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Submit New Journal entitled "THE ANALYSIS OF SLIDING SURFACE IN ALO WATERSHED, GORONTALO DISTRICT, INDONESIA"

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Aang Panji Permana <aang@ung.ac.id>

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Cover Letter

January 08, 2021

Editor in Chief of <u>News of the National Academy of Sciences of the Republic of</u> Kazakhstan-Series of Geology and Technical Sciences

Dear Editor of <u>News of the National Academy of Sciences of the Republic of Kazakhstan</u> Series of Geology and Technical Sciences,

We are submit a manuscript for consideration of publication in <u>News of the</u> <u>National Academy of Sciences of the Republic of Kazakhstan-Series of Geology and Technical</u> <u>Sciences</u>. The manuscript is entitled "**THE ANALYSIS OF SLIDING SURFACE IN ALO WATERSHED, GORONTALO DISTRICT, INDONESIA**" to be considered published.

The method and results of our research the level of novelty are high.

These informations are very interesting for the development <u>Geotechnical Engineering</u> and <u>Engineering Geology</u> in the field for scientists, researchers, and lecturers who read our journals.

This manuscript has not been published elsewhere and that it has not been submitted simultaneously for publication elsewhere. Thank you for receiving our manuscript and considering

it for review. We value the time of the Board of Editor and we await your response from the Board of Editor.

Thank you very much for your consideration.

Yours Sincerely,

Aang Panji Permana

Geology Engineering Department, Faculty of Gorontalo State University, Indonesia General Sudirman Street No 6, Gorontalo City Phone: 082196535845 Mathematics and Science,



Email<u>: aang@ung.ac.id</u> **3 Lampiran**

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THE ANALYSIS OF SLIDING SURFACE IN ALO WATERSHED, GORONTALO DISTRICT, INDONESIA

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Abstract- Alo watershed is the sub- watershed within the system of Limboto watershed which directly disembogues to Limboto Lake. Land degradation happened in the Alo watershed is caused by the agricultural system that does not apply land conservation techniques such as terracing and mounds and it triggers erosion and landslide. The method used in this research is geoelectric method with Wenner Alpha configuration; while the data analysis utilizes resistivity imaging method which produces two-dimensional cross-sectional images. In total, there are seven trajectories with a length of 170-180 meters each. The result of the research presents the slip surfaces of 7 locations are located in 3-17 meters depth with the inclination of 11° -79° trending dominantly northwest and one location trending southeast.

Keywords: Alo Watershed, Gorontalo, Sliding Surface

Introduction. There are not many pieces of research covering landslides in Gorontalo province. The latest research shows that the landslides occur in there are rotational slide, planar slide, slide flow, and rock block slide. The landslides are commonly affected by the slope and surface shape of the slope [1, 2]. Alo watershed is the sub- watershed located in Limboto basin system which directly disembogues into Limboto Lake. Alo watershed is one of the largest sediment contributors to Limboto Lake of 0.0342 kg/sec. According to the latest survey conducted by JICA study team, annual sediment volume is estimated around 5.04 x 10^6 m³/year (or 5,500 m³/km²/year). Therefore, if the incoming sediment volume cannot be controlled, it is predicted that within 25 years the Limboto Lake will be filled with sediment [3]. Alo watershed has the biggest sediment contribution of 947,187.87 ton and its SDR reaches 0.59. It reveals that 59% of the eroded sediment will get into Limboto Lake. As the result, the lake will be a land because of silting process [4]. Alo watershed located on Tibawa sub-district has various levels of erosion ranging from very low, low, medium, and high risk. The trigger of these levels of erosion risk is inappropriate utilization of the land [5].

According to the Regional Geological Map of Tilamuta Sheet, scale 1:250,000 [6], Alo watershed is composed from tertiary and quaternary rocks. The rock formations in the Alo watershed are Diorite Bone (Tmb), Bilungala volcanic rock (tmbv), Dolokapa Formation (Tmd), Pinogu Volcanic Rock (TQpv), and Reef Limestones (Q1). Referring to the latest research, the name of new limestone formation is Limboto Limestone Formation. This formation consists of two to three microfacies with shallow marine paleobathymetry that have undergone tectonic uplift [7, 8, 9,10]. The slope on Alo watershed is dominated by gentle slopes with slopes ranging from 8 - 15% with a percentage area of 3.14%, and slopes of 15 - 25% are 25.74%. Land usage in Alo watershed is dominated by arid agricultural land with an area percentage of 38.07%, secondary forest of 21.29%, plantation of 14.78%, shrubs of 20.30%, paddy field of 4.17%, and residential area of 1.38%. In general, the practice of agricultural land management in this area has not applied a land conservation technique. The social condition of Alo watershed community in terms of educational level, education level of people residing in Alo watershed is said to still low. Many people agree that farming areas are open. In addition, many people do not quite know about erosion, but many claims to know about erosion. Habits are carried out from generation to generation in cultivations / agricultural practices. There are 78% of the people living in the Alo watershed who agree to log to create farming areas. In cultivating agricultural area, 86% of farmers do not make changes in land cultivation practices and only 14% of farmers follow the advancement of land processing techniques [11].



Figure 1. Map of research location in Alo Watershed, Gorontalo District

Methodology. The Alo watershed in the Gorontalo district, with an area of 24,222.41 acres, located at the coordinates of N 00° 44' 52.715" and E 122° 49' 33.206' to N 00° 39' 59.192" and E 122° 49' 12.778" shall be chosen as the research site. The sampling location is in the Tibawa and Limboto sub-districts (Figure 1). Research data is a slip surface that occurs in the Alo sub-watershed. The measurement itself is conducted in seven locations, namely North Isimu Village and Labanu Village, Tibawa Subdistrict, Gorontalo District. Geoelectric measurements are carried out using the Electrical Resistivity Tomography (ERT) method to estimate the boundary or sliding surface below the surface. The ERT method is often used for landslide investigations because the main factors affecting resistance are soil type, porosity and water content [12,13,14,15].

ERT can present 2D and 3D cross-sections of soil and rock resistance distribution, with maximum resolution and depth of measurement depending on the configuration of the electrode [16]. The depth measurement target that can be achieved is approximately 1/5 of the maximum stretch length, i.e. the distance from the first electrode to the last electrode in one line [17]. One measurement line uses the Wenner-Alpha electrode configuration with a stretch

length of 180 m for a depth target of about 35 m. Additionally, the acquisition of ERT measurements uses the Wenner-Alpha electrode configuration. The data analysis technique used in this study was a 2D inversion using the 3.54.44 version of RES2DINV based on the least - squares optimization method [18]. Landslide field analysis was performed by adding topographic data to the 2D inversion model using the RES2DINV program [19]. In addition, drill holes BH-01 and BH-02 were added for the calibration and correlation of subsurface resistance prices.

Result and Discussion. The measurement result of the resistivity value and rock type at the research location are shown in Table 1. The data in Table 1 shows that the rock types at 7 locations consist of clay, gravel, sand, limestone and dacite. Geoelectric measurement in research area refers to the inversion result of 2D resistivity imaging on the lines.



Figure 2. Cross section of 2D resistivity imaging at location 1

Location 1: Geoelectric measurements at location 1 are in North Isimu Village, 180 meters long, with a southwest-northeast trend (Figure 2). The slip plane is usually characterized by a contrasting field between high and low resistance values. Based on the rock resistance value, the slip plane at location 1 is estimated to be in the limestone layer as a layer with a high resistance value. The upper layers of the slip plane with resistance values of less than 674 Ω m were detected or suspected to be clay, gravel and sand layers. The limestone layer, which is a boundary plane or a slip plane, is detected at a depth of about 5-7 meters and has a high resistance of between 674-10,950.5 Ω m with an apparent slope of about 8° to the southwest. On the basis of the apparent slope, the actual slope is 47° to the northwest.



Figure 3. Cross section of 2D resistivity imaging at location 2

Location 2: Geoelectric measurement at location 2 is at North Isimu Village, 180 meters long, with a south-north trend (Figure 3). Based on the rock resistance value, the slip plane at location 2 contains layers of clay, gravel, sand, limestone and dacite. The slip plane at location 2 is estimated to be in the plane of contrast between low and high resistance values. The upper layers of the slip plane with resistance values of less than 692 Ω m are thought to be rock layers, i.e. clay, gravel and sand layers. The limestone layer, which is a slip plane, was detected at a depth of about 3 meters and has a high resistance of 692-9,479 Ω m with an apparent slope of about 11° southwest. Based on the apparent slope, the actual slope to the northwest is 79°.



Figure 4. Cross section of 2D resistivity imaging at location 3

Location 3: Geo-electric measurement at location 3 North Isimu Village with a length of 170 meters trending southwest – northeast (Figure 4). Based on the rock resistance value, the slip plane at location 3 is estimated to be in the contrasting plane between low and high resistance values, i.e. in the limestone layer. A layer of clay, gravel, and sand is thought to be the upper layer of the slip plane, which has a resistance value of less than 796 Ω m. The limestone layer, which is a slip plane, is detected at a depth of about 5-8 meters and has a high resistance of 796-10,552.5 Ω m with an apparent slope of about 7° to the southwest Based on the apparent slope, the actual slope is 74° to the northwest.

