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Preliminary Groundwater Assessment using Electrical Method at Quaternary Deposits Area

Z A M Hazreek[1*,2], **A G A Raqib**[1], **M Aziman**[1], **A T S Azhar**[1], **A T M Khaidir**[1], **Y M Fairus**[1], **Rosli S**[2], **I M Fakhrurrazi**[3] and **R A Izzaty**[1]

[1]Faculty of Civil and Environmental Engineering, Universiti Tun Hussein Onn Malaysia, 86400 Batu Pahat Johor, MALAYSIA

[2] School of Physics, Universiti Sains Malaysia, 11800 USM Penang, MALAYSIA

[3]Faculty of Engineering Technology, Universiti Malaysia Pahang, 26600 Gambang Pahang MALAYSIA

Corresponding author: hazreek@uthm.edu.my

Abstract. Alternative water sources using groundwater has increasingly demand in recent years. In the past, proper and systematic study of groundwater potential was varies due to several constraints. Conventionally, tube well point was drilled based on subjective judgment of several parties which may lead to the uncertainties of the project success. Hence, this study performed an electrical method to investigate the groundwater potential at quaternary deposits area particularly using resistivity and induced polarization technique. Electrical method was performed using ABEM SAS4000 equipment based on pole dipole array and 2.5 m electrode spacing. Resistivity raw data was analyzed using RES2DINV software. It was found that groundwater was able to be detected based on resistivity and chargeability values which varied at 10 – 100 Ωm and 0 – 1 ms respectively. Moreover, suitable location of tube well was able to be proposed which located at 80 m from the first survey electrode in west direction. Verification of both electrical results with established references has shown some good agreement thus able to convince the result reliability. Hence, the establishment of electrical method in preliminary groundwater assessment was able to assist several parties in term groundwater prospective at study area which efficient in term of cost, time, data coverage and sustainability.

1. Introduction

Water present underground in soil or rock was define as groundwater. The storage of groundwater was called an aquifers derived from consolidated or unconsolidated geomaterials. Nowadays, the demands of water in various consumption has increased thus require additional support from alternative sources such as groundwater. Several application of groundwater was related to domestic and industrial sector such as for public supply, agriculture, aquaculture, irrigation, livestock, factory, mining, etc. Moreover, water sources from groundwater were commonly economic and less pollution compared to the other sources. According to [1], one of the most significant and broadly available water resources is groundwater which people perception is still unclear and misleading due to its hidden environment. In order to extract groundwater from aquifer, tube well with specific design need to be carefully constructed on suitable location. In the past, groundwater exploration experienced difficulty in decision making particularly to locate the best possible point of tube well in order to obtain high productivity and quality of groundwater. Consideration of tube well location need to be study properly since it will influence its efficiency related to quantity and cleanness. For example, drilling well need to be penetrated and reached the formation of groundwater. Moreover, tube well location need to be located far enough from septic tank, wastewater treatment pond, landfill or other waste area in order to prevent its contamination.

In recent years, land use has being developed rapidly thus require groundwater to support those activities. Development has being expanded thus involving problematic area such as soft soil, hilly and rural area. Consequently, groundwater exploration require additional tool for its assessment study due to obtained suitable tube well location. Previous approach to drill the tube well may expose to uncertainties due to subjective judgment of respective parties. As a result, unproductive tube well may produced thus consider inefficient in term of cost, time and sustainability. As a result, the solutions to these challenges will require multidisciplinary research across the social and physical sciences and engineering [2].

Nowadays, geophysical techniques has increasingly adopted in engineering [3] – [10], environmental [11] – [15], archeological [16] – [20] and mining studies [21] – [23]. Geophysical techniques are defined as studying an earth based on physics properties. Some of the related physics properties used in geophysical techniques are electrical resistivity, chargeability, velocity, density, magnetic susceptibility, etc. Based on those properties, specific geophysical equipment was invented namely electrical resistivity, seismic refraction and reflection, ground penetrating radar, gravity, magnetic, etc. Several advantages of geophysical techniques were related to its good efficiency in term of cost, time, data coverage and sustainability. Geophysical methods can be implemented more quickly and less expensively and can cover larger areas more thoroughly [7] [24] – [28]. Field operational and data processing can be performed rapidly compared to the other conventional method particularly when working at difficult and challenging sites. Location of target interest may able to be define indirectly thus assisting to localize searching in a large areas. Large data coverage (2 or 3 dimensional perspective) able to be produced based on most of geophysical method. As reported by [29], the applications of geophysical method will applicable to minimize environmental destruction due to its non-destructive measurement thus preventing unnecessarily excavation. Furthermore as reported by [28], it provides a large-scale characterization of the physical properties under undisturbed conditions. Most of geophysical techniques used surface methods which consider non destructive method during its field measurement thus able to preserve our environment by minimizing site destruction. However, the successful performance of geophysical method may influenced by fundamental physical constraint (e.g. penetration, resolution, and signal to-noise ratio) [30,31].

