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Oceanographic Data Analysis of Parappe Beach, Majene Regency, in Breakwater Planning

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***Abstract*— Determining the location and dimensions of coastal protection structures, especially breakwaters, must take into account oceanographic data so that the structure can function effectively to protect the coast from damage caused by waves and currents. The method employed in this study is a quantitative approach, utilizing secondary data from the Meteorology, Climatology, and Geophysics Agency (BMKG), National Bathymetry data (BATNAS), and primary data collected directly through field observations, including sedimentation and tidal data. Based on the research conducted, the sedimentation rate for point 1 was 402.405 cm3/year. Point 2 was 503.006 cm3/year. Point 3 was 955.713 cm3/year. For tidal data obtained, the Higher High Water Level (HHWL) is 1.78 m, the Mean High Water Level (MHWL) is 1.2053 m, the Mean Sea Level (MSL) is 0.9203 m, the Mean Low Water Level (MLWL) is 0.6353 m, and the Lower Low Water Level LLWL) is 0.20 m. The dominant wind for 10 years blew from the north, with a maximum wind speed of 11 knots and an effective fetch length of 398.21 km. From the wave forecast, the breaking wave height (Hb) is 76.44 meters, the breaking wave depth (db) is 3.822 meters, the maximum wave height is 2 meters, and the period is 7 seconds.**

Keywords— sedimentation, tides, waves.

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I. Introduction

The problem at Parappe Beach in Majene Regency, West Sulawesi Province (Fig.1), is seawall damage caused by abrasion. Seasonal waves have damaged the beach, posing a threat to the safety of surrounding facilities and infrastructure, particularly in tourist areas. This issue must be addressed by taking into account the various factors set out in the Ministry of Public Works Regulation No. 9 of 2010 on coastal protection [1].

Coastal areas play a crucial role in supporting national development, both ecologically, socially, and economically. The coast is a hub for fishing, tourism, maritime transport and residential development [2-6]. However, coastal areas also face numerous complex problems, particularly those related to marine dynamics, such as abrasion, erosion, tidal flooding, and damage caused by waves and ocean currents [7-12]. These phenomena cause significant ecological and economic losses, making it necessary to implement appropriate mitigation efforts.

Coastal erosion, also known as abrasion, is a severe form of coastal degradation caused by wind, rain, currents, waves and human activities. Human activities, such as deforestation of mangroves, mining of sea sand and coral reefs in several locations, have contributed significantly to coastal erosion due to the resulting loss of protection from waves and storms. Abrasion is the erosion or reduction of the coastline due to wave activity, currents and tides. In this context, land subsidence causes the ground surface to sink, leading to flooding by seawater and changes to the coastline [13].

One widely used strategy for addressing coastal erosion issues is the construction of coastal protection structures, such as breakwaters, groins, seawalls and revetments [14-18]. The design and planning of coastal protection structures is greatly influenced by local oceanographic conditions, such as wave parameters, currents, tides, winds and seabed morphology [19]. These oceanographic data are required to calculate the hydrodynamic forces acting on the structure, determine its dimensions, and estimate potential changes to the coastline resulting from its interaction with the surrounding environment [20].

A breakwater is a structure designed to reduce the impact of waves by absorbing some of their energy. This structure reduces the energy of waves reaching the waters and beaches behind it, providing protection. One of the ecological functions of breakwater structures is to create new habitats. Breakwaters built with large rock piles form cavities that can serve as habitats where marine life can play, feed, shelter, and reproduce [21].

Inaccurate use of oceanographic data can result in coastal protection structures not functioning optimally. It can even cause new problems, such as changes in current patterns, excessive sedimentation, or erosion at other locations around the structure [11]. Several studies have shown that many failures of coastal structures are caused by limitations in the oceanographic data used for planning purposes. In Indonesia, for example, the planning of most coastal protection structures still relies on secondary data with relatively short observation periods. This results in designs that are less suited to actual sea conditions [22].

