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Study Of Changes In The Manggar Baru Coastline Using Numerical Methods

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KEYWORDS
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ABSTRACT – Coastline's change was caused by the movement of sediments influenced by waves, wind, and materials around the shore. The movement of sediments around the coast resulted coastal dynamics marked by abrasion and erosion. In the Balikpapan region, especially on the East Balikpapan Coast near the Makassar Strait, causing high waves on the beaches in this area, one of the areas that was once affected was Manggar Baru Beach, where there was a settlement less than 10 meters from the shoreline. With the changes in the coastline, it could lead to floods, changes in the area, damage to facilities around the coast, and so on. This study modeled with the help of an application to understand the characteristics of the coastline to get trends in the present and projected future changes for disaster mitigation. It was also found that the average changes in 2024 were 0.829 m/year, in 2027 were 1.984 m/year, in 2032 were 3.982 m/year, and in 2042 were 7.689 m/year. Changes that occurred in Manggar Baru Beach were predominantly experiencing Erosion every year.

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INTRODUCTION

The coastline is considered the barrier between land and sea [1]. This limiter has large dynamic changes triggered by sediment transport caused by wind, tidal waves, oceanography, location, coastal conditions and other things [2]. The geographical condition of Balikpapan beach is located in the Makassar Strait which allows waves to be generated by the wind. This area is used as a park or beach tourism for the local community. As for Balikpapan, the coastline changes were quite high in East Balikpapan where groynes were added, marked by beach erosion and sedimentation. One of the beaches in East Balikpapan is the beach in the Manggar Baru area. On Manggar Baru beach there are residential locations and several houses are located close to the coastline up to 10 meters and several houses are below the coastline. It is known that it was discovered by conducting field observations that in 2011 there had been an additional 50 meters of beach, the tendency for changes in the Manggar Baru beach had a tendency to experience abrasion on the south side and sedimentation at the river mouth [3]. The study location of Manggar Baru Beach is visible within the ABCD boundaries in Figure 1.

Changes in the coastline itself can cause things in the form of deterioration of the coastline or damage to coastal facilities and infrastructure if abrasion occurs and can also cause flooding due to the closure of river estuaries if sedimentation occurs [4]. Case studies regarding damage to coastal areas also occurred in West Sumatra Province with a coastline of ±420 km, it was found that 40% experienced damage caused by waves, causing quite large losses every year [5]. Case studies in other areas in Paiton District experienced an increase in coastline area due to industrial site development [6]. Another study also found that on the coast of the Cirebon region from 1915 to 2019 there was accretion of up to 585 hectares resulting in plantations, rice fields and so on [7]. In the case study, Pekalongan City experienced changes in the coastline with abrasion which caused damage to the embankments and deterioration of the coastline, causing the entrance of sea water to rise onto land and causing tidal flooding in the coastal areas of Pekalongan City [8]. Sudden changes in coastal areas can cause contradictions and difficulties in terms of the economy, society, ecology and environment of coastal areas throughout the world [9]. Meanwhile, by considering the problems and importance of things that can be caused by changes in the coastline as a result of abrasion and accretion (sedimentation) as well as considering the existence of problems in the form of geographic location, the natural conditions of the Manggar Baru beach, a simulation was carried out to determine the changing conditions of the Manggar Baru beach. This research will analyze how the condition of the Manggar Baru coastline will change in the future using numerical methods with actual data to see how the coastline will change over 2 years (2024), 5 years (2027), 10 years (2032), and 20 years. (2042) which will come to the existing conditions (2022) on Manggar Baru beach.

Figure 1. Study location

METHOD

Based on the explanation above, it is necessary to carry out research on changes in coastlines in the area around Manggar Baru Village. The research location is at coordinates 1°13'52.38"S, 116°57'41.88"E to coordinates 1°13'19.20"S, 116°58'19.68"E. The research location is divided into 3 regional areas, namely the beach tourism area, fishermen's housing and pond cultivation areas. Balikpapan has been designated as a Minapolitan area through the decision of the Mayor of Balikpapan which is intended by the Dictum of Unity in Manggar Village and Manggar Baru Village, East Balikpapan District with an area of 200 Ha, this area is expected to be developed into a marine and fisheries economic development area [3]. The conditions of the research location can be seen in Figure 2.

