Subsurface Mapping of Ground Water using Schlumberger Configuration in Upstream of Brantas River, Batu area, East Java, Indonesia

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ABSTRAK

Pengukuran resistivitas secara sounding telah dilakukan di daerah Batu, Jawa Timur, Indonesia, yang merupakan daerah hulu dari sungai Brantas. Tujuan dari penelitian ini adalah untuk mengidentifikasi sumber air yang terdapat di daerah hulu dari sungai Brantas ini. Agar supaya bisa menentukan ketebalan dari aquifer aliran dari air tanah ini, maka dilakukan pengukuran secara mapping pada 6 daerah mata air yang dipilih untuk mewakili 108 mata air yang ada di daerah Batu ini. Pengumpulan data dilakukan dengan menggunakan konfigurasi Schlumberger, di sekitar daerah mata air dengan panjang lintasan 400 meter, dengan lebar spasi 10 meter. Pemrosesan data dan interpretasi menggunakan software IP2WIN, Progress 3, dan Rockwork 15, yang memungkinkan penggambaran distribusi resistivitas batuan bawah permukaan dalam 1 dan 3 Dimensi. Hasil interpretasi menunjukkan terdapatnya lapisan batuan yang terbentuk dari akibat aktivitas vulkanik. Struktur batuan tersebut terdiri dari batuan breksi gunungapi, tuf breksi, pasiran tuff, tuf dan lava. Batuan breksi gunungapi, tuf breksi, tuf dan lava memiliki porositas yang kecil karena memiliki ukuran butir yang kecil dan halus, serta memilki permeabelitas yang rendah, sehingga tidak mampu untuk menyimpan dan mengalirkan air. Lapisan batuan ini diperkirakan berfungsi sebagai lapisan impermeabel dan selanjutnya dapat berfungsi untuk menahan air tanah yang dapat meresap ke bawah, sehingga air tanah akan mengalir secara horizontal. Sedangkan batu pasir memilki porositas yang besar karena memilki butir batuan yang membulat dengan permeabelitas yang besar, sehingga mampu menyimpan air dan mengalirkannya dalam jumlah yang berarti

Kata kunci : Schlumberger, Batu, air tanah, metode resistivitas sounding, permeabilitas

ABSTRACT

A Resistivity sounding survey of groundwater was performed around the upstream of Brantas river, Batu area, East Java, Indonesia. The goal of this study is to identify the water resources. In order to determine the aquifer thickness and the ground water flow, it was done a mapping in the 6 spring water area, as a representative of 108 spring water in the study area. Acquisitions are taken by six lines using Schlumberger configuration around the spring water at length of measurement line about 400 m with electrode spacing 10 m. Data processing and interpretation were using IP2WIN, Progress 3, and Rockwork 15, which allowed in 1D and 3D scheme to present the distribution of real resistivity below the surface. Interpretation of the results indicate the presence of a layer of rock that is formed due to volcanic activity. The rock structure is composed of volcanic rock breccia, tuff breccia, sandy tuff, tuff and lava. Rocks of volcanic breccia, tuff breccia, tuff and lava have small porosity due to having a small grain size and smooth, and have the low permeability, so it is not able to store and drain water. This rock layer is expected to function as an impermeable layer and can further serve to hold water that can seep into the ground below, so that the ground water will flow horizontally. While sandstone has a great porosity because it has a rounded rock grains with large permeability, so as to save water and running it in a number of significant.

Keywords : Schlumerger, Batu, groundwater, sounding resistivity method, permeability

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INTRODUCTION

Water is one of the basic needs for human life, therefore, availability of water that meets the quality requirements in accordance with the standard requirements, the quantity is sufficient and available at any time (continuous). The quality and quantity of water is strongly influenced by climate change in the local area [1]. For that, the government of East Java tried to conserve the water resources intensively.

The locations as the center of water resources conservation in East Java is Upstream of Brantas River in Batu city. It is known that Batu City has sufficient water resources in terms of quantity large with good water quality conditions. Furthermore, the Batu city also have high potential of the ground water. In the Batu city there are 108 spring water and spread in all the city area (Figure1). Large springs debit namely Binangun spring water in Bumiaji, Dok spring water in Junrejo, Pande spring water in Temas, Umbul spring water in Bumiaji, Torong Belok spring water in Songgokerto, and Talun spring water in Bumiaji. In general, these spring waters are used by PDAM Malang city and Batu city, the peoples in the local area, and irrigation. In the field, it is known that some springs are still active, semi-active, and not active. This is caused by the environmental conditions around the spring water. It is necessary to conserve the environment around the spring water so the spring water that are not active can be active again.