	Location 1		Loca	tion 2	Locat	tion 3	Location 4		Location 5		Locati	on 6	Location 7		
	North Isim	u 1 Village	North Isim	u 2 Village	North Isim	u 3 Village	North Isim	u 4 Village	North Isim	North Isimu 5 Village		Village	Labanu	Labanu 2 Village	
N	(0°39'5	2.6" N,	(0°40'3.5" N,	122°52'41.4"	(0°40'1	9.6" N,	(0°40'3	9.1" N,	(0°41'17	7.41" N,	(0°44'43	.3" N,	(0°45')	05.2" N,	
NO	122°52'3	36.7" E) -	E) - (0°	40'9" N.	122°52'5	1.26" E) -	122°53'7	7.1" E) –	122°53'3	1.6" E) -	122°50'57	.2" E) -	122°51'	07.3" E) -	
	(0°39'5	5.5" N.	122°52'	43.3" E)	(0°40'2	4.9" N.	(0°40'	36" N.	(0°41'2	1.4" N.	(0°44'45	.3" N.	(0°45')	(0°45'05.5" N,	
	122°52'41.6" E)				122°52'5	5.19" E)	122°53'	1.89" E)	122°53'	28.2" E)	122°50'5	1.8" E)	(0°15°0015°14, 122°51'01.7" E)		
	Electrical		Electrical		Electrical		Electrical		Electrical		Electrical		Electrical		
	Resistance	Type of	Resistance	Type of	Resistance	Type of	Resistance	Type of	Resistance	Type of	Resistance	Type of	Resistance	Type of	
	(Om)	Layer	(Om)	Layer	(Om)	Layer	(Om)	Layer	(Om)	Layer	(Om)	Layer	(Om)	Layer	
1	0 - 27.9	Clay	0-137	Clay	(2211)	Clay	0-15.8	Clay	0 - 1 29	Clay	0-0.89	Clay	0-3.44	Clay	
2	27.9 - 54.3	Clay	13.7	Clay	7 11 - 16 5	Clay	15.8 -	Clay	4 29 -	Clay	0.89-2.05	Clay	3 44-8 22	Clay	
2	21.7 - 54.5	Ciay	32.15	Ciay	7.11 - 10.5	Ciay	34.25	Ciay	11 605	Ciay	0.09-2.05	Ciay	5.44-0.22	Ciay	
3	543-806	Clay	32.15	Clay	165-259	Clay	34.25 -	Clay	11.695 -	Clay	2 05-3 21	Clay	8 22-13	Clay	
5	54.5 - 60.0	Ciay	50.6	50.6		Ciay	52.7	Ciay	10.1	Ciay	2.05-5.21	Ciay	0.22-15	Ciay	
4	80.6 -	Clay	50.6 -	Clay	25.9 -	Clay	52.7 -	Clay	19.1 -	Clay	3 21-7 36	Clay	13-30.9	Clay	
-	156.8	Ciuy	118.8	City	60.05	City	114 35	Ciuy	51.85	Ciay	5.21 7.50	Citay	15 50.7	City	
5	156.8 - 233		118.8 - 187		60.05 -	Clay	114 35 -		51.85 -	Clay	7 36-11 5	Clay	30.9-48.8	Clay	
5	10010 200		110.0 107		94.2	Citay	176		84.6	Chuy	/100 1110	Citty	5017 1010	Citay	
6	233 - 453 5	Gravel and	187 - 439 5	Gravel &	94.2 -		176 - 381	Gravel &	84.6 -		11 5-26 5	Loamy	48 8-	Gravel &	
Ŭ	200 10010	Sand	107 10710	Sand	218.6		170 501	Sand	230.3		1110 2010	Sand	116.4	Sand	
7	453.5 - 674		439.5 - 692		218.6 - 343	Gravel &	381 - 586		230.3 -	Gravel &	26.5-41.5	Loamy	116.4-184	Gravel &	
						Sand			376	Sand		Sand		Sand	
8	674 –	Limestone	692 - 1,122	Limestone	343 - 796		586 -	Limestone	376 -		41.5-95.25	Gravel &	184-438	Gravel &	
	1,310.5						1,269.5		1,023			Sand		Sand	
9	1,310.5 -	Limestone	1,122 -	Limestone	796 - 1,249	Limestone	1.269,5 -	Limestone	1,023 -		95.25-149	Gravel &	438-692	Gravel &	
	1,947		2,562				1,953		1,670			Sand		Sand	
10	1,947 -	Limestone	2,562 -	Limestone	1,249 -	Limestone	1,953 -	Limestone	1,670 -		149-342.5	Gravel &	692-	Limestone	
	3,788		6,020.5		2,898.5		4,233		4,544.5	Dry		Sand	1,649.5		
11	3,788 –	Limestone	6,020.5 -	Limestone	2,898.5 -	Limestone	4,233 -	Limestone	4,544.5 -	Gravel	342.5-536	Gravel &	1,649,5-	Limestone	
	5,629		9,479		4,548		6,513		7,419	-		Sand	2,607		
12	5,629 -	Limestone	9,479 –	Dacite	4,548 -	Limestone	6,513 -	Limestone	7,419 –		536-1,232.5	Limestone	2,607-	Dacite	
	10,950.5		22,277		10,552.5		14,113		20,188				6,214		
13	10,950.5 -	Dacite	22,277 –	Dacite	10,552.5 -	Dacite	14,113 -	Dacite	20,188 -	Dacite	1,232.5-1,929	Limestone	6,214-	Dacite	
	16,272		35,075		16,557		21,713		32,957				9,821		
14	16.272 -	Dacite	35,075 -	Dacite	16,557 -	Dacite	21,713 -	Dacite	32,957 -	Dacite	1,929-4,432.5	Dacite	9,821-	Dacite	
	31.656		82,430		38,418.5		47,052.5		89,681				23,406.5		
15	31.656 -	Dacite	82,430 -	Dacite	38,418.5 -	Dacite	47,052.5 -	Dacite	89,681 -	Dacite	4,432.5-6,936	Dacite	23,406.5-	Dacite	
	47.040		129,785		60,280		72,392		146,405				36,992		
16	> 47.040	Dacite	> 129,785	Dacite	> 60,280	Dacite	> 72,392	Dacite	>146,405	Dacite	> 6,936	Dacite	> 36,992	Dacite	

Table 1. Electrical Resistance Value and Types of Rock Layers at the Research Location

Source : Analysis Result in 2021



Figure 5. Cross section of 2D resistivity imaging at location 4

Location 4: Geo-electric measurement at location 4 in North Isimu Village with a track length of 180 meters trending northeast – southwest (Figure 5). The limestone layer which is a slip plane is detected at a depth of about 4-5 meters which has a high resistivity ranging from 586-14,113 Ω m with an apparent slope of about 3° to the southwest. Based on the apparent slope, the actual slope is 56° trending the northwest.



Figure 6. Cross section of 2D resistivity imaging at location 5

Location 5: Geo-electric measurement at location 5 in North Isimu Village with a track length of 180 meters trending southeast – northwest (Figure 6). The slip area is estimated to have low and high resistance values, namely in the dacite layer. The upper layers of the slip plane with resistance values of less than 20,188 Ω m are thought to be layers of clay, gravel, sand and dry gravel. The igneous rock layer of the dacite, which is a slip plane, was detected at a depth of about 17 meters, which has a high resistance of >20,188 Ω m, with a true dip of about 11° to the southeast.

Location 6: Geo-electric measurement at location 6 in Labanu Village with a track length of 180 meters trending east – west (Figure 7). The slip area is estimated in low and high resistance values, namely in the dacite layer. The upper layers of the slip plane with resistance values of less than 536 Ω m are thought to be layers of clay, loamy sand, gravel and sand. The limestone layer, which is a slip plane, was detected at a depth of about 2 meters, which has a resistance of > 536 Ω m, with a true dip of about 13° to the east.



Figure 7. Cross section of 2D resistivity imaging at location 6

Location 7: Geo-electric measurement at location 7 in Labanu Village with a track length of 180 meters trending east – west (Figure 8). The slip area is estimated in low and high resistance values, namely in the dacite layer. The upper layers of the slip plane with resistance values of less than 692 Ω m are thought to be layers of clay, gravel and sand. The limestone layer, which is a slip plane, was detected at a depth of about 2-5 meters, which has a resistivity of > 692 Ω m, with a true dip of about 11° to the east.



Figure 8. Cross section of 2D resistivity imaging at location 7

Conclusion. Based on the results of the interpretation and analysis, it can be concluded that the two-dimensional cross-section of the track at locations 1, 2, 3, 4 and 7 is thought to be the structure of the subsurface soil in the form of clay, gravel and sand. The line at location 5 has a subsurface layer of dry gravel under the sand. The track at location 6 has a sub-surface layer of loamy sand under the layer of clay. The slip plane is interpreted as a limestone layer in lines 1, 2, 3, 4, 6 and 7, while the slip plane in line 5 is assumed to be in a dacite igneous rock layer. The results showed that the landslide slip fields at 7 locations were approximately 3-17 meters deep with a slope angle of 11° - 79° with trending dominantly northwest and one location with a southeast trend.

