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Determination of potential groundwater sources using electrical resistivity imaging (ERI) in Lojing, Gua Musang

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Abstract. The study area is located at the sub-district of Lojing, Gua Musang, Kelantan. The dimension of the study area is approximately 25km2. This study aims to determine the possibility of groundwater existence using Electrical Resistivity Imaging (ERI) method. The lithology of the study area is a metamorphic rock which is schist and the parent rock for schist is a sedimentary rock. Schist has a characteristic that not suitable for groundwater accumulation between grains, therefore the groundwater may exist within the fractured zones. In Kelantan, it used both groundwater and surface water treatment as their main resources for daily uses. However, continuous extraction of groundwater can cause depletion and continuous contamination of the river and reduces the quality of water treatment. Therefore, new sources of groundwater are needed to support the water storage. The study area has a high potential of groundwater located in the subsurface. ERI results show that the subsurface consists of low resistivity material such as sedimentary rocks that can store groundwater in a large volume. Therefore, the study area is highly potential as a zone for groundwater accumulation.

1. Introduction

Groundwater is a broadly used and important source of water to face increasing demand for industry, agricultural and industrial needs. Groundwater is naturally occurring water formed under the subsurface caused by the water from the surface that acts as recharges agent. Approximately 22% of the Earth's total freshwater is groundwater and it comprises about 97% of all liquid freshwater available which is used for human consumption [1]. Groundwater is the continual availability and good natural quality makes it a significant source of water supply for both rural and urban areas of any country [2].

In Kelantan, it used both groundwater and surface water as their water resources. In urban area, it more to groundwater resources is used more compares to rural area which prefer more on surface water resources. The uses of both resources are to sustain the water resources. Kelantan and Perlis highly utilized groundwater as freshwater source, whereas other states such as Terengganu, Pahang, Sarawak, and Sabah used groundwater as a supplement in their water supply system [3]. In order to maintain the quality of water resources, it is important to develop the requisite knowledge and skills to safeguard our catchments and river basins without altering socio-economic growth [3]. They also stated that in water resource investigations, groundwater models are used to simulate the flow of water in aquifers, and when calibrated, may be used to simulate the long-term behaviour of an aquifer under various management schemes.

Groundwater can be found at alluvial plain due to its naturally good capacity of recharging the groundwater. Alluvial plain is a large area of flat land surfaces that forming from the deposition of sediments such as sand, silt and clay. The sediments are coming from the highland that has eroded due to weathering process, then transported by water flowing to the lowland and deposited over time until the sediments increase and forming alluvial soil. The geophysical method can be used to determine the potential groundwater sources such as resistivity method. Therefore, a more accurate model of the subsurface lithologic units would be a 2-D model which provides information about the resistivity variations in the vertical as well as the lateral direction along the survey line [4]. This paper aims to determine the potential groundwater sources in Lojing area, Gua Musang, Kelantan.

2. Methodology

2.1 Geological setting

Kelantan is one of the state in Malaysia that is located in north-east of Peninsular Malaysia. The study area is located in the western part of Gua Musang (Figure 1). Gua Musang is located at the southern part of Kelantan and it is the largest district in Kelantan with total area is 7,979.77 km^2. In the western part of Gua Musang district, there is a sub-district of Lojing area that has been chosen as location for study area. The study area is located near with the Kelantan – Pahang border in the east and also near with the Orang Asli Lojing Berhad Cooperative. The dimension of the study area is approximately 25km^2 km and the area is isolated and located far from town with no housing either in or outside around the study area.

