Hydrogeology estimation using geo-electric survey in Sekotong, Lombok Barat

A H Rabinah1*, Kusnadi2, J D Anggraeni2, M Arisalwadi3 and E Agustriani2

1Civil Engineering, Politeknik Negeri Semarang, Indonesia
2Geological Experts Association of West Nusa Tenggara, 3Institusi Teknologi Kalimantan, Indonesia

*Email : aiunrabinah@gmail.com

Abstract. Hydrogeological conditions can provide information on movement and groundwater conditions, which have a significant influence on mining activities, especially underground mining. Research using geo-electric has been applied in various fields. This study aims to analyze the distribution of aquifers in the Sekotong area and provide basic planning tools to regulate underground mining in NTB Province. This study uses a geo-electric survey to assess hydrogeological conditions in underground mining by using the specific vertical electric sounding (VES) of Schlumberger array method, with 3 points (BP 01, 02, and 03). The output from the geo-electric survey shows that the apparent resistivity curve is being checked using IP2Win software. The results of this study indicate the value of the resistive type is between 3 - 25 Ωm; it can be concluded that the aquifer layer is at a depth of 1.5 m to 60 m. However, from data analysis, it was shown that the study area was formed by half of the tuff layer and cracked breccias. Therefore, below 60 m depth, it is indicated that permeable layers formed by volcanic breccia and lava are present.

1. Introduction

Nusa Tenggara Barat Province in Indonesia has many mining potentials as the income-generating source of the region. One of the important mining sites in NTB Province is the Sekotong sub-district in Lombok Barat District. Hydrogeological condition of the region has been one of the important factors to consider in the decision-making processes of issuing the licensing for mining. The hydrogeological condition can inform the movements and groundwater conditions, which have significant influences on the mining activities, especially underground mining. Groundwater contained in geological formations in the permeability layer is called aquifers. This research aims to analyze the distribution of aquifer in Sekotong area and provide basic planning tools for regulating underground mining in NTB Province.

Hydrogeological and geophysical investigations are often conducted to assess the groundwater potential of a particular area. Geophysical investigations, although sometimes plagued with ambiguities and uncertainties in interpretation, provide a rapid and cost-effective means of deriving distributed information on subsurface hydrogeology [1]. The use of geophysical methods for both groundwater resource mapping and water quality evaluation has increased dramatically over the last decade [2].

Although various hydro-geophysical techniques are available, electrical resistivity is a popular method because of its low cost, simple operation, and efficiency in areas with high contrasting resistivity, such as between the weathered overburden and the bedrock [3]. Geo-electrical techniques are essentially concerned with the measurement of electrical resistivities of subsurface materials, which
preferentially provides information on the different geological layers, structures and the associated occurrence of groundwater [4][5][6][7].

2. Method
This research uses the geo-electric survey to assess the condition of hydrogeology in underground mining. Using the specific vertical electric sounding (VES) of Schlumberger array method, with 3 points of measurements (BP 01, 02, and 03), this method is expected to gain data about the existing condition of hydrogeology in the region (Figure 1). Schlumberger testing scheme in Figure 2. Whereas for testing the quality of water in the residents well near to the project area measured two parameters which are Electrical Conductivity (EC) and Total Dissolved Solid (TDS). Moreover, we also measured three parameters of water quality of taste, color, and scent.

Figure 1. Map of Geoelectric and water quality testing location

Figure 2. Geoelectric Testing with Schlumberger Method [8]
V_p at any point P in the ground is equal to the sum of the voltages from the two electrodes, \( V_p = V_A + V_B \) where \( V_A \) and \( V_B \) are the potential contributions from the two electrodes, A (+1) and B (-1). The potential at electrode M and N are [8]:

\[
V_M = \frac{\rho I}{2\pi} \left[ \frac{1}{AM} - \frac{1}{MB} \right] \\
V_N = \frac{\rho I}{2\pi} \left[ \frac{1}{AN} - \frac{1}{NB} \right] 
\]

However, it is far easier to measure the potential difference, \( \delta V_{MN} \), which can be rewritten as:

\[
\delta V_{MN} = V_M - V_N 
\]

