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Delineating of Groundwater Aquifer Potential Using Vertical Electrical Sounding (VES) Methods in Giriloyo, Wukirsari Village, Imogiri District, Bantul Regency, Special Region of Yogyakarta

Desi Kiswiranti [1,*], Dina Tania[2], Nurul Dzakiya[3], and Prita Hanani[4]

[1]Department of Geological Engineering IST AKPRIND Yogyakarta, Jl. Kalisahak No. 28 Balapan Yogyakarta, Indonesia.
[2,3]Department of Geological Engineering IST AKPRIND Yogyakarta, Jl. Kalisahak No. 28 Balapan Yogyakarta, Indonesia.
[4]Bachelor Degree in Department of Geological Engineering, IST AKPRIND Yogyakarta, Jl. Kalisahak No. 28 Balapan Yogyakarta, Indonesia

*Corresponding Author: kiswiranti@akprind.ac.id

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Abstract

The geophysical investigation in Giriloyo, Wukirsari Village, has defined the groundwater potential zones. The research region underwent a geophysical examination utilizing the electrical resistance method, which comprised the vertical electrical sounding (VES) technique and the Schlumberger array system. The study area is surrounded by common rock types such as lava, tuff, agglomerate, and alluvial. In the study region, five lines were explored. Data for subsurface resistivity were gathered with an Oyo McOhm type 2115. IPI2win, a piece of computer software that analyzes data and automatically interprets apparent resistivity, was used to examine the data. The VES data showed the varied nature of the subsurface geological sequence. The geoelectrical cross-sections along the profile of (VES 2-3-4-1) show an aquifer, which stretches from the southeast towards the northwest part of the basin. Tuff is seen to have formed shallow aquifers due to the top weathered part at VES-2 and 3, while Quartz chlorite calcite (VES-4) and Plagioclases (VES-1) are devoid of shallow aquifers. The higher-elevation lithological areas recharge the low-elevation aquifer zones. At VES 2 and 3, relatively low resistivity values (< about 100 Ωm) have been observed. A field observation at these locations reveals that these lithologies are highly fractured with a weathering profile of up to 10 m. Thus, these are the sites where groundwater potential zones can be marked (figure 4). The high resistivity (about 3162 Ωm regions is observed extending at the VES-4; this may be due to the least weathered Quartz chlorite calcite at high elevation. VES-1 is also located on the plagioclase and shows a slight resistivity zone, which could be considered a groundwater recharge zone. This profile shows the high possibility of groundwater potential due to the zone of lineaments.

Keywords: Giriloyo, VES methods, Groundwater, Aquifer, Topsoil

1. Introduction

Water is a critical need for life, so the search for groundwater sources is continuously carried out to meet life's needs during dry and rainy seasons (Dzakiya *et al.,* 2021). Water is a renewable resource in three forms: liquid, solid, and gaseous. Groundwater is essential for irrigation, industry, and domestic purposes. Groundwater is the primary source of potable water supply for domestic, industrial, and agricultural uses. The scarcity of groundwater increases daily due to rapid population, urbanization, industrial and agricultural-related activities, natural calamities, etc. The impact on soil and groundwater is alarming, with years of devastating effects on humans and the ecosystem (Mohammad & Yuliani, 2017). The study of groundwater geology is beneficial for all the activities of human life. Groundwater is more advantageous than surface water. The water scarcity problem affects the human chain and other living things. To meet the water demand, people depend more on aquifers. There are two end members in the spectrum of types of aquifers: confined and unconfined (with semi-confined aquifers being in between them).

One of these groundwater sources is located in

Giriloyo Village, Imogiri Regency, Bantul Regency, DI Yogyakarta Province, research area. Imogiri district is one of the areas in Bantul Regency that has experienced relatively rapid development in the industrial, agricultural, tourism, and domestic sectors. This causes the need for groundwater to increase, causing degradation of its quality and quantity. Furthermore, the people who live and visit these areas will affect the market and availability of groundwater in this area, so research is needed to examine this so that there is no gap between the availability and the need for groundwater.

The aquifer base in the Yogyakarta-Sleman Groundwater Basin is composed of rock formations that are impermeable, semi-impermeable, or non-aquifer in nature (Figure 1). In the southern part of the Groundwater Basin, the non-aquifer rock formations are composed of the Sentolo Formation, which is composed of claystone and limestone in the western region, and in the eastern part, it is written of the Semilir Formation, and the Nglanggran Formation which consists of Tertiary volcanic rocks in the form of volcanic sandstones and breccias. Volcano is very loud and compact (Hendrayana & Putra, 2004).