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The article has been sent for review

Kotak Masuk

Редакционный отдел Академии наук PK <akadem.nauk@mailen.ui>8 Jan 20.57

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Good day! The article is registered in the journal because minor revison "News of the National Academy of Sciences of the Republic of Kazakhstan-Series of Geology and Technical Sciences".

Редакция Академии наук Республики Казахстан

----- Пересылаемое сообщение ------

От кого: Aang Panji Permana <<u>aang@ung.ac.id</u>>

Кому: Академия наук РК <<u>akadem.nauk@mail.ru</u>> Дата: Суббота, 9 января 2021, 11:18 +06:00

Тема: Submit New Journal entitled "THE ANALYSIS OF SLIDING SURFACE IN ALO WATERSHED, GORONTALO DISTRICT, INDONESIA"

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THE ANALYSIS OF SLIDING SURFACE IN ALO WATERSHED, GORONTALO DISTRICT, INDONESIA

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Abstract- Alo watershed is the sub- watershed within the system of Limboto watershed which directly disembogues to Limboto Lake. Land degradation happened in the Alo watershed is caused by the agricultural system that does not apply land conservation techniques such as terracing and mounds and it triggers erosion and landslide. The method used in this research is geoelectric method with Wenner Alpha configuration; while the data analysis utilizes resistivity imaging method which produces two-dimensional cross-sectional images. In total, there are seven trajectories with a length of 170-180 meters each. The result of the research presents the slip surfaces of 7 locations are located in 3-17 meters depth with the inclination of 11° -79° trending dominantly northwest and one location trending southeast.

Keywords: Alo Watershed, Gorontalo, Sliding Surface

Introduction. There are not many pieces of research covering landslides in Gorontalo province. The latest research shows that the landslides occur in there are rotational slide, planar slide, slide flow, and rock block slide. The landslides are commonly affected by the slope and surface shape of the slope [1, 2]. Alo watershed is the sub- watershed located in Limboto basin system which directly disembogues into Limboto Lake. Alo watershed is one of the largest sediment contributors to Limboto Lake of 0.0342 kg/sec. According to the latest survey conducted by JICA study team, annual sediment volume is estimated around 5.04 x 10^6 m³/year (or 5,500 m³/km²/year). Therefore, if the incoming sediment volume cannot be controlled, it is predicted that within 25 years the Limboto Lake will be filled with sediment [3]. Alo watershed has the biggest sediment contribution of 947,187.87 ton and its SDR reaches 0.59. It reveals that 59% of the eroded sediment will get into Limboto Lake. As the result, the lake will be a land because of silting process [4]. Alo watershed located on Tibawa sub-district has various levels of erosion ranging from very low, low, medium, and high risk. The trigger of these levels of erosion risk is inappropriate utilization of the land [5].

According to the Regional Geological Map of Tilamuta Sheet, scale 1:250,000 [6], Alo watershed is composed from tertiary and quaternary rocks. The rock formations in the Alo watershed are Diorite Bone (Tmb), Bilungala volcanic rock (tmbv), Dolokapa Formation (Tmd), Pinogu Volcanic Rock (TQpv), and Reef Limestones (Q1). Referring to the latest research, the name of new limestone formation is Limboto Limestone Formation. This

Commented [LS1]: Add ORCID ID for the other two authors

formation consists of two to three microfacies with shallow marine paleobathymetry that have undergone tectonic uplift [7, 8, 9,10]. The slope on Alo watershed is dominated by gentle slopes with slopes ranging from 8 - 15% with a percentage area of 3.14%, and slopes of 15 - 25% are 25.74%. Land usage in Alo watershed is dominated by arid agricultural land with an area percentage of 38.07%, secondary forest of 21.29%, plantation of 14.78%, shrubs of 20.30%, paddy field of 4.17%, and residential area of 1.38%. In general, the practice of agricultural land management in this area has not applied a land conservation technique. The social condition of Alo watershed is said to still low. Many people agree that farming areas are open. In addition, many people do not quite know about erosion, but many claims to know about erosion. Habits are carried out from generation to generation in cultivations / agricultural practices. There are 78% of the people living in the Alo watershed who agree to log to create farming areas. In cultivating agricultural area, 86% of farmers do not make changes in land cultivation practices and only 14% of farmers follow the advancement of land processing techniques [11].



Figure 1. Map of research location in Alo Watershed, Gorontalo District

Methodology. The Alo watershed in the Gorontalo district, with an area of 24,222.41 acres, located at the coordinates of N 00° 44' 52.715" and E 122° 49' 33.206' to N 00° 39' 59.192" and E 122° 49' 12.778" shall be chosen as the research site. The sampling location is in the Tibawa and Limboto sub-districts (Figure 1). Research data is a slip surface that occurs in the Alo sub-watershed. The measurement itself is conducted in seven locations, namely North Isimu Village and Labanu Village, Tibawa Subdistrict, Gorontalo District. Geoelectric measurements are carried out using the Electrical Resistivity Tomography (ERT) method to estimate the boundary or sliding surface below the surface. The ERT method is often used for landslide investigations because the main factors affecting resistance are soil type, porosity and water content [12,13,14,15].

ERT can present 2D and 3D cross-sections of soil and rock resistance distribution, with maximum resolution and depth of measurement depending on the configuration of the electrode [16]. The depth measurement target that can be achieved is approximately 1/5 of the maximum stretch length, i.e. the distance from the first electrode to the last electrode in one line [17]. One measurement line uses the Wenner-Alpha electrode configuration with a stretch length of 180 m for a depth target of about 35 m. Additionally, the acquisition of ERT measurements uses the Wenner-Alpha electrode configuration. The data analysis technique used in this study was a 2D inversion using the 3.54.44 version of RES2DINV based on the least - squares optimization method [18]. Landslide field analysis was performed by adding topographic data to the 2D inversion model using the RES2DINV program [19]. In addition, drill holes BH-01 and BH-02 were added for the calibration and correlation of subsurface resistance prices.

Result and Discussion. The measurement result of the resistivity value and rock type at the research location are shown in Table 1. The data in Table 1 shows that the rock types at 7 locations consist of clay, gravel, sand, limestone and dacite. Geoelectric measurement in research area refers to the inversion result of 2D resistivity imaging on the lines.



Commented [LS2]: Cross-sectional 2D resistivity imaging of the seven study sites was combined into one image.

Figure 2. Cross section of 2D resistivity imaging at location 1

Location 1: Geoelectric measurements at location 1 are in North Isimu Village, 180 meters long, with a southwest-northeast trend (Figure 2). The slip plane is usually characterized by a contrasting field between high and low resistance values. Based on the rock resistance value, the slip plane at location 1 is estimated to be in the limestone layer as a layer with a high resistance value. The upper layers of the slip plane with resistance values of less than 674 Ω m were detected or suspected to be clay, gravel and sand layers. The limestone layer, which is a boundary plane or a slip plane, is detected at a depth of about 5-7 meters and has a high resistance of between 674-10,950.5 Ω m with an apparent slope of about 8° to the southwest. On the basis of the apparent slope, the actual slope is 47° to the northwest.



Commented [LS3]: Cross-sectional 2D resistivity imaging of the seven study sites was combined into one image.

Figure 3. Cross section of 2D resistivity imaging at location 2

Location 2: Geoelectric measurement at location 2 is at North Isimu Village, 180 meters long, with a south-north trend (Figure 3). Based on the rock resistance value, the slip plane at location 2 contains layers of clay, gravel, sand, limestone and dacite. The slip plane at location 2 is estimated to be in the plane of contrast between low and high resistance values. The upper layers of the slip plane with resistance values of less than 692 Ω m are thought to be rock layers, i.e. clay, gravel and sand layers. The limestone layer, which is a slip plane, was detected at a depth of about 3 meters and has a high resistance of 692-9,479 Ω m with an apparent slope of about 11° southwest. Based on the apparent slope, the actual slope to the northwest is 79°.



Commented [LS4]: Cross-sectional 2D resistivity imaging of the seven study sites was combined into one image.

Figure 4. Cross section of 2D resistivity imaging at location 3

Location 3: Geo-electric measurement at location 3 North Isimu Village with a length of 170 meters trending southwest – northeast (Figure 4). Based on the rock resistance value, the slip plane at location 3 is estimated to be in the contrasting plane between low and high resistance values, i.e. in the limestone layer. A layer of clay, gravel, and sand is thought to be the upper layer of the slip plane, which has a resistance value of less than 796 Ω m. The limestone layer, which is a slip plane, is detected at a depth of about 5-8 meters and has a high resistance of 796-10,552.5 Ω m with an apparent slope of about 7° to the southwest Based on the apparent slope, the actual slope is 74° to the northwest.

