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The lithology of Flood Prone Areas Using the Vertical Electrical Sounding (VES) Method

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Abstract

Rock lithology modeling of flood-prone areas has been carried out using the Vertical Electrical Sounding (VES) method in Rawa Makmur village, Bengkulu city. Field data acquisition using a stretch length of 160 with the MAE X612-EM Geoelectric tool forming a straight line. VES method, using Excel software for resistivity variations with depth and Progress lithology modeling. This research aims to determine the subsurface condition of flood-prone areas and the characteristics of rocks that make up flood-prone areas. The results of this study can be concluded that the Rawa Makmur village is dominated by sand (0,2-50 Ωm), silty sand (1-35 Ωm), gravel sand (20-150 Ωm) and clay (65-250 Ωm) at several points. VES 1, VES 2, VES 3, VES 4, VES 5, VES 8, and VES 9 have a shallow water table of 1-10 meters, close to the Rawa Makmur river and have a rock structure that is saturated with water so that it cannot absorb moisture on the surface and becomes a flood puddle. The characteristics of rocks that make up flood-prone areas are porous stones such as sand and gravel saturated with water. Sites that are not prone to flooding in the Rawa Makmur village at points VES 6 and VES 7 are dominated by the rock structure of sand (20-65 Ωm), gravel sand (100-200 Ωm), and dry gravel (100-1000 Ωm).

Introduction

Bengkulu has 70% flat topography and 30% small hills and swamps [1]. The western part of Bengkulu city is lowland and directly adjacent to the Indian Ocean. Hence, the air humidity is high in water vapor, while the eastern part of Bengkulu is a plateau in the Bukit Barisan mountain range, which has erosion potential [2]. This geographical condition causes the area below the slopes of the mountains and towards the west to have high rainfall. High rainfall potentially causes several areas in Bengkulu city close to rivers and beaches to experience flood disasters [3]. The morphological condition of the Bengkulu coast has bays that drain into rivers and become densely populated settlements, one of which is the village of Rawa Makmur, which is vulnerable to flooding [4]. The community of Rawa Makmur, which often experiences floods, has problems obtaining clean water. The water brought by the community has poor water quality. For the issues faced by the people of Rawa Makmur, it is necessary to measure the Vertical Electrical Sounding (VES) Geoelectric method to see the rock lithology of flood-prone areas such as Rawa Makmur village, Bengkulu city.

The Vertical Electrical Sounding (VES) method is a geoelectric measurement technique that aims to estimate changes in resistivity as a function of depth at the measurement point. The measurement results of the VES method for subsurface and shallow sediments are very effective because the VES method provides model results in the form of lithology, physical properties of rocks, and thickness and depth of subsurface layers [5]. Different electrode spacings are used in the sounding technique, as the distance between electrodes determines the depth of investigation. The most commonly used electrode configuration is the Schlumberger configuration. Vertical Electrical Sounding (VES) can use the sounding method for groundwater, tectonics, petrology, metallic mineral exploration, and geotechnical purposes [6].

Geological Setting

The geological conditions of Rawa Makmur village have two geological formations, Alluvium formation (Qa) and Swamp Deposits formation (Qs), shown in Figure 1. Rawa Makmur village has Qa formation has a reasonably wide distribution. The Qa consists of gravel, sand, silt, mud, and clay. The Qs formation is spread in the western and eastern parts of the village. The Qs formation comprises sand, silt, clay, and gravel.

