http://journal.uir.ac.id/index.php/JGEET

E-ISSN : 2541-5794
P-ISSN : 2503-216X

Journal of Geoscience,
Engineering, Environment, and Technology
Vol 10 No 3 2025

RESEARCH ARTICLE

Analysis of Potential New Flood Basin in Ratu Agung Sub-district Using the HVSR Method

Yelda Apriana, Refrizon*, Muchammad Farid, Jonah Onawa, Meno Hardianza, Yuni Setyowati, Sendiya Verentina

[1] *Physics department, Geophysics Study Program, Faculty of Mathematics and Natural Science University of Bengkulu,Bengkulu, 383 71, Indonesia.*

* Corresponding author : refrizon@unib.ac.id
Tel.:+628-53-6951-8039

Received: May 21, 2025; Accepted: Sep 12, 2025.
DOI: 10.25299/jgeet.2025.10.3.22541

Abstract

Indonesia is a tropical country with high rainfall and diverse topography, making it prone to flooding. In Bengkulu City, the flood risk is particularly high in low-lying and flood basins, which are critical zones for flood risk mitigation. This study aims to analyze the characteristics of rock types and water infiltration potential that may trigger new flood basins in Ratu Agung District, Bengkulu City. The microtremor method was applied to assess soil properties based on the dominant frequency (f_0), amplification factor (A_0), and sediment layer thickness. The analysis showed (f_0) values ranging from 1.13 to 8.55 Hz and (A_0) values ranging from 0.74 to 4.59. HV-Inv analysis results indicate shear wave velocity V_s values between 53 and 894 m/s, with five sediment layers reaching a depth of 100 m. Higher V_s values generally represent denser, less porous rock, limiting infiltration and increasing surface runoff, which elevates flood potential. The findings of this study are expected to serve as a reference for flood risk mitigation, especially in minimizing infrastructure damage and social impacts in Bengkulu City.

Keywords: Basin, Bengkulu City, Flood, Microtremor, Shear wave velocity.

1. Introduction

Bengkulu city is located on the western side of Sumatra Island, at coordinates 3° 45' S to 3° 59' S and 102° 14' E to 102° 22' E (Meinita et al., 2022). Geographically, Bengkulu city has a varied topography, consisting of lowlands, hills, and coastal areas (Rozi, 2020). In terms of elevation, Bengkulu is located at an altitude of 0 to 16 meters above sea level, with 70% of the area consisting of relatively flat plains and 30% comprising small hills and wetlands (Suherianti et al., 2018).

The lowland and basin areas in this region are prone to flooding, as water tends to accumulate in low-lying areas. This condition causes rainwater runoff to be concentrated in the basin areas, increasing the risk of inundation. Impermeable areas usually consist of geological formations composed of sandstone, silt, clay, and gravel layers, creating natural basins with varying water absorption capacities (Septian et al., 2020).

Ratu Agung District consists mostly of low-lying basin areas that are prone to waterlogging, making it highly susceptible to prolonged waterlogging, especially after heavy rainfall. Many locations in this area are affected by flooding, with the duration of waterlogging largely determined by local characteristics such as clay or alluvial soils, which have low water infiltration capacity.

Basins contribute to the prolonged receding of standing water. This waterlogging often takes the form of large floods that continue even after rainfall has stopped. This risk is further exacerbated in areas with poor drainage systems, making basin areas particularly vulnerable to waterlogging (Sambas, 2017).

Areas with characteristics resembling swamps or paddy fields exhibit distinctive hydrological dynamics. In the dry season, these areas typically dry out due to low water supply, while in the wet season, they become zones of significant water accumulation (Hafiyyan et al., 2015).

Water infiltration is often limited by low-permeability layers such as clay or alluvial deposits, which prevent water from penetrating into deeper layers. As a result, stagnant water becomes difficult to drain and persists for a long time. This phenomenon reflects the limited water absorption capacity of the area (Arrosyidah et al., 2024).

To analyze the characteristics of soil layers or soil stiffness that may contribute to water accumulation, the Horizontal to Vertical Spectral Ratio (HVSR). This method measures parameters such as dominant frequency (f_0), amplification factor (A_0), dominant period, and shear wave velocity (V_s), which help in understanding the characteristics of soil layers and subsurface structures.

Through the analysis of these parameters, the characteristics of soil layers affecting water infiltration and the potential for water accumulation can be identified. This method serves as an effective tool for supporting flood risk mitigation planning and land management. Measurements using the HVSR microtremor method provide an overview of the subsurface soil structure, rock types (Arintalofa et al., 2020), and basins that are potentially prone to flooding. This approach helps in better predicting flood risks, thereby supporting more effective disaster mitigation planning.

Previous research by Setyowati et al.(2024) demonstrated the use of geophysical methods, particularly the HVSR technique, in mapping shear wave velocity (V_s) and evaluating subsurface conditions, which further supports its application in flood risk analysis research in Bengkulu City, which remains limited, particularly in understanding V_s variations in flood-prone areas. The majority of studies, especially in Ratu Agung District, primarily focus on seismic vulnerability, such as Refrizon et al. (2013), in comparison to flood analysis. Although the HVSR method has been widely applied, detailed local data for the Bengkulu region, particularly in basins with high flood risk, remains insufficient.

This study aims to examine the characteristics of rock formations and soil layers that may contribute to the formation of new flood basins. The results are expected to contribute to flood mitigation efforts in Bengkulu City and emphasize the importance of geological and topographical understanding for spatial planning.

1.1 Horizontal to Vertical Spectral Ratio (HVSR)

To analyze the characteristics of soil layers or soil stiffness that may contribute to water accumulation, this study uses the horizontal-to-vertical spectral ratio (HVSR) method. Will analyze data obtained from seismometers through direct recordings. This analysis helps in gaining insights into the properties of the subsurface structure (Praja et al., 2023). This method uses the ratio of horizontal to vertical spectra to estimate the dominant frequency and local geological amplification.

$$\boldsymbol{HVSR = T_{SITE}} = \frac{\sqrt{[(S_{NORTH-SOUTH})^2+(S_{EAST-WEST})^2}}{S_{Vs}} \quad (1)$$

1.2 Amplification Factor (A_0)

Waves generated by significant density contrasts between different rock layers are referred to as the amplification factor (*A₀*). Rock density influences the amplitude of seismic waves, affecting the magnitude of wave amplitudes in both hard and soft layers (Al Ayubi et al., 2020).