	Location 1		Loca	tion 2	Locat	tion 3	Location 4		Location 5		Locati	on 6	Location 7		
	North Isim	u 1 Village	North Isim	u 2 Village	North Isim	u 3 Village	North Isim	u 4 Village	North Isim	North Isimu 5 Village		Village	Labanu	Labanu 2 Village	
N	(0°39'5	2.6" N,	(0°40'3.5" N,	122°52'41.4"	(0°40'1	9.6" N,	(0°40'3	9.1" N,	(0°41'17	7.41" N,	(0°44'43	.3" N,	(0°45')	05.2" N,	
NO	122°52'3	36.7" E) -	E) - (0°	40'9" N.	122°52'5	1.26" E) -	122°53'7	7.1" E) –	122°53'3	1.6" E) -	122°50'57	.2" E) -	122°51'	07.3" E) -	
	(0°39'5	5.5" N.	122°52'	43.3" E)	(0°40'2	4.9" N.	(0°40'	36" N.	(0°41'2	1.4" N.	(0°44'45	.3" N.	(0°45')	(0°45'05.5" N,	
	122°52'41.6" E)				122°52'5	5.19" E)	122°53'	1.89" E)	122°53'	28.2" E)	122°50'5	1.8" E)	(0°15°0015°14, 122°51'01.7" E)		
	Electrical		Electrical		Electrical		Electrical		Electrical		Electrical		Electrical		
	Resistance	Type of	Resistance	Type of	Resistance	Type of	Resistance	Type of	Resistance	Type of	Resistance	Type of	Resistance	Type of	
	(Om)	Layer	(Om)	Layer	(Om)	Layer	(Om)	Layer	(Om)	Layer	(Om)	Layer	(Om)	Layer	
1	0 - 27.9	Clay	0-137	Clay	(2211)	Clay	0-15.8	Clay	0 - 1 29	Clay	0-0.89	Clay	0-3.44	Clay	
2	27.9 - 54.3	Clay	13.7	Clay	7 11 - 16 5	Clay	15.8 -	Clay	4 29 -	Clay	0.89-2.05	Clay	3 44-8 22	Clay	
2	21.7 - 54.5	Ciay	32.15	Ciay	7.11 - 10.5	Ciay	34.25	Ciay	11 605	Ciay	0.09-2.05	Ciay	5.44-0.22	Ciay	
3	543-806	Clay	32.15	Clay	165-259	Clay	34.25 -	Clay	11.695 -	Clay	2 05-3 21	Clay	8 22-13	Clay	
5	54.5 - 60.0	Ciay	50.6	50.6		Ciay	52.7	Ciay	10.1	Ciay	2.05-5.21	Ciay	0.22-15	Ciay	
4	80.6 -	Clay	50.6 -	Clay	25.9 -	Clay	52.7 -	Clay	19.1 -	Clay	3 21-7 36	Clay	13-30.9	Clay	
-	156.8	Ciuy	118.8	City	60.05	City	114 35	Ciuy	51.85	Ciay	5.21 7.50	Citay	15 50.7	City	
5	156.8 - 233		118.8 - 187		60.05 -	Clay	114 35 -		51.85 -	Clay	7 36-11 5	Clay	30.9-48.8	Clay	
5	10010 200		110.0 107		94.2	Citay	176		84.6	Chuy	/100 1110	Citty	5017 1010	Citaj	
6	233 - 453 5	Gravel and	187 - 439 5	Gravel &	94.2 -		176 - 381	Gravel &	84.6 -		11 5-26 5	Loamy	48.8-	Gravel &	
Ŭ	200 10010	Sand	107 10710	Sand	218.6		170 501	Sand	230.3		1110 2010	Sand	116.4	Sand	
7	453.5 - 674		439.5 - 692		218.6 - 343	Gravel &	381 - 586		230.3 -	Gravel &	26.5-41.5	Loamy	116.4-184	Gravel &	
						Sand			376	Sand		Sand		Sand	
8	674 –	Limestone	692 - 1,122	Limestone	343 - 796		586 -	Limestone	376 -		41.5-95.25	Gravel &	184-438	Gravel &	
	1,310.5						1,269.5		1,023			Sand		Sand	
9	1,310.5 -	Limestone	1,122 -	Limestone	796 - 1,249	Limestone	1.269,5 -	Limestone	1,023 -		95.25-149	Gravel &	438-692	Gravel &	
	1,947		2,562				1,953		1,670			Sand		Sand	
10	1,947 -	Limestone	2,562 -	Limestone	1,249 -	Limestone	1,953 -	Limestone	1,670 -		149-342.5	Gravel &	692-	Limestone	
	3,788		6,020.5		2,898.5		4,233		4,544.5	Dry		Sand	1,649.5		
11	3,788 –	Limestone	6,020.5 -	Limestone	2,898.5 -	Limestone	4,233 -	Limestone	4,544.5 -	Gravel	342.5-536	Gravel &	1,649,5-	Limestone	
	5,629		9,479		4,548		6,513		7,419	-		Sand	2,607		
12	5,629 -	Limestone	9,479 –	Dacite	4,548 -	Limestone	6,513 -	Limestone	7,419 –		536-1,232.5	Limestone	2,607-	Dacite	
	10,950.5		22,277		10,552.5		14,113		20,188				6,214		
13	10,950.5 -	Dacite	22,277 –	Dacite	10,552.5 -	Dacite	14,113 -	Dacite	20,188 -	Dacite	1,232.5-1,929	Limestone	6,214-	Dacite	
	16,272		35,075		16,557		21,713		32,957				9,821		
14	16.272 -	Dacite	35,075 -	Dacite	16,557 -	Dacite	21,713 -	Dacite	32,957 -	Dacite	1,929-4,432.5	Dacite	9,821-	Dacite	
	31.656		82,430		38,418.5		47,052.5		89,681				23,406.5		
15	31.656 -	Dacite	82,430 -	Dacite	38,418.5 -	Dacite	47,052.5 -	Dacite	89,681 -	Dacite	4,432.5-6,936	Dacite	23,406.5-	Dacite	
	47.040		129,785		60,280		72,392		146,405				36,992		
16	> 47.040	Dacite	> 129,785	Dacite	> 60,280	Dacite	> 72,392	Dacite	>146,405	Dacite	> 6,936	Dacite	> 36,992	Dacite	

Table 1. Electrical Resistance Value and Types of Rock Layers at the Research Location

Source : Analysis Result in 2021



Figure 5. Cross section of 2D resistivity imaging at location 4

Location 4: Geo-electric measurement at location 4 in North Isimu Village with a track length of 180 meters trending northeast – southwest (Figure 5). The limestone layer which is a slip plane is detected at a depth of about 4-5 meters which has a high resistivity ranging from 586-14,113 Ω m with an apparent slope of about 3° to the southwest. Based on the apparent slope, the actual slope is 56° trending the northwest.



Figure 6. Cross section of 2D resistivity imaging at location 5

Location 5: Geo-electric measurement at location 5 in North Isimu Village with a track length of 180 meters trending southeast – northwest (Figure 6). The slip area is estimated to have low and high resistance values, namely in the dacite layer. The upper layers of the slip plane with resistance values of less than 20,188 Ω m are thought to be layers of clay, gravel, sand and dry gravel. The igneous rock layer of the dacite, which is a slip plane, was detected at a depth of about 17 meters, which has a high resistance of >20,188 Ω m, with a true dip of about 11° to the southeast.

Location 6: Geo-electric measurement at location 6 in Labanu Village with a track length of 180 meters trending east – west (Figure 7). The slip area is estimated in low and high resistance values, namely in the dacite layer. The upper layers of the slip plane with resistance values of less than 536 Ω m are thought to be layers of clay, loamy sand, gravel and sand. The limestone layer, which is a slip plane, was detected at a depth of about 2 meters, which has a resistance of > 536 Ω m, with a true dip of about 13° to the east.

Commented [LS5]: Cross-sectional 2D resistivity imaging of the seven study sites was combined into one image.

Commented [LS6]: Cross-sectional 2D resistivity imaging of the seven study sites was combined into one image.



Commented [LS7]: Cross-sectional 2D resistivity imaging of the seven study sites was combined into one image.

Figure 7. Cross section of 2D resistivity imaging at location 6

Location 7: Geo-electric measurement at location 7 in Labanu Village with a track length of 180 meters trending east – west (Figure 8). The slip area is estimated in low and high resistance values, namely in the dacite layer. The upper layers of the slip plane with resistance values of less than 692 Ω m are thought to be layers of clay, gravel and sand. The limestone layer, which is a slip plane, was detected at a depth of about 2-5 meters, which has a resistivity of > 692 Ω m, with a true dip of about 11° to the east.



Figure 8. Cross section of 2D resistivity imaging at location 7

Conclusion. Based on the results of the interpretation and analysis, it can be concluded that the two-dimensional cross-section of the track at locations 1, 2, 3, 4 and 7 is thought to be the structure of the subsurface soil in the form of clay, gravel and sand. The line at location 5 has a subsurface layer of dry gravel under the sand. The track at location 6 has a sub-surface layer of loamy sand under the layer of clay. The slip plane is interpreted as a limestone layer in lines 1, 2, 3, 4, 6 and 7, while the slip plane in line 5 is assumed to be in a dacite igneous rock layer. The results showed that the landslide slip fields at 7 locations were approximately 3-17 meters deep with a slope angle of 11° - 79° with trending dominantly northwest and one location with a southeast trend.

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Add translations of titles and abstracts in Russian/Kazakh.