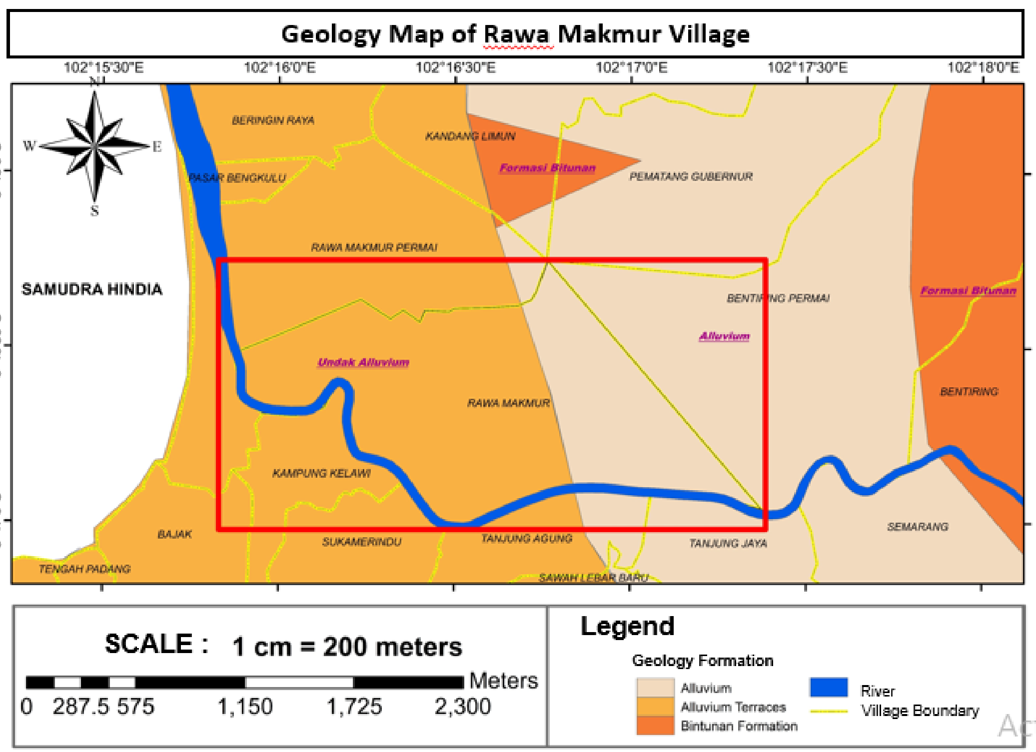


Figure 1. Geology Map of Rawa Makmur Village

Theory

Geoelectricity is a geophysical method that studies the nature of the earth's electrical currents and how they are detected at the surface. The measurement includes naturally occurring potentials and winds due to current injection into the soil. Therefore, there are many electroelectric methods, one of which is the resistivity method [7]. Geo-electrical methods using the Schlumberger configuration can detect inhomogeneities in subsurface rock formations. In general, rock formations are not perfectly homogeneous. The position of the rock formation near the surface dramatically affects the measurement results. The measured value is apparent resistivity. In reality, the ground consists of rock layers whose resistivity varies depending on the position of the electrodes Figure 2. The Schlumberger configuration uses four electrodes with two potential electrodes and two current electrodes arranged in a straight line, making the possible electrode distance more minor than the current electrode distance. The measured value is apparent resistivity (ρ_a). The working principle of this method, using the formula [8]. :

M and N are potential electrodes and A and B are current electrodes with each electrode distance, $r_1 = (L - l), r_2 = (L + l), r_3 = (L + l), r_4 = (L - l\,)$. Where $L = AB/2$ and $l = MN/2$.

$$K = \pi \frac{(L^2 - l^2)}{2l} \tag{1}$$

$$\rho_a = K \frac{V}{I} \tag{2}$$

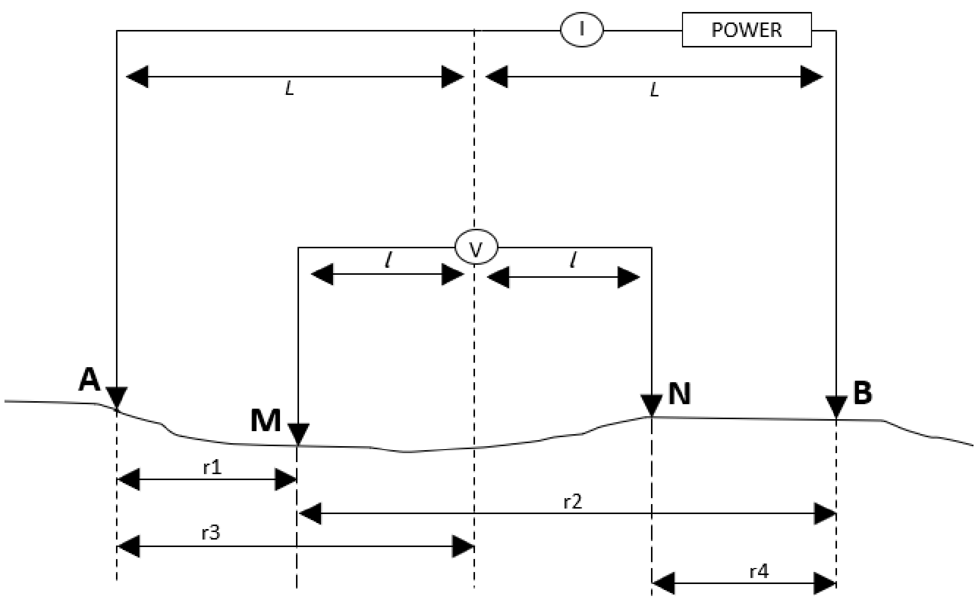


Figure 2. Schlumberger Configuration [9]

Methodology

This research wants to see the subsurface conditions of the Rawa Makmur village, a flood-prone area. This study's results will show how the characteristics of the rocks that make up the flood-prone area have low absorption capacity, so this area is very vulnerable to flooding. This research uses the MAE X612-EM Geoelectric tool in Rawa Makmur village, Bengkulu city. Field data acquisition was carried out on May 28-29, 2022, as many as 9 sounding points spread across the Rawa Makmur village, with the length of the track at each sounding point being 160 meters. The measurement trajectory is in the form of a line or straight line by adjusting the conditions of the measurement area. An illustration of measurements in the field can be seen in Figure 3. The results of field measurements are a 1D model, which is processed with Excel and Progress software.