The classification of the amplification factor (A0) values is presented in Table 1.

Table 1. Classification of $\boldsymbol{A_0}$ (Demulawa, M., dan Druwati, 2021)

Zone	Classification	Amplification Value
1	low	$A < 3$
2	Moderate	$3 \le A < 6$
3	High	$6 \le A < 9$
4	Very High	$A \ge 9$

1.3 Dominant Frequency (f_0) (Hz)

Dominant frequency (f_0) is the most frequently occurring frequency, considered as the frequency of the layer. The presence of thick sediment layers with high or low permeability, which influence water absorption capacity, can be identified through the dominant frequency (Bagus Hermawan et al., 2022). The soil classification based on dominant frequency values is summarized in Table 2.The dominant frequency indicates the rock layers in a region and determines the wave velocity in that area based on the relationship:

$$f_0 = \frac{V_s}{4h} \quad (2)$$

Table 2. Soil Classification Based on Dominant Frequency Values (Simanjuntak et al., 2017).

Soil Classification	Natural Frequency (Hz)	Soil Description
Type I	6.67-20	Tertiary or older rocks, such as hard sandy gravel.
Type II	4-6.67	Alluvial deposits, including sandy gravel, sandy hard clay, clay, loam, etc. Depth: 5-10 m
Type III	2.5-4	Alluvial deposits are almost similar to Type II, with the difference being the presence of an unidentified formation. Depth: 10-30 m.

1.4 Flood

Flooding is defined as the overflow of water from higher to lower elevations (Felix & Sentosa, 2020). During heavy rainfall and when soil infiltration capacity is low, especially in densely populated residential areas near river streams, surface runoff that cannot be absorbed by the soil increases the risk of flooding (Mahmud et al., 2021). Flooding also occurs when the drainage capacity is exceeded and the soil becomes saturated, usually in areas with low topography and high rainfall (Irawan et al., 2018).

Areas with low topography and high rainfall, where high rainfall and saturated soil infiltration increase (Irawan et al., 2018). The overflow of water exceeding the river's capacity or when the river cannot contain the incoming water is called a flood (Parwata & ; Wirya Sastrawan, 2021). Population growth increases the risk of flooding by putting pressure on infrastructure and the environment, which can lead to significant environmental damage. Therefore, proper drainage management is required (Latue & Latue, 2023).

Soil characteristics and topography influence the likelihood of flooding. Soils with measured parameters of low infiltration capacity, flat or basin-like topography, and prolonged high rainfall are more susceptible to flooding and waterlogging (Rulan, 2019). Depression areas in lowlands are prone to waterlogging if not properly managed and lacking an adequate drainage system. If water cannot be effectively contained, these depressions will experience significant flooding (Septian et al., 2020). As a result, to reduce the risk of flooding, proper land management and an efficient drainage system are essential, especially in areas with high-risk topography and geology.

1.5 Shear Wave Velocity (V_s) (m/s)

Shear wave velocity V_s is a term used to describe the speed of seismic waves traveling through a medium, which can be adjusted based on the properties of the soil layers it passes through (Ariyanto et al., 2024). The propagation velocity of waves is influenced by the properties of soil or rock, including rock density, water content, and rock compaction level. Interrelated with each other, shear density, shear modulus, and shear wave velocity increase with depth due to pressure, temperature, and mineral structure changes (Marjiono et al., 2015). Rock permeability significantly affects the water infiltration system into the soil. In hydrology, permeability refers to how quickly rainwater or surface runoff can seep into the ground. Shear wave velocity can provide data on sediment layer thickness, rock type, and its hardness level (Indra et al., 2019). The classification of shear wave velocity (Vs) values according to site class is shown in Table 3.

Table 3. V_s Value Classification (Praja et al., 2023).

No	Site Class	*Vs* (m/s)
1	SA (Hard Rock)	>1500
2	SB (Rock)	750 -1500
3	SC (Stiff Soil, Very Dense Soil, and Soft Rock)	350 -750
4	SD (Medium Soil)	175 -350
5	SE (Soft Soil)	<175

Shear wave velocity V_s values can be used to classify soil types and sediment layer characteristics. Low V_s values typically indicate the presence of alluvial layers or loose soil layers, which tend to have low infiltration and low soil bearing capacity, increasing surface water accumulation and the potential for waterlogging (Sunardi et al., 2019).