Groundwater is water below the ground surface and contained in an aquifer layer. Groundwater has many geological formations known as aquifers (Kodoatie, 2010). An aquifer can be defined as a formation containing a saturated permeable material that generates a sufficient amount of water to form wells and springs. Rocks that are aquifers are capable of storing and transmitting water. Sand and unconsolidated gravel is a characteristic feature of aquifers (Rotz *et al.,* 2017).

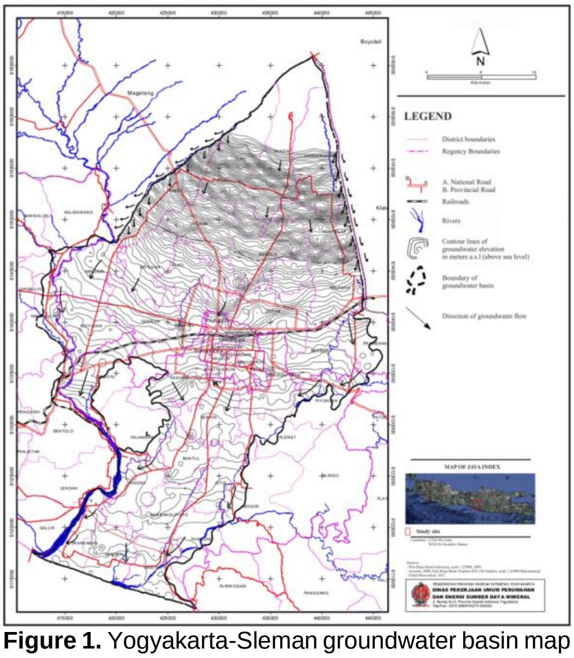

Figure 1. Yogyakarta-Sleman groundwater basin map (Hendrayana and Putra, 2004)

The Giriloyo area is thought to be an ancient volcano that has the potential to be developed into tourism (Figure 3). This ancient volcano experienced a long period of superimposed volcanism, building the Kebo-Butak Formation and Nglanggeran Formation during the Early to late Middle Miocene (Sri Mulyaningsih *et al.,* 2018). Gunung Sewu Geopark, as an advanced protector of natural and geological heritage, governs the crucial development of tourism. Establishing Gunung Sewu Geopark will also bring up Giriloyo tourism, create new jobs, increase economic activities, and enhance community capacity (Sri Mulyaningsih *et al.,* 2019). Geotourism is a natural tourism activity that focuses on the geological appearance of the earth's surface to encourage understanding of the environment and culture, appreciation and conservation, and local wisdom (Maulana, 2019). Wukirsari Village, located on Giriloyo, has geotourism potential. Geological and geoelectric surveys have been carried out to support the tourism potential, mainly to provide clean water.

Based on the exposure of the problem, it is a necessary solution to find the existence of deep groundwater by using geophysical measurements. The geoelectric method is one of the geophysical measurements used to locate the aquifer *(Richard et al.*, *et al.,* 2018). The reason for the wide use of the electrical process is that it is inexpensive, fast, and a non-invasive technique that yields valuable information about subsurface conditions (Clark & Page, 2011). The geoelectric method is the most widely used, and the result is quite good. This geoelectric method is intended to obtain a description of subsoil and the presence of groundwater and minerals at a certain depth (M.H. *et al.,* 1996). This geoelectric method is because different materials will have different types of resistance when electrified. Groundwater has a lower resistance class than mineral rocks (Halik & Widodo, 2008).

2. Methods

Of all surface geophysical methods, the electrical resistivity method has been applied most widely for groundwater investigations. They may be helpful, at some stage in the hydrogeological procedure, to answer questions concerning the local geology. Such questions are specific to the context of the study. However, they can be grouped as a function of aquifer typology and classed into the aquifer geometry and the parameters describing the storage and flow characteristics (Menke, 2018). The prospector may also wish to measure electrical conductivity, where groundwater salinity may be an issue. Examples are the use of electrical resistivity profiling and vertical electrical sounding methods in the delineation of various aquiferous units of Wukirsari village.

The electrical resistivity method can be best employed to estimate the overburden and the thickness of weathered/fractured zones with reasonable accuracy. Though both Wenner and Schlumberger electrode configuration methods are popularly used, the Schlumberger electrode configuration method is more suited to the study area, ensuring better results. The technique has practical, operational, and interpretational advantages over other methods, such as the Wenner method of electrode arrangement (Zohdy *et al.,* 1974).