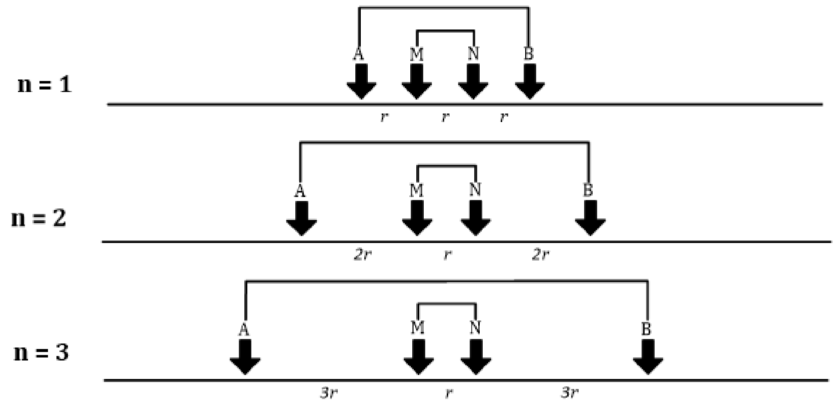


Figure 3. Illustration of field measurements [10]

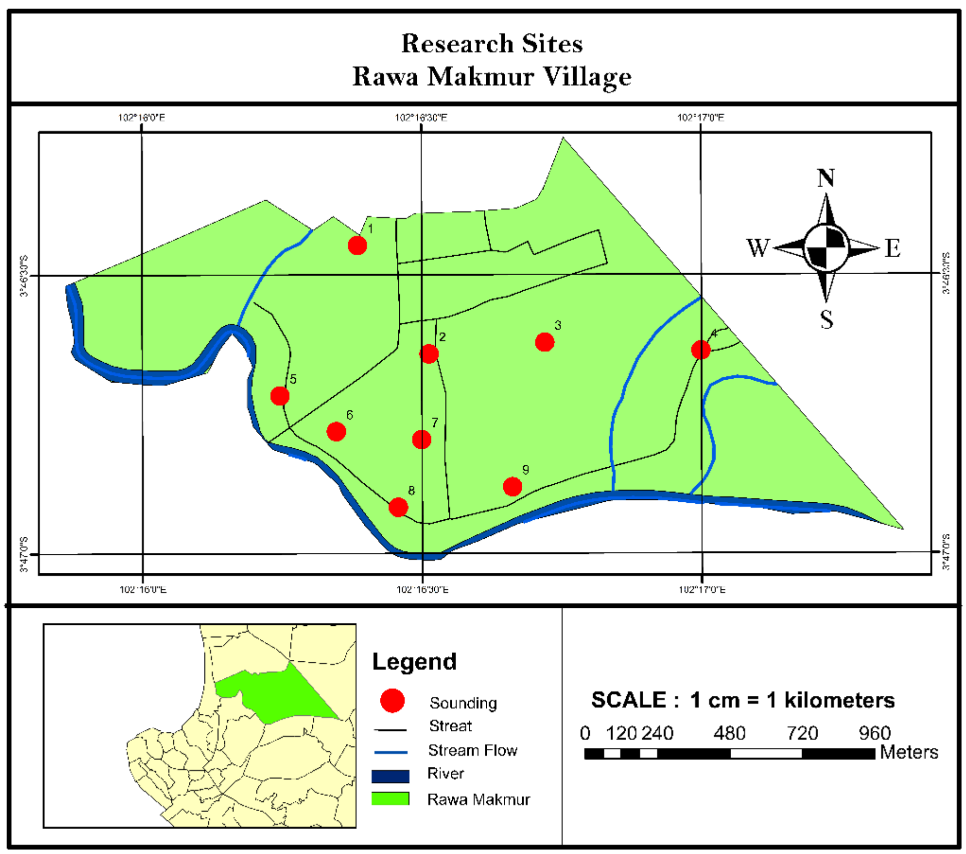


Figure 4. Research location map

Result and Discussion

Interpret 1D geoelectric data using the table of resistivity values by Telford [8] and adjust to the geological conditions of the data collection location. The results of each point have different depths, thicknesses, and rock resistivity values in each layer. The curve is generated from the least-squares inversion process based on the electrical properties of rocks below the earth's surface [11].

