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Landslide investigation using Electrical Resistivity Imaging (ERI) method at Kg. Chuchoh Puteri, Kuala Krai, Kelantan, Malaysia

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Abstract. The possible landslide in Kg. Chuchoh Puteri, Kuala Krai, Kelantan were investigated using the electrical resistivity imaging (ERI) technique. The survey for the collecting of data was conducted along six lines. Each survey line was 200 meters long, with 5 meters between electrodes. ABEM Terrameter LS 1 is used to record all the data and RES2DINV software is used to process it. While conducting the geophysical survey, the relationship between resistivity and conductivity is reciprocal. A pole-dipole array configuration was utilised in survey Lines 1, 2, 4 and 5 and in survey Lines 3 and 6, a Schlumberger array configuration. Survey Lines 2, 3, and 6 are primarily indicated as having a high probability of experiencing a landslide using the pseudosection 2-D profile. The findings reveal varying resistivity at a depth of study between 40 and 80 meters for a survey line length of 200 meters. In general, the resistivity survey's seven pseudosections showed two distinct types of soils: dry residual soil (1–1500 Ωm) and weathered volcanic rocks (>1500 Ωm). Residual soils with varying saturation levels, hard soil and weathered volcanic rock, have dominated the soil profile. These profiles can generally be divided into two (2) zones: thin/thick layers of loose to dense residual soils (10–100 Ωm; Zone A) and thin/thick layers of dense and hard material (> 1000 Ωm).

1 Introduction

Landslide appraisal and hazard zonation are both necessary steps in the management and prevention of landslides in a systematic manner. In hilly areas, landslides are considered the most dangerous geological hazard [1, 2]. Evaluation of the contributing elements is required in order to reduce the harm caused by landslides [3]. These elements are influenced by geology, geomorphology, land use and cover, rainfall, seismicity, artificial activity, etc. [4].

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Both qualitative and quantitative methods may be used to accomplish the same goals. However, qualitative methods tend to be more in-depth. The prediction of the susceptibility of landslides using quantitative methodologies is based on the facts and interpretation of such data. In addition to this, the objective nature of quantitative methods eliminates the subjectivity inherent in qualitative approaches. Each method may consider a unique combination of causal factors and uses a disctinct set of tools for causal factor assessment and investigation [3].

Electrical resistivity imaging (ERI) is a technology that does not destroy the subsurface being investigated. The purpose of ERI is to explore variations in electrical resistance by passing an electrical current across the subsurface via cables attached to the ground. The method most frequently used to characterise landslides is electrical resistivity tomography (ERT) [5]. The use of ERT in landslide investigations to determine the shear zone, lithological contrast, kinds of soil and rock, moisture contents, and slope morphology has been demonstrated to be non-invasive, time- and cost-effective [6, 7, 8]. This study proposes investigating landslide potential using Electrical Resistivity Imaging (ERI).

2 Geological setting

The study area is located in Kg. Chuchoh Puteri, Kuala Krai Kelantan (Figure 1). The lithology in this area is subdivided into three separate strata. Recent rock formations were placed higher in the stratigraphic column. Most of the soil in the study region is alluvium. The Cretaceous period marks the first known appearance of alluvium soil. The sandstone is used to make the second layer. This rock first began to take shape during the Paleozoic. Quartzite rock, which forms the third layer, was initially deposited during the Cretaceous period. Similar to sandstone, the Paleozoic period was the time of the formation of this rock. The geology of the peninsula of Malaysia is separated into three main zones: the Western Belt, the Central Belt, and the Eastern Belt [9]. The Eastern Belt is composed of clastics and carbonates that date back to the Carboniferous and Permian periods, while the Central Belt is mostly composed of sediments that date from the Mesozoic and Permian eras. The Koh Formation, which can be found just above the Gua Musang Formation, is what distinguishes the most northern region of Kelantan [10]. Fossil evidence suggests that the sedimentary rock in the Kuala Krai region dates from the Carboniferous to the Triassic. However, most of the volcanic and sedimentary rocks found nearby are millions of years older, from the Carboniferous to the Permian. The Gua Musang formation is made up of alternating layers of calcareous and argillaceous rocks, arenaceous, and volcanic [10]. The Mesozoic epoch is responsible for this geological formation.

