SSRG International Journal of Geo-informatics and Geological Science
ISSN: 2393 – 9206 / https://doi.org/10.14445/23939206/IJGGS-V9I2P102
Volume 9 Issue 2, 10-14, May-Aug 2022

Original Article

Water Aquifers Depth Estimation at Kedungpedaringan Village, Kepanjen Using Geoelectric—Schlumberger Configuration Method

Nur Rohmah Adinda Putri Ningsih[1], Sukir Maryanto[1,2,*], Rendi Pradila Hab Sari[2], Yusuf Krishna[1], Anang Sujoko[3], Ruslin Anwar[4], Didik Rahadi Santoso[1]

[1] *Faculty of Mathematics and Natural Sciences, Universitas Brawijaya, Malang, Indonesia*
[2] *Brawijaya Volcano and Geothermal Research Center, Universitas Brawijaya, Malang, Indonesia*
[3] *Faculty of Social and Political Sciences, Universitas Brawijaya, Malang, Indonesia*
[4] *Faculty of Engineering, Universitas Brawijaya, Malang, Indonesia*

Received: 31 March 2022 Revised: 30 June 2022 Accepted: 14 July 2022 Published: 04 August 2022

Abstract - *Kedungpedaringan is a village that is included in the Kepanjen sub-district, Malang Regency, with a village area of about 2 km^2. The lack of groundwater availability that can be used for residents around this area and for the development of tourist villages encourages this research. Investigation of aquifers containing groundwater has been carried out in this village using the geoelectric method of the Schlumberger configuration. Three datum points were acquired to the West of the Brantas river with a length of 250-300 meters to obtain penetration >50m below ground level. The 1D resistivity model shows the groundwater aquifer is at a fairly deep depth, with the condition of the subsurface layer being dominated by sandy pumice.*

Keywords - *Groundwater, Aquifer, Geoelectric, Schlumberger, Resistivity.*

1. Introduction

Kedungpedaringan is a village that is included in the Kepanjen sub-district, Malang Regency, with a village area of about 2 km^2. The number is estimated at 3742 people and is dominated by farmers' livelihoods. This village is located east of the Kepanjen District Government Center and has 2 hamlets, Ngadiluwih and Krajan.

Kedungpedaringan is traversed by Brantas river. It is one of the villages in the Kepanjen sub-district, which has land with a slope of 2-15%, covering an area of 103.65 Ha and an altitude of 350 meters above sea level. [1] This area is surrounded by several mountains, such as Mount Kawi, Anjasmoro, Welirang, Semeru, and Kendeng mountains.
Based on its geology (Fig. 1), this location is dominated by volcanic rocks originating from the remnants of Butak volcanic deposits in the form of igneous lava rock deposits (Qpvb) and tuff deposits (Qptm), which were formed during the quarternary zone. Qpvb is a lava rock dominated by basaltic lava, breccia and sandy tuff, while coarse-fine tuffs and pumiceous dominate Qptm and andesitic fragments. In general, the rock formations in this area have a medium to a high level of soil and rock strength.

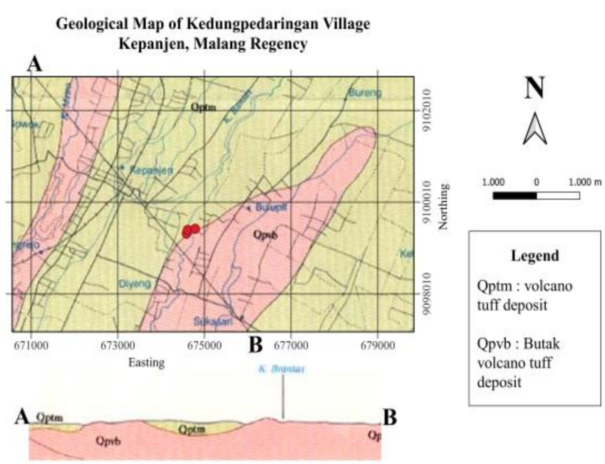

Fig. 1 Geological map of Kedungpedaringan village, Kepanjen sub-district, Malang Regency. The data source is from the Geological Map of the Turen Quadrangle, Java. [2] **A red circle indicates the measurement point of the Schlumberger configuration.**

This village is included in the city of Kepanjen, whose area is very suitable as a residential area. From the tourism sector, Kedungpedaringan village has Kanjuruhan Stadium as its tourism icon. Since mid-2020, the Kanjuruhan stadium area has been built as a Tangguh Semeru Tourism Village to improve the villager's economy. The development of this Tangguh tourist village must also be accompanied by qualified facilities to attract visitors to this place. One of the most important facilities is the availability of clean water. The availability of clean water is important for toilets and ablution places for prayer purposes around tourist sites. Not only for tourism needs but the availability of clean water is also needed by the people in Kedungpedaringan village, especially for the villagers.

