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To cite this article: N Sulaiman *et al* 2022 *IOP Conf. Ser.: Earth Environ. Sci.* **1102** 012027

IOP Conf. Series: Earth and Environmental Science 1102 (2022) 012027 doi:10.1088/1755-1315/1102/1/012027

Groundwater exploration using Electrical Resistivity Imaging (ERI) at Kemahang, Tanah Merah, Kelantan

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Abstract. The electrical resistivity imaging (ERI) method was conducted at Kemahang, Tanah Merah, Kelantan. This study intends to explore the potential for groundwater resources in the study area. The greatest way for locating groundwater is ERI, a technique that doesn't alter the composition or functionality of the soil. ERI survey is concerned with the resistivity (Ωm) value of subsurface rocks. The Pole-Dipole array was used for this study, and a total of two survey lines were used. Each survey line was 200 m long, with 2.5 m between electrodes. ABEM Terrameter LS Toolbox is used to record all the data, and RES2DINV software is used to process it. All the data are processed in two-dimensional (2D) resistivity profiles will give a better understanding of the geological environment and enable the detection of groundwater. The findings indicate fluctuating resistivity with a range of 1-4000 Ωm and an inquiry depth of roughly 45 m. High resistivity zones of 4000 Ωm indicate values for granitic rock, whereas low resistivity zones of 10-800 Ωm reveal values for the area's fractured aquifer, which is viewed as a potential water carrying zone (bedrock). Bedrock is found to be around 50 m below the indicated fractured aquifer layer, which is located at a depth of about 25 m. By measuring the depth of the fractured zone for probable zones with low resistivity values, this study provides an idea of the potential groundwater resources.

1. Introduction

The world's groundwater supply continues to decline with the greatest reductions occurring in Asia, South America, and North America although groundwater is a renewable resource. Water rights refer to the framework for allocating water resources to water users where such a framework exists [1]. The water that is in the unsaturated soil layer (soil water) will support vegetative life in surface meanwhile the water in the saturated soil layer (groundwater) becomes water deposits in the soil layer which can come out through the spring (artesian), or live in the subsoil as fossil water [2]. Layers that are easy for water to pass through soil is called as a permeable layer, such as a layer of sand or gravel. Whereas layers that are difficult for groundwater to pass through, this is called as an impermeable layer, such as clay or solid rock. The layers of rock that can capture, storing and releasing water is called as an aquifer [2]. Surface water is critically important in supplying water to streams and wetlands, and in providing water for irrigation, manufacturing, electricity power and other uses. As a result of fast population expansion and worldwide environmental change, groundwater resources are likely to become increasingly important in the near future [3]. Groundwater defined as water located beneath the ground surface in soil pore spaces and in the fractures of lithologic water formations [4]. It can be an alternative source of water.

Malaysia is estimated to have about 5,000 billion cubic meters of groundwater with the capability to process about 64 billion cubic meters a year. The large savings should be used by the government in an effort to address the problem of clean water supply, especially during the dry season or river pollution.

Groundwater has less treatment waste than polluted surface water, thus making the cost of treating it much cheaper. It is sustainable as it is less affected by climate change and its management is environmentally friendly. A geophysical approach that can be used to identify likely groundwater sources is the resistivity method. Therefore, a 2-D model of the subsurface lithologic units would be more accurate if it included information regarding resistivity variations along the survey line in both the vertical and lateral directions [5]. The highly potential of groundwater zone is interpreted based on the low resistivity value [6]. The successful implementation of electrical resistivity imaging method aided in identifying the sources of failure in the subsurface, thereby preventing damage to the surrounding structure and materials investigated [7]. This paper aims to explore the groundwater potential resources at Kemahang, Tanah Merah area by using Electrical Resistivity Imaging (ERI).

2. Geological setting

The study area is located in Tanah Merah, Central Kelantan which is an urban area and close to East-West Highway (Figure 1). Geologists from Malaysia and Thailand have been concentrating on Tanah Merah since they completed a geological investigation of the two nations' border in 2006. Comparable to the Khlong Min Formation in Thailand, where dinosaur remains have been discovered, is the Panau Bed at Bukit Panau. Observed plant fossils indicate that the Panau Bed, which is Cretaceous in age, was deposited in a land environment [8]. Kelantan region is underlain by Quarternary alluvium, which is composed of sand, gravel, silt, and clay. The alluvium is fluvial and marine in nature, and it is underlain by igneous and metamorphic rocks. The thickness of the alluvium varies from a few meters in the foothills more than 150 m near the coast. The formation of Quarternary alluvium consists of thick sands and clays in Kelantan was aided by major rivers. In the eastern part of Kelantan, a thick sequence was deposited, resulting in the formation of good aquifers in the sand layers.