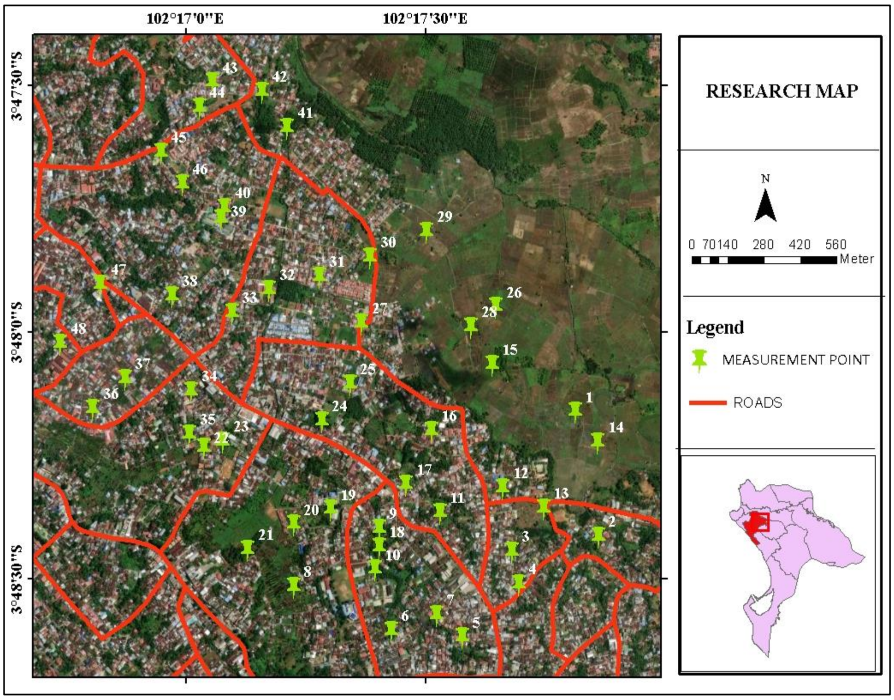


Fig. 1 Research Location Map

3. Method

3.1 Regional Geology

The geological formation of Ratu Agung District consists of alluvial terraces (Qat) and coral limestone (Ql). Alluvial terraces (Qat) are the youngest surface deposits, from the Holocene Quaternary period, composed of sand, silt, clay, and gravel, formed by river, coastal, and swamp deposits (Suhartini et al., 2019).

The formations of siltstone and compact clay have lower infiltration capacity, increasing the risk of flooding: soil with a very fine texture has a high potential for flooding, which can be further exacerbated by flat or basin-like topography during heavy rainfall.

3.2 Acquisition Data

The research was conducted in Bengkulu City, specifically in Ratu Agung District. This study was carried out in November 2024 with 47 measurement points, with a spacing of approximately 200-300 meters between points. The data processing was conducted in the physics laboratory. The data collection in this study was conducted by the Department of Physics, Faculty of Mathematics and Natural Sciences (FMIPA), Bengkulu University. A portable short-period seismograph was used, consisting of a PASI Mod Gemini 2 Sn-1405 seismometer as the sensor for recording, following SESAME instructions, with a frequency of 200 Hz and a recording duration of 30 minutes.

Before conducting the research, a preliminary survey was carried out to assess the field conditions and terrain. The measurement and data collection requirements in the field were determined by SESAME (Marcellini, 2006). Microtremor data acquisition was conducted by connecting the sensor to a laptop and aligning the instrument to face north. The measured parameters included: (1) Dominant frequency (f_0) determines the number of frequencies detected from sediment layers. (2) Amplification factor (A_0), indicates the density contrast between rock layers. (3) Shear wave velocity (V_s) describes how fast shear waves propagate through geological materials.

Data processing was carried out using the HVSR technique, resulting in an HVSR curve that had undergone windowing and signal transformation from the time domain to the frequency domain (FFT). After obtaining the HVSR curve, an analysis of the amplification factor (A_0) and dominant frequency (f_0) was conducted to describe subsurface structures. Additionally, the V_s value was determined using HV-Inv analysis, which provided shear wave velocity (V_s), sediment layer thickness, and rock density.

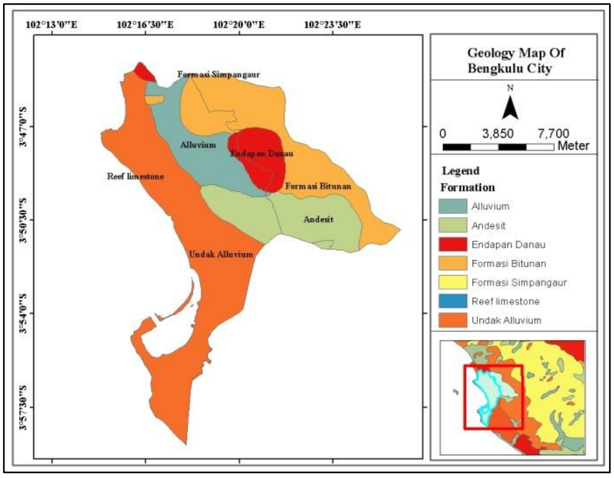


Fig. 2 Geological Map of Bengkulu City (Suhartini et al., 2019)

3.3 Forward Modelling

Forward modeling in this study was carried out conceptually and numerically to explain the relationship between the dominant frequency (f_0) and the subsurface layer properties. The initial estimation of sediment thickness and site amplification is based on empirical relationships between dominant frequency (f_0) and sediment thickness as described by Seht & Wohlenberg, (1999), developed further by Parolai et al. (2002), and discussed by Nakamura et al. (2008). The assumed shear wave velocity (V_s) and density (ρ) values for each layer were derived from standard literature. The classification of Vs values is shown in Table 3, while the typical material properties and input parameters used for forward modeling are listed in Table 4. To improve the reliability of the conceptual model, the theoretical HVSR curve was matched to the observed HVSR data using the HV-Inv software.

This inversion software adjusts the V_s, density, and layer thickness iteratively to obtain the best-fit model. The principle of this approach is based on the theoretical framework proposed by Sánchez-Sesma et al. (2011), which explains how Rayleigh and Love waves in a layered medium generate the resonance peak observed in the HVSR curve. The contrast of seismic impedance, determined by Vs and density differences between layers, controls the amplification and the dominant frequency response.

Table 4. Typcal material properties and input parameters used for forward modeling (adapted from Telford W M et al. (1990).

No	Material	Thickness (m)	Density (kg/m^3)
1	Alluvium	5	1800
2	Sediment	15	1900
3	Bedrock	-	2200

4. Results

4.1 Microtremor Data using the HVSR Method

Data acquisition using the HVSR method was conducted at 49 location points distributed in the basin area of Ratu Agung District, Bengkulu City. The results of direct measurements were in the form of seismic wave signals with three components: a vertical component (up and down) and horizontal components (north-south and east-west).

The data were analyzed using HVSR inversion, which provides an overview of subsurface characteristics such as sediment layer thickness, rock type, and geological structure based on V_s values and A_0. As shown in Figure 4.1, which illustrated the HVSR data processing, the selected data were natural ground vibration data in the time domain with small amplitudes. Subsequently, smoothing was performed with constant coefficients (b = 20, 40) and a time window of 20.00 s, resulting in an H/V curve. The resulting curve is shown in Figure 3.