3 Methodology

Using the ABEM Terrameter LS 1, the Electrical Resistivity Imaging (ERI) procedure is carried out. The ERI method can employ resistivity measurements to determine the subsurface material and condition because each material has a distinct resistivity value. Over the research region, electrical resistivity measurements were taken along six (6) lines. Pole-dipole and Schlumberger array testing configurations were used, together with two resistivity land cables and forty-one (41) electrodes. All 41 electrodes were spaced equally apart by 5 m, resulting in a 200 m total length for the electrical resistivity investigation. An electrode buried beneath the surface during setup will inject an electrical current from ABEM into the earth. A reading for subsurface resistivity will appear on the ABEM's display. Schlumberger array was employed to collect the data because it could offer a dense near-surface resistivity data cover. Groundwater and sand-clay borders may be seen as horizontal structures thanks

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to the array's strong vertical resolution [11]. Schlumberger's array also allowed it to fulfil deeper subsurface profiles within constrained space. The Electrical Resistivity Imaging (ERI) method uses the ole-dipole array configuration, which employs the three electrodes C1, P1, and P2. While C1 and C2 are current electrodes, P1 and P2 are potential electrodes. This pole-dipole array, increasingly employed in geotechnical applications, is particularly useful for identifying lateral resistivity differences. Using commercially available RES2DINV software [12], raw data from acquisition data were first processed to produce an inverse model that roughly approximates the subsurface structure. The data were processed using the inversion procedure of RES2DINV to generate 2-D resistivity pseudosection, as suggested by [13].

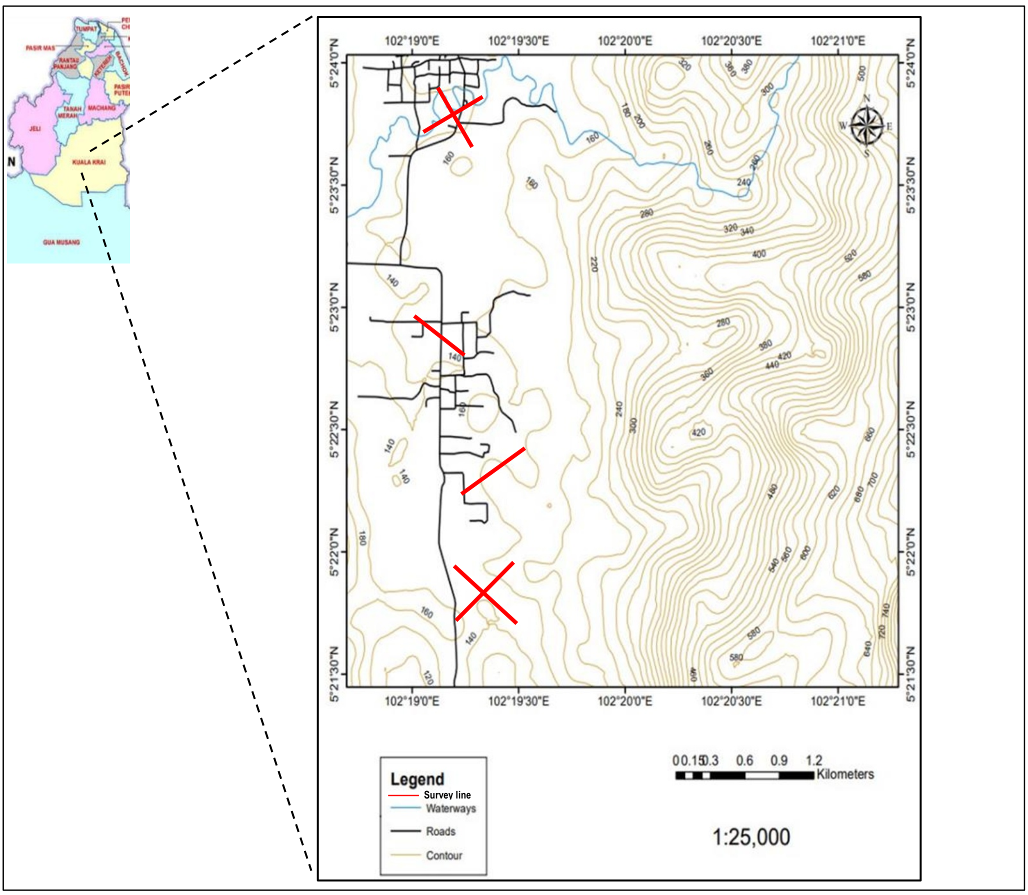

Figure 1. The base map of the study area indicates six survey lines at Kg. Chuchoh Puteri, Kuala Krai