In general, the soils in Batu city growing by volcanic materials from some volcanoes around the Batu city, which are influenced by Arjuno and Anjasmoro Volcanoes in the north, and Panderman Mountain in the south. Distributions of vertical and lateral volcanic rocks are very irregular and rich of cracks and joints. This condition makes the geological model of ground water flow and the aquifer layer becomes irregular. The existences and flow of the ground water in a region are strongly influenced by the geological conditions such as lithology, stratigraphy, and structure [2]. Based on this condition, to determine the characteristic aquifers of ground water in study area, we use the geoelectrical method.

Geoelectrical measurement is intended to determine the distribution and thickness of aquifers that exist in the study area [3, 4, 5]. By knowing the aquifer which have high potential of water, it is expected to be a reference for formulating and alternatives recommendation policy for the government of East Java in order to save the spring water around the upstream of the Brantas river.

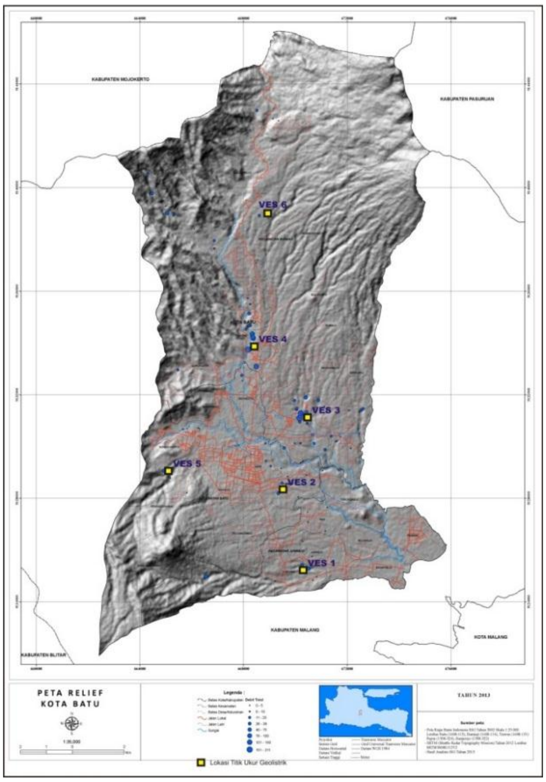

Figure. 1. Map location of the study area in around the upstream of Brantas river in Batu city. Blue circle shows the spring water distribution; Yellow rectangular shows the geoelectrical sounding position in study area. VES 1 located in Dok spring water in Junrejo; VES 2 located in Pande spring water in Temas; VES 3 located in Binangun spring water in Bumiaji; VES 4 located in Umbul spring water in Bumiaji; VES 5 located in Torong Belok spring water in Songgokerto; VES 6 located in Talun spring water in Bumiaji.

METHODS

Study Site. In getting information below the surface such as resistivity with depth in around the upstream of Brantas river, we investigated the area using geoelectrical method especially using geolectrical sounding (Schlumberger configuration). The Geoelectrical investigation was performed on

12 – 15 of October 2013. The study area is located at coordinates between 112^0 28' 13'' and 112^0 35' 37" E, and 7^0 43' 19'' and 7^0 56' 20'' S, with a total coverage area of about 20,006 hectares. Measurements were taken at 6 locations in around spring water, which are considered to represent all of spring water in around the upstream of the Brantas river. For more detail, location and the lines of measurement of the geoelectrical survey can be seen in the Figure 1.

The basic principle of the subsurface structure prediction with the geoelectrical investigation is by injecting the electric current into the earth through two electrodes. The potential different and resistance are measured at ground level by using two potential electrodes which are not polarized. From this values, it is then performed the calculation of the resistivity values [6-8].

The acquisition data used Schlumberger configuration, as shown in Figure 2. Schlumberger Configuration data acquisition process was performed by moving outward current electrode and potential electrode in the fixed spacing.

The process of data acquisition in the upstream of Brantas river using Schlumberger configuration was done with a long stretch of AB mostly 400 meters (Figure2). The Number of measurement for this configuration are 6 points around the highest spring water debit, which are located in Dok in Junrejo, Pande in Temas, Binangun in Bumiaji, Umbul in Bumiaji, Torong Belok in Songgokerto and Talun in Bumiaji. By measurements using the Schlumberger configuration, it will be obtained the apparent resistivity using equation 1:

$$\rho_a = \frac{V}{I} 2\pi \frac{(a+b)}{b} \qquad (1)$$

Where: ρa = apparent resistivity, π = 3.14, a = 200 meter; b = 5 meter; V = Voltage, I = currents, n : integer number = 1,2,3,4,5.