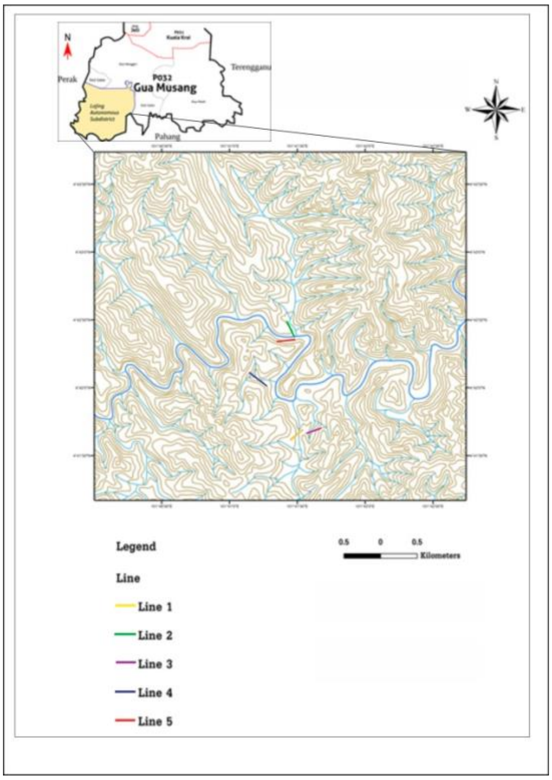

Figure 1. Map of study area indicates the survey line of groundwater potential in Lojing, Gua Musang.

Gua Musang, Kelantan is located in the Central Belt of Peninsular Malaysia that stretches from Kelantan to Johor. In the western part of the Central Belt are Upper Palaeozoic rocks of the Gua Musang and Aring Formation in south Kelantan and Taku Schist in east Kelantan [5] Mapped by [6], the Gua Musang Formation estimated to be 650 m thick, is made up of crystalline limestone, interbedded with thin beds of shale, tuff, chert nodules and subordinate sandstone and volcanic.

[7] stated that the argillaceous sandstone is fine to medium grained with angular quartz in a matrix of limonitic or carbonaceous clay. Volcanic in Gua Musang Formation varies from rhyolitic to andesitic and include tuff, lava flows and agglomerate. Based on [8] lava flows are very subordinate. Flow banded spherulitic rhyolite trachyte, trachyandesite, and andesite lavas are associated with shale and water-deposited tuff and probably were extruded on the seafloor.

To the west of Gua Musang town, in Kuala Betis area, rocks similar to and identified as the Gua Musang Formation overlie a conglomerate-sandstone sequence conformably [9,10]. Limestones in Gua Musang are estimated constitutes about 80% of the total rocks exposed in the Gua Musang – Merapoh area but decreased rapidly towards the north and south [11]. Figure 2 shows the distribution of Gua Musang Formation in Gua Musang.

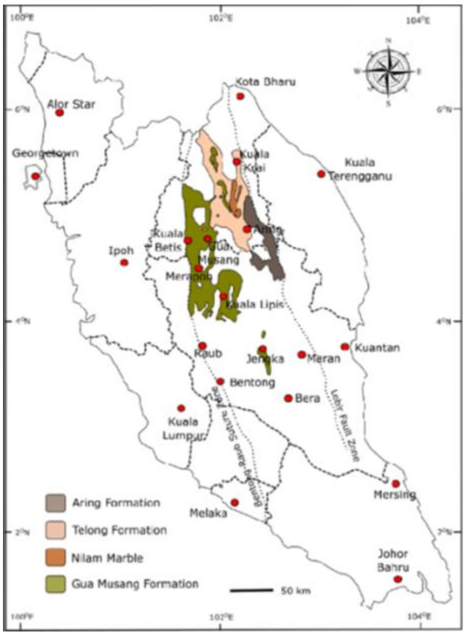

Figure 2. Distribution of Gua Musang Formation in Gua Musang [12].

