U Karst
Volume 08 Number 01 Year 2024

ISSN (*Online*) 2581-2157
ISSN (*Print*) 2502-9304

Available Online at
https://ojs.unik-kediri.ac.id/index.php/ukarst/index

https://dx.doi.org/10.30737/ukarst.v8i1.5557

Unveiling Subsurface Characteristics of Cliff Land in Sibang, Bali Through Geoelectric Investigation

N. A. Diana[1*], G. E. Mareta[2]

[1*] *Department of Civil Engineering, Faculty of Engineering, Janabadra University, Yogyakarta, Indonesia*

[2]*Department of Civil Engineering, Faculty of Engineering, Institut Teknologi Adhi Tama Surabaya, Surabaya, Indonesia*

Email: [1*]nurayu@janabadra.ac.id, [2]ganecaefamareta@gmail.com

A R T I C L E I N F O

Article History :
Article entry : 31 – 03 – 2024
Article revised : 05 – 04 – 2024
Article received : 26 – 04 – 2024

Keywords **:**
Cliff Soil, Geoelectrical, Geological Risk Management, Geology Subsurface.

IEEE Style in citing this article :
N. A. Diana and G. E. Mareta,, "Unveiling Subsurface Characteristics of Cliff Land in Sibang, Bali Through Geoelectric Investigation," U Karst, vol. 8, no. 1, pp 67 – 81, 2024, doi: 10.30737/ukarst.v8i1.5557.

A B S T R A C T

The unique geological formations and environmental dynamics of cliffs underscore the significance of comprehending soil composition and structural integrity for diverse applications, such as infrastructure development and environmental conservation. Geoelectrical needs to be done because the underground geological conditions of the cliff must be researched and assessed first before construction is carried out so that construction failure does not occur. This research aims to reveal the subsurface characteristics of cliff soil in Sibang, Bali through geoelectrical investigation. This research was conducted by evaluating the soil condition in the field using the geoelectric resistivity method to the ability of a material to inhibit the flow of electric current and geological regional theories. At points BL-01 and BL-04, there is a significant potential risk of landslides due to the thick layer of breccia, especially during high rainfall or additional loads in the area. Point BL-02 also has a potential risk of landslides due to the thick layer of basalt and wet sand. Meanwhile, points BL-03 and BL-05 are more ideal locations for construction because they consist of relatively stable hard rock. Point BL-06 outside the development zone has layers of gravel, weathered tuffa and andesite which could be considered for future development. Thus, a deep understanding of the geological characteristics of each point is important to manage risks and ensure the safety and sustainability of construction projects in that area.

1. Introduction

Mountainous cliffs are dynamic geological features shaped by intricate interactions between geological processes and environmental forces. Understanding the subsurface

ISSN (*Online*) 2581-2157
N. A. Diana / U Karst Vol 08 No. 01 Year 2024 ISSN (*Print*) 2502-9304

characteristics of cliff soils is crucial for various purposes, including infrastructure development, environmental conservation, and hazard mitigation [1][2][3]. Sibang is an area located in the southern of Bali, Island Indonesia. Geographically, Sibang is around the coordinates -8.5502427,115.233377.

The region is renowned for its stunning natural landscapes and rich geological diversity. The existence of traditional Balinese villages that maintain local wisdom and authentic Balinese culture, creates special tourism potential in this region. Cliff land in Sibang has great potential for various developments that can support development and environmental preservation. The natural beauty and cliff landscape are the main attractions for sustainable tourism development. Infrastructure development such as roads or tourist facilities such as hiking trails and photography spots can increase tourist visits and have a positive impact on the local economy. In addition, preserved and conserved clifflands can play an important role in maintaining biodiversity and maintaining natural ecological functions[4][5].

To realize these things, the complexities of cliff soil dynamics need to investigate the subsurface characteristics of the cliffs in Sibang. The cliff areas in Sibang are prone to erosion and instability, posing significant risks to infrastructure, settlements, and the environment. This will provide a deeper understanding of the geological conditions and potential risks, thereby assisting in planning and sustainable development in the region. Previous research in geotechnical engineering has explored various methods to assess soil stability and subsurface characteristics in different geological conditions. One of the method that has been applied is geoelectricity studies, aimed to characterizing soil properties in urban environments. It investigates the relationship between electrical resistivity and soil texture, moisture content, and compaction. Findings indicate that geoelectrics offer valuable insights into soil characteristics in urban area, aiding in land use planning and infrastructure development [2][6][7]. Additionally, there is research exploring the use of geoelectrical imaging techniques for environmental characterization, particularly in identifying subsurface features such as contaminants and geological structures. Integration of electrical resistivity tomography with other geophysical methods has proven capable to delineating subsurface anomalies with high resolution [8][9][10]. The findings underscore the importance of environmental remediation projects and groundwater management. The lack of comprehensive knowledge about the subsurface composition exacerbates these risks, making it imperative to conduct a geoelectrical investigation to uncover vital insights into the soil structure and composition [11][9].

