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Numerical Modeling of Long Shore Transport Rate in Coastal Structure Planning

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ABSTRACK

Demak Regency is one of the regencies in the coastal region north of Central Java, which has a abrasion. The coastal area of Surodadi, Sayung Subdistrict, Demak Regency is one of the areas that experienced severe abrasion. The purpose of this study is to analyze the coastal dynamics that occur and design appropriate conservation and rehabilitation systems to reduce the impact of abrasion and coastal protection. This study uses primary data carried out at 2016. The analyzes carried out were wind, wave, tidal analysis, shoreline changes and analysis of recommendation structures. The protection scenorio plan uses two alternative structures namely breakwater and seawall. Analysis using a breakwater indicates that the results of sedimentation due to the structure are unsatisfactory. After 10 years, the breakwater produces ± 100 m sedimentation from the initial coastline. The modeling results show that the seawall can prevent further abrasion in the study site even if it does not cause sedimentation (except on the coastline that juts into the mainland).

Keywords: *abrasion, surodadi, hydrodynamics, seawall, breakwater*

INTRODUCTION

Coastal abrasion occurs in several regions in Indonesia, one of them is in Central Java. Demak Regency is one of the regencies in the coastal region north of Central Java, which has a severe abrasion. The occurrence of abrasion on the coast of Demak Regency is mostly caused by development activities in other regions which result in changes in the hydrodynamic pattern of waters which results in prolonged abrasion in coastal areas. Sayung Subdistrict experienced severe coastal abrasion which caused damage to the coastal area. Areas affected by abrasion are Surodadi, Timbusloko, Bedono and Sriwulan village (Ondara et al, 2016) which Sayung Subdistrict with the worst impact. The intensity increases, there is a long puddle of 6-8 hours every day, and it gets worse each year (Subardjo et al., 2015).

Figure 1. Research area in Surodadi waters, Demak regency, Central Java

Surodadi village is located in the northern coastal area of Java which has a coastline of 4.41 kilometers and one of the areas experiencing significant abrasion. Abrasion has been increasingly severe since the mid-1990s, especially in Sayung Subdistrict where abrasion and rob often occur due to coastal reclamation for residential and industrial development in Semarang which is directly adjacent to the West (Setyowati, 2010). In 2005, the area of Bedono Village which was adjacent to Surodadi Village was forced to be relocated because it sank and was often submerged to as high as 1.5 meters. Before the 1980s, Surodadi Village included areas that had quite a lot of mangrove forests. After the 1980s, forest destruction began to occur because there was a function of land conversion into a pond area which caused massive logging of mangrove forests. Sayung Subdistrict is an abrasion area in Demak Regency which was most affected by sea level rise in the North Coast of Java. The condition is increasingly worrying because the sea level rise has reached the national road, Java Pantura line. Rob flooding also affects the lives of coastal communities because they have to adapt to tidal flooding (Desmawan et al, 2012), besides that if these conditions are not immediately addressed it will have an impact not only on the social and economic life of the communities in the region, but also on the regional region Central Java as a whole. The purpose of this study is to analyze the coastal dynamics that occur and design appropriate conservation and rehabilitation systems to reduce the impact of abrasion. The structural design obtained from this research can be used as a basis in policy making related to the implementation of abrasion disaster management that will continue to occur

MATERIALS AND METHODS

This research began with a comprehensive literature study conducted before the study began. From the results of the literature study, the research objectives and research methods are further refined based on the latest data and information and put forward three aspects, namely GIS, oceanography, and coastal vulnerability. Furthermore, data collection is carried out directly in the field to retrieve primary and secondary data as material for analysis and for the process of validation and verification of coastal vulnerability and threatening factors. The research area is in the waters of Surodadi Village in Sayung District, Demak Regency, Central Java. The primary data used in this study is bathymetry, tides and flows and data collection were carried out in 2016.

