Geoelectrical resistivity survey for subsurface investigation in karst area

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Abstract. Karst area is vulnerable for the sinkhole disaster, especially in the area where the housing for the community was developed on it. This paper discusses the use of geoelectrical resistivity survey to investigate the possibility of void in the subsurface to avoid the sinkhole disaster in the housing area. Two geoelectrical resistivity surveys with wenner configuration have been conducted on the flat area where the limestone outcrops were found around 500 m from it. The electrodes spacing were adjusted at 2 m in order to coverage higher resolution of the electrical subsurface data. Some direct resistivity measurements have been conducted prior to the geoelectrical resistivity survey for obtaining the true resistivity value of some material in order to support geoelectrical resistivity interpretation. The results show that the resistivity value for the wet limestone is ranging from 170-240 ohm.m, while the clay material ranges from 30 to 170 ohm.m. The resistivity surveys indicate the occurrence of limestone in the subsurface at the depth 9 m downward. Generally, the geoelectrical resistivity survey can depict the possibility of the zone where the sinkhole disaster may occur in the future.

1. Introduction
The ground collapse is not only caused by the force of gravity alone, generally caused by low soil retention force, increased external load or hydraulic conditions and high-water content in the soil. Water contributes to all three factors as the water enters the unsaturated soil through surface water infiltration and water seepage in the soil.

Soil layers that are caused by puddles and heavy rain occur with a long period will trigger the occurrence of land collapse due to disruption of the equilibrium slope, caused by various human activities and nature itself. Land debris not only leads to material loss, but can also lead to the loss of life, including humans. Various efforts have been made to overcome the problem that is by anticipating the occurrence of land collapse. The main problem in the limestone bedrock area is sudden holes appear on the surface and create a big void. Sinkhole is formed when the acid rain water dissolves limestone or the like under the soil. The limestone dissolved by acid rain makes a large cavity and can tear the ground on it because it can no longer support the surface soil weight. As a result, the open field, road and house can puncture suddenly. Sinkhole usually occurs in areas with limestone formations, the main cause is the dissolution of the surrounding rocks due to the influence of water and cave formed beneath the soil surface [1].

Geoelectrical methods are very commonly used in conducting subsoil investigations for various cases. For the case of groundwater potential and it possibility to the contamination with nitrate, it have been reported by Islami et al. [2, 3, 4, 5], which is the dispersion of nitrate content in pore water and in
a shallow aquifer can be monitored by this method. Islami et al [6, 7] also reported that the presence of heavy metal content in the aquifer and the presence of brackish water can also be plotted and mapped by geoelectrical resistivity method. Other researchers also reported that the geoelectrical resistivity method could be used to detect the presence and quality of groundwater located in coastal areas [8, 9, 10].

In this paper the discussion on the use of geoelectrical resistivity method to investigate subsurface on areas where limestone rock can be found above ground level will be examined. This investigation focused on the searching for possible sinkhole zone due to an underground aperture. This is a very important thing to do before undertaking the development of the area for housing because the presence of void in the subsurface can harm the community around it. Figure 1 shows the location map of the study area obtained from Google Earth. The hill at north-eastern in the map is consisted of the limestone.

![Location Map](image)

**Figure 1.** The location of study area obtained from the Google Earth

### 2. Methodology
In order to produce a precise and accurate interpretation, before conducting the geoelectrical resistivity surveys, some resistivity measurements were made directly on the surface of some outcrops as well as on the existing sediments around the study site [3]. The measured outcrops were dry limestone, wet limestone, wet clay-sand and dry clay-sand. These measurements were carried out with a Wenner configuration, which was the electrode distance of 5 cm apart. As Telford said [11] that the measured material resistivity value will be the true resistivity value if the distance of the electrode is as small as possible.

The geoelectrical resistivity surveys were done by using Abem Terrameter SAS4000. The configuration used was Wenner array because it has a better signal strength compared than the other configurations. The distance of the electrode spacing was 2 m with total electrode of 41 and 61 m, respectively. The survey orientation was North to South direction. The maximum length of the resistivity surveys were 80 m due to the space was not enough. Data processing is done by using Res2DInv software developed by Loke [12]. In the inversion process, there was an error value (rms) which shown the magnitude of the model error made. This error was obtained from the amount of data differences of the existed raw data and the predicted data from the model. Interpretation of geoelectrical resistivity model was generated based on the data obtained from resistivity measurements.
directly on the ground surface. Resistivity data processing was done using Res2Dinv software that uses Least Square algorithm. The Least Square algorithm in Res2Dinv software consists of two kinds of algorithms are: Standard Smoothness-Constrain Least Square Inversion, it is used for zones with boundaries between materials tends to be gradual or has no sharp contact. The second, Robust Constrain Least Square Inversion, it is used for zones with sharp material contact boundaries such as fault zones or intrusive rock contacts-metal mineral linings.

