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STUDY ON COASTAL SEDIMENT PROPERTIES AND WATER QUALITY AT PANTAI PERPAT, BATU PAHAT, JOHOR

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Abstract:

This study was conducted at Pantai Perpat, Batu Pahat, Johor, to investigate the correlation between suspended sediment concentration and particle size distribution. The objectives included identifying water quality parameters, assessing suspended sediment levels, and studying correlations across coastal zones. Water and sediment samples were collected from twelve stations using the grab sampler method, with parameters such as pH, temperature, total suspended solids (TSS), turbidity, sediment size, and moisture content analyzed in designated laboratories. Variability in coastal water quality was observed, with pH values ranging from 7.40 to 7.77 and temperatures from 24.97°C to 26.33°C, indicating acceptable levels. Zone 1 exhibited high turbidity (699 NTU) and TSS concentration (12,393.33 mg/L), suggesting potential issues. Sediment size distribution varied among coastal zones: Zone 1 had a mix of various sediment sizes, primarily silty clay, while Zones 2, 3, and 4 consisted mainly of sandy sediments. Correlations between turbidity and median grain size (D50) varied across the zones, with strong correlations in Zone Middle Tide (MT) ($R^2 = 0.7836$) and Zone High Tide (HT) ($R^2 = 0.5846$), and a weak correlation in Zone Low Tide (LT) ($R^2 = 0.0124$). Strong correlations were also found between TSS and D50 in Zone MT ($R^2 = 0.9924$), with moderate and weak correlations in Zones HT ($R^2 = 0.3384$) and LT ($R^2 = 0.146$), respectively. Understanding water quality and sediment characteristics is crucial for effective environmental management and coastal planning. These findings provide valuable insights for decision-makers involved in coastal development projects. Further research should focus on long-term monitoring and sediment transport dynamics to support sustainable coastal management.

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Suspended Sediment Concentration, Particle Size Distribution, Turbidity, Total Suspended Solids

Introduction

Coastal areas, where land interfaces with the ocean or sea, are significant landforms characterized by intricate interactions and exchanges between land, ocean, and atmosphere (Ouillon, 2018). These regions are sculpted through particle erosion, transport, and deposition processes, along with the movement of nutrients and contaminants (Ouillon, 2018). Sedimentary materials such as sand, silt, clay, and shells are transported and deposited along the shoreline by wave action, contributing to the formation and evolution of coastal environments. These areas are vital in natural ecosystems, supporting diverse habitats and facilitating human activities like tourism, recreation, transportation, and fisheries (Hoepffner & Zibordi, 2009).

To address challenges posed by coastal sediment dynamics, this study focuses on Pantai Perpat, a coastal area in Batu Pahat, Johor, known for its economic contribution to tourism. The research investigates the correlation between suspended sediment concentration (SSC) and particle size distribution (PSD) at this location. By exploring suspended sediment dynamics, the study aims to provide essential insights for developing integrated conservation management plans, contributing to the preservation and sustainable management of coastal and environmental areas.

Literature Review

Sediment transport, influenced by natural processes such as erosion, weathering, and the actions of wind, water, and gravity, is crucial in shaping coastal landscapes (Mustapa, 2018). Beaches, fundamental components of the coastal landscape, consist of sediments with varying granulometry, ranging from large boulders to fine sand or mud. These environments are often considered non-point sources of pollution, carrying and depositing materials in new locations from various origins (Sadeghi et al., 2012). A coastal system is an open system receiving input from multiple sources, including significant amounts of sediment from rivers, terrestrial erosion, and marine coastal erosion (Hordern, 2003).

The dynamic and complex process of sediment transport is primarily driven by fluid flow forces from water, wind, or human activities. For water-driven sediment transport, rivers and streams are the primary conduits for sediment movement (Parker, 2016). River flow exerts shear stress on the riverbed, dislodging sediment particles and transporting them downstream (Earle, 2015). This process, known as fluvial transport, shapes river channels and redistributes soil and sediments across landscapes.

Coastal sediment movement is characterized by the zigzag pattern of particles along beaches due to wave action and their orbital motion (McLachlan et al., 2021). Longshore sediment transport contributes to the formation and evolution of barrier islands and beaches, impacting the dynamics of coastal ecosystems. Additionally, tidal currents in estuaries and tidal flats redistribute sediments within these coastal systems (Nickling, 2019). These processes are essential for maintaining the balance and structure of shoreline environments.