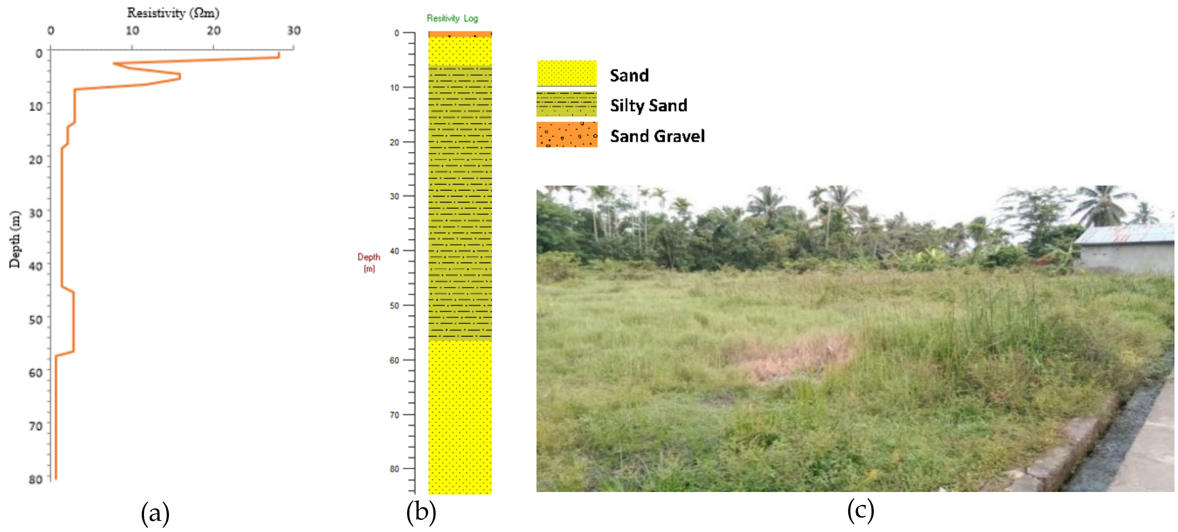


Figure 5. VES 1 (a) variations of resistivity with depth, (b) lithology of VES 1, (c) VES 1 location

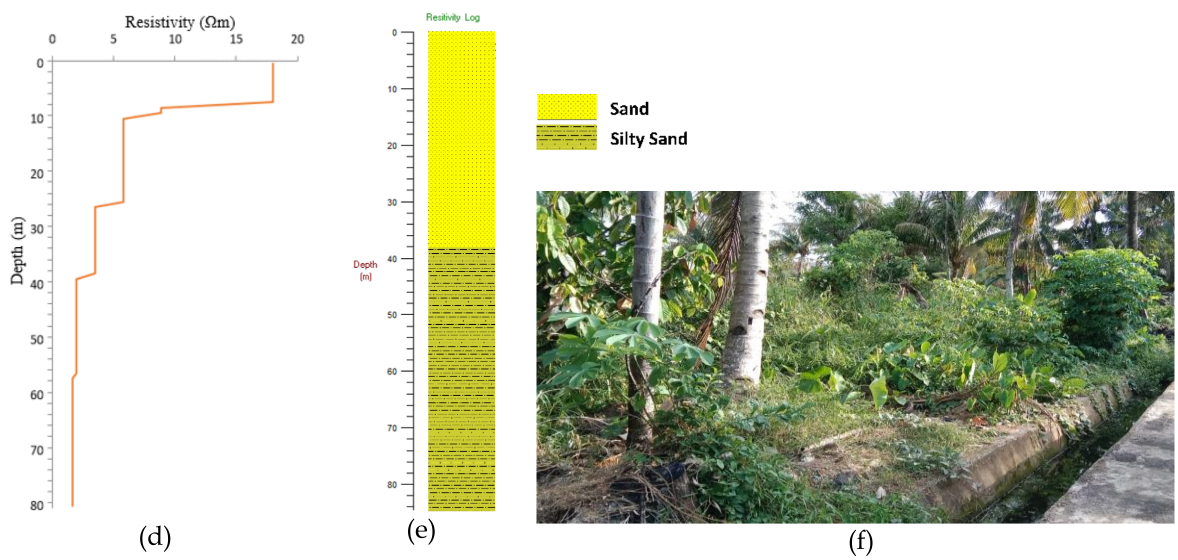


Figure 6. VES 2 (d) variations of resistivity with depth, (e) lithology of VES 2, (f) VES 2 location