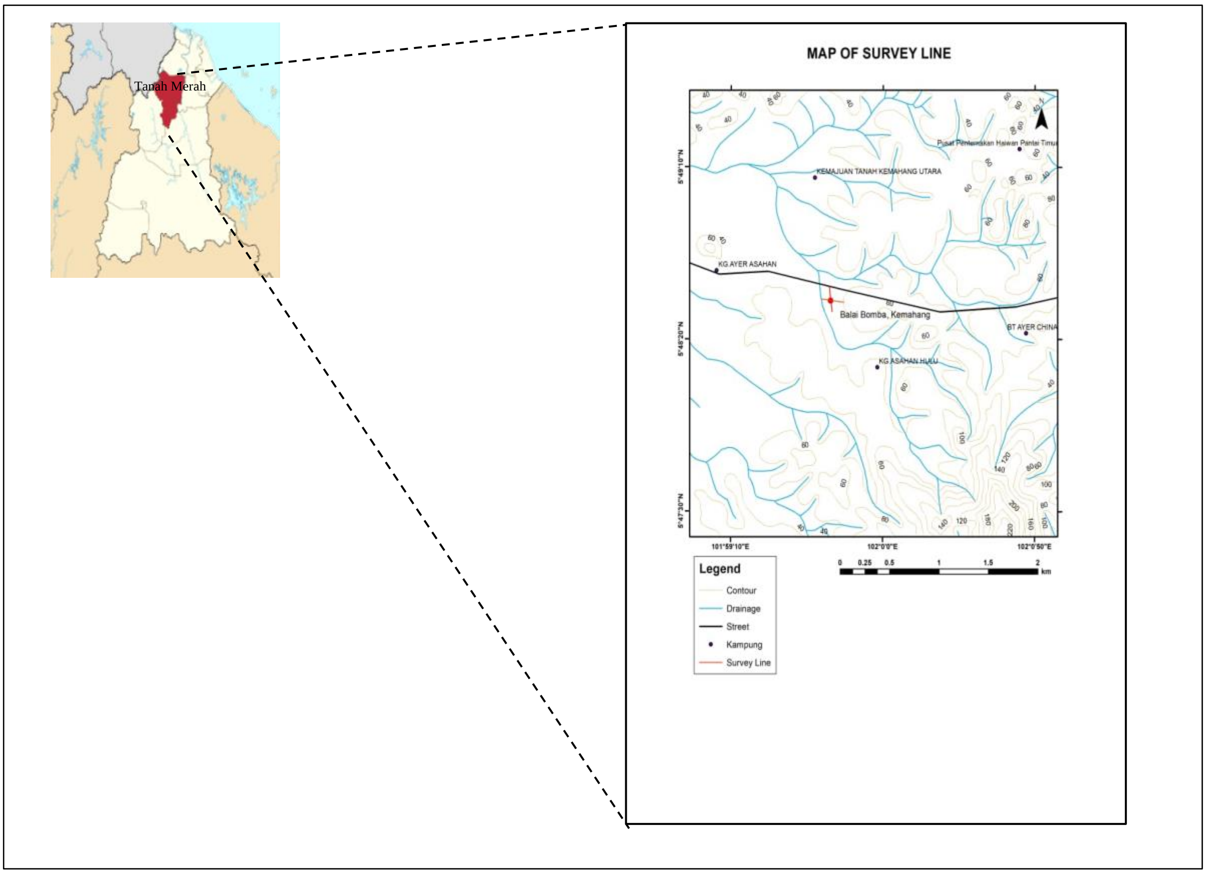

Figure 1. Basemap of study area indicates the two survey lines of groundwater potential at Kemahang, Tanah Merah

This study area consists of three formations which are Telong Formation, interbedded formation and Kemahang Granite formation. Telong Formation is the oldest formation in the stratigraphy unit which ages from Permian. From the previous study by [9], the origin of Telong Formation name is from Sungai Telong, South Kelantan. Its lower boundary overlies Gua Musang Formation and the top boundary overlain by Koh Formation. Telong Formation includes sequence of predominantly argillite associated with some tuff which is turbidites. Sungai Telong located at the upper reaches of Sungai Aring in south Kelantan. Is also has shallow marine environment with occasional pyroclastic.