https://dx.doi.org/10.30737/ukarst.v8i1.5557

ISSN (*Online*) 2581-2157
ISSN (*Print*) 2502-9304

While existing studies may offer valuable insights into geoelectrical methods and soil characterization techniques, they often lack the specificity required to address the unique challenges posed by cliff environments in this particular region [12] [13] [14]. Thus, geoelectrical methods emerge as valuable tools for analyzing soil conditions on cliffs in the Sibang region However, it's noteworthy that such research has not been conducted in this area previously. This study aims to investigation geoelectrical to unravel the hidden attributes of cliff soil in Sibang, Bali. By employing advanced geophysical techniques such as electrical resistivity tomography (ERT) and electromagnetic induction (EMI). An investigation will be carried out to map the subsurface structure, moisture distribution, and lithological variations along the cliff face [15][16][8][17][18]. Therefore, conducting geoelectrical studies in Sibang can provide better insights into subsurface soil characteristics on cliffs, which is crucial for infrastructure development and environmental conservation in the region. By unraveling the subsurface characteristics of cliff soil in Sibang, Bali, this research endeavors to provide valuable insights for informed decision-making and sustainable development initiatives in coastal regions worldwide.

2. Research Method

This research was conducted by evaluating the soil condition in the field using the geoelectric resistivity method to the ability of a material to inhibit the flow of electric current and geological regional theories. Both methods can very accurately produce rock consistency conditions in soil layers based on their depth. A total of, 6 measurement points were obtained which are listed in the measurement coordinate for the construction of resort villa plans in **Table 1**. Sampling was conducted for sounding and profile creation. Analysis was carried out to determine the rock consistency conditions within the soil layers at various depths.

Table 1. Geoelectric Measurement Coordinate Points.

No.	Station	UTM	X	Y
1.	BL-01	50	0303392	9052062
2.	BL-02	50	0303394	9052129
3.	BL-03	50	0303378	9052070
4.	BL-04	50	0303387	9052058
5.	BL-05	50	0303366	9052104
6.	BL-06	50	0303396	9052097

Source: Field Data, (2023).

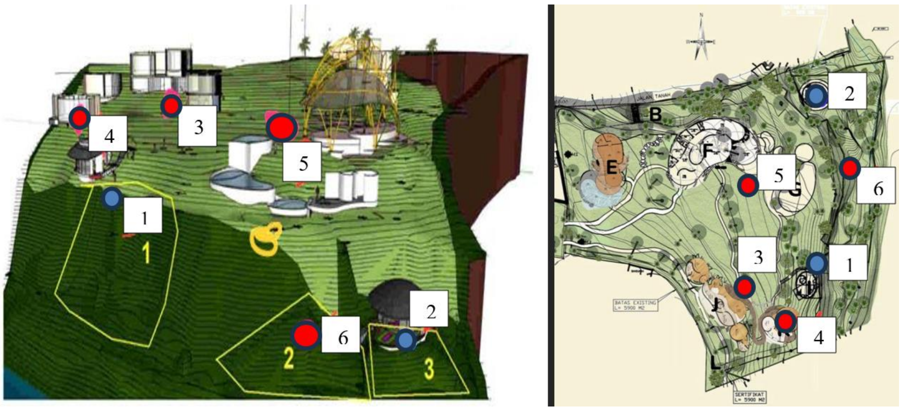
Figure 1 shows each survey point has a depth of 60 meters from the ground surface. Geoelectric measurements typically involve conducting surveys at specific coordinate points

https://dx.doi.org/10.30737/ukarst.v8i1.5557

70 - 81
ISSN (*Online*) 2581-2157
ISSN (*Print*) 2502-9304

to map the subsurface characteristics of an area. These coordinate points are selected strategically to ensure adequate coverage and representation in Sibang, Bali.

Sampling for sounding using stratified purposive sampling method, based on topographic levels or strata. Besides, the sounding path is also selected based on criteria as follows, track length ≥410 m, the track is straight, not winding. Several sounding paths are measured the parameters will use the configuration in **Table 2**, to determine resistivity variations below the surface in the vertical direction. In each, The track will be made at 6 sounding points for electrode measurements. Sampling for profiling using stratified purposive sampling method, based on topographic levels.

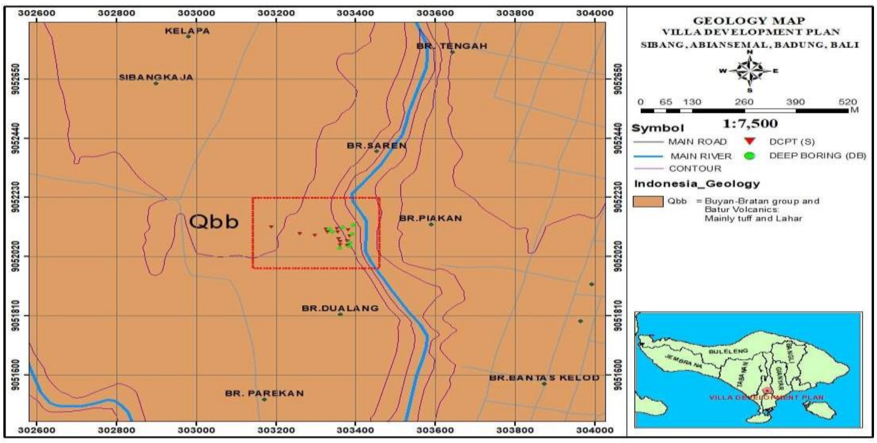


Source: Field Data, (2023).

