

Identification of Abrasion-Prone Areas Based on Vertical Electrical Sounding (VES) at Geotourism Beach Pasar Bawah South Bengkulu

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ABSTRACT

This research was conducted to investigate abrasion-prone areas using the Vertical Electrical Sounding (VES) method at Pasar Bawah Manna Beach, South Bengkulu Regency. Data collection using a track length of 200 with the MAE X612-EM geoelectric tool that runs along the abrasion-prone area. Data processing using IP2WIN software and satellite images. This study aims to determine the subsurface of abrasion-prone areas and rock characteristics of abrasion. The results of this study indicate that the research location has seawater intrusion that seeps into the aquifer with a resistivity value of (0.763 - 8.01 Ωm) and the rock formation of the research area is dominated by alluvium rocks including gravel (130 - 356.2 Ωm), clay (14.65 Ωm), silt (16.5 - 61.41 Ωm), sand (258 - 313 Ωm), sandstone (97.6 Ωm), gravel (1496 Ωm), and limestone (2560 Ωm). Based on satellite image data, abrasion-prone is identified from several points in the study area that have significant shoreline changes at sounding point 1 where the point from 2008 to 2023 shows that abrasion has occurred quite significantly over the past 15 years, where at Sounding point 1 abrasion occurs along ± 23 meters / year. The findings of this research are expected to provide knowledge about disaster mitigation in sustainable tourism governance.

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I. INTRODUCTION

Bengkulu has an area of approximately 144.52 km² and is located on the western side of the island of Sumatra. Its seafront line is 525 km long, while its eastern region is surrounded by hills with fertile highlands. The western side, on the other hand, consists of a small area of low-lying land that stretches from north to south and has hilly contours. In terms of location, Bengkulu is located at the coordinates of 30°45' - 30°59' N/S and 102°14' - 102°22' E (Rika Widianita, 2023). Bengkulu has an interesting geographical location, especially in the coastal area of South Bengkulu Regency. One of the places worth visiting is Pasar Bawah Beach, which is located in Pasar Bawah Village, Pasar Manna District. This beach is located about 3 kilometers from the center of Manna City, so it can be reached easily by visitors (Julkrismi, 2018). Coastal areas that are easily affected by change need to be protected through effective management, so that they can be used to meet the needs of life and livelihoods of residents (Pratama et al., 2016). The coastline is the boundary between land and water that is constantly changing due to natural factors and human activities (Aryastana et al., 2016). Natural factors that influence changes in the coastline include hydrological, geological, climatic, and vegetation processes, as well as hydro-oceanographic processes such as waves, currents, tides, and climate change (Ramadhani et al., 2021). The shoreline is considered to be advancing if there are signs of deposition or uplift of the land. Meanwhile, the coastline is called backward if there is abrasion or sinking of the land (Yuliani & Rejeki, 2020).

Changes in coastal areas should be understood not only on a temporary basis, but also over a period of time. Temporary changes in the shoreline do not indicate that the beach is unstable, which is related to the analysis of shoreline change that refers to the dynamic equilibrium of the beach area. Dynamic equilibrium refers to the condition of a beach that, when viewed over a period of time (such as one year), does not permanently grow or decline. However, at certain times, the beach may increase or decrease according to the season. To accurately understand changes in the beach, observation poles with known coordinates are required, and are installed in locations prone to abrasion and monitored monthly (for at least one year) (Munandar & Kusumawati, 2017).

Pasar Bawah Beach has suffered serious damage due to continuous abrasion. The abrasion process that takes place in the Pasar Bawah Beach area cannot be separated from the geological conditions and physical oceanographic and hydrodynamic factors that exist in the area. Abrasion is a process that occurs when waves and ocean currents erode coastal areas, which can cause damage to the physical form of coastal water areas. This process is generally triggered by natural imbalances that occur in the coastal area (Lubis et al., 2020). Coastal abrasion is a significant risk for communities living in coastal areas. If this process continues unabated, it can erode the soil, which in turn will endanger the residence of people in coastal areas. Handling abrasion disasters must be carried out continuously by carrying out disaster mitigation efforts (Elya Kartika Rinjani et al., 2022). Soil abrasion in Bancar Subdistrict is triggered by land subsidence due to excessive groundwater extraction, which reduces the availability of water in soil pores and causes flooding, thereby increasing the risk of abrasion and coastal abrasion (Ima Nurmalia Permatasari, 2021). Research on abrasion has been conducted by (Supiyati et al., 2017) The results show that in the last 10 years, the coastline has experienced an average erosion of 12.63–18.48 m/year, with the highest rate in Muara Sambat, Maje, and a sedimentation rate of 10.62–18.74 m/year, with the highest rate in Semidang Gumai. These changes are influenced by natural factors such as coastal morphology, waves, coastal materials, and human activities such as uncontrolled sand mining.

