Mitigation of Land Movement Using Self Potential Method In Ling-Anjung Region, Sumedang Regency

B Santoso [1*], Setianto [2], M U Hasanah [1], B Wijatmoko [1], E Supriyana [1], I H Mohammad [1]

[*1] Department of Geophysics, FMIPA, Universitas Padjadjaran, Indonesia
[2] Department of Physics, FMIPA, Universitas Padjadjaran, Indonesia

*E-mail : budi@geophys.unpad.ac.id

Abstract. Land movement occurs due to reduced soil strength which is affected by water pressure. The Self Potential (SP) method is a geoelectric method that can detect well the flow of groundwater. The Self Potential method can also be used to detect the presence of debris flow in the form of weathered soil, tuff sand, cobble gravel and other rock fragments that have mixed with water. Based on the results of the SP measurement, debris flow has a medium SP with a value (3 - 12) mV, rock that has shifted (sandstone associated with andesite fragment) has a SP value < 2mV, while water seepage and water flow has an SP value (13 - 36) mV.
***Keywords* :** mitigation, land movement, self potential, Ling-Anjung

1. Introduction

Ling-Anjung region, Pasanggrahan Baru District, Sumedang Regency is a vulnerable area of land movement. The land movement in this area is still active to day. This can be seen from the condition of the houses of the residents who experienced cracks and the erosion that is still going on until now. Land movement is a geological event that occurs due to the movement of slope-forming material in the form of soil, rock or a combination of these types of material to a lower place due to the influence of gravitational force [1]. Land movement is a geological phenomenon to get a new balance due to the influence of external disturbances that causes a reduction in shear strength and an increase in soil shear stress [2;3].

According to Silitonga [4] the geology of the study area consisted of: volcanic breccias and andesite lava flows - basalt (the result of old volcanic breccia, Qvb), volcanic lava which showed tectonic joints and columnar joints of old volcanoes (Qvl), tuff sand, lapilli , breccia, lava and agglomerates, some of which originate from Mt. Tangkubanparahu and Mt. Tampomas (Qyu).

Generally geomorphology of Ling-Anjung is undulating hills, with slope: (20 - 70) degrees (Figure 1). Land movements occur on steep slopes with slopes > 40^{O} with altitude (565 - 675) m above sea level. Based on the geomorphology, then the Ling-Anjung is a hilly area. Hills are susceptible areas of land movement [5]. If the area experiences ground movement, it will affect the form of geomorphology and cause damage to homes and infrastructure [6;7].

Land movements in the Ling-Anjung region, Sumedang Regency in the form of debris flow that moves from the top of the cliff (south) towards the Sumedang highway (North). Debris flow is a phenomenon where mixing of water, mud and gravel flows at high velocity. One of the triggers of land movement in the study area is the presence of rainwater. The water-saturated soil layer will result in reduced soil strength, so that the soil is unstable and land movements occur.

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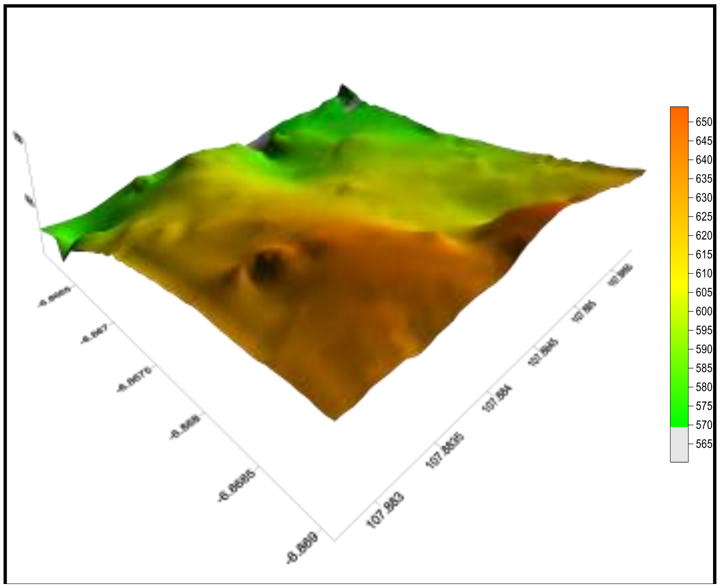