Groundwater assessment using geophysical techniques particularly based on electrical method was popularly being adopted from past to present [32] – [37]. However, the application of electrical method in soft soil may experience difficulty particularly in interpretation stage due to the tomography similarity contrast. Moreover, electrical properties with particular reference to resistivity may expose to the overlapping values of different types of soft soil geomaterials due to its wide range of highly conductive resistivity values. Conventional reference tables of resistivity geomaterials used for anomaly interpretation also sometimes was difficult to decipher due to its wide range of variation and overlapping values [5,38]. Consequently, geophysical methods are incapable to stand alone in order to provide solutions to any particular problems [39,40]. Hence, the success at any site investigation works is based on the integration of method [39]. According to [41], studies that relate to geophysical data and geotechnical properties are much rarer and lesser known. Even the potential of geophysical techniques in groundwater assessments are yet to be realized, the application of this techniques are still not being fully utilized yet because it is still not being fully explored by the civil engineers due to their less exposure and expertise in this field. Geophysical method has a good prospect in order to solve some of the problems related to the conventional site investigation methods [42]. Hence, this study was performed to establish the application of electrical methods with particular reference to resistivity and induced polarization in groundwater prospective.

2. Methodology

2.1 Study area

Study area was located at Parit Raja, Batu Pahat area (Figure 1) specifically at construction site of Darul Hikmah School. Site topography was relatively flat which surrounded by housing village and palm oil plantation. Distance of site from Batu Pahat Town was around 18 km. Site work was easily access via all common land transportation modes such as car, lorry, van, motorcycle, etc. General geology of peninsular Malaysia has well being documented by Minerals and Geoscience Department Malaysia. Based on geological map shown in Figure 1, study area was located at quaternary period consists of unconsolidated deposits from clay and silt (marine). In general, the present of this type of materials will exhibits soft soil phenomenon due to its high water content derived from high water table of lowland areas. Moreover, high rainfall intensity which was commonly occurred in tropical climate country as Malaysia also has contribute to the increment of water table thus promoting to the soft soil phenomenon and groundwater storage in study areas. However, fine particle of soils such as clay and silt may associate with low hydraulic conductivity which may influence the effectiveness of groundwater recharge and quality extracted from the existing tube well. Hence, several testing such as pumping and water quality test need to be performed thoroughly in order to obtain comprehensive results and conclusion. Based on site observations, soft soil condition related to wet clay and silt geomaterials can easily found in study area. These evident can be used as an indicator regarding the composition of subsurface profile that possibly consists of homogeneous soft soil geomaterials. Furthermore, previous nearest available borehole record has revealed that thick soft soil (up to 40 m) with particular reference to clayey and silty soil has being widely found at most of the Parit Raja area.