If the Earth is assumed to have an isotropic homogeneous property, with this assumption, the measured resistivity is a true resistivity and independent of the spacing of the electrode. In fact, the Earth consists of layers with different, so the measured potential is the influence of the layers. Then the measured resistivity is not a resistivity price for one layer only, it is mainly for wide spacing to avoid the 2, so the measured potential is the influence of the layers. Then after inversion, the limestone is expected with wet condition rather than with dry condition. Based on the Table 1, the dried limestone has the resistivity higher than 4000 ohm.m. The higher resistivity value is due to the current is relatively hard to flow within it. Whilst, the limestone with relatively wet, will be around 150-280 ohm.m. The reduction of resistivity value are due to the current relatively easy to flow in the conductive zone of the wet material. At the depth in the field, the limestone is expected with wet condition rather than with dry condition. The dried sandy clay is expected with the resistivity value ranging from 500-800 ohm.m, whilst, if they are in the wet condition, it will be reduced to be less than 150 ohm.m. All these data in the Table 1, will be used as a guidance in the interpretation of resistivity profile obtained in this research.

| No | Material                     | Resistivity (ohm.m) |
|----|------------------------------|---------------------|
| 1  | Limestone (dry)              | 4124-7211           |
| 2  | Limestone (wet)              | 151-286             |
| 3  | Sandy clay (relatively dry)  | 510-823             |
| 4  | Sandy clay (wet)             | <150                |

The resistivity result of the line 1 and line 2 can be seen in the Figure 2. The line 1 was done by 5 iterations with error rate of 3.4%. This error rate is acceptable because it is less than 20% [12]. When it tried to add the iteration process, the error value was decreased a little bit; however, the shape of subsurface is not reasonable geologically.

The lower to medium resistivity value of ranging from 30 - 178 Ωm can be observed in the material layer zone at the depth of ranging from 0.5 m - 9 m (marked with 4 in the survey line 1). The possible types of rocks within this zone are clay to sand with wet condition. In these zones, there is not possible to construct heavy construction because the coating is not binding each other so that there could be a direct decline in the land. The layers in the same a-averaging area, which distinguishes them, depend on the absorption of the water content in the coating. In the zone marked with 2, it is a limestone zone with a resistivity value of 178 - 240 Ωm. The possibility of the creation a hole is relatively higher within this zone. There is no suggestion for developing any buildings on the surface to avoid the sinkhole disaster.

The Figure 2 (bottom) shows the resistivity survey of line 2. The same pattern with the line 1 can be recognising within the whole resistivity profile of this line 2. The higher resistivity value is still appeared at the same side of the resistivity profile. The same clay – sand zone as appeared in the line 1 is also appeared in the line 2. Whilst, the limestone zone were recognised orienting with the west to
east direction. This is indicating that the limestone is continuing along the survey space of two line surveys.

Generally, the possibility of sinkhole disaster is still occurred at the study area. This is indicated with the appearance of the limestone in the subsurface. In this research there was no drill well was done to prove the occurrence of limestone at the depth. However, based on the direct surface measurement at the outcrop, it can be making sure that interpretation is possible for indication of the limestone.

4. Conclusion
The geoelectrical resistivity method is one type of geoelectric method that studies the properties of underground to investigate the subsurface. Physical quantities measured in this method are the rock type resistance due to the potential field and current occurring beneath the earth's surface. The combination of direct resistivity measurement and subsurface measurement has gave a better result. The direct surface resistivity measurement is very useful in supporting the resistivity interpretation. Interpretation of geoelectrical resistivity data shows the presence of limestone rocks below the surface at the certain depth. Thus, the construction of housing with a relative weight is not recommended in this area to avoid the occurrence of sinkhole disaster.

Acknowledgment
I would like to deliver many thanks to University of Malaya, Malaysia, especially to Department of Geology, Faculty of Sciences for their hospitality during the research collaboration of the 2016-2019 period. I thank also to the Field Crew during the data accusation, and to the geophysical laboratory staff

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