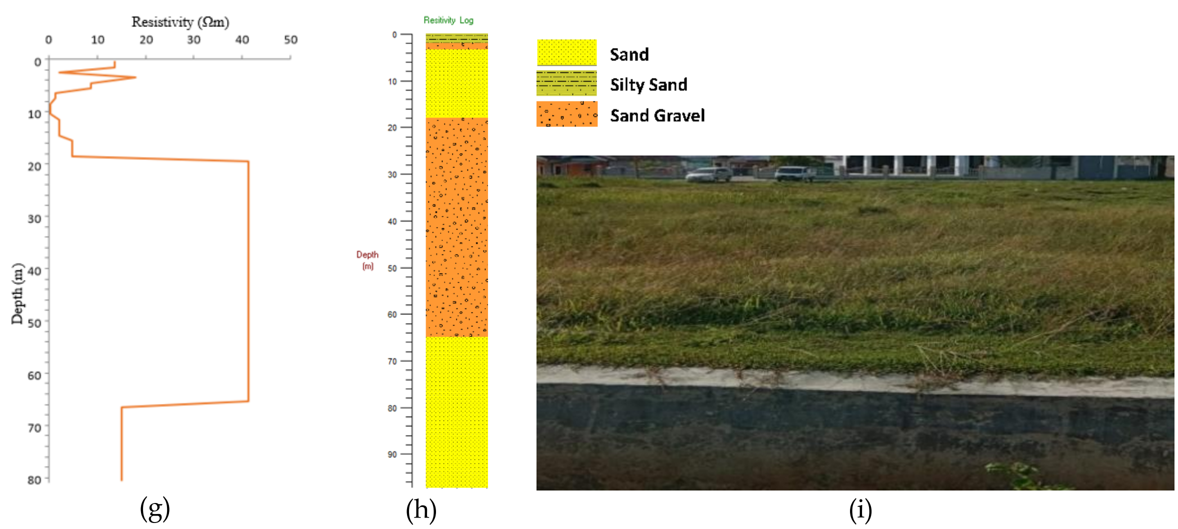
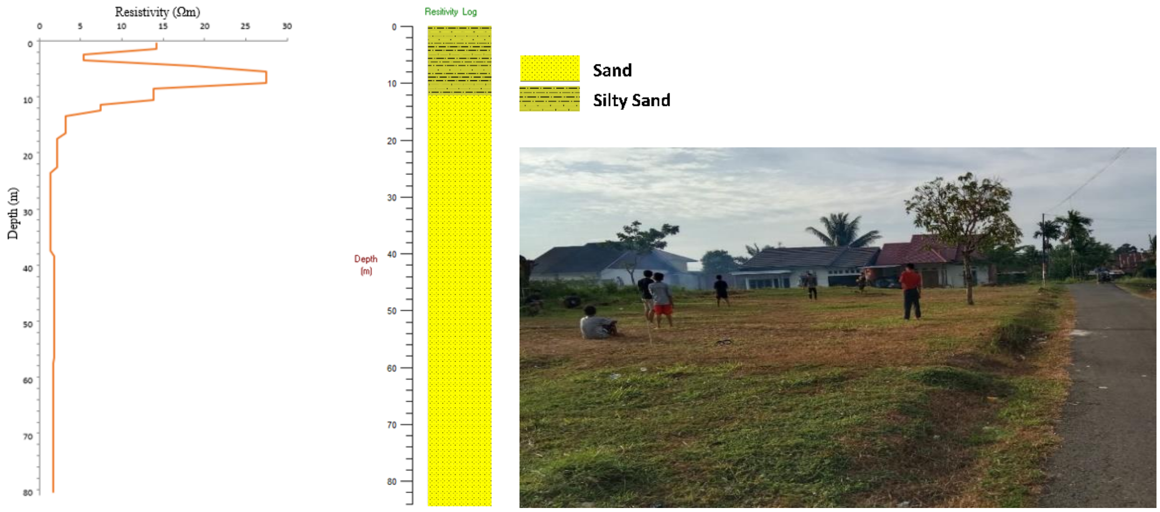
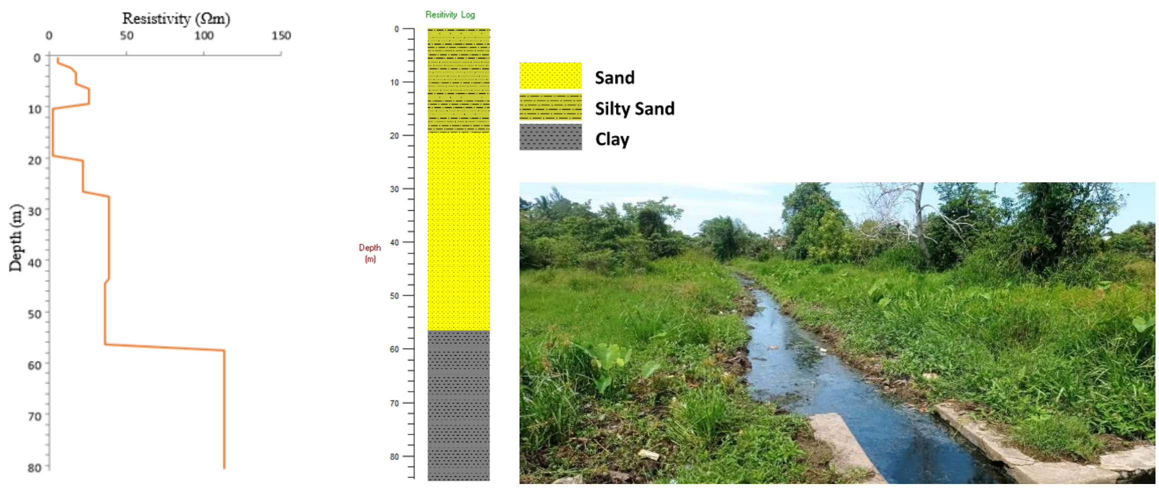


Figure 7. VES 3 (g) variations of resistivity with depth, (h) lithology of VES 3, (i) VES 3 location



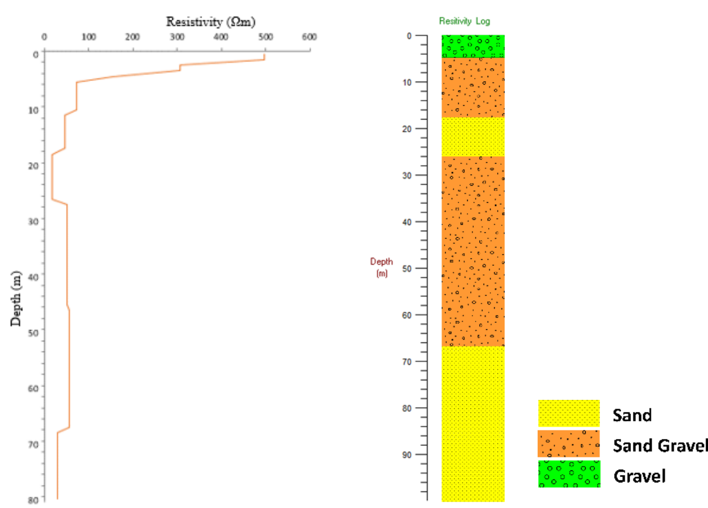
(j) (k) (l)

