Application of vlf method to identify flow patterns of underground river in the karst area Ngargoharjo, Wonogiri

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Application of vlf method to identify flow patterns of underground river in the karst area Ngargoharjo, Wonogiri

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Abstract. Study about potency of underground river is indispensable as an effort to resolve the problem of drought in the karst area of Ngargoharjo Wonogiri. This study aimed to identify the pattern flow of underground river in the Village Ngargoharjo based subsurface structures. The method used is very low frequency (VLF) method with tilt angle mode which measurement has five tracks, each track is 700 meters and consists of 37 measurement points. Based on the results obtained ekivalen current density values in the range of 10% to 35% which are interpreted as a conductive anomaly in the form of an underground river. Underground river in the village of Ngargoharjo have a flow pattern that starts from the spring in the Gedangan flowing to the Southwest toward Pakel Kopek Sinkhole. Underground river over there is a upstream of the river, so the water debit is small.

1. Introduction

Ngargoharjo village is a karst area which is included in Gunungsewu Geopark. Karst is an area that has a unique hydrological system with the constituent rocks that have well-developed secondary porosity [1]. Based on the geological map sheet-Giritontro Surakarta, the research areas are included in Wonosari formation that dominated by coral limestone. The limestone is composed of massive coral limestone in the south and bedded chalky limestone in the north [2]. Joints, cracks, faults and bedding planes are factors that contribute in karstification process [3], into which dissolution occurs. Limestone as constituent rock are easily dissolved by water, thus forming cavities with large diameter. Cavities were formed in the surface causes water will pass in to the underground and accumulated at the base flow (baseflow) that form underground rivers. As a result of karst area will look barren and dry on the surface because potency of water in the karst area more dominant in underground than on the surface [4]. Potency of underground river that has not been optimally used cause drought problem in Ngargoharjo village.

Identification about flow patterns of underground river is indispensable as an effort to resolve the problem of drought in the Ngargoharjo village. VLF method is a geophysical method that used for shallow exploration by utilizing the presence of conductive objects on earth [5]. VLF method commonly used in the exploration of underground rivers by utilizing the conductive properties of water. This method is suitable for producing a clear response and the acquisition process is relatively easy, so it can cover rough terrain and large regional in the karst areas.

Basic theory of VLF method is Maxwell's equations that describe the propagation of electromagnetic waves associated with the electric field and the magnetic field.

$$\nabla \times \boldsymbol{E} = \frac{-\partial \boldsymbol{B}}{\partial t} \quad (1)$$

$$\nabla \times \boldsymbol{H} = \boldsymbol{J} + \frac{\partial \boldsymbol{D}}{\partial t}. \quad (2)$$

If the magnetic field (H) and electrical field (E) are assumed to be an exponential fuction of time, then the vectorial equation:

$$\nabla^2 \boldsymbol{H} = (i\omega\mu\sigma\boldsymbol{H}) - (\omega^2\varepsilon\mu\boldsymbol{H}). \quad (3)$$

The working principle of the VLF method can be described as Figure 1. The electromagnetic waves were emitted by the VLF transmitter have a magnetic field component is referred as the primary field. This magnetic field will induce rocks in the subsurface and then appears the induced current (Eddy current). Eddy currents will generate a secondary magnetic field. Receiver in VLF's tool will capture the primary field and the secondary field on the surface.

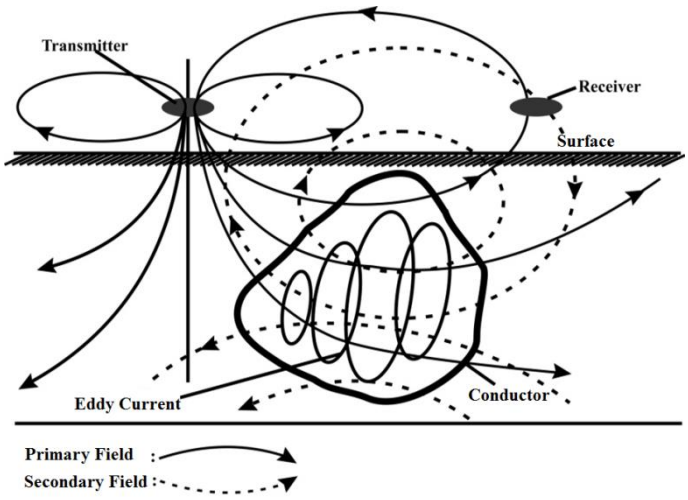

Figure 1. The working principle of the VLF method

2. Methods

This research was done by observation and directly measurement in the Ngargoharjo village on March 2017 and followed by processing and data interpretation. The survey design research as shown in Figure 2.

