GEOPHYSICAL AND BOREHOLE LOGGING DATA CORRELATION: A STUDY OF SUBSURFACE CHARACTERIZATION

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Abstract. Subsurface geological data play an important role in groundwater exploration activities and other engineering geology applications. However, this data is still minimal and not well documented in several locations and related agencies in the Pasir Muncang, Kedung Banteng, and Sukanegara areas of Banyumas Regency. Most of the research locations are composed of soil from bedrock weathering, and many other locations have been filled with the results of human activities, such as rice fields, industry, and residential areas. This research is expected to provide a guideline for a more accurate study of subsurface geology using subsurface resistivity surveys or other geophysical methods. This study uses a correlation analysis of data from subsurface resistivity survey interpretation results, resistivity logging, and lithology descriptions of groundwater drilling wells. The data comes from three nearby locations: Kedung Banteng, Pasir Muncang, and Sukanegara. The subsurface resistivity survey data is accurate and can be used as a guide for subsurface geological studies up to a depth of 25 metersThe correlation between subsurface resistivity survey data and resistivity logging data reached 91%, but decreased with increasing depth.

Keywords: subsurface, geophysical, logging data

1. Introduction

Important subsurface geological information is obtained for various regional development and monitoring activities, including groundwater exploration. Things that need to be observed, this information is sometimes still minimal and difficult to obtain, including the lack of documentation for previous research reports. The acquisition of subsurface geological information is also expensive and cannot fast to obtain.

Subsurface resistivity data are relatively inexpensive and easier to obtain than borehole logging data. But the weakness of subsurface resistivity data is that it is relatively inaccurate and difficult to reach deeper rock layers. In contrast, borehole logging data are accurate and can reach great depths, but are relatively expensive and difficult.

Another obstacle to obtaining subsurface geological data from cheap and fast subsurface resistivity surveys is that most of the locations have decayed to soil and converted into residential and urban, agricultural and industrial land. It is hoped that this research and publication will contribute to the initial subsurface geological information of the research sites from subsurface resistivity data.

This study aims to determine the accuracy and correlation of subsurface geological information on rock resistivity from subsurface resistivity surveys and groundwater borehole logging measurements. This is necessary to determine the distribution of rock characteristics and lithology vertically at shallow depths for exploration of groundwater resources or other engineering. From this study, it is expected to become a guideline for the use of subsurface resistivity data for groundwater exploration in the Pasir Muncang, Kedung Banteng, and Sukanegara areas of Banyumas Regency and its surroundings.

Regional Geology

Pasir Muncang, Kedung Banteng, Sukanegara areas and its surroundings is composed of alluvium rock formations, quaternary volcanic rocks from the eruption of Old and Young Slamet Volcanoes and tertiary sedimentary rocks. The Tapak Formation (Tpt) is the oldest rock in the research location. This tertiary sedimentary rock is composed of coarse grained, blackish colored sandstones and conglomerates, localized andesite breccias. At the top it consists of limestone sandstones and green marl which contain mollusc fossil fragments. This lithology is about 500 meters thick [1]. Above the Tapak Formation, Slamet Tua Volcano Lava Deposits (Qls) are deposited, which are composed of lahar with volcanic rock layer and andesite-basalt fragments, with a diameter of 10-50 centimeters. This sediment distribution covers a flat area. On top of the Old Slamet product, the volcanic eruption products of Young Slamet are deposited in the form of lava, breccias and tuffs that form hills and plains (Qvs). On top of the volcanic rock of the Slamet volcano, alluvium is deposited which is composed of sand and clay lithology that is currently formed (resen) [1] (Figure 1).

