Scholars Journal of Engineering and Technology (SJET)
Abbreviated Key Title: Sch. J. Eng. Tech.
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A Unit of Scholars Academic and Scientific Society, India
www.saspublishers.com

ISSN 2347-9523 (Print)
ISSN 2321-435X (Online)

Application of Geoscanner Methods for Groundwater Investigation in Grobogan District, Central Java, Indonesia

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Original Research Article

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Article History
Received: 11.04.2018
Accepted: 20.04.2018
Published: 30.05.2018

DOI:
10.36347/sjet.2018.v06i05.002

Abstract: One of the solutions for water shortage in Grobogan District is groundwater utilization. The purpose of this research were to analyze the hydrogeological conditions and rock lithology constituent, and investigation of groundwater potential in this area.. This research was conducted using resistivity method with geoscanner application in six measurement points from July to September 2016. The research used the result of resistivity measurement from geoscanner as primary data while hydrogeological and geological maps were used as secondary data. Interpretation of the apparent resistivity data were performed with Res2dinV software that gave a curve resistivity model. The result showed that rock resistivity in the area ranging between 0.06 - 821 Ωm. Generally, there is composed of the lithology consist of rock, limestone, marl, limestone sandy, clay stone and alluvium deposits. The confined aquifer and unconfined aquifer depressed are at six measurement points in the aquifer and were classified in small to medium productivity. At measurement point A-01, A-04, A-05 and A-06 were found unconfined aquifer layer at 20 - 50 m under soil surface with 20 - 40 m of thickness. The confined aquifer were found at A-01, A-02, A-03, A-04 and A-06 between 40 - 110 m under soil surface with thickness of 25 - 40 m.
Keywords: geoscanner, Grobogan, groundwater, resistivity.

INTRODUCTION

Grobogan district is one of the regions in Central Java province that the main economic activity is in the agricultural sector [1]. The district includes territory of Jratunseluna river basin (Jragung, Tuntang, Serang, Lusi and Juwana).

In the sub-basin there are buildings irrigation construction, that is: Butak Reservoir, Simo, Nglangon, Kedungombo Dams, Dumpil, Sidorejo weirs, Sedadi, Lanang and other irrigation networks. Although the distribution of water is not optimal, but the presence of reservoirs is so important for those areas which are under flow reservoir.

In fact, Grobogan District having water shortage in the dry season [1]. The drought that occurred in Grobogan has a negative impact on agricultural product. The utilization of groundwater will be one of a solution to supply clean water for households, offices, trades, agricultures, and industries. Excessive groundwater pumping will decrease groundwater level and trigger a land subsidence. It is necessary to conduct hydrogeological study to determine the potential of groundwater storage in this area. One of the way is by using resistivity method consist geoscanner method.

Geoscanner method is a geophysical method is to determine the subsurface resistivity distribution by making measurements on the ground surface [2]. From these measurements, the true resistivity of the subsurface can be estimated. The ground resistivity is related to various geological parameters such as the mineral and fluid content, porosity and degree of water saturation in the rock. Electrical resistivity surveys have been used for many decades in hydrogeological, mining and geotechnical investigations.

This method used an instrument was designed with many electrodes (multichannel), full automatic with injection current sampling performed every 2-5 seconds. This tool provides results with high accuracy and resistivity measurements can be carried out simultaneously up to 16 electrodes, and can also be increased into 32, 48, 64, 128 electrodes or more (up to 1000). Thus it will save time and energy as well as more efficient in the measurement of subsurface resistivity.

Geoscanner surveys (vertical sounding) is intended to estimate the thickness of the groundwater-containing layer (aquifer). Aquifer on a layer usually present in sandy or porous layer [3]. Meanwhile, to predict the spread of groundwater in the lateral direction was used correlation technique between the wells. Based on the results of this survey, it will be recommended the proper drill point to penetrate the expected deptht so that groundwater will be obtained in abundace.

This research aims to analyze the hydrogeological conditions, rock lithology constituent and aquifer characteristics at the site of measurement. So, it can be known the presence of aquifers layer in Grobogan District with geoscanner method approach.

METHOD

Locatian and Time

The study was conducted in Grobogan District, Central Java, from July to September 2016. It is between 7°1'58" - 7°12'48"S and 110°35'59"- 110°49'46"E.

Equipments and Materials

The materials were used in this research are primary data and secondary data. The primary data was used is resistivity data. Secondary data was used are administrative, topography, hydrology, geology and hydrogeology maps.

The equipments were used is a geoscanner tools, compass, GPS, calculators and computers equipped with ArcGIS, Surfer and Res2DinV software. Geoscanner measurements performed with geoscanner 48 ch, automatic resistivity (ARES) type G4, 48 unit steel electrode, two units of multi-cable 250 m and 500 m.

Data Collection and Analysis

The selection of measurement point location is based on hydrogeological conditions, sampling method and spatial conditions and is related to regional development plans. Illustration of the resistivity measurements of rock at the study site with geoscanner method is shown in Figure-1 [4]. The resistivity configuration was used is the pole-dipole configuration.

