Groundwater Exploration in the Bedrock Area using Geoelectrical Resistivity Survey

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Abstract. The geoelectrical resistivity survey has been successfully used to explore the groundwater accumulation in the fractured zone of the bedrock area. The geoelectrical resistivity surveys with Wenner configuration were conducted perpendicular to the possibility of fracture zones. The resistivity profiles show that the sediment thickness vary from 5 m to about 30 m with resistivity value of less than 200 ohm.m. Whilst the bedrock zone is indicated with resistivity value of more than 1500 ohm.m. The possibility of groundwater is observed both in the fractured zone of the bedrock and in the sediment, which is indicated with the resistivity value of about 30-80 ohm.m. Generally, the fractured groundwater has been found between the undulations zones appear on the surface.

1. Introduction
The thickness of the sediment in an area depends on the condition of igneous rocks (bedrock) around the area. If bedrocks are exposed on the surface, it can be concluded that the sediment in the area is very thin, and even in a certain place the sediment cannot be found. The size of this sediment thickness becomes an important variable to determine how much the amount of groundwater can be stored in the sediment, so that in areas with igneous rocks that are in shallow depths, the possibility of groundwater should be cultivated from the fractures of the bedrocks. However, the exploration of groundwater in the shallow bedrock area is needed in order to obtain the water resources for the certain purposes.

The geoelectrical resistivity method has been used in various exploration fields. For groundwater exploration, Islami et al. [1, 2] reported that the use of this method is very useful in determining subsurface geomorphology so that this method is suitable to show the potential and less potential zones of the aquifer. Khaki et al. [3, 4] investigated the possibility of seawater intrusion in coastal areas and also studied groundwater in wetland areas. Baharuddin et al. [5] assessed the intrusion of seawater for agricultural sustainability in coastal areas. In addition to groundwater exploration, Islami et al. [6, 7, 8] also used geoelectrical resistivity survey and combined with hydrochemical method to study and monitor the presence of nitrate in groundwater with the different soil and source of nitrate. Not only that, the use of geoelectrical resistivity methods combined with seismic surveys is also used to explore the geomorphology of gravity flows in a cracking basin so as to obtain better results [9]. The geoelectrical resistivity data also gives better results when combining it with the Landscape image in interpretation [10].

In this paper, the use of geoelectrical resistivity survey was examined to explore the groundwater potential in which the bedrock is exposed around the surface in several places. The result of the
The geoelectrical resistivity survey is expected to provide information on the presence of groundwater potential in the crack zone of bedrock.

2. Methodology
Prior to conducting the geoelectrical resistivity surveys, the observation and searching the survey sites were made using Google Earth to make it easier to find the right location. By using Google earth, the possibility of bedrock fractures can be predicted by looking at the pattern of undulations from the surface. This pattern then indicated the fracture direction and parallel to the undulations.

The geoelectrical resistivity surveys were conducted using the Abem Terrameter SAS 4000. The Wenner arrangement was used as the electrode configuration, which it provides a high signal ratio compared to other configurations [11]. The total number of electrodes was 61 and it can penetrate the depth of about 60 meters. Then the data was processed by using Res2DInv [12] software to produce a two dimensional resistivity profile.

In several locations, some outcrop of rock samples and sediment were measured the resistivity value using direct measurement at the site. These measurements are intended to obtain the true resistivity value of the earth's material. The result of these measurements was used to interpret the profile of geoelectrical resistivity model.

3. Results and Discussion
Table 1 shows the result of direct resistivity measurement at some outcrops in site where the resistivity survey was conducted. Based on these data, the fresh bedrock has a resistivity value above 4000 ohm.m, weathered bedrock and meta-sediment have resistivity value ranging from 400 to 1500 ohm.m. The relatively dry sediment has a value of about 300-800 ohm.m. Whilst, fully saturated sediments has resistivity value of 30-200 ohm.m, and it is depending on the size of sediment grain.

| No | Material                                      | Resistivity (ohm.m) |
|----|----------------------------------------------|---------------------|
| 1  | Fresh granite bedrock (wet)                  | 4000-12000          |
| 2  | Weathered bedrock and meta-sediment (wet)    | 400-1500            |
| 3  | Fine Sediment (relatively dry)               | 300-500             |
| 4  | Coarse Sediment (relatively dry)             | 400-800             |
| 5  | Fine Sediment (wet)                          | 30-150              |
| 6  | Coarse Sediment (wet)                        | 80-200              |

Figure 1 shows the resistivity value in the coloured scale. These scales were obtained from the measurements result in the Table 1. On this coloured scale, the value of resistivity is starting from the aquifer potential, up to a high resistivity value indicating the presence of bedrock.

The profiles of geoelectrical resistivity model obtained from the field are given in Figure 1. Interpretations of resistivity profile are also given in the figure. The result shows that resistivity profiles consist of three major zones. The first zone is the resistivity value with less than 80 Ωm, which is correlating to sandy clay mix with silt. The second zone is resistivity with value around 80-200 Ωm that corresponds from medium to coarse sand. The third zone is resistivity value of more than 400 Ωm corresponding to the bedrock (metasediment and granite). The possibility of bedrock fracture is observed at the depth of more than -30 m in the Figure 2 (A) and (B). These zones are possible for fracture groundwater prospect. However, the basement depth is relatively deeper (> 40 m depth). As a recommendation, location and depth of propose well are given in the resistivity model. In the Figure 2 (B), there is no possibility of fractured bedrock found. The potential groundwater is observed at the shallow aquifer (at the depth of less than -10 m relative to the mean sea level).
4. Conclusion
In this study, the subsurface conditions can be clearly described and interpreted by using the geoelectrical resistivity survey. In addition to the subsurface geomorphology, the probability of aquifer thickness, as well as groundwater potentials can be traced through the profiling of geoelectrical resistivity model. Fracture zones are easily observed at the zone of relatively lower resistivity value.
between the zones with higher resistivity value. The low resistivity value is due to the presence of water in the fracture zone of the bedrock.

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