Figure 1. Geomorphology of Ling-Anjung, Sumedang Regency

Water flow in the soil can be detected from its self potential value (electrokinetic potential). The flow rate of water in the medium is proportional to the hydraulic gradient. The difference in water level compared to the distance between two points is called the hydraulic gradient head (∇H). Electrokinetic potential equation of Helmoltz-Smoluchowski :

$$\nabla V = \frac{\varepsilon_r \varepsilon_0 \zeta \rho g}{\eta \sigma_w} \nabla H = -C\nabla H \qquad (1)$$

where ζ: zeta potential, ε_r : relative liquid dielectric constant, ε_0 : dielectric constant in vacuum, η : fluid viscosity, C : electrohydraulic conductivity constant, ρ : fluid mass density (kg/m^3), g : gravity constant (9.81 m/s^2) dan H : height of water fluid (hydraulic head).
Groundwater flow normally (Darcy's Law):

$$\frac{Q}{A} = \frac{k}{\eta} \nabla P = \frac{k \rho g}{\eta} \nabla H = -K\nabla H \qquad (2)$$

where Q : flow rate (volume / time), A : Cross-*section area*, k : intrinsic permeability, dan K : hydraulic conductivity. $Q/A = v$ is Darcy's velocity (cm/s).

If equation 1 is connected with equation 2, then the fluid flow velocity (Darcy's law) will be obtained as follows:

$$v = K\nabla H = \frac{K}{C}\nabla V \quad (3)$$

where v : water flow rate (LT^{-1}), *k:* intrinsic permeability, (L^2), K : hydraulic conductivity (cm/det), η : fluid viscosity ($ML^{-1}T^{-1}$), *C :* electrohydraulic potential coefficient (mVolt/cm), ∇V : electrokinetic potential gradient ($MLI^{-1}T^{-3}$).

Equation (3) shows the relationship between fluid flow velocity (ground water) and electrokinetic potential anomaly (self potential), then the velocity of water flow is directly proportional to the value of self potential. If the rate of seepage of water in the soil is higher, the self potential at ground level will be higher too.

Mitigation of land movements can be well identified using the Self Potential Method [8;9], can also be used to determine groundwater flow in the land movement area [10] and get its hydrological pattern [11]. SP method is a geoelectric method that is very cheap, the measurement is fast in determining the groundwater flow and determining the field of land movement.

2. Experimental Section

2.1. Tools and Materials

The tools and materials used in this research are :

- Digital multimeter Fluxe 1567
- Porous pot
- Porous pot connecting cable with multimeter

Porous pot is metal electrodes that are hung in saturated solutions (such as copper in a copper sulfate/$CuSO_4$ solution) in a porous place.

2.2. Methods used

The Geophysical Method used in this reaearch is the Self Potential (SP) method. The Self potential (SP) method is a passive method, because the measurements are carried out without injecting electric current through the soil surface, the natural potential difference in soil is measured through two points on the ground. Measurable potential ranges between several millivolts to 1 volt.

Data acquisition of self potential uses fixed base method. In this method one electrode is at a fixed point (reference point), while the other electrode moves / moves away from the reference point for each measurement. The self-potential measurement scheme using the Fixed Base Method is shown in Figure 2.

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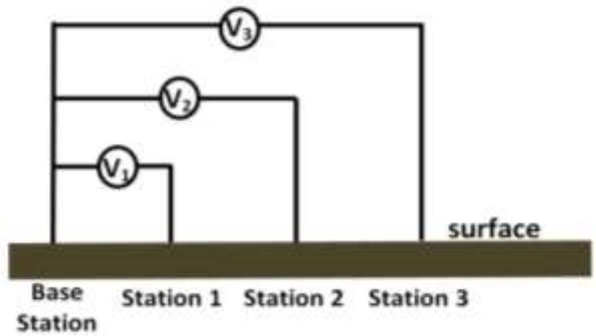

Figure 2. Method of SP Acquisition with Fixed Base Method

3. Results and Discussion

The results obtained in this research were 3 section of self potential (SP). The position of the self potential line is shown in Figure 3. Line 1 and line 2 directed north-south, while line 3 is east-west.