2.2 Data Interpretation

Electrical Resistivity Imaging (ERI) method was done by using Wenner, Schlumberger and pole-dipole array configuration. These surveys were conducted in five lines with each length of survey line is 200 m with 41 electrodes. These surveys lines were chosen mostly based on the lineament. Survey line that has been processed will be interpreted by comparing the resistivity value from the result with the standard actual resistivity value. Resistivity meter with type of ABEM is placed in the middle of the 200 m straight line, where a 100 m line will be at the left side of ABEM and another 100 m at the right side of ABEM. The spacing between electrodes for 200 m lines is 5 m. Electrical current from ABEM will be injected into the ground via electrode that has been planted into the surface during the set-up. Resistivity reading of subsurface will appear on the screen of ABEM. Wenner array consists of four electrodes which are A, M, N and B. The outer electrodes which are A and B are current electrodes, meanwhile the inner electrodes which are M and N are potential electrodes. With the Wenner array, the resistivity of subsurface layers is found by increasing the distance between the electrodes while maintaining the location of the center point of the array and detection of horizontal changes of resistivity is achieved by moving the four electrodes across the surface while maintaining constant electrode separation [13].

3. Results and Discussion

Evaluation of the existence of groundwater in the hard rock area was done in the study area. In North Kelantan, the abundance of groundwater is controlled the type of landform consist of alluvium. Alluvium has the characteristics of unconsolidated materials and can bear water compare to the study area that has the lithology of hard rock. Groundwater in hard rock area only can be found in the fractured area, where there is an opening in the rock that can accumulate and storage water. The existence of groundwater can be monitored by using geophysical survey of Electrical Resistivity Imaging (ERI) method. ERI method can determine the subsurface material and condition by using the resistivity value as every material has different resistivity values. Figure 3 shows the standard value of resistivity and conductivity for various types of materials.

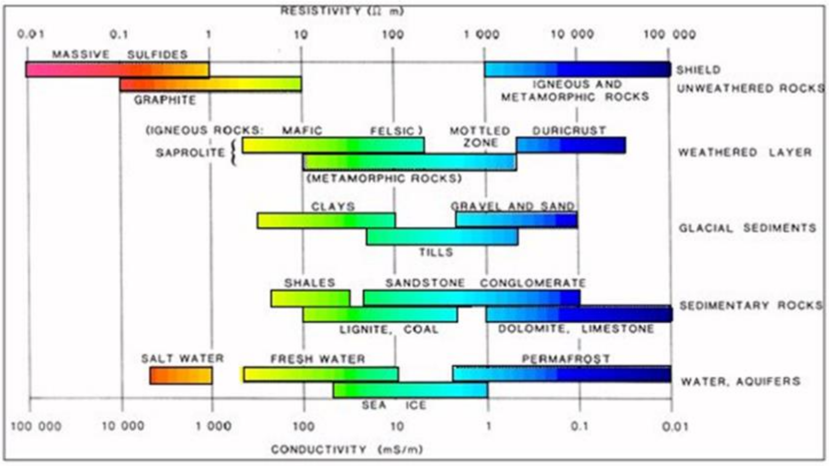

Figure 3. Standard resistivity value and conductivity [14].

3.1 Survey Line 1

The first location of this survey line is located at the lineament with coordinate 04° 41' 38.01" N and 101° 41' 27.78" E. The direction of the survey line is SW-NE and using Pole-Dipole configuration. The total percentage of RMS error is 13.3% for resistivity although many bad datum has been eliminated (Figure 4). Minimum resistivity value in this survey line is 0.5Ωm and the highest is 14,000Ωm with depth more than 30m. Based on Figure 4, the pseudosection 2-D profile is divided into three zones – Zone A, Zone B and Zone C. Zone A has a high potential of groundwater with resistivity value below than 200Ωm. For Zone B the ranges of resistivity value are between 300Ωm until 5,000Ωm which is the standard resistivity value for sedimentary rock such as limestone, sandstone and shale. Zone C is for the material with high resistivity value that ranges between 5,000Ωm until 14,000Ωm. High resistivity value is indicating to the hard materials such as granite, slate and quartzite type of rocks. Groundwater potential for this location is stored in two types which are in fractured rocks and in sediments. Zone A at the bottom of the pseudosection is stored in sediments while Zone A at the top of pseudosection is stored in fractured rocks.