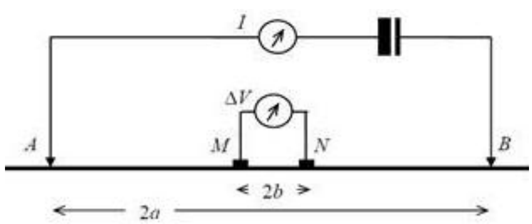

Figure 2. Electrode Position in Schlumberger configuration

During the data aquisation, the instrument will read a voltage (V), and current (I), while the value of MN and AB (distance) has been determined, as well as the "n".

The results of data processing from Schlumberger measurement will be combined with geological and hydrological information will be used to determine and describe the subsurface structure and lithology in the study area. The low apparent resistivity indicated the aquifer zone. So, the determination of the distribution and thickness of aquifer are based on the resistivity (low resistivity) of the layers.

RESULT AND DISCUSSION

Geologically, the typical rocks in the study area is dominated by volcanic deposits which are tuffs, lava, lava breccia, andesite, and basalt. The permeability of the rock in study area is from high to medium. High permeabilities occur especially in sandy tuff, sediment lava vesicular, and lava flows. The Productivity of aquifer is high and distribute in the large area. The aquifer model and depth range is very varying [2, 9].

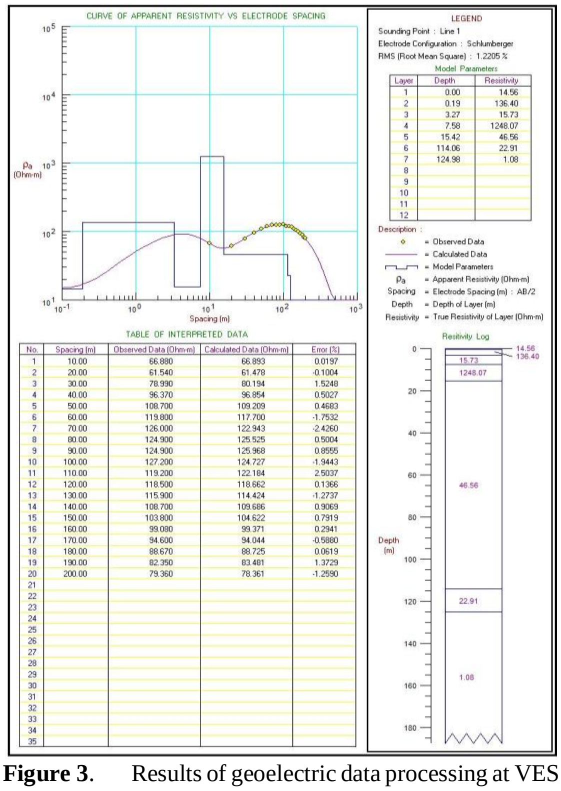

Figure 3. Results of geoelectric data processing at VES 1. Resistivity Log on red column show the subsurface structure base on the distribution of the resistivity to a depth at 180 meters

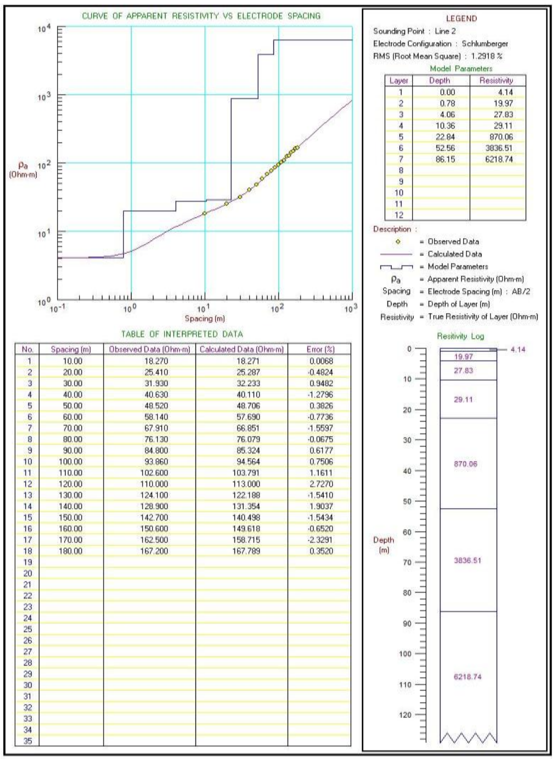

Figure 4. Results of geoelectric data processing at VES 2. Resistivity Log on red column show the subsurface structure base on the distribution of the resistivity to a depth at 120 meters.