Figure 3. Position of Measurement Line SP

In Figure 4 shows the cross section of the Self Potential (SP) line 1. At distance: (10 - 210) m there is a lens pattern with a value of 2 mV (black) which is suspected to be rock that has shifted (tuff sand / breccia), while the SP anomaly with value: (3-12) mV (yellow-green color) is thought to be a flow of debris. The debris flow is weathered soil, tuff sand, cobble gravel and other rock fragments that have mixed with water. High self potential with value: (13 - 36) mV (blue color) indicated that water seeps into the ground through the rock fracture structure found on the surface and flows from the top of the slope towards the bottom of the slope. The presence of this water flow affects the shear strength and shear stress of the soil, causing the soil material to shift so that the land movement occurs.

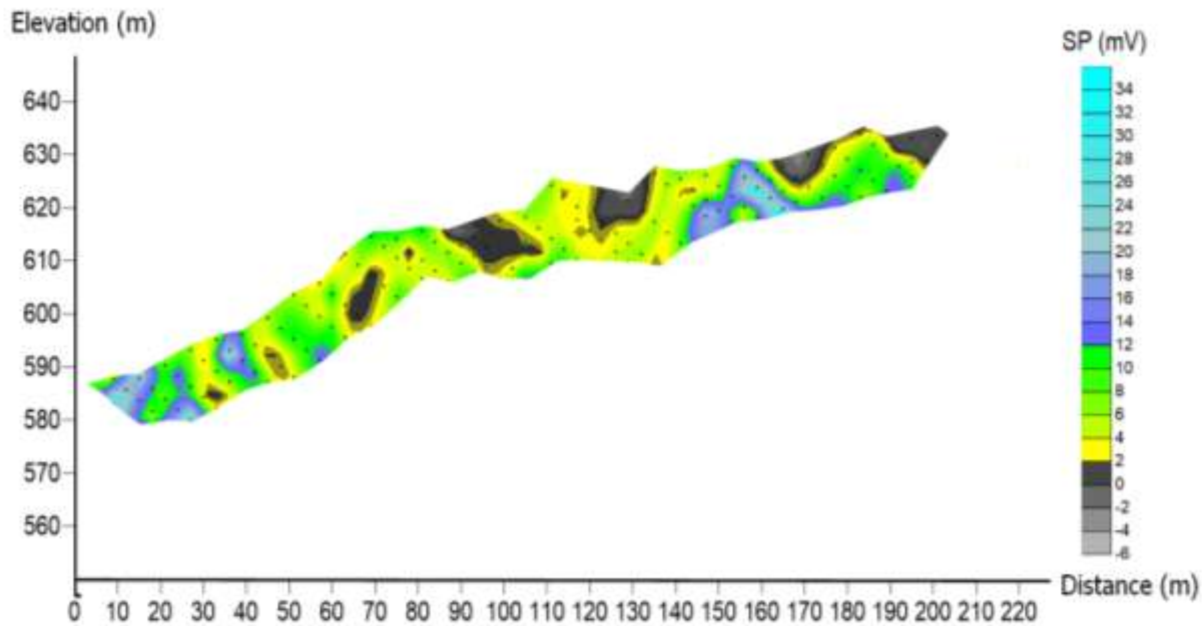

Figure 4. SP Section of Line 1

In Figure 5 shows the Self Potential Section of line 2. In the near surface layer there is a lens pattern with a value of: (2-10) mV (yellow-green color) which is indicated to be a layer of soil that has shifted in the form of debris flow (mixing water with soil consisting of weathered soil, tuff sand, cobble gravel and other rock fragments). The very low SP value with a value of < 2 mV is indicated as a breccia fragment located at a distance of 30m and 170m. At the bottom layer there is a high SP anomaly which is found in almost all parts of the cross section, indicated groundwater flow associated with Tufa rock. The water contained in the Tufa layer is such consolidated water, which is obtained from the result of infiltration from the ground. Tufa has small porosity and is almost water resistant. The water contained in the Tufa layer will press the soil horizontally and vertically if the layer is saturated, so that Soil Strength above the tuff layer will decrease and experience soil shifting.