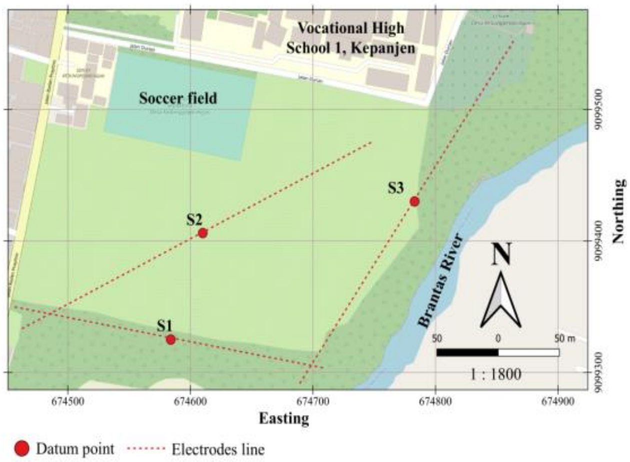

Fig. 2 Design survey for data acquisition

In this case, the residents do not know the depth and how the groundwater distribution is dug in wells in the Kedungpedaringan Village area, Kepanjen District, Malang Regency, East Java. Several factors make it difficult for Kedungpedaringan village to search for groundwater. From the land slope factor, this village is included in category 2, with a moderate slope ranging from 2-15%.

If we look again at the geological map in Figure 1, it can be seen that this area tends to be covered by lava rock during the quarter and a few layers of sedimentary rock in the western part of the village. Lava rocks are usually categorized as igneous rocks that are hard and less permeable than sedimentary rocks; thus, although the slope of the land does not affect it, due to the compact rocks, rainwater will only seep into the top layer of the lava rock towards lower areas or denser areas which have rocks with better absorption capacity. In addition, the dredging of the land around the Brantas River, the dense population, and also hardening of the soil in the form of paving installations have reduced the water catchment area even though the rainfall in this village is quite large, like 2100 mm/year with 170 rainy days/year. [1] As result of not being matched by sufficient catchment areas and areas where water can gather causes residents have difficulty getting water. Besides, groundwater is needed to irrigate agriculture and small to large industries in the village.

We conducted groundwater identification using the geophysical (geoelectric) method in the Kedungpedaringan village. The geoelectric method is often used for shallow targets, including groundwater surveys. [3-6] This method has several configurations according to the searching target, whether the target is lateral or vertical. In this activity, we will use the Schlumberger configuration because it is considered good enough to produce sounding or depth data. [7]

2. Materials and Methods

The three datum points using the Schlumberger configuration were set according to Fig. 2. This location was in the South part of Vocational High School 1 Kepanjen, Ngadiluwih street, Kedungpedaringan Village, Kepanjen District, Malang Regency, East Java. The distance between the ground and the Brantas river is about 7-10 meters. Thus, we hypothesized the depth of the aquifer is estimated to be deeper than 10 meters.

The data collection method in this Schlumberger configuration consisted of 4 electrodes (2 currents AB and 2 potentials MN) plugged in, as shown in Fig. 3. Because the potential distance MN is always fixed while the current AB is moving, the resulting datum is only a point of depth. The pseudodepth value of this configuration can be in the range of 1/3 or 1/5 of the span AB. Rollmeter stretches were carried out along 250-300 meters to reach depths more than 50 meters below the surface. Data acquisition was carried out using a resistivity meter SRN. Data processing was carried out using the IP2WIN program to determine the depth, thickness, and vertical subsurface resistivity values. This resistivity (ρ) value can be calculated using Equation 1 [8] in [9]:

$$\rho = KV/I \qquad (1)$$

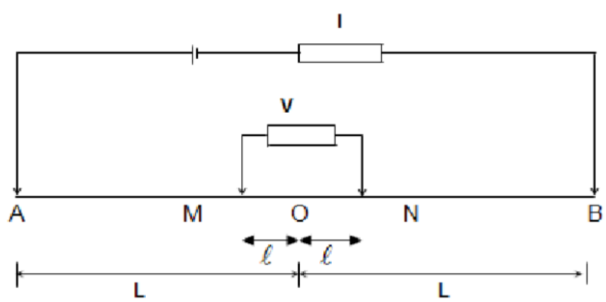

Fig. 3 Schlumberger configuration acquisition design. The potential electrode MN is fixed, and the current electrode AB moves with the AM and NB distance always the same.