Global climate change and the damage it causes are caused by various factors, including global warming that results in the greenhouse effect. This has led to sea level rise due to higher water waves, especially in the northern coastal areas of Java (Rumahorbo et al., 2023). Extreme climate change caused by tropical cyclones and minimal vegetation exacerbates abrasion. Planting mangroves and casuarina trees is effective in retaining sediment, reducing waves, restoring ecosystems, and protecting the coastline when done on a large scale and properly maintained (Ervianto, 2019).

Research on shoreline changes (Rahmawati et al., 2024) The average coastline change is ± 8 m/year, with severe abrasion at points 1, 2, 4, 6, and 8 (± 3.4 –8 m/year), while points 3 and 7 experience low abrasion (± 0.1 –0.5 m/year). The rock types consist of soil, clay, and limestone to a depth of ± 30 m.

The shallow limestone layer at points of severe abrasion makes it more vulnerable, while at points of low abrasion this layer is deeper and therefore able to withstand waves.

Disaster mitigation can be done with several strategic steps. First, it is important to understand the level of damage caused by abrasion and to know the areas affected (Elya Kartika Rinjani et al., 2022). Regular education, relocation of settlements in high-risk zones, prevention of new construction in vulnerable areas, and coastal management involving the community are needed to reduce vulnerability and maintain the sustainability of the coastal environment. (Ima Nurmalia Permatasari, 2021). Structural mitigation is the physical measures taken to reduce the risk of abrasion. Various structural mitigation measures that can be implemented include the construction of breakwaters, abrasion reduction devices, groins, shelters on stilts, and setting up evacuation areas during disasters. In addition, there are also several mitigation measures that use artificial ecosystems that can be implemented, such as planting mangroves or shrimp cypress in sandy beach areas (Suhendra, et al., 2019). This research applies the Vertical Electrical Sounding (VES) geoelectric method using the Schlumberger setup (Riskawati & Abdullah, 2021). This method was chosen because of its ability to detect changes in resistivity values vertically. In this way, similar underground layers can be recognized through the variations that occur at the potential electrodes (Darmiati et al., 2020).

Data processing in this study was carried out using IP2Win software and satellite images. The models obtained consisted of 2D modeling, as well as maps showing shoreline changes over the past 15 years. The findings of this study are expected to illustrate the abrasion disaster. This study aims to mitigate disasters for the Government and the Community in tourism management to respond to emergency situations at Pasar Bawah Beach, Pasar Manna District, South Bengkulu Regency. VES was chosen because it is efficient, inexpensive, and sensitive to changes in vertical resistivity, making it effective for mapping soil layers, water content, and saline intrusions that are directly related to abrasion potential.

