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Main Aquifer Analysis Using Vertical Electrical Sounding to Determine the Location of Drilling Well

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Abstract
Water is an important aspect of life. People need clean water for their household needs. Problems arise when the supply of clean water does not meet the needs of the community as felt by the residents of Madurejo Village, Prambanan District, Sleman Regency, Yogyakarta. In the dry season, the groundwater level decreases so that the air supply decreases. This study aims to analyze the existence of aquifers that can meet the needs of the community throughout the year. This research has a research flow starting from surveys, field orientation, field measurements, analysis of measurement results, then the location of aquifer locations. The measurement method in the field uses a vertical sounding geoelectric method with a Schlumberger array. This measurement has the main objective of identifying the subsurface as a potential aquifer in Madurejo Village, Prambanan District, Sleman Regency, Yogyakarta. Method of measuring rock resistivity by injection of subsurface currents. Data retrieval is carried out at 2 points with a track length (AB) of 150 to 250 meters. for processing using interpretation software with the final result in the form of rock lithology. This research uses IP2WIN Software and Progress 3.0. The results showed that the two points were close to the existence of the aquifer. The software analyzes at a depth of 9.35-51.5 m at sounding point 1 and 60-80.8 m at sounding point 2 is an aquifer layer. The study concluded that wells could be drilled at both points.

Keywords: geophysics, groundwater, VES, Schlumberger

INTRODUCTION

Water is a basic need for individual life, ecosystem, and social life (Yang et all,2020). Living things are very dependent on water. All living things need water for their metabolism. Not only for the body, humans need water for other aspects of life. other aspects such as the industrial sector, development, infrastructure, and the economy also need water (Cosgrove & Loucks, 2015). the use of surface water and ground water such as domestic use, and other non-domestic uses by the industrial and commercial sectors are mostly carried out in urban areas (Kizhisseri, 2021). For agricultural production areas groundwater will remain the main source for irrigation and maintenance of their crops (Siebert et al, 2010). Agriculture can thrive in some deserts in the presence of water pumped from the ground or taken from other areas (Fetter, 2014). Therefore, studying the water cycle is useful for the foundation of sustainable development (Yang et al, 2021). The hydrological cycle is a complex cycle involving interactions between the atmosphere, lithosphere, biosphere, and anthroposphere, and is also strongly influenced by human activities and socio-economic development. Utilization of water resources must be wise with regard to social and environmental impacts (Bargawa, 2017). Rapid climate change and increased development on vacant land can affect the global water cycle. Changes in the water cycle cause many problems related to water availability (Guangchao et al., 2021) Residents of Madurejo Village, Prambanan District, Sleman Regency feel the same problem regarding with insufficient water availability. This problem often occurs in the dry season. Therefore, it is necessary to find groundwater that can meet the needs of the population throughout the year. It is important to identify groundwater aquifers that meet community needs and manage them effectively (Fraser et al, 2020). Basically, groundwater reserves are found in various aquifer systems (Alley, 2006).