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The rapid development of nearshore and coastal economies has led to increased pollution and degradation of water quality, with suspended sediment emerging as a major concern. Suspended sediment refers to particles, including micro-sized colloidal material, that float in the water column and are transported by natural factors like erosion and human activities such as development and mining (Najib et al., 2020; Mahabeer & Tekere, 2021). Water quality is significantly influenced by suspended sediment, which affects aquatic health, irrigation, soil conservation, and flood control (Womber et al., 2019). Changes in SSC in rivers directly influence the SSC reaching the ocean (Dai et al., 2016). Excessive sedimentation of materials like gravel, sand, and silt can adversely affect coastal areas' socioeconomic and ecological roles (Li et al., 2021).

PSD provides critical insights into the characteristics of granular materials or particles dispersed in a fluid. PSD is typically quantified based on the mass of particles within each size category, often revealing the geological history and environmental conditions of a region (Lemenkova, 2018). Numerous size-grade schemes exist, with particle size determined by weighing the proportion collected in a series of sieves and calculating the proportion of particles with different diameters.

Methodology

The methodology used for investigating sediment properties in Pantai Perpat, Batu Pahat, Johor, consists of several major steps. These steps include water and sediment sampling, on-site analysis, laboratory analysis, data analysis, and lastly, interpretation. Combining these steps provides a comprehensive understanding of the sediment characteristics and contributes to the overall knowledge of coastal sediment dynamics in the study area.

Sampling Location

In this study, a total of 12 sampling stations were carefully chosen based on factors such as their distance from the coast, tidal patterns, topography, and the conditions of the sample stations. The arrangement of the water and sediment sampling stations is presented in Table 1, while the location of these stations is illustrated in Figure 1. This approach is particularly valuable for assessing spatial variations and obtaining time-averaged measurements of water quality parameters (Simpson, 2024). These strategically selected stations ensure representative sampling and offer valuable insights into sediment dynamics in the study area.

For sediment sampling, grab collection using scoops and spoons was employed. As highlighted by Kasich et al. (2012), using scoops and spoons is a cost-effective, readily available, and user-friendly method for sampling sediments across various sediment types.

Table 1: Arrangement of the water and sediments sampling station

	A	B	C	D
High Tide (HT)	1	4	7	10
Middle Tide (MT)	2	5	8	11
Low Tide (LT)	3	6	9	12

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Figure 1: Location Of The Water And Sediments Sampling Station

Sampling Analysis

The sample analysis in this study included both on-site analysis and laboratory analysis methods. In this sub-chapter, the procedure of the analysis is discussed to portray the work that is done in order to achieve the objectives of the study.

On-site Analysis

On-site analysis was performed directly at the study site using portable instruments or testing kits. The on-site analysis in this study focused on measuring the water samples' pH and temperature. pH measures water's acidity or alkalinity, while temperature provides information about thermal conditions. These parameters are important for assessing water quality and can be influenced by surrounding factors. The pH and temperature tests were conducted using a pH meter and a portable in-situ temperature measuring device (model Voltage Tester, RCYAGO, China), respectively. Multiple readings were taken around the 12 sampling stations at random locations to ensure representative and consistent values. The on-site analysis allowed for immediate evaluation of certain parameters at the study site, providing real-time information about water quality. It considered the influence of surrounding conditions over time, contributing to a comprehensive understanding of the samples.

Laboratory Analysis

Laboratory analysis involves conducting tests and experiments on collected samples to determine their physical properties. In the case of water analysis, parameters such as turbidity and total suspended solids were analyzed to assess water quality. Sediment analysis involved determining moisture content and particle size distribution. A filter paper method was used for total suspended solids (TSS) analysis. The sample was filtered, dried, and weighed to determine the concentration of suspended solids. Turbidity tests were conducted using a turbidity meter to measure the cloudiness of water samples caused by suspended particles.