Wind Data Analysis

Analysis of wind data is divided into three main stages, namely annual wind data, wind data for 10 years, and maximum daily wind data for 10 years. The analyzed wind data is then processed and presented in the form of annual and 10-year wind roses using the WRPLOT View application to make it easier to understand direction distribution and wind speed (Habibie et al, 2011). This stage serves to determine the dominant wind direction and grouping based on direction and speed. The maximum daily wind data for 10 years serves to calculate the height and period of waves that occur in the waters (Fagherazzi et al, 2009). Wind measurements are carried out on land while the formula used is for aquatic wind conditions, so wind data will be transformed from mainland wind data to sea level wind data (Cardone, 1969).

Wave Data Analysis

This analysis is a wave forecasting that occurs due to the influence of the average wind speed that occurs on the surface of the water. Wind data on land will be transformed into wind data on the surface of the water. Wave transformation analysis includes effective fetch analysis, wind stress factor (U_A), refraction coefficient, shoaling coefficient (Vincent, 1985) and breaking wave calculations performed to calculate the maximum wave height that occurs. From the value of wind stress and effective fetch, it can be known how much the period value and wave height (Bottema et al., 2008).

Fetch

Feth length calculation uses the help of AutoCad software so that it has a fairly high accuracy in determining fetch length. The fetch calculation is effective for the following forms of irregular generation areas (Triatmodjo, 1999):

$$F_{eff} = \frac{\sum x_i cos\propto_i}{cos\propto_i} \text{ ....(1)}$$

with x_i is the projection of the radial distance in the wind direction and $\propto_i$ is the angle between the fetch path which is observed in the direction of the wind. In coastal protection building planning, adequate wave height data is needed for certain predetermined purposes (Ruggiero et al., 1996). The following is the analysis used in the selection of planned wave height in this study.

Wave Period

This analysis is based on the type of construction to be built and the value of the protected area. For guidance on determining the planned return period of waves, use the following table 1.

Table 1. Guidelines for selection of wave types and periods

Number	Building type	Wave Plan	
		Type	T_{period}
1	*Rubble structure*	H_{33}	10-1000 ys
2	Struktur semi-saku	H_{10}-H_1	10-1000 ys
3	*Rigid structure*	H_1-H_{maks}	10-1000 ys

(Yuwono, 1992)

Probability Distribution Function

To predict waves with a certain period Gumbel distribution is used by estimating significant wave height with various return periods and wave direction coefficients (Persson et al., 2010).

Repeat Period and Wave Direction Coefficient

In determining the height and maximum wave period that occur based on changes in depth, a relationship between the maximum wave height and the maximum wave period is calculated using the hindcasting method to get the equation from the relationship graph. Then the equation obtained from the graph of the relationship is used fortunately to calculate the wave period in the deep sea which will be used to calculate the value of the refraction coefficient. Then calculate the value of the shoaling coefficient to get a new wave height value (Tajima et al., 2003). Calculations are carried out using available graphs, namely graphs that state the relationship between H'_0/gT^2 and Hb/H'_0. The Hb value is obtained from the plot between the values of H'_0/gT^2 and the slope of the beach (Triatmodjo, 2012).

Tidal Data Analysis

The tidal data used is the primary data measured from March 4, 2016 to March 22, 2016. The results of the analysis of tidal data processing (Ondara et al, 2018) are tidal graphs, HHWL *(Higest High Water Level)*, MHWL *(Mean High Water Level)*, MWL *(Mean Water Level)*, MLWL *(Mean Low Water Level)* dan LLWL *(Lowest Low Water Level)*.