II. METHOD

2.1 Regional Geology

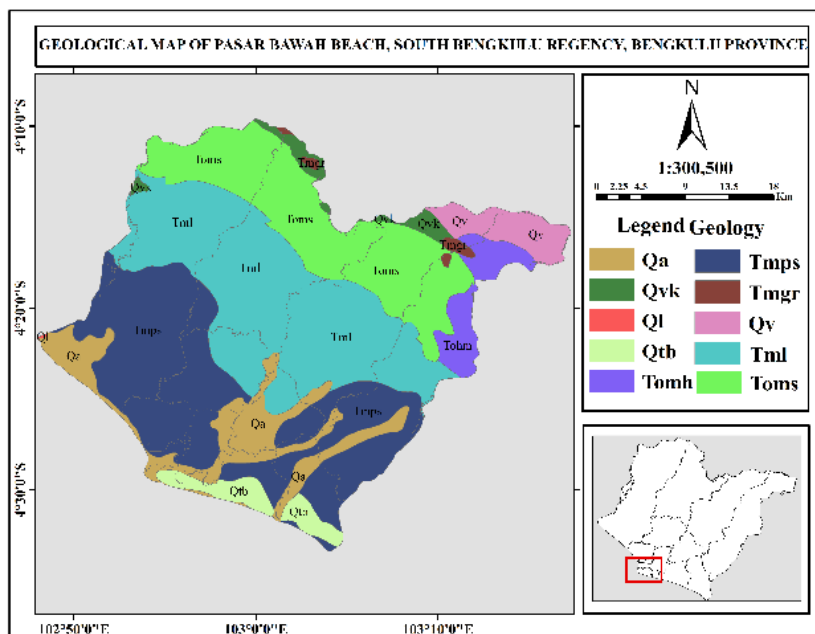


Figure 1 Geologic Map of Manna South Bengkulu (Gafoer, S., Amin, T.C., 2012)

Pasar Bawah Beach, South Bengkulu Regency, Indonesia, is located in a geological area with various rock formations., as described by (Gafoer, S., Amin, T.C., 2012) (Figure 1). The rock formations in the study area vary depending on the geographical location and specific geological conditions in each region. The coastal area of Pasar Bawah Manna, South Bengkulu Regency (red box on the geological map) is dominated by soft alluvial formations (Qa).

2.2 Research Method

This research was conducted in October 2024 at Pasar Bawah Beach Tourism Area, Pasar Manna District, South Bengkulu Regency. The research area is located at coordinates $4^{\circ}10' - 4^{\circ}32' \text{ N}$ and $102^{\circ}48' - 103^{\circ}16' \text{ East}$. This study used the Vertical Electrical Sounding (VES) geophysical method with a Schlumberger configuration (Figure 2). The research was conducted in an area of 2,750 m with 30 VES points in areas prone to abrasion. The distance between electrodes was determined according to the target depth, with the current electrodes (A–B) gradually widened ($AB/2 = 1\text{--}200 \text{ m}$) to reach greater depths, while the potential electrodes (M–N) were kept close to the center of the path ($MN/2 = 0.5\text{--}10 \text{ m}$) for accurate potential difference measurements. The comparison of the AB distance, which is much greater than the MN distance, ensures that the sounding results represent the vertical conditions below the surface.

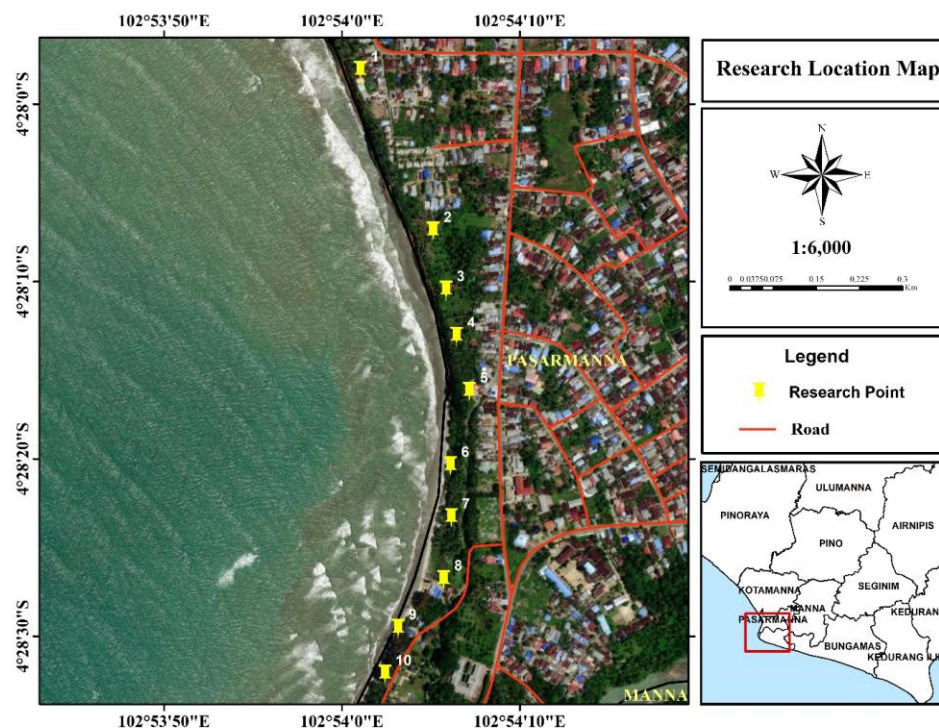


Figure 2 Map of the research location of 10 points in the Pasar Bawah Manna Beach area

Field data was processed using IP2Win software through $AB/2$ and ρ_a (apparent resistivity) inputs, followed by inversion and automatic minimization processes with layer selection until the error was $< 5\%$ (Figure 3). After matching the auxiliary curve with the measurement data, the comparison results will be displayed. If the error rate is still high, refine the data by selecting Edit Curve on the toolbar, then save the improvements. Next, the data obtained is combined to form a two-dimensional (2D) cross-section through the process of correlating VES points by selecting the Add File option in the File menu on the toolbar.