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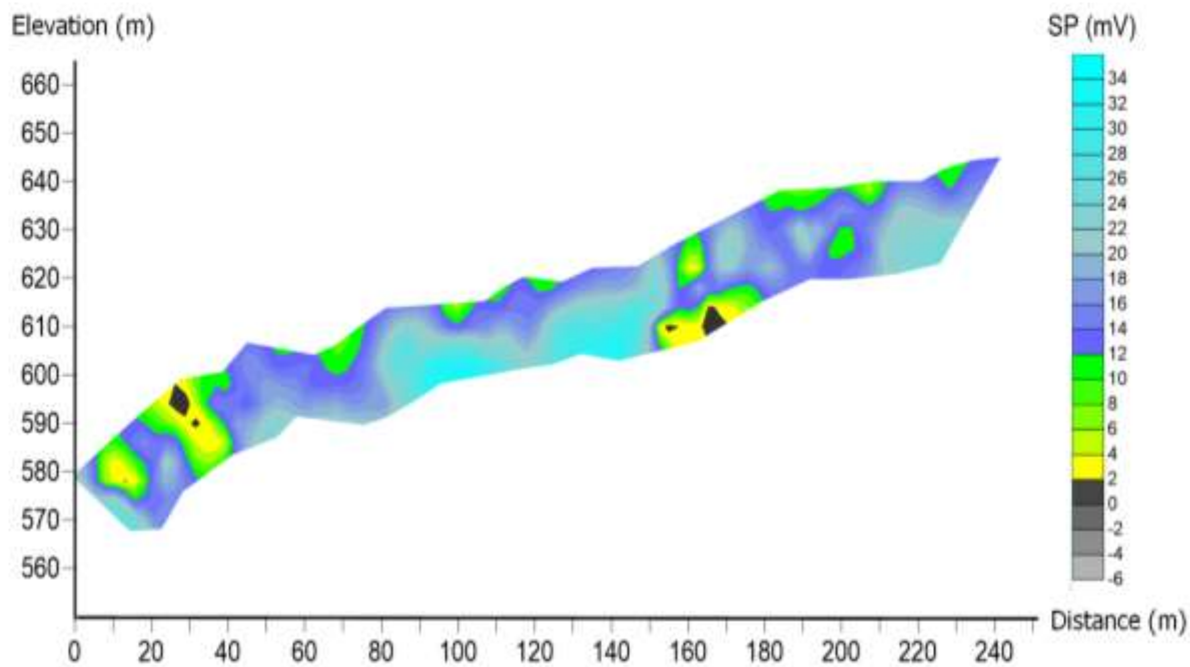

Figure 5. SP Section of Line 2

In Figure 6 it shows SP section of line 3. The SP anomaly pattern on the line 3 is different from the SP anomaly pattern on the line 1 and the line 2, because the SP section of line 3 directed the West-East (parallel to the slope) while cross sections of line 1 and 2 cut the slope (North-South). Anomaly SP with a high value > 12 mV (blue) is located at 15m, (95 - 125) m, 170m and 230m, high SP values indicate an indication of water flow or water seepage. On the cross section of SP there is a lens pattern with low SP anomaly with < 2mV (black color) value showing a solid layer of rock that has a shift. Indication of the debris flow (mixing of water and soil) is present in SP section with SP anomaly value (6 - 12) mV (yellow-green color).

Based of the Self Potential (SP) section on line 1, line 2 and line 3, the SP anomaly that indicated land movement can be detected, because the land movement is affected by the flow of water. This Self