Figure 8. VES 4 (j) variations of resistivity with depth, (k) lithology of VES 4, (l) VES 4 location



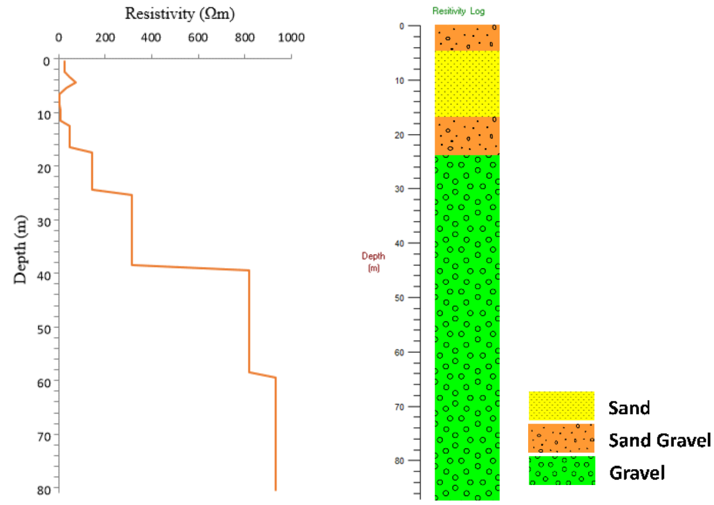
(m) (n) (o)

Figure 9. VES 5 (m) variations of resistivity with depth, (n) lithology of VES 5, (o) VES 5 location



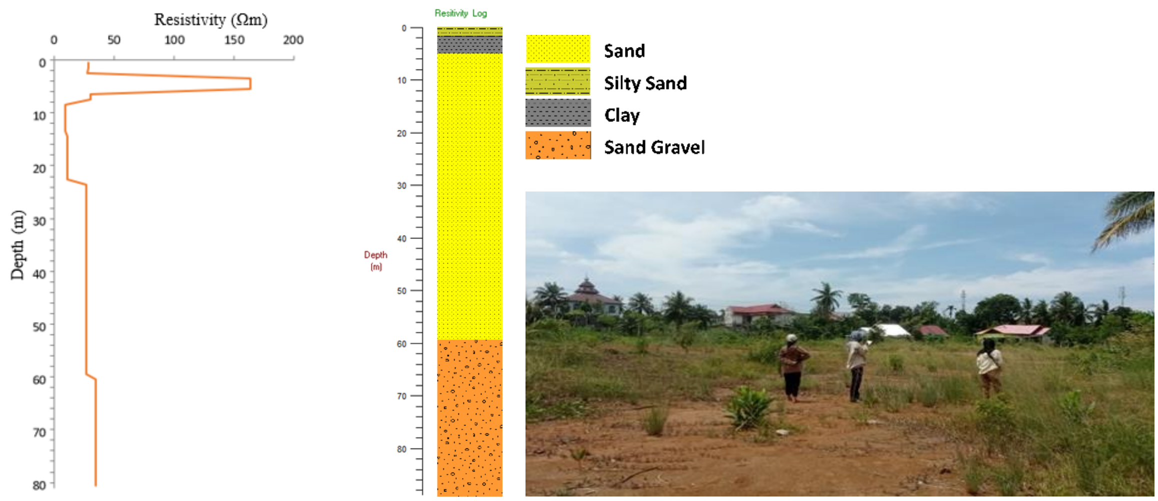
(p) (q)

Figure 10. VES 6 (p) variations of resistivity with depth, (q) lithology of VES 6



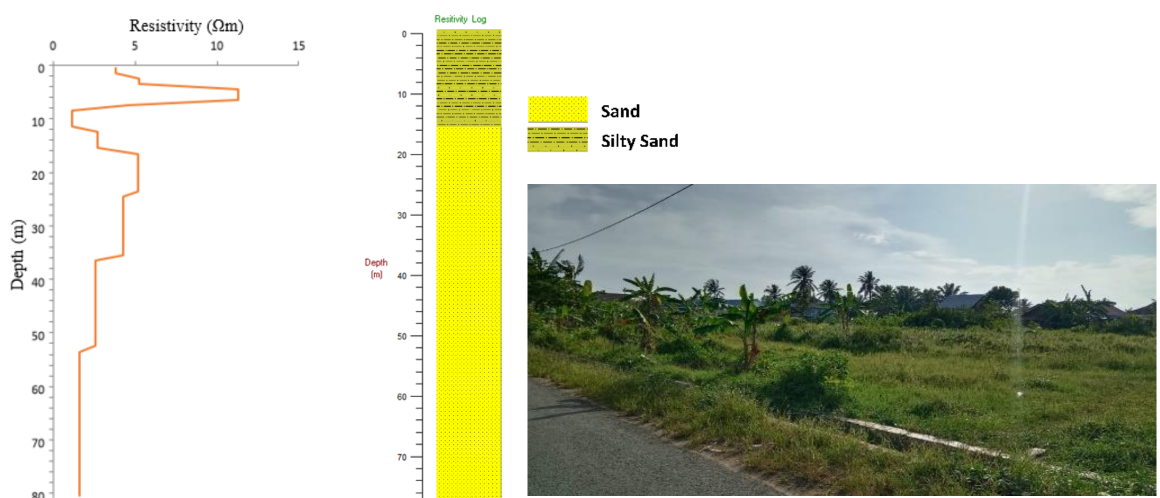
(r) (s)