Figure 2. Fisherman's Residential Area (a) and Tourism Area (b) Location Study

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This journal regarding coastline changes was carried out through several stages of collecting bathymetric and coastline data on Manggar Baru beach, calculating wind speed and angle of incidence, fetch calculations, wave forecasting calculations, bottom sediment analysis and finally simulating coastline changes using auxiliary applications. The data entered in the auxiliary application is bathymetry obtained from BATNAS and coastline obtained from Google Earth to obtain coordinates and elevation of the research location as in Figure 3 regarding Balikpapan bathymetry and Manggar Baru coastline below.

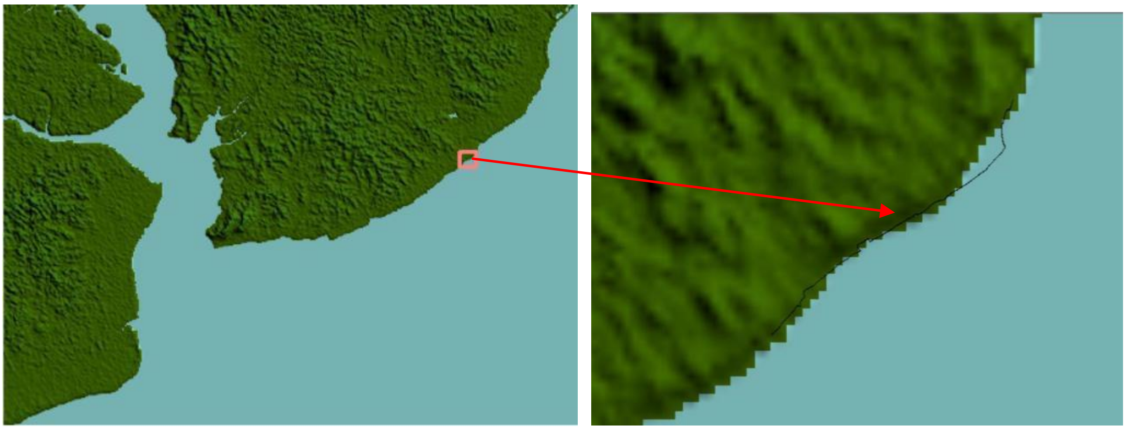

Figure 3. Left Image of Balikpapan Bathymetry and Right Image of Coastline

This study also uses calculations of angles and wind speeds for the last 12 years which will then be used in wave hindcasting to obtain the height and period of significant waves. An analysis of the size of the sediment around the coastline was carried out with the aim of obtaining D50 [10]. After getting the results of each analysis, modeling is then carried out using numerical methods with the help of applications for calculating changes in coastlines. The results that can be seen are the magnitude of changes in the existing coastline conditions of the coastline in the coming years in the form of graphs or numbers.

Numerical Methods

Numerical methods will use actual data from investigations regarding the causes of coastline changes. The factors that influence coastline changes require the following actual data [11]:
1. Beach bathymetry
2. Coastline
3. Wind and Fetch
4. Waves
5. Flow
6. Ups and downs
7. Bottom sedimentation
8. Coastal protection buildings

Calculations using numerical methods can be used to determine the effect of coastlines changes that will occur with variations in the simulation time period [1].

Wind Analysis

Wind is circulation parallel to the earth's surface. Wind is created because there are changes or differences in temperature between one place and another. Study data can be obtained from ECMWF in the form of U and V components, with the U value being the wind speed in the east-west direction while the V value is the wind speed in the north-south direction [12]. By calculating the wind speed value, it is obtained using equation 1 as follows [13].

$$\sigma = \sqrt{U^2 + V^2} \quad (1)$$

With is the resultant wind speed, U is the wind speed in the direction of vectors X and V is the wind speed in the direction of vector Y. Also required is the angular value of the resultant
wind speed with equation 2 as follows.

$$\sigma_{\mathrm{d}} = arctan \frac{V}{U} \quad (2)$$

With is the angle from which the wind speed comes. The results of the angle calculation will be produced in radian form so that further calculations can be calculated based on the location in the Cartesian plane to obtain the angle size.