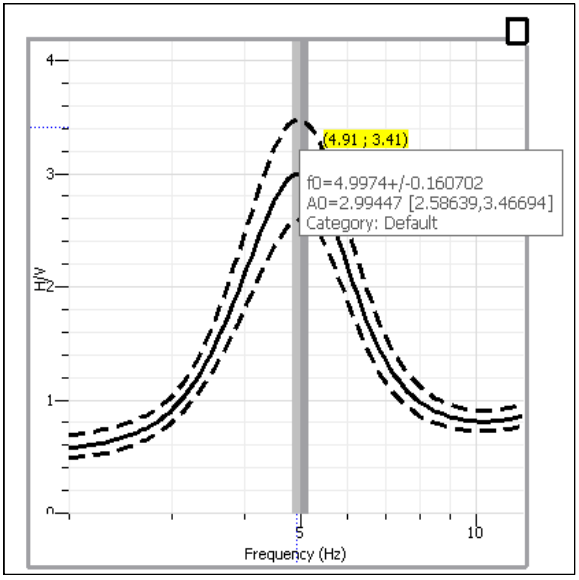


Fig. 3 HVSR Curve at Mesurement Point

Figure 3 shows the H/V curve where the horizontal axis represents the dominant frequency (f_0) and the vertical axis represents the amplification factor (A_0) while the dashed line indicates dispersion or deviation and the thick black line is the H/V curve.

4.2 Dominant Frequency (f_0) H_Z

A low dominant period value indicates a thick sediment layer, with the values at each point varying due to different soil conditions or soil properties and types at each research point. A high f_0 value indicates a thin sediment layer and a hard structure, and a low f_0 value indicates a thick sediment layer and a soft structure (Refrizon et al., 2024).

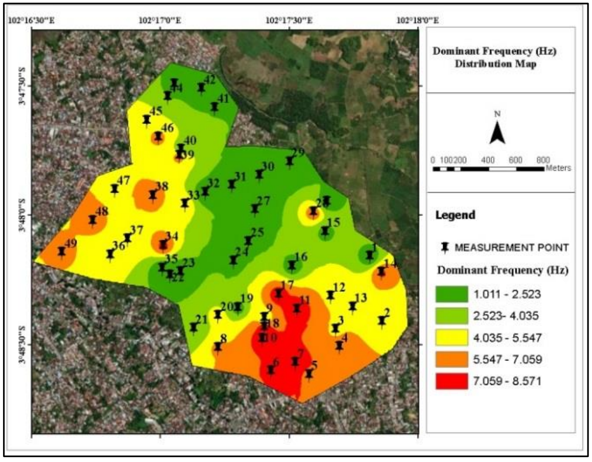


Fig. 4 Dominant Frequency (f_0) Distribution Map

Figure 4 shows the variation of f_0 values in the research area, which range from 1.011 to 8.577 Hz, indicating the sediment layer thickness of the research area.

4.3 Amplification factor (A_0)

A high amplification A_0 value indicates a thick, soft sediment layer, suggesting less dense or compact material, such as clay. This layer typically has high porosity but low permeability, causing water to be retained more on the surface than absorbed into the soil. Conversely, a low amplification value indicates a denser material, such as consolidated sand. This material has high permeability, allowing water to infiltrate the soil, thus reducing the risk of puddling or flooding.

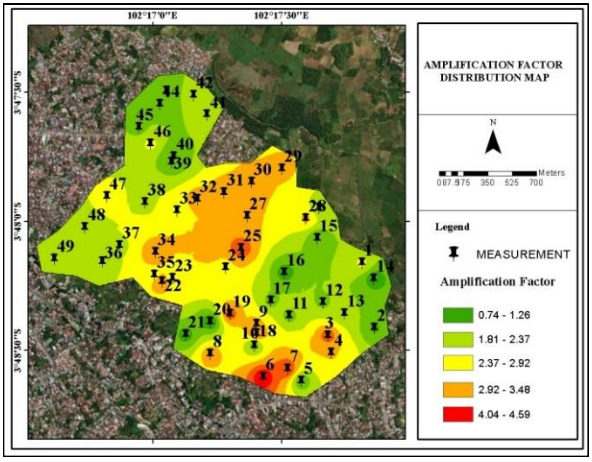


Fig. 5 Amplification Factor (A_0) Distribution Map

The variation of amplification values, ranging from 0.74 to 4.59, observed at each research point within the study area is depicted in Figure 5.

4.4 Elevation

The elevation of the research area was obtained from the National Digital Elevation Model (DEMNAS), which was then processed to create an elevation model. This was done to visualize the topography of the research area, which is in the form of a basin.

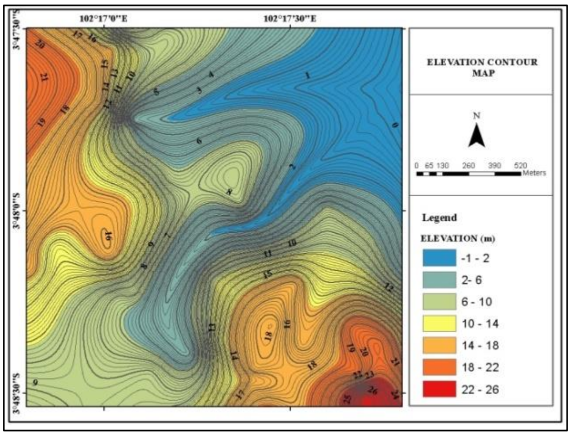


Fig. 6 Elevation of Research Area

4.5 Shear Wave Velocity (V_s) (m/s)

The analysis of shear wave velocity V_s at depths of 5 meters, 10 meters, 20 meters, and 30 meters reflects the characteristics of soil and rock in the research area. The V_s map at a depth of 5 meters ranges from 102 to 895 m/s, with low V_s values distributed in the basin and rice field areas, while higher V_s values are found in areas with higher elevations based on the research location survey.