To determine the location and dimensions of coastal protection structures, it is necessary to analyze oceanographic data, including information on sedimentation, ocean currents, tides, bathymetry, wind,

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and waves. This is preliminary data for designing coastal protection structures. Measurements of sedimentation, ocean currents, and bathymetry are helpful in determining their location [23]. Meanwhile, data on wind, tides, and waves help determine the dimensions of buildings. This data is used to determine the most effective designs and locations for structures that protect the coast from damage caused by waves and currents.

II. METHOD

A. *Time and Location of Research*

The research was conducted from March 1, 2024, to May 1, 2024. The research location was Parappe Beach, East Banggae Subdistrict, Majene Regency, West Sulawesi Province, with coordinates 33°33′04″S, 118°58′33″E (Fig. 1).

Figure. 1. Parappe Beach

B. *Research Materials and Tools*

Primary data consists of direct field research, such as sedimentation and tidal measurements. Secondary data includes wind data obtained from the Meteorology, Climatology, and Geophysics Agency (BMKG) and bathymetric data obtained from the National Bathymetry Agency (BATNAS). Sedimentation measurements were taken at three locations using sediment traps (Fig. 2). The construction of the sediment device is described as follows [24]—about suspended samplers, which are designed to capture suspended sediments.

C. *Data Analysis*

The parameters used in the data analysis are wind, wave, sedimentation and tidal data.

1) Wind Data

Wind data is analyzed to obtain the corrected wind speed. Based on this data, a wind rose is created to determine the dominant wind direction. Next, fetch is calculated to determine the wave height and period [25].

$$\text{Fetch effective} = \frac{\Sigma \cos\alpha \cdot x}{\Sigma \cos\alpha} \quad (1)$$

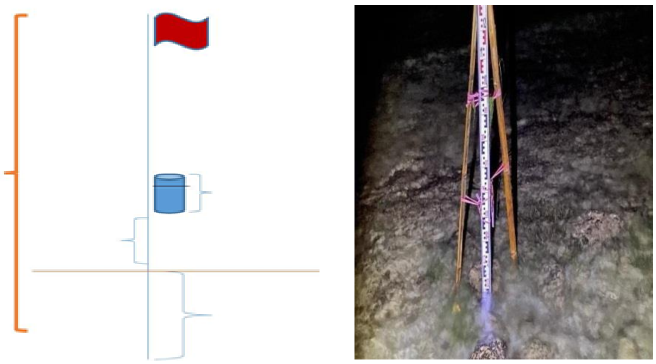

Figure. 2. Sediment trap construction

2) Wave

Wave analysis in deep waters is performed using wind data. This data will then be used to plan wave breakers.

3) Sedimentation.

The sedimentation rate is calculated using the following formula:

The average sedimentation velocity is calculated using the following formula:

$$V = \frac{\pi r^2 h}{t}$$

Where v = sedimentation velocity, π = constant, r = pipe radius, h = sediment high in the pipe, and t = time duration

The average sedimentation rate is calculated using the following method:

$$X = \frac{\Sigma X_i}{n} \quad (3)$$

Where $\bar{x}$ = mean, x_i = tribal – I, and n = total data.

The sediment volume is then calculated as follows,

$$V = \pi r^2 h \quad (4)$$

Where V = volume (m^3), π = konstanta, r = pipa radius, h = sediment high, and bathymetry

The bathymetry data used comes from the BATNAS database. The results of the processing are figures showing sea floor contours and patterns of channel movement. These can be used to determine the depth of the breakwater structure.

4) Pasang Surut

Tidal data was obtained from field research conducted over a period of 16 days in March 2024. This data was then processed using the Admiralty 15-point scheme eight method to obtain the maximum and minimum tidal data for each day. The tidal elevation of Parappe Beach in March 2024 is shown in **Table 4**. A graph showing sea level fluctuations can be created from this tidal data and can be used to determine sea level elevation.

III. Results and Discussion

Sedimentation

Sedimentation measurements were taken at three locations along the Parappe coast, with weekly observations made over a three-week period. The results of these measurements are as follows.