In practically all surveys, the potential difference between two points (normally on the ground surface) is measured. A typical arrangement with 4 electrodes is shown in Figure 2. The potential difference is then given by

$$\Delta V = \frac{\rho I}{2\pi}\left[\frac{1}{C1P1} - \frac{1}{C2P1} - \frac{1}{C1P2} + \frac{1}{C2P2}\right] \ldots . (1)$$

The above equation gives the potential that would be measured over a homogenous half space with a 4 electrodes array.

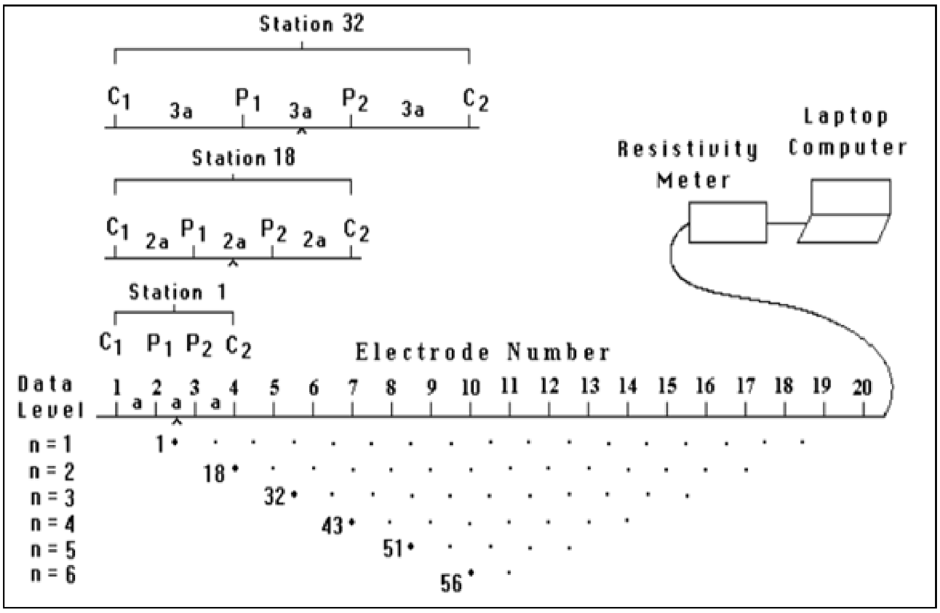

Fig-1: Illustration of measurement using geoscanner

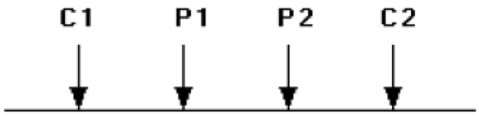

Fig-2: A conventional array with four electrodes to measure the subsurface resistivity

Actual field surveys are invariably conducted over an inhomogenous medium where the subsurface resistivity has a 3-D distribution. The resistivity measurements are still made by injecting current into the ground through the two current electrodes (C1 and C2 in Figure 2), and measuring the resulting voltage difference at two potential electrodes (P1 and P2). From the current (I) and potential (ΔV) values, an apparent resistivity (*Pa*) value is calculated [5].

$$Pa = k\frac{\Delta V}{I} \quad \text{..........................} \ (2)$$

Where, $k = \frac{2\pi}{\frac{1}{C1P1}-\frac{1}{C2P1}-\frac{1}{C1P2}+\frac{1}{C2P2}}$

k is a geometric factor that depends on the arrangement of the four electrodes. Resistivity measuring instruments normally give a resistance value, R = ΔV/I, so in practice the apparent resistivity value is calculated by

$$Pa = kR \quad \text{..............} \ (3)$$

The calculated resistivity value is not the true resistivity of the subsurface, but an apparent value that is the resistivity of a homogeneous ground that will give the same resistance value for the same electrode arrangement. The correlation between the apparent resistivity and the true resistivity is a complex relations Resistivity data are interpreted in the resistivity models curves with Res2DinV software. Geoscanner processing data scheme is presented in Figure 3. The resistivity inversion data is then used to create a model of a 2D cross-section of each track. Model 2D cross section gives an overview of rock lithology constituent subsurface in this area.