Coastline Change Analysis

Analysis of shoreline and protective changes in shoreline is done with Genesis software (Young et al., 1995). Shoreline changes depend on the magnitude of the wave height and the wave period that occurs. Inputs from the program are SHORL, SHORM, WAVES and SEAWL. GENESIS (Generalized Model for Simulating Shoreline) is a numerical modeling system designed to simulate shoreline changes, with this model can be estimated the value of longshore transport rates and changes in coastline due to sediment transport without or with the presence of a coastal safety structure for a certain period. The calculation process is carried out by making longshore transport predictions based on the shape of the beach face, while for coastline forecasting calculations will be carried out by considering the aspects of longshore transport that occur (Pranoto, 2008).

The longshore transport rate (Q) has a unit of m^3 / year, because its movement is parallel to the coast, there are two alternative movements, namely right and left relative to an observer standing on the beach facing the sea. The movement from the left right is given a notation (Q_{lt}) and a rightward movement (Q_{rt}) so that the gross sediment transport rate (gross) is obtained $Q_g = Q_{lt} + Q_{rt}$ and the net transport rate $Q_n = Q_{lt} - Qrt$.

Numerical calculations of longshore transport are carried out using the modified equation from the equation:

$$Q\ (+) = 1/2\ \ (Q_g + Q_n) \text{ ....(2)}$$

$$Q\ (-) = 1/2\ \ (Q_g - Q_n) \text{.........(3)}$$

with the results of modification will produce a longshore transport value of:

$$Q = \frac{(H^2 C_g)_B}{8\left(\frac{\rho s}{\rho} - 1\right) a (1{,}416)} \left(\frac{k_1}{2} \sin 2\theta_b - \frac{k_2 \cos \theta_b}{1{,}461 \tan \beta x}\right) \text{ ....(4)}$$

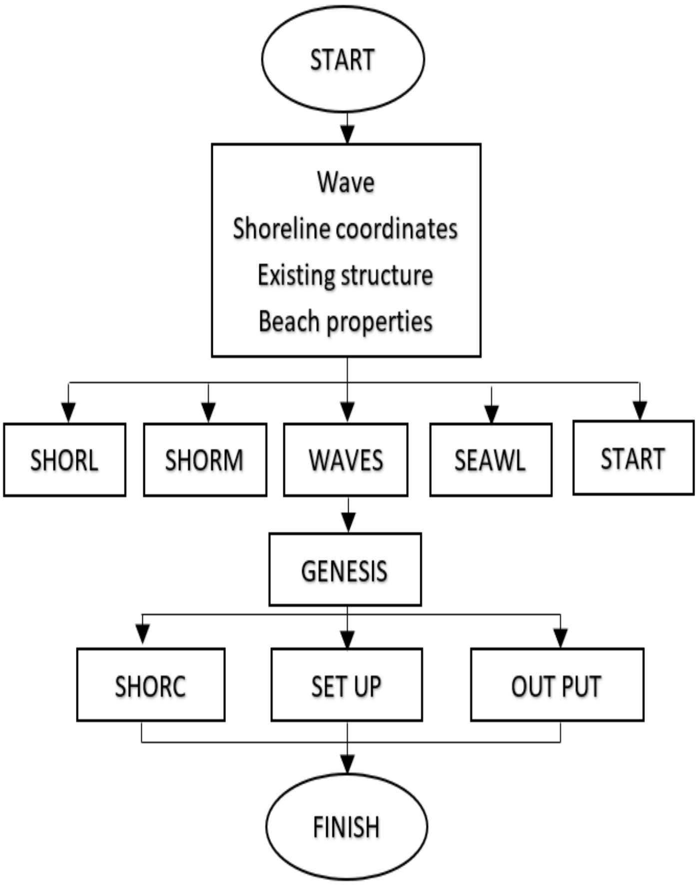

Diagram 1. Numerical modeling flowchart using GENESIS

Recommendation Analysis

After the results of the analysis and processing of data are grouped according to the identification of the problems that occur, then several alternatives are determined for effective problem solving. Of the several alternatives available, consideration is taken in selecting appropriate and efficient forms of protection. After an effective form of protection has been chosen, detailed analysis is carried out which includes:

a. Layout of building structure
b. Calculation of building structure
c. Visualize details of building structure

RESULTS AND DISCUSSION

Tidal data obtained in the field, processed by the admiralty method so that the tidal graph is generated (Figure 2). In addition, tidal analysis includes tidal constants which include S_0, M_2, S_2, N_2, K_2, K_1, 0_1, P_1, M_4 and MS_4.