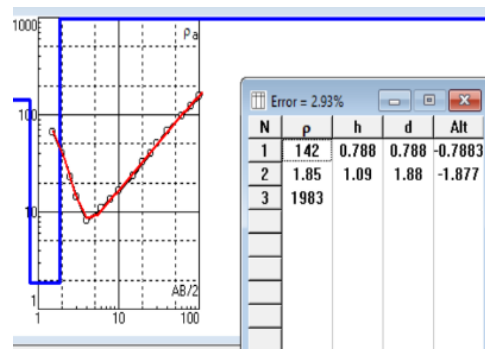


Figure 3. Error less than 5%

III. RESULT AND DISCUSSION

Table 2 Results of data interpretation at each VES site (Telford, W. M., L. P. Geldart, 1990; Sinaga et al., 2023)

VES	Layer	Resistivity Value ($\Omega.m$)	Thickness (m)	Depth (m)	Lithology
1	1	142	0.788	0.788	Gravel
	2	1.85	1.09	1.88	Saline sandstone
2	1	274.1	0.75	0.72	Gravel
	2	14.65	0.5115	1.262	Clay
	3	61.41	1.231	2.493	Silt
	4	23.26	6.793	9.285	Clay
	5	356.2	12.83	22.12	Gravel
3	1	314	0.86	0.86	Gravel
	2	97.6	3.25	4.11	Sandstone
4	1	311	0.75	0.75	Gravel
	2	16.5	0.987	1.74	Alluvium
	3	313	2.39	4.13	Sand
	4	15.1	18.5	22.6	Alluvium
5	1	30.1	0.767	0.767	Silt
	2	0.58	1.06	1.83	Saline sandstone
6	1	0.763	0.763	0.763	Saline sandstone
	2	1.54	1.06	1.06	Saline sandstone
7	1	258	0.83	0.83	Sand
	2	4.46	9.95	10.8	Saline sandstone
8	1	1495	0.898	0.898	Sandy Gravel
	2	1.61	1.1	2	Saline sandstone
9	1	130	0.78	0.75	Gravel
	2	57.8	1.13	1.88	Silt
10	1	2560	0.78	0.78	Limestone
	2	8.01	0.827	1.61	Saline sandstone
	3	45.6	2.31	3.92	Silt
	4	10.4	5.98	9.9	Clay

Pasar Bawah Manna beach in South Bengkulu Regency is an area that is quite vulnerable to abrasion disasters. Abrasion disaster in this area occurs due to the process of soil abrasion (Farid et al., 2024). Based on satellite image analysis from 2008 to 2023, the coastline at Pasar Bawah, South Bengkulu Regency, has experienced rapid erosion over the past 15 years. As shown in Figure 4, points 1–5 have experienced erosion at a rate of between ± 16 and ± 29 meters per year. Meanwhile, points 6–10 have not experienced erosion because of their solid rock structure and protection by sea walls. In

addition, the area has been managed as the Pasar Bawah Beach tourist area, so the condition of the beach is relatively stable.

Figure 5 shows a 2D resistivity cross-section that is a combination of research points from point 1 to point 10. Interpretation of the 2D resistivity cross-section shows that abrasion at the study site is triggered by Saline sandstone with low resistivity values, especially at point 5, which has the potential for severe abrasion. Areas that are still relatively safe are located at points 2, 3, and 4 because they are still dominated by hard rock. Therefore, the government and the community need to pay special attention to point 5 for abrasion mitigation in the future.