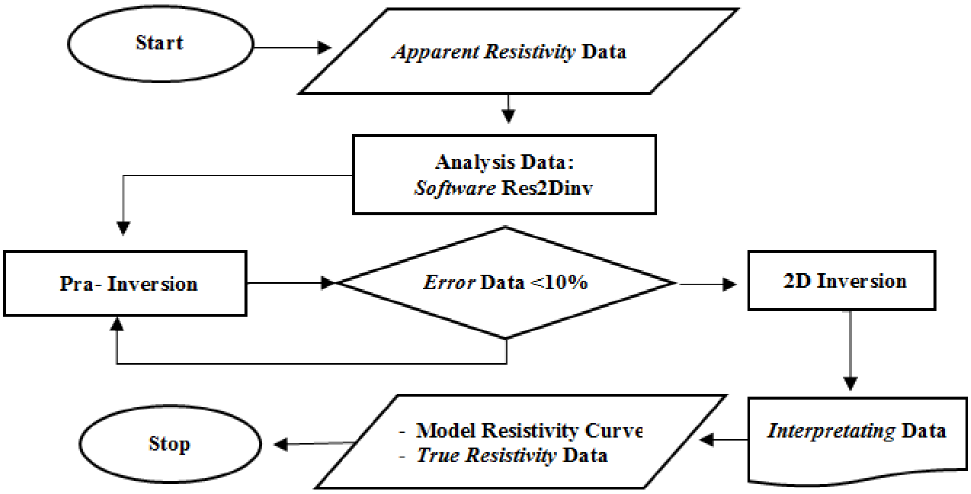

Fig-3: Flow diagram of geoscanner processing

The resistivity of common rocks, soil materials and chemicals is shown in Figure-4 [6]. Igneous and metamorphic rocks typically have high resistivity values. The rock resistivity is highly dependent on the fracture rate, and the percentage of the fractures is filled with groundwater. Thus certain rocks type can have a large range of resistivity, from about 1000 to 10 million Ω·m, depending on whether it is wet or dry. This characteristic is useful in detecting fracture zones and other weathering features, such as in engineering and groundwater surveys.

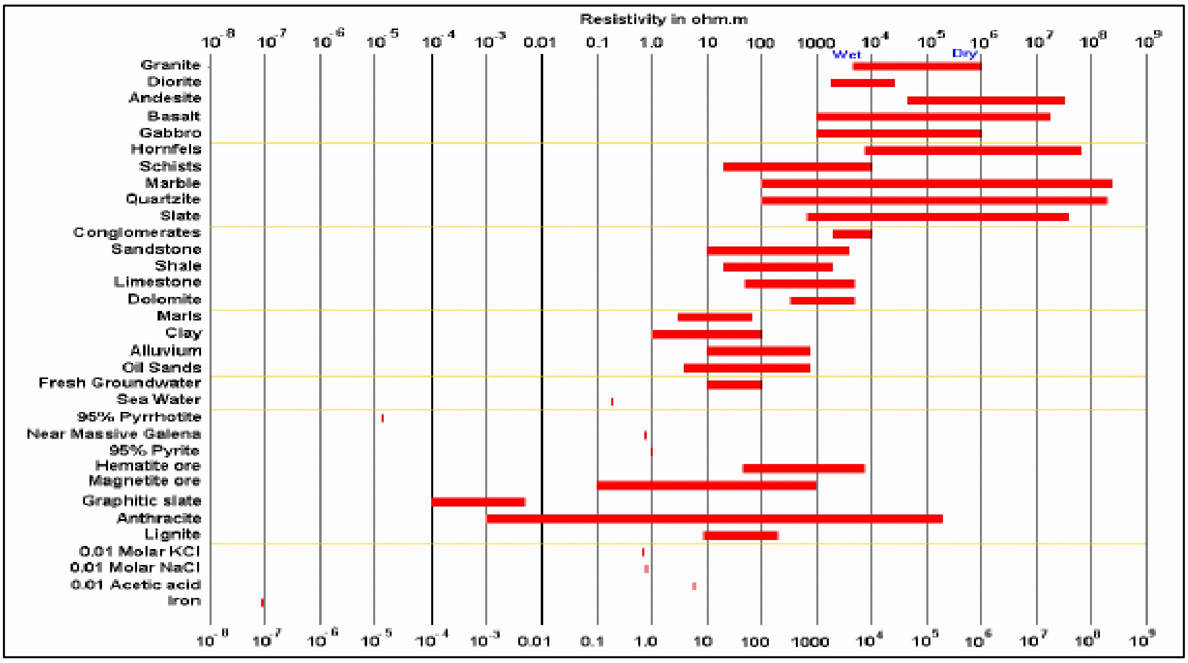

Fig-4: The resistivity of common rocks, soil materials and chemicals

RESULT AND DISCUSSION

Geological conditions

Stratigraphically, the study area is divided into two sedimentation basins, which the Rembang basin and Kendeng basin [7]. Regionally, in this area there are many geological structures, such as anticline, syncline, ride fault and down fault. Geological map of the Grobogan can be found in geological map of the Salatiga quadrangle and Ngawi quadrangle scale 1 : 100,000. It is shown in Figure-5 [8, 9].

