Detection of Potential Shallow Aquifer Using Electrical Resistivity Imaging (ERI) at UTHM Campus, Johor Malaysia

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Abstract. In recent years, Electrical Resistivity Imaging (ERI) has become part of important method in preliminary stage as to gain more information in indicate the hidden water in underground layers. The problem faces by engineers is to determine the exact location of groundwater zone in subsurface layers. ERI seen as the most suitable tools in exploration of groundwater as this method have been applied in geotechnical and geo-environment investigation. This study was conducted using resistivity at UTHM campus to interpret the potential shallow aquifer and potential location for borehole as observation well. A Schlumberger array was setup during data acquisition as this array is capable in imaging deeper profile data and suitable for areas with homogeneous layer. The raw data was processed using RES2DINV software for 2D subsurface image. The result obtained indicate that the thickness of shallow aquifer for both spread line varies between 7.5 m to 15 m. The analysis of rest raw data using IP showed that the chargeability parameter is equal to 0 which strongly indicated the presence of groundwater aquifer in the study area.

1. Introduction

Geophysical method is the common technique used by geophysicists in discover the earth surface. It applies the principles of physics in studying the earth. Geophysics has been developed rapidly throughout the years and has become choice in various studies and investigations on the subsurface. The application is capable in study and explore various ground resources such as groundwater, minerals and hydrocarbon. This method involved in interpretation of soil properties, layering and composition of the subsurface, cavities and structures or bodies generally found underground which have different physical characteristics from their geological surroundings [1]. The utilization of geophysical method known for its effectiveness in civil engineering works than most conventional method due to concern of time, cost and quality [2]. It plays an important part in preliminary survey as to determining the subsurface condition at study area to facilitate for further work.

Most of geophysical method used in field are Electrical Resistivity Imaging (ERI). ERI survey carried out basically to determine the subsurface resistivity distribution by making measurements on the ground surface [3]. Known as a non-destructive method, this technique able to reduce the interruption and damage to site due to its surface technique [4]. Hence, it could be considered as sustainable technique due to preservation of environment during data acquisition. The technique also offers chances to overcome some of problem exist in most conventional ground investigation.
techniques [4]. Besides, this method also known for its less time consuming and low cost but still provide larger characteristics of the physical properties under undisturbed conditions [5]. There were several problems in conventional method as it provides information at actual drilling point only that lead the interpolation between borings to determine conditions can involve some of uncertainties [6]. However, the conventional method nowadays had been use as reference and comparison to ERI result as to interpret the general picture for the study area. Table 1 shows the resistivity value of common rocks, soil and water use in electrical resistivity method. However, the overlap value resistivity of different classes of rock and soil were depending on several factors such as porosity, degree of water saturation and concentration of dissolved salt [7].

Groundwater is very important component of water resources in nature. Groundwater is defined as water that beneath in earth surface in soil pore spaces and in fracture of rock formations [8]. It is known as alternative water supply for all living things. The problem faces by engineers is to determine the exact location of groundwater zone in subsurface layer. ERI is part of geophysics used as preliminary step involve in any groundwater exploration. It has been applied for many years to determine the thickness of layered media as well to map geological environment of existing aquifer.

Besides, has been proved to be most effective technique in mapping groundwater resource as groundwater movement and existence are largely localized and hard to determine [9]. With a support borehole data and imaging obtained, the reliable information regarding groundwater can be produced. Successful implementation of this tools had help especially engineers to identify the sources of failure in subsurface thus prevent surrounding structure and material investigated to be damage [6].

### Table 1. Resistivity value for common rocks and soil materials [10].

| Materials                  | Resistivity (ohm-m) |
|----------------------------|---------------------|
| **Igneous/Metamorphic**    |                     |
| Granite                    | $5 \times 10^3 - 10^8$ |
| Weathered granite          | $1 \times 10^2$     |
| Basalt                     | $10^3 - 10^6$       |
| Quartz                     | $10^3 - 2 \times 10^6$ |
| Marble                     | $10^2 - 2.5 \times 10^8$ |
| Schist                     | $20 \times 10^4$    |
| **Sediments**              |                     |
| Sandstone                  | $8 - 4 \times 10^3$  |
| Conglomerate               | $2 \times 10^3 - 10^4$ |
| Shale                      | $20 - 2 \times 10^3$ |
| Limestone                  | $50 - 4 \times 10^2$ |
| **Unconsolidated sediment**|                     |
| Clay                       | $1 - 100$           |
| Alluvium                   | $10 - 800$          |
| Marl                       | $1 - 70$            |
| Clay (wet)                 | $20$                |
| **Groundwater**            |                     |
| Fresh water                | $10 - 100$          |
| Salt water                 | $0.2$               |