Add Information about the author

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Sel, 19 Jan 04.32

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Dear Editor

thank you for the information

Regards Aang Panji Permana

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Rusia Inggris

Terjemahkan pesan

Nonaktifkan untuk: Rusia

Хатыңыз келді! Письмо поступило!

ВНИМАНИЕ! ОБЯЗАТЕЛЬНО! Для размещения статьи необходимо указать шестнадцатизначный код ORCID каждого автора. При отсутствии данного кода следует зарегистрироваться на сайте www.orcid.org, регистрация длится 1 минуту. Указать ссылку на публичную запись, пример: <u>https://orcid.org/0000-0000-0000-</u> Ф.И.О., e-mail. В статье ОБЯЗАТЕЛЬНО ссылаться на ранее вышедшие статьи в наших журналах и указывать DOI журнала, в какой Вы подаете статью. DOI журнала на 1 странице Требований на сайте <u>nauka-nanrk.kz</u> - Об Академии - Журналы НАН РК. http://nauka-nanrk.kz/ru/%D0%B8%D0%B7%D0%B4%D0%B0%D0%B0%D0%B8%D1%8F/

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19 Jan 2021 04.34

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Dear Editor

Soon we'll be sending signatures of all authors. thanks for the information

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Aang Panji Permana

Revised Results/Authors Response

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2 Mar 2021 13.03

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Dear Editor

Good afternoon, we are sending proof of approval for journal publication from all authors through proof of signature of all authors and revised results. Thank you for your attention.

Regards Aang Panji Permana

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THE ANALYSIS OF SLIDING SURFACE IN ALO WATERSHED, GORONTALO DISTRICT, INDONESIA

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Abstract- Alo watershed is the sub- watershed within the system of Limboto watershed which directly disembogues to Limboto Lake. Land degradation happened in the Alo watershed is caused by the agricultural system that does not apply land conservation techniques such as terracing and mounds and it triggers erosion and landslide. The method used in this research is geoelectric method with Wenner Alpha configuration; while the data analysis utilizes resistivity imaging method which produces two-dimensional cross-sectional images. In total, there are seven trajectories with a length of 170-180 meters each. The result of the research presents the slip surfaces of 7 locations are located in 3-17 meters depth with the inclination of 11° -79° trending dominantly northwest and one location trending southeast.

Keywords: Alo Watershed, Gorontalo, Sliding Surface

Introduction. There are not many pieces of research covering landslides in Gorontalo province. The latest research shows that the landslides occur in there are rotational slide, planar slide, slide flow, and rock block slide. The landslides are commonly affected by the slope and surface shape of the slope [1]. Alo watershed is the sub-watershed located in Limboto basin system which directly disembogues into Limboto Lake. Alo watershed is one of the largest sediment contributors to Limboto Lake of 0.0342 kg/sec. According to the latest survey conducted by JICA study team, annual sediment volume is estimated around 5.04 x 10^6 m³/year (or 5,500 m³/km²/year). Therefore, if the incoming sediment volume cannot be controlled, it is predicted that within 25 years the Limboto Lake will be filled with sediment [2]. Alo watershed has the biggest sediment contribution of 947,187.87 ton and its SDR reaches 0.59. It reveals that 59% of the eroded sediment will get into Limboto Lake. As the result, the lake will be a land because of silting process. Alo watershed located on Tibawa sub-district has various levels of erosion ranging from very low, low, medium, and high risk. The trigger of these levels of erosion risk is inappropriate utilization of the land [3].

According to the Regional Geological Map of Tilamuta Sheet, scale 1:250,000 [4], Alo watershed is composed from tertiary and quaternary rocks. The rock formations in the Alo watershed are Diorite Bone (Tmb), Bilungala volcanic rock (Tmbv), Dolokapa Formation (Tmd), Pinogu Volcanic Rock (TQpv), and Reef Limestones (Q1). Referring to the latest research, the name of new limestone formation is Limboto Limestone Formation. This formation consists of two to three microfacies with shallow marine paleobathymetry that have undergone tectonic uplift [5,6]. The slope on Alo watershed is dominated by gentle slopes with slopes ranging from 8 - 15% with a percentage area of 3.14%, and slopes of 15 - 25% are 25.74%. Land usage in Alo watershed is dominated by arid agricultural land with an area percentage of 38.07%, secondary forest of 21.29%, plantation of 14.78%, shrubs of 20.30%, paddy field of 4.17%, and residential area of 1.38%. In general, the practice of agricultural land

management in this area has not applied a land conservation technique. The social condition of Alo watershed community in terms of educational level, education level of people residing in Alo watershed is said to still low. Many people agree that farming areas are open. In addition, many people do not quite know about erosion, but many claims to know about erosion. Habits are carried out from generation to generation in cultivations / agricultural practices. There are 78% of the people living in the Alo watershed who agree to log to create farming areas. In cultivating agricultural area, 86% of farmers do not make changes in land cultivation practices and only 14% of farmers follow the advancement of land processing techniques [7].





Methodology. The Alo watershed in the Gorontalo district, with an area of 24,222.41 acres, located at the coordinates of N 00° 44' 52.715" and E 122° 49' 33.206' to N 00° 39' 59.192" and E 122° 49' 12.778" shall be chosen as the research site. The sampling location is in the Tibawa and Limboto sub-districts (Figure 1). Research data is a slip surface that occurs in the Alo sub-watershed. The measurement itself is conducted in seven locations, namely North Isimu Village and Labanu Village, Tibawa Subdistrict, Gorontalo District. Geoelectric measurements are carried out using the Electrical Resistivity Tomography (ERT) method to estimate the boundary or sliding surface below the surface. The ERT method is often used for landslide

investigations because the main factors affecting resistance are soil type, porosity and water content [8,9,10,11].

ERT can present 2D and 3D cross-sections of soil and rock resistance distribution, with maximum resolution and depth of measurement depending on the configuration of the electrode [12]. The depth measurement target that can be achieved is approximately 1/5 of the maximum stretch length, i.e. the distance from the first electrode to the last electrode in one line [13]. One measurement line uses the Wenner-Alpha electrode configuration with a stretch length of 180 m for a depth target of about 35 m. Additionally, the acquisition of ERT measurements uses the Wenner-Alpha electrode configuration. The data analysis technique used in this study was a 2D inversion using the 3.54.44 version of RES2DINV based on the least - squares optimization method [14]. Landslide field analysis was performed by adding topographic data to the 2D inversion model using the RES2DINV program [15]. In addition, drill holes BH-01 and BH-02 were added for the calibration and correlation of subsurface resistance prices.

Result and Discussion. The measurement result of the resistivity value and rock type at the research location are shown in Table 1. The data in Table 1 shows that the rock types at 7 locations consist of clay, gravel, sand, limestone and dacite. Geoelectric measurement in research area refers to the inversion result of 2D resistivity imaging on the lines in seven location shown in Figure 2.

Location 1: Geoelectric measurements at location 1 are in North Isimu Village, 180 meters long, with a southwest-northeast trend. The slip plane is usually characterized by a contrasting field between high and low resistance values. Based on the rock resistance value, the slip plane at location 1 is estimated to be in the limestone layer as a layer with a high resistance value. The upper layers of the slip plane with resistance values of less than 674 Ω m were detected or suspected to be clay, gravel and sand layers. The limestone layer, which is a boundary plane or a slip plane, is detected at a depth of about 5-7 meters and has a high resistance of between 674-10,950.5 Ω m with an apparent slope of about 8° to the southwest. On the basis of the apparent slope, the actual slope is 47° to the northwest.

Location 2: Geoelectric measurement at location 2 is at North Isimu Village, 180 meters long, with a south-north trend. Based on the rock resistance value, the slip plane at location 2 contains layers of clay, gravel, sand, limestone and dacite. The slip plane at location 2 is estimated to be in the plane of contrast between low and high resistance values. The upper layers of the slip plane with resistance values of less than 692 Ω m are thought to be rock layers, i.e. clay, gravel and sand layers. The limestone layer, which is a slip plane, was detected at a depth of about 3 meters and has a high resistance of 692-9,479 Ω m with an apparent slope of about 11° southwest. Based on the apparent slope, the actual slope to the northwest is 79°.