Rearranging this so that resistivity \( \rho \) is the subject:

\[
\rho = \frac{2\pi \delta V_{MN}}{I \left( V_M - V_N \right)^{-1}} 
\]

3. Result and Discussion

Based on the Geological Map of Sheet Lombok [9], the investigation area located in the Pengulung Formation (TOMP). This formation is a unit of old volcanic rocks consisting of breccias, lava, and tuffs with limestone lenses containing sulfide ore and quartz veins. This formation is lined up with the Kawangan formation, broken through by dacite and basal (Tmi) rock formation, crushed not in harmony with the Ekas (Tme) formation, Kalipalung (TQp) and Alluvium (Qa) Formations (Figure 3).

![Figure 3](image-url)  
**Figure 3.** Geological map of the investigation area

The geoelectric measurement results in the form of a pseudo-resistance curve are then analyzed using the IP2Win software, which is the inversion of an ideal model that is adjusted so that it approaches the field curve. The type of resistance value at each point of the estimate can be correlated or connected so that the distribution of the layers will see. The layer distribution data displayed in the form of an
estimated type of VES Resistivity values and cross-section layers of contrast resistivity values (Figure 4).

Figure 4. Estimate type of resistance and a cross-section contrast of type resistances

The results of the population well test (Table 1) show the surface area around the location of the value of electrical conductivity (DHL) and TDS is very high. Under a depth of 60 m, the number of pores and cracks of rock is less so that this layer classified as an impermeable layer of aquitard water.

Base on cross-section, the top layer is a cover land with an average thickness of 1 - 1.5 m, this layer tends to be dry with an average resistivity of over 200 Ω. The lower layer indicated as an aquifer layer or layer of the water shipper. This layer has a small resistance value ranging from 3 - 25 Ω with an average thickness of 20 m. Layers that have a resistivity value of fewer than 7 Ω indicated as layers that are affected by metal elements from pyrite and sulfide minerals. This layer tends to be in the upper surface into 10 m, while the deeper layers have less content. Interpretation of the geoelectric measurements at each detailed point in Table 2.

Table 1. Water quality in local community wells near to the project area

| No. Sample | Coordinate | Altitude | Ground water level | TDS | Temperature | DHL |
|------------|------------|----------|--------------------|-----|-------------|-----|
| 1          | X: 150°53’44.4” Y: 8°47’9.8” | 42 m     | 1.5 m              | 2,343 | 30°        | 4,105 |
| 2          | X: 150°53’44.4” Y: 8°47’9.8” | 30 m     | 3.5 m              | 347  | 31°        | 696  |
| 3          | X: 150°53’44.4” Y: 8°47’9.8” | 29 m     | 9.5 m              | 635  | 30°        | 1,334 |
| 4          | X: 150°53’44.4” Y: 8°47’9.8” | 28 m     | 5 m                | 1,011| 31°        | 2,010 |

Table 2. VES resistivity measurement in Brambang Village Batuputh Sekotong District