Potential (V) and current (I) were recorded three times to obtain the average value during the acquisition of geoelectrical data, and the geometry factor (K) could be calculated according to the electrode installation based on the configuration used. For Schlumberger configuration K based on Figure 3 can be obtained from [10]:

$$k = \pi \frac{L^2}{o}\left(1 - \frac{o^2}{4L^2}\right) \qquad (2)$$

3. Results and Discussion

Based on the VES resistivity data processing results, a vertical VES curve is obtained to represent the interpretation results with the actual resistivity value table to determine groundwater. 3 vertical VES curves are obtained from S1, S2, and S3. Among the three points, S3 is the point that has the Resistivity Log data with the deepest depth of about 275 m, and the smallest error is in S2 at 5.2653%. This study's estimation of rock and aquifer types is based on various research sources (Table 1). The VES resistivity data processing results can be seen in Table 2-4.

Table 1. Resistivity in some materials. We adjusted the table according to the geology of the study area

Material/Rock	Resistivity (ohm.m)	References
Groundwater in the igneous rock area	30-300	[11], [12]
Gravel sand	58-1x10^4	[13], [14]
Coarse Tuff	80-150	[15],
Sandy Tuff	15-80	[15], [16], [17]
Fine Tuff	>150	[15]
Tuff	2000 (wet)-10^5 (dry)	[7]
Basaltic Lava	600-4x10^7	[7], [12], [13], [18], [19]
Clay	0,1-100	[16] , [18], [19], [20]
Alluvium	10-800	[18], [19], [21]
Groundwater	10-100	[7], [14], [18], [21]
Top Soil	1-14,6	[16], [22]
Breccia	62-1000	[16], [17], [23]
Lava	100-5x10^4	[7]
Andesit	1,7 x 10^2 (wet) – 4,5 x 10^4 (dry)	[7]

We can see in Tables 2-4 that the resistivity value variated from 4,89-18717,20 Ωm. We interpreted the lithologies of each layer based on these values and related them to the geological condition in the study area. If we look at Table 2-4, the rock resistivity value increases at a certain depth, reaches the maximum resistivity value at some points, decreases, and then increases again. Thus, we tried to model the subsurface layer according to the general form of the apparent resistivity curve for the layered structure. [24]

The top layer of the three measurements (KDVes-1 to KDVes-3) has a very low resistivity (4.89-26.78 Ωm) and is indicated as an alluvium layer dominated by clay. This top layer has varying depths at the three measurement points. In KDVes-1, the top layer depth is between 0-16.5 meters. In KDVes-2, the depth ranges from 0-35 meters, while in KDVes-3, the depth is 0-18 meters.

In KDVes-1, we indicated the presence of 3 layers consisting of several different resistivity values. At a depth of 0-16.5 meters, the resistivity value of the layer is 6.96-12.42 Ωm and is indicated as the top layer. Then the resistivity value increases but is still included as a layer with low resistivity, which is 45.87-244.3 Ωm at a depth of 16.5-32 meters. The third layer has a very low resistivity value of 10.14-39.8 Ωm at a depth of more than 32 meters.

Table 2. The layer at point KDVes-1

Depth (m)	Resistivity (Ωm)	Type
0-14	6,96	Very Low
14-16,5	12,42	Very Low
16,5-20	238,11	Low
20-28	45,87	Very Low
28-32	244,3	Low
32-39	10,14	Very Low
39-75	39,80	Very Low
75-112	19,72	Very Low

In KDVes 2, we indicated 5 layers. The top layer is at a depth of 0-35 meters and has a low resistivity of 4.89-26.78 Ωm. Then the resistivity value tends to increase according to the depth, namely from 35-143 meters and is indicated as compact rock and may not have the groundwater potential. The resistivity value decreases again at a depth of more than 143 meters (38.84 Ωm), and we indicated that the aquifer is at this depth.

Table 3. The layer at point KDVes-2

Depth (m)	Resistivity (Ωm)	Type
0-17,5	24,73	Very Low
17,5-30	26,78	Very Low
30-35	4,89	Very Low
35-47	534,62	intermediate
47-80	931,01	intermediate
80-90	247,10	Low
90-143	18717,20	High
143-210	38,84	Very Low

In KDVes-3, we detected 6 layers where the top layer is at a depth of 0-18 meters with a resistivity value of 6.25-21.76 Ωm. Furthermore, the second layer has a resistivity value of 2062.23 Ωm and is 18-60 meters deep. The third layer has a resistivity value of 298. Ωm with a depth of 60-72.5 meters, and the fourth layer has a resistivity value of 5.42 Ωm and a depth of about 72.5-82 meters. The fifth layer is at a depth of 82-152.5 meters and a resistivity value of 797.46 Ωm. The resistivity value decreases at depths below 152.5 meters, ranging from 112.66 to 295.05 Ωm.