Figure 11. VES 7 (r) variations of resistivity with depth, (s) lithology of VES 7



(t) (u) (v)

Figure 12. VES 8 (t) variations of resistivity with depth, (u) lithology of VES 8, (v) VES 8 location



(w) (x) (y)

Figure 13. VES 9 (w) variations of resistivity with depth, (x) lithology of VES 9, (y) VES 9 location

Table 1. Interpretation in each VES site

Site	Layer	Depth (m)	Thickness (m)	Resistivity (Ωm)	Lithology
VES 1	1	0-1	1	28,9	Gravel Sand
	2	1-6	5	13	Sand
	3	6-80	74	2	Silty Sand
VES 2	1	0-9	9	22,27	Sand
	2	9-80	71	5,78	Silty Sand
VES 3	1	0-2	2	13,53	Silty sand
	2	2-3	1	27,85	Gravel Sand
	3	3-18	15	0,29	Sand
	4	18-65	47	41,36	Gravel Sand
	5	65-90	25	14,98	Sand
VES 4	1	0-12	12	5,3	Silty sand
	2	12-80	68	25	Sand
VES 5	1	0-20	20	2,51	Silty sand
	2	20-56	36	22,04	Sand
	3	19-56	37	113,17	Clay
VES 6	1	0-4	4	497,67	Gravel
	2	4-18	14	154,94	Gravel Sand
	3	18-26	7	17,92	Sand
	4	26-67	41	47,32	Gravel Sand
	5	67-90	27	29,16	Sand
VES 7	1	0-4	4	27,65	Gravel Sand
	2	4-16	12	2,88	Sand
	3	16-24	8	143,45	Gravel Sand
	4	24-80	56	933,29	Dry Gravel
VES 8	1	0-2	2	17	Silty sand
	2	2-5	3	238,35	Clay
	3	5-59	54	9,06	Sand
	4	59-80	18	35	Gravel Sand
VES 9	1	0-16	16	1,17	Silty sand
	2	16-70	20	5	Sand

This research was carried out in a flood-prone area with several problems due to inundation by water after a flood disaster. One of the problems is the need for more clean water and the inundation of community houses even during the dry season. The research area is suspected of having a low absorption capacity, and the subsurface structure is dominated by malleable rock. This condition requires research to see the flood-prone area's subsurface structure and the characteristics of the constituent rock. The results of this study provide information and solutions for flood-prone areas in mitigating flood disasters such as making Biopori holes.

The measurement results in each VES prone to flooding have high homogeneity, one of which can be seen in Figure 6. The dominating rock structure in this flooded area is sand, silty sand, and clay. These rock types have high porosity [12] and can store water in their rock pores [13], making clay an impermeable layer. The water stored in the pores of this rock is called groundwater, characterized by stones with a small resistivity [14]. After surveying the research location, information about the water obtained by the community in VES 1, VES 2, VES 3, VES 4, VES 5, VES 8 and VES 9 had poor water quality. The results of each 1D lithology model in VES 1, VES 2, VES 3, VES 4, VES 5, VES 8 and VES 9 are dominated by silt and sand rocks which are thought to cause the water obtained to have poor water quality. Another factor suspected to be the cause of poor water quality is groundwater that results from infiltration from the muddy Makmur Swamp. The VES 4 area is a swamp filled with laterite soil by the local community to become a construction site for houses in the vicinity Figure 8.

(l) is closest to the stream flow, so the water obtained in this area has a slightly brownish colour. The VES location close to the river becomes a discharge or groundwater release area [15]. At VES 3 at a depth of 7 meters, brackish water, sandstone, and groundwater result from infiltration from the swamp [16]. The results of each 1D lithology model in VES 1, VES 2, VES 3, VES 4, VES 5, VES 8 and VES 9 have a low water table of 1-10 meters below the surface. This low water table indicates that the rock structure that makes up the Makmur Swamp is saturated with water.

VES 6 and VES 7 are hilly areas and have no problems obtaining clean water. The difficulty experienced by the community at this location is that the district's dug wells dry up during the dry season. Because the measurement location is undulating and hilly, it becomes a recharge area or an area that can become a catchment area for water filling in rock pores [17]. The lithology in the VES 6 and VES 7 measurement areas shows that it is not saturated with water, so this measurement area is not prone to flooding. VES 6 and VES 7 are due to the geological conditions that are on cliffs and steep so that water is not stagnant.

