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Presumption of Ground Water Depth Using the Schlumberger Configuration Geoelectrical Method

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Abstract

The occurrence of drought in 2019 in the study area is one of the environmental problems that complicate local people's lives. Observation data state that the research location is classified into drought-prone regions. This location needs further identification, whether it belongs to meteorological drought or hydrological drought. This study focuses on studying subsurface aquifer conditions, especially determining the depth of freshwater location. This study aimed to determine the subsurface aquifer's characteristics and estimate the depth of freshwater as a clean water source. The research method used is the geoelectrical resistivity test of the Schlumberger configuration. Data processing and modeling were carried out to obtain resistivity data that represented subsurface rock types. The results obtained are the lithology of the area comprising the study area consisting of fine-grained sediments. The value of the resistivity range assumed to be the aquifer layer is 20 - 40 Ωm. The presence indication of an aquifer layer measures point 2 with an expression of the number of aquifers of two layers, namely at a depth of 12.2 meters and 71.5 meters, and at measuring point 4 with an indication of the number of aquifers in one layer at a depth of 79.2 meters.

Keyword: Drought, Groundwater Aquifers, Geoelectrical, Schlumberger configuration

I. INTRODUCTION

The long dry season in 2019 caused several areas in Yogyakarta to experience drought. One of the affected villages is Wukirsari Village, Imogiri District, Bantul Regency, DIY. This village has been experiencing drought since July 2019. The shortage has led to water dropping from the village government to meet clean water needs. According to the map level of drought vulnerability in Bantul Regency, the area is also in the drought-prone category. The absence of groundwater sources that can be reached by the community causes the site to experience drought. Besides, damage to the catchment area

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due to human activities has resulted in the loss of the catchment area, which should function as a water source.
The condition of groundwater availability that is not optimal has made residents experience water shortages, especially during the dry season. Therefore, we need research to estimate groundwater depth below the surface to explore the availability of clean water. This study limited to the study of subsurface aquifer conditions, especially determining the depth position. This study aimed to determine the subsurface aquifer's characteristics and estimate freshwater/groundwater depth as a clean water source. For this purpose, The theoretical implication of this research is that choosing the right location with the geoelectric method can sharpen the results of the analysis on the suitability of finding groundwater aquifer

II. LITERATURE REVIEW

Groundwater is water that occupies rock pores below the soil surface in the saturated zone (Walton, 1970; Todd, 1980; Feter, 1994 in Santosa, 2014). Groundwater is one of the water resources on earth that can meet daily needs, such as drinking water. The availability of groundwater is always associated with the condition of healthy, inexpensive groundwater and has abundant availability (Santosa, 2014). There are several types of groundwater in nature, one of which is an aquifer. Aquifers are rock formations capable of storing and releasing large amounts of water (Todd, 1980). Porosity is An aquifer's ability to hold water reserves, while permeability is the ability to pass water. Both aquifer characteristics significantly affect the aquifer's ability to store groundwater reserves (Santosa, 2014). Water that cannot be held on the surface to seep into the soil to the saturation zone is groundwater. The soil layer or rock above that is not customary to water is called the zone of aeration. Ariefin, R. F., & Purnama, I. L. S. (2019). Based on its geological formation position, groundwater can be classified into three types, such as free groundwater, semi-depressed groundwater, and depressed groundwater (Todd, 1980). Ground groundwater is groundwater above the impermeable geological layer to the groundwater-surface (water table) below the ground surface. This groundwater is in the unconfined aquifer (Iskandar, N. M., & Adji, T. N., 2017). Based on Abduh, M. (2012), Depressed groundwater is contained between 2 layers of impermeable rock (aquiclude-aquiclude). Semi-depressed groundwater or leaky aquifer, namely groundwater, is limited by an impermeable layer at the bottom and a semi-impermeable layer. Apart from these three aquifers, aquifers are not located in the water-saturated zone but in the aeration zone, commonly referred to as perched aquifer. Floating aquifers are local aquifers that are located above the water table. This aquifer is accommodated above the impermeable area like clay lenses (Fetter, 1994 in Santosa, 2014). The geoelectrical method uses the assumption that the earth is an isotropic homogeneous rock. The rock resistivity value obtained at the time of measurement is considered the actual rock resistivity value (Usman, B., Manrulu, R. H., Nurfalaq, A., & Rohayu, E. 2017) While actually, the earth is a homogeneous anisotropy rock. At the time of measurement, the resistivity value is considered as apparent resistivity value or apparent rho (ρa). Meanwhile, the actual resistivity value will be significantly influenced by the measurement spacing (Sedana, D., & Tanauma, A. (2015). Figure 1. Shows the electrode configuration that is often used in resistivity surveys and is equipped with a geometric factor equation for each structure.