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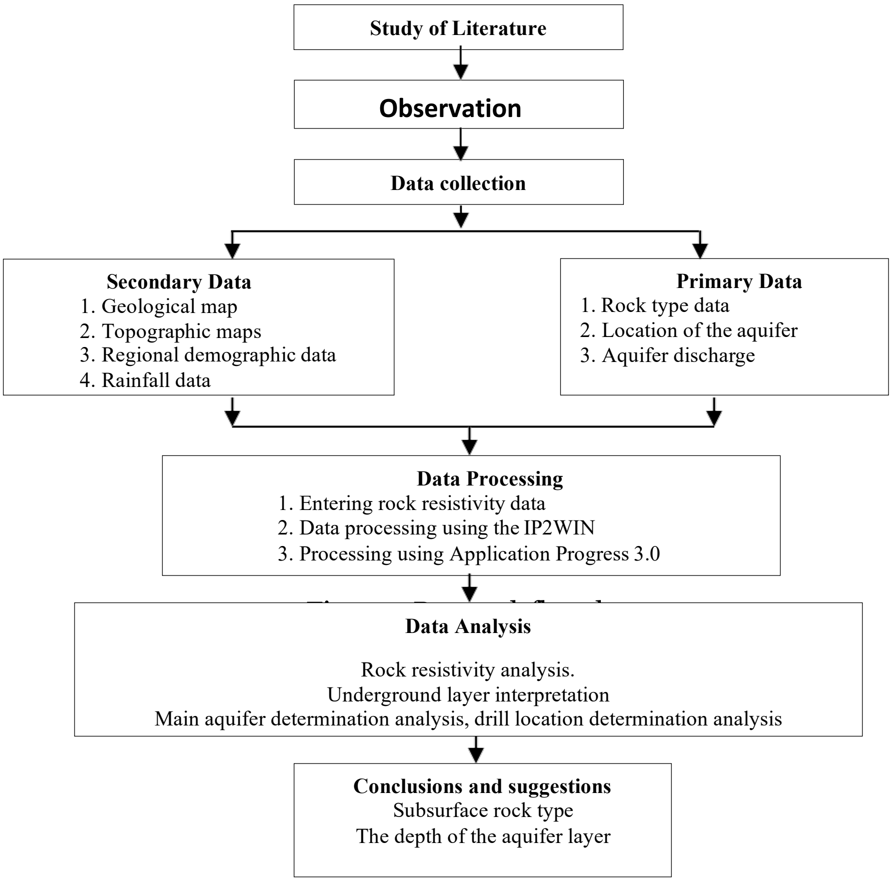
LITERATURE REVIEW

The main aquifer estimates are investigated in various studies. Based on (Abdulrazzaq, 2020), the geoelectric method is the right method for finding aquifers. Aquifers are underground layers of water-bearing rocks or geological formations that produce abundant groundwater and can be used economically (Salako, 2018). Groundwater is an abundant, inexpensive, safe resource for humans if explored properly (Umar et al, 2017). Inadequate water supply is a problem in the community, this occurs due to poor water management and the high demand for water that exceeds its availability. Therefore, the search for the main aquifer becomes an alternative problem solution to meet the needs of water resources (Emmanuel et al, 2020). The main purpose of this study was to determine the depth and thickness of the aquifer using one of the geophysical methods (Sihotang et al, 2018). The electrical resistivity technique is a geophysical method that is widely used in the search for groundwater sources (Bairu, 2013). This method utilizes the resistivity properties of rocks to observe the subsurface conditions of the earth (Jamaluddin, 2017). Resistivity is an important parameter to analyze the physical state of the subsurface, which is related to the material and subsurface conditions (Joel et al, 2020). Each rock type has its own resistivity value. with different resistivity values, it will be easy to classify rock layers and estimate aquifers.

RESEARCH METHODOLOGY

This study's research methodology consists of study of literature, observation, data collection, data analysis, conclusions and suggestion. Figure 1 shows the flow chart of this research methodology.



The Vertical Electrical Sounding method is very commonly used for groundwater search because of easy sampling, low operating costs, and more accurate results. The measurement procedure in the VES method is by flowing an electric current into the ground. The electric injection is done by using a pair of current electrodes that are plugged into the ground within a certain distance. The current flow that is injected into the ground causes an electric voltage in the ground which will later be read in the potential electrode. So, with measurements in the field, the potential will be obtained at a point at a distance (r) from the current source which can be expressed as follows:

$$V_r = \frac{I\rho}{2\pi}\left(\frac{1}{r}\right) \tag{1}$$

With this assumption, the measured resistivity is the actual resistivity and does not depend on the electrode distance. But in reality, the earth is composed layers with different resistivities, so the measured potential is the effect of these layers. Therefore, the measured resistivity value appears to be the resistivity value for only one layer. The measured resistivity is actually the apparent resistivity (ρa). The apparent resistivity (ρa) at 2 current electrodes can be formulated as follows:

$$V = V_M - V_N \tag{2}$$

$$V = \frac{I\rho}{2\pi}\left[\left(\frac{1}{AM} - \frac{1}{BM}\right) - \left(\frac{1}{AN} - \frac{1}{BN}\right)\right] \tag{3}$$

$$\rho = \frac{\Delta V}{I} 2\pi\left[\left(\frac{1}{AM} - \frac{1}{BM}\right) - \left(\frac{1}{AN} - \frac{1}{BN}\right)\right]^{-1} \tag{4}$$