4 Results and Discussion

4.1 Survey Line 1 and Line 2

In a NW-SE orientation, the electrical resistivity study for survey Line 1 is on the hill crest. In this survey line, the lowest resistivity value is 2 Ωm, and the highest is 1200 Ωm. Based on the site's combination of undulating and flat ground level, a penetration depth of up to 80 m was achieved. According to the pseudosection profile (Figure 2), the likelihood that a landslide will occur in the research area is only marginally high. Usually, the pseudosections from the resistivity survey have shown two categories of materials, dry residual soil (1- 1500 Ωm) and weathered volcanic rocks (> 1500 Ωm). The findings indicate that there is no water in the topsoil. The ground was dry and not wet. The resistivity image further illustrates the extreme depth of the water source. The top weathered rock zone reaches a depth of 50 meters, which has a higher resistivity value than the solid rock zone. According to Figure 2, the soil profile has been predominantly composed of residual soils with varying degrees of saturation, hard soil and weathered volcanic rock. This profile can generally be divided into two (2) zones: a thin layer of loose to dense residual soils (10-100 Ωm) and a thick layer of dense firm material (> 200 Ωm). Due to undulation conditions, each zone's thickness varied between 0 – 10 m (Zone A) and 30 m and above (Zone B). Solutions to specific problems cannot be found using geophysical methods alone [14, 15].

4.2 Survey Line 2

In a NE-SW orientation, the electrical resistivity survey for survey Line 2 is on the hill crest. In this survey line, the lowest resistivity value is 20 Ωm, and the highest is 8500 Ωm. Based on the site's combination of undulating and flat ground level, a penetration depth of up to 80 m was achieved. The possibility for a landslide to occur in the research area is moderately high, according to the pseudosection profile (Figure 3), which is based on the contrast of resistivity. Typically, the pseudosections from the resistivity survey have shown two categories of materials, dry residual soil (1- 1500 Ωm) and weathered volcanic rocks (> 1500 Ωm). The findings demonstrate that there is water in the topsoil. The resistivity image further demonstrates the modest depth of the water source. According to Figure 3, residual soils with varying degrees of saturation, hard soil and weathered volcanic rock make up the majority of the soil profile. This profile can generally be divided into two (2) zones: a thick layer of loose to dense residual soils (10–100 Ωm), and a thin layer of dense and hard material (> 1000 Ωm). Due to the terrain's undulations, each zone's thickness varied between 40 m and over (Zone A) and 0 – 20 meters (Zone B).

4.3 Survey Line 3

Survey Line 3's electrical resistivity survey operates in a NW-SE direction. In this survey line, the lowest resistivity value is 20 Ωm, and the highest is 2500 Ωm. Based on a combination of the site's undulating and flat ground level, a penetration depth of up to 40 m was reached. The possibility for a landslide to occur in the research area is moderately high, according to the pseudosection profile (Figure 4), which is based on the contrast of resistivity. In general, the pseudosections from the resistivity survey have shown two categories of materials, dry residual soil (1- 1500 Ωm) and weathered volcanic rocks (> 1500 Ωm). The findings demonstrate the presence of water at shallow depths. According to Figure 4, residual soils with varying degrees of saturation, hard soil and weathered volcanic rock make up the vast majority of the soil profile. This profile can generally be divided into two (2) zones: a thick layer of loose to dense residual soils (10–100 Ωm), and a thin layer of dense and hard material (> 1000 Ωm). Each zone's thickness fluctuated between 30 m and over (Zone A) and 0 -10 m (Zone B) as a result of the undulation condition.

4.4 Survey Line 4 and Line 5

Electrical resistivity survey results for survey Line 4 point in a NW-SE direction, whereas those for Line 5 point in a NE-SW direction. The lowest resistivity value for survey Lines 4 and 5 is 10 Ωm, while the greatest ranges are from 1500 to 3000 Ωm. The site's combination of flat and undulating ground level allowed for a penetration depth of up to 80 meters. According to the pseudosection 2-D profile (Figures 5 and 6), which is based on the contrast of resistivity, a landslide is not likely to happen in the study area. Usually, the pseudosections from the resistivity survey have shown two categories of materials, dry residual soil (1- 1500 Ωm) weathered volcanic rocks (> 1500 Ωm). The findings suggest the presence of water at a great depth. Based on Figures 5 and 6, it was determined that residual soils with varying degrees of saturation, hard soil to weathered volcanic rock predominated the soil profile. This profile is typically divided into two (2) zones, which correspond to a thin layer of loose to dense residual soils (10–100 Ωm) and a thick layer of dense and hard material (> 1000 Ωm). Due to undulation conditions, each zone's thickness varied between 0 – 20 m (Zone A) and 40 m and above (Zone B).

