AN ACCURACY TEST OF "SCHLUMBERGER" VERTICAL ELECTRICAL SOUNDING METHOD IN A SANDBOX MODELLING

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Abstract - In groundwater exploration, a geophysical method is needed to provide information and an overview of the subsurface conditions of the study area, and the most common practice for giving subsurface information is a geoelectric method or resistivity method. During the acquisition of groundwater exploration, Schlumberger Vertical Electrical Sounding (VES) is the most preferred due to convenience and effectiveness. Schlumberger configuration will produce a subsurface profile vertically at an observation point and is the initial step to estimate the presence of aquifers in the groundwater exploration area. However, this method has several geological considerations leading to the inaccurate subsurface interpretation that the presence of dipping layers and subsurface structures such as fault are the main factors. Thus, the presence of that features can affect the modeling of resistivity values and subsurface thickness during interpretation process of the resistivity method. This then becomes the basis of the authors conducting a study that aims to determine the accuracy of the layer thickness produced by the VES resistivity method. However, the existence of subsurface structures is also difficult to predict if there are no supporting by surface data, hence the study modeling of subsurface conditions using a sandbox model will be carried out.

DOI: 10.3997/2214-4609.201900420
Url: http://www.earthdoc.org/publication/publicationdetails/?publication=96978
ISBN: 9781510862692
Title: EAGE-HAGI 2nd Asia Pacific Meeting on Near Surface Geoscience and Engineering

Introduction

In subsurface research especially for groundwater, a method is needed that can provide information and an overview of the subsurface conditions of the area to be explored. One common method for providing subsurface information is the geoelectric method/resistivity method. The resistivity method can produce information in the form of 1-D to 3-D data based on the acquisition method used. The Vertical Electrical Sounding (VES) method is the most common method used in groundwater exploration. This method is a resistivity method that produces a subsurface profile vertically at an observation point. The configuration that is often used to do VES is the Schlumberger Configuration.

In groundwater exploration, schlumberger configuration is used as an initial step to estimate the presence of aquifers in the exploration area. This method has several factors that can cause doubt on the interpretation of subsurface conditions obtained. The presence of slope and subsurface structures such as fault can affect the modeling of resistivity values and subsurface thickness by the resistivity method. This then becomes the basis of the authors conducting a study that aims to determine the accuracy of the layer thickness produced by the VES resistivity method with schlumberger configuration. This method is used to display subsurface information, therefore the truth and accuracy of this method need to be ascertained. The existence of subsurface structures is also difficult to predict if there are no supporting surface data. On the basis of these conditions, in this study modeling of subsurface conditions using a sandbox model will be conducted. The modeling aims to determine the level of precision and accuracy of resistivity modeling carried out by knowing the modeled subsurface conditions.

Theory

Potential differences that occur in rocks are caused by electrochemical activity in rocks or mechanical activity that occurs (Telford et al., 1990). The flow of electric current in rocks can be classified into three types, namely electrical conduction, electrolytic conduction, and dielectric conduction (Telford et al., 1990).

In this study three types of samples were used, namely quartz sand, iron sand (magnetite) and clay. Based on Telford (1990) quartz minerals have a very high resistivity value of 4×10^{10} - 2×10^{14} Ohm-m in a dry state which is included in the insulator mineral. The same source also mentions magnetite resistivity values having resistivity values ranging from 5×10^{-5} - 5.7×10^{3} Ohm-m so that they are included in good conductor minerals. In conditions of saturated water, clay will have a low resistivity value because it binds electrons which can channel electrolytes and produce maximum electrolytic activity (Roberts et al., 1998).

In applying subsurface conditions, one of the properties of rocks that can be a clue is the rock resistivity value or the inhibitory value of rock electricity in terms of unit length (Burger et al., 2006). In the resistivity method, direct current is flowed to the ground surface and the potential difference between the two points is calculated. The potential difference obtained by the flow of current along with increasing depth results in a measurement of resistivity values that vary, so that information about material and subsurface structures is obtained (Sharma, 1976).

The resistivity method measures the potential difference at a point on the surface of the earth that is generated by direct current down the surface. This will then refer to the spread of resistivity below the surface and end with the interpretation of the constituent material beneath the earth. In this resistivity method some of the basic electricity associated includes resistance, current flow, and potential (Burger et al., 2006).

In the Lateral Profiling method, the resistivity variation of the material is measured horizontally at a certain depth (Telford et al., 1980). This procedure is most often used in mineral exploration to detect rock ore bodies that have different resistivity values or the presence of anomalies in measuring resistivity values (Reynolds, 1997). In fact, the subsurface conditions are not homogeneous and the resistivity value obtained is not the original resistivity, but the apparent resistivity (ρ_a). Interpretation methods are needed to obtain original resistivity values (Reynolds, 1997). The value of apparent resistivity depends on the geometry of the configuration used which is defined as the geometry factor (K).