Provided according to Schlumberger's rule: MN 1/5 AB the potential difference between M and N is

$$\Delta V = V_M - V_N = \frac{I\rho}{2\pi}\left[\left(\frac{1}{AM} - \frac{1}{BM}\right) - \left(\frac{1}{AN} - \frac{1}{BN}\right)\right] = \frac{I\rho}{2\pi}\left(\frac{8MN}{AB^2 - MN^2}\right) \tag{5}$$

The Schlumberger configuration is a sounding technique, the distance between the current and the electrode varies, so only the current is transferred. This configuration is most often used to find water sources. Ideally, the MN (potential) distance is made as small as possible, so that the MN distance is caused by the limited sensitivity of the measuring instrument, so when the AB (current) distance is relatively large, the MN distance must be changed. theoretically unchanged.

FINDING AND DISCUSSION

The data used in this study uses the Schlumberger Geoelectric Method configuration. Observation data processing in the field is carried out based on the assumptions according to Robinson: (a) The subsurface consists of several layers bonded by a horizontal boundary, and there is a contrasting resistivity between boundary layers, (b) Each layer is considered to have a certain thickness, except for the lowest layer with infinite thickness, (c) Each layer is considered homogeneous isotropic, (d) No source other than current is injected over the earth's surface, and (e) The injected current is direct current (DC). From data processing with software, here are the results of data interpretation:

Line 1

The results of the software interpretation on the first line with 150 meters length of the line there is a prediction of a sandy tuff layer containing natural water at a depth of 9.35-51.5 meters with an aquifer thickness of 42.15 meters.

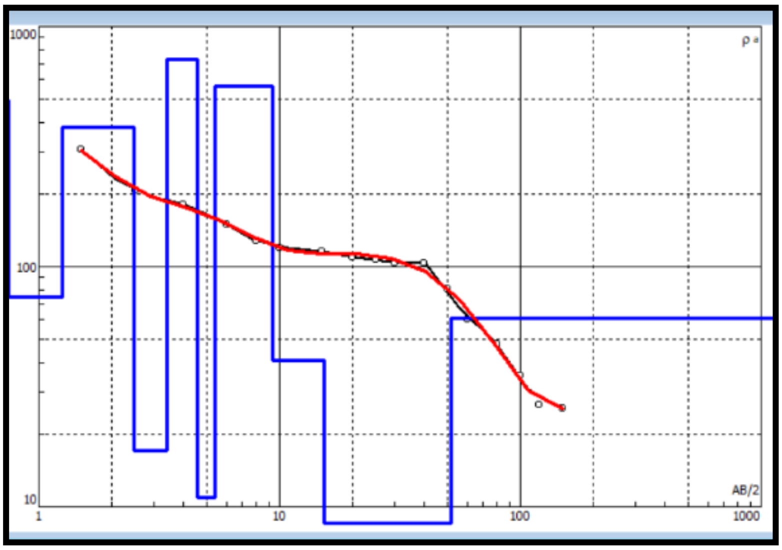
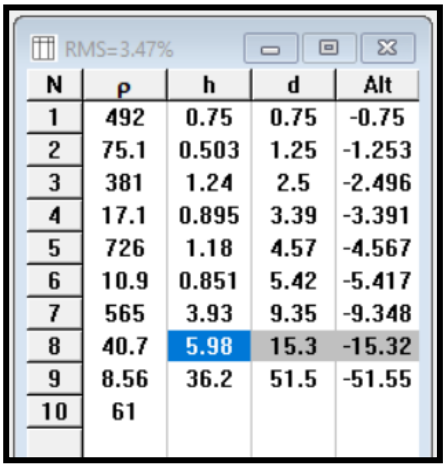