Conclusion

The rock lithology of flood-prone areas in Rawa Makmur village, Bengkulu city using the Vertical Electrical Sounding (VES) method, shows that the structure of the rock layer is saturated with water and causes flooding. Areas were most vulnerable to flooding at research locations VES 1, VES 2, VES 3, VES 4, VES 5, VES 8, and VES 9. This area has a low topography with an elevation of 1-2 meters. Areas not prone to flooding at research locations VES 6 and VES 7 are unsaturated with water and are at an elevation 3-10 meters higher than the surrounding area.

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References

[1] Badan Pusat Statistik Provinsi Bengkulu, “Kota Bengkulu berada pada elevasi antara 0 – 16 m dpl dengan 70% topografi datar dan 30 % berbukit kecil dan rawa,” 2015. https://bengkulukota.bps.go.id/ (accessed Mar. 15, 2022).

[2] Dinas Kesehatan Provinsi Bengkulu, *Profil Kesehatan Provinsi Bengkulu*. Bengkulu: Dinas Kesehatan Provinsi Bengkulu, 2015. [Online]. Available: https://medium.com/@arifwicaksanaa/pengertian-use-case-a7e576e1b6bf

[3] M. E. Sulaiman *et al.*, “Analisis Penyebab Banjir,” *J. Geogr. Gea*, vol. 20, no. 1, pp. 39–43, 2020.

[4] Swarsono, Supiyati, and B. Harlianto, “Strengthening of Tsunami Wave Heights Geometry Structure Due To Trap Gulf Structur Geometry Serut River Rawa,” in *Prosiding Semirata 2015 bidang MIPA BKS-PTN Barat Universitas Tanjungpura Pontianak*, 2015, pp. 284–291.

[5] H. S. Salem, “Modelling of lithology and hydraulic conductivity of shallow sediments from resistivity measurements using Schlumberger vertical electric soundings,” *Energy Sources*, vol. 23, no. 7, pp. 599–618, 2001, doi: 10.1080/00908310119202.

[6] W. Lowrie, *Fundamentals Of Geophysics, Second Edition*. 2007.

[7] L. Hendrajaya and I. Arif, "Monograf, Geolistrik Tahanan Jenis," *Lab. Fis. Bumi ITB. Inst. Teknol. Bandung, Bandung*, 1990.

[8] W. M. Telford, L. P. Geldart, and R. E. Sheriff, *Applied geophysics*, vol. 127, no. 3212. Cambridge, 1931. doi: 10.1038/127783a0.

[9] J. M. Reynolds, *An Introduction to Applied and Environmental Geophysics*. England: John Wiley & Sons Ltd, Baffins Lane, Chichester, West Sussex PO19 IUD, 1997.

[10] M. . Loke, *A Practical Guide to 2-D and 3-D Surveys*. Penang, Malaysia, 1999.

[11] M. H. Loke, *2-D and 3-D Electrical Imaging Surveys*, no. May. 2004.

[12] M. R. Setiawan, R. M. Badri, and A. Singarimbun, "A Study Awal Pendugaan Akuifer Air Tanah di Kampus Itera dengan Metode Geolistrik Konfigurasi Schlumberger," *J. Sci. Appl. Technol.*, vol. 2, no. 1, pp. 40–46, 2019, doi: 10.35472/281445.

[13] I. Irwan, "Three-Dimensional Resistivity Model for Ground Water Exploration in Volcanic Zone of Tidar Pleteau, Malang, East Java," *Indones. Phys. Rev.*, vol. 3, no. 1, pp. 30–37, 2020, doi: 10.29303/ipr.v3i1.39.

[14] F. X. Anjar *et al.*, "Analisis Zona Resapan Dan Keluaran Air Tanah Di Desa Kutayu, Kabupaten Brebes Analysis of Groundwater Recharge and Discharge Zones in Kutayu Village, Brebes Regency," vol. 16, no. 2, pp. 97–104, 2020, [Online]. Available: http://dinarek.unsoed.ac.id

[15] R. Maria, "Hidrogeologi dan Potensi Resapan Air Tanah Sub Das Cikapundung Bagian Tengah," *J. Ris. Geol. dan Pertamb.*, vol. 18, no. 2, p. 21, 2008, doi: 10.14203/risetgeotam2008.v18.13.

[16] A. S. Wijaya, "Aplikasi Metode Geolistrik Resistivitas Konfigurasi Wenner Untuk Menentukan Struktur Tanah di Halaman Belakang SCC ITS Surabaya (Halaman 1 s.d. 5)," *J. Fis. Indones.*, vol. 19, no. 55, pp. 1–5, 2015, doi: 10.22146/jfi.24363.

[17] Darsono, "Identifikasi Akuifer Dangkal dan Akuifer dalam dengan Metode Geolistrik (Kasus : Di Kecamatan Masaran), Indonesia Journal of Applied Physics.," *Surabaya Univ. Sebel. Maret.*, vol. 1, no. April, pp. 40–49, 2016.