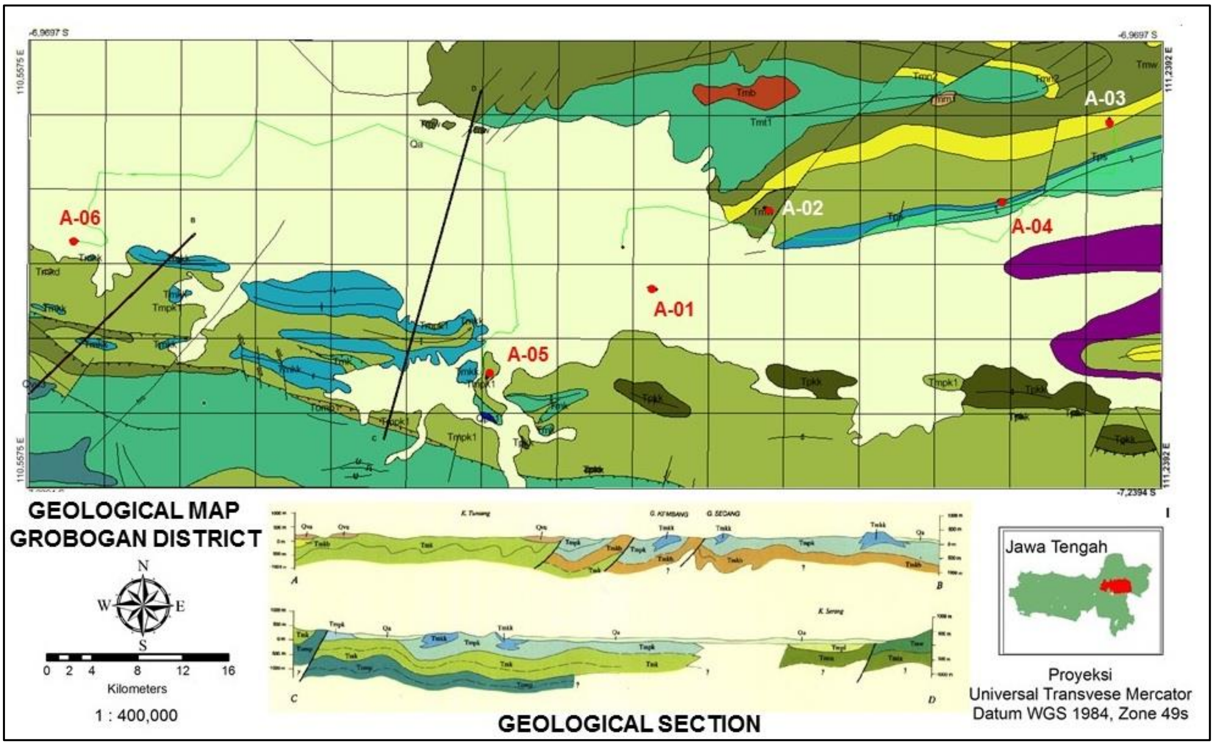

Fig-5: Geological map of the Grobogan

The measurement points located above the formations Qa (A-01 and A-06), Tps (A-04), Tmpl (A-03), Tmpk (A-05), and Tmw (A-02). Qa is an alluvial formation, holocene age, consisted of cobble, pebble, sand and clay. Tps is a selorejo formation, Pliocene age and consisted of limestone. Tmpl is a ledok formation, early miocene age, consisted of glauconitic sandstone, limestone and marl. Tmpk is a Kalibeng formation, miocene age, consisted of massive marl in the upper part, marl intercalating with tuffaceous and marl in the upper part, biocalcarenite in the lower part. Tmw is a Wonocolo formation, miocene age, consisted of marl intercalating with calcareous sandstone in the upper part, platy limestone in the lower part.

Hydrogeology condition

The hydrogeological condition in research area controlled by the distribution of lithology, topography and geological structure in this area. Hydrogeological map of Grobogan is shown in Figure-6 [10]. Figure 6 shown that Grobogan district had 5 aquifers system, there are: poorly productive aquifers of local importance, moderately productive aquifers, locally productive aquifers, extensive productive aquifers and region without exploitable groundwater.

