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Estimation of the Position and Potential of Aquifers Using Geo-Electrical Methods in the Framework of Drill Wells in Volcanic Areas

I Nengah Simpen [a]

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Corresponding Author [a]

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aquifer;
drilled well;
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position;
potential;

Abstract

Water sources in volcanic areas are rather difficult to obtain. For this reason, a method is needed to determine the existence of a water source. One of them is the Geoelectric method. In this study, the obtained resistivity physical quantities are used to determine the position and calculate the aquifer potential. In this study, three groups of rocks were found, namely, the rock group with resistivity values of 174 Ω.m – 400 Ω.m, this group is thought to have no water, not suitable for drilling. The rock group by resistivity 115 Ω.m - 174 Ω.m, this group is suspected of having water but little, not suitable for drilling. Rock group by the resistivity of 115 Ω.m below, namely at position 115-155 this area is the position of the aquifer, suitable for drilling, in this area, it is suspected that there is an aquifer with an average depth monitored by the tool 16.5 - 42.5 m or a thickness of 26 m. The transmissivity value obtained was 15.47 (m2/day). This means that drilled wells as a source of water which will later be constructed have very good potential if they are only used for domestic purposes, but are still not good for irrigation purposes.

Contents

[a] Earth Physics Laboratory, Physics Department, Mathematics and Science Faculty, Udayana University, Denpasar, Indonesia

1 Introduction

Problem background

A volcanic area is an area consisting of a stretch of rock originating from a volcano. Volcanic areas are usually fertile, so residents can cultivate crops, but in this area, water is often constrained.

Figure 1. A fertile volcanic area with Mount Batur in the background, Bali

One of the volcanic areas where this research was conducted is Songan Village. Songan Village is a village located at the foot of Mount Batur which is administratively located in the Kintamani sub-district, Bangli Regency, Bali Province. The area of Songan Village is 28.89 km2. Mount Batur is one of the active volcanoes in Indonesia, but the eruption is small, and not dangerous (Wikipedia, 2022). As a result, the land around Mount Batur is fertile, and very suitable for agriculture as long as there is sufficient water. Residents use a lot to grow onions, chillies, vegetables, tomatoes and others. Water is obtained from rainwater, Lake Batur water uses a pump, and some also use wells, both dug wells and drilled wells (Liu et al., 2021; Seldén et al., 2009). The problems that arise are that there is no rainwater throughout the year/month, lake water is only suitable for relatively close places, well water can not be dug just anywhere and produce water, sometimes water is found in making wells but the potential is not possible. The main problem is the reliability of the availability of water. For this reason, the local community took the initiative to build boreholes as a source of water (Loke et al., 2013; Kiessling et al., 2010; Chandra et al., 2008).

Water sources in volcanic areas such as the Mount Batur area are rather difficult to obtain (Ugwu et al., 2016). For this reason, a method is needed to determine the existence of a water source. One of them is the Geoelectric method (Simpen & Redana, 2019), later after the water source is obtained and the potential is considered sufficient, then drilling is carried out. Bore well water in quality and quantity can be relied upon as long as the water is obtained from the aquifer (Miller & Singh, 1994; Pittman et al., 2011). This study aims to determine the drilling point and estimate the potential of the borehole to be constructed based on the hydrological parameters. The results of this study are expected to be used by local farmers or policymakers to provide water for both agriculture and drinking water for the population (Helena et al., 2000; Ying et al., 2003; Yoon et al., 2011).

Basic theory
Geoelectric theory

Geoelectric is one of the geophysical methods that study the nature of the flow of electricity on the earth (Pujianiki & Simpen, 2018). The geoelectric method is more effective if used for shallow exploration, unable to provide information on layers at depths of more than 300 m or 450 m. This method is widely used in the field of engineering geology such as determining the depth of bedrock, searching for aquifers (groundwater), and is also used in geothermal exploration (Todd, 1980). Of all the physical properties of rocks and minerals, resistivity shows a very large variation in value. In metallic minerals, values range from 10−8 Ω.m to 107 Ω.m (Todd, 1980). If a rock has a variety of compositions, it will produce a varying resistivity range. Thus the maximum possible resistivity range is from 1.6 x 10−8 (pure silver) to 1016 Ω.m (pure sulfur). The resistivity variation of the earth material is shown in Table 1 (Todd, 1980).