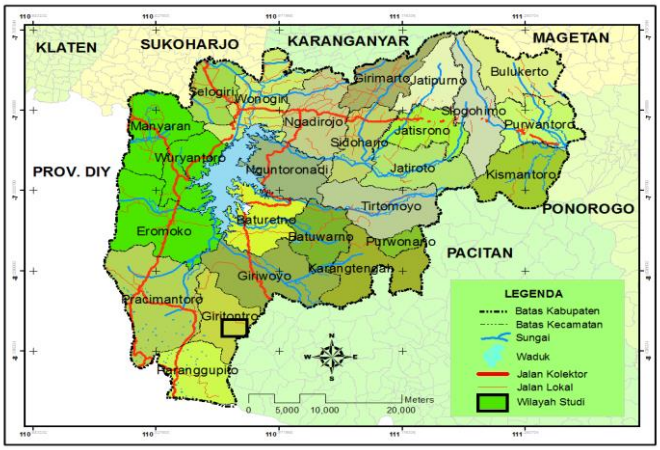

Figure 2. Map of Survey Design

The acquisition process is done with data collection using T-VLF accordance with the parameters (Table 1) in order to obtain tilt values and elliptical. Each track has direction from west to east and first track was start from south and then second track on the north of first track and also for the others tracks. Furthermore, the data processing was done by using a linear filter to obtain the values of relatively current density which represent the conductivity of rocks in the subsurface. The process of interpretation was based on geological map sheet Giritontro-Surakarta and 2D models and pseudo 3D model of relatively current density.

Table 1. Parameters of data acquisition

Parameter	Parameter Values
Track	5
The length of each track	700 m
Spacing measurement point in the track	20 m
The number of measurement points per track	37 points
Spacing between the tracks	60 m
The frequency used	19800 Hz
Data measured	Tilt (%), ellipticity (%), Hhor, Hver

3. Result and Discussion

Figure 3 is a 2D model of relatively current density in the track 1 until track 5. In the picture explains that low conductivity anomalies are imaged by a brown color and high conductivity anomalies are imaged by the blue color. The pattern of low conductivity anomaly is interpreted as an association of limestone cavities which are empty or filled by air and the massive limestone rocks that have little conductivity value (resistive). The presence of air in the cavities of limestone rocks make an increase in resistivity values [6].

High conductivity anomaly patterns are connected each other and flowing from the northeast to the southwest. If correlated with the identification of underground river flow patterns, the pattern can be interpreted as an underground river. The existence of an underground river came from catchment areas in Gedangan village and also from sinkholes on the surface. This underground river flows into the sinkhole pakel kopek. The previous researchers showed that sinkhole pakel kopek was connected with underground caves that have a water flow. This flow is called as an underground river [7].

Water that found in sinkhole pakel kopek have small debit, this is because the underground river in the Ngargoharjo village was assumed as the upper reaches of the tributaries. This study has not covered all underground river flows because the research conducted only focuses on the Ngargoharjo village area. But based on anomaly patterns it can be assumed if the debit of underground river will be greater in the south-west.

On the southeastern part of the spring also has high conductivity anomaly with spread pattern. This anomaly was suspected as a water catchment area from rainwater and accommodated in uvala or negative morphology in karst area. Potency of ground water was influenced by the presence of catchment areas [8] due to the presence of catchment areas is an important factor in the forming process of an underground river. Rain that occurs in karst areas mostly flow towards uvala and form the catchment area. Catchment area become one of the water supplier in system of underground rivers.