Figure 1. Geoelectric Measurement Coordinate Point.

2.1 Geology Regional Theoris

In general, the rock layers in the review area are Bayan-Bratan Group and Batur Volcanics (Qbb) as predicted by the geological description from (www.indonesia-geospasial.com). In **Figure 2** the following Geological map of soil investigation area in Bali.



Source: www.indonesia-geospasial.com

Figure 2. Geological Map of Soil Investigation Area

https://dx.doi.org/10.30737/ukarst.v8i1.5557

ISSN (*Online*) 2581-2157
ISSN (*Print*) 2502-9304

a. Bayan-Bratan Group and Batur Volcanics (Qbb)

The Bayan-Bratan Group and Batur Volcanics (Qbb) mainly consist of tuffaceous and lavaceous. Tuff is commonly in a light to dark brown color due to the process of weathering and leaching of its mineral. In general, the mineral content of tuff is more complex in the deeper layer, such as iron, aluminum, peats, and clay. While material formed from volcanic mountains has coarse grain size like sand and gravel.

Interpret the resistivity data in conjunction with stone-type information to characterize the subsurface geology. **Table 2** is the correlation of resistivity data for Different types of stones.

Table 2. Correlation of Resistivity Data with Stone Type.

No	Resistivity Ωm	Color	Rock Type
1	> 100.000	(red)	Andesite
2	20.000 - 50.000	(orange)	Breccia
3	10.000 - 20.000	(yellow)	Lava
4	5000 - 10.000	(light green)	Gravel
5	2000 - 5000	(green)	Tuff
6	1000 - 2000	(light blue)	Weathered Tuff
7	200 - 500	(dark blue)	Sand
8	< 200	(black)	Weathered Sand

Source: www.indonesia-geospasial.com

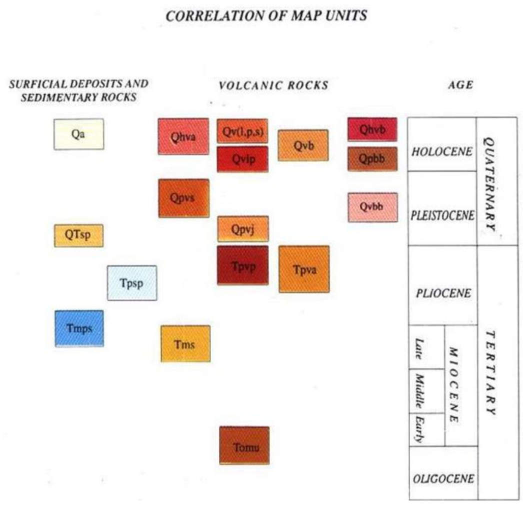
b. Structure and Tectonics

Recognized structures in Bali are fault & lineaments, generally trending WNW-ESE with area minor NE-SW direction. The oldest tectonics in the area are presumed to be present in late Oligocene, followed by volcanic activities. Andesitic to basaltic volcanics of the Ulakan Formation is the product of this volcanism. The volcanic activity took place until the early Miocene, Late Mocene is characterized by the deposition of the Surga Formation containing volcanic product. During the Late Miocene – Early Pliocene, reef limestone of the Selatan Formation was deposited.

The Southern area of the sheet. In the late Early Pliocene – early Late Pliocene volcanic activity led to produce the Pulaki Volcanics unit; followed by a deposition of the Prapatagung Limestone. Late Pliocene – Early Pleistocene is characterized by the deposition of volcanic breccia, lava, tuff, and fine to coarse clastic and carbonates. The volcanic activity takes place to the present time [19][20].

https://dx.doi.org/10.30737/ukarst.v8i1.5557

ISSN (*Online*) 2581-2157
N. A. Diana / U Karst Vol 08 No. 01 Year 2024 ISSN (*Print*) 2502-9304