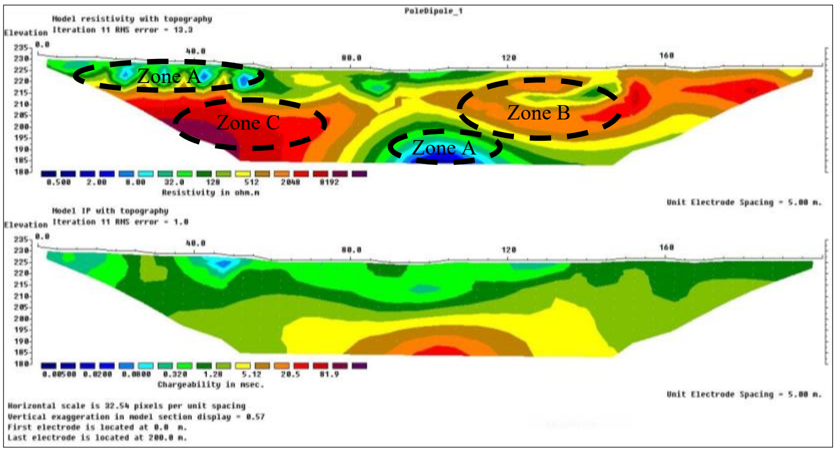

Figure 4. Pseudosection 2-D resistivity profile for Line 1.

3.2 Survey Line 2

The second line of the survey is located at stream which also a lineament. The coordinate of the second location is 04° 42' 26.08"N and 101° 41' 27.56"E and the direction of the second line are N-S and using Wenner array configuration. Figure 5 shows the total percentage of RMS error is 5.7% with the minimum resistivity value 5.0Ωm and the maximum resistivity value is 1,000Ωm. This highest resistivity value is lower than the highest resistivity value for survey line 1. This may due to the location of this survey line that located at the stream and the surrounding of the stream which is wet. Pseudosection of this survey line is only divided into two zones – Zone A and Zone B. The resistivity value for Zone A is ranges from 0.00Ωm until 200Ωm that indicated to the groundwater. For Zone B, the resistivity value ranges between 200Ωm until 1,000Ωm. With maximum depth of penetration that is only 30m, this result shows that there is no hard materials with resistivity value more than 5,000Ωm. Zone B only consists of soft sedimentary rock that has resistivity value below than 1,000Ωm such as clay type.

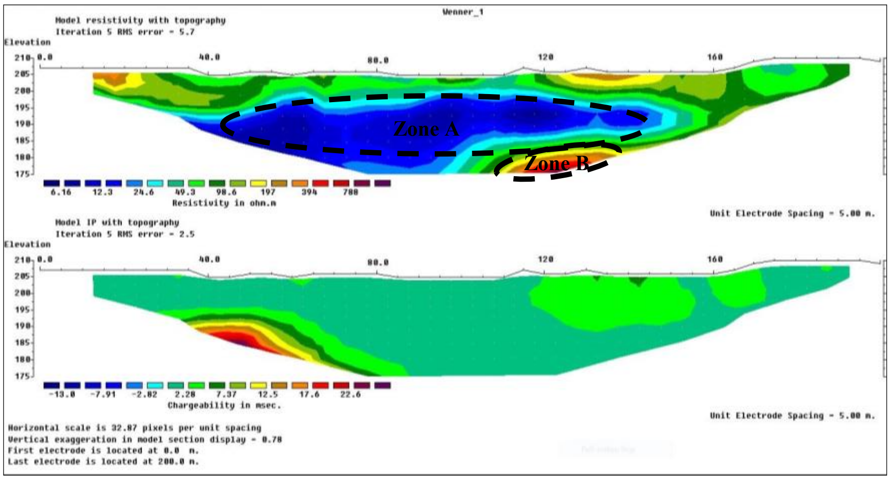

Figure 5. Pseudosection 2-D resistivity profile of Line-2.