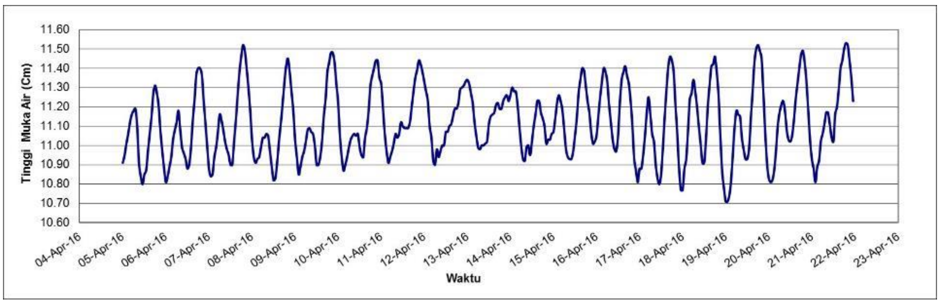

Figure 2. Tidal graph of Demak waters

Table 1. The value of the tidal harmonic component

Constituents	Amplitude	Different phase
M2	0.09	233.88
S2	0.06	193.47
N2	0.07	152.17
K2	0.02	193.47
K1	0.11	58.71
O1	0.07	142.37
P1	0.04	58.71
M4	0.01	201.93
MS4	0.00	193.24
SO	6.52	0.00

Calculation of the analysis of tidal components will produce an average sea level, tide face (Z_0), lowest low water level, and highest highest water level. The results of the calculation of the elevation in the tides are shown in table 2

Table 2. Results of the calculation of tidal harmonic components

Information	Elevation (cm)
Highest High-Water level (HHWL)	11.65
Mean High Water level (MHWL)	11.04
Mean Sea Level (MSL)	11.12
Mean low Water level (MLWL)	10.62
Lowest Low Water level (LLWL)	10.58

Windrose* dan *Waverose

The results of windrose and waverose (Figure 3) show the largest percentage of coming direction is in the east, but the direction of wind and waves comes in overall dominant from the direction between the west and north (around the North West). This could be due to incomplete wind data so that the results of windrose and waverose are not conical (too diffuse).

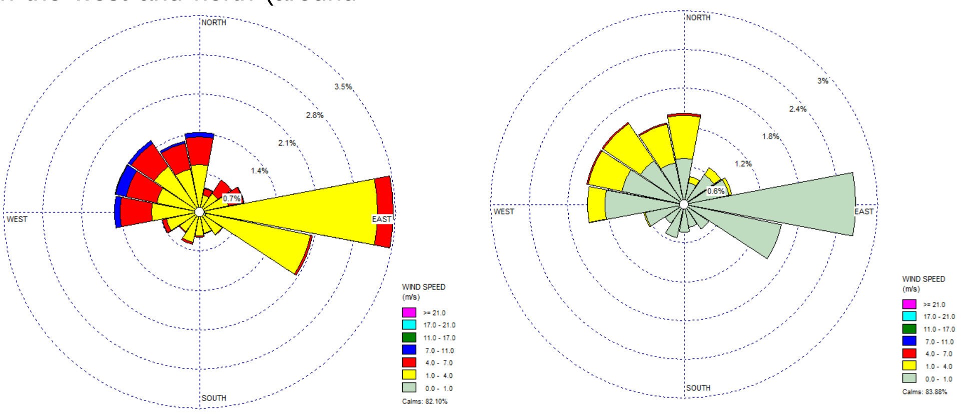

Figure 3. Windrose and Waverose of Sayung, Demak 2003-2012

With the location of the beach facing north, it can be concluded that the coming wave direction will be dominant from the North West (top left) and the shoreline current will drop along the coast.

