Lithology and characteristic of landslide in Gombel Hill by 2D geoelectric resistivity method using dipole-dipole configuration

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Abstract. Gombel hill locates at Semarang, Central Java, Indonesia. Based on Semarang’s susceptibility map zone, Gombel hill is belong to high susceptibility and instability zone. Instability may cause faults to Gombel hill area, unfortunately the geosciences research in Gombel is still lack. The geophysical survey has been conducted using 2D geoelectric resistivity method with dipole – dipole configuration to identify the lithology of landslide at Gombel hill. The data have been collected from three lines. The first and third line have 100 m length, and the second line have 80 m length with 5 m space in each lines. The data were processed and modelled using Res2Dinv software. From the first line, suspected there are two layers which formed the structure of the subsurface. The second line suspected there are three layers which formed the structure of the subsurface. And the last line suspected there are two layers which formed the structure of the subsurface. Overall, the landslide of Gombel hill area can be found with depth 5 m – 6 m and found at contact between clay and clay rock layer. We expect the results can be used for mitigation hazard and planning the developing infrastructure in Gombel area.

Keyword: Resistivity, geoelectric, dipole-dipole, Gombel

1. Introduction
 Geoelectrical method is widely used by geophysicist and geotechnic to find water aquifer (Todd, D.K, 1980), ground sub surfaces structure with shallow depth (Reynolds, 1997), to identify a fault, landslide area, and ground water waste pollution (Suhendra, 2006) and (Juandi, 2003). This method can be done to get 1D, 2D, even 3D model where every model is obtained through acquisition with different configurations. 1D modeling is obtained by using Wenner or Schlumberger method, and the 2D modeling is obtained by using dipole-dipole method, pole-dipole method, or the combination of Wenner-Schlumberger method. And 3D modeling can be obtained by using pole-pole, pole-dipole, or dipole-dipole method. (Loke, 2000).

Gombel is a hilly area in the Southern part of Semarang City. Gombel is one of the hills which is located between the old Gombel road and new Gombel road, moreover the geological formation consists of Kaligetas formation and Kerek formation. Around this area, there is a fault that clearly
exposed. Moreover, base on Semarang’s susceptible map (Figure 1), Gombel hill is belong to high susceptibility zone, so the ground will easy to move. This makes the area is very susceptible and instability. This instability may cause faults to Gombel hill area. The faults that exist in this area are horizontal fault which has direction from East to West, and the reverse fault which has direction from Southeast to Northwest.

**Figure 1.** Susceptibility Zone Map at upper Semarang area, the pinks color are high instability land, yellow is middle instability land and green is stable area.

If the ground is easy to move, it will be dangerous for people who live around that area. Otherwise Gombel area has still lack in geoscience research such as identify the subsurface lithology and structure. Based on that phenomena we study geophysical research which objective to identify the lithology of landslide that exist in Gombel Hill using 2D dipole – dipole geoelectrical method and how deep the landslide. The result may help the related government to plan the mitigation hazard and develop the infrastructures in Gombel hill area.

2. Geology of Gombel Hill

Based on the Gombel geological map as presented in Figure 2. Wahjono, 2002 was described there are three types of rock, the alluvium sedimentary, breccia rock from Kaligetas formation, and clay rock from Kerek formation. The Breccia rock were exposed on the slope of the Mt. Gombel with brownish-black weathering, and the fresh one is yellowish-grey, compact, hard, composed by fragments with size 3-30 cm. Most of breccia rock has gone through intensive fault and the fault had been filled with secondary material.

**Figure 2.** Geological map of Gombel area, red lines are line of geoelectric measurement.
Clay rock in this area are spread throughout most of the lower part of the slope of Mt Gombel and composed of clay rock with some thin silt stone and a bit of sands. This rock mostly exposed on the surface and showed the intensive weathering and avalanche. Geological structure of this area is the fault structure with North-South direction and marked by straight escarpment along the Gombel old road and exists the spring along the fault with large debit (Sendang Penganten spring). The secondary fault is cutting the main fault with West-East direction (Wahjono, 2002).

3. Methodology
Geoelectric method is one of the geophysical method which utilize the current to know the substance of earth subsurface and determine the resistivity distribution under the surface by doing the measurement on the surface. The resistivity is very concerned with geological parameters such as mineral, liquid content, porosity, percentage of water-filled fault, and water saturation degree on the rock (Singh, 2004).