Figure 1. Sounding curve VES 1



N	ρ	h	d	Alt
1	492	0.75	0.75	-0.75
2	75.1	0.503	1.25	-1.253
3	381	1.24	2.5	-2.496
4	17.1	0.895	3.39	-3.391
5	726	1.18	4.57	-4.567
6	10.9	0.851	5.42	-5.417
7	565	3.93	9.35	-9.348
8	40.7	5.98	15.3	-15.32
9	8.56	36.2	51.5	-51.55
10	61			

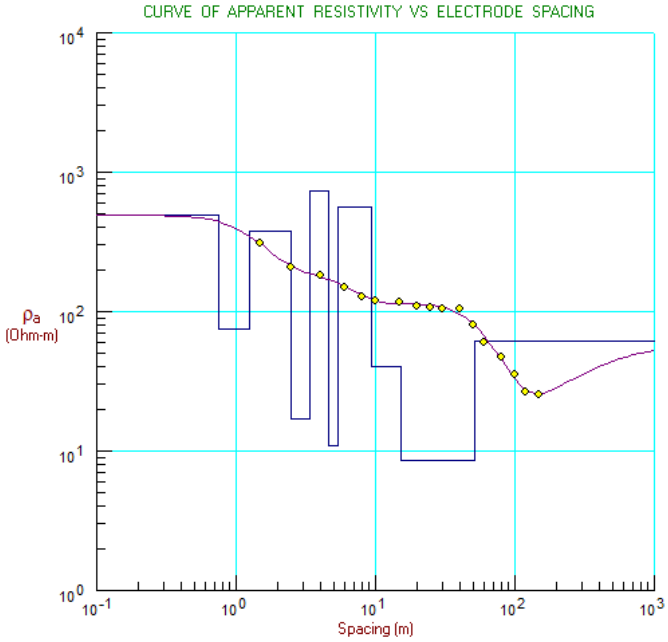
Figure 2. Sounding curve data results VES 1

Table 1. Rock type VES 1

ρ	Depth (m)	Rock type
492	0 – 0.750	Lavas
75.1	0.750 – 1.253	Sandy tuff
381	1.253 – 2.496	Lavas
17.1	2.496 – 3.391	Sandy tuff
726	3.391 – 4.567	Lavas
10.9	4.567 – 9.348	Sandy tuff
565	9.348 – 15.32	Lavas
40.7	15.32 – 51.5	Sandy tuff
8.56	51.5 - ∞	Sandy tuff

To see the results of the layering, the depth and resistivity results from the interpretation of the IP2WIN software are used as input data to be reprocessed in the Progress 3.0 software.

CURVE OF APPARENT RESISTIVITY VS ELECTRODE SPACING



LEGEND

Sounding Point : LINE 1
Electrode Configuration : Schlumberger
RMS (Root Mean Square) : 4.4070 %

Model Parameters

Layer	Depth	Resistivity
1	0.00	492.00
2	0.75	75.10
3	1.25	381.00
4	2.50	17.10
5	3.39	726.00
6	4.57	10.90
7	5.42	565.00
8	9.35	40.70
9	15.30	8.56
10	51.50	61.00
11		
12		

Description :
- ◆ = Observed Data
- —— = Calculated Data
- ⊓⊔ = Model Parameters
- ρa = Apparent Resistivity (Ohm-m)
- Spacing = Electrode Spacing (m) : AB/2
- Depth = Depth of Layer (m)
- Resistivity = True Resistivity of Layer (Ohm-m)

TABLE OF INTERPRETED DATA

No.	Spacing (m)	Observed Data (Ohm-m)	Calculated Data (Ohm-m)	Error (%)
1	1.50	309.010	305.450	-1.1522
2	2.50	206.940	211.787	2.3424
3	4.00	181.480	178.134	-1.8438
4	6.00	150.260	152.054	1.1937
5	8.00	127.410	131.757	3.4115
6	10.00	120.150	120.565	0.3453
7	15.00	115.980	113.822	-1.8603
8	20.00	109.810	113.485	3.3464
9	25.00	106.360	111.701	5.0220
10	30.00	104.040	107.966	3.7737
11	40.00	103.690	96.197	-7.2261
12	50.00	80.750	81.717	1.1978
13	60.00	60.480	67.509	11.6223
14	80.00	47.560	45.534	-4.2599
15	100.00	35.050	33.165	-5.3785
16	120.00	26.510	27.588	4.0648
17	150.00	25.620	25.766	0.5705
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Resitivity Log