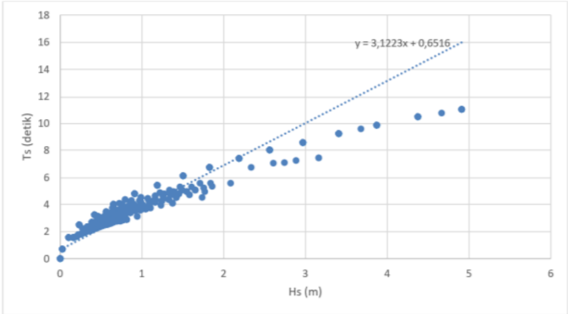

Figure 4. Graph of Hs vs Ts value comparison

GENESIS Calibration

GENESIS calibration results are the most optimal K1 and K2 values in modeling and the K1 and K2 values obtained for the Sayung case modeling are 0.3 and 0.5 with an% error of 8.93%. The error percentage is obtained from the difference between the reference coastline and the coastline from the calibration results.

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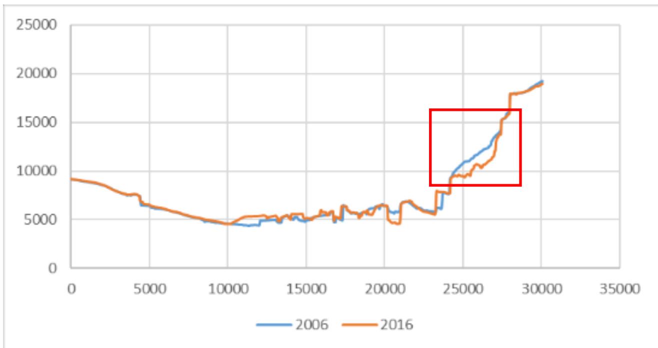

Figure 5. Range of maps used in modeling

Seen in Surodadi waters (Figure 6) there is a significant change in coastline in coastal areas. These changes occur along the coast with a length of 3 km with the middle part being the most experienced part of abrasion.

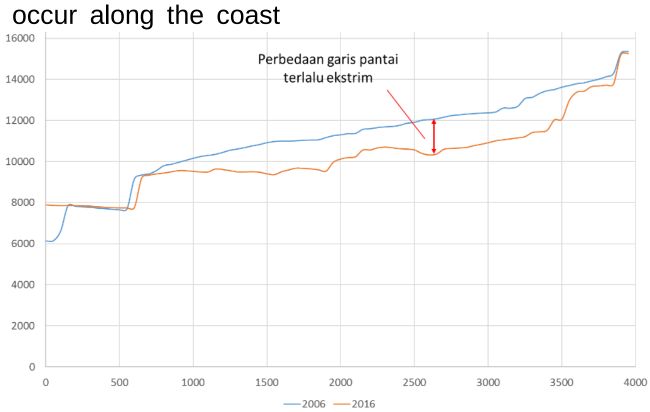

Figure 6. Differences in calibrated coastlines

To determine the position of the protective coast in the form of a breakwater, 3 alternatives are made with consideration to oceanographic conditions and also the depth of the water. In this first scenario, the breakwater is placed 100 meters from the coast and is located on the sloping coastal area and predominantly silt sediments. The length of the breakwater is 100 meters and aims to reduce the energy of the waves moving towards the beach.