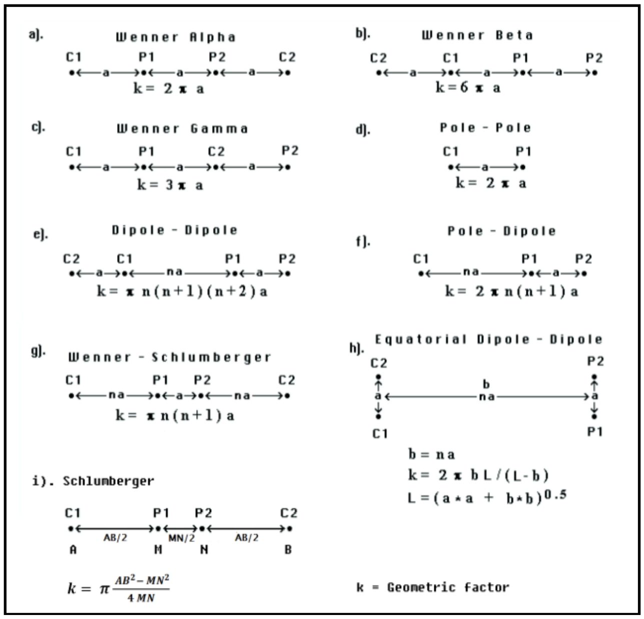

Figure 1. Electrode Configuration used in resistivity measurement and Geometry Factors (Modified Loke, 1999)

The calculation of the resistivity value obtained in the field is not an actual resistivity value. Still, an apparent value with homogeneous resistivity below the surface will provide the same resistance value for the same configuration. To determine the real resistivity value below the surface, an inversion of the apparent resistivity value is performed using a computer program. The rocks in the earth have different resistivity values for each stone.

The difference in resistivity value is influenced by eight factors that affect the resistivity value. Therefore, measurements in an area will have a resistivity value that is different from other regions.

Table 1.
Table of rock resistivity values (Telford .et.al, 1990)

Material	Resistivity (Ω•m)	Conductivity (Siemen/m)
Igneous and Metamorphic Rocks		
Granite	$5x10^{3} - 10^{6}$	$10^{-6} - 2x10^{-4}$
Basalt	$10^{3} - 10^{6}$	$10^{-6} - 10^{-3}$
Slate	$6x10^{2} - 4x10^{7}$	$2.5x10^{-8} - 1.7x10^{-3}$
Marble	$10^{2} - 2.5x10^{8}$	$4x10^{-9} - 10^{-2}$
Quartzite	$10^{2} - 2x10^{8}$	$5x10^{-9} - 10^{-2}$
Sedimentary Rocks		
Sandstone	$8 - 4x10^{3}$	$2.5x10^{-4} - 0.125$
Shale	$20 - 2x10^{3}$	$5x10^{-4} - 0.05$
Limestone	$50 - 4x10^{2}$	$2.5x10^{-3} - 0.02$
Soils and waters		
Clay	1 - 100	0.01 - 1
Alluvium	10 - 800	$1.25 x10^{-3} - 0.1$
Groundwater (fresh)	10 - 100	0.01 - 0.1
Sea water	0.2	5
Chemicals		
Iron	$9.074x10^{-8}$	$1.102x10^{7}$
0.01 M Potassium chloride	0.708	1.413
0.01 M Sodium chloride	0.843	1.185
0.01 M acetic acid	6.13	0.163
Xylene	$6.998x10^{16}$	$1.429x10^{-17}$