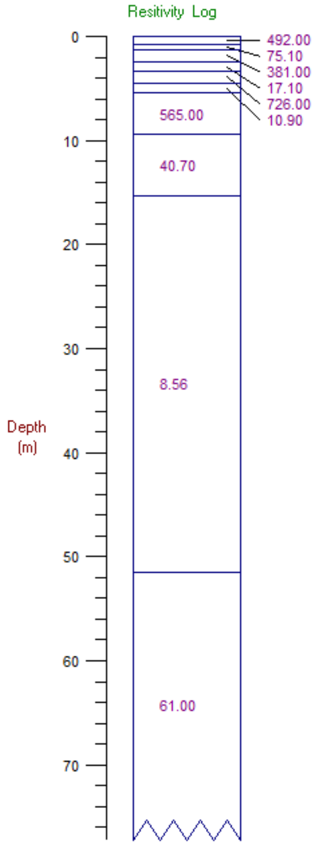


Figure 3. Sounding curve VES 1 with *Progress 3.0*

The first trajectory point is at coordinates X:441349, Y: 9138475 with an altitude of -/+ 121 m above sea level. Based on the processed geoelectrical data, it is indicated that the resistivity value of 300-500 Ohm.m is a surface layer with a depth of 0-2.5 m consisting of clay, sand, tuff, then at a depth of 2.5 – 3.4 m is an indication of sandy tuff with a value of resistivity of 17.1 Ohm.m which can be indicated to contain water, then at a depth of 3.4 – 4.6 m is an indication of a lava layer with a resistivity of 726 Ohm.m. At a depth of 4.6 – 9.3 m is an indication of sandy tuff with a resistivity of 10.9 Ohm.m so it is predicted that there will be natural water, the next layer at a depth of 9.348 – 15.32 m with a resistivity value of 565 Ohm.m is indicated as a layer of lava and at a depth of 15.32 – 51.5 m has a resistivity value of 40.7 Ohm. meter this layer is identified as a sandy tuff layer and is predicted to be a layer containing natural water.

Line 2

The results of the software interpretation on the second line with 150 meters length of the line there is a prediction of a sandy tuff layer containing natural water at a depth of 60-80.8 meters with an aquifer thickness of 20 meters.