3.3 Survey Line 3

The third line is located near the lineament of the first survey line at coordinate 04° 41' 39.29"N and 101° 41' 36.73"E. The type of electrode configuration used is Schlumberger array with line direction W-E. Based on Figure 6 the total percentage of RMS error is 5.7% with a range of resistivity value is between 30Ωm and 5,000Ωm. Division of zone for this pseudosection is the same as the previous which only divide into two zones – Zone A and Zone B. Resistivity value for Zone A is ranges between 30Ωm until 200Ωm and the region of the potential groundwater seems divided into top and bottom of pseudosection. The top region of groundwater potential may store in fractured rocks located at shallow depth because near the surface. Zone B has ranges of resistivity value between 300Ωm until 5,000Ωm. This subsurface has a sedimentary rock with resistivity value low than 5,000Ωm such as limestone and shale.

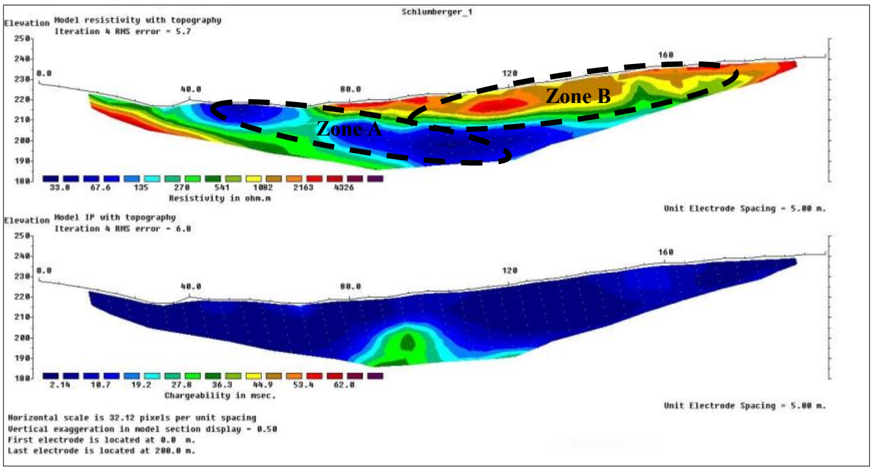

Figure 6. Pseudosection 2-D resistivity profile of Line 3.

3.4 Survey Line 4

The fourth line is placed with crossing a stream and the coordinate is 04° 42'3.94"N and 101° 41'11.28"E. Stream was chosen because the stream will act as recharge materials for groundwater. Therefore, there was a possibility that there is groundwater in the area. The type array configuration used is Wenner and the direction of the line survey is SE–NW. Figure 7 shows the total percentage of RMS error is 5.7% with resistivity value range between 30Ωm until 7,000Ωm. This pseudosection also divided into two zone – Zone A and Zone B. Zone A is a zone for potential groundwater and at this location, Zone A is located at the top of pseudosection, near the surface. This Zone A may categorize as shallow groundwater because near with the surface. This survey line is lined crossing a stream which may become a reason for the shallow groundwater. Surface water of the stream may act as a recharge for the shallow groundwater. The resistivity value for Zone A ranges between 30Ωm until 200Ωm. For Zone B, the resistivity value ranges from 200Ωm to 3,000Ωm which indicate that Zone B consist of sedimentary rocks such sandstone and limestone.