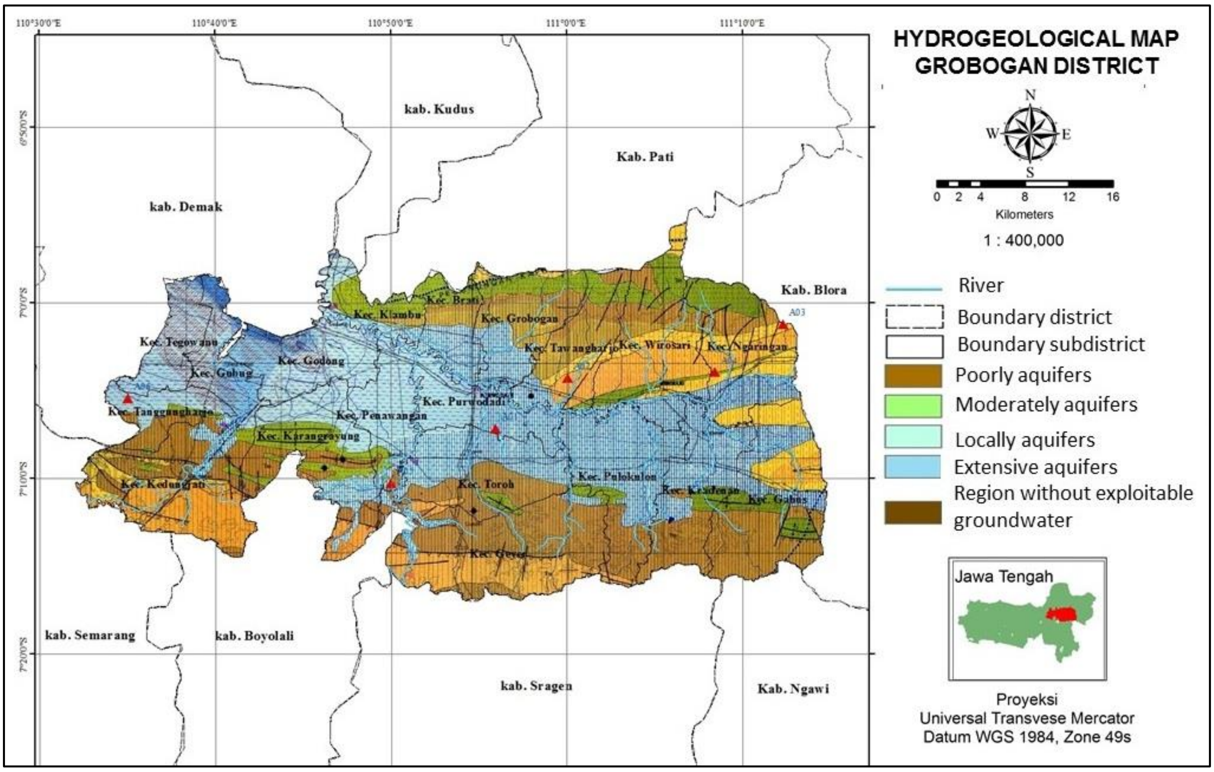

Fig-6: Hydrogeological map of the Grobogan

Groundwater Investigation

This research was conducted by using resistivity method with geoscanner application in six measurement points. The track of A01, A02, A03, A04, A05 an A06 is shown in Figure 7. The results are interpreted of resistivity models curves with Res2DinV software. It suggests that this area composed by rock, limestone, marl, limestone sandy, clay stone and alluvium deposits with resistivity value ranging from 0.06 to 821 Ωm. The resistivity value interpreted in the form of the order type of lithology is used as a reference prediction composer and rock type coating constituent. The division interval resistivity value in the study area are presented in Table-1.

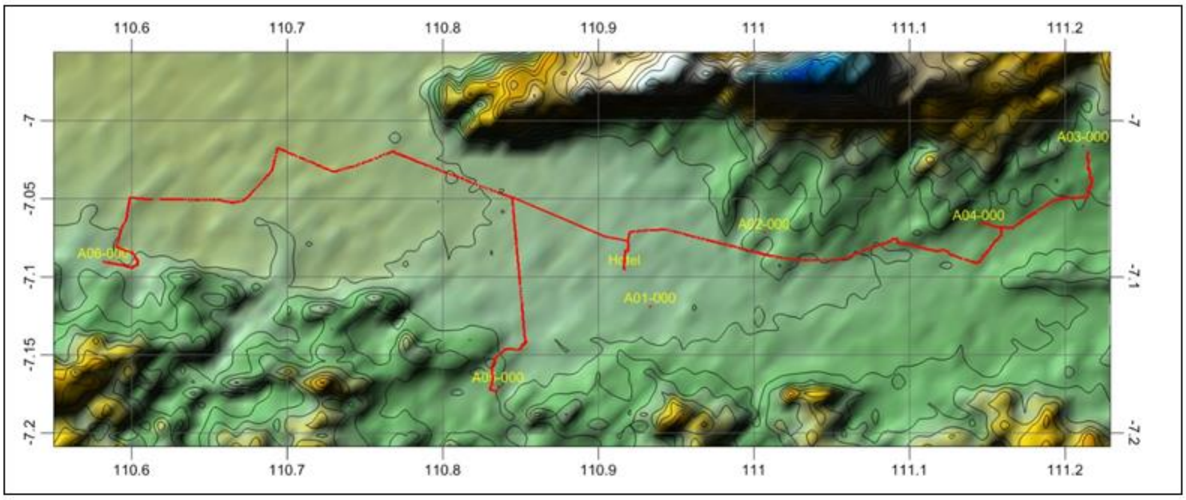

Fig-7: Track of geoscanner measurement points

Table-1: Value of distribution interval resistivity

Resistivity value (Ωm)			Rock type
0.06	-	8.90	Clay
1.55	-	15.20	Sandy claystone

0.32	-	14.00	Marl
6.00	-	9.00	Sandy marl
9.30	-	39.00	Sand
7.60	-	54.00	Calcareous standtone
6.25	-	182.00	limestone sandy
46.80	-	725.00	Limestone

The measurement point A01 in Ngraji village, Purwodadi Subdistrict located at coordinates 7˚7'9"S and 110˚55'57"E. Based on the hydrogeological map, this area is above the alluvium formation (Qa) that included locally productive aquifers which any time will be depleted if used continuously. The results of the interpretation data is shown in Figure 8. The resistivity value between 6.24 - 609 Ωm. The unconfined and confined aquifer layer shown in blue colours. Located of unconfined aquifer at a depth of 40 m from soil surface with thickness of 20 m. Lithology layer consisted of sand, clay and grave. Confined aquifer located at a depth of 40 m from soil surface with thickness of 30 m and lithology layer consisted of clay, sand, gravel, claystone and marl. Rock layer at a depth of 100 m from soil surface has a high resistivity value is more than 50 Ωm. This layer is thought to be impermeable layers (aquiclude). Aquiclude is a water-saturated rock layers that contain water but are not able to release it, such as clay.