The principal of the method is to inject current into the earth so the potential value from the subsurface rock can be obtained. Ohm’s law said that, the voltage V from a material depends on the current I which passing through it and the resistance R that already in the material. Ohm’s law also assumes that the resistance R is not dependent on I (R is constant) but there a condition where R doesn’t constant and said as a non-liner and formulated as equation 1.

\[ V = I R \]  

If it is assumed that the current flows through the medium under surface consists of different layers of materials and it has different resistivity. If the layers are horizontal, then the resistivity \( \rho \) of a layer formulated with equation 2.

\[ \rho = R \frac{A}{L} \]  

where L is the length of a material, A is the size of cross-sectional area which assumed as homogeneous cylindrical conductive (Herman, 2001).

This study has been done with three different lines. The first line has 100 m distance with spacing distance 5 m. The second line has 80 m distance with spacing distance 5 m. And the third line also has 100 m distance with spacing distance 5 m. Data acquisition acquired by using geoelectric method with dipole-dipole configuration. This configuration has electrodes formation as shown in the Figure 3 (Darsono, 2012)

Figure 3. Electrodes formation for dipole-dipole configuration (Darsono, 2012)

Figure 3 were explain that \( r_1 \) is \( C_1 P_1 \) or \( n_a \), \( r_2 \) is \( C_2 P_1 \) or \( n_a+a \), \( r_3 \) is \( C_1 P_2 \) or \( na+a \), and \( r_4 \) is \( C_2 P_2 \) or \( na+2a \). Geometry factor for dipole-dipole configuration shown at the equation 3 below:

\[ k = \pi n (n + 1)(n + 2) a \]
with k is the dipole – dipole configuration, \( \alpha \) is the spacing between two electrodes, \( na \) is the spacing between potential electrode with current electrode and n is integers number (Reynolds, 1997).

4. Result and discussion

Result of the research were presented in several figure that consists of resistivity cross section. Figure 4 is a resistivity cross-section at line 1. First line has coordinate at 7° 2’ 21,22” S and 110° 25’ 14,81” T with 100 m distance and 5 m spacing distance between electrodes. The resistivity cross-section above shows the depth which obtained from data processing is about 6 meters with resistivity interval value start from 0 \( \Omega \)m to 61.3 \( \Omega \)m.

Also from the cross-section above, it can be interpreted that there are two layers which build line 1 sub surface. The first layer has resistivity value from 0 \( \Omega \)m to 6.76 \( \Omega \)m with depth between 0 meters to 5 meters and supposed it is clay. Furthermore, the second layer has resistivity value from 6.77 \( \Omega \)m to 61.3 \( \Omega \)m with depth more than 6 meters and supposed it is clay rock. The interpretation above can be proven by drilling data which took at measurement area. According to drilling data (Figure 5), 0 m – 7 m depth has three layers, they are sandy clay, clay, and clay rock. But in the cross-section at line 1 shows that there are just two layers, this is due to the resistivity between sandy clay and clay have almost the same range, so it can be assumed that those two layers is a single layer.

Based on the interpretation above, it can be assumed that the landslide can be found on the contact between clay and clay rock layer (black stripe) at depth 5 meters to 6 meters. Because of the layer of clay is unstable layer. If there is a changes of mass which occurred due to construction of building or addition of water from rain, the structure that impermeable will not be able last long and landslide will occur.

![Figure 4. Resistivity Cross-section at Line 1](image-url)
Figure 5. Drilling Data at Line 1 (Wibowo, 2008)

Line 2
Figure 6 shows a resistivity cross-section at line 2 which coordinate at 7°02’ 28,62” S and 110° 25’ 14,42” T. with 80 m distance and 5 m spacing distance between electrodes. The resistivity cross-section above shows the depth which obtained from data processing is about 9 meters with resistivity interval value start from 0 Ωm to 181 Ωm.

Also from the cross-section above, it can be interpreted that there are three layers which build line 2 sub surface. The first layer has resistivity value from 0 Ωm to 12.8 Ωm with depth between 0 meters to 6.79 meters and supposed it is clay. Furthermore, the second layer has resistivity value from 12.9 Ωm to 74.8 Ωm with depth between 6.8 meters to 7.5 meters and supposed it is clay rock. The last layer has resistivity value between 74.9 Ωm to 181 Ωm with depth more than 7.5 meters and supposed to be the rock of vulcano breccia which formed from Mt. Ungaran product.