II.1.Schlumberger Configuration

The geoelectrical resistivity method is a method that is widely used in the world of exploration, especially groundwater exploration because the resistivity of rocks is very sensitive to its water content (Manrulu, RH, Nurfalaq, A., & Hamid, ID 2018). The basic idea of this method quite to merely considering the earth as a resistor. The resistivity or resistivity geoelectrical method is a group of geoelectrical methods used to study subsurface conditions by studying electric currents' properties in rocks below the earth's surface. This method's principle is that an electric current is injected into the natural world through two current electrodes. In comparison, the potential difference that occurs is measured through two potential electrodes. The measurement results of present and possible electric differences can be obtained from the variation in the price of electrical resistivity in the layer below the measuring point. Based on the investigation's purpose, the resistivity method can be divided into two, namely mapping and sounding. The geoelectrical resistivity mapping method is a resistivity method that aims to study the horizontal variations in the resistivity of the subsurface layers. Therefore, this method uses a fixed electrode spacing for all datum points on the earth's surface. In contrast, the resistivity sounding method aims to study the vertical resistivity variations of the subsurface layers of the earth. In this method, measurements at one measuring point are carried out by varying the electrode distance (Prihastiwi, F. E. 2016). Changing the electrode spacing is not done arbitrarily, but starting with a small electrode distance then increasing gradually. This electrode distance is proportional to the depth of the detected layer. In the Schlumberger configuration, the current and potential electrode configurations are placed, as shown in Figure 2 below.

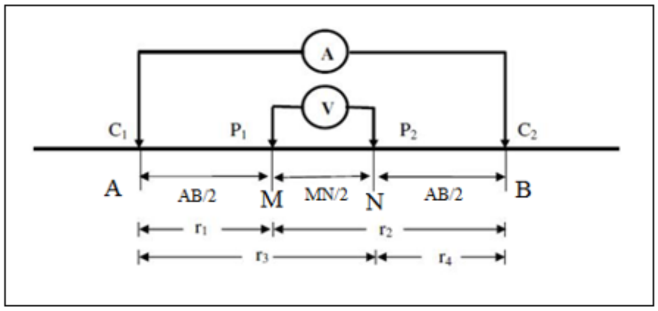

Figure 2. Electrode Arrangement of the Schlumberger Configuration
(Modified Loke, 2004)

In this case, the current electrode and the potential electrode have a different distance; that is, the current electrode is a maximum of five times the distance between the potential electrodes. Note that the four electrodes with the datum point must form a line. With the displacement of the current electrode and the potential electrode is shown in Figure 2

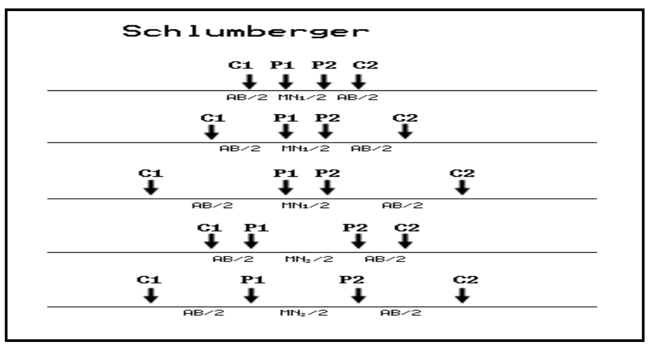

Figure 3. Electrode Displacement of the Schlumberger Configuration
(Modified Loke, 1999)

In resistivity mapping, the electrode spacing does not change for each observed datum point (magnitude a is fixed). In contrast, at sounding resistivity, the electrode spacing is gradually increased, starting from a small value to a considerable amount, for one sounding point. The limit of the magnification of the electrode space depends on the ability of the tool used.