The principle of the geoelectric method is to inject an electric current through a pair of current electrodes, C_1 and C_2 (Figure 2). Meanwhile, the voltage/potential values are measured by electrodes P_1 and P_2 (Telford *et al.,* 1990). The raw data retrieved from the field are current (I) and voltage (V). These two parameters could calculate resistance (*R*) and Resistivity (ρ). The general VES method is used for shallow exploration (less than 500 m) and is often used for shallow and deep groundwater searches. In addition, it can distinguish differences in subsurface layers according to different types of lithology. A lower resistivity value indicates the existence of aquifers compared to the surrounding environment because aquifers contain water capable of conducting.

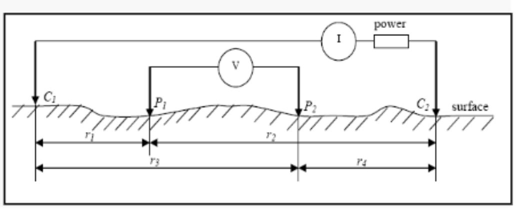

Figure 2. Model of two current electrodes and two potential electrodes (Rotz *et al.,* 2017)

A total of 5 vertical electrical soundings were carried out. Field data acquisition was carried out rapidly since it requires mainly the movement (adjustment) of the current electrodes. Electrodes were laid out with non-conducting measuring tapes. The field procedure expands the current electrodes 'C_1C_2' while keeping the potential 'P_1P_2' relatively fixed. For each reading, the current was sent into the ground through C_1 and C_2, which set up the measured potential difference between the potential electrodes P_1 and P_2; the magnitude of the potential difference developed measures the electrical resistance between probes. The opposition is, in turn, a function of the electrodes' geometrical configuration and the ground's electrical parameters. The electrode separation ($C_1C_2/2$) varies from 1 to 300 m. An Oyo McOhm type 2115 was used to measure and record the resistance of the subsurface. For each electrode combination for which a sounding was made, a reading of resistance R of the volume of earth material within the electrical space of the electrode configuration was obtained. The product of configuration factors *K* and *R* was then made to get the earth material's apparent resistivity. The apparent resistivity measured with this configuration is given as

$$\rho_a = \pi \left[\left({C_1C_2}/{2} \right)^2 - \left({P_1P_2}/{2} \right)^2 / b \right] * {V}/{I} \qquad (1)$$

ρ_a is apparent resistivity, C_1C_2 and P_1P_2 express current and potential electrode spacing, ΔV is the potential difference, and *I* is electric current.

This was subsequently done on all the point data obtained for each VES station to give the set of apparent resistivity values supplied for computer modeling using the IP2WIN program for the iteration to get the geoelectrical parameters. The way apparent resistivity values increase or decrease with each electrode separation forms the basis for the quantitative interpretation of the electrical resistivity data. A qualitative understanding of the sub-surface resistivity distribution can be performed by observing the shape of the curve. In the curve matching method, an arc is drawn by plotting apparent resistivity against electrode spacing, and this is interpreted by matching the field curve with the master curve.

3. Results and Discussion

Interpretations of vertical electrical sounding data using IPI2WIN software to generate geoelectrical layers. The information from these geoelectric layers enhances the identification and interpretation of layer parameters, including the number of layers and their apparent resistivities, thicknesses, depth, curve type, and aquifer systems. Groundwater accumulates in the interconnected pores spaces within the Lithologic units. The shape of the VES curves depends on the thickness of each layer, the number of layers in the subsurface, and the ratio of the resistivity of the layer. The geoelectric characteristics give the respective layer resistivity values and thickness.

The geoelectrical cross-sections along the profile of (VES 2-3-4-1) show an aquifer (black to a blue color), which stretches from southeast towards northwest part of the basin (figure 4). Tuff is seen to have formed shallow aquifers due to the top weathered part at VES-2 and 3, while Quartz chlorite calcite (VES-4) and Plagioclases (VES-1) are devoid of shallow aquifers. The higher-elevation lithological areas recharge the low-elevation aquifer zones. At VES 2 and 3, relatively low resistivity values (< about 100 Ωm) have been observed. A field observation at these locations reveals that these lithologies are highly fractured with a weathering profile of up to 10 m. Thus, these are the sites where groundwater potential zones can be marked (figure 4). The high resistivity (about 3162 Ωm regions is observed extending at the VES-4; this may be due to the least weathered Quartz chlorite calcite at high elevation. VES-1 is also located on the plagioclase and shows a slight resistivity zone, which could be considered a groundwater recharge zone. This profile shows the high possibility of groundwater potential due to the zone of lineaments.