In calculating the wind analysis after obtaining the wind angle and wind speed, several corrections are needed due to the differences between land wind and sea surface wind, so calculations are carried out with corrections for elevation, stability, location effects and drag coefficient using equation 3 as follows [14].

$$U_W = R_T \times R_L \times (U_{10})_L \quad (3)$$

Where U_W is a correction for the influence of the observation location, R_T is a stability correction (1.1), R_L is a stability correction, and U_{10} is the wind speed at a height of 10m. Next, the results of the U_W calculation are used to find the wind shear coefficient using the following equation 4.

$$U_A = 0{,}71\ U_W^{1{,}23} \quad (4)$$

U_A is the wind shear coefficient that will be used in wave forecasting calculations.

Analysis Fetch

The length of the area where the wind blows with a constant direction and speed is called the fetch, which is known to be an effective fetch length of ≤ 200 km. As for calculations The effective fetch calculation can be used as follows [15].

$$F_{eff} = \frac{\Sigma X_i Cos\alpha}{\Sigma Cos\alpha} \quad (5)$$

With is the average effective fetch, is the length of the fetch segment measured from the start point of observation to the end of the fetch, and is the size of the angle formed at the fetch.

Wave Analysis

Waves on the coast originate from the transfer of energy by wind gusts from the inner sea and then propagate towards the coast, causing deformation (change in shape) [16]. Breaking waves are further divided into 3 surf zone areas, swash zone and breaker zone. The surfzone is part of the breaking wave and also the boundary area for rising and falling waves on the beach. Wave analysis can be found in Figure 4 with the following calculation scheme [14].

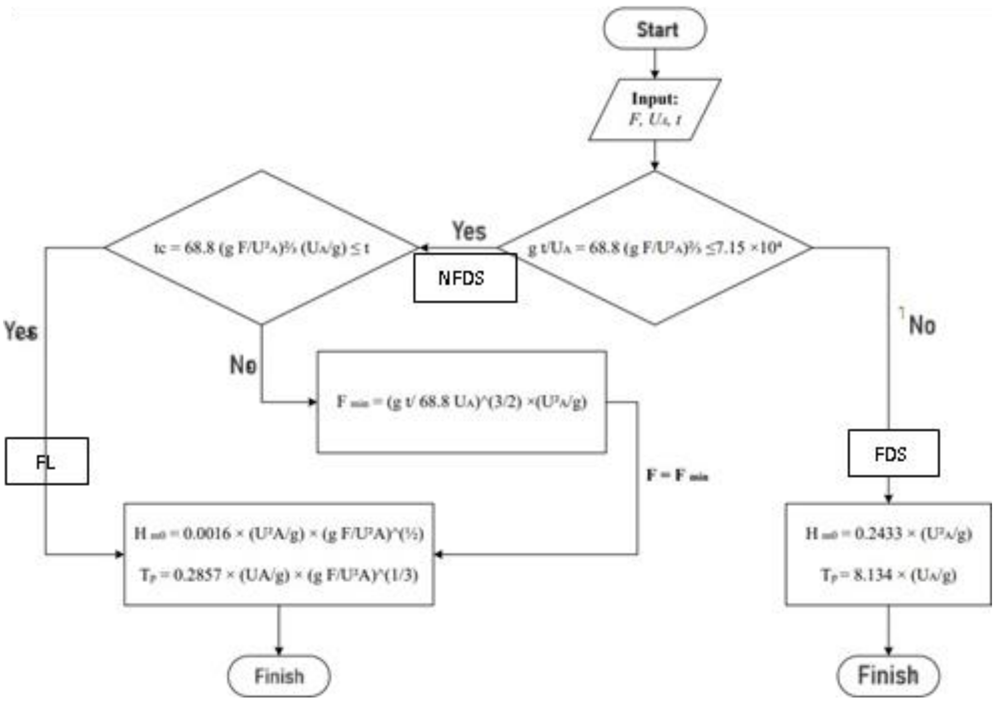

Figure 4. Wave Forecast Calculation Scheme

With F is the effective fetch, UA is the wind shear coefficient, g is gravity, tc is the time the wind blows, Fmin is the minimum fetch, FDS is the fetch developed sea, NFDS is the non-fully developed sea, DL is duration limited, and FL is fetch developed.