The more sensitive and the greater the current generated by the device, the more flexibility it is to increase the electrodes' spacing so that the deeper layers are detected.In the Schlumberger configuration resistivity method, the subsurface layer is assumed to consist of horizontal layers. The formula for finding the depth in this method is between 0.1 and 0.3 times the length AB. For example, the length of AB is 1 km, then the depth reached is between 100 and 300 m, depending on the type of bedding. In the conductive basement, it can be seen that the length AB is shorter than the resistive one. (J. Bernard, 2003)

III. RESEARCH METHODOLOGY

This measurement was carried out on August 16, 2020. The size was carried out in four points, measured in the Wukirsari Village, Imogiri District, Bantul Regency. Four measurement points have been taken, namely the first point measured in Secangan Hamlet, the second point in Tuwondo Hamlet, then the third and fourth points measured in Nogosari Hamlet.

Figure 4. Map of Location and Actual Path in the field

Research on geoelectrical sounding uses measurement equipment such as the following:

a. Resistivity meter (Oyo McOhm EL Model 2119)
b. 12V battery, used as a current source
c. Four electrodes, two current electrodes, and two potential electrodes
d. Four coils of cable 300 m long
e. Ten connector cables, to connect the electrodes with wires, cables with tools, and tools with current sources (batteries)
f. Hammer, for inserting electrodes
g. HT 3 pieces, to join the operator to the electrode man and the field crew
h. Garmin GPSCSX 76 handheld type, to determine the measurement position
i. Compass, to measure the direction of the measurement path
j. Data table, to record the measurement results in the form of current I in mA, potential V in mV
k. Multimeter, to determine the condition of the cable and determine whether the current can be connected to the tool and electrodes or not
l. Umbrella, to cover the equipment from sunlight or rain.

Figure 5. Geoelectrical measuring equipment

The flow chart for field data collection is described in Figure 6

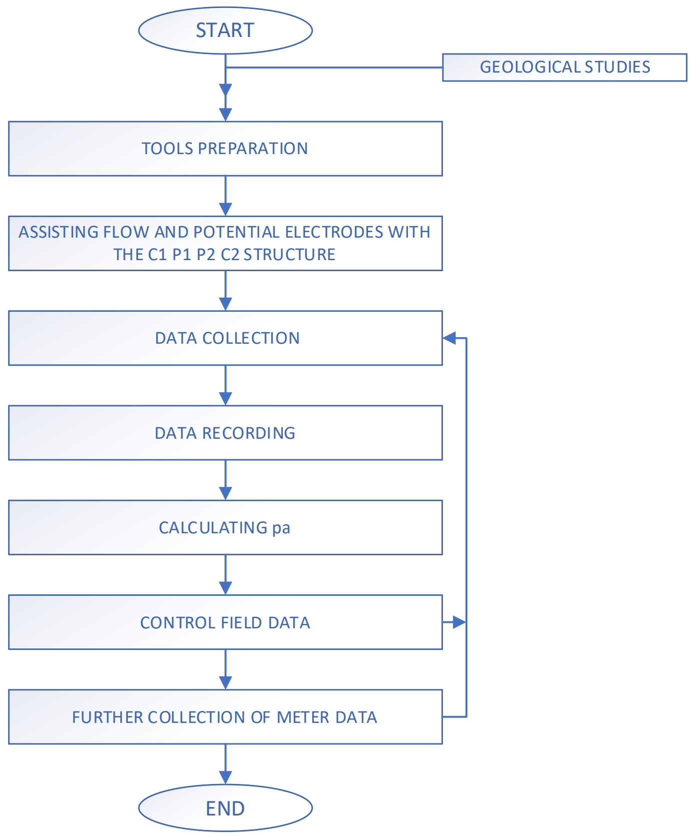

Figure 6. Research Flowchart

An explanation of the data collection steps is as follows:

i. Before carrying out data collection, it is better if you know the research area's geological conditions.
ii. Data collection begins with tools such as connecting the resistivity meter with cables, electrodes, and current sources (batteries).
iii. Mark data retrieval points.
iv. Check all equipment before starting data acquisition, such as checking whether the current is connected to the device or not using a multimeter.
Turn on the resistivity meter and set the tools to select the measurement method and configuration used.
Start measuring at the first measuring point, for example, at a position:
C1 = 3 m
P1 = 0.5 m
P2 = 0.5 m
C2 = 3 m

v. Record the potential value V and current I on the datasheet, then calculate the apparent resistivity value by using equation IV.1:
$\rho a = V / I.\ K$ (IV.1)
vi. Calculate the apparent resistivity value.
vii. Move the electrode to the next point and check the current
viii. Perform data retrieval at the next point.
ix. Record the potential value V and current I in the data table
x. The measurement is carried out repeatedly in the order from number 7 to 11 for the next meter.

The flow chart for field data processing is shown in Figure 7

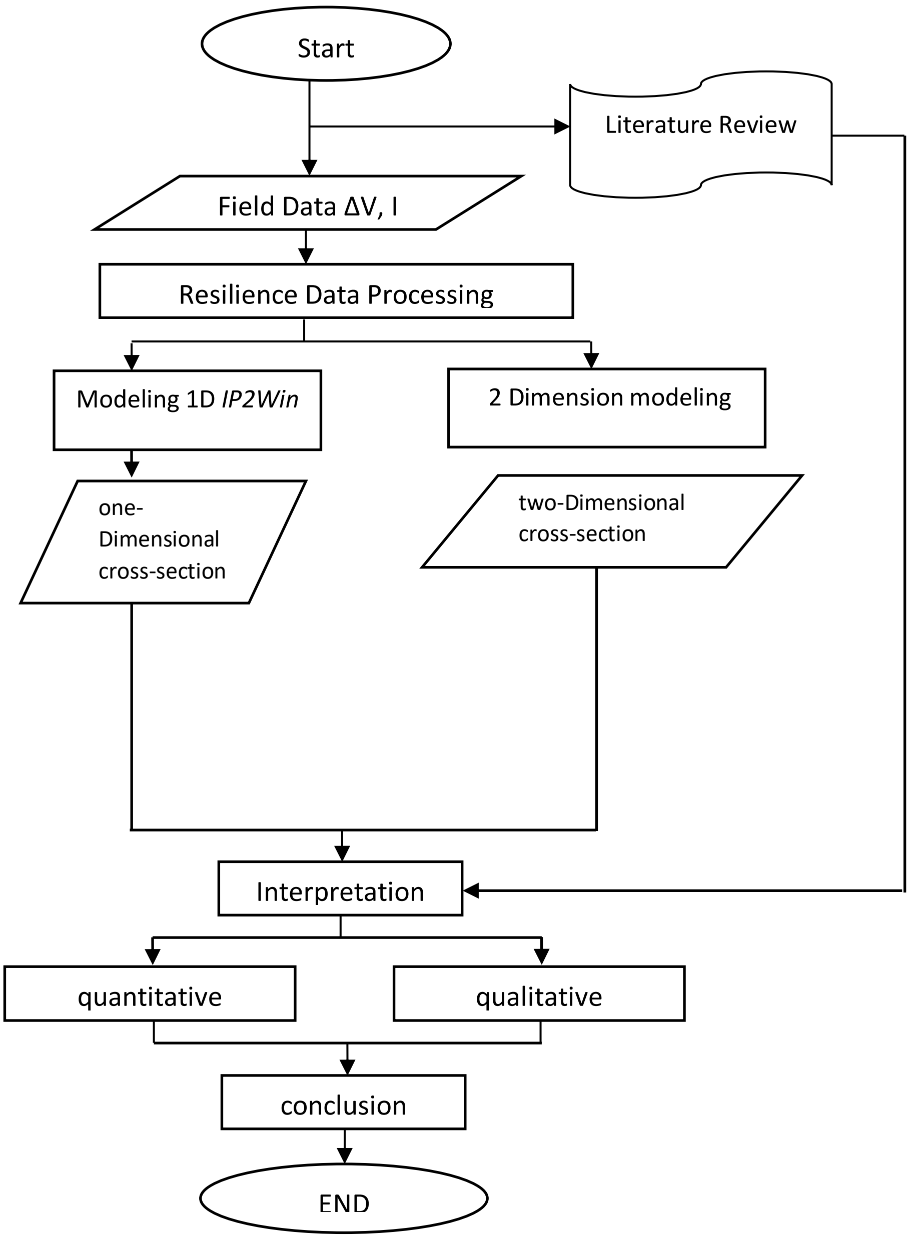

Figure 7. Data Processing Flowchart

Data processing is a process carried out after collecting field data. The processing of sounding geoelectric data using the concept of anisotropy or heterogeneity processing is as follows:

i. Literature studies are carried out before processing data, such as knowing previous research data, geological information, and measurement survey design.