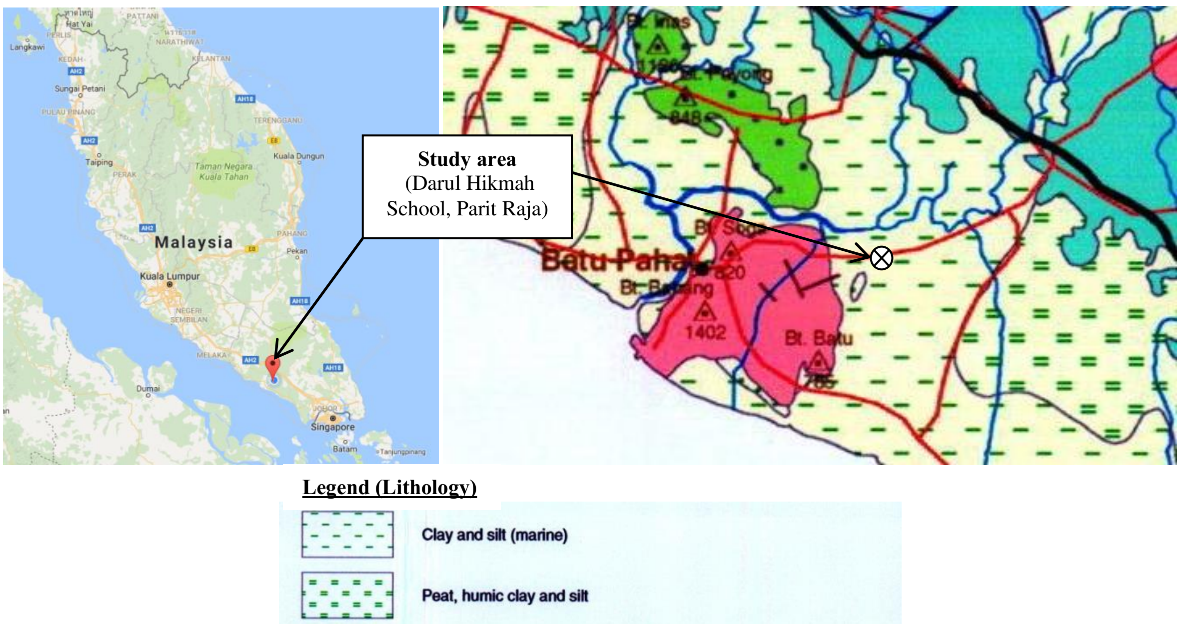

Figure 1. Study area (left) and Geology of study area (right) [43]

2.2 Electrical method

Electrical method (electrical resistivity and induced polarization survey) was performed using ABEM Terrameter SAS4000 equipment set. A single (1) electrical spread line was performed at study area specifically based on site constraints. A maximum of 61 numbers of electrodes (electrical resistivity and induced polarization method) were peg at the ground surface based on four resistivity land cables and 2.5 meter of equal electrode spacing. Field arrangement and survey traverse which was oriented west to east direction was shown in Figure 2 and 3 respectively. The Pole-dipole array was used during the field measurement due to its dense near-surface coverage of electrical resistivity and chargeability data. Moreover, the array was able to provide some greater depth of profiles within the spaced limitation faced during the data acquisition (field measurement). Data processing was performed using commercialize RES2DINV software of [44] to provide an inverse model that approximates the actual subsurface structure. The inversion algorithm of RES2DINV was used to process the data, as proposed by [45] in order to obtain the 2-D resistivity and chargeability results.

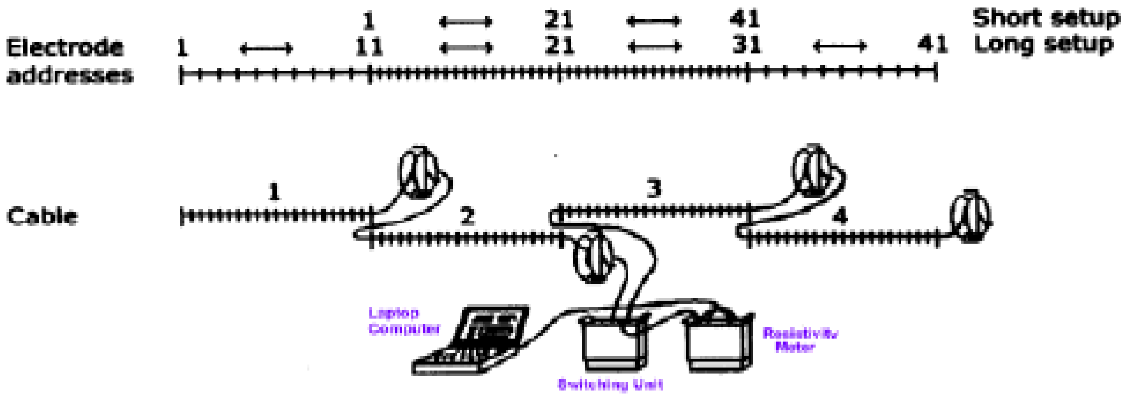

Figure 2. Field arrangement of electrical survey performed at study area [46]