Basic Sediment Analysis

Sediments can be divided based on several categories and their natural characteristics such as porosity, falling speed, density, composition, shape, grain size, and so on. It is known that grain size in sediments plays an important role in

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providing an overview of the resistance of transport agents. The representative size is defined as 50% of the weight of the sediment retained on the sieve or what is commonly known as the median diameter with D50 [17]. In this study, 11 points were used which were considered to describe the sediment at the research location and then the average D50 value was calculated to obtain a representative size of the area as in Figure 5.

Figure 5. Distribution of Sediment Granule Collection Points

The selection of sediment collection locations was chosen based on direct observations at the location by determining the affected areas and was considered to represent coastal conditions [18]. From laboratory results to calculations, the representative sediment size in the new manggar area is 0.366 mm.

Sediment Movement

For sediment transport, the sediment transport equation is used with the following equation [19].

$$Q = \left(H^2 C_g\right)_b \left(\alpha_1 sin^2\theta_{bs} - \alpha_2 sin^2\theta_{bs}\frac{\partial H}{\partial x}\right)_b \quad (6)$$

Where Q is the transport rate, H is the wave height, Cg is the wave speed, b is the subscript indicating the breaking wave, is the angle of the wave breaking. Parameters a1 and a2. Also obtained are the values a1 and a2 from equations 7 and 8 as follows.

$$a_1 = \frac{k_1}{16(S-1)(1-p)(1{,}416)^{\frac{5}{2}}} \quad (7)$$

$$a_2 = \frac{k_2}{8(S-1)\tan\beta\,(1{,}416)^{\frac{7}{2}}} \quad (8)$$

With K1 being the empirical coefficient (0.58 to 0.77) and K2 being the empirical coefficient ((0.5 to 1)× K1), S is ps/p, ps is the density of the sediment (2.65 x103 kg/ m3), p is the density of sea water (1.03 x 103 kg/m3), ρ is the basic porosity of the soil (0.4) and Tan β is the average basic slope of the coastline.

Calibration and Evaluation

Calibration and evaluation were carried out to obtain simulation results as similar as possible to real world conditions [20], suitability of the model to changes in coastline with an error tolerance of 20%, which was obtained using equation 9 as follows [19]. It is known that x is the coastline digitized by Google Earth and x′ is the coastline calculated by numerical methods. Calibration results are found by doing trial and error on the values of K1 and K2. From the calculation results, it was found that the appropriate K1 and K2 values for this calculation were respectively 0.58 and 0.58. As for the relative error, it was found that the smaller the average difference between the simulation results and real-world conditions, the closer the simulation is to real-world conditions in terms of describing the changes that occur.

RESULTS AND DISCUSSION

The results of the analysis of calculations using actual data that have been collected will be used for calculations using numerical methods to obtain changes in the coastline so that the value of changes in the Manggar Baru coastline will be obtained divided into STA 0 to STA 1150. From the results of calculations using the assistance application, it is illustrated in the form of a graph of changes in coastline.

Changing Coastline Conditions Existing 2022 against 2024, 2027, 2032, and 2042

The result of changes in shoreline conditionsexisting in 2022 compared to future years in 2024, 2027, 2032 and 2042, depicted numerically as in Table 1 below.