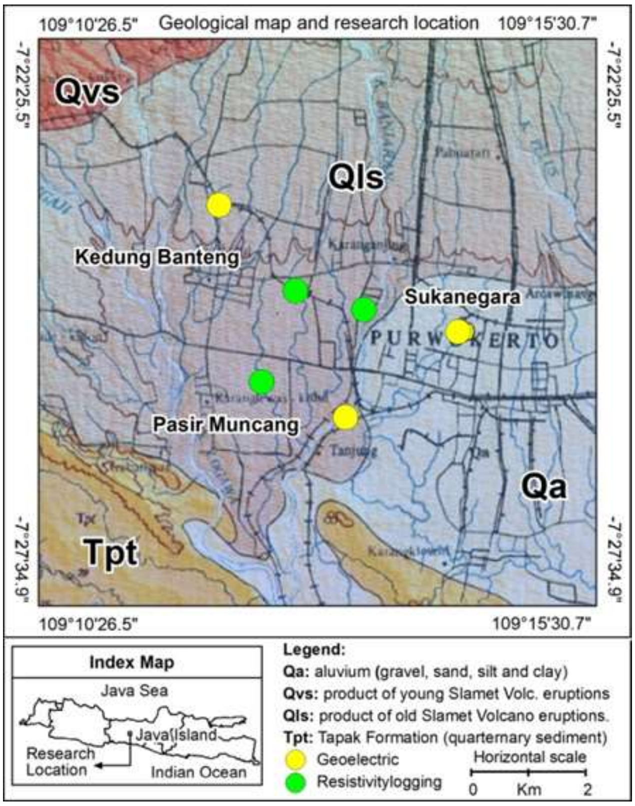

Figure 1. Map of research locations.

Previous Research

Several studies have been carried out in the context of exploring groundwater resources. Anomohanran and Orhiunu use subsurface resistivity surveyity and borehole logging to study groundwater quality for community needs in Nigeria [2]. Subsurface resistivity surveyity is also used to investigate seawater intrusion and groundwater quality in Semarang City of Indonesia [3]. The use of subsurface resistivity survey methods and borehole lithology data has been carried out to identify detailed shallow groundwater aquifer layers [4].

Bundang and colleagues (2020) conducted a study on the correlation of pyroclastic rock thickness using subsurface resistivity survey resistivity data and borehole logs to determine the vertical distribution of lithology in the Pinrang Region of Sulawesi, Indonesia [5]. The interpretation of subsurface resistivity survey data often faces ambiguities. To overcome this obstacle, subsurface resistivity survey data needs to be correlated with resistivity data from logging and borehole cutting [6].

From these recent studies, research on the accuracy and correlation of resistivity values from subsurface resistivity survey measurements and well logging has never been carried out. The research topic regarding this matter has never been carried out in research sites, so this research was carried out.

Basic Theory

The subsurface resistivity survey resistivity method uses an artificial current source that is injected below the surface through two electrodes (C1-C2). The flow of electric current will generate a potential between the other two electrodes (P1-P2) (Figure 2) [7]. The flow of electric current (*I*) and the potential (V) are used to calculate the apparent resistivity of subsurface lithology (ρa) with the following equation [8]:

$$\rho a = k\Delta V/I \quad (1)$$

$$k = \pi((AB/2)^2 - (MN/2)^2)/MN \quad (2)$$

Information:

ρa : apparent resistivity (Ωm)
k : geometric factor (m)
ΔV : potential difference (volt)
π : constant is 3.142
I : electric current (ampere)
AB : distance between current electrodes (m)
MN : distance between potential electrodes (m)

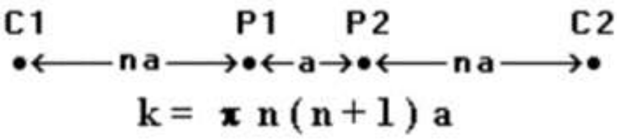

Figure 2. Wenner-Schlumberger dipole-dipole configuration (7).

Correlation statistical analysis can be used to determine the strength of the relationship between variables, for example environmental variables and floods [9]. The value of the coefficient of determination or R^2 is commonly used to check how much variation and the relationship between these variables. A very low R^2 value (less than 0.5) indicates that the two variables are uncorrelated. Meanwhile, the R^2 value between 0.5-0.8 indicates an inadequate correlation [10]. R^2 value greater than 0.8 indicates the variables are correlated.