Table 1
Variations in the value of the resistivity of the earth's material

Material type	Resistivity value (Ohm meter)
Air	0
Sandstone	200 – 8.000
Sand	1 – 1.000
Clay	1 – 100
Groundwater	0,5 – 300
Saltwater	0,2
Dry gravel	600 – 10.000
Alluvium	10 – 800
Wet gravel	100 – 600

The quantities measured in the Geoelectrical Method are the amount of the injected current and the potential difference due to the strong current. Based on these two quantities, the apparent resistivity will be obtained. This method uses four electrodes. One way to configure the four electrodes is the Wenner configuration, namely the distance AM = MN = NB (Telford et al., 1990; Solehudin et al., 2022):

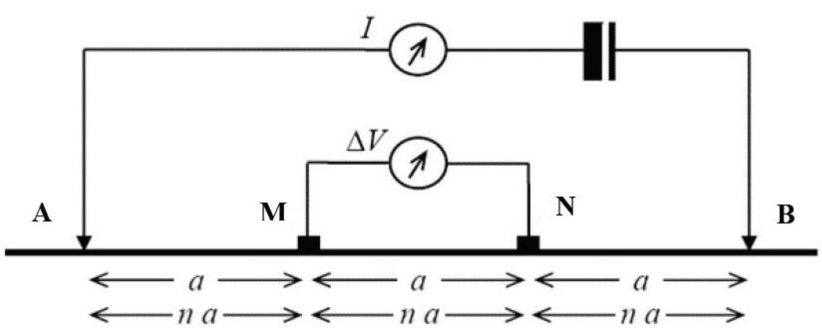

Figure 2. *Werner electrode* configuration

The apparent resistivity (ρ) is obtained:

$$\rho = K\frac{\Delta V}{I} \quad \text{.....................} (1)$$

Where $K = \frac{2\pi}{\left(\frac{1}{AM}-\frac{1}{BM}\right)-\left(\frac{1}{AN}-\frac{1}{BN}\right)}$

$$K = 2\pi a \text{ ....}(2)$$

Where ρ is rock resistivity, K: is constant, I: is injected current, V: potential difference, a, AM, BM, AN, BN for each electrode distance used.

Hydraulic Parameters

Research using the Geoelectric method will get the resistivity (ρ) and aquifer thickness (h). These two quantities are used to calculate the hydraulic parameters, namely hydraulic conductivity (K) and transmissivity (T). The relationship between thickness (h) and resistivity (ρ) with hydraulic parameters is as follows (Darisma et al., 2020; Khusna et al., 2021; Maitama et al., 2022; Ugwu et al., 2016).

$$K = 8.10^{-6}\, e^{-0{,}0013\,\rho} \quad \text{............ (3)}$$
$$T = K\, h \quad \text{................................(4)}$$

K represents Hydraulic conductivity; T represents Transmissivity (T); h represents the thickness of the aquifer. Hydraulic conductivity (K) is how far water can pass through an aquifer in one unit of time (Hudak, 2004) depending on the nature of the fluid (water) and rock properties, such as porosity, grain size, grain arrangement and grain shape, and distribution. The value of hydraulic conductivity (K) for several types of rock can be seen in the following table (Todd, 1980).

Table 2
Hydraulic Conductivity (K) Values of Some Rocks

Rock	K (m/day)	Batuan	K (m/day)
Coarse gravel	150	Clay	0,0002
Medium gravel	270	Limestone	0,94
Gravel	450	Dolomit	0,001
Coarse sand	45	Schist	0,2
Medium sand	12	Slate	0,00008
Fine sand	2,5	Tuff	0,2
Medium sandstone	3,1	Basalt	0,01
Fine sandstone	0,2	Weathered Gabbro	0,2
Silt	0,08	Weathered Granite	1,4

Source: Todd (1980)

Transmissivity (T) is the ability of the aquifer to transmit water horizontally through a vertical plane, which passes through the thickness of the aquifer, and one unit of hydraulic gradient (Hudak, 2004). Transmissivity (T) is related to hydraulic conductivity (K). The transmissivity equation (T) can be written as:

$$T = K.\, h \quad \text{........................ (5)}$$

Underground water potential based on the value of transmissivity according to the U.S. Dept. of the Interior in Wibowo (2012) can be seen in Table 3.