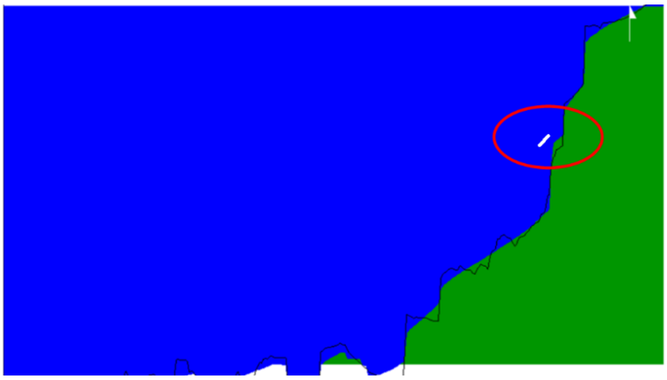

Figure 7. The first alternative breakwater modeling image

In the second scenario, the breakwater is placed 50 meters from the coast and is located on a sloping beach area and predominantly silt sediment. The length of the breakwater is 100 meters and aims to reduce the energy of the waves moving towards the beach

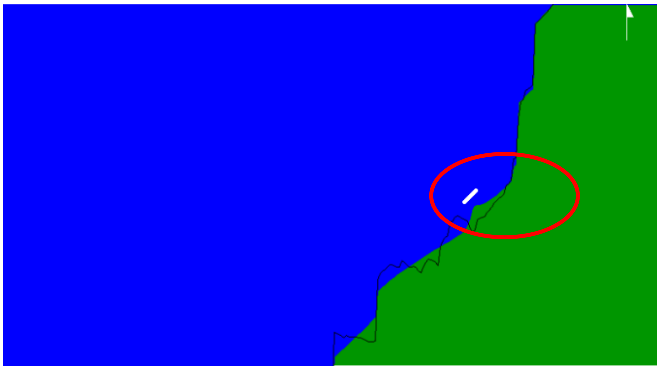

Figure 8. Image of the second alternative breakwater modeling

In the third scenario, the breakwater is placed 50 meters from the coast and is located on a sloping beach area and predominantly silt sediment. The number of breakwaters is 2 pieces and is located parallel to the breakwater length of 100 meters each and aims to reduce the wave energy moving towards the beach.

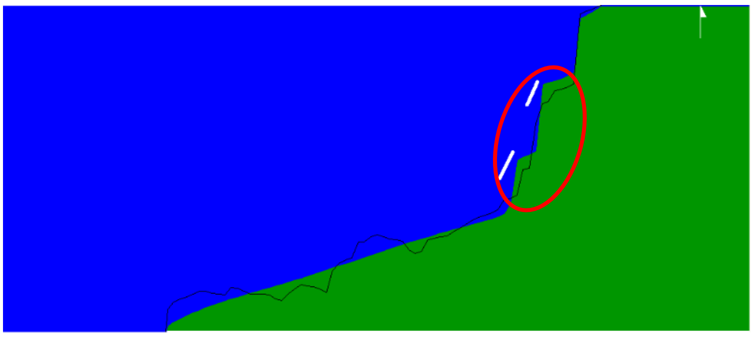

Figure 9. Image of the third alternative breakwater modeling

From two examples of detached breakwater modeling (Figure 9) it can be seen that the results of sedimentation due to the presence of a structure are unsatisfactory. After 10 years, the breakwater produces ± 100 m sedimentation from the initial coastline. Given the economic and environmental conditions of the research sites that need immediate handling, alternative detached breakwater is not the best treatment that can be done.