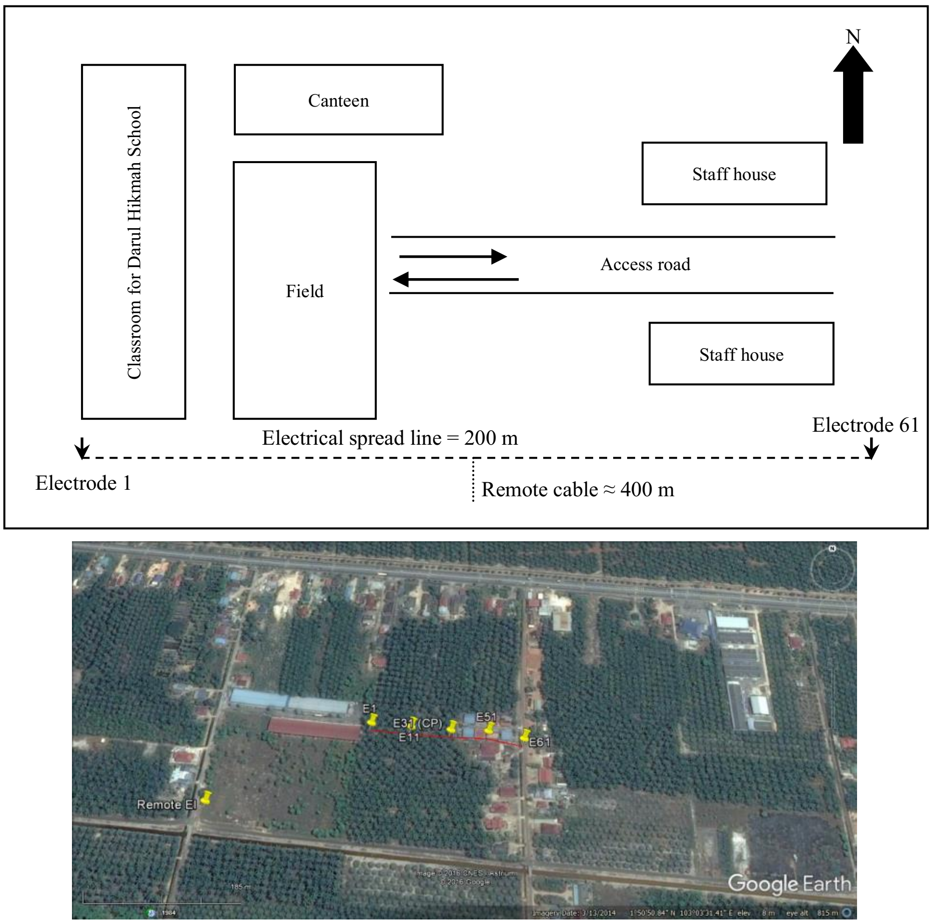

Figure 3. Study area layout based on plan view (top) and google map (bottom) showing the alignment (Westeast) of spread lines performed at Darul Hikmah School

3. Results and Discussions

A single profile of two-dimensional (2-D) electrical resistivity and chargeability tomography (ERT and ECT) were obtained from the field surveys at the selected area in Darul Hikmah School. Subsurface profile mapping generated by surface mapping of electrical method was generated based on tomography outcome as shown in Figures 4 and 5. Verification of results interpretation was based on established references. According to Figure 7, subsurface profile consists of saturated clayey and silty soil anomaly (resistivity value, ρ = 1 – 80 Ωm) due to its highly conductive geomaterials. According to [47], resistivity value for clay and saturated silt was varied at 0 – 100 Ωm. Moreover, resistivity value for clayey and silty soil was varied at 5 – 150 subjective to its composition and water content [48] and [49]. Furthermore, [50] has recorded that resistivity value for clays was varied at 1 – 100 Ωm. Based on [51], electrical resistivity for waters (surface and natural) was varied at 1 – 100 Ωm. As reported by [7], resistivity data exhibits a low value for a fine soil such as clayey and silty while the coarser soil such as sand and gravel will produce a higher resistivity value. Fine grain soils such as clay and silt poses higher minerals composition namely kaolinite, illite, montmorillonite and vermiculite which allows the ease of the current propagation in soils thus produces low resistivity value in contrast with coarse soil (sand and gravel). Electrical resistivity value (ERV) was determined by measuring the potential difference at points on the ground surface which caused the propagation of direct current through the subsurface [52]. Electrical resistivity may influenced by several factors such as the concentration and type of ions in pore fluid and grain matrix of geomaterials via the process of electrolysis where the current was carried by ions at a comparatively slow rate [49]. According to [26], a soil's electrical resistivity value generally varies inversely proportional to the water content and dissolved ion concentration as clayey soil exhibit high dissolved ion concentration, wet clayey soils have lowest resistivity of all soil materials while coarse, dry sand and gravel deposits and massive bedded and hard bedrocks have the highest ERV. As reported by [5] – [8] and [53], soil resistivity value can be varied due to the variation of basic geotechnical properties such as moisture content, densities, void ratio, porosity and grain size fraction. Moreover, condition such as porosity, degree of saturation, salt concentration in pore fluid, grain size, size gradation, temperature and activity may influence to the electrical resistivity value variations [54]. Furthermore, geometrical factor derived from different array adopted in data acquisition may also differ the electrical resistivity values [55,56].