Table 3
Groundwater Potential Based on Transmissivity and Use

Transmissivity (m2/day)	Domestic	Irrigation
<1	Ugly	Very ugly
1-8	Moderate	Very bad
8-50	Good	Very ugly
50-300	Very good	Ugly
300-1000	Very good	Moderate
1000-10.000	Very good	Good
>10.000	Very good	Very good

Source: *U.S Dept. of the Interior dalam Wibowo (2012)*

Potential aquifers based on aquifer thickness are classified into (Maitama et al., 2022)

Table 3
Classification of Potential Aquifers Based on Thickness

No.	Aquifer Thickness (m)	Category
1	< 10	Bad
2	10-20	Moderat
3	>20	Good

Source: (Maitama et al., 2022)

2 Materials and Methods

Research site

The research uses the Geoelectric method. The tool used is the SkillPro geoelectric set with Werner configuration. The research location is in Songan Village, Kintamani District, Bangli Regency, the geographical position is around 8,2403210 latitude; 115.403289 East Longitude (Figure 3).

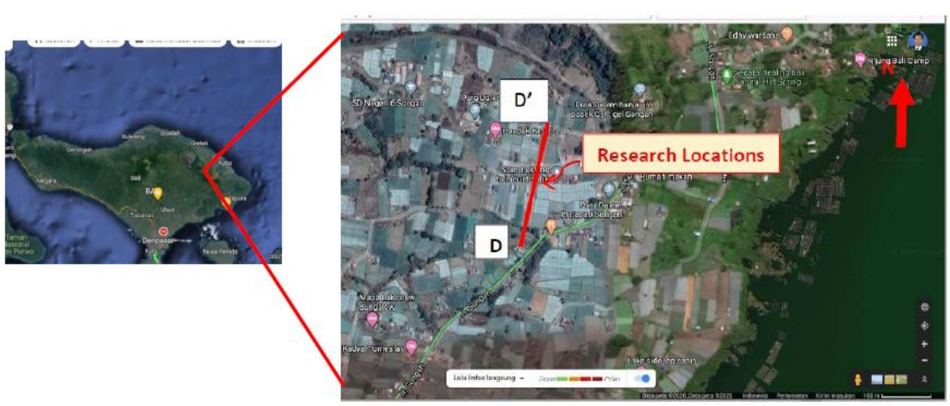

Figure 3. Research Locations
Surce: https://www.google.com/maps/@-8.2412233,115.4034718,765m/data=!3m1!1e3!5m1!1e1

Research steps

The steps taken in conducting the research are as follows: a. Creating a measuring path b. Electrode installation c. Measurement cable installation d. Taking measurements e. Data analysis f. Report generation Number, track position and depth of measurement, on request. In this study, first made a track with a length of 235 m as shown in Figure 3.

Data analysis method

The data was obtained in the form of apparent resistivity data. To obtain real resistivity data, the apparent resistivity data were then analyzed using the Res2dinv program. The data recorded by the SkillPro resistivity meter is converted into data in the form of *.DAT so that it can be used as input for the Res2dinv program. Then the output of the Res2dinv program can directly provide an overview of the resistivity cross-section of the measurement path. This image is interpreted.

3 Results and Discussions

Research Results

The result of the research is a real resistivity cross-sectional image of the measurement path of the Res2dinv program output. Images can be seen below:

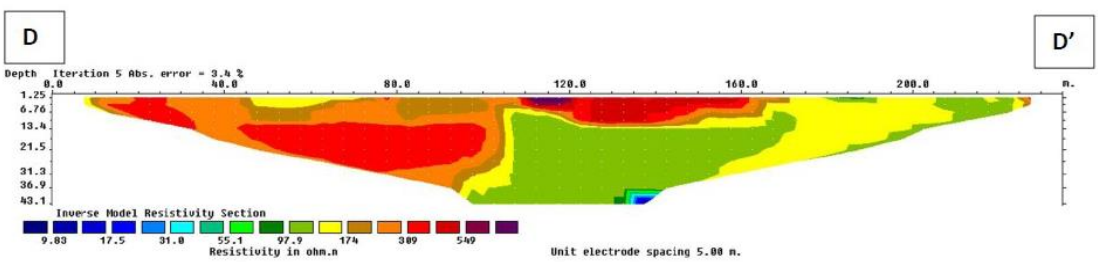

Figure 4. The cross-sectional contour of the real resistivity measurement path

Estimating the position of the aquifer

Based on the measurement data, it appears that the cross-section of the layers can be grouped into three resistivity groups as shown in Figure 5, namely:

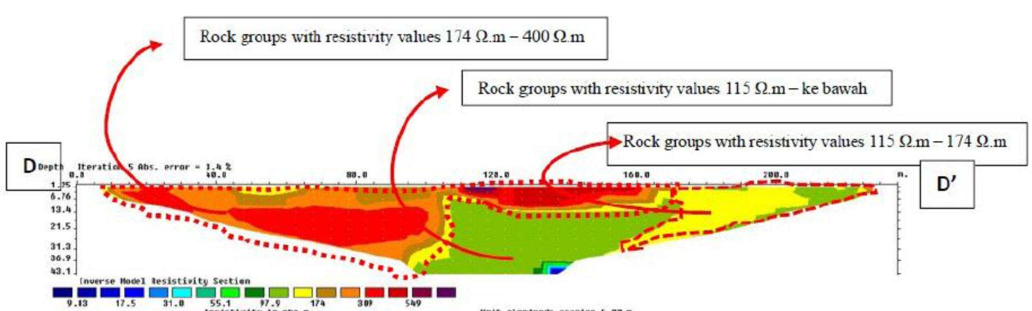

Figure 5 Grouping of rocks

a) Rock groups with resistivity values of 174 Ω.m – 400 Ω.m, this group is thought to have no water, not suitable for drilling.

b) The rock group by resistivity 115 Ω.m - 174 Ω.m, this group is suspected to have water but little, not suitable for drilling.
c) Rock groups by a resistivity of 115 Ω.m and below, namely at positions 115-155 this area is an aquifer position, suitable for drilling, in this area, it is suspected that there are aquifers with an average depth monitored by the tool 16.5-42.5 m or 26 m thick.

At depths greater than 42.5 m it is not monitored by the tool so further research is needed to determine the lower limit of the aquifer.

Estimation of aquifer potential

Based on the results of geoelectrical measurements, it was found that the resistivity (ρ) in the aquifer area was 115 .m with a thickness (h) of 26 m. Entering the results of this calculation in equations (1) and (2), we get:

$K = 8.10^{-6}\, e^{-0,0013\,\rho}$ .... (3)

$= 0,595$ (m/day)

$T = K\,h$ ....(5)

$= 0,596 * 26$

$= 15,47$ (m^2/day)

Taking into account the K value obtained, then compared with the K value in Table 1, the aquifer is thought to be a rather fine sandstone (between fine sand and medium sand). This sand is thought to have come from the eruption of Mount Batur. The transmissivity value obtained was 15.47 (m2/day). This means that drilled wells as a source of water which will later be constructed have very good potential if they are only used for domestic purposes, but are still not good for irrigation purposes (Sukarasa & Paramarta, 2020; Simpen et al., 2018). If we look at the thickness of the existing aquifer, which is greater than 26 m, then this aquifer is a good aquifer. It also appears that not at every point when drilling is carried out, water will be obtained as stated by Ugwu et al. (2016).

4 Conclusion

The results of this study can be concluded that there is an underground aquifer with sufficient potential that it is feasible to drill for agricultural purposes. It is recommended that drilling be carried out at positions 115 – 155 or from the roadside (land boundary) to 40 m into the land, a depth of 16.5 is suspected to have met water. Drilling may be carried out to a depth of 43 m.

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The authors would like to thank all the members of the Onion and Tomato Farmer Group in Songan Village, Kintamani District, Bangli Regency, Bali Province for the time given to conduct the research. However, it should also be noted that this activity is only limited to research and academic calculations, no drilling and well testing has been carried out. This requires further action.

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Biography of Author

Dr. Ir. Drs. I Nengah Simpen, M.Si, IPM, ASEAN.Eng
was born in Karangasem on August 2, 1960. Education Elementary School (1968-1973), Junior High School (1974-1976) and High School (1977-1980) in Karangasem. Bachelor of Physics Education obtained at Udayana University (1980-1985). Through the Pre-Masters Program (Matriculation) at the Bandung Institute of Technology / ITB (1989-1990), he succeeded in entering the Masters / Masters Program (1990-1993) at the Bandung Institute of Technology / ITB. The Doctoral/S3 Program (2012-2016) was completed at Udayana University. Engineer Professional Program in Engineering Physics Vocational Program at Udayana University in 2020. From 1987-2001 as a Physics Lecturer at Malang State University. 2001-present as a lecturer at Udayana University. Active as a lecturer in the Physics Study Program, Faculty of Mathematics and Natural Sciences, Udayana University and also teaches in the Civil Engineering Study Program and the Environmental Engineering Study Program, Faculty of Engineering, Udayana University. The subjects taught are Basic Physics, Geoelectrics, Engineering Geology, and Groundwater. Currently registered as a member of the Indonesian Physics Association (HFI), the Association of Indonesian Groundwater Experts (PAAI), the Association of Indonesian Engineers (PII), and ASEAN Engineering. Interest in the fields of Earth Physics, Geoelectrics and Groundwater.
Email: simpen.nengah@yahoo.com