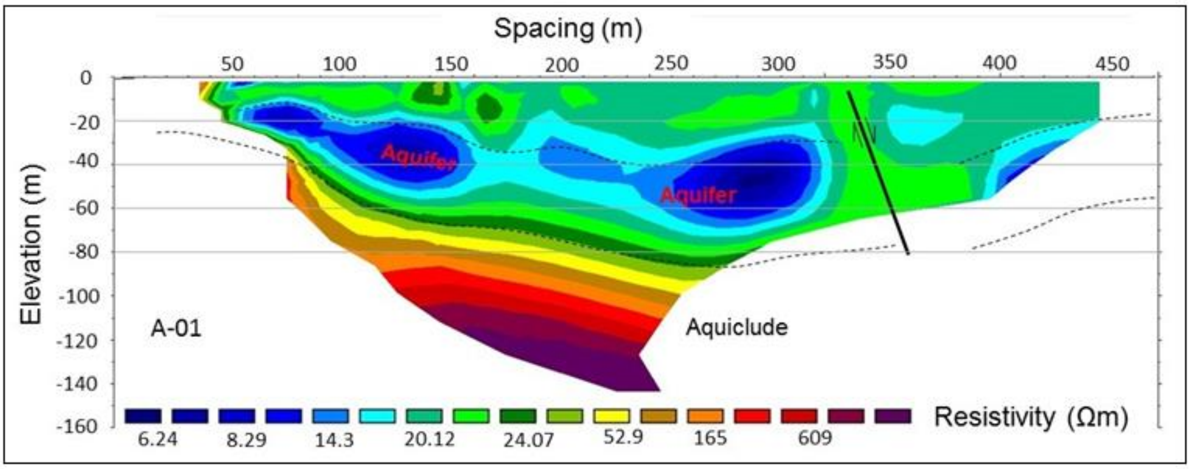

Fig-7: Resistivity model point A01

The measurement point A02 in Pojok village, Tawangharjo Subdistrict is located at coordinates 7˚4'15.95"S and 111˚0'3.72"E. This areas include the Wonocolo formation and moderately productive aquifers. It is locally aquifer but the extent of the aquifer that is big enough then estimated it is considerable potential for exploitation. The results of the interpretation data is shown in Figure 8. The resistivity value between 0.24- 759 Ωm. Unconfined aquifer located at a depth of 50 m from soil surface with thickness of 20 m. Lithology layer consisted of layer of sand, gravel, claystone and marl. While the aquifer layer allegedly dominated by sandy clay. Also visible aquiclude layer and faulted zone or zone of fractures in rocks that have been shifted due to natural disasters such as earthquakes.

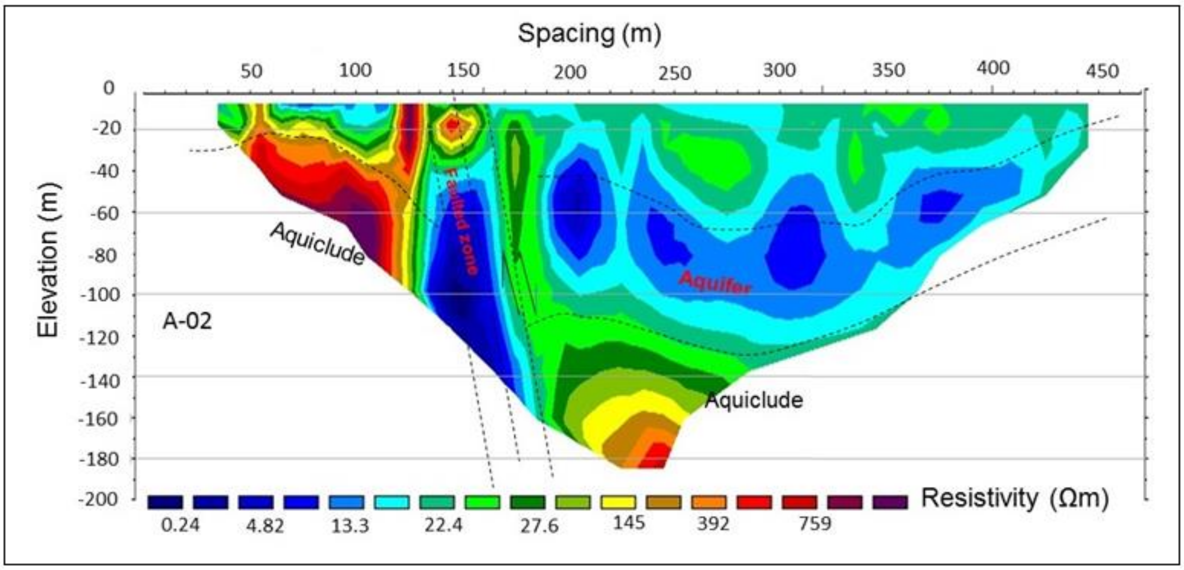

Fig-8: Resistivity model point A02

The measurement point A03 located in Belor village, Ngaringan Subdistrict at coordinates 7˚1'13.01"S and 111˚12'19.4"E. The results is shown in Figure 9. This area is estimated that unconfined and confined aquifer. Potential of groundwater at the measurement belong to a small productive aquifer with indicated by a blue configuration. The unconfined aquifer was found at a depth of 30 m from soil surface with a thickness of 30 m and consisted of calcareous standtone. The confined aquifer was found at a depth of 70 m from soil surface with a thickness of 40 m and consisted of sandy clay. The aquiclude layer was found at a depth of more than 140 from soil surface.