According to Figure 5, subsurface profile was interpreted being dominated by groundwater anomaly due to its induced polarization value which varied at 0 – 1 ms. Basically, the ability of groundwater electrical chargeability was zero due to its highly conductive material. Moreover, [50] has reported that the chargeability of groundwater was 0 ms. Hence, it was prove that the interpretation of Figure 5 was in line with theoretical and results obtained. Furthermore, minor spot of alluvium and was interpreted at Figure 8 due to its chargeability value of less than 9. According to [50], chargeability of alluvium and gravel was varied at 1 – 4 ms and 3 – 9 ms respectively. Generally, chargeability of common geomaterials can be influenced by the existing of sulphide mineralization, clay content, pore-water salinity and discontinuity of geomaterials.

The interpretation of groundwater potential at highly conductive geomaterials (clayey and silty soil) may experience difficulty due to the resistivity overlapping values of clayey, silty soil and groundwater. Hence, induced polarization result was introduced in order to minimize or solve the problem. Induced polarization result was able to differentiate different types of geomaterials precisely based on its small range values of chargeability properties. Based on Figure 4, it was difficult to interpret the prospect of groundwater since the anomaly was dominated by very conductive geomaterials which possibly consist of clay, silt or groundwater. Those highly conductive geomaterials poses high similarity of electrical resistivity value which varied at 1 – 150 Ωm. However, high potential of groundwater anomaly may able to be interpreted clearly at nearly left center of the Figure 5. This interpretation was due to its chargeability value of less than 1 ms representing groundwater. Hence, the suitable point of tube well was located at 77.5 m from the first electrode in west direction. However, the potential of groundwater sources in study area may reduce due to its geological condition as discussed previously.

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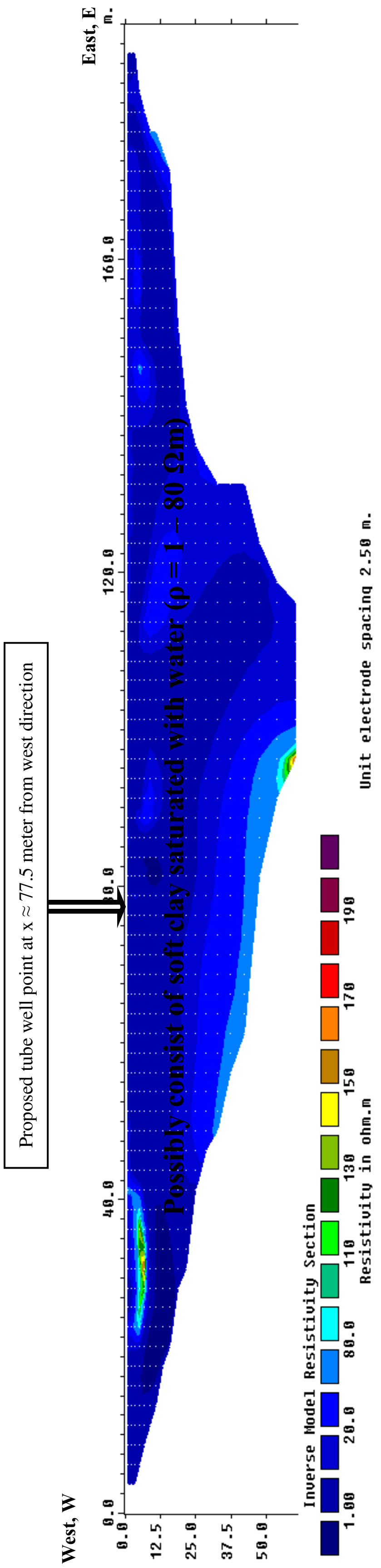