TABLE 1.
MEASUREMENT OF SEDIMENTATION RATE AT POINT 1

Measurement	High (cm)	Volume (cm^3)	Sedimentation rate	
			(cm^3/week)	(cm^3/year)
1	2	40.52	5.79	301.804
2	3.5	70.9	10.13	528.157
3	2.5	50.65	7.24	377.255
Mean	2.67	54.02	7.72	402.405

TABLE 2.
MEASUREMENT OF SEDIMENTATION RATE AT POINT 2

Measurement	High (cm)	Volume (cm^3)	Sedementation rate	
			(cm^3/week)	(cm^3/year)
1	3	60.77	8.68	452.706
2	4	81.03	11.58	603.608
3	3	60.77	8.68	452.706
Mean	3.33	67.52	9.65	503.006

TABLE 3.
MEASUREMENT OF SEDIMENTATION RATE AT POINT 3

Measurement	High (cm)	Volume (cm^3)	Sedimentation rate	
			(cm^3/week)	(cm^3/year)
1	7	141.81	20.26	1056.314
2	7	141.81	20.26	1056.314
3	5	101.29	14.47	754.51
Mean	6.33	128.303	18.33	955.713

Based on the measurement results in Tables 1–3, the sedimentation rate at point 1 ranges from 5.79 to 10.13 cm^3/week, with an average rate of 7.72 cm^3/week. The annual sedimentation rate ranges from 301.804 to 528.157 cm^3 per year, with an average of 402.405 cm^3 per year. For point 2, the range is 8.68–11.58 cm^3/week, with an average sedimentation rate of 9.65 cm^3/week. The annual sedimentation rate ranges from 452.706 to 603.608 cm^3/year, with an average of 503.006 cm^3/year. For point 3, the range is 14.47–20.26 cm^3/week, with an average sedimentation rate of 18.33 cm^3/week. The range for the annual sedimentation rate is 754.51–1056.314 cm^3/year, with an average of 955.713 cm^3/year.

The highest sedimentation rate at Parappe Beach is found at Point 3, which is located in the Parappe fishing boat estuary area. This is due to sediment flowing from the mainland. The port estuary will also experience high sedimentation due to sediment flowing into it from the mainland . The lowest sedimentation rate is at point 1, which is far from the mouth of the Parappe fishing boat. The following map shows the average sedimentation rate along the Parappe coast (Fig. 3).

Tide

Tides were measured every hour, 24 hours a day, for 15 days. The following data was obtained from these measurements.