The resistivity measurements at the study area are apparent resistivity. The apparent resistivity data was processed using inversion method with mathematical equations to obtain the real resistivity value [6, 9, 10, and 11]. In this study, the apparent resistivity data input was processed by using the IPI2WIN and PROGRESS 3 softwares. The results obtained in the form of a graphic display and resistivity logs, indicate the actual value of the resistivity rocks at each sounding point. The results were then performed in 3-D modeling interpretation using rockwork software. The results of processing one dimension can be seen in the Figure 3 and Figure 4. There are four more results actually, but we only show two pictures.

Interpretation was doned for each points. Therefore it will be obtained the subsurface structure of each sounding point, so that it will be known the rock types (lithology) and aquifer characteristics. The results of geoelectrical data interpretation of the subsurface structure at each measuring point is up to a depth about 200 meters below the surface and it shows the subsurface structure (variation of lithology) in the around the Upstream of Brantas River. The first layer is generally identified as the soil (top soil), then the following by tuff, volcanic breccia, Conglomerates, clay, and sandy tuff layers as the aquifer and target of this research.

The interpretation of the subsurface structure from the geoelectrical data around the upstream of Brantas River area at 6 sounding points indicated that the sandy tuff layer at shallow depth and deeper part layer has high potential as the aquifers. More detail about interpretation result of subsurface structure around the upstream of Brantas River for the lines 1 and 2 are described in Table 1 and Table 2

Table 1. Interpretation of subsurface in VES 1

Depth (m)	Thickness (m)	Resistivity (Ω.m)	Estimation Lithology
0 – 0,2	0,2	14,6	Soil
0,2 – 3,3	3,1	136,4	Breccia
3,3 – 7,6	**4,3**	**15,7**	**Sandy Tufa**
7,6 – 15,4	7,8	1248,0	Conglomerates
15,4 – 114,1	**109,6**	**46,6**	**Sandy Tufa**
114,1– 125,0	**11,0**	**22,9**	**Sandy Tufa**
125,0 -185	60,0	1,1	Clay

Table 1 shows two sandy tuff layers, which are very thick which is about 124 meters and very potential as aquifer layers. The first layer with a thickness about 4 meter at a depth of 3-7 meters. Estimation of the ground water flow in the this aquifer layer was from Panderman mountain. While the second layer with a thickness of 120 meters at a depth between 15 and 124 meters, the ground water flow was estimated from Kawi-Butak volcano.

Table 2. Interpretation of subsurface in VES 1

Depth (m)	Thickness (m)	Resistivity (Ω.m)	Estimation Lithology
0 - 0,8	0,8	4,1	Soil
0,8 – 4,1	**3,3**	**20,0**	**Sandy Tuff**
4,1 – 10,4	**6,3**	**27,8**	**Sandy Tuff**
10,4 – 22,9	**12,8**	**29,1**	**Sandy Tuff**
22,9 – 52,6	29,3	870,1	Conglomerates
52,6 – 86,2	33,6	3836,5	Lava
86,2 - 120	33,8	6218,7	Lava

Table 2 indicates visible layers of Sandy tuff that is not too thick which is about 20 meters, at a depth from 1 to 21 meters below the surface. Subsurface water flow in this aquifer layer is estimated from the young Anjasmara Volcano.

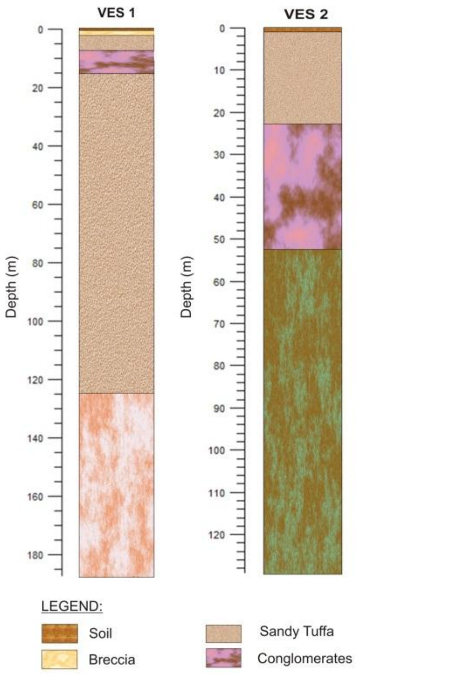

Figure 5. Interpretation result of geoelectrical data in 1D scheme in measuring of point VES 1 and VES 2.