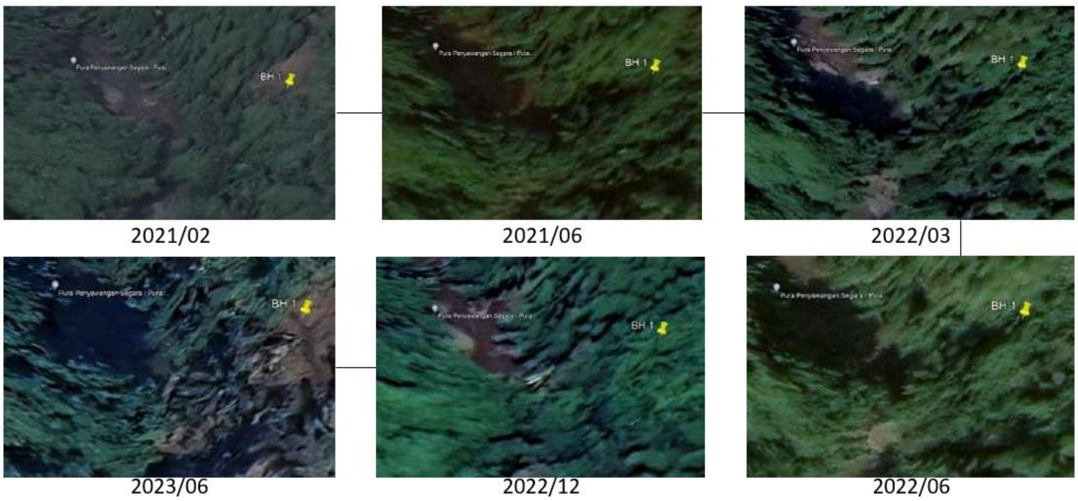
Source: www.indonesia-geospasial.com

Figure 3. Correlation of Map Unit of the Soil Investigation Area

3. Results and Discussions

3.1 Geology Regional

The location of the BH 1 drill point shown above the cliff has changed from year to year. In 2021 it was shown that the cliff location had a slope. At the beginning of 2022, it was shown that the location of the BH 1 drill point had traces of landslides and there were traces of a rainwater path to the river, and at the end of 2022 the rainwater path was closed and had a slope. Meanwhile, in mid-2023, the condition of the BH 1 drill point location will have a flat area and the cliff slope will be even steeper [21][22][23]. With these conditions it can be concluded that this location is not original soil and the age of the soil layer is relatively young.



Source: www.indonesia-geospasial.com

Figure 4. Google Earth Analysis.

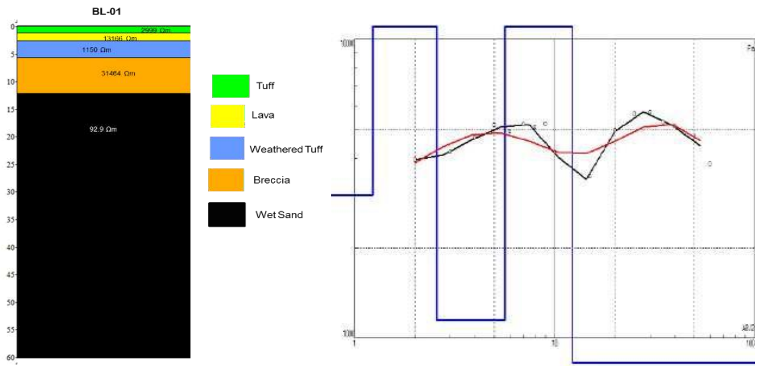
https://dx.doi.org/10.30737/ukarst.v8i1.5557

ISSN (*Online*) 2581-2157
ISSN (*Print*) 2502-9304

Significant changes in slope morphology and the surrounding environment can be important signs of potential geological hazards in the area. Therefore, it is recommended to immediately clean up the landslide material that is blocking the road and and not cutting down all the trees around the slope area. Combining geoelectric and soil investigations with landslide mitigation strategies can provide a comprehensive approach to address the underlying causes and potential risks associated with landslides.

3.2 Geoelectric Measurement

To obtain a subsurface model study location based on resistivity values, inversion was carried out on the five data obtained from each VES point whose results are shown in **Figure 5 – Figure 10**. The following are the results of geoelectric measurements at each point.



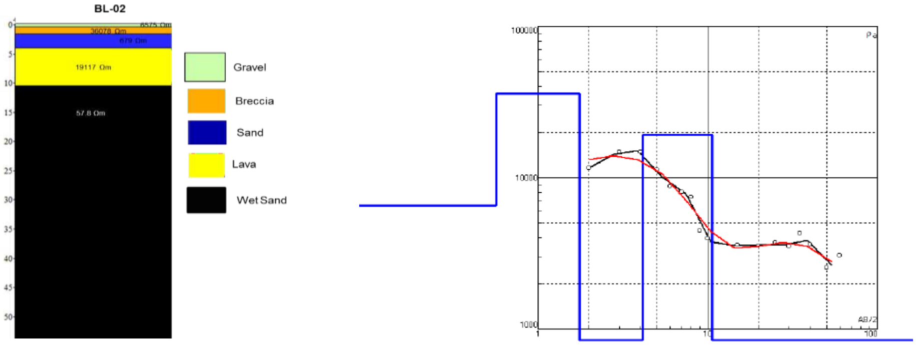
Source: Field Data, (2023).