	Location 1		Loca	tion 2	Loca	tion 3	Loca	tion 4	Locat	tion 5	Locati	on 6	Location 7		
	North Isim	u Village 1	North Isim	u Village 2	North Isim	u Village 3	North Isim	u Village 4	North Isim	u Village 5	Labanu V	illage 1	Labanu	Village 2	
N	(0°39'5	52.6" N,	(0°40'3.5" N,	122°52'41.4"	(0°40'1	9.6" N,	(0°40'3	9.1" N,	(0°41'17	7.41" N,	(0°44'43	.3" N,	(0°45'))5.2" N,	
INO	122°52'3	36.7" E) -	E) - (0°	40'9" N.	122°52'5	1.26" E) -	122°53″	7.1" E) –	122°53'3	1.6" E) -	122°50'57	.2" E) -	122°51'07.3" E) -		
	(0°39'5	5.5" N.	122°52'	43.3" E)	(0°40'2	4.9" N.	(0°40'	36" N.	(0°41'2	1.4" N.	(0°44'45	.3" N.	(0°45')	(0°45'05.5" N,	
	122°52'	41.6" E)		,	122°52'5	5.19" E)	122°53'1.89" E)		122°53'28.2" E)		122°50'51.8" E)		122°51'01.7" E)		
	Electrical		Electrical	7 0 6	Electrical	T (Electrical		Electrical		Electrical	T (Electrical	m (
	Resistance	Type of	Resistance	Type of	Resistance	Type of	Resistance	Type of	Resistance	Type of	Resistance	Type of	Resistance	Type of	
	(Ωm)	Layer	(Ωm)	Layer	(Ωm)	Layer	(Ωm)	Layer	(Ωm)	Layer	(Ωm)	Layer	(Ωm)	Layer	
1	0-27.9	Clay	0-13.7	Clay	0-7.11	Clay	0-15.8	Clay	0-4.29	Clay	0-0.89	Clay	0-3.44	Clay	
2	27.9 - 54.3	Clay	13.7 -	Clay	7.11 - 16.5	Clay	15,8 -	Clay	4.29 -	Clay	0.89-2.05	Clay	3.44-8.22	Clay	
		5	32.15	, i i i i i i i i i i i i i i i i i i i			34.25	5	11.695	5				5	
3	54.3 - 80.6	Clay	32.15 -	Clay	16.5 - 25.9	Clay	34.25 -	Clay	11.695 -	Clay	2.05-3.21	Clay	8.22-13	Clay	
			50.6				52.7		19.1		-				
4	80.6 -	Clay	50.6 -	50.6 – Clay		Clay	52,7 -	Clay	19.1 –	Clay	3.21-7.36	Clay	13-30.9	Clay	
	156.8		118.8	118.8			114.35		51.85						
5	156.8 - 233		118.8 - 187		60.05 -	Clay	114,35 -		51.85 -	Clay	7.36-11.5	Clay	30.9-48.8	Clay	
					94.2		176		84.6						
6	233 - 453.5	Gravel and	187 - 439.5	Gravel &	94.2 -		176 - 381	Gravel &	84.6 -		11.5-26.5	Loamy	48.8-	Gravel &	
		Sand		Sand	218.6			Sand	230.3			Sand	116.4	Sand	
7	453.5 - 674		439.5 - 692		218.6 - 343	Gravel &	381 - 586		230.3 -	Gravel &	26.5-41.5	Loamy	116.4-184	Gravel &	
						Sand			376	Sand		Sand		Sand	
8	674 –	Limestone	692 - 1,122	Limestone	343 - 796		586 -	Limestone	376 -		41.5-95.25	Gravel &	184-438	Gravel &	
	1,310.5						1,269.5		1,023			Sand		Sand	
9	1,310.5 -	Limestone	1,122 -	Limestone	796 - 1,249	Limestone	1.269,5 -	Limestone	1,023 -		95.25-149	Gravel &	438-692	Gravel &	
	1,947		2,562				1,953		1,670			Sand		Sand	
10	1,947 –	Limestone	2,562 -	Limestone	1,249 -	Limestone	1,953 -	Limestone	1,670 -		149-342.5	Gravel &	692-	Limestone	
	3,788		6,020.5		2,898.5		4,233		4,544.5	Dry		Sand	1,649.5		
11	3,788 –	Limestone	6,020.5 -	Limestone	2,898.5 -	Limestone	4,233 -	Limestone	4,544.5 -	Gravel	342.5-536	Gravel &	1,649,5-	Limestone	
	5,629		9,479		4,548		6,513		7,419			Sand	2,607		
12	5,629 –	Limestone	9,479 –	Dacite	4,548 -	Limestone	6,513 -	Limestone	7,419 –		536-1,232.5	Limestone	2,607-	Dacite	
	10,950.5		22,277		10,552.5		14,113		20,188				6,214		
13	10,950.5 -	Dacite	22,277 –	Dacite	10,552.5 -	Dacite	14,113 -	Dacite	20,188 -	Dacite	1,232.5-1,929	Limestone	6,214-	Dacite	
	16,272		35,075		16,557		21,713		32,957				9,821		
14	16.272 -	Dacite	35,075 -	Dacite	16,557 -	Dacite	21,713 -	Dacite	32,957 -	Dacite	1,929-4,432.5	Dacite	9,821-	Dacite	
	31.656		82,430		38,418.5		47,052.5		89,681				23,406.5		
15	31.656 -	Dacite	82,430 -	Dacite	38,418.5 -	Dacite	47,052.5 -	Dacite	89,681 -	Dacite	4,432.5-6,936	Dacite	23,406.5-	Dacite	
	47.040		129,785		60,280		72,392		146,405				36,992		
16	> 47.040	Dacite	> 129,785	Dacite	> 60,280	Dacite	> 72,392	Dacite	>146,405	Dacite	> 6,936	Dacite	> 36,992	Dacite	

Table 1. Electrical Resistance Value and Types of Rock Layers at the Research Location

Source : Analysis Result in 2021



Figure 2. Cross section of 2D resistivity imaging at 7 lines at the research location

Location 3: Geo-electric measurement at location 3 North Isimu Village with a length of 170 meters trending southwest – northeast. Based on the rock resistance value, the slip plane at location 3 is estimated to be in the contrasting plane between low and high resistance values, i.e. in the limestone layer. A layer of clay, gravel, and sand is thought to be the upper layer of the slip plane, which has a resistance value of less than 796 Ω m. The limestone layer, which is a slip plane, is detected at a depth of about 5-8 meters and has a high resistance of 796-10,552.5 Ω m with an apparent slope of about 7° to the southwest Based on the apparent slope, the actual slope is 74° to the northwest.

Location 4: Geo-electric measurement at location 4 in North Isimu Village with a track length of 180 meters trending northeast - southwest. The limestone layer which is a slip plane is detected at a depth of about 4-5 meters which has a high resistivity ranging from 586-14,113 Ω m

with an apparent slope of about 3° to the southwest. Based on the apparent slope, the actual slope is 56 $^{\circ}$ trending the northwest.

Location 5: Geo-electric measurement at location 5 in North Isimu Village with a track length of 180 meters trending southeast - northwest. The slip area is estimated to have low and high resistance values, namely in the dacite layer. The upper layers of the slip plane with resistance values of less than 20,188 Ω m are thought to be layers of clay, gravel, sand and dry gravel. The igneous rock layer of the dacite, which is a slip plane, was detected at a depth of about 17 meters, which has a high resistance of >20,188 Ω m, with a true dip of about 11° to the southeast.

Location 6: Geo-electric measurement at location 6 in Labanu Village with a track length of 180 meters trending east - west. The slip area is estimated in low and high resistance values, namely in the dacite layer. The upper layers of the slip plane with resistance values of less than 536 Ω m are thought to be layers of clay, loamy sand, gravel and sand. The limestone layer, which is a slip plane, was detected at a depth of about 2 meters, which has a resistance of > 536 Ω m, with a true dip of about 13° to the east.

Location 7: Geo-electric measurement at location 7 in Labanu Village with a track length of 180 meters trending east - west. The slip area is estimated in low and high resistance values, namely in the dacite layer. The upper layers of the slip plane with resistance values of less than 692 Ω m are thought to be layers of clay, gravel and sand. The limestone layer, which is a slip plane, was detected at a depth of about 2-5 meters, which has a resistivity of > 692 Ω m, with a true dip of about 11° to the east.

Conclusion. Based on the results of the interpretation and analysis, it can be concluded that the two-dimensional cross-section of the track at locations 1, 2, 3, 4 and 7 is thought to be the structure of the subsurface soil in the form of clay, gravel and sand. The line at location 5 has a subsurface layer of dry gravel under the sand. The track at location 6 has a sub-surface layer of loamy sand under the layer of clay. The slip plane is interpreted as a limestone layer in lines 1, 2, 3, 4, 6 and 7, while the slip plane in line 5 is assumed to be in a dacite igneous rock layer. The results showed that the landslide slip fields at 7 locations were approximately 3-17 meters deep with a slope angle of 11° - 79° with trending dominantly northwest and one location with a southeast trend.

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АЛО СУ ҚОЙМАСЫНДАҒЫ СЫРҒАНАУ БЕТІН ТАЛДАУ, ГОРОНТАЛО АУДАНЫ, ИНДОНЕЗИЯ

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АНАЛИЗ ПОВЕРХНОСТИ СКОЛЬЖЕНИЯ В ВОДОРАЗДЕЛЕ АЛО, РАЙОН ГОРОНТАЛО, ИНДОНЕЗИЯ

Аннотация. Водораздел Ало - это суб-водораздел в системе водораздела Лимбото, который непосредственно сливается с озером Лимбото. Деградация земель, произошедшая в водосборном бассейне Ало, вызвана сельскохозяйственной системой, которая не применяет методы сохранения земель, такие как террасирование и насыпи, что вызывает эрозию и оползни. Метод, используемый в этом исследовании, является геоэлектрическим методом с конфигурацией Альфа Веннера, в то время как анализ данных использует метод визуализации удельного сопротивления, который создает двумерные изображения поперечного сечения. Всего существует семь траекторий, длиной 170-180 метров каждая. В результате исследования представлены поверхности скольжения в 7 местах, расположенных на глубине 3-17 метров с наклоном 110-79°, направленным преимущественно на северо-запад, и в одном месте, направленном на юго-восток. Ключевые слова: водораздел ало, Гронтало, поверхность скольжения.