The factors causing abrasion in the study area are due to the presence of fairly strong and continuous ocean waves, which cause rock abrasion. Stronger waves accelerate the process of rock abrasion with a lithological composition of clayey sandstone. This layer is categorized as an alluvial sediment formation, which has low permeability with high porosity. The higher the porosity (empty space in the rock), the lower the resistivity. The 2D models of Saline sandstone in the study area are very significant based on the information obtained. Saline sandstone is located at several research points, such as points VES 1, 5, 6, 7, 8, and 10 indicating significant abrasion due to seawater intrusion with low resistivity ($0.75 \Omega\text{m}$). The hard rock layer ($130\text{--}5537 \Omega\text{m}$), consisting of gravel, sandstone, breccia, and limestone, is relatively thin and has begun to erode, while the dominant formations are easily eroded silt and clay. These findings confirm the need for mapping abrasion-prone zones and disaster mitigation in geotourism areas near residential areas.

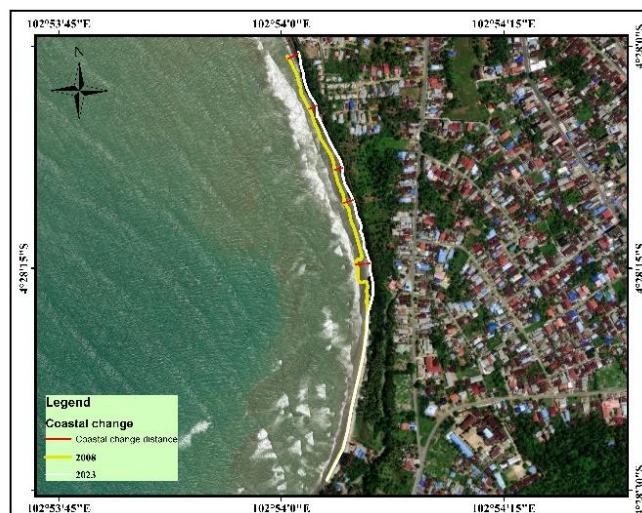


Figure 4 Shoreline changes (2008-2023) at points 1-10 at Pasar Bawah Beach, Manna, South Bengkulu.

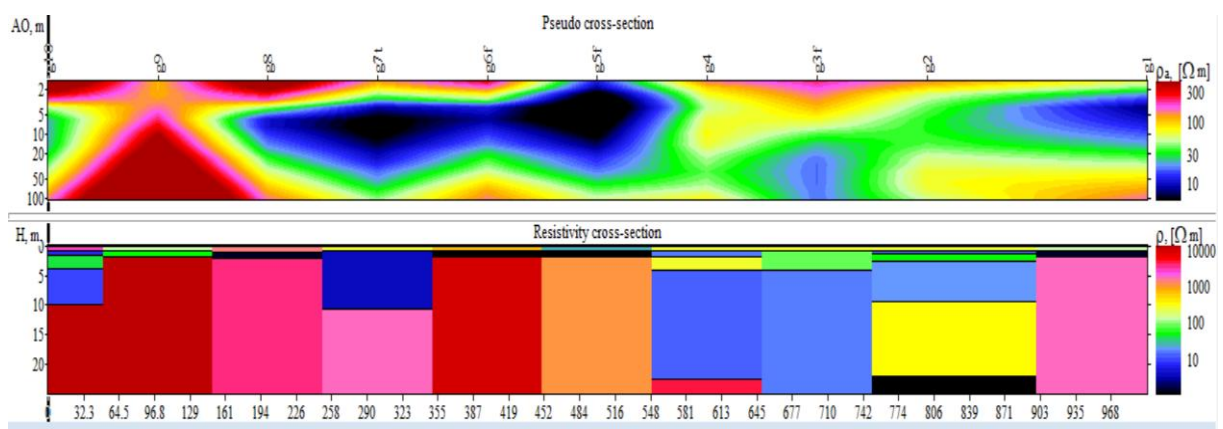


Figure 5 Two-dimensional resistivity cross-section model and relationship between VES points 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10

IV. CONCLUSION

Research in the geotourism area of Pasar Bawah Beach, Manna, South Bengkulu found salt sandstone in an aquifer with a resistivity value of 0.763–8.01 Ωm and alluvial deposits such as gravel, clay, mud, sand, sandstone, passive gravel, and limestone. Satellite imagery data shows significant changes to the coastline, particularly at measurement point 5, which has experienced erosion of approximately 29 meters from 2008 to 2023. These findings are expected to support disaster mitigation efforts in sustainable tourism management.

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