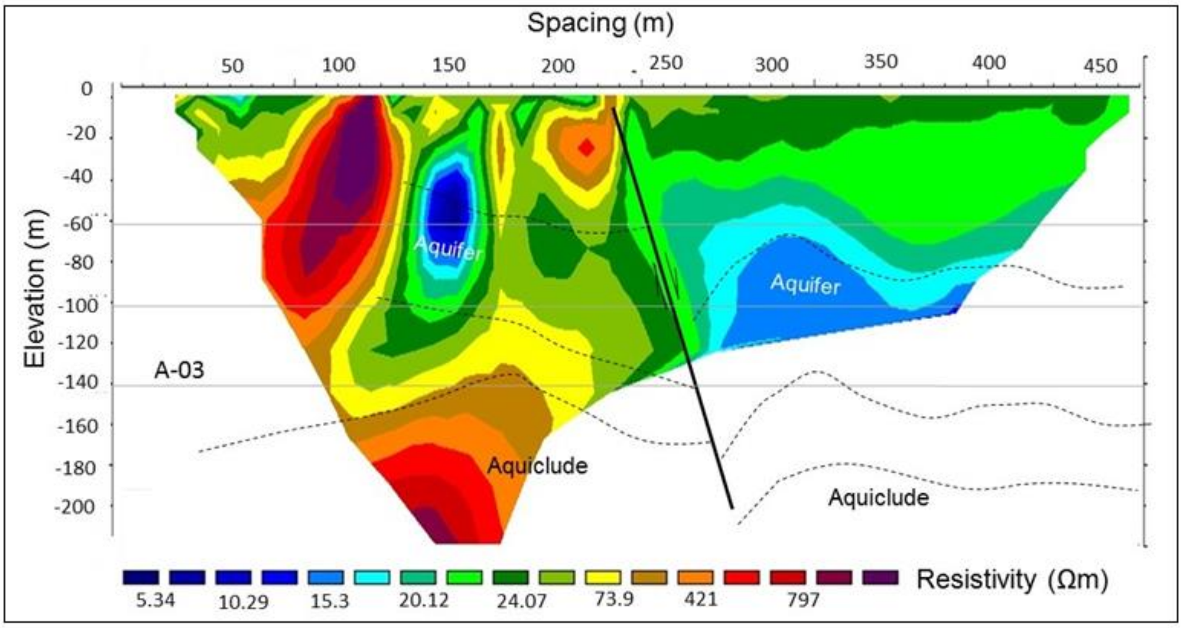

Fig-9: Resistivity model point A03

The measurement point A04 in Pendem village, Ngaringan Subdistrict at coordinates 7˚3'57.39"S and 111˚8'26.14" E. The results of the interpretation data is shown in Figure-10. This area is above on selorejo formation and potential groundwater including small class. Lithology layer consisted of sand, clay and gravel layers. Unconfined aquifer was found at a depth of 20 - 40 m from soil surface with thickness of 20 m.. Confined aquifer located at a depth of 45 m with a thickness of 25 m. Both aquifer layer more dominated sandy clay with a blue color configuration. Aquiclude layer can found at a depth of 100 m from soil surface which dominated by a limestone.

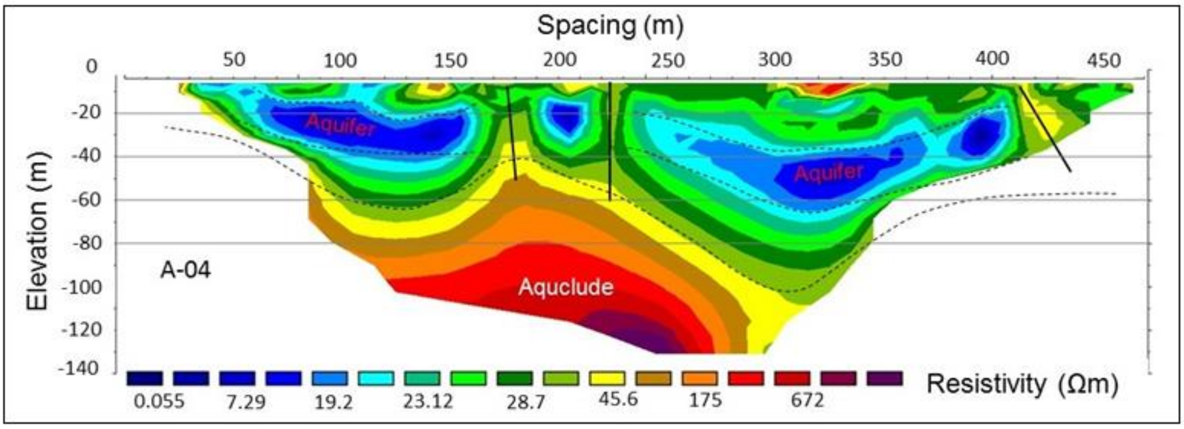

Fig 10: Resistivity model point A04

The point A05 located at Lajer village, Penawangan subdistrict and coordinates 7˚10'15.53"S and 110˚50'0.7"E. The results is shown in Figure 10. In this area there are two layers of the unconfined aquifer that is locally aquifers which blue color configuration. The first of aquifer was found at a depth of 30 m from soil surface with thickness of 40 m and consisted of sandy clay layer. The second aquifer located at a depth of 20 m from soil surface with a thickness of 40 m and dominated by sandy marl layer. Aquiclude layer was found at a depth of 130 m from soil surface with estimated soil layer is calcareous sandstones.