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THE ANALYSIS OF SLIDING SURFACE IN ALO WATERSHED, GORONTALO DISTRICT, INDONESIA

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Abstract- Alo watershed is the sub- watershed within the system of Limboto watershed which directly disembogues to Limboto Lake. Land degradation happened in the Alo watershed is caused by the agricultural system that does not apply land conservation techniques such as terracing and mounds and it triggers erosion and landslide. The method used in this research is geoelectric method with Wenner Alpha configuration; while the data analysis utilizes resistivity imaging method which produces two-dimensional cross-sectional images. In total, there are seven trajectories with a length of 170-180 meters each. The result of the research presents the slip surfaces of 7 locations are located in 3-17 meters depth with the inclination of 110 -790 trending dominantly northwest and one location trending southeast.

Keywords: Alo Watershed, Gorontalo, Sliding Surface.

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Regards Aang Panji Permana

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THE ANALYSIS OF SLIDING SURFACE IN ALO WATERSHED, GORONTALO DISTRICT, INDONESIA

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NEWS

OF THE ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN Satbayev University

SERIES OF GEOLOGY AND TECHNICAL SCIENCES

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THE ANALYSIS OF SLIDING SURFACE IN ALO WATERSHED, **GORONTALO DISTRICT, INDONESIA**

Abstract. Alo watershed is the sub-watershed within the system of Limboto watershed which directly disembogues to Limboto Lake. Land degradation happened in the Alo watershed is caused by the agricultural system that does not apply land conservation techniques such as terracing and mounds and it triggers erosion and landslide. The method used in this research is geoelectric method with Wenner Alpha configuration; while the data analysis utilizes resistivity imaging method which produces two-dimensional cross-sectional images. In total, there are seven trajectories with a length of 170-180 meters each. The result of the research presents the slip surfaces of 7 locations are located in 3-17 meters depth with the inclination of 11° -79° trending dominantly northwest and one location trending southeast.

Keywords: Alo Watershed, Gorontalo, Sliding Surface

Introduction. There are not many pieces of research covering landslides in Gorontalo province. The latest research shows that the landslides occur in there are rotational slide, planar slide, slide flow, and rock block slide. The landslides are commonly affected by the slope and surface shape of the slope [1]. Alo watershed is the sub-watershed located in Limboto basin system which directly disembogues into Limboto Lake. Alo watershed is one of the largest sediment contributors to Limboto Lake of 0.0342 kg/sec. According to the latest survey conducted by JICA study team, annual sediment volume is estimated around 5.04 x 106 m³/year (or 5,500 m³/ km²/year). Therefore, if the incoming sediment volume cannot be controlled, it is predicted that within 25 years the Limboto Lake will be filled with sediment [2]. Alo watershed has the biggest sediment contribution of 947,187.87 ton and its SDR reaches 0.59. It reveals that 59% of the eroded sediment will get into Limboto Lake. As the result, the lake will be a land because of silting process. Alo watershed located on Tibawa sub-district has various levels of erosion ranging from very low, low, medium, and high risk. The trigger of these levels of erosion risk is inappropriate utilization of the land [3].

According to the Regional Geological Map of Tilamuta Sheet, scale 1:250,000 [4], Alo watershed is composed from tertiary and quaternary rocks. The rock formations in the Alo watershed are Diorite Bone (Tmb), Bilungala volcanic rock (Tmbv), Dolokapa Formation (Tmd), Pinogu Volcanic Rock (TQpv), and Reef Limestones (Q1). Referring to the

latest research, the name of new limestone formation is Limboto Limestone Formation. This formation consists of two to three microfacies with shallow marine paleobathymetry that have undergone tectonic uplift [5,6]. The slope on Alo watershed is dominated by gentle slopes with slopes ranging from 8 - 15%with a percentage area of 3.14%, and slopes of 15 - 25% are 25.74%. Land usage in Alo watershed is dominated by arid agricultural land with an area percentage of 38.07%, secondary forest of 21.29%, plantation of 14.78%, shrubs of 20.30%, paddy field of 4.17%, and residential area of 1.38%. In general, the practice of agricultural land management in this area has not applied a land conservation technique. The social condition of Alo watershed community in terms of educational level, education level of people residing in Alo watershed is said to still low. Many people agree that farming areas are open. In addition, many people do not quite know about erosion, but many claims to know about erosion. Habits are carried out from generation to generation in cultivations / agricultural practices. There are 78% of the people living in the Alo watershed who agree to log to create farming areas. In cultivating agricultural area, 86% of farmers do not make changes in land cultivation practices and only 14% of farmers follow the advancement of land processing techniques [7].



Figure 1. Map of research location in Alo Watershed, Gorontalo District

Methodology. The Alo watershed in the Gorontalo district, with an area of 24,222,41 acres, located at the coordinates of N 00o44' 52.715" and E 1220 49' 33.206' to N 000 39'59.192" and E 122° 49'12.778" shall be chosen as the research site. The sampling location is in the Tibawa and Limboto sub-districts (Figure 1). Research data is a slip surface that occurs in the Alo sub- watershed. The measurement itself is conducted in seven locations, namely North Isimu Village and Labanu Village, Tibawa Subdistrict, Gorontalo District. Geoelectric measurements are carried out using the Electrical Resistivity Tomography (ERT) method to estimate the boundary or sliding surface below the surface. The ERT method is often used for landslide investigations because the main factors affecting resistance are soil type, porosity and water content [8,9,10,11].

ERT can present 2D and 3D cross-sections of soil and rock resistance distribution, with maximum resolution and depth of measurement depending on the configuration of the electrode [12]. The depth measurement target that can be achieved is approximately 1/5 of the maximum stretch length, i.e. the distance from the first electrode to the last electrode in one line [13]. One measurement line uses the Wenner-Alpha electrode configuration with a stretch length of 180 m for a depth target of about 35 m. Additionally, the acquisition of ERT measurements uses the Wenner-Alpha electrode configuration. The data analysis technique used in this study was a 2D inversion using the 3.54.44

version of RES2DINV based on the least - squares optimization method [14]. Landslide field analysis was performed by adding topographic data to the 2D inversion model using the RES2DINV program [15]. In addition, drill holes BH-01 and BH-02 were added for the calibration and correlation of subsurface resistance prices.

Result and Discussion. The measurement result of the resistivity value and rock type at the research location are shown in Table 1. The data in Table 1 shows that the rock types at 7 locations consist of clay, gravel, sand, limestone and dacite.Geoelectric measurement in research area refers to the inversion result of 2D resistivity imaging on the lines in seven location shown in Figure 2.

Location 1: Geoelectric measurements at location 1 are in North Isimu Village, 180 meters long, with a southwest-northeast trend. The slip plane is usually characterized by a contrasting field between high and low resistance values. Based on the rock resistance value, the slip plane at location 1 is estimated to be in the limestone layer as a layer with a high resistance value. The upper layers of the slip plane with resistance values of less than 674 Ω m were detected or suspected to be clay, gravel and sand layers. The limestone layer, which is a boundary plane or a slip plane, is detected at a depth of about 5-7 meters and has a high resistance of between $674-10,950.5\Omega m$ with an apparent slope of about 8° to the southwest. On the basis of the apparent slope, the actual slope is 47° to the northwest.

Location 2: Geoelectric measurement at location 2 is at North Isimu Village, 180 meters long, with a south-north trend. Based on the rock resistance value, the slip plane at location 2 contains layers of clay, gravel, sand, limestone and dacite. The slip plane at location 2 is estimated to be in the plane of contrast between low and high resistance values. The upper layers of the slip plane with resistance values of less than 692 Ω m are thought to be rock layers, i.e. clay, gravel and sand layers. The limestone layer, which is a slip plane, was detected at a depth of about 3 meters and has a high resistance of 692-9,479 Ω m with an apparent slope of about 11° southwest. Based on the apparent slope, the actual slope to the northwest is 79°.

Location 3: Geo-electric measurement at location 3 North Isimu Village with a length of 170 meters trending southwest – northeast. Based on the rock resistance value, the slip plane at location 3 is estimated to be in the contrasting plane between low and high resistance values, i.e. in the limestone layer. A layer of clay, gravel, and sand is thought to be the upper layer of the slip plane, which has a resistance value of less than 796 Ω m. The limestone layer, which is a slip plane, is detected at a depth of about 5-8 meters and has a high resistance of 796-10,552.5 Ω m with an apparent slope of about 7° to the southwest Based on the apparent slope, the actual slope is 74° to the northwest.