2. Methods

The research for this publication is located in the Pasir Muncang, Kedung Banteng, and Sukanegara areas of Banyumas Regency area and its surroundings. The location has three different places. Each location has resistivity measurement data from subsurface resistivity survey and logging wells. The three places are: Kedung Banteng, Pasir Muncang, Sukanegara.

The rock resistivity interpretation is derived from the subsurface resistivity survey measurement data carried out by the contractor under the supervision of the Tirta Satriya Banyumas Regional Government Drinking Water Company, Central Java, Indonesia. The subsurface resistivity survey survey was carried out in 2018 [11] [12] [13]. Interpretation of rock resistivity and lithology from logging data was also carried out by the same agency from measurement and drilling cutting for the 2016-2020 period [14] [15] [16].

From two or three points subsurface resistivity survey interpretation is then compared with logging data at each adjacent location. Then select only one that best fits the logging data visually. From the two rock resistivity data, from subsurface resistivity survey and logging measurements then compared and determined at what depth the subsurface resistivity survey resistivities value still correlates with the resistivities of borehole logging. From the correlation data of the two resistivities data, it is then calculated how strong the correlation is.

3. Result and Discussion

Interpretation of the measurement results of subsurface resistivity survey resistivity and well logging drilling juxtaposed in adjacent locations. There are three locations for subsurface resistivity survey resistivity measurement and logging. From two or three subsurface resistivity survey points at each location, one is selected which is the most suitable visually with the resistivity loging graph pattern at each location. The results of plotting the subsurface resistivity survey resistivity graph and logging for the three locations are presented in Figures 2-4.

The results of the correlation analysis of the two resistivity values (from the interpretation of subsurface resistivity survey and logging measurements) show that the average coefficient of determination (R^2) at the depth interval of 0-100 and 0-25 meters is 0.38 and 0.91 (Figures 5-10 and Table 1). From the calculation of the R^2 value, it can be seen that the two graphs of the interpretation of subsurface resistivity survey and logging measurements are compatible and correlate only to a shallow depth, namely 0-25 meters.

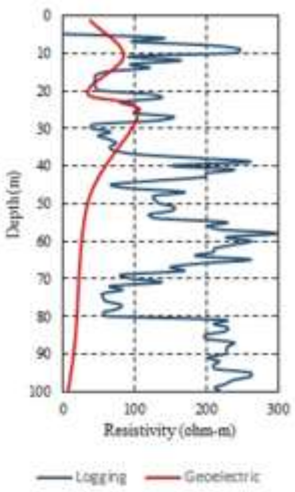

Figure 2. Graph of rock resistivity values interpreted by subsurface resistivity survey and logging measurements, Kedung Banteng location.

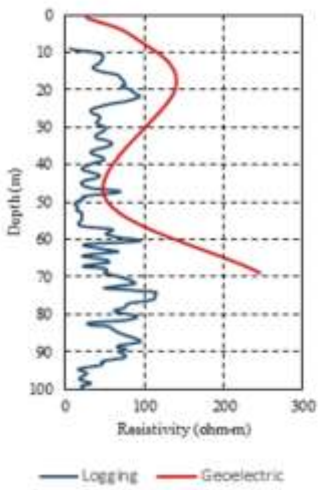

Figure 3. Graph of rock resistivity values interpreted by subsurface resistivity survey and logging measurements, Pasir Muncang location.

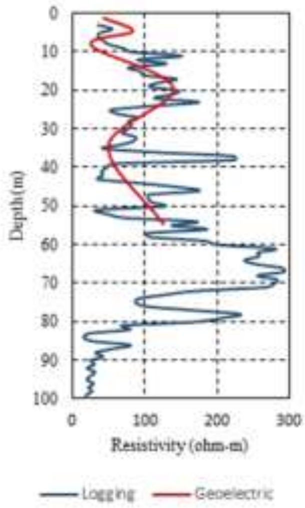

Figure 4. Graph of rock resistivity values interpreted by subsurface resistivity survey and logging measurements, Sukanegara location.