Based on the range of resistivity values shown in Table 1, we indicate that the top layer in this study is an impermeable clay; thus, it tends only to drain water from the surface. The top layer contains fresh water on the surface, but it depends on seasonal conditions and surface water supply; thus, during the dry season, it will be drought. When viewed from a depth that ranges from 0-35 meters, this possibility is what makes the surrounding community unable to find groundwater at a depth of less than that. Then, it is probably volcanic breccia for areas with resistivity values around 100-300 Ωm. [25] At point KDVes-1, there is a layer between these 2 breccia layers and is indicated as sandy tuff. This can be seen from the geological formations in the study area (Figure 1), where this area is dominated by breccia and sandy tuff. Thus, the area with very high resistivity values in KDVes-2 may be possible as a very compact and impermeable basaltic lava.

Table 4. The layer at point KDVes-3

Depth (m)	Resistivity (Ωm)	Type
0-10	21,76	Very Low
10-15	6,25	Very Low
15-18	13,20	Very Low
18-60	2062,23	High
60-72,5	298,58	Low
72,5-82	5,42	Very Low
82-152,5	797,46	Intermediate
152,5-185	295,05	Low
185-277	112,66	Low

Fig. 4 shows a 1D resistivity cross-section that has been matched with the references of resistivity value. After interpreting the cross-section, we can see that from the 3 VES points, there is a distribution of rock where each geoelectric point has detected the presence of aquifer layers with different depths. At a point, KDVes-1 is identical to the distribution of sandy tuff with a depth of about 32 meters. For the KDVes-2 point, the groundwater potential is in the 5th layer with a depth of about 149 meters.

Thus by looking at rock characteristics and curves regardless of different depths, the paths at the KDVes-1 and KDVes-2 can be assumed to have aquifer layers containing greater groundwater. This groundwater flows towards KDVes-2 following the law, which states water flows from a high place to a lower place. It can also be proven by slicing the geological map in Figure 1. The data acquisition point is right between the Qptm and Qpvb rock formations, forming a basin most likely to accommodate groundwater.

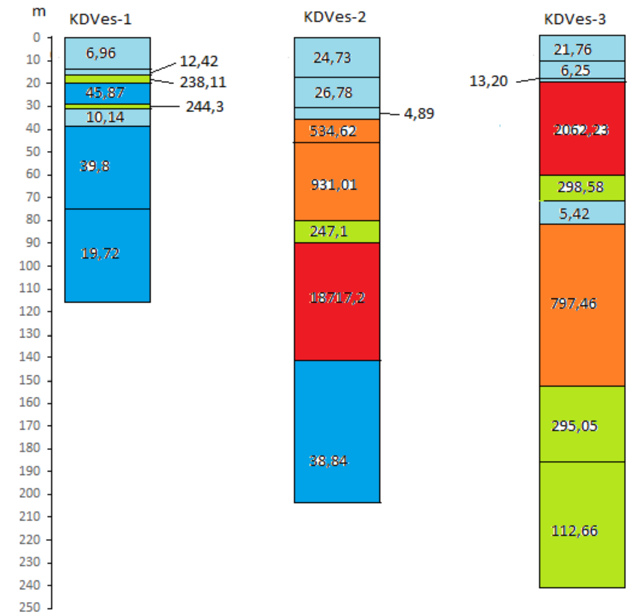

Fig. 4 Resistivity Log Interpretation Results. KDVes-1 to KDVes-3 are the results of measurements at points S1-S3

4. Conclusion

Based on the results described above, the continuity of sandy tuff is at a depth of 32-75 meters on KDVes1 and 143-210 meters on KDVes-2. It indicates that these two locations are aquifers containing groundwater. When viewed from the difference in height between the three, it is estimated that KDVes-2 is a gathering place for groundwater in the aquifer, while KDVes-1 and KDVes-3 are probably aquifers whose groundwater is not fixed but as a waterway when going to KDVes-2.

Funding Statement

His research was funded by Research institutions and community service Universitas Brawijaya by contract number [540.29.5/UN10.C10/PM/2021].

Acknowledgements

The authors thank the Kedungpedaringan village aparatus who have provided facilities and a team of surveyors during the geoelectric data acquisition process.

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