Sieve analysis was used to determine the particle size distribution of sediment samples. Sediment samples were passed through a series of sieves with different mesh sizes, and the retained particles on each sieve were weighed to calculate the percentage of particles in different size ranges. Hydrometer analysis was conducted on fine-grained sediments to measure particle settling time and determine particle size distribution. The moisture content of sediment samples was determined using the oven drying method. The samples were dried in an oven, and the weight loss was used to calculate the moisture content. The laboratory analysis provided precise and accurate measurements, allowing for a detailed understanding of the physical properties of the samples in the study area.

Data analysis

The study used various methods and techniques to analyze different data types, including pH, temperature, total suspended solids (TSS), turbidity, sieve and hydrometer data, moisture content, and correlation analysis. Microsoft Excel 2019 was used as the software tool for conducting data analysis, and specific formulas were applied to calculate relevant statistical measures and parameters.

pH, Temperature, and Turbidity Data Analysis

The average pH, temperature, and turbidity values of the water samples for each station were calculated using the arithmetic mean formula. The arithmetic mean was calculated to determine the average value for each variable at each station.

Total Suspended Solid Data Analysis

The sediment samples' total suspended solids (TSS) data were analyzed using the weight measurement method with filter papers. The difference in weights before and after drying the sediment was used to calculate the TSS for each water sample at each station.

Sieve Data Analysis

A common technique for determining the particle size distribution of sediment samples is sieve analysis. The sieve data analysis involved calculating the cumulative percentage retained on each sieve based on the weight of particles retained.

Hydrometer Data Analysis

Sieve analysis is complemented by hydrometer analysis, which focuses on the smaller subset of soil particles. Hydrometer analysis involved several formulas to determine particle size distribution, including calculations for hydrometer reading, particle diameter, effective depth, modified hydrometer reading, and percentage by mass.

Moisture Content Data Analysis

The moisture content of the sediment samples for each station was calculated by measuring the weights of water and dry solids for each sample. The weight of water was determined by measuring the weight of the wet sample before drying, and the weight of dry solids was obtained by weighing the sample after drying to remove all moisture (Hossain et al., 2021).

Results and Discussion

The next part offers a comprehensive exploration of the study's outcomes and their analysis, delving into the interconnections among various parameters.

The pH, Temperature, Turbidity, And Total Suspended Solids Test for The Water Samples

The water quality in the different zones of Pantai Perpat can be assessed based on the pH, temperature, turbidity, and total suspended solids (TSS) values obtained from the water samples. Table 2 shows the results of the pH, temperature, turbidity, and total suspended solids test for the water samples from four zones in Pantai Perpat. According to U.S. Environmental Protection Agency (2016), a pH value of 7 is considered neutral, values below 7 indicate acidity, and values above 7 indicate alkalinity. Based on the pH value data, it can be observed that the pH values for all four zones fall within a range between 7.40 and 7.77. This indicates that the sediments in these zones have an alkaline nature. This pH range suggests a relatively balanced and stable environment for aquatic organisms (Schreiber, 2024). In terms of

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temperature, the temperature value data Zone 2 has the highest average temperature, which is 26.33°C, Zone 4 has a temperature of 25.77°C, Zone 3 comes next at 25.47°C, and Zone 1 has a temperature of 24.97°C. Based on the temperature data, it is observed that the sediments of the samples in Zone 2 have a higher heat capacity and can absorb and store more heat energy, resulting in a higher temperature result.

Table 2: Results of the pH, Temperature, Turbidity, And Total Suspended Solids Test For The Water Samples

Parameter	Zone 1	Zone 2	Zone 3	Zone 4
pH	7.43	7.40	7.77	7.63
Temperature (°C)	24.97	26.33	25.47	25.77
Turbidity value (NTU)	699.0	112.43	48.13	52.83
Total suspended solids (mg/L)	12393.33	223.33	410.00	143.33

Turbidity values provide insights into water clarity of the water. Zone 1 exhibits the highest turbidity value of 699.0 NTU, indicating poorer water quality in terms of cloudiness. Zones 2, 3, and 4 show lower turbidity values, suggesting better water clarity and potentially healthier ecosystems. The water quality in Pantai Perpat varies among the different zones. Zone 1 shows higher turbidity values, indicating poorer water quality and potential environmental impacts. Zones 2, 3, and 4 exhibit lower turbidity, suggesting relatively better water clarity and potentially healthier ecosystems. It is essential to consider the combined effects of pH, temperature, and turbidity when assessing water quality and understanding its impact on aquatic organisms and the overall ecosystem dynamics.