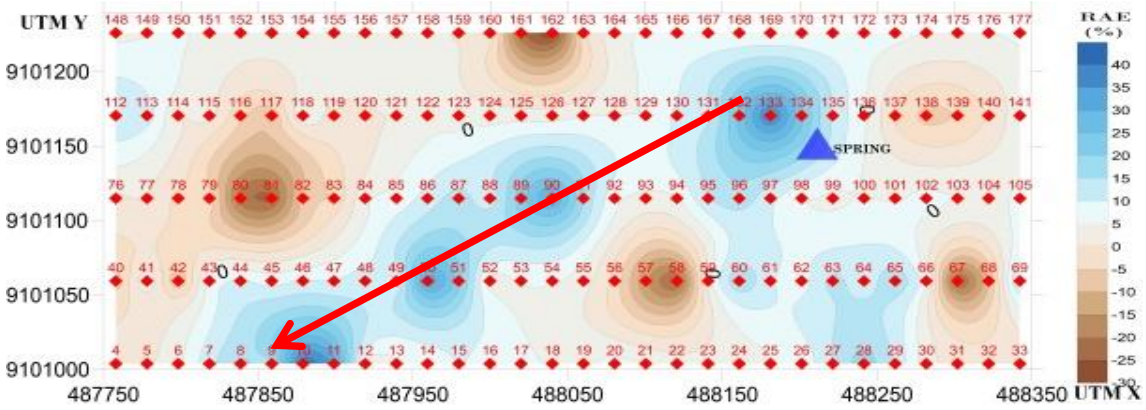

Figure 3. Model 2D of conductivity's anomaly

Pseudo 3D model was conducted to make the underground river flow patterns correlated with the depth, so interpretation will be easier. Based on the results of pseudo 3D modeling shows that there are some high conductivity anomalies were imaged in blue color that has a shape like a cave. These anomalies were assumed as an underground river, because the underground river usually flowing through the underground caves [9]. High conductivity anomaly not describe the shape and condition of the underground river in full, because it still contained anomalous effect of leach-watersheds located around the hall underground river.

Based contour conductivity, the anomaly values increase toward the southwest. It can be seen from the increasingly blue color image to the southwest. Increasing the anomaly values show that the flow patterns of underground river have a stream to the southwest. Underground river depth ranges from 30-50 meters below the surface.

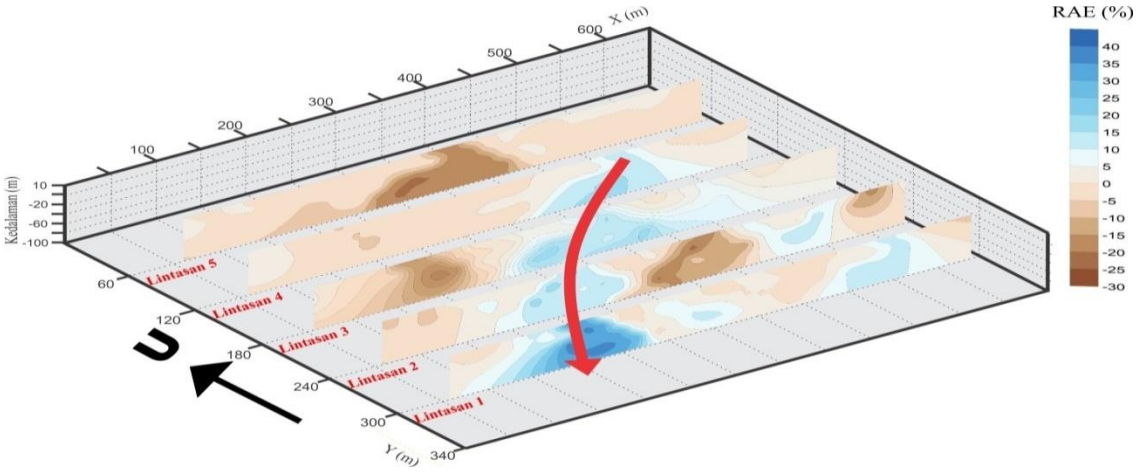

Figure 4. Model pseudo 3D of conductivity's anomaly

4. Conclusion

From the research that has been done can be taken several conclusions that underground layer structure in karst areas Ngargoharjo Giritontro Wonogiri Regency Village consists of limestone, limestone hollow and massive limestone. Underground river that found there have flow patterns that start from locations around the spring in Gedangan village and flowing to Southwestern toward sinkhole Pakel Kopek. Based on the result, underground river in Ngargoharjo Karst region is an area of a particle so that only produces water with a relatively small debit.

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