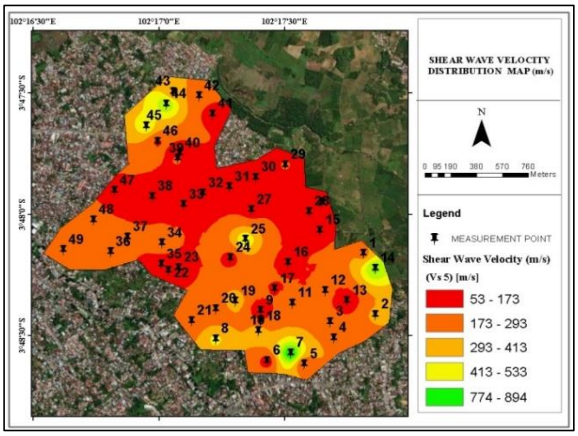


Fig. 7 Shear Wave Velocity(*V_s*) at 5 m Depth

At a depth of 5 meters, the V_s values range from 53 to 894 m/s. Areas with low V_s values tend to be located in basin areas, indicating that the soil layers in this area are still dominated by loose sediments. At a depth of 5 meters, or 5, the variation in V_s values in the research area is dominated by low V_s values, as shown in Figure 7, with low V_s values indicated by the color red.

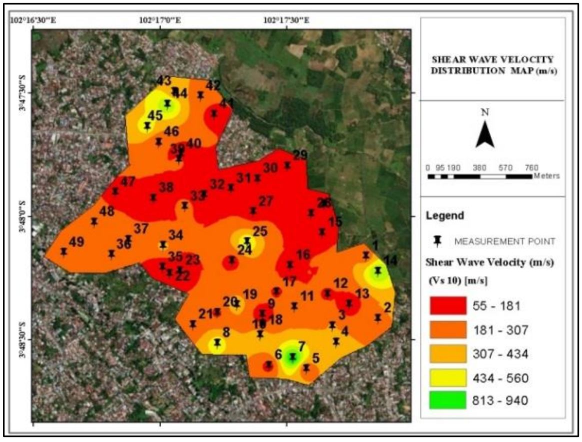


Fig. 8 *Vs* at 10 m Depth

At a depth of 10 meters, the V_s values range from 55 to 940 m/s. Areas with low V_s values tend to be located in basin areas, liable to flooding due to poor permeability, as seen in Figure 8. In this figure, red areas indicate regions with low V_s values, while green areas indicate high V_s values.

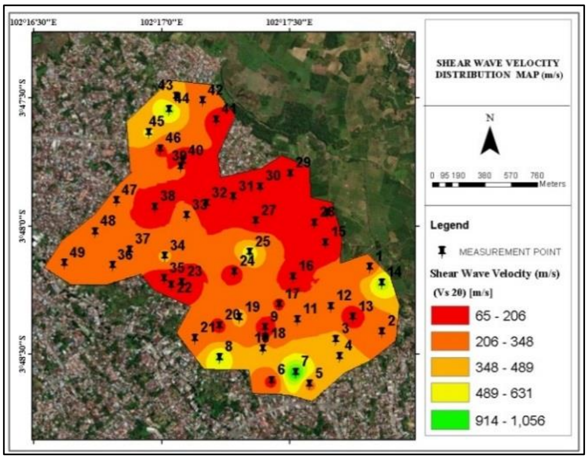
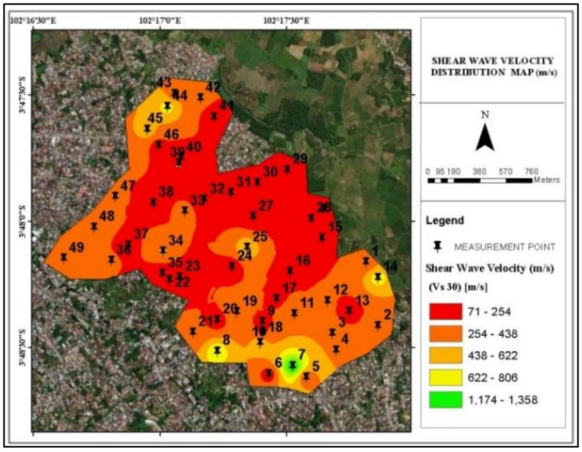


Fig. 9 V_S at 20 m Depth (m/s)

At a depth of 20 meters, the V_s values range from 65 to 1,056 m/s. Areas with low V_s values tend to be located in basin areas, susceptible to prolonged inundation due to inadequate infiltration, according to Maria et al. (2018).



Fig, 10 V_S at 30 m Depth (m/s)

At Vs 30, the variation in shear wave velocity values is shown. With V_s values ranging from 71 m/s to 1,358 m/s, indicating differences in soil layer characteristics at each research point. Areas with orange and red colors have V_s values ranging from 71 m/s to 655 m/s reflecting soft to medium soils. At several points with V_s values greater than 831 m/s, this indicates harder layers or denser soils.

5. Discussion

Data analysis from point T1 yielded a dominant frequency of 1.13 to 8.55 Hz. The comprehensive range of dominant frequency values, as illustrated in Figure 3, spans from 1.13 to 8.55 Hz. Lower frequency values generally suggest the presence of thick and soft sediment layers. The lowest f_0 value was observed at point 29, and the highest f_0 value at point 11. The amplification factor A_0 values ranged from 0.74 to 4.59, with the highest A_0 value recorded at point 7.

Based on Figure 4, the dominant frequency (f_0) values refer to Kanai (1983) in Table 2, ranging from 4 to 6.67 (class II). This range indicates the dominance of alluvial materials such as gravelly sand, sandy hard clay, clay, and loam. In

Figure 5, the distribution of amplification values A_0 based on the table according to Ratdomopurbo (2008). With values less than 3, which are classified as low, the research area is dominated by A_0 values in the low category, indicated by the color yellow, while high values are indicated by the color red. The rock density, which corresponds to the rock formations in the area, has a value range of 1000 kg/m^3 to 3000 kg/m^3.

Low dominant frequency (f_0) values and high amplification A_0 values are located at points 25-32, which, based on field surveys, are rice fields and marsh-like areas with low or concave elevations. These areas are almost always waterlogged due to limited drainage, and water tends to accumulate in low-lying areas, increasing the risk of prolonged inundation, especially during the rainy season or periods of high rainfall, according to (Yasa et al., 2022).