TSS is a measurement that indicates the concentration of solid particles suspended in water. It includes a variety of particulate matter such as silt, clay, organic matter, and other fine particles. The TSS values can be used as an approximation of the suspended sediment concentration in the study area. Table 3 shows the total suspended solids test for the water samples. Based on the results, observe significant variations in the levels of suspended sediment concentration. Zone 1 has the highest TSS value of 12393.33 mg/L, indicating a significantly higher concentration of suspended solids compared to the other zones. This suggests that Zone 1 has a higher level of sediment or particulate matter in the water, potentially indicating a higher sediment load. Zone 4 has the lowest TSS value of 143.33 mg/L, suggesting a relatively lower concentration of suspended solids compared to the other zones. Zones 2 and 3 have intermediate TSS values of 223.33 mg/L and 410.00 mg/L, respectively, indicating moderate levels of suspended sediment concentration. The variations in TSS values among the zones reflect differences in the sediment load and the presence of suspended particles in the water. This information can be valuable for understanding the distribution and levels of suspended sediment concentration in the study area.

The Moisture Content for The Water Samples

In the study, various methods and techniques were used to analyze different types of data, including pH, temperature, total suspended solids (TSS), turbidity, sieve and hydrometer data, moisture content, and correlation analysis. Microsoft Excel 2019 was used as the software tool for conducting data analysis and specific formulas were applied to calculate relevant statistical measures and parameters. Moisture content represents the amount of water present in a substance or material. It is expressed as a percentage of mass or volume (Hossain et al., 2021). Moisture content is used in soil classification systems to categorize soils into different classes.

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Figure 2 shows the moisture content data for Zones 1, 2, 3, and 4 at Pantai Perpat across different tide levels. Based on the moisture content data for Zones 1, 2, 3, and 4 at Pantai Perpat at high tide, the moisture content shows that Zone 1 has the highest water content, followed by Zone 2, Zone 4, and the lowest moisture content in Zone 3. At middle tide, the moisture content shows that Zone 1 has the highest water content, followed by Zone 4, Zone 3, and then Zone 2. At low tide, the moisture content shows that Zone 1 has the highest water content, followed by Zone 4, Zone 3, and Zone 2.

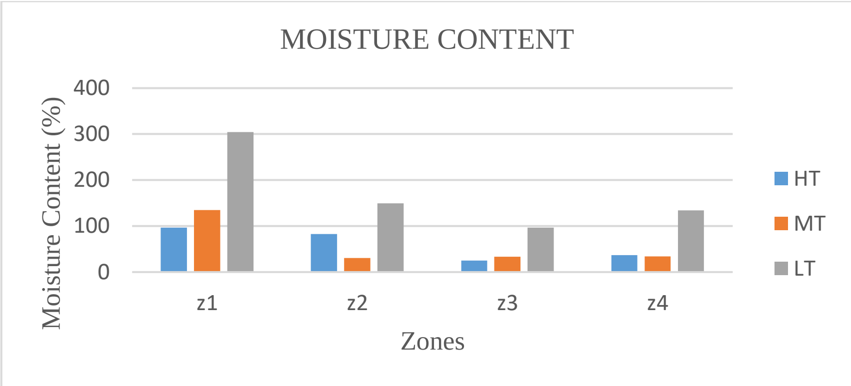

Figure 2: Result Of The Moisture Content For All Zones At Pantai Perpat

These observations show that the moisture content varies with changing tide levels within each zone. Zone 1 consistently has the highest moisture content among the zones, regardless of the tide level. Zone 4 generally follows with the second highest moisture content, while Zone 3 and Zone 2 exhibit relatively lower moisture content. The moisture content of sediment influences its water-holding capacity and permeability. Based on this study, higher moisture content indicates greater water retention and higher water-holding capacity, particularly in fine sediments, while lower moisture content suggests lower water-holding capacity and better drainage in coarse sediments. Sediment characteristics can influence moisture content variations with tide levels. This analysis provides insights into the moisture dynamics and distribution within the different zones at Pantai Perpat, which can contribute to the classification and characterization of soils in this area.