The three most commonly used configurations are Wenner, Schlumberger, and dipole-dipole configurations. In Schlumberger configuration, spacing of two potential electrodes is different from the distance between two current electrodes. As schlumberger configuration, the distance from the center to the current electrode is represented by b and the distance from the center to the potential electrode is represented by a. In this configuration, the value of b is greater than or equal to 5 times the value of $2a$ (Reynolds, 1997). The value of apparent resistivity from this configuration is obtained by using the following formula:

$$\rho a = \frac{\pi b^2}{2a}\left(1 - \frac{2a^2}{4b^2}\right).\frac{\Delta V}{I}$$

In this research, Schlumberger configuration is used which is the most commonly used method for sounding purposes. This configuration has advantages in sounding requirements because in this method the depth values that can be obtained will be greater at the same arrays distance in other configurations (Reynolds, 1997).

Methods

The research conducted was carried out through several stages to achieve the research objectives. Stages of research include, (a) Making resistivity measuring devices, in this study, two resistivity measuring devices were made using materials commonly found. The first tool is intended to measure the original resistivity value of the material to be used. The second tool can be arranged in such a way as to obtain the value of rock resistance and current flowing in the Schlumberger configuration with a combination of two multimeters to measure the current and voltage generated from the current flowing into the sandbox model based on Stanley (1981) with slight modifications (**Fig 1**). (b) Measurement of resistivity, with the original resistivity measuring instrument having the working principle of flowing into the geological material to be measured, to obtain the original resistivity value of the material. (c) Making sandbox models, intended to reconstruct layered subsurface conditions (**Fig 2**). (d) Data analysis stage, measurements taken in this study are miniatures of research in the field. The AB/2 distance which is generally made in meters is made in cm size. This is done because the size of the sandbox is limited. In the program used (PROGRESS) modeling cannot be done using units of centimeters so that a small AB/2 value is likened to a value in meters. In the IPI2WIN program which can enter a small AB/2 value, modeling is done with the actual value and the value of float in meters until it is found that there is no difference in the results of the depth interpretation.

Discussions

Measurements in each layer produce different resistivity values for each layer even with the same material. This condition occurs because there is no equal amount of water in each layer. The difference in resistivity values from each sample that is too small in saturated conditions is also a consideration so the condition of the sandbox is not 100% saturated.

Comparisons are made to the depth value and original resistivity of the sandbox model. The model that is compared is a model that uses computer forward modeling and a model that uses forward modeling based on original values. The original resistivity value of the model is obtained from direct measurements, while to get a more accurate thickness value from each line sampling is done at the center point of the line.

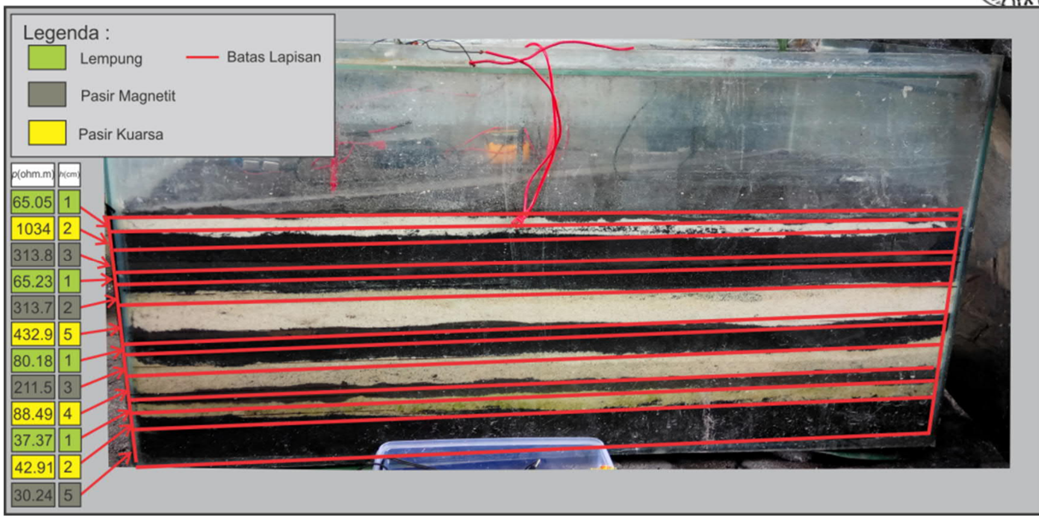

Figure 1 *The original resistivity value of each layer in the horizontal layer model*