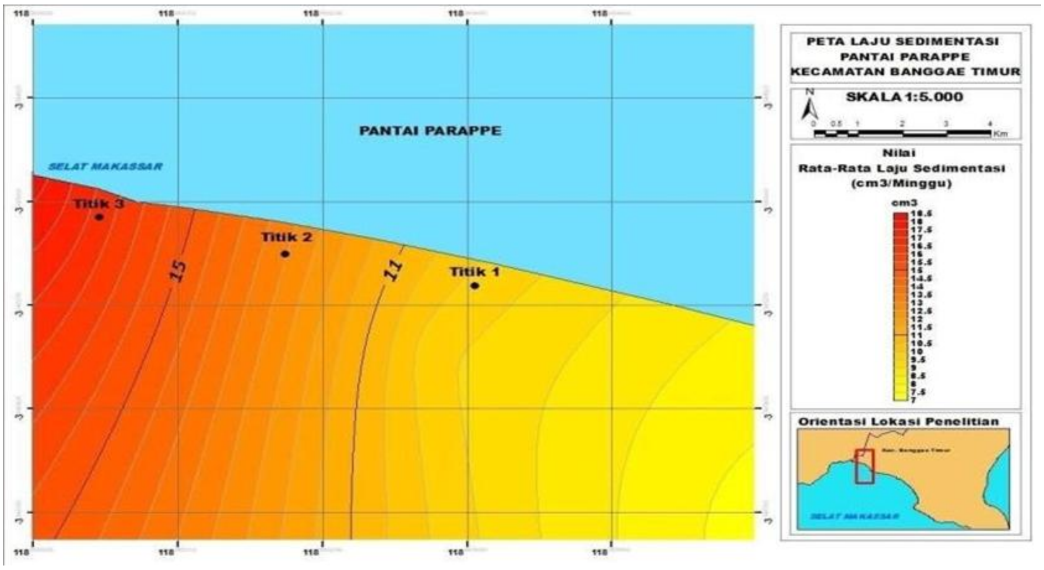

Figure. 3. Sediment rate map

TABLE 4.
TIDES DATA

DATE	0	1	2	3	4	5	6	7	8	9	10	11
02/03/2024	40	20	20	29	29	30	120	120	120	120	120	120
03/03/2024	50	20	20	20	30	30	110	120	128	125	129	120
04/03/2024	45	25	25	25	30	35	84	90	115	126	125	125
05/03/2024	40	35	31	20	25	30	95	100	115	125	130	134
06/03/2024	70	50	40	35	20	60	110	110	120	123	125	130
07/03/2024	70	50	50	37	35	30	80	85	85	95	95	110
08/03/2024	79	65	60	50	40	35	55	70	80	85	100	120
09/03/2024	90	60	60	55	45	30	60	65	70	72	72	70
10/03/2024	95	70	75	60	60	50	60	70	70	75	80	70
11/03/2024	80	70	60	65	40	35	50	60	70	70	75	73
12/03/2024	110	90	70	60	30	35	60	63	65	70	77	72
13/03/2024	60	53	65	68	40	38	50	53	60	75	70	75
14/03/2024	50	40	35	57	90	120	50	55	60	70	72	70
15/03/2024	30	20	30	40	65	80	130	159	166	160	145	120

DATE	12	13	14	15	16	17	18	19	20	21	22	23
02/03/2024	120	120	120	120	120	120	109	110	124	100	80	70
03/03/2024	115	90	85	100	90	100	109	110	110	109	90	70
04/03/2024	120	110	100	115	110	100	110	120	110	95	80	60
05/03/2024	140	130	120	120	125	135	135	120	110	100	90	70
06/03/2024	120	130	130	140	140	150	140	142	135	113	100	75
07/03/2024	106	120	135	150	150	149	158	140	110	98	90	90
08/03/2024	120	135	135	145	155	162	161	135	145	128	112	85
09/03/2024	82	90	122	120	150	165	178	160	145	140	120	100
10/03/2024	75	100	140	140	150	150	115	150	140	145	130	120
11/03/2024	75	70	70	95	110	130	135	145	150	130	110	95
12/03/2024	80	70	90	100	110	112	142	140	110	135	125	100
13/03/2024	70	65	67	110	119	120	125	140	127	110	90	65
14/03/2024	85	70	70	80	100	115	127	110	120	110	70	60
15/03/2024	118	100	110	90	110	130	125	120	120	90	65	50
16/03/2024	118	115	122	100	90	118	125	127	120	115	70	65

A graph showing sea level fluctuations can be created from this tidal data and used to determine sea level elevation. This plan uses the Admiralty 15-piantan Scheme 8 method to determine the tides (Fig. 4)

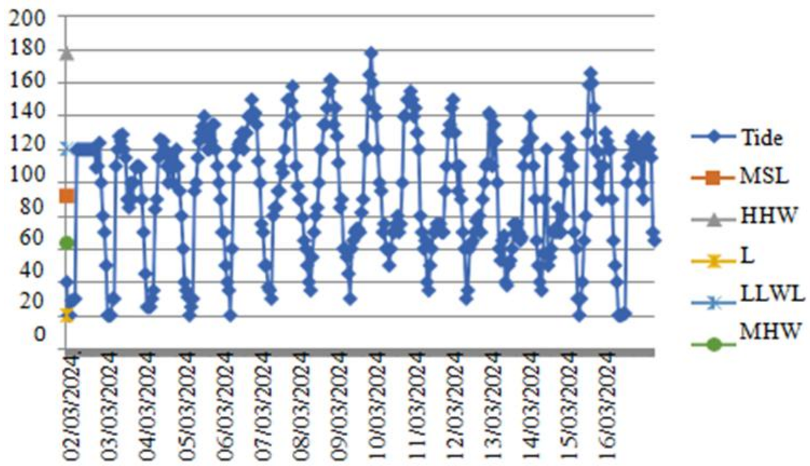

Figure. 4. Tides Graphic

As can be seen from the graph

- Higher High Water Level (HHWL) = 1,78 m
- Mean High Water Level (MHWL) = 1,2053 m
- Mean Sea Level (MSL) = 0,9203 m
- Mean Low Water Level (MLWL) = 0,6353 m
- Lower Low Water Level LLWL = 0,20 m