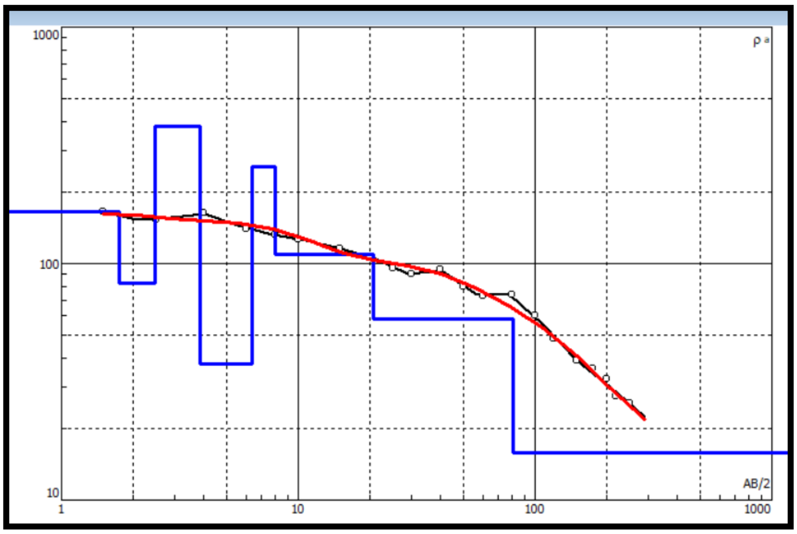


Figure 4. Sounding curve VES 2

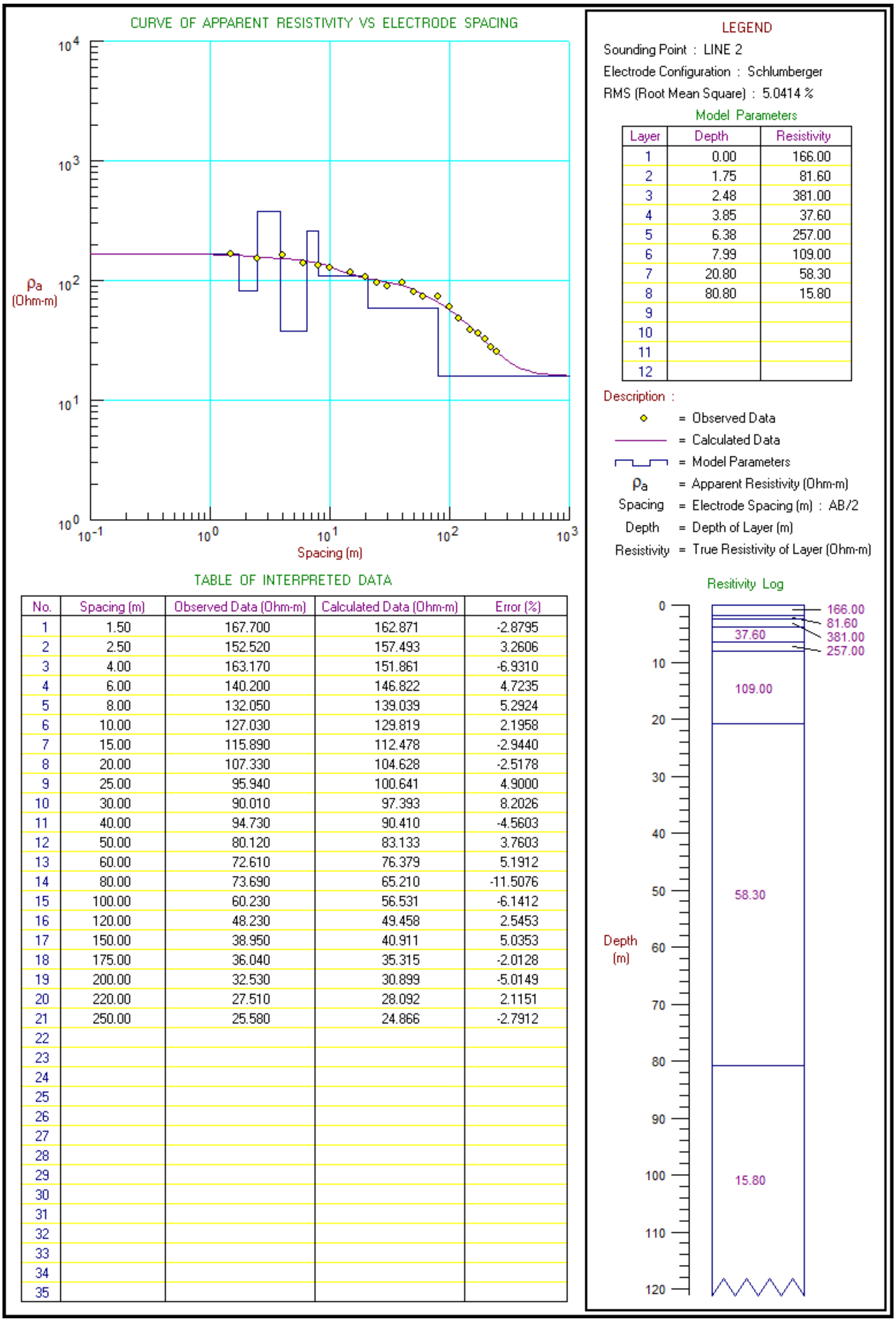
RMS=4.67%

N	ρ	h	d	Alt
1	166	1.75	1.75	-1.753
2	82.6	0.73	2.48	-2.484
3	381	1.37	3.85	-3.849
4	37.6	2.53	6.38	-6.381
5	257	1.61	7.99	-7.988
6	109	12.8	20.8	-20.75
7	58.3	60	80.8	-80.78
8	15.8			