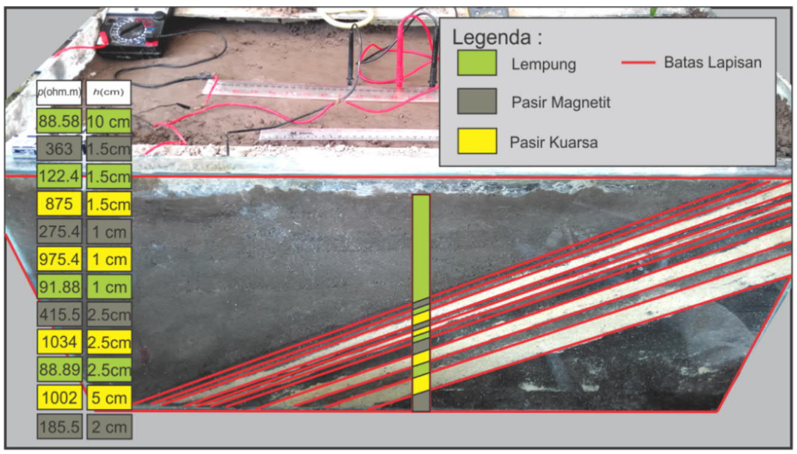

Figure 2 *The original resistivity value of each layer in the dipping layer model.*

Visually the difference in the log model with the original value is not too significant, but the change in the resistivity value of each layer is quite significant. These results are probably a result of adjustments made by the software to the existing resistivity values to match the number of layers and the depth values found on the calculation curve.

The modeling results are also compared through the deviation table of each layer which is interpreted to be the same layer. The comparison of the line M-10 still shows deviation values that are not too large in the resistivity and depth layers, while other measurements have very high deviation values. Measurements of direct resistivity to the layers were carried out on each unit of rock that was considered different in the outcrop near the measurement point and thickness measurements were carried out using the meassured section (MS) measurement method on the same outcrop.

The modeling results on the measurement path are in the direction of the slope of the layer after comparison resulting in a comparison that is less precise than the value of the depth and the value of resistivity. This happens due to electric currents flowing under the surface not flowing in the same layer due to the slope effect. Comparison of manual forward modeling log models also does not produce an appropriate resistivity value, some layers have resistivity values that are very incompatible with the sample data taken so that the type cannot be determined exactly.

The deviations or deviations from all comparisons are also presented in table form. In the table the comparison of resistivity, thickness, and depth values of each layer is presented in decimal form. A large deviation value, namely the ratio of the slope direction. This reinforces the influence of the slope structure above 10^{o} on the geoelectric measurement of the VES Schlumberger method (the slope of the layers in the field is 15^{o}).

Conclusions

The results of the modeling and comparison of the results of modeling to several existing parameters such as layer thickness, depth of layer, original resistivity value and also the value of the RMS model conclude as follows:

1. Layer modeling from the Schlumberger resistivity method produces the thickness and resistivity values readings that are right in the layer that gets thicker as depth increases.
2. The curve adjustment results using the depth value and original resistivity as a calculation curve (forward modeling) have better accuracy in terms of layer variation, but have a significant value of original resistivity and depth.
3. The effect of slope on the measurement of the Schlumberger VES geoelectric method is very large at a slope above 10^{o}. This is shown from the results of measurements on slope 30^{o} (M-30A, M-30B, M-30C), slope of 20^{o} (M-20), and slope of 15^{o} (N145^{o}E) where the measurement results are not even close to resistivity and depth of model and original field conditions. In measurements in the direction of slope 10^{o} (M-10) Results that are quite accurate and can still be equated with the original conditions can be obtained.

References

Burger, H. Robert, Sheehan, Anne F., dan Jones, Craig H. [2006] *Introduction to Applied Geophysics – Exploring The Shallow Subsurface*, W. W. Norton & Company., New York, USA.

Reynolds, John M. [1997] *An Introduction to Applied and Environmental Geophysics*, John Wiley & Sons Ltd, Baffins Lane, Chichester, West Sussex PO l9 IUD, England hal: 418-488.

Roberts, J. J., Carlberg, E., dan Lin, W. [1998] *Electrical Properties of Tuff from the ESF as a Function of Water Saturation and Temperature*, Lawrence Livermore National Labolatory.

Sharma, P.V. [1976] *Methods in Geochemistry and Geophysical : Geophysical Metods in Geology*, 3rd Ed., Elsevier Science Publishing Co.,Inc., New York, USA.

Telford, W.M., Geldart, L.P. dan Sherif, R. E. [1990] *Applied Geophysics*, 2rd Ed., Cambridge University Press., Camridge, UK hal 522-577.