Wind data

- Wind data are required to determine the distribution of wind direction and speed at a given location. Wind data from 2014 to 2024 was obtained from the Majene Meteorological Station of the Meteorology, Climatology and Geophysics Agency (BMKG) in West Sulawesi. The results are presented in the form of a wind rose (Fig. 5).

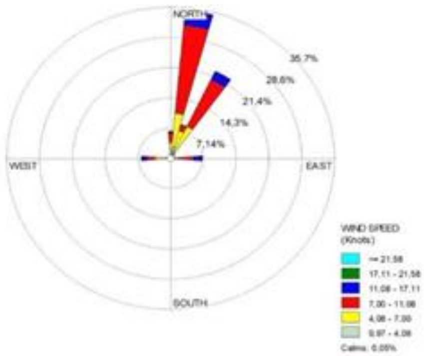

Figure. 5. Dominant wind direction

As shown in the figure, by examining the obtained wind rose and considering the direction of the coast, it can be observed that the dominant wind direction over the past 10 years has been moving northward, with a maximum wind speed of 11 knots. The dominant wind direction can be determined from the wind rose and used to calculate the effective fetch length (Fig. 6).

Figure 6. Dominant wind direction

TABLE 5.
CALCULATION OF AVERAGE EFFECTIVE FETCH LENGTH

α	cos (α)	X (km)	cos (α).x (km)
42	0.7431	801	595.2231
36	0.809	686	554.974
30	0.866	272	235.552
24	0.9135	528	482.328
18	0.9511	231	219.7041
12	0.9781	221	216.1601
6	0.9945	584	580.788
0	1	570	570
6	0.9945	519	516.1455
12	0.9781	535	523.2835
18	0.9511	126	119.8386
24	0.9135	358	327.033
30	0.866	211	182.726
36	0.809	179	144.811
42	0.7431	150	111.465
	13.5106		**5380.0319**

The effective fetch value can be calculated based on Table 5 as follows.

$$\text{Fetch effective} = \frac{\Sigma \cos\alpha \,.\, x}{\Sigma \cos\alpha} = \frac{5380.0319}{13.5106} = 398.21\ km$$

Bathimetri

The bathymetric data used for the design were obtained from BATNAS [24]—the processing results in figures showing a draft of the seabed. Movement patterns can also be seen based on seabed contours, and the depth of breakwater structures can be determined (Fig. 7).

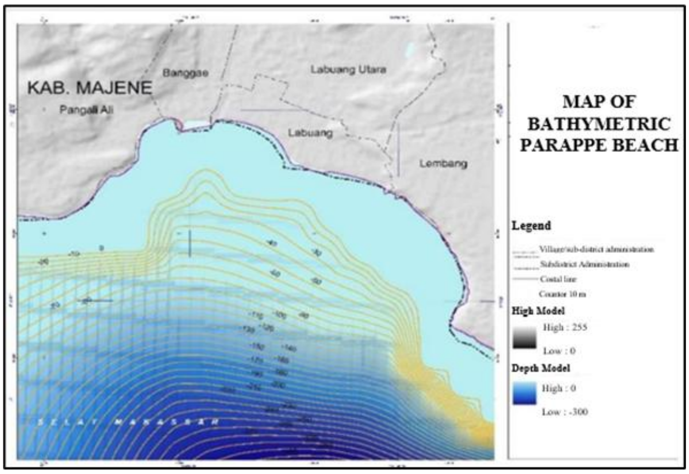

Figure 7. Bathymetry map

The bathymetric contours follow the Parappe coastline, displaying a colour gradient ranging from light to dark. The deeper the seabed, the darker the colour. The colour gradient represents distances of 10 metres for each depth. The distance between depth changes is greater for changes from 10 to 50 metres than for changes from 50 to 200 metres, indicating that the Parappe coastline slopes gently for one kilometre and then becomes steeper. This bathymetric contour mapping helps determine the location of coastal protection structures