Interbedded formation at Kuala Long was from Mesozoic era and Cretaceous-Jurassic period. Its stratigraphy unit is metamorphed sandstone (metasandstone) which is located at the northern part of the study area. It is mainly interbedded metasandstone, siltstone and shale.

The Kemahang Granite is a batholitic granitic mass in north-west Kelantan near the Thai border. The body is surrounded by Taku Schists on all sides except the west, which is surrounded by Permo-Triassic sediments and metamorphic rocks such as slates, phyllites, marbles, and metavolcanics. Kemahang Granite is in Tertiary age. The main feature is alkaline feldspar microcline phenocrysts. Kemahang granite is located at the southern part of the study area.

Groundwater is only available in a few areas, including Pasir Puteh (alluvium), Kuala Krai/Gua Musang (fractured volcanic bedrock), and Jeli (fractured igneous bedrock). These have yet to be developed and used. Kelantan is currently at the forefront of groundwater abstraction for potable water supply usage. This vital source of water should be explored further, particularly to meet the demands of the districts of Kota Bharu, Bachok, Tumpat, and Pasir Mas.

3. Methodology

The presence of groundwater can be detected and monitored by using geophysical survey of Electrical Resistivity Imaging (ERI) method. Since each material has a unique resistivity value, the ERI method can use it to ascertain the subsurface material and condition. In the studied region, two electrical resistivity survey lines totaling 200 metres in length and 41 electrodes have been run. A 100 m line will be at the left side of ABEM and another 100 m line will be at the right side of ABEM. ABEM Terrameter LS 1 is situated in the middle of the 200 m straight line. For 200 m lines, the distance between electrodes is 5 m. An electrode will be inserted into the ground and used to inject electrical current from ABEM. An electrode that was buried in the surface during the setup will be used to inject electrical current from ABEM into the earth. A subsurface resistivity reading will be displayed on the ABEM's screen.

Electrical Resistivity Imaging (ERI) method was done by using pole-dipole array configuration and consists of three electrodes which are C_1, P_1 and P_2. C_1 is act as current electrodes, meanwhile P_1 and P_2 are potential electrodes. With the pole-dipole array, this array is especially useful for measuring lateral resistivity changes and has been increasingly used in geotechnical applications. In the Pole-dipole array, the potential measurement electrodes are relatively close together, the equipotential lines at each electrode contact on the surface may be considered as the edges of curved equipotential surfaces extending below the surface [10]. The processed data was then interpreted by refereeing to resistivity values based on Table 1.

The chargeability of earth materials is primarily an electrochemical effect caused by a variety of factors, not all of which are fully understood [11]. When ground is charged, it behaves as if resistivity were a complex quantity. In other words, when ground responds to an oscillating input current, a phase shift occurs. As a result, chargeability can be measured in a variety of ways, including time domain and frequency domain techniques. Aspects influencing a sample's chargeability including the particle grain size in the sample, the minerals that are present, the nature and mobility of ions in pore fluids, the particulars of microscopic interactions between solid surfaces and fluids and the amount of surface area contained within a given volume.

4. Results and Discussion

The results of data processing and ERI data inversion are in the form of 2-D resistivity cross-sections (pseudosection). The pseudosection show the distribution of resistivity of the rock at various depths. The resistivity value of the rock is represented by a color gradation in the cross-section. Resistivity table rock (Table 1) is used to find out the type of rock represented by the resistivity value. The lower section surface is interpreted based on the resistivity value and also matched with conditions in the field. The

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2-dimensional resistivity imaging at Kemahang, Tanah Merah is classified into two zones; low resistivity value zone (<100 Ωm) and high resistivity value zone (>100 Ωm). The low resistivity zone is interpreted as water saturated zone (presence of groundwater) while high resistivity zone is interpreted as unsaturated zone or bedrock (granitic rock). As a result, the groundwater bearing zone can be accurately predicted and detected by combining resistivity and chargeability values.

Table 1. The resistivity and chargeability value at Kemahang area and its interpretation [12].