Table 1 Changes in Coastline Study Locations Against Conditions Existing

Changes in the Coastline of Study Locations Regarding Conditions Existing(2022)									
No	**STA**	**2024**	**Ket 2024**	**2027**	**Ket 2027**	**2032**	**Ket 2032**	**2042**	**Ket 2042**
	m	**m**		**m**		**m**		**m**	
1	0	0	Nothing Changes	0	Nothing Changes	0	Nothing Changes	0	Nothing Changes
2	50	2,69	Accretion	4,31	Accretion	4,74	Accretion	2,5	Accretion
3	100	3,33	Accretion	5,19	Accretion	4,81	Accretion	-0,17	Erosion
4	150	1,47	Accretion	1,36	Accretion	-1,67	Erosion	-9,84	Erosion
5	200	-2,73	Erosion	-6,77	Erosion	-13,48	Erosion	-24,83	Erosion
6	250	-7,9	Erosion	-15,47	Erosion	-25,26	Erosion	-39,04	Erosion
7	300	-9,49	Erosion	-18,46	Erosion	-29,48	Erosion	-44,2	Erosion
8	350	-7,29	Erosion	-14,96	Erosion	-24,85	Erosion	-38,72	Erosion
9	400	-1,3	Erosion	-4,51	Erosion	-10,8	Erosion	-22,08	Erosion
10	450	2,79	Accretion	3,85	Accretion	2,01	Accretion	-5,41	Erosion
11	500	1,73	Accretion	3,2	Accretion	3,65	Accretion	0,04	Accretion
12	550	0,03	Accretion	0,41	Accretion	1,09	Accretion	0,17	Accretion
13	600	-0,8	Erosion	-1,14	Erosion	-0,78	Erosion	-0,18	Erosion
14	650	-0,21	Erosion	-0,21	Erosion	0,36	Accretion	1,82	Accretion
15	700	1,12	Accretion	2,02	Accretion	3,21	Accretion	5,3	Accretion
16	750	1,13	Accretion	2,26	Accretion	3,89	Accretion	6,35	Accretion
17	800	0,31	Accretion	1,26	Accretion	2,92	Accretion	5,31	Accretion
18	850	0,93	Accretion	1,97	Accretion	3,39	Accretion	5,15	Accretion
19	900	1,06	Accretion	1,91	Accretion	2,66	Accretion	3,22	Accretion
20	950	0,29	Accretion	0,3	Accretion	-0,17	Erosion	-1,1	Erosion
21	1000	-0,97	Erosion	-2,33	Erosion	-4,31	Erosion	-6,56	Erosion
22	1050	-2,39	Erosion	-5,1	Erosion	-8,16	Erosion	-10,93	Erosion
23	1100	-3,7	Erosion	-6,71	Erosion	-9,36	Erosion	-11,34	Erosion
24	1150	0	Nothing Changes	0	Nothing Changes	0	Nothing Changes	0	Nothing Changes

Changes in Coastline Study Locations Against Conditions Existing (2022)									
No	**STA**	**2024**	**2024**	**2027**	**2027**	**2032**	**2032**	**2042**	**2042**
	m	**m**		**m**		**m**		**m**	
Average		**-0,829**	**Erosion**	**-1,984**	**Erosion**	**-3,982**	**Erosion**	**-7,689**	**Erosion**

The changes that occurred in 2024, 2027, 2032 and 2042 were found that the longer the simulation, the greater the changes in the Manggar Baru coastline, with the dominant erosion occurring from year to year. In the changes to the Manggar Baru coastline, continuous changes predominantly occur at STA 150 - STA 450, gradually experiencing decline or erosion. In this section the beach is also used as a tourist spot and also several residential houses and public facilities will be affected by erosion because it is still using a foundation site. The comparison results were obtained in graphical form representing changes in the Manggar Baru coastline from conditions existing to predictions of coastline changes in 2024, 2027, 2032 and 2042 can be seen in Figure 6, a comparison graph of coastline changes.