4.5 Survey Line 6

On the top of the slope crest, the electrical resistivity survey for survey Line 6 is NE-SW in direction. In this survey line, the lowest resistivity value is 4 Ωm, and the highest is 4000 Ωm. Based on a combination of the site's undulating and flat ground level, a penetration depth of up to 40 m was reached. The pseudosection profile (Figure 7) suggests the likelihood for a landslide to occur is slightly high in the study area based on the resistivity contrast. Typically, the pseudosections from the resistivity survey have shown two categories of materials, dry residual soil (1- 1500 Ωm) and hard soil to weathered volcanic rocks (> 1500 Ωm). The findings demonstrate the presence of water at shallow depths. According to Figure 7, residual soils with varying degrees of saturation, hard soil and weathered volcanic rock make up the majority of the soil profile. This profile can generally be divided into two (2) zones: a thick layer of loose to dense residual soils (10–100 Ωm), and a thin layer of dense and hard material (> 1000 Ωm). Due to the undulation condition, each zone's thickness fluctuated between 30 m and above (Zone A) and 0 m to 10 m (Zone B). A low electrical resistivity value (ERV) will signal the presence of a weak zone, which may have a high water content or highly conductive materials, according to [16]. Therefore, it is conceivable to assume that the high conductive zone, which frequently contained water, would cause the weak zone of subsurface geomaterials in a natural slope to have a low resistivity value [17].

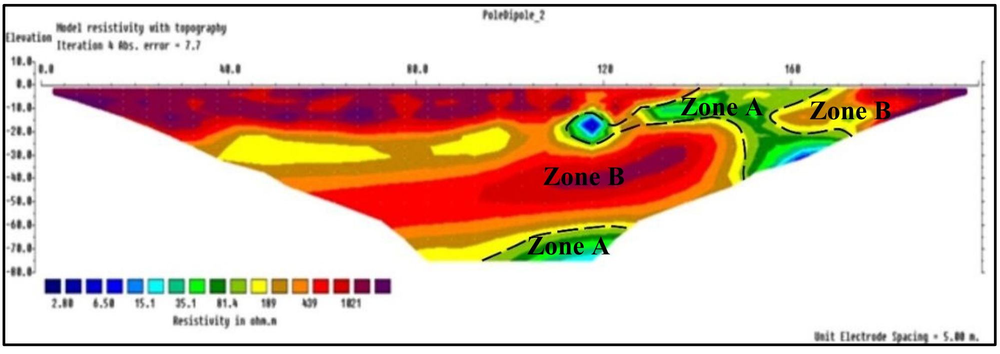

Figure 2. Pseudosection 2-D resistivity profile for Line 1.

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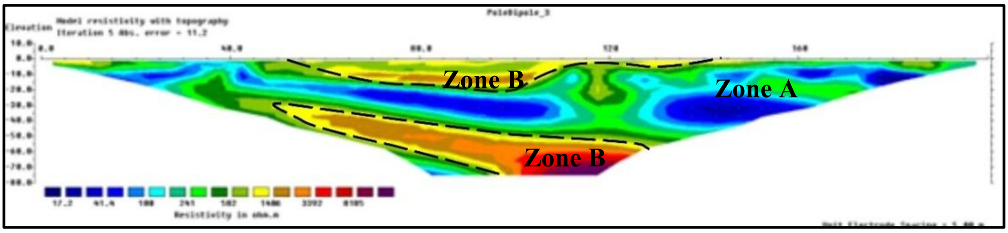

Figure 3. Pseudosection 2-D resistivity profile for Line 2.

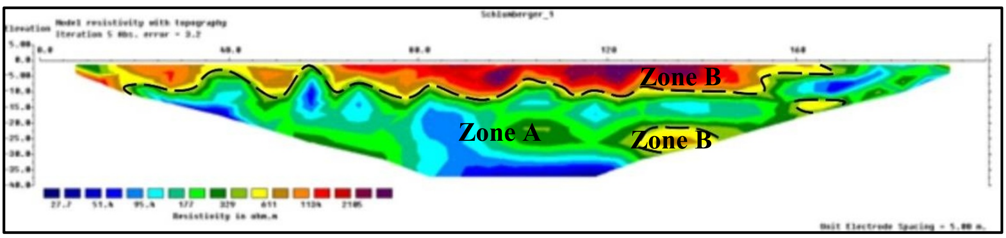

Figure 4. Pseudosection 2-D resistivity profile for Line 3.