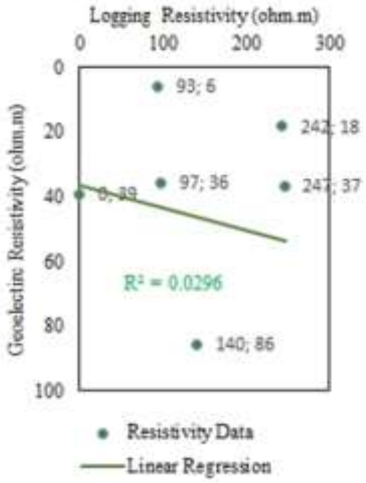

Figure 5. Correlation of resistivity values from subsurface resistivity survey and logging data, Kedung Banteng location (0-100 meter).

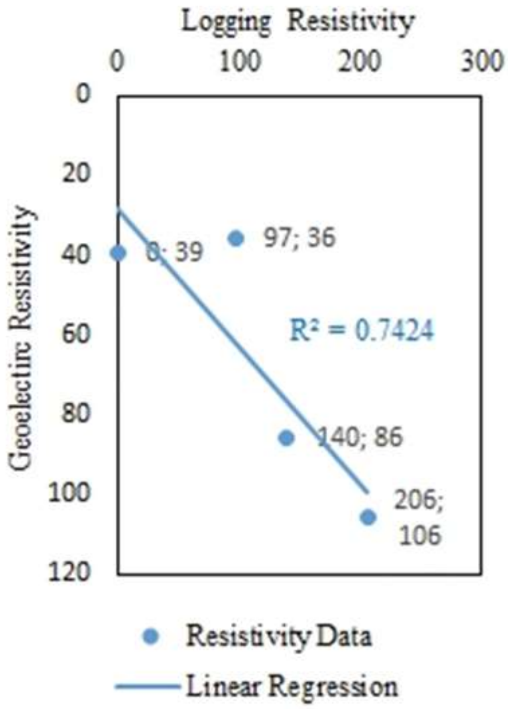

Figure 6. Correlation of resistivity values from subsurface resistivity survey and logging data, Kedung Banteng location (0-25 meter).

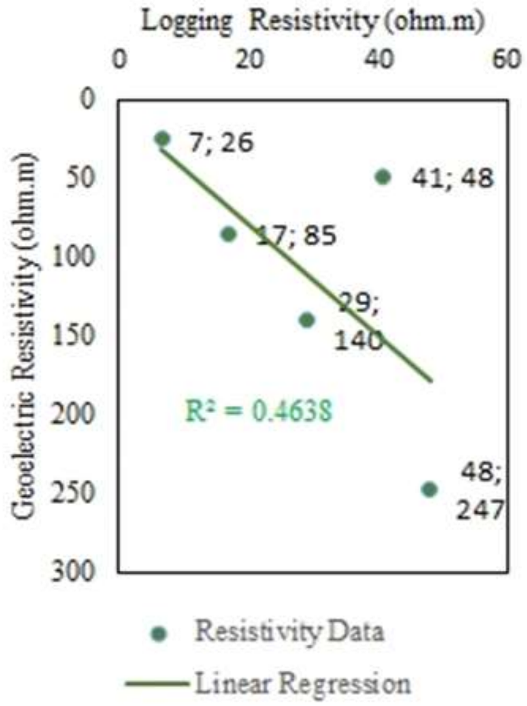

Figure 7. Correlation of resistivity values from subsurface resistivity survey and logging data, Pasir Muncang location (0-100 meter).