Groundwater potential aquifers-producing zones have been delineated through an investigation conducted by the electrical resistivity survey. Weathered and fractured horizons have been identified in the study area underlying VES stations, and all of these constitute the aquifer zones. Good prospects, therefore, exist for groundwater development in the study area where the depth to the basement is relatively thick and has favorable low resistivity. In contrast, those with thin depth to bedrock and high resistivity value have a lower potential for an aquifer. The electrical resistivity data, therefore, gives reasonably accurate results, among other methods that can be used to understand the subsurface layers and basement configuration in groundwater prospecting.

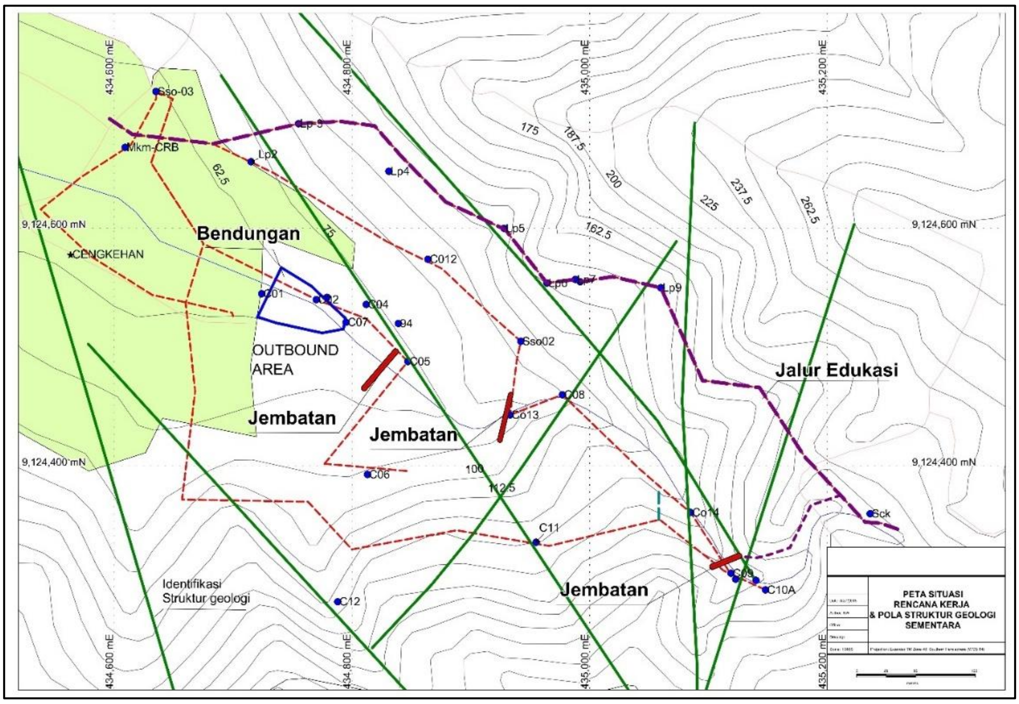

Figure 3. Map of the study area

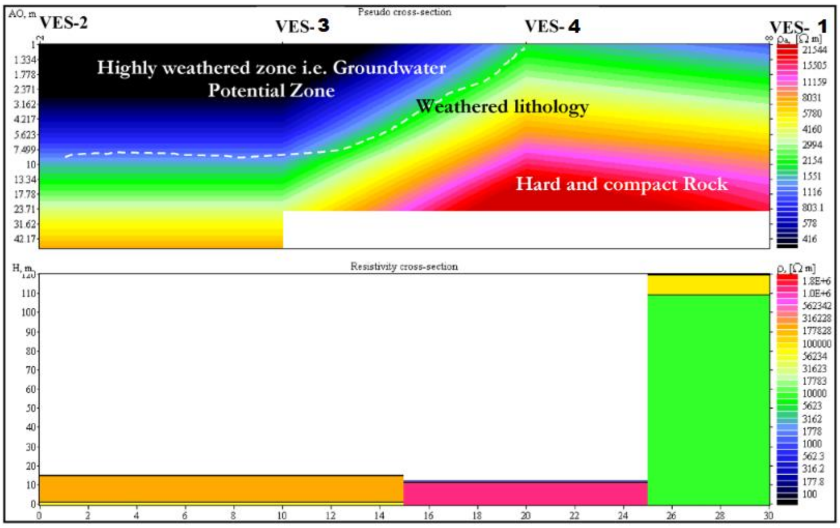

Figure 4. Longitudinal geoelectric sections along VES 2-3-4-1 profiles.

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