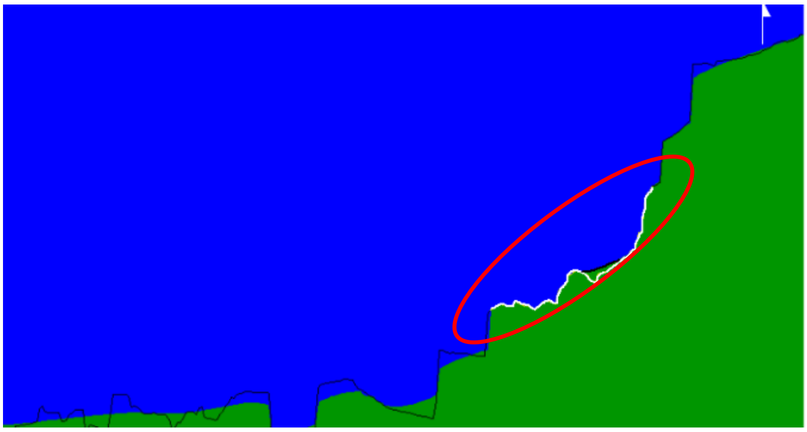

Figure 10. Picture of the first alternative seawalls modeling

In the first scenario using seawall (Figure 10), so that it is placed right on the beach with the aim of reducing abrasion and seawall structure is also expected to be able to reduce the incoming wave. The construction of a seawall along the coastline of the location overcomes the problem of abrasion that occurs but does not provide sedimentation (except on the coastline that juts into the land).

For the second scenario, the coastline in the second example does not retreat because it is squeezed by two seawalls, but when it reaches the left end of the beach and there is no more built up the abrasion occurs again. Although the second example seems more efficient and efficient, the construction process will be more difficult compared to the first example. In addition, GENESIS cannot model extreme conditions such as floods and storms, even though this will affect the entire coastline that is not protected in the second example. Therefore, from the two examples it is better to use the first example.

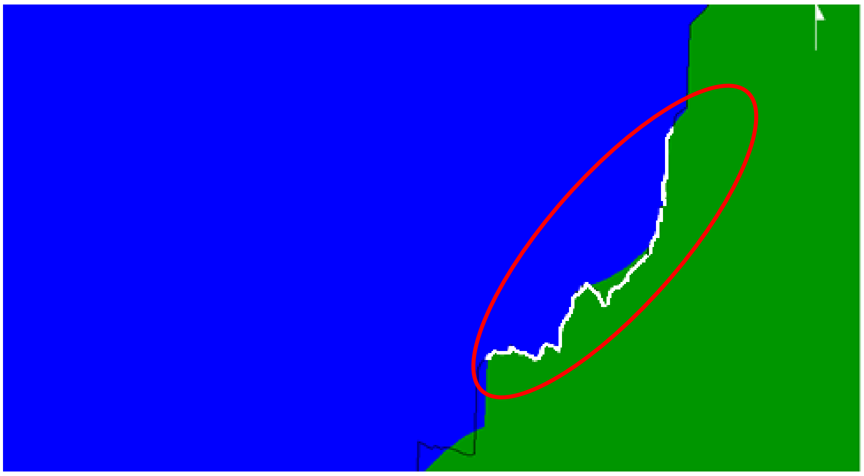

Figure 11. Model image of the second alternative seawalls

Both examples give almost the same results even though in the second example only a few small seawall are built close together (the distance between seawall 100 m. Based on the results of modeling, seawall development is a more appropriate alternative in dealing with abrasion that occurs at the research site. can prevent further abrasion at the study site even if it does not cause sedimentation (except on the shoreline that juts into the land). If an alternative that can produce sediment is desired (the already submerged land can return), the author recommends reclamation.

In general, there are two alternative types that can be done namely handling abrasion without or accompanied by the return of lost land. The handling of abrasion without the return of lost land is done by building a seawall along the coastline of the abrasion area accompanied by planting a parallel mangrove forest so that the defense against abrasion becomes stronger. While the handling of abrasion along with the return of lost land is carried out by performing reclamation in areas lost due to abrasion. Reclamation is carried out from land using dry sand (sand from land) to minimize disruption to marine ecosystems and residents in the area around the project. During reclamation, relocate residents who reside at the project site and provide employment for the residents. Relocation is carried out to facilitate the work of reclamation and provide comfort for the victims of abrasion. After reclamation is complete, build a seawall and plant a new mangrove mangrove line to prevent abrasion from happening again.

CONCLUSIONS AND SUGGESTION

The case to be examined is the coastline decline in Sayung, Demak due to abrasion and sea level rise. The research