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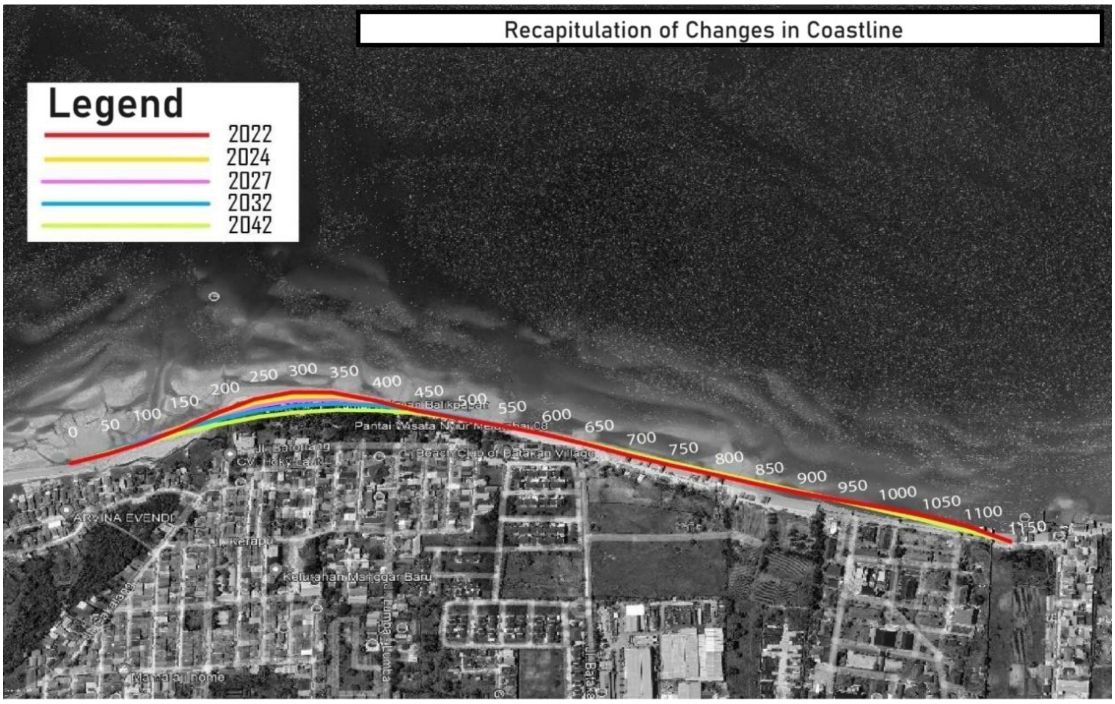

Figure 6. Future Coastline Changes Against Conditions Existing

It can be seen from Figure 6 that changes in the coastline have occurred significantly based on coastline forecasting at STA 150 to STA 500 with impacts in the form of continuous erosion, while at STA 650 to STA 900 there has been accretion. In the surrounding areas affected by erosion, there are recreation areas with several residential areas using site foundations, while in areas experiencing accretion, residential areas use the concept of houses on stilts. Looking at the shape of the distribution of buildings, adjustments are needed to the location of residential construction so that it has a building shape with a house on stilts concept to minimize the impact of changes in the coastline. The overall results of the changes obtained are summarized in Table 2 below.

Table 2 Recapitulation of Changes in Coastline Results for the 2022 Coastline

No.	Year	Average Change	Highest Accretion	Ultimate Erosion	Total Accretion	Total Erosion
		m				
1	2024	-0.82917	3.33	-9.49	16.88	-36.78
2	2027	-1.984167	5.19	-18.46	28.04	-75.66
3	2032	-3.9829167	4,81	-29.48	32.73	-128.86
4	2042	-7.68917	6.35	-44.2	29.86	-214.4

From Table 2 it is found that the largest average change to existing conditions occurs in 2042 with dominant erosion of 214.4 meters. Then it was found that the highest accretion to existing conditions was 6.35 meters in 2042 at STA 750. The highest erosion occurred in 2042 at 44.2 meters at STA 300. The areas affected by accretion were fishing residential areas. Meanwhile, STA 300 which is experiencing erosion is a tourism and residential area.

CONCLUSION

It was found from the results of numerical method calculations that the magnitude of changes in coastlines for 2024, accretion and erosion were 17 m/year and 36.78 m/year, for 2027 accretion and erosion were 28 m/year and 75.25 m/year., for 2032 accretion and erosion will be 32 m/year and 128.32 m/year, and in 2042 the accretion and erosion will be 29.86 m/year and 214.4 m/year. This is caused by waves and the impact of sediment moving along the coastline over a long period of time so that the changes that occur are quite significant. For coastal buildings that are close to the coastline, it is necessary to adjust the shape of the building to help reduce the influence of changes in the coastline.

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