Low f_0 values, which typically indicate high water permeability, are countered by the presence of clay layers and rice field areas, further exacerbated by concave topography. This combination can hinder water absorption into the soil, leading to a higher potential for waterlogging in the region. Conversely, high f_0 values and low A_0 values, as observed at points 4, 5, 14, 17, 20, 38, 39, 45, 48, and 49, correspond to areas with relatively high elevations and hard soil layers, according to field surveys. These locations are characterized by Undak alluvium rock formations, composed of silt or clay, which exhibit low permeability, thus affecting the soil's water absorption capacity, according to (Hura et al., 2024).

Areas with high topography tend to drain water more rapidly, reducing waterlogging. Sand and gravel layers with high porosity can absorb more water, as indicated by high f_0 values. Conversely, areas with high f_0 and A_0 values in the Undak alluvium formation exhibit low permeability, so even though water flows to lower areas, the potential for waterlogging remains due to surface runoff.

The basin in the research area, as depicted in Figure 6, is shown in blue, representing rice fields and marsh-like areas. The low topography supports water accumulation in these areas, leading to frequent waterlogging. In addition to the low topography, water tends to be retained for extended periods during the rainy season due to low porosity, which limits material storage capacity. Low permeability further hinders water infiltration into the soil, causing water to remain on the surface and resulting in prolonged waterlogging.

Shear wave velocity (V_s) values identify soil material characteristics, including porosity and permeability. V_s values are directly proportional to rock density, where lower indicates soft sedimentary layers (Hadi et al., 2021). Then the rock density will decrease, ranging from 100 to 2000 m/s. Shear wave velocity (V_s) values vary across different layers, such as at depths of 5, 10, 20, and 30 meters. High V_s values indicate denser materials, such as bedrock or consolidated clay or sand, with low porosity due to material compaction and limited void space; V_s values increase with increasing depth.

The analysis of shear wave velocity (V_s) at depths of 5 m, 10 m, 20 m, and 30 m reveals variations in values that correlate with lithological characteristics and waterlogging potential in the study area. Based on the obtained V_s distribution maps, several areas with low V_s values were identified, indicating potentially poor geotechnical properties and contributing to waterlogging potential.

At a depth of 5 m, V_s values range from 55 m/s to 894 m/s. The majority of the area exhibits low V_s values, particularly in the central and southern regions of the study site, with values ranging from 55 m/s to 894 m/s. These low V_s values, points 15, 16, 29, 26, 28, and 47, although showing no consistent pattern, are located within basin areas, thereby increasing waterlogging potential. This indicates a dominance of loose and highly porous alluvial soil layers, exhibiting low drainage capacity and high water retention, according to Yullia et al. (2022), and further exacerbated by the condition of the area being rice field areas based on field surveys.

At a depth of 10 m, V_s values range from 55 to 940 m/s, exhibiting a similar pattern to that observed at 5 m depth, namely a dominance of low values in the central and southwestern regions. The relatively soft soil conditions result in poor drainage, exacerbating waterlogging during periods of high rainfall. Points such as 29, 27, 32, 28, 15, and 12, located in rice field and marsh areas within the basin, demonstrate that loose and highly porous soil layers are a primary factor contributing to the increased risk of waterlogging in Ratu Agung District, Bengkulu City.

At a depth of 20 m, the V_s value range increases to 65 m/s to 1,057 m/s. Although there is an increase in V_s values in some areas, regions with low Vs values are still widespread, particularly in the central part of the study area. This indicates that the soil layers in this area are still dominated by loose sediments to that depth, which can trap water and increase the duration of waterlogging.

At a depth of 30 m, V_s values range from 71 m/s to 1,359 m/s. According to the soil classification by the National Earthquake Hazards Reduction Program (NEHRP), areas with V_s values less than 180 m/s are categorized as soft soil, while areas with V_s values between 180 and 360 m/s fall into the stiff soil category. In the 30 m V_s distribution map, most of the study area shows V_s values in the soft to stiff soil category, indicating that this area has a high risk of waterlogging due to limited drainage capacity. High V_s values (>6) m/s indicate that the layer contains clay and is water-saturated, while V_s values between 3 and 6 indicate loose sand layers and are water saturated. Furthermore, soil density ranging from 500 to 3000 kg/m³ indicates variations in density values within the study area, where lower densities suggest looser and more porous soil, which retains water longer and increases flood risk.

Overall, areas with low V_s values have a higher risk of waterlogging because their soil has low permeability and high porosity, causing water to be retained longer (Jarwanto et al., 2024). Therefore, further studies on the hydrological and geotechnical characteristics of this area are necessary to mitigate future waterlogging.

6. Conclusions

The HVSR microtremor method effectively identifies waterlogging potential in basin areas. This study show f_0 values (1.13–7.8 Hz), A_0 values (0.74–4.59), and V_s values ranging from 53 to 1,358 m/s at depths of 5–30 m, reflecting lithological variations from soft soil to denser rock.

Areas with V_s values below 360 m/s, low f_0 values, and high A_0 values tend to have soft soil with low permeability, thereby increasing the risk of prolonged waterlogging. Most of the study area is dominated by loose sediments and highly porous alluvial soil, which has limited water absorption capacity, hindering natural drainage and increasing waterlogging potential during periods of high rainfall.

This method can be used as a preliminary study to understand subsurface conditions and assist in spatial planning and flood mitigation. However, further validation with other methods such as soil permeability tests and hydrological modeling is still needed for more accurate analysis.

Acknowledgements

We extend our deepest gratitude to Universitas Bengkulu and the Geophysics Department for their assistance and support throughout this research. Our special thanks are conveyed to Refrizon and Prof. M. Farid, our supervising lecturers, who provided valuable insights during the writing of this article, and to the team members for their technical corrections and assistance in data collection and processing. We also express our appreciation to the Geophysics Department for providing research facilities and the necessary data for this study.