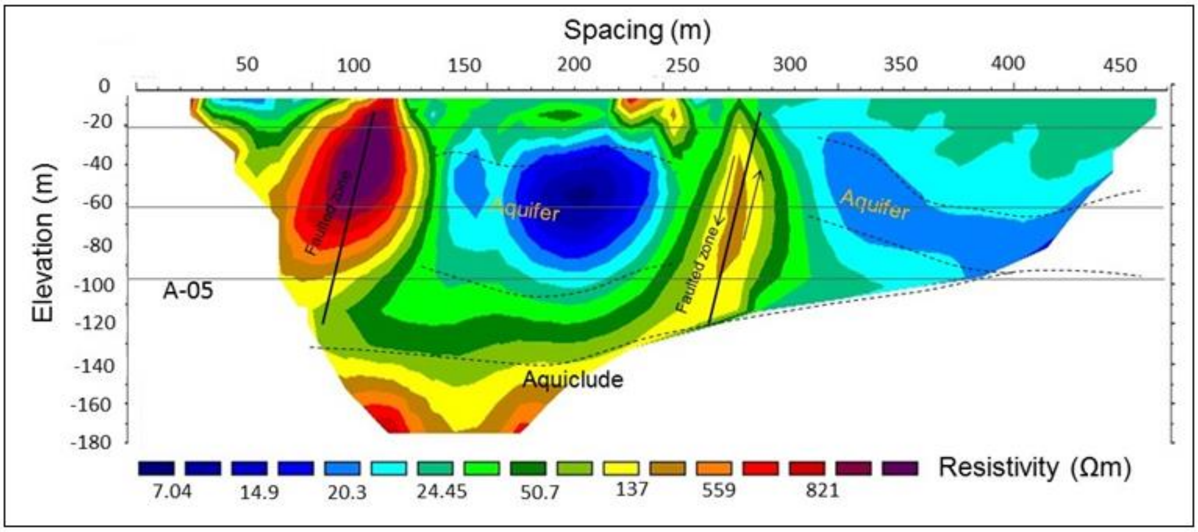

Fig 11: Resistivity model point A05

The point A06 in Brabo village, Tanggungharjo Subdistrict located at coordinates 7˚5'25.73"S and 110˚35'1.7"E. The results is shown in Figure 11. Potential of groundwater in this area including small class and locally aquifer. Unconfined aquifer layer was found at 20 m from soil surface with thickness of 40 m and consisted of sand. Confined aquifer found at a depth 40 m from soil surface wih thickness of 40 m. There are three faulted zones that occur at the measurement point which is likely due to nearby on the earthquake source.

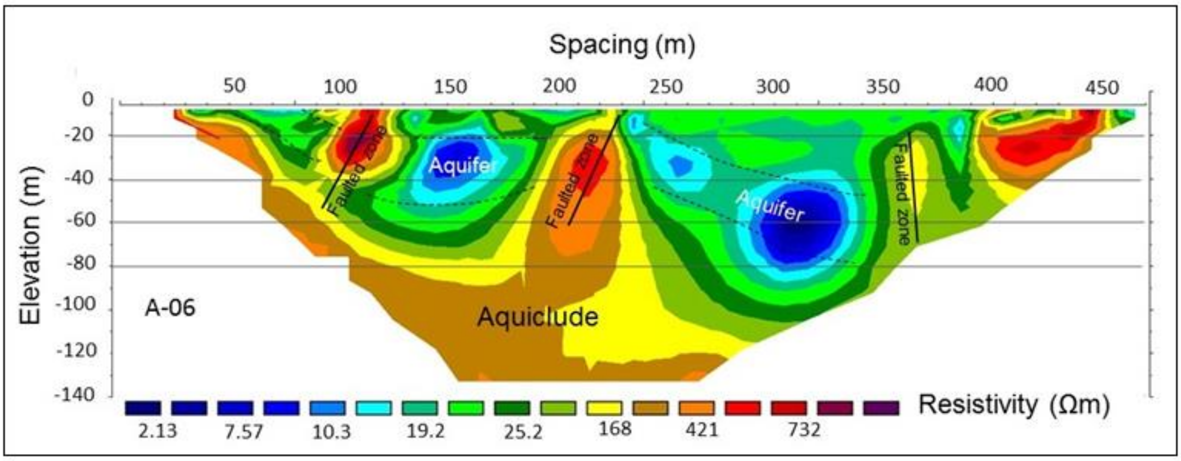

Fig-12: Resistivity model point A06

CONCLUSION

- The geological formation in Grobogan district consisted of Qa, Tmpk, Tmpl, Tps, Tmw and Qp.
- Grobogan district had 5 aquifers system, there are: poorly productive aquifers, moderately productive aquifers, locally productive aquifers, extensive productive aquifers and region without exploitable groundwater.
- The rock resistivity in the area had a value ranging between 0.06 - 821 Ωm and it were composed of rock, limestone, marl, limestone sandy, clay stone and alluvium deposits.
- The confined aquifer and unconfined aquifer depressed are at six points of measurement in the aquifer category of small to medium productivity.
- Unconfined aquifer was found at depth 20 - 50 m from soil surface at point A-01, A-04, A-05 and A-06. The confined aquifer was found at A-01, A-02, A-03, A-04 and A-06 point between 40 - 110 m from soil surface with thickness of 25 - 40 m.

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