ii. Field data is input into Microsoft. Excel, includes space, potential V, and current I, then calculates the resistance value to obtain apparent resistivity
iii. The next process is processing pseudo resistivity data (ρ) into actual ρ with the concept of anisotropy.
This processing begins by looking for the assumed depth value (a) and the depth replacement assumption (Za).
a = (AB⁄2) / 1,5 (IV.2)
Za = (a_ (n-1) + (a_n - a_ (n-1))) / 2 (IV.3)
Where AB / 2 is the current electrode distance, a_ (n-1) is the depth at the previous spacing point, a_n is the center at the spacing point to be searched.
iv. Schlumberger data processing is performed using IP2WIN software, while Wenner - Schlumberger data processing uses RES2DINV software. This processing is intended to obtain depth and dimensions that are suspected of being a utility.
v. Furthermore, the correlation between measurement points is carried out to determine the condition of the sub-surface layer
vi. 2D sections, 1D modeling, and additional information (literature) will be correlated to obtain a good view of the subsurface, including interpreting the utility's position and dimensions.

IV. RESULT AND DISCUSSION

The research was conducted in Wukirsari Village, Imogiri District, Bantul Regency, where the research location is shown in Figure 8.

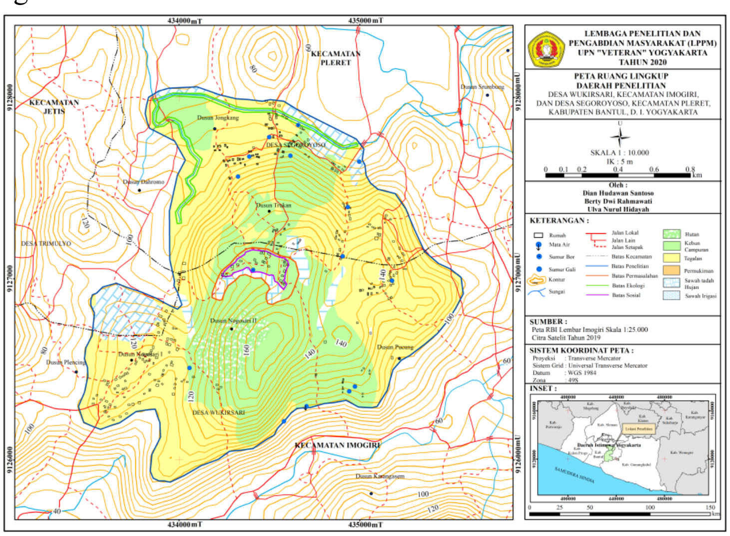

Figure 8. Scope Map of the Research Area

IV.1. Dimensional Inversion Analysis Sounding 1 (434382,9127814 / Secangan)