Correlation of Suspended Sediment Concentration and the Particle Size Distribution

Table 3 shows the R^2 value and correlation equation for turbidity and TSS with D_{50}. The D_{50} parameter was obtained through sieve and hydrometer analysis. Figure 3(a) shows the correlation between turbidity and D_{50} (MT), while Figure 3(b) shows the correlation between TSS and D_{50} (MT). Based on Table 3, it is shown that both suspended sediment concentration (TSS) and turbidity in the MT area have relatively high R^2 values, with TSS having an R^2 value of 0.9924 and turbidity having an R^2 value of 0.7836. These high R^2 values indicate a strong relationship between particle size (represented by D_{50}) and both TSS and turbidity. The R^2 value of 0.9924 for TSS suggests that a significant portion of the variability in TSS readings can be attributed to particle size in the MT area. Similarly, the R^2 value of 0.7836 for turbidity indicates that a substantial proportion of the variation in turbidity measurements can be explained by particle size.

The strong R^2 values observed for both total suspended solids (TSS) and turbidity in the MT area suggest a notable correlation between these two parameters, particularly in relation to particle size (D_{50}). The high R^2 value of 0.9924 for TSS indicates that particle size explains a

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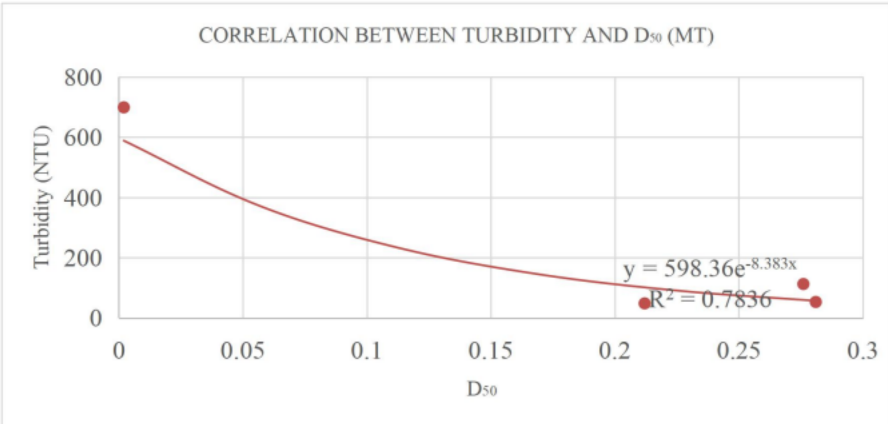
substantial amount of the variability in TSS measurements. This implies that as the size of particles increases, the concentration of suspended solids also tends to increase significantly. Conversely, the R^2 value of 0.7836 for turbidity indicates a comparatively weaker yet statistically significant relationship. Since turbidity is a measure of water clarity affected by suspended particles, higher TSS levels typically correlate with increased turbidity.

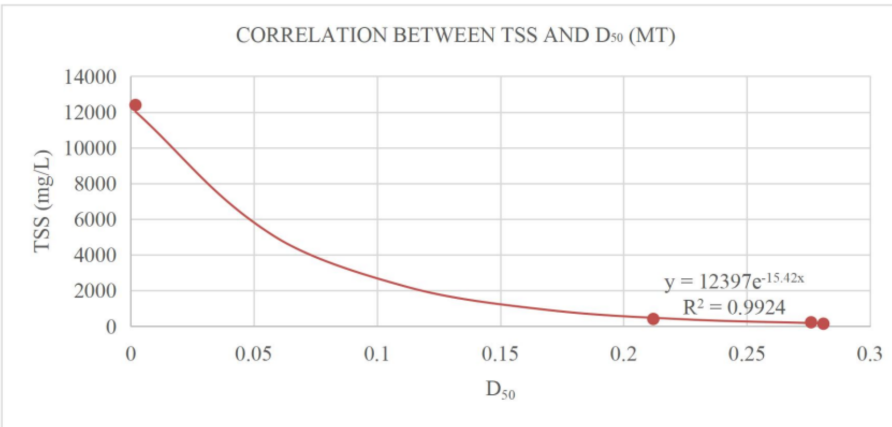
The correlation between TSS and turbidity is due to the way suspended particles scatter light in the water column. Larger and more numerous particles increase light scattering, thereby raising turbidity levels. TSS quantifies the mass of solids suspended in water, while turbidity quantifies the light-scattering effect of those solids. This direct relationship indicates that as TSS increases due to larger or more abundant particles, turbidity also rises, affecting water quality and clarity.