| No. Kode | Coordinate | Location | Top | Bottom | Thickness | pa | Lithology       | Error   |
|----------|------------|----------|-----|--------|-----------|----|-----------------|---------|
| BP-01    | X: 115.8963611 Y: -8.78536111 | Brambang, Batuputh village | 0   | 1.3    | 1.3       | 212| Bed soil        | 6.74%   |
|          |            |          | 1.3 | 20     | 18.7      | 16 | Tuff Sandstone  |         |
| No. Kode | Coordinate | Location | Top | Bottom | Thickness | pa  | Lithology                                | Error |
|----------|------------|----------|-----|--------|-----------|-----|------------------------------------------|-------|
| Z 35 m  |            |          | 20  | 60     | 30        | 20  | Crack of volcanic breccia Breccia and lava in bulk condition |       |
|          |            |          |     | > 60   |           | 85.2|                                          |       |
| BP-02    | X: 115.8966111 | Brambang, Batuputh village | 0   | 0.4    | 0.4       | 30.1| Bed soil                                 | 2.58% |
|          | Y: -8.78588888 |            | 0.4 | 0.9    | 0.5       | 2.33| Saturated with sulfide and iron ore       |       |
| Z 39 m  |            |          | 0.9 | 11.5   | 10.6      | 7.41| Tuff Sandstone with sulfide and iron ore  |       |
|          |            |          | 11.5| 21.6   | 10.1      | 53.4| Sisipan breksi pada tuff sandstone        |       |
|          |            |          | 21.6| 39.1   | 17.5      | 5.6 | Tuff Sandstone with sulfide and iron ore  |       |
|          |            |          |     | > 39.1 |          | 10.3| Breccia and lava in bulk condition        |       |
| BP-03    | X: 115.896 | Brambang, Batuputh village | 0   | 0.3    | 0.3       | 283 | Bed soil                                 | 4.85% |
|          | Y: -8.78588888 |            | 0.3 | 0.9    | 0.6       | 2.67| Saturated with sulfide and iron ore       |       |
| Z 39 m  |            |          | 0.9 | 2.2    | 1.3       | 34.4| Crack of breccia/limestone Tuff Sandstone |       |
|          |            |          | 2.2 | 4.6    | 2.4       | 3.98| Tuff Sandstone with sulfide and iron ore  |       |
|          |            |          |     | > 58   |           | 15.2| Breccia and lava in bulk condition        |       |

4. Conclusion
From the results of geoelectric measurements of aquifer layers at a depth of 1.5 to 60 m, in the investigation area with a type of resistivity value of 3 - 25 Ωm. The type of rock is interpreted as a tuff layer and crack breccias. Under a depth of 60 m, it indicated as a watertight layer with layers of volcanic breccia rock and solid lava.

References
[1] P. Kearey and M. Brooks, An Introduction to Geophysical Exploration, second ed. Blackwell Scientific, Oxford: Oxford Publishing House, 1991.
[2] A. Morgan L, M. Abu and A. N. Nasir, "Vulnerability Assessment of Groundwater to Contamination Using Electrical Resistivity Method at the Open Dumpsite in Gosa, Abuja, Nigeria," *Journal of Geology & Geophysics*, vol. VII, no. 2, pp. 1-9, 2018.
[3] W. M. Telford , L. P. Geldart and R. E. Sheriff , Applied Geophysics (2nd edition), Cambridge: Cambridge University Press, 1990.
[4] N. K. Abdullahi, I. B. Osazuwa and P. O. Sule, "Application of Integrated Geophysical Techniques in The Investigation of Groundwater Contamination: A Case Study of Municipal Solid Waste Leachate," *Ocean Journal of Applied Sciences*, vol. IV, no. 1, pp. 7-25, 2011.

[5] H. Chang, L. PingLin, C. H. Yang and T. P. Wang, "Geoelectrical Mapping of The Soil and Groundwater Contaminated Site: Case Study from Taiwan," in *7th International Conference on Environmental and Engineering Geophysics & Summit Forum of Chinese Academy of Engineering on Engineering Science and Technology*, China, 2016.

[6] M. I. Mohamaden, A. Z. Hamouda and S. Mansour, "Application of electrical resistivity method for groundwater exploration at the Moghra area, Western Desert, Egypt," *The Egyptian Journal of Aquatic Research*, vol. XLII, no. 3, pp. 261-268, 2016.

[7] M. O. Olorunfemi and S. A. Fasuyi, "Aquifer types and the geoelectric/hydrogeologic characteristics of part of the central basement terrain of Nigeria (Niger State)," *Journal of African Earth Sciences (and the Middle East)*, vol. XVI, no. 3, pp. 309-317, 1993.

[8] J. M. Reynolds, An Introduction to Applied and Environmental Geophysics, Chichester: John Wiley and Sons Ltd, 1997.

[9] A. S. Mangga, S. Atmawinata, B. Hermanto, B. Setyogroho and T. C. Amin, *Peta Geologi Lembar Lombok, Nusa Tenggara Barat*, Bandung: Pusat Penelitian dan Pengembangan Geologi, 1994.