In clarify the interpretation of the results, it was made of subsurface lithology prediction model based on the difference value of the resistivity. The results of the model estimation of subsurface lithology for the lines 1 and 2 can be seen in Figure 5. Differences resistivity values is indicated by color differences.

Figure 5 shows the model of the rock layer for the lines 1 and 2. The aquifers are in a depth from 15 to 125 meters and between 1 and 22 meters respectively. Then, the model in three dimensional of the aquifer for the line 1,2 and 5 is shown in Figure 6.

Based on the interpretation of subsurface structures using geoelectrical method, it indicates that the subsurface in this area consists of volcanic rock that was formed from volcanic activity. The rock structure are composed of volcanic rock breccia, tuff breccia, sandy tuff, tuff and lava. Volcanic rocks breccia, tuff breccia, tuff and lava have small porosity because it has a small grain size and smooth and also have low permeability and is unable to keep and flow the water. So the rock layer as an impermeable layer and may keep the water for not going down to the bottom layer and the water will flow horizontally. While sandstone has good porosity because it has a rounded rock grains with large permeability, so it can save the water and running it in a meaningful amount.

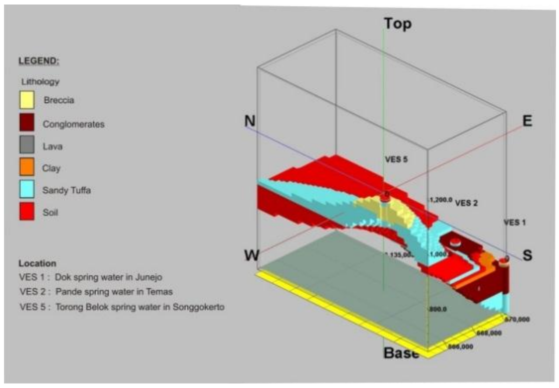

Figure 6. Interpretation result of geoelectric data in 3D scheme in around the upstream of Brantas river in measuring point VES 1, VES 2, and VES 5.

The presence of inserts sandy tuff rocks in the subsurface structure cause the flow of water into and accumulates in aquifers. The source of this spring water is locally and it comes from rainfall water infiltration. So that the flow of water that accumulates in aquifers depend on rainfall. Discharge of water in the aquifer will increase when rainfall increases.

CONCLUSSION

The results of data processing and interpretation of geoelectrical resitivity using Schlumberger configuration for structure prediction and ground water aquifers in the upstream of Brantas river shows the sandy tuff layer is very potential as an aquifer. This layer has a thickness of about 100 meters, which is under measuring point VES 1 that located in the Dok spring water. Beside that the spring water in Binangun area is very thick, which is about 60 meters.

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REFERENCES

[1] Sosrodarsono, Suryono dan Konsaku, Takeda. (2003). *Hidrologi untuk Pengairan*. Jakarta. Pranya Paramita.

[2] Todd. D.K. (1980). *Groundwater Hydrology*. 2 nd Edition. Jhon Willey & Sons. New York.

[3] Hendrajaya, L dan Idam A. (1990) *Geolistrik Tahanan Jenis*. Bandung: Laboratorium Fisika Bumi, Jurusan Fisika FMIPA ITB.

[4] Herman, Rbell. (2001) *An Introduction to Electrical Resistivity in Geophysics.* Department of Chemistery and Physics Departement of Geology, Radford University.

[5] Reynold, J.M. (1997). *An Introduction to Applied and Envirinmental Geophysics.* John Willey and Sons Lid., New York.

[6] Susilo, Adi. (2010) *Laporan Penelitian Geolistrik di Proyek Pembangunan Waduk Serbaguna JATIBARANG, SEMARANG tahun 2010*. Universitas Brawijaya (TIDAK dipublikasikan).

[7] Tachjudin. (1990) *Metode Eksplorasi Tahanan Jenis*. Bandung. Laboratorium Geofisika dan Vulkanologi Jurusan Teknik Geologi, ITB.

[8] Telford, W.M., L.P. Geldart, , R.E. Sheriff, dan D.A. Keys. (1982). *Applied Geophysics*. London. Cambridge University Press.

[9] Sheriff, R.E. (1986) *Encyclopedic Dictionary of Exploration Geophysics, 3rd edt*. Sidney. Cambridge University Press.

[10] Singh, K.B, Lokhande, R.D and Prakash, A. (2004). Multielectrode Resistivity Imaging Technique for the Study of Coal Seam. Central Mining Research Institute. *Journal of Scientific and Industrial Research.* Vol. **63**: Pp 927-930.

[11] Verhoef, (1994). *Geologi Untuk Teknik Sipil*. Erlangga. Jakarta.