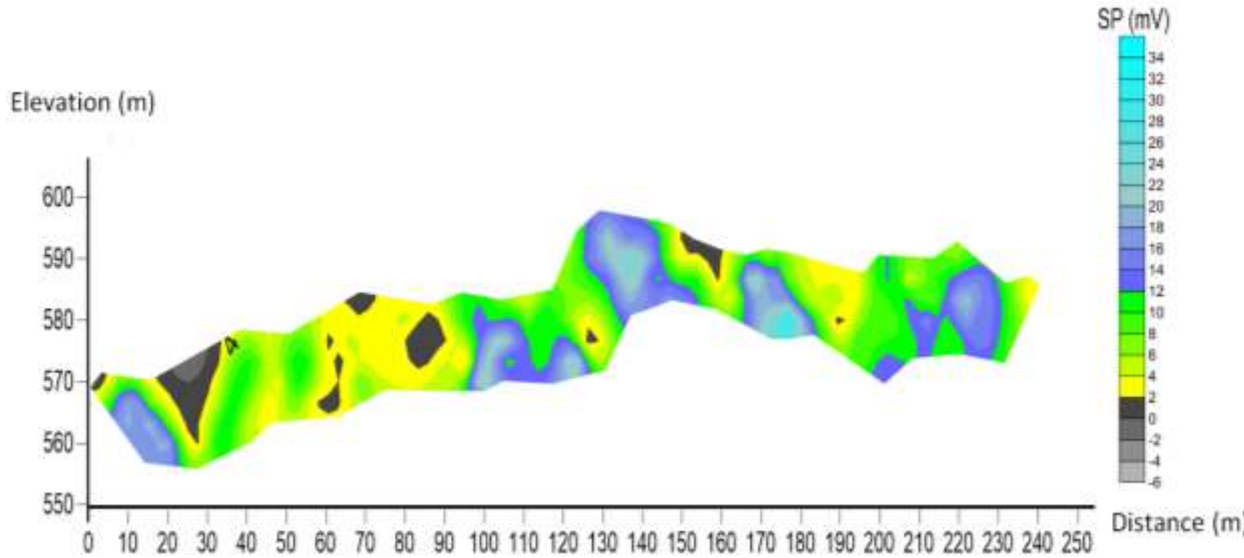

Figure 6. SP Section of Line 3

Potential method is sensitive to the movement of materials containing water such as debris flow. Mitigation of land movement with the self potential method can be used as supporting data in designing cliff reinforcement.

4. Conclusion

Mitigation of land movement by the Self Potential (SP) method can identify land movement (lens pattern - in the SP section) with SP value < 2mV, while water flow and groundwater seepage can be detected from high SP values > 12mV. This water is one of the factors that trigger the occurrence of land movements. The debris flow (mixing water with soil consisting of weathered soil, tuff sand, cobble gravel and other rock fragments) can be identified from the results of measurements of SP with medium values: (6 - 12) mV.

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References

[1] Chowdhury R N 1978 *Slope Analysis* Elsevier Amsterdam
[2] Sassa K and Canuti P 2009 *Landslides Disaster Risk Reduction* Springer-Verlag Berlin Heidelberg oke,M.H.

[3] Malamud B D, Turcotte D L, Guzzetti F and Reichenbach P 2004 Landslide Inventories and Their Statistical Properties *Journal of Earth Surface Processes and Landforms* 29 (6) 687–711

[4] P H Silitonga 1973 *Geological Map of Sheet of Bandung Java* Geological Research and Development Center

[5] Bell R, Petschko, H Röhrs M and Dix A 2012 Assessment of Landslide Age, Landslide

[6] Crozier M J 2010 Landslide Geomorphology: An Argument for Recognition, With Examples rom New Zealand. *J.Geomorphology* 120 (1-2) p3–15

[7] Korup O, Densmore A L and Schlunegger F 2010 The Role of Landslides in Mountain Range Evolution *J.Geomorphology* **120** (1-2) p77–90

[8] A.Boleve, J.Vandemeulebrouck, J.Grangeon, 2012, Dyke Leakage Lozalization and Hydraulic Permeability Estimation Through Self Potential and Hydro-Acoustic Measurements : Self Potential Abacus Diagram for Hydraulic Permeability Estimation and Uncertainty Computation, *J.Applied Geophysics 8, p17-28*

[9] Fawu Wang, Austin Chukwueloka-Udechukwu Okeke, Tetsuya Kogure, Tetsuya Sakai, Hisao. G. Colangelo, V. Lapenna, A. Perrone , S. Piscitelli, L. Telesca, 2006, 2D Self-Potential tomographies for studying groundwater flows in the Varco d'Izzo landslide (Basilicata, southern Italy), *J.Engineerng Geology, Vol.88, p274-286.*

[11] Laurence Jouniaux, Alexis Maineult, Véronique Naudet , Marc Pessel, Pascal Sailhac, 2009, Review of self-potential methods in hydrogeophysics Revue des méthodes de potentiel spontané en hydrogéophysique, Comptes Rendus Geoscience, Vol.341, p928-936.