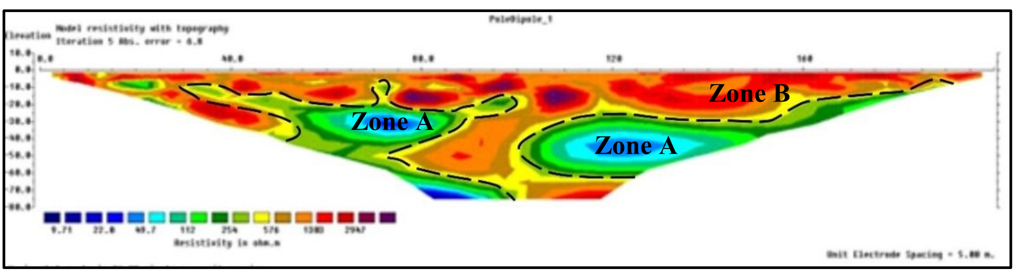

Figure 5. Pseudosection 2-D resistivity profile for Line 4.

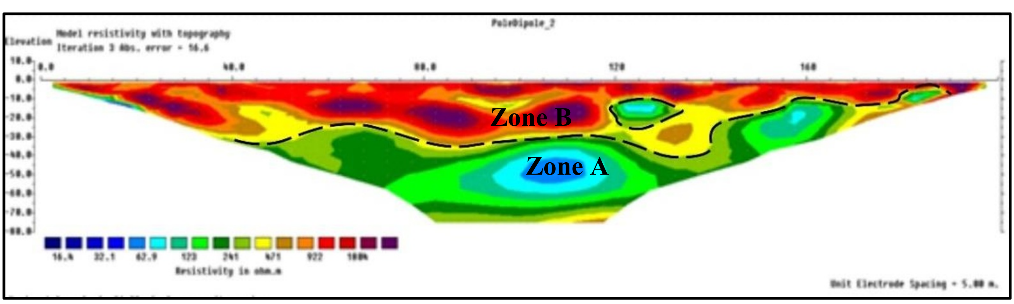

Figure 6. Pseudosection 2-D resistivity profile for Line 5.

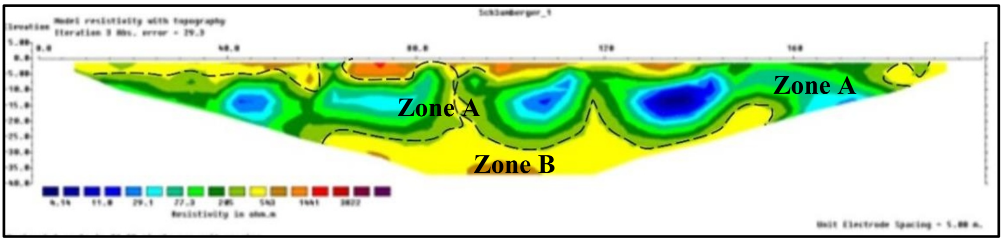

Figure 7. Pseudosection 2-D resistivity profile for Line 6.

5 Conclusion

Electrical resistivity imaging (ERI) was successfully used to investigate the probable landslide. According to the analysis of the pseudosection 2-D profile, high potential landslides due to low resistivity values and undulating conditions were found at depths of 5–10 m (survey Line 2), 10–20 m (survey Line 3), and 5–20 m (survey Line 6) from the ground level of the resistivity Lines 2, 3, and 6, respectively. In general, the resistivity survey's seven pseudosections showed two distinct types of soils: permeable to dry residual soil (1–1500 Ωm) and hard soil to weathered volcanic rocks (>1500 Ωm). Residual soils with varying saturation levels, dense/hard soil, and weathered volcanic rock have dominated the soil profile. These profiles can generally be divided into two (2) zones: zone A, which is composed of a thin/thick layer of loose to dense residual soils (10–100 Ωm), and zone B, which is composed of a thin/thick layer of dense and hard material (> 1000 m). The findings have demonstrated that this strategy helped identify water sources and probable landslides to support the traditional method. This geophysical method is appropriate for our risk assessment of prospective landslides since it may complement other traditional methods and save time and money, particularly using a 2-D surface style of inquiry. The drilling approach ought to be carried out to increase the precision and accuracy of these findings.

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