Resistivity value (Ωm)	Resistivity Legend	Interpretation
1-100	10.0 30.0 50.0 70.0 100	Fractured rock saturated with water
> 100	300 800 2000	Fractured to fresh solid rocks
Chargeability value (millisecond, ms)	Chargeability Legend	Interpretation
0 – 10	0.00 2.00 6.00 10.0	Fractured rocks contain fresh water
> 10	20.0 30.0 40.0 50.0	Fresh solid rock zone

4.1 Survey Line 1

The survey line is N-S in direction. The total percentage of RMS error is 8.9% for resistivity (Figure 2). Minimum resistivity value in this survey line is 10 Ωm and the highest is 4,000Ωm with depth more than 50m. Based on the contrast of resistivity and chargeability values, all of the profile lines show the potential of groundwater around the study areas. The potential groundwater zones for pseudosection 2-D resistivity Line 1 are within a distance of 80 to 110 m, with depths ranging from 40 m to more than 60 m at the fractured zone. The results show that there is no water present in the topsoil. The surface was dry and was not damp. The resistivity image also confirms that the water source is very deep underground and it is from the schist and there is no water in the top layers of the soil. The top weathered rock zone extends down to a depth of 20m and has larger resistivity value than solid rock zone. Granite rocks are expected to be present with the resistivity value of 4000 Ωm. Meanwhile, the resistivity value for the weathered rock zone ranges between 800 Ωm to 4000 Ωm. For chargeability, the value of solid rock zone is higher than weathered rock zone which ranges from 30 to 60ms while at weathered rock zone, the value is lower which is only from 0 to 25ms. For chargeability, the value at the solid rock zone is higher than weathered rock zone which ranges from 30 to 60ms while at weathered rock zone, the value is lower which is only from 0 to 25ms.

4.2 Survey Line 2

The survey line runs from east to west. Figure 3 shows an overall RMS error percentage of 14.1% with a minimum resistivity value of 10 m and a maximum resistivity value of 4,000 m with a depth range of up to 50 m. The pseudo-section of this survey line is showing the water bearing zone within a distance of 80 to 110 m, with approximately 20 m depth and labelled as fractured aquifer. Furthermore, the results show that there is no water in the top soil. The resistivity profile confirms that the water source is very deep underground and interpreted at a schist. The top weathered rock zone extends to a depth of 40m. Granite rocks with a resistivity of 4000Ωm are expected to be present. The weathered rock zone has a resistivity value that ranges between 800 Ωm to 4000 Ωm. While the fresh solid rock zone has a low resistance range of 10 Ωm to 800 Ωm which is lower than the resistivity value at weathered rock zone. The value of chargeability at the solid rock zone is higher than the value at the weathered rock zone, which ranges from 30 ms to 60 ms, whereas the value at the weathered rock zone is lower, ranging from 0 ms to 25 ms. The most potential groundwater zone is on this area.In terms of chargeability, the value at the solid rock zone is higher than the value at the weathered rock zone, which ranges from 30 to 60ms, whereas the value at the weathered rock zone is lower, ranging from 0 to 25ms. The most potential groundwater zone is on profile Line 2.