Based on the interpretation above, it can be assumed that the landslide can be found on the contact between clay and clay rock layer (black stripe) at depth 6 meters to 7 meters. This is the same case with the case at line 1 which the layer of clay is unstable layer. If there is a changes of mass which occurred due to construction of building or addition of water from rain, the structure that impermeable will not be able last long and landslide will occur easily.
Figure 6. Resistivity Cross-section at Line 2

Line 3

The third line has coordinate at 7°02’ 18,54” S and 110° 24’ 21,53” T. with 80 m distance and 5 m spacing distance between electrodes. The resistivity cross-section presented in Figure 7 which shows the depth which obtained from data processing is about 6.79 meters with resistivity interval value start from 0 Ωm to 16 Ωm

Figure 7. Resistivity Cross-section at Line 3

Base on the cross-section Figure 7 and drilling data (Figure 8), it can be interpreted that there are two layers which build line 3 sub surface. The first layer has resistivity value from 0 Ωm to 6,79 Ωm with depth between 0 meters to 5 meters and supposed it is clay. Furthermore, the second layer has resistivity value from 6.8 Ωm to 16 Ωm with depth more than 6 meters and supposed it is clay rock.

The interpretation above can be proven by drilling data which took at measurement area. According to drilling data, 0 m to more than 15 m depth has three layers, they are sandy clay, clay, and clay rock. But in the cross-section at line 3 shows that there are just two layers, this is due to the resistivity between sandy clay and clay have almost the same range, so it can be assumed that those two layers is a single layer.
The result from cross-section at line 1 and line 3 are almost the same. Based on the interpretation above, it can be assumed that the landslide can be found on the contact between clay and clay rock layer (black stripe) at depth 5 meters to 6 meters. Because of the layer of clay is unstable layer. If there is a changes of mass which occured due to construction of building or addition of water from rain, the structure that impermeable will not be able last long and landslide will occur. In addition, in this line was found a fault appearance (red square) and appropriate with the geological map which indicate the reverse fault.

**Conclusion**

2D geoelectrical resistivity method with dipole-dipole configuration has been used for finding landside location with three lines measurement area. It found that the landslide which exist at measurement area in Gombel hill are 5 meters to 6 meters depth at the first line, 6 meters depth at the second line, and 5 meters to 6 meters depth at the third line and they assumed found at the contact between the clay and clay rock which have unstable structure. Moreover to solving the instability land in Gombel area is needed construction engineering kind of grouting technique which is a liquid were injected with pressure according to water pressure test into the cavity and fracture than the liquid is in certain times will become physically and chemically solid.

**References**

[1]. Todd D.K. 1980 *Groundwater Hydrology Second Edition* (New York: John Wiley & Sons, Inc.)
[2]. Reynolds J.M. 1997 *An Introduction to Applied and Environmental Geophysics* p 418
[3]. Suhendra 2006 *Pencitraan Konduktivitas Bawah Permukaan dan Aplikasinya Untuk Identifikasi*
Penyebaran Limbah Cair Dengan Menggunakan Metode Geolistrik Thanan Jenis 2-D
(Jurnal Gradien Vol.2(1)) p105-108

[4]. Juandi M. 2003 Aplikasi Metode Geolistrik dalam Menganalisis Distribusi Limbah Kelapa Sawit
(Jurnal Natur Indonesia, 5(2)) p 119-123

[5]. Loke M.H. 2000 Electrical Imagine Surveys For Environmental and Engineering Studies. A
Practical Guide To 2-D And 3-D Surveys (Standford: Standford University Press)

[6]. Wahjono 2012 Evaluasi geologi teknik atas kejadian gerakan tanah di Kompleks Perumahan
Lereng Bukit Gombel-Semarang (Kasus longsoran Gombel, 8 Februari 2002) (Buletin
Geologi Tata Lingkungan Vol. 13 No. 2) p 32-43

[7]. Singh K.B, Lokhande R.D, Prakash A. 2004 Multielectrode Resistivity Imaging Technique For
The Study Of Coal Seam (Central Mining Research Institute: Jurnal of Scientific and
Industrial Research, Vol. 63 ) p 927-930

[8]. Herman R. 2011 An Introduction to Electrical Resistivitas in Geophysics (Journal of American
Association of Physics Teachers Vol 69) p 943-952

[9]. Darsono 2012 Landslide Identification using 2D Resistivity in Pablengan Area Indonesian
(Journal of Applied Physics (2012), no. 1, vol. 2) p 58