-clay, mudstone, sandstone, tuff, sandy silt soils, and fresh water.

From these results, if drilling is to be conducted at this location, it is recommended to do so at a distance of 120 meters from the zero point of the investigation, at the coordinate position 8°9'41" SL and 113°43'20" EL. The reason is that the test results show resistivity data between 5.86 Ωm and 57.3 Ωm with the layers estimated to contain groundwater, silt-clay, mud stone, sandstone, tuff, sandy silt, and fresh water.

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