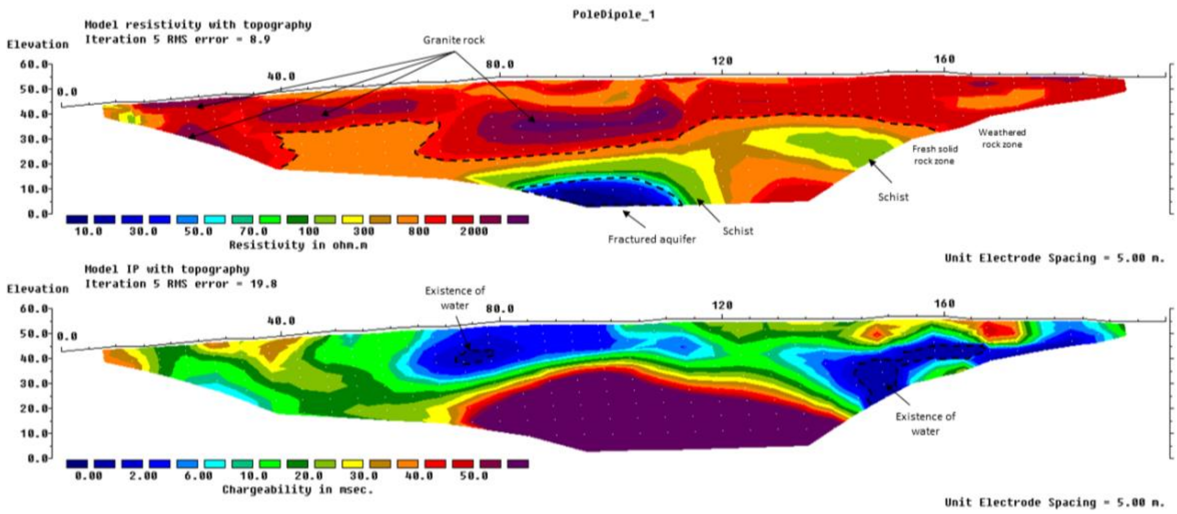

Figure 2. Pseudosection 2-D resistivity profile for Line 1

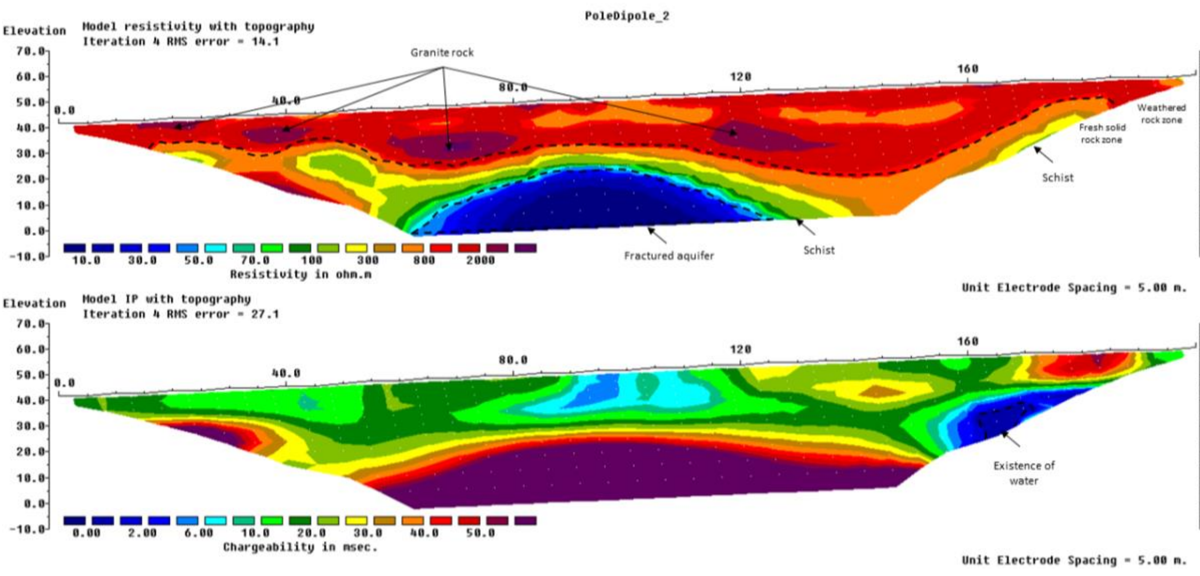

Figure 3. Pseudosection 2-D resistivity profile of Line 2

5. Conclusion

The study region has a high potential for groundwater, which is depicted as a fractured aquifer at a depth of 10 m in line survey 1's pseudosection 2-D profile and at a depth of 20 m in line survey 2's pseudosection 2-D profile. In terms of chargeability, the solid rock zone has a value that is higher than the weathered rock zone and varies from 30 to 60 ms, while the weathered rock zone has a value that is lower and ranges from 0 to 25 ms. The outcome of the pseudosection profile reveals that the water-bearing zone collected across a sizable area. On profile line 2, the most likely groundwater zone is located. This is proven by the presence of a fire station and groundwater in the survey area, both of which have been supplied with water. To improve the accuracy and precision of these findings, the drilling procedure should be used. The existence of groundwater sources in the Kemahang region was demonstrated by the Electrical Resistivity Imaging (ERI) technique.

Acknowledgement
We wish to thanks FerroGeo Services for providing the resistivity dataset. We also would like to express our sincere gratitude to Universiti Malaysia Kelantan for providing the funding (Short Term Grant Scheme, SGJP: R/SGJP/A0800/ 01725A/ 001/2019/00597) to complete this research.

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