References

Agus Ariyanto, A. F., , Yudha Styawan , Intan Andriani Putri, W. E. J., Prasetyo, N., & , Reza Rizki, R. W. (2024). Kemiling Dan Sekitarnya Seismic Vulnerability Microzonation Through Hvsr Microtremor Analysis in the Kemiling. *JGE (Jurnal Geofisika Eksplorasi)*, *10*(02).

Al Ayubi, S. S., Karyanto, K., Haerudin, N., Rasimeng, S., & Wibowo, R. C. (2020). Zonasi Site Effect Dan Analisis Bahaya Penguatan Gempa Menggunakan Metode Dsha Untuk Menentukan Pga Di Kabupaten Sumba Barat Daya. *Indonesian Physical Review*, *3*(2), 38–53. https://doi.org/10.29303/ipr.v3i2.44

Arintalofa, V., Yulianto, G., & Harmoko, U. (2020). Analisa Mikrotremor Menggunakan Metode HVSR untuk Mengetahui Karakteristik Bawah Permukaan Manifestasi Panas Bumi Diwak dan Derekan Berdasarkan Nilai Vp. *Jurnal Energi Baru Dan Terbarukan*, *1*(2), 54–61. https://doi.org/10.14710/jebt.2020.9276

Arrosyidah, M. R., Djayus, Mislan, & Munir, R. (2024). Laju Infiltrasi Air di Lubang Biopori pada Berbagai Jenis Tanah di Kelurahan Loa Bakung. *Jurnal Geosains Kutai Basin* , *7*(1), 1–8.

Bagus Hermawan, H., Taufiq Ridlo, D., Nasirudi, & Dewi Triastianti, R. (2022). Identifikasi Potensi Likuifaksi Berdasarkan Analisis Data Mikrotremor Di Desa Trimurti, Srandakan, Bantul. *Jurnal Rekayasa Lingkungan*, *Vol. 22*(No. 2), 1–6.

Demulawa, M., dan Druwati, I. (2021). Analisis Frekuensi Natural dan Potensi Amplifikasi Menggunakan Metode HVSR. *Edu Research*, *10*(1), 59–63.

Felix, L., & Sentosa, G. S. (2020). Simulasi Sumur Resapan Berdasarkan Analisis Perbandingan Ketinggian Air Banjir Di Kelapa Gading Jakarta. *JMTS: Jurnal Mitra Teknik Sipil*, *3*(3), 797. https://doi.org/10.24912/jmts.v3i3.8289

Hadi, A. I., Farid, M., Refrizon, R., Harlianto, B., Hudayat, N., & Krisbudianto, M. (2021). Pemetaan Potensi Kerentanan Gempabumi Pada Kota Bengkulu Menggunakan Data Mikrotremor dan Metode Analytical Hierarchy Process. *Jurnal Fisika Flux: Jurnal Ilmiah Fisika FMIPA Universitas Lambung Mangkurat*, *18*(2), 105. https://doi.org/10.20527/flux.v18i2.9479

Hafiyyan, Q., Marsudi, & Nurhayati. (2015). *DINAMIKA ALIRAN AIR TANAH PADA LAHAN RAWA PASANG SURUT*. Universitas Tanjung Pura.

Hura, J., Gulo, M., Nias, U., & Nias, U. (2024). *Analisis permeabilitas tanah berpasir dan tanah lempung dalam hubunganya dengan manajemen irigasi*. *01*, 60–67.

Indra, I., Efendi, R., & Abdullah, A. (2019). Estimasi Kecepatan Gelombang Geser Bawah Permukaan Pada Lapisan Dangkal Menggunakan Data Mikrotremor di Daerah Mamboro. *Gravitasi*, *17*(2), 10–19. https://doi.org/10.22487/gravitasi.v17i2.12418

Irawan, M. F., Hidayat, Y., & Tjahjono, B. (2018). Penilaian Bahaya Dan Arahan Mitigasi Banjir Di Cekungan Bandung. *Jurnal Ilmu Tanah Dan Lingkungan*, *20*(1), 1–6. https://doi.org/10.29244/jitl.20.1.1-6

Jarwanto, Annisa, & Sihombing, T. (2024). Analisis Permeabilitas Tanah Sebagai Upaya Penanganan Genangan Air di Kecamatan Banjarbaru Utara, Kalimantan Selatan. *Jurnal Review Pendidikan Dan Pengajaran*, *7*(2), 3815–3818.

Latue, T., & Latue, P. C. (2023). Pemodelan Spasial Daerah Rawan Banjir di DAS Batu Merah Kota Ambon. *Buana Jurnal Geografi, Ekologi Dan Kebencanaan*, *1*(1), 1–13. https://doi.org/10.56211/buana.v1i1.341

Mahmud. (2021). Hubungan Curah Hujan Terhadap Limpasan Permukaan dan Sedimen pada Berbagai Penggunaan Lahan di DAS Arui, Kabupaten Manokwari. *Jurnal Ilmu Tanah Dan Lingkungan*, *23*(2), 85–92. https://doi.org/10.29244/jitl.23.2.85-92

Marcellini, A. (2006). *Guidelines for the Implementation of the H / V Spectral Ratio Technique on Ambient Vibrations*. *December*, 1–69.

Maria, R., Rusydi, A. F., Lestiana, H., & Wibawa, S. (2018). Hidrogeologi Dan Potensi Cadangan Airtanah Di Dataran Rendah Indramayu. *RISET Geologi Dan Pertambangan*, *28*(2), 181. https://doi.org/10.14203/risetgeotam2018.v28.803

Marjiono, A. Soehaim, J. H. setiawa. (2015). Penentuan bidang gelincir longsoran berdasarkan karakteristik fisis batuan dengan seismik bias dangkal di daerah cililin, bandung. *Geo-Environment*, *XVI*(6), 387–394.

Meinita, F., Johan, Y., Hartono, D., Susatya, A., & Brata, B. (2022). Analisis Kesesuaian Dan Daya Dukung Kawasan Untuk Pengelolaan Ekowisata Pantai Kota Bengkulu. *Naturalis: Jurnal Penelitian Pengelolaan Sumber Daya Alam Dan Lingkungan*, *11*(2), 151–157. https://doi.org/10.31186/naturalis.11.2.24228

Munawaroh, F., Masdya, Y., Baqiya, M. A., & Triwikantoro, T. (2024). Indonesian Physical Review. *Indonesian Physical Review*, *7*(2), 250–258.