Wave

Once the average effective fetch and wind speed are known, wave height and period can be calculated using wave forecasting charts [26]. The wind speed on land (UL) is 11 knots, which is equivalent to 5.6 metres per second. Based on the relationship between wind speeds on land and at sea, the wind speed at sea (RL) is 1.3

$$R_L = \frac{U_W}{U_L}$$, so that the wind speed at sea

$$(U_W) = R_L .\, U_L = 1.3 \times 5.65 \text{ m/s} = \mathbf{7.345\ m/s}$$

Wind stress factor:

$$U_A = 0.71\, U_W^{1.23} = 0.71\,(7.345)^{1.23} = \mathbf{8.25\ m/s}$$

Based on the wave forecast graph, the wave height and period can be obtained for UA = 8.25 m/s and fetch = 398.21 km. Wave height (H): **2 m** Wave period (T): **7 s**

Breakwater Dimensions

Wavelength

$L = 1.56\ T^2$

$= 1.56\ 7^2$

$=$ **76,44 m**

The wave breaks at that moment $\frac{d}{L} \leq \frac{1}{20}$

$d \leq \frac{1}{20} . L$

$d \leq \frac{1}{20} . L$

$d \leq 3.822$ m

As breakwaters are built before waves break, they are constructed at a minimum depth of 4 metres.

Breakwater Dimensions:

4 metres from ground level to SWL.

1 m from SWL.

The breakwater is 40 m long, with a 30 m distance between breakwaters.

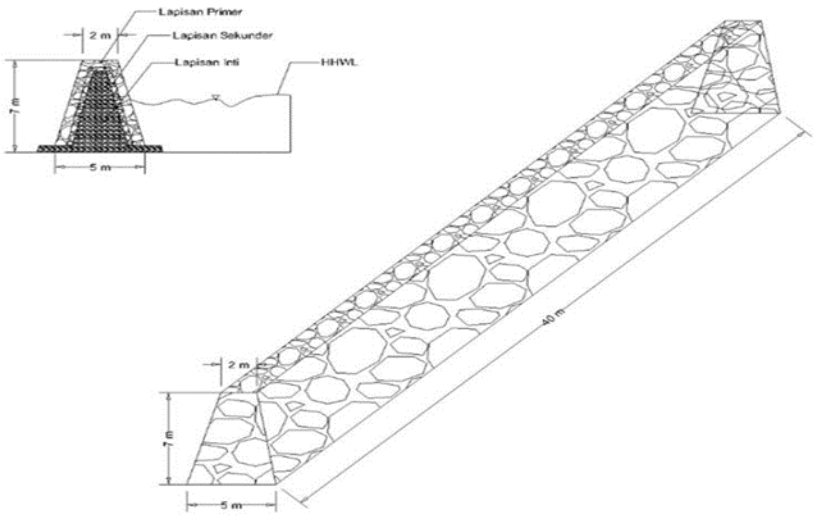

Figure 8. Breakwater design

IV. Conclusion

Analysis of oceanographic data for Parappe Beach revealed the following average sedimentation rates: point 1: 402.405 cm³/year, point 2: 503.006 cm³/year, point 3: 955.713 cm³/year The Higher High Water Level (HHWL) is 1.78 metres, the Mean High Water Level (MHWL) is 1.2053 metres, the Mean Sea Level (MSL) is 0.9203 metres, the Mean Low Water Level (MLWL) is 0.6353 metres and the Lower Low Water Level (LLWL) is 0.20 metres. The dominant wind direction over the past ten years has been northward, with a maximum wind speed of 11 knots and an effective fetch length of 398.21 kilometres. The wave height (Hb) is 76.44 metres and the wave depth (Db) is 3.822 metres. This wind data is used in wave forecasting. Wave forecasting indicates a maximum wave height of 2 metres with a period of 7 seconds.

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