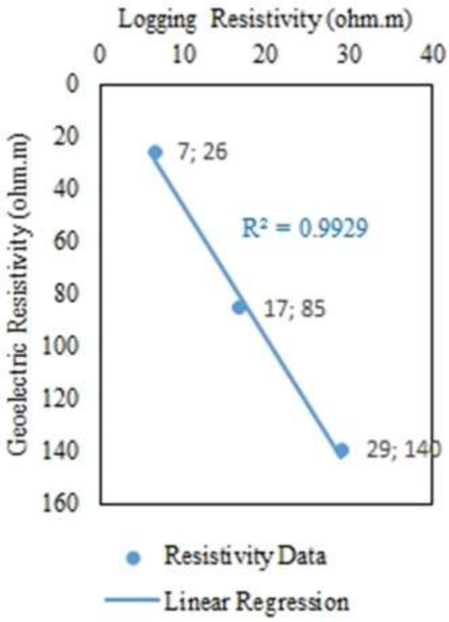

Figure 8. Correlation of resistivity values from subsurface resistivity survey and logging data, Pasir Muncang location (0-25 meter).

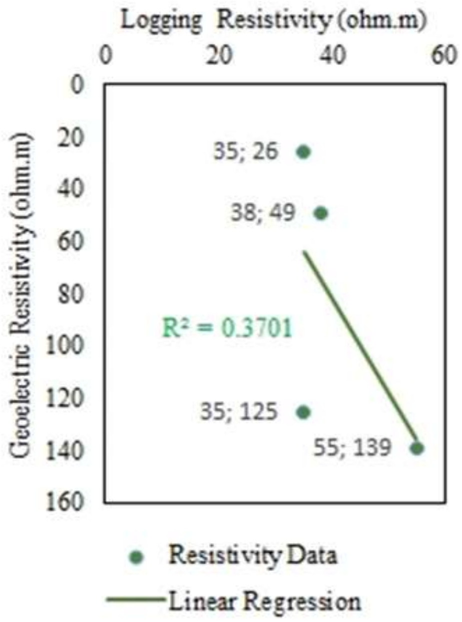

Figure 9. Correlation of resistivity values from subsurface resistivity survey and logging data, Sukanegara location (0-100 meter).

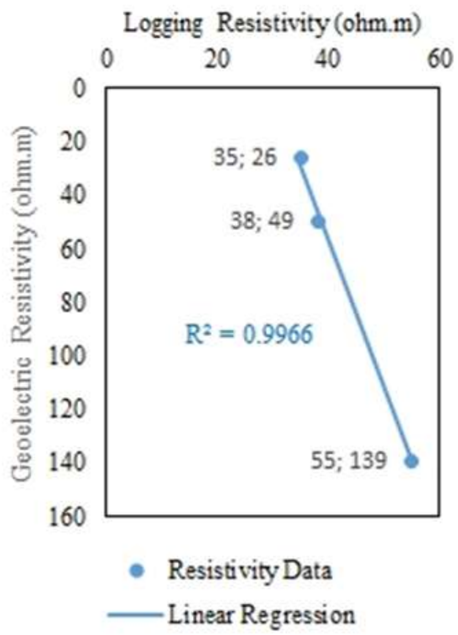

Figure 10. Correlation of resistivity values from subsurface resistivity survey and logging data, Sukanegara location (0-25 meter)

The resistivity value of the subsurface resistivity survey measurement results is increasingly inaccurate at deeper depths. This is related to the strength of the electric current which is getting weaker at deeper depths. Another factor is, the stretch of the subsurface resistivity survey device is used, the longer the stretch, the deeper the electric current reaches the depth of the rock. The limitation of the span of the subsurface resistivity survey measuring instrument is a problem in itself in this case and many other cases.

Table 1. List of determination coefficients (R^2).

No.	Location	R^2 (0-100 m)	R^2 (0-25 m)
1	Kedung Banteng	0.30	0.74
2	Pasir Muncang	0.46	0.99
3	Sukanegara	0.37	1.00
	Average	0.38	0.91

Note: R^2 is the coefficient of determination

4. Conclusion

The results of subsurface resistivity surveys or measurements can be used as a guide and benchmark for groundwater exploration activities in the Pasir Muncang, Kedung Banteng, and Sukanegara areas of Banyumas Regency. Resistivity survey results are accurate to a depth of 25 meters for interpretation of the subsurface conditions of those research sites. The correlation between subsurface resistivity surveys data and logging well data to depths of 100 and 25 meters are 38% and 91%.

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