Nakamura, Masataka, Suzumura, Jun-ichi, Hanada, & Kazufumi. (2008). An Estimation Method Of Frequency Response Functions and Its Application To Microtremor. *14th World Conference on Earthquake Engineering (14WCEE)*, *1*.

Parolai, S., Bormann, P., & Milkereit, C. (2002). Parolai2002. *Bulletin of the Seismological Society of America*, *92*(6), 2521–2527.

Parwata, I. W., & ; Wirya Sastrawan, I. W. (2021). Undagi : Jurnal Ilmiah Arsitektur Universitas Warmadewa. *Jurnal Ilmiah Arsitektur Universitas Warmadewa*, *9*(1), 105–113.

Praja, N. K., Sitti Lasmi Mangininsih, Nia Kurnia Praja, Hasria, & Azhar. (2023). Pemetaan Lapisan Tanah Menggunakan Data Mikrotremor HVSR dan Dampaknya Terhadap Daya Dukung Tanah di Kawasan Kota Kendari. *Jurnal Geologi Dan Sumberdaya Mineral*, *24*(1), 51–58. https://doi.org/10.33332/jgsm.geologi.v24i1.724

Refrizon, Arif, I. H., Kurnia, L., & Tria, O. (2013). Analisis Percepatan Getaran Tanah Maksimum dan Tingkat Kerentanan Seismik Daerah Ratu Agung Kota Bengkulu. *Prosiding Semirata FMIPA Universitas Lampung*, 323–328.

Rozi Wahyudi. (2020). *Pemetaan dan Perencanaan Mitigasi Bencana Di Provinsi Bengkulu*. 57.

Rulan, S. A. (2019). Strategi Penanganan Banjir Genangan Di Kota Pekanbaru (Studi Kasus: Sub Das Siban). *Paper Knowledge*, 1–196.

Sambas, A. M. (2017). Kajian Kawasan Berpotensi Banjir dan Mitigasi Bencana Banjir pada Sub Daerah Aliran Sungai (DAS) Walanae Kecamatan Dua Boccoe

Kabupaten Bone. *Tesis*, 1–172.

Sánchez-Sesma, F. J., Rodríguez, M., Iturrarán-Viveros, U., Luzón, F., Campillo, M., Margerin, L., García-Jerez, A., Suarez, M., Santoyo, M. A., & Rodríguez-Castellanos, A. (2011). A theory for microtremor H/V spectral ratio: Application for a layered medium. *Geophysical Journal International*, *186*(1), 221–225. https://doi.org/10.1111/j.1365-246X.2011.05064.x

Seht, M. I. Von, & Wohlenberg, J. (1999). Microtremor Measurements Used to Map Thickness of Soft Sediments. *Bulletin of the Seismological Society of America*, *89*(1), 250–259. https://doi.org/10.1785/bssa0890010250

Septian, A., Elvarani, A. Y., Putri, A. S., Maulia, I., Damayanti, L., Pahlevi, M. Z., & Aswad, F. H. (2020). Identifikasi Zona Potensi Banjir Berbasis Sistem Informasi Geografis Menggunakan Metode Overlay dengan Scoring di Kabupaten Agam, Sumatera Barat. *Jurnal Geosains Dan Remote Sensing*, *1*(1), 11–22. https://doi.org/10.23960/jgrs.2020.v1i1.25

Setyowati, Y., Farid, M., Hadi, A. I., Helinnes, P., Gumanty, U., Raihana, H., Rahmat, A., & Ansory, A. (2024). *Subsurface Sediment Layer Analysis at the Dendam Tak Sudah Lake Flyover Construction Site in Bengkulu City Using the HV-Inv Method*. *16*(2), 187–197.

Simanjuntak, A. B., Yuliyanto, G., & Harmoko, D. U. (2017). Analisis resiko kebencanaan gempa bumi data mikrotremor di Desa Fulolo Kecamatan Alasa Kabupaten Nias Utara. *Youngster Physics Journal*, *6*(4), 360–367.

Suhartini, C. E., Mase, L. Z., & Farid, M. (2019). Mikrozonasi Percepatan Tanah Maksimum Akibat Gempabumi 12 September 2007 Di Kecamatan Ratu Agung Kota Bengkulu. *Civil Engineering and Built Environment Conference 2019*, *September*, 90–99.

Suherianti, S., Mayub, A., & Farid, M. (2018). Potensi rawan banjir kecamatan muara bangkahulu sebagai penunjang pembelajaran materi pemanasan global di SMPN 11 Kota Bengkulu. *PENDIPA Journal of Science Education*, *2*(1), 93–99. https://doi.org/10.33369/pendipa.2.1.93-99

Sunardi, B. (2019). Vs30 Mapping and Soil Classification in The Southern Part of Kulon Progo Using Rayleigh Wave Ellipticity Inversion. *JGISE: Journal of Geospatial Information Science and Engineering*, *1*(2), 58–64. https://doi.org/10.22146/jgise.39780

Telford W M, Geldart L P, Sheriff R E, & A, K. D. (1990). 2015.118629.Applied-Geophysics.pdf. In *Applied Geophysics 2nd Edition*.

Yasa, I. W., Suteja, I. W., Putra, I. B. G., Merdana, I. N., & Sidemen, I. A. O. S. (2022). Biopori Untuk Peresapan Limpasan Air Hujan dan Pengendalian Genangan di Dusun Tanah Embet Kecamatan Batulayar. *Jurnal Pengabdian Magister Pendidikan IPA*, *5*(4), 241–245. https://doi.org/10.29303/jpmpi.v5i4.2476

Yullia, L., Herawati, H., & Kartini. (2022). Pemetaam Zona Kerawanan Banjir Desa Wajok Hilir dan Konsep Penanganannya. *Jurnal Teknik Kelautan, PWK, Sipil Dan Tambang*, *Vol 9*, *No*(1), 1–10.