Figure 5. Sounding curve data results VES 2

Table 2. Rock type VES 2

ρ (Ohm.m)	Depth (m)	Rock type
166	0 – 1.75	Top soil
82.6	1.75 – 2.48	Sandy tuff
381	2.48 – 3.85	Lavas
37.6	3.85 – 6.38	Sandy tuff
257	6.38 – 7.99	Lavas
109	7.99 – 20.8	Sandy tuff
58.3	20.8 – 80.8	Sandy tuff
15. 8	80.8 - ∞	Sandy tuff



Layer	Depth	Resistivity
1	0.00	166.00
2	1.75	81.60
3	2.48	381.00
4	3.85	37.60
5	6.38	257.00
6	7.99	109.00
7	20.80	58.30
8	80.80	15.80
9		
10		
11		
12		

No.	Spacing (m)	Observed Data (Ohm-m)	Calculated Data (Ohm-m)	Error (%)
1	1.50	167.700	162.871	-2.8795
2	2.50	152.520	157.493	3.2606
3	4.00	163.170	151.861	-6.9310
4	6.00	140.200	146.822	4.7235
5	8.00	132.050	139.039	5.2924
6	10.00	127.030	129.819	2.1958
7	15.00	115.890	112.478	-2.9440
8	20.00	107.330	104.628	-2.5178
9	25.00	95.940	100.641	4.9000
10	30.00	90.010	97.393	8.2026
11	40.00	94.730	90.410	-4.5603
12	50.00	80.120	83.133	3.7603
13	60.00	72.610	76.379	5.1912
14	80.00	73.690	65.210	-11.5076
15	100.00	60.230	56.531	-6.1412
16	120.00	48.230	49.458	2.5453
17	150.00	38.950	40.911	5.0353
18	175.00	36.040	35.315	-2.0128
19	200.00	32.530	30.899	-5.0149
20	220.00	27.510	28.092	2.1151
21	250.00	25.580	24.866	-2.7912
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Figure 6. Sounding curve VES 2 with *Progress 3.0*

The second trajectory point is at coordinates X: 441384, Y;9138491 with an altitude of -/+ 119 m above sea level. Based on geoelectrical data processing, the interpretation is that the first layer has a resistivity value of 100-400 Ohm.m is a surface layer with a depth of 0-4 m consisting of clay, sand, tuff, then at a depth of 4-6.4 m is an indication of sandy tuff with a value of resistivity 37.6 Ohm.m which can be indicated to contain surface water, then at a depth of 6.4 – 8 m is an indication of a lava layer with a resistivity of 257 Ohm.m. At a depth of 8 – 21 m is an indication of a lava layer with a resistivity of 109 Ohm.m, the next layer at a depth of 21-81 m with a resistivity value of 58.3 Ohm.m is identified as a sandy tuff layer and is predicted to be a layer containing natural water.

CONCLUSION AND FURTHER RESEARCH

Based on the results and discussion above, the geoelectric vertical electrical sounding (VES) method has proven to be effective in finding groundwater potential in an area. From two sounding points conducted around the study area, it was found that the rock lithology consists of sandy tuff and lava. Sounding poin line 1 is suspected there is a sandy tuff layer containing natural water at a depth of 9.35-51.5 meters with an aquifer thickness of 42.15 meters. Sounding 2 is suspected there is a sandy tuff layer containing natural water at a depth of 60-80.8 meters with an aquifer thickness of 20 meters. The result of all soundings are reveal that there is an aquifer potential in that area. The study concluded that wells could be drilled at both points. For further research, the addition of water discharge testing and water quality testing in the laboratory is highly recommended. The addition of this test is useful to find out the quality and quantity ofwater.

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