2. Study Area

The study area for this study is located at Universiti Tun Hussein Onn Malaysia (UTHM) Batu Pahat Johor with coordinate of 1.8586° N and 103.0856° E. The total area of UTHM is approximately about 219828.734 m². Most of this area are low infiltration rate of 0.004 – 0.007 mm/s and low land area with around 0.5 m to 2.0 m above mean sea level [11]. The area has a humid tropical atmosphere with annual rainfall about 2961 mm and temperature roughly from 24 °C to 33 °C. Meanwhile, study by
[12] indicate that the top and subsoil in UTHM area is occupied mostly by clay in which the rate of infiltration is low (0.004 – 0.007 mm/s).

UTHM area is locate near to coastal area (Pantai Rengit) about 20 km. Thus, this area found as a layer of soil sediments and fossils formed due to tidal effects for centuries. Acidity levels are also influence by the existence of patches saltwater identified exists and trapped in the clay layer which the movement to drain are limited. Indirectly, it had some impact on the presence of undesirable concentrations [13]. In consonance with [14] it is predicted that UTHM area and its surrounding previous was a muddy and sandy coastal area, and the water containing have a high calcium and chloride due to ancient salt water intrusion at quaternary era and effects of karts under the land surface, respectively. Figure 1 illustrate the study area at Parit Raja, Johor while Figure 2 illustrate the master plan of UTHM campus.

![Figure 1. Study area.](image1)

![Figure 2. UTHM master plan map.](image2)

3. Methodology
In electrical resistivity survey, high resolution, reliable and good imaging are depending on choices of electrode configuration or normally known as array [15]. In data acquisition, there are various types of array that suitable to be applied which depends on several factors. Wenner, Schlumberger, Dipole-dipole and Pole-dipole were the common array used in investigate the underground layer. The array configuration has a substantial influence on the resolution, sensitivity and depth of investigation. The different between each array has its own specific advantages and limitations. It relays on the objective of the survey and other factors example depth of heterogeneity to be mapped, vertical and horizontal of subsurface and the ability of type of subsurface at previous study area [7]. These entire configurations will be functional by inducing an electric current into the earth through two current (C1 and C2) electrodes and measuring the resulting voltage at two potential electrodes (P1 and P2).

Meanwhile, Induced Polarization (IP) survey had been conducted as one of method in geophysical in classifying between sediments of diverse lithological composition. It measures the chargeability of soil materials when the voltage is applied upon it which is fundamentally different from resistivity survey. Recently, IP survey was carried out as to perform environmental survey and mapping of geological faults. In fine grained soil, resistivity survey may unable to distinguish the soil layers due to non-abrupt changes in resistivity value. Thus, IP was commonly used in study of clay minerals as well as hydrogeological and engineering investigation.

Moreover, if the borelog data is unobtainable and thus the verification of groundwater was noncapable to be done, IP method could be carried out along with resistivity survey. This is due to resistivity value of clay material which is stated in similar range with water in resistivity value, thus it’s hard to distinguish them without borelog data as UTHM also well known to be surrounded by marine clay. Nevertheless, IP method was easily in distinguish both clay and water as the clay material is more polarizable than that of water as stated in Table 2.
Table 2. Chargeability value [10].

| Material     | Chargeability (ms) |
|--------------|---------------------|
| Groundwater  | 0                   |
| Alluvium     | 1 – 4               |
| Gravels      | 3 – 9               |
| Sandstones   | 3 – 12              |
| Schist       | 5 – 20              |
| Limestone    | 10 – 20             |
| Granite      | 10 – 50             |
| Shale        | 50 – 100            |

During data acquisition, Schlumberger array was used as this array is capable in imaging deeper profile data and suitable for areas with homogeneous layer. The Schlumberger array has a slightly better horizontal coverage compared to Wenner array due to greater concentration of high sensitivity values to both horizontal and vertical structures. Moreover, the median depth of investigation for this type of array is 10% more larger compare to Wenner array for the same distance [7] Schlumberger array with 2.5 m equal electrode spacing and two cables with total layout length of 100 m was used in interpret the potential shallow aquifer in this study. Figure 3 below illustrate the electrode arrangement for Schlumberger array.