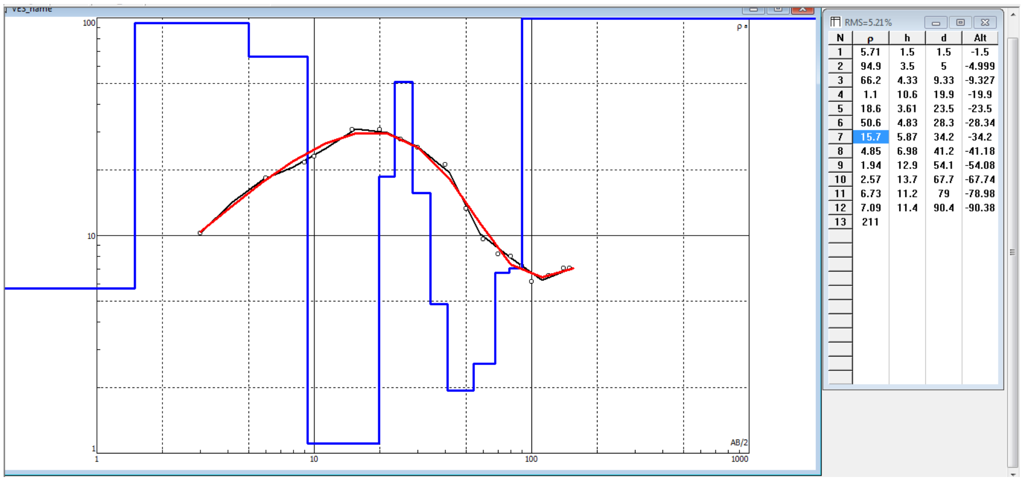

Figure 9 Sounding point 1

Based on the VES measurement point inversion (sounding 1), in general, the lithology of the study area is composed of fine-grained sediment/pyroclastic. The resistivity value range between 1 - 20 Ωm is interpreted as a tuff with low resistivity and functions as a clay cap. The resistivity value of 20 - 40 Ωm is interpreted as an aquifer layer in the form of sandstones. Resistivity values of more than 40 - 200 Ωm are interpreted as massive sandstones that tend to be tight. At this measuring point, up to a depth of 90 meters, no resistance pattern is thought to be an aquifer layer.

IV.2. Sounding 2 (434975,9127652/area Tuwondo)

Figure 10 Sounding Point 2

Based on the VES measurement point inversion (sounding 2), the lithology of the study area is generally composed of fine-grained sediment/pyroclastic. The resistivity value range between 1 - 20 Ωm is interpreted as a tuff with low resistivity and functions as a clay cap. The resistivity value of 20 - 40 Ωm is interpreted as an aquifer layer in the form of sandstones. Resistivity values of more than 40 - 200 Ωm are interpreted as massive sandstones that tend to be tight. At this measuring point, there are two indications of resistivity that represent the presence of aquifers below the surface, namely at a depth of 12.2 meters with a resistivity value of 21.1 meters and an estimated thickness of the aquifer layer of 3.6 meters, and a depth of 71.5 meters with a resistivity value—23 Ωm with an aquifer layer thickness of 15.6 meters.

IV.3. Sounding 3 (434460,9127042/area Nogosari 1)