Table 3: R^2 Value And Correlation Equation For Turbidity And TSS with D_{50}

Parameter		HT	MT	LT
Turbidity (NTU)	R^2 value	0.5846	0.7836	0.0124
	Equation, y	267.58e-6.031x	598.36e-8.383x	129.8e-1.06x
TSS (mg/L)	R^2 value	0.3384	0.9924	0.146
	Equation, y	1741e-7.498x	12397e-15.42x	1038.2e-5.939x



(a)



(b)

Figure 3: Correlation between D_{50} (MT) and: (a) Turbidity (b) TSS

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These findings show that particle size has a notable influence on the suspended sediment concentration and turbidity in the MT area. It explains that as the particle size (represented by D_{50}) increases or decreases, there is a corresponding change in the TSS readings and turbidity levels. The increase in D_{50} leads to significant reductions in both turbidity and TSS. Larger particles settle out of the water more easily, resulting in clearer water with fewer suspended solids. For instance, as D_{50} increases from 0.05 to 0.2, turbidity decreases from around 800 NTU to nearly zero, while TSS drops from about 10,000 mg/L to almost zero. This inverse relationship illustrates the critical role of particle size in determining the clarity and cleanliness of water. The sediment in the MT area is composed of silty clay and sand particles, which are fine and light. These particles are suspended in the water column, making the MT area suitable for predicting turbidity and suspended sediment concentration (SSC) values. The diverse particle size distribution, ranging from small silty clay particles to coarser sand particles, contributes to the fine and light characteristics of the sediment. The fine and light sediment particles increase turbidity by remaining suspended and scattering light. The strong relationship between particle size and suspended sediment concentration further supports the notion that sediment particles of varying sizes, such as silty clay, sand, or silt, have a significant impact on the overall suspended sediment concentration in the MT area. Different particle sizes can have distinct settling velocities, transport properties, and interactions with water flow, leading to variations in suspended sediment concentration.

Conclusions

In conclusion, the findings provide valuable insights into water quality, sediment concentrations, and their relationships in the study area. The results showed some variability in coastal water quality. The pH values observed ranged from 7.40 to 7.77, falling within an alkaline range. This indicates a relatively balanced and stable environment for aquatic organisms, as alkaline pH values are generally favorable for their survival and well-being. Furthermore, the temperature measurements ranged from 24.97°C to 26.33°C, indicating acceptable levels. The observed variations in temperature among the different zones suggest differences in heat capacity, with Zone 2 exhibiting the highest average temperature. Besides that, high turbidity, total suspended solids in Zone 1 (699 NTU), and total suspended solids concentration (12,393.33 mg/L) indicated potential issues with water clarity and sedimentation, suggesting potential issues in this area. This shows a higher concentration of sediment particles in the water column. The analysis also showed varying degrees of correlation across different zones. Zones MT (R^2=0.7836) showed strong correlations between turbidity and median grain size (D50), followed by Zone HT (R^2=0.5846), while Zone LT (R^2=0.0124) showed a weak correlation. Zone MT (R^2=0.9924) showed a strong correlation between total suspended solids (TSS) and D50, while Zones HT (R^2=0.3384) and LH (R^2=0.146) showed moderate and weak correlations, respectively. The correlation between particle size and turbidity/TSS emphasizes the significant influence of particle size on suspended sediment concentration. It is important to understand the relationship between turbidity and TSS for water quality assessment and management. Elevated TSS levels can have negative impacts on the environment, such as reduced light penetration for aquatic plants and changes to the habitat for aquatic organisms. Monitoring both of these factors is essential for effective water quality management, especially in areas that are vulnerable to runoff and sedimentation. This study's findings have important implications for environmental management and coastal development planning. It will provide valuable insights that will contribute to sustainable coastal development practices and ensure the long-term preservation of Pantai Perpat's coastal ecosystem. To further advance this study, future studies should focus on long-term monitoring to understand the temporal trends and patterns in water quality and sedimentation parameters. By collecting data over an extended period, it can identify any gradual changes or trends that may occur and gain a more comprehensive understanding of the ecosystem's dynamics.

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