![Electrode arrangement for Schlumberger array](image)

**Figure 3.** Electrode arrangement for Schlumberger array [7].

The equipment used for measurement of resistivity are listed are shown in Figure 4. Basically, the equipment consists of three main components which are source, inducer and record. The power source of data acquisition was generated by dry cell battery while steel electrode act as current inducer and Terrameter SAS 4000 was used to record the apparent resistivity data. In reducing the excessive of reading error after analysis, the equipment must be setup appropriately accordance to procedure of work. Besides, the area of study should be free from any surface structure as to avoid less interruption along the survey line during the electrode plant.
4. Result and Discussion

Based from the imaging generated from spread line in Figure 5, it was observed that the resistivity value of soil materials lay beneath the spread line was at a range of 0.1 $\Omega$m to 10 $\Omega$m. The layer could interpret as mostly clay layer and by the information from geological map, it expressed that the land is mostly covered in clay and it was the same as resistivity result. The layers showed not much variation as there could be non-consolidated clay mineral such as shale materials.

However, from the chargeability imaging, it was detected that the layer could be classified by soil materials chargeability value. Most part of the region has a chargeability value ranged from 0.4ms to 1ms. [10] pointed out that the materials which would have such chargeability value is alluvium which is made up of clay, silt, sand or gravel. In addition, the image also discovered some of the region have a much higher chargeability value compared to the surrounding minerals. The chargeability value of that region ranged from 50 ms to 500 ms. Besides, according to [10] such region could possibly contain sandstone or highly consolidated clay which is shale stone. Region of very low chargeability value were scattered around but most notably at distance of 40 m to 47.5 m with a depth of 7.5 m to 15 m, it was noted that the region has a chargeability value of 0 to 0.4 ms. This indicated that such zone has a high possibility of presence of groundwater.

Figure 4. Resistivity equipment set.
Figure 5. Resistivity imaging at spread line 1.

Meanwhile, for spread line 2 illustrate in Figure 6 indicate that most of the subsurface area at a depth of 0 to 6 m could be classified as clay material since it has a resistivity value ranging from 0 to 20 Ωm. Based on the preliminary study, it is shown that the surface area is mostly covered by clay mineral and thus able to verify the data obtained. However, at the horizontal distance of 50 m to 62.5 m from the first electrode, it could be observed that there is a distinct layered zone at a depth of 7.5 m to approximately 18 m from the ground surface. The layered zone has a resistivity value ranging from 25 Ωm to 65 Ωm. According to [10], the materials which give such value could possibly be sandy clay, silt, sand or shale. On the other hand, the induced polarization data revealed that the chargeability value of the soil materials lie are mostly ranged from 0.8 ms to 10 ms. The potential materials which would have such chargeability value are alluvium, gravels or sandstones. Fine grain soils such as clay and silt poses higher minerals composition namely kaolinite, montmorillonite and vermiculite which will allow the ease of current propagation in soils thus produce low resistivity value in contrast with coarse soil such as sand and gravel [16]. Moreover, at distance of 60 m to 72.5 m from first electrode, the chargeability value rise until 20 ms to 100 ms forming an oval shaped region at roughly 7.5 m below the ground surface. [10] have classified that mineral with equivalent chargeability values is shale. Furthermore, the location of potential groundwater is indicated at distance of around 40 m from the first electrode with a depth of 10 m to 15 m. This is due to the zone that shown no chargeability value. Besides, the chargeability value of groundwater is 0 and thus the location has high probability of having the shallow groundwater.
5. Conclusion
Electrical resistivity survey was successfully performed at UTHM as to detect the potential shallow aquifer in this area. Based from the data obtained for both of spread line indicate that the presence of groundwater depth or thickness is varies between 7.5 m to 15 m. The IP was also performed during data acquisition in assists the location of potential groundwater. This is due to resistivity that could not stay alone in identify groundwater as clay and groundwater varies between the same range and it could cause difficulty in spotted the presence of groundwater as UTHM itself stand at area of marine clay. Therefore, ERI and IP survey were applicable in investigating subsurface profile characteristics which is cost and time effective.

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