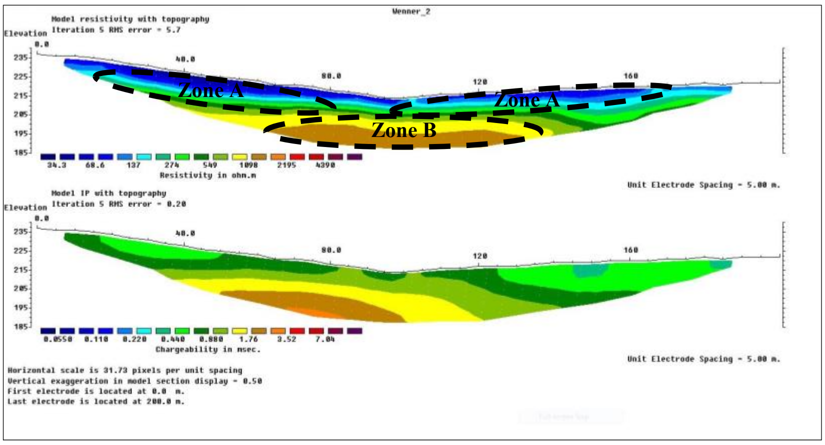

Figure 7. Pseudosection 2-D resistivity profile of Line 4.

3.5 Survey Line 5

The fifth line is located near with the main river, Sg. Berok with coordinate 04° 42' 20.35"N and 101° 41' 25.39"E. This fifth line was also chosen due to the possibility of the main river act as a recharge material if there is groundwater. Type of electrode configuration for this line is Pole-Dipole and the direction of the survey line is W–E.

Figure 8 shows the total percentage of RMS error is 18% which is higher than the limit with a depth of penetration is more than 30m. Minimum resistivity value for this survey line is 3.0Ωm and the maximum resistivity value is 70,000Ωm. The pseudosection of this result is divided into three zones – Zone A, Zone B and Zone C. Zone A has resistivity value ranges between 3.0Ωm until 200Ωm. Potential groundwater of this location is high and may have a lot of groundwater stored at the subsurface. The survey line that lined right beside the main river that can become the reason as the main river act as a recharging agent for the groundwater. Resistivity value for the Zone B is ranges between 200Ωm until 5,000Ωm. For this range of resistivity value, Zone B may consist of sedimentary rocks such sandstone, limestone and shale. Zone C is a zone for hard materials with a high resistivity value and for this survey line the highest resistivity value is 70,000Ωm. With this highest resistivity value, Zone C may consist of granite, basalt and quartzite.

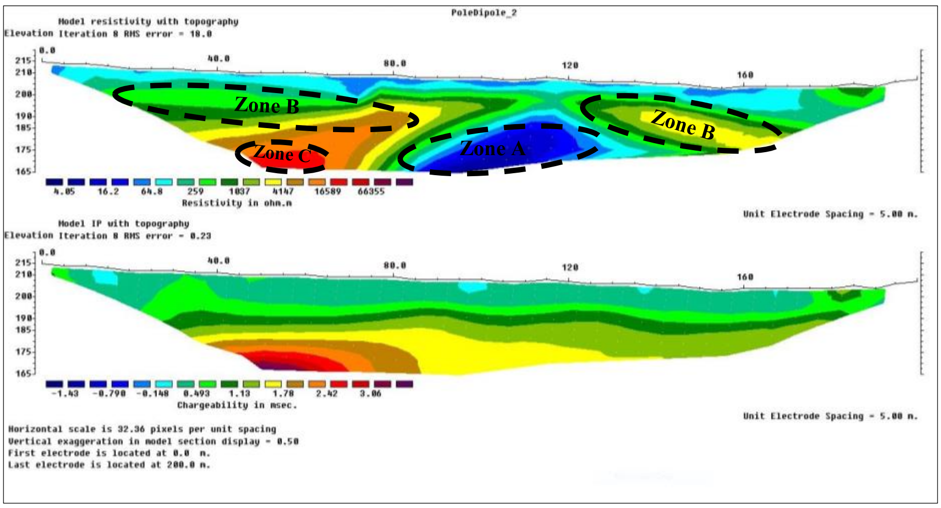

Figure 8. Pseudosection 2-D resistivity profile of Line 5.

4. Conclusion

The study area has a high potential of groundwater but not in a fractured zone based on the results given. Pseudosection 2-D profile for line surveys 2, 3, 4 and 5 shows existing of potential groundwater based on the low resistivity value for every line survey. The result of pseudosection shows that the groundwater zone was accumulated in a large dimensional area. The drilling method should be applying to make these findings more accurate and precise.

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