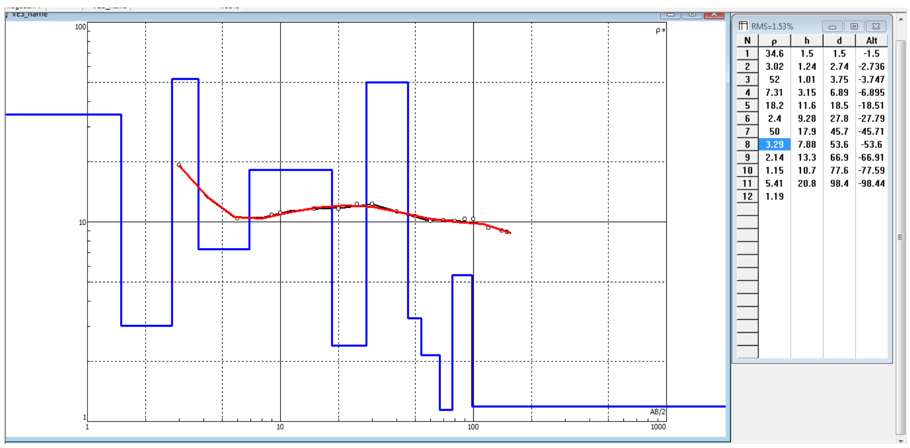

Figure 11. Sounding Points 3

Based on the VES measurement point inversion (sounding 3), in general, the lithology of the study area is composed of fine-grained sediment/pyroclastic. The resistivity value range between 1 - 20 Ωm is interpreted as a tuff with low resistivity and functions as a clay cap. The resistivity value of 20 - 40 Ωm is interpreted as an aquifer layer in the form of sandstones. Resistivity values of more than 40 - 200-ohm meters are interpreted as massive sandstones that tend to be tight. At this measuring point, up to a depth of 90 meters, no resistance pattern is thought to be an aquifer layer.

IV.4.Sounding 4 (434279,9127018/Nogosari 2)

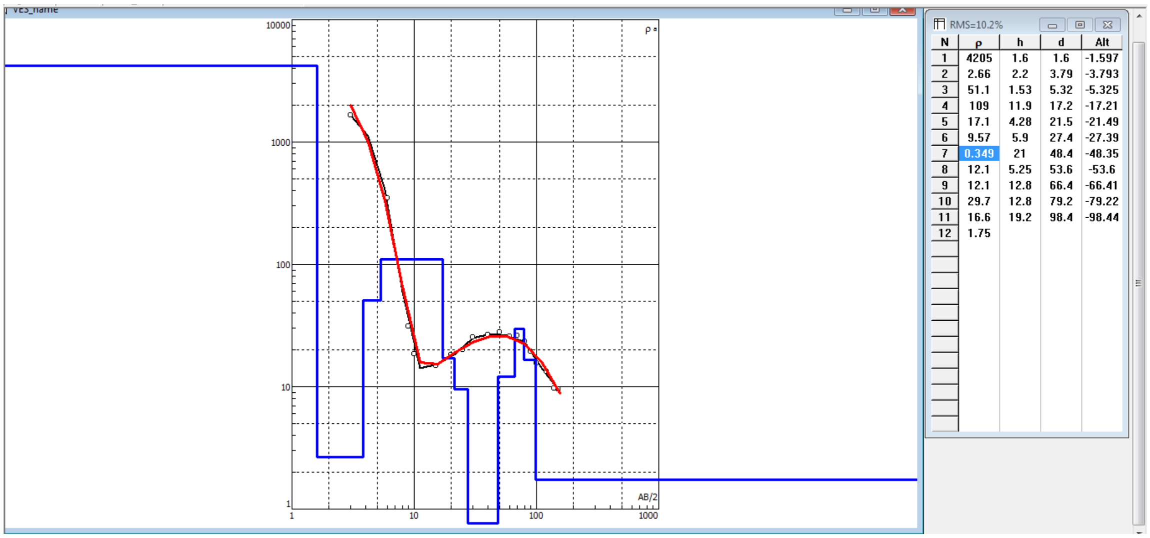

Figure 12. Sounding Points 4

Based on the VES measurement point inversion (sounding 4), in general, the lithology of the study area is composed of fine-grained sediment/pyroclastic. The resistivity value range between 1 - 20 Ωm is interpreted as a tuff with low resistivity and functions as a clay cap. The resistivity value of 20 - 40 Ωm is interpreted as an aquifer layer in the form of sandstones. Resistivity values of more than 40 - 200-ohm meters are interpreted as massive sandstones that tend to be tight. At this measuring point, there are two indications of resistivity that represent the presence of aquifer below the surface, namely at a depth of 79.2 meters with a thickness of the aquifer layer of 12.8 meter

V. CONCLUSION

This study concludes that the lithology of the area comprising the study area consists of fine-grained sediments. The value of the resistivity range assumed to be the aquifer layer is 20 - 40 Ωm. The indication of the presence of an aquifer layer is at measuring point 2 in Tuwondo Hamlet with an indication of the number of aquifers of two layers, namely at a depth of 12.2 meters and 71.5 meters, and at measuring point 4 in Dusun Nogosari II with an indication of the number of aquifers one layer is at center 79.2 meters.

Acknowledgments

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