Figure 5. Geoelectric Measurement Result at BH BL-01 Point

The location of the BL-01 geoelectric point is in polygon zone 1 where the main building will be built, at this point it is in a location with a rather steep slope. From the geoelectric results for this point, it was found that there are 5 layers (rock layers) with a total depth reaching a depth of 60 meters from the top of the ground surface. At the top of this surface there is tuff and lava to a depth of almost 3 meters then below it to a depth of 6 meters there is weathered tuff with a thickness of about 3 meters. Under the weathered tuff layer, there is a breccia layer to a depth of 12 meters with a breccia thickness of almost 7 meters. After that, there is a layer of wet sand from a depth of 12 meters to a depth of 60 meters. With indications that there is thick wet sand supported by steep topography, this indicates a significant potential risk of landslides, especially during high rainfall or if there is additional load on the area. The breccia layer found beneath the weathered tuff layer is quite large in thickness, which can affect slope stability and amplify the potential risk of landslides if there is an external disturbance such as an earthquake or human activity.

https://dx.doi.org/10.30737/ukarst.v8i1.5557

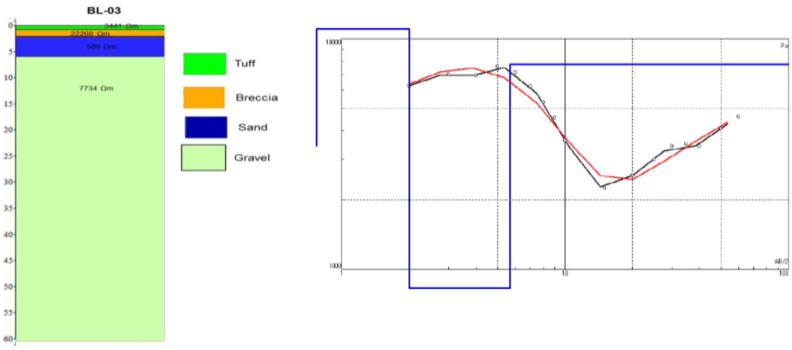
74 - 81
ISSN (*Online*) 2581-2157
ISSN (*Print*) 2502-9304



Source: Field Data, (2023).

Figure 6. Geoelectric Measurement Result at BH BL-02 Point

BL-02 point is above a large boulder in zone/polygon 3 and in that area, judging from the sketch we received, it appears that a building will be erected in the area. At this point the top layer is filled with layers of gravel and breccia to a depth of 2 meters, below that there is sand with a thickness of 2 meters then there is a layer of lava to a depth of more than 10 meters with a thickness of around 6 meters, there is a layer of wet sand from a depth of more than 10 meters to a depth of 60 meters. With indications that there is thick wet sand and there is some evidence of chunks breaking away from the parent rock, this has the potential for landslides if rainfall is intensive and there is a load on the area.



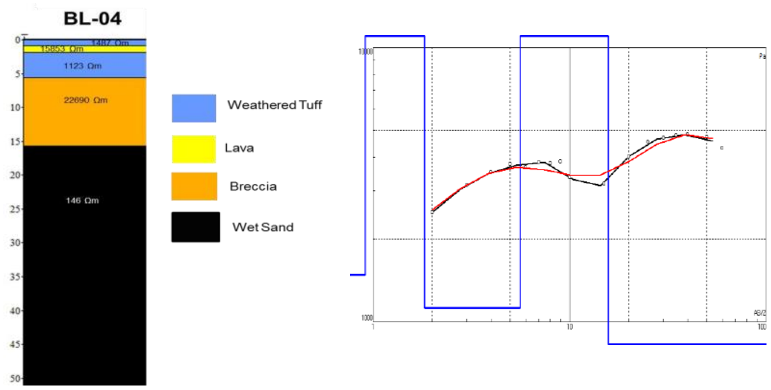
Source: Data Analysis, (2023).

Figure 7. Geoelectric Measurement Result at BH BL-03 Point

BL-03 point is at the top in an area that is quite spacious and not steep in the area that will be built. At this point the top is filled with a layer of tuff and breccia to a depth of 2 meters from the ground surface, below that there is a layer of sand to a depth of almost 6 meters and below that there is a layer of gravel from a depth of 6 meters to a depth of 60 meters from the ground surface. From result of geoelectric analysis, this point is ideal for constructing a building because judging from the layers, it is filled with relatively hard rock.

https://dx.doi.org/10.30737/ukarst.v8i1.5557

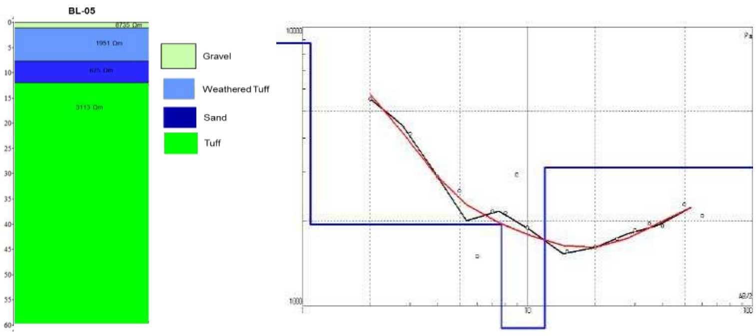
ISSN (*Online*) 2581-2157
ISSN (*Print*) 2502-9304



Source: Data Analysis, (2023).

Figure 8. Geoelectric Measurement Result at BH BL-04 Point

BL-04 point is at the top of BL-01 point in this area. The topography is quite steep, and around this area,.At the top of this layer consists of weathered tuff and lava to a depth of almost 2 meters from the ground surface, below the lava layer there is weathered tuff again to a depth of almost 6 meters. The breccia layer which is quite thick is in the fourth layer with a thickness of around 10 meters to a depth of almost 16 meters, there is a layer of wet sand from a depth of 16 meters to a depth of 60 meters. As at BL-01 point, with indications of thick wet sand and supported by steep topography, this has the potential for landslides if rainfall is intensive and there is a load on the area.



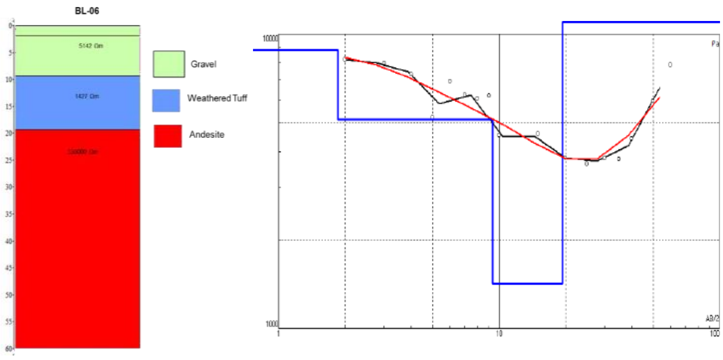
Source: Data Analysis, (2023).

Figure 9. Geoelectric Measurement Results at BH BL-05 Point

BL-05 point represents the swimming pool and hall building. At the top of this layer consists of a gravel layer to a depth of 1 meter from the ground surface, then there is a layer ofweathered tuff to a depth of almost 8 meters from the ground surface, after that there is a sand layer to a depth of almost 12 meters with a thickness of about 4 meters, an indication of the layer. tuff ranging from a depth of 12 meters to a depth of 60 meters. This area is ideal for building one or several buildings

https://dx.doi.org/10.30737/ukarst.v8i1.5557

ISSN (*Online*) 2581-2157
ISSN (*Print*) 2502-9304



Source: Data Analysis, (2023).

Figure 10. Geoelectric Measurement Result at BH BL-06 Point

BL-06 point is outside zone/polygon 2. At the top of this layer consists of a layer of gravel which is very thick to almost a depth of 10 meters from the ground surface, then there is a layer of weathered tuff to a depth of almost 20 meters from the ground surface with a fairly thick thickness of around 10 meters, below that is a layer Andesite from a depth of almost 20 meters to a depth of 60 meters above the ground surface.

3.3 Description of Soil Type Based on Geoelectric Survey and Drilling Result

Based on the results of the geoelectric survey at point BH BL-01, it is stated that the soil is dominated by cemented sand material attached to Figure 11. Meanwhile, based on the results of the drilling test, it is stated as follows:

Corebox at 0 – 5 m **Corebox at 5 – 10 m**

Corebox at 10 – 15 m **Corebox at 15 – 20 m**

Source: Field Data, (2023).

Figure 11. Corebox Soil Material

https://dx.doi.org/10.30737/ukarst.v8i1.5557

ISSN (*Online*) 2581-2157
ISSN (*Print*) 2502-9304

Figure 11 above at a depth of 0 to 1 m is the Sandy silt soil type, at a depth of 1 to 4 m is a sandy soil type, at a depth of 4 to 5 is weathered breccia rock, depth of 5 to 9 m is weathered breccia rock, at a depth of 9 to 10 m is a weathered breccia rock, depth of 10 to 15 m is weathered breccia rock with a very dense consistency, and depth of 15 to 17 m is a weathered breccia, at a depth of 17 – 20 is a breccia and tuffa.

The discovery of various types of soil and rock at various depths at the research location shows the complexity of subsurface characteristics in the region. The presence of clayey sandy soil at initial depths could potentially influence groundwater infiltration and increase the risk of erosion, while the presence of breccia rocks indicates a complex geological history and may be related to past volcanic activity. The discovery of breccia rocks that have been eroded at various depths reflects the weathering and degradation processes that occurred over a long period of time. The very dense consistency of the breccia rock at a depth of 10 to 15 meters indicates the possible presence of a strong rock layer below the ground surface, which could influence slope stability and geotechnical behavior in the area. In addition, the presence of breccia and tuff at deeper depths indicates the potential for older volcanic deposits below the ground surface, which could potentially influence the geology and hydrology conditions in the region as a whole.

Based on the results documented in the core box above, it can be stated that the soil type is suitable based on the geoelectric survey and drilling tests that have been carried out. This supports that the type of rock is young rock with a discontinuous description (massive rock) which was destroyed by the drill bit during the drilling test [15][24] [23][25].In the analysis of geoelectric test results and secondary data, as well as the correlation of geological data maps, it was found that the field test results matched the secondary data of geospatial data. At the geoelectric test location, BL 01-BL 06 shows that there are varying layers of soil. The results show that the area generally consists of Sibang Bali, caused by weathered limestone, tuff, and sand.

4. Conclusions

Based on the results of geoelectric measurements, it can be concluded that the type of rock displayed at each survey point is a type of young rock formed from the weathering of rock or sedimentation of hardened lava and the bottom layer is dominated by cemented sand. Based on Google Earth data, it was found that the BL-01 area was formed by landslides that occurred in previous years, therefore it is necessary to analyze the Safety Factor values on the

https://dx.doi.org/10.30737/ukarst.v8i1.5557

slopes that cover this area. At points BL-01 and BL-04, there is a significant potential risk of landslides due to the thick layer of breccia, especially during high rainfall or additional loads in the area. Point BL-02 also has a potential risk of landslides due to the thick layer of basalt and wet sand. Meanwhile, points BL-03 and BL-05 are more ideal locations for construction because they consist of relatively stable hard rock. Point BL-06 outside the development zone has layers of gravel, weathered tuffa and andesite which could be considered for future development. Thus, a deep understanding of the geological characteristics of each point is important to manage risks and ensure the safety and sustainability of construction projects in that area. Combining geoelectric and soil investigations with landslide mitigation strategies can provide a comprehensive approach to address the underlying potential geological structures that may influence landslide susceptibility.

5. Acknowledgments

The authors thankfully acknowledge the Soil Invertigation and Survey by PT. Geomarine Survey Dinamika and also the experts for making valuable suggestion to improve the quality and content of this research.

ISSN (*Online*) 2581-2157
ISSN (*Print*) 2502-9304

References

[1] K. Karimah, A. Susilo, E. A. Suryo, A. Rofiq, and M. F. R. Hasan, "Analysis of Potential Landslide Areas Using Geoelectric Methods of Resistivity in The Kastoba Lake, Bawean Island, Indonesia," *J. Penelit. Pendidik. IPA*, vol. 8, no. 2, pp. 660–665, 2022, doi: 10.29303/jppipa.v8i2.1414.

[2] O. T. Ojo, I. J. Chiaka, and A. I. Mark, "Geophysical Subsurface Mapping Using the Electrical Resistivity Technique: A Comprehensive Study of the Petroleum Training Institute Main Campus in Effurun," *Indones. J. Earth Sci.*, vol. 4, no. 1, p. A846, 2024, doi: 10.52562/injoes.2024.846.

[3] H. Mustafa, A. Maulana, U. R. Irfan, and A. Tonggiroh, "The Geoelectric approach to Analyzing the Profile of Post-Mining Nickel Laterite Deposits in the Motui District, North Konawe Regency, Indonesia," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 1134, no. 1, p. 012035, 2023, doi: 10.1088/1755-1315/1134/1/012035.

[4] U. Nuramadani, H. Halauddin, S. Suhendra, D. I. Fadli, A. P. Panjaitan, and J. E. E. Sinaga, "Assessment of Landslide Susceptibility Microzonation using Microtremor Measurements Along Mountain Road in North Bengkulu–Lebong, Bengkulu Province," *J. Geocelebes*, vol. 7, no. 2, pp. 130–137, 2023, doi: 10.20956/geocelebes.v7i2.25476.

[5] Basuki, N. Sulistiawati, D. Verdian, and Z. Naely, "The Sensitivity Level of Landslide Risk Using Geographic Information System on the Slopes of Mount Argopura, East Java, Indonesia," *J. Degrad. Min. Lands Manag.*, vol. 11, no. 1, pp. 4949–4959, 2023, doi: 10.15243/jdmlm.2023.111.4949.

[6] A. S. Akingboye and I. B. Osazuwa, "Subsurface geological, hydrogeophysical and engineering characterisation of Etioro-Akoko, southwestern Nigeria, using electrical resistivity tomography," *NRIAG J. Astron. Geophys.*, vol. 10, no. 1, pp. 43–57, 2021, doi: 10.1080/20909977.2020.1868659.

[7] A. Ferhat *et al.*, "A Geoelectric Approach for Karst Groundwater Analysis," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 998, no. 1, 2022, doi: 10.1088/1755-1315/998/1/012012.

[8] B. G. M. Saka, R. O. Tarru, E. Lolang, and A. Pakiding, "Identification of Slip Area in Makale Selatan District Using the Geoelectric Method," *J. Geocelebes*, vol. 7, no. 1, pp. 77–88, 2023, doi: 10.20956/geocelebes.v7i1.23654.