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Table

tion 7	Village 2 5.2" N,	7.3" E) - 5.5" N, 01.7" E)	Type of Layer	Clay	Clay	Clay	Clay	Clay	Gravel & Sand	Gravel &	Gravel &	Gravel & Sand	Limestone	Limestone	Dacite	Dacite	Dacite	Dacite	Dacite
Locat	Labauu 7 (0°45'0	122°51°0 (0°45°0 122°51°1	Electrical Resistance (Ωm)	0-3.44	3.44-8.22	8.22-13	13-30.9	30.9-48.8	48.8-116.4	116.4-184	184-438	438-692	692- 1.649.5	1,649,5- 2,607	2,607- 6,214	6,214- 9,821	9,821- 23,406.5	23,406.5- 36,992	> 36,992
on 6	illage 1 122°50°57.2"	45.3" N, L.8" E)	Type of Layer	Clay	Clay	Clay	Clay	Clay	Loamy Sand	Loamy Sand	Gravel &	Gravel & Sand	Gravel & Sand	Gravel & Sand	Limestone	Limestone	Dacite	Dacite	Dacite
Locatio	Labanu Vi (0°44°43.3" N, 1	E) - (0°44 ⁷ 2 122°50'5	Electrical Resistance (Ωm)	0-0.89	0.89-2.05	2.05-3.21	3.21-7.36	7.36-11.5	11.5-26.5	26.5-41.5	41.5-95.25	95.25-149	149-342.5	342.5-536	536-1,232.5	1,232.5-1,929	1,929-4,432.5	4,432.5-6,936	> 6,936
ion 5	Village 5 .41" N,	1.6" E) - 1.4" N, 28.2" E)	Type of Layer	Clay	Clay	Clay	Clay	Clay		Gravel & Sand			Drv	Gravel		Dacite	Dacite	Dacite	Dacite
Locat	North Isimi (0°41'17	122°53'3 (0°41'2 122°53'2	Electrical Resistance (Ωm)	0 - 4.29	4.29 – 11.695	11.695 – 19.1	19.1 – 51.85	51.85 - 84.6	84.6 - 230 3	230.3 - 376	376 - 1 023	1,023 – 1.670	1,670 - 4.544.5	4,544.5 - 7,419	7,419 – 20,188	20,188 – 32,957	32,957 - 89,681	89,681 – 146,405	>146,405
ion 4	Village 4 , 122°53'7.1"	– 16" N, .89" E)	Type of Layer	Clay	Clay	Clay	Clay		Gravel & Sand		Limestone	Limestone	Limestone	Limestone	Limestone	Dacite	Dacite	Dacite	Dacite
Locat	North Isum (0°40'39.1" N	E) (0°40'3 122°53'1	Electrical Resistance (Om)	0 - 15.8	15,8 - 34.25	34.25 - 52.7	52,7 - 114.35	114,35 – 176	176 – 381	381 - 586	586 - 1 269 5	1.269,5 - 1.953	1,953 - 4.233	4,233 - 6,513	6,513 – 14,113	14,113 – 21,713	21,713 – 47,052.5	47,052.5 - 72,392	> 72,392
ion 3	J Village 3 9.6" N,	.26" E) - L9" N, 5.19" E)	Type of Layer	Clay	Clay	Clay	Clay	Clay		Gravel & Sand		Limestone	Limestone	Limestone	Limestone	Dacite	Dacite	Dacite	Dacite
Locat	North Lsim (0°40'1	122°52'51 (0°40'2, 122°52'5	Electrical Resistance (Ωm)	0 - 7.11	7.11 - 16.5	16.5 - 25.9	25.9 - 60.05	60.05 - 94.2	94.2 - 218.6	218.6 - 343	343 – 796	796 - 1,249	1,249 – 2.898.5	2,898.5 - 4,548	4,548 – 10,552.5	10,552.5 - 16,557	16,557 - 38,418.5	38,418.5 - 60,280	> 60,280
on 2	, Village 2 122°52'41.4"	0'9" N, 3.3" E)	Type of Layer	Clay	Clay	Clay	Clay		Gravel &		Limestone	Limestone	Limestone	Limestone	Dacite	Dacite	Dacite	Dacite	Dacite
Locati	North Isimu (0°40'3.5" N,	E) - (0°4 122°52'4	Electrical Resistance (Ωm)	0 - 13.7	13.7 – 32.15	32.15 - 50.6	50.6 – 118.8	118.8 - 187	187 - 439.5	439.5 - 692	692 - 1,122	1,122 – 2.562	2,562 - 6,020.5	6,020.5 – 9,479	9,479 – 22,277	22,277 - 35,075	35,075 - 82,430	82,430 – 129,785	> 129,785
ion 1	u Village 1 2.6" N,	6.7" E) - 5.5" N, 11.6" E)	Type of Layer	Clay	Clay	Clay	Clay		Gravel and Sand		Limestone	Limestone	Limestone	Limestone	Limestone	Dacite	Dacite	Dacite	Dacite
Locat	North [sim] (0°39'5	122°52'3 (0°39'5 122°52'4	Electrical Resistance (Ωm)	0 - 27.9	27.9 - 54.3	54.3 - 80.6	80.6 - 156.8	156.8 - 233	233 - 453.5	453.5 - 674	674 - 1 310 5	1,310.5 - 1.947	1,947 – 3.788	3,788 – 5,629	5,629 - 10,950.5	10,950.5 - 16,272	16.272 - 31.656	31.656 - 47.040	> 47.040
	Ĩ	N		1	2	3	4	5	9	7	8	6	10	Π	12	13	14	15	16

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Source: Analysis Result in 2021

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Figure 2. Cross section of 2D resistivity imaging at 7 lines at the research location

Location 4: Geo-electric measurement at location 4 in North Isimu Village with a track length of 180 meters trending northeast - southwest. The limestone layer which is a slip plane is detected at a depth of about 4-5 meters which has a high resistivity ranging from 586-14,113-m with an apparent slope of about 3° to the southwest. Based on the apparent slope, the actual slope is 56 ° trending the northwest.

Location 5: Geo-electric measurement at location 5 in North Isimu Village with a track length of 180 meters trendingsoutheast - northwest. The slip area is estimated to have low and high resistance values, namely in the dacite layer. The upper layers of the slip plane with resistance values of less than 20,188 -m are thought to be layers of clay, gravel, sand and dry gravel. The igneous rock layer of the dacite, which is a slip plane, was detected at a depth of about 17 meters, which has a high resistance of >20,188 -m, with a true dip of about 11° to the southeast.

Location 6: Geo-electric measurement at location6 in Labanu Village with a track length of 180 meters trendingeast - west. The slip area is estimated in low and high resistance values, namely in the dacite layer. The upper layers of the slip plane with resistance values of less than $536\Omega m$ are thought to be layers of clay, loamy sand, gravel and sand. The limestone layer, which is a slip plane, was detected at a depth of about 2 meters, which has a resistance of > 536 Ω m, with a true dip of about 13° to the east.

Location 7: Geo-electric measurement at location 7 in Labanu Village with a track length of 180 meters trending east - west. The slip area is estimated in low and high resistance values, namely in the dacite layer. The upper layers of the slip plane with resistance values of less than $692\Omega m$ are thought to be layers of clay, gravel and sand. The limestone layer, which is a slip plane, was detected at a depth of about 2-5 meters, which has a resistivity of > $692\Omega m$, with a true dip of about 11° to the east.

Conclusion. Based on the results of the interpretation and analysis, it can be concluded that the two-dimensional cross-section of the track at locations 1, 2, 3, 4 and 7 is thought to be the structure of the subsurface soil in the form of clay, gravel and sand. The line at location 5 has a subsurface layer of dry gravel under the sand. The track at location 6 has a sub-surface layer of loamy sand under the layer of clay. The slip plane is interpreted as a limestone layer in lines 1, 2, 3, 4, 6 and 7, while the slip plane in line 5 is assumed to be in a dacite igneous rock layer. The results showed that the landslide slip fields at 7 locations were approximately 3-17 meters deep with a slope angle of 110 -79° with trending dominantly northwest and one location with a southeast trend.

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АЛО СУ ҚОЙМАСЫНДАҒЫ СЫРҒАНАУ БЕТІН ТАЛДАУ, ГОРОНТАЛО АУДАНЫ, ИНДОНЕЗИЯ

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АНАЛИЗ ПОВЕРХНОСТИ СКОЛЬЖЕНИЯ В ВОДОРАЗДЕЛЕ АЛО, РАЙОН ГОРОНТАЛО, ИНДОНЕЗИЯ

Аннотация. Водораздел Ало - это суб-водораздел в системе водораздела Лимбото, который непосредственно сливается с озером Лимбото. Деградация земель, произошедшая в водосборном бассейне Ало, вызвана сельскохозяйственной системой, которая не применяет методы сохранения земель, такие как террасирование и насыпи, что вызывает эрозию и оползни. Метод, используемый в этом исследовании, является геоэлектрическим методом с конфигурацией Альфа Веннера, в то время как анализ данных использует метод визуализации удельного сопротивления, который создает двумерные изображения поперечного сечения. Всего существует семь траекторий, длиной 170-180 метров каждая. В результате исследования представлены поверхности скольжения в 7 местах, расположенных на глубине 3-17 метров с наклоном 110-79°, направленным преимущественно на северо-запад, и в одном месте, направленном на юго-восток.

Ключевые слова: водораздел ало, Гронтало, поверхность скольжения.

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