Figure 4: Electrical resistivity tomography in West-east direction

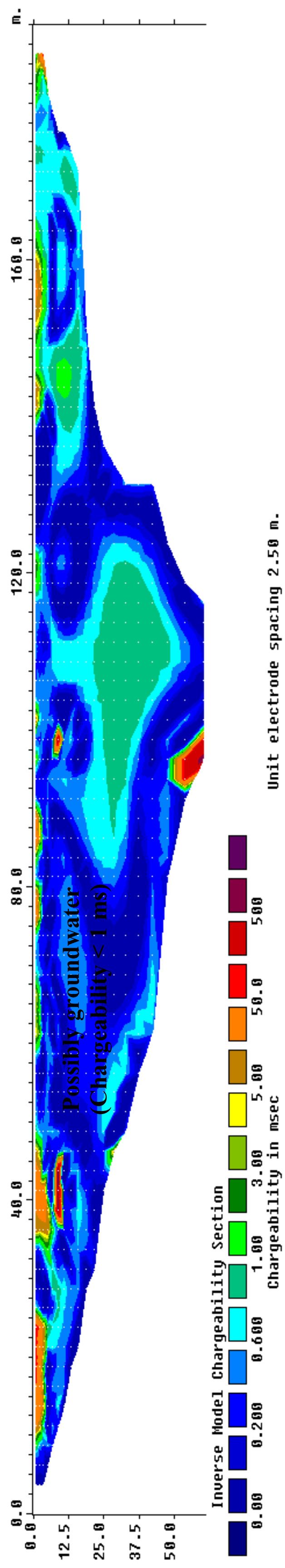

Figure 5: Induced polarization tomography in West-east direction

Theoretically, fine particle of soil such as clay and silt may pose low hydraulic conductivity thus contributing to the low ability of groundwater recharge after the water being extracted. According to [1], storage and movement of groundwater may influenced by porosity and permeability. Porosity and permeability influenced the storage and mobility of groundwater due to its ability of consolidated or unconsolidated materials to retain and allow water passing through the materials [57]. For example, fine grain soil (clay and silt) have more porosity compared to the coarse grain soil (sand and gravel) thus able to stored more water. However, fine grain soil experience small porosity thus slower the movement of water (low permeability) compared to coarse grain soil. As a result, test well need to be performed in order to extend this preliminary groundwater assessment in order to determine comprehensive and concrete judgment thus able to finalize the decision making for implementation of groundwater sources project in study area.

4. Conclusion

Geophysical method with particular reference to electrical technique (electrical resistivity & induced polarization) was successfully replicated the subsurface profile geomaterials at the studied area. The geometry and electrical properties (resistivity and chargeability) distribution of subsurface profile at study area was determined by analyzing electrical resistivity and chargeability data obtained and the result has generally shown a very good agreement with previous references. Based on both electrical results, it was found that the subsurface profile has been dominated by highly conductivity materials (resistivity = 1 – 80 Ωm & chargeability < 1 ms). Induced polarization method was able to compliment electrical resistivity method due to its smaller range of chargeability value thus producing better interpretation regarding the target interest (groundwater). Hence, the mechanics and physical characteristics of the groundwater can be easily recognized. It was found that study area may have good potential of groundwater sources as referred to the electrical images. Several limitations such as site accessibility and geological condition experienced in study area may able to influence the groundwater image depth and its recharge ability effectiveness. It was recommended to map deeper subsurface image due to its high potentiality of groundwater resources. However, deeper electrical imaging was unable to be investigated due to site accessibility constraint. Moreover, geological condition of this area (quaternary deposits geomaterials) may influence the performance of the groundwater in term of its recharge ability. Finally, the application of electrical method in conjunction with previous established information was applicable in preliminary study of groundwater potential assessment. This technique was demonstrated effectively due to its ability to contribute early information regarding the subsurface geomaterials which consider fast, cheap, large result (2-D image) and environmental friendly (non-destructive method).

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