[9] S. J. Ikard, K. C. Carroll, D. F. Rucker, R. F. Adams, and S. C. Brooks, "Geoelectric Characterization of Hyporheic Exchange Flow in the Bedrock-Lined Streambed of East Fork Poplar Creek, Oak Ridge, Tennessee," *Geophys. Res. Lett.*, vol. 50, no. 8, 2023, doi: 10.1029/2022GL102616.

[10] S. O. Elkhateeb, W. Dosoky, A. Mohamed, and M. A. Abbas, "Geoelectric and Mineralogical Studies for Foundation Soil Characterization in New Luxor City, Upper Egypt," *Arab. J. Geosci.*, vol. 15, no. 13, pp. 1–12, 2022, doi: 10.1007/s12517-022-10450-6.

[11] J. Malone-Leigh, J. Campanyà, P. T. Gallagher, M. Neukirch, C. Hogg, and J. Hodgson, "Nowcasting Geoelectric Fields in Ireland Using Magnetotelluric Transfer Functions," *J. Sp. Weather Sp. Clim.*, vol. 13, no. 46, 2023, doi: 10.1051/swsc/2023004.

[12] S. G. Field and W. Java, "Landslide Susceptibility Analysis in Kabandungan District and Salak Geothermal Field, West Java," *J. Geogr. Lingkung. Trop.*, vol. 4, no. 2, 2020, doi: 10.7454/jglitrop.v4i2.75.

[13] S. Feranie and A. Et., "Recent developments in the use of geoelectric resistivity for landslide surveys: an overview," *Gravity*, vol. 9, no. 2, 2023, doi: 10.30870/gravity.v9i2.19876.

[14] I. . M. et all, "Quantitative interpretation of geoelectric inverted data with a robust probabilistic approach," vol. 88, no. 3, 2023, doi: 10.1190/GEO2022-0133.1.

[15] D. H. Hasibuan and A. F. Ismaili, "Bumi Berdasarkan Data Standard PentrationTest (SPT) Studi Kasus Proyek Bandara Baru Yogyakarta International Airport," vol. 06, no. 150, pp. 1–9, 2019.

[16] E. Yuwono, "Estimating Geoelectric for The Clean Water Necessity Prediction (Case Study : Abdul Rachman Saleh Airport Malang)," vol. 3, no. 1, pp. 1–8, 2022.

[17] A. Syafnur, H. Jibran, and W. D. Tonapa, "Investigation of Groundwater Aquifer Using Electrical Resistivity Method Wenner-Schlumberger Array Mattoangin Village, Bantimurung District, Maros Regency," *J. Geocelebes*, vol. 2, no. 1, 2023, doi: 10.20956/geocelebes.v7i1.23302.

[18] M. et all, "Geoelectrical Model of Geothermal Spring in Ie Jue Seulawah Deriving From 2D Vlf-Em and Dc Resistivity Methods," pp. 59–69, 2023, doi: 10.5937/jaes0-38014.

ISSN (*Online*) 2581-2157
ISSN (*Print*) 2502-9304

[19] N. A. D. C. Dewi and R. P. Jaya, "Analisis Potensi Likuifaksi Pada Project Pembangunan Gudang Peti Kemas Tanjung Perak," *Univ. Janabadra Yogyakarta*, vol. 312, pp. 978–623, 2021.

[20] S. J. Ikard *et al.*, "Geoelectric Monitoring of the Electric Potential Field of the Lower Rio Grande before, during, and after Intermittent Streamflow, May–October, 2022," *Water (Switzerland)*, vol. 15, no. 9, 2023, doi: 10.3390/w15091652.

[21] A. Cardil, S. Monedero, G. Schag, and M. Tapia, "Jo u rn a ro of," *J. Alloys Compd.*, p. 165187, 2021, doi: 10.1016/j.bgtech.2023.100033.

[22] S. Huang, Y. Lyu, G. Wu, H. Sha, and Y. Peng, "Seismic resistance performance of a utility tunnel in saline soil foundation based on new cementitious composite materials," *Lat. Am. J. Solids Struct.*, vol. 17, no. 1, pp. 1–16, 2020, doi: 10.1590/1679-78255854.

[23] D. Singh and V. Kumar, "Slope Stability Analysis of Highway Embankment by Using GEO5 Software," *Lect. Notes Civ. Eng.*, vol. 280, no. September, pp. 249–257, 2023, doi: 10.1007/978-981-19-4739-1_24.

[24] V. L. et All, "Analysis of the Geoelectric Field in Sweden Over Solar Cycles 23 and 24: Spatial and Temporal Variability During Strong GIC Events," *Sp. Weather*, vol. 21, 2023, doi: 10.1029/2023SW003588.

[25] G. O. Adesola, O. Gwavava, K. Liu, and S. Szalai, "Hydrological Evaluation of the Groundwater Potential in the Fractured Karoo Aquifer Using Magnetic and Electrical Resistivity Methods: Case Study of the Balfour Formation, Alice, South Africa," *Int. J. Geophys.*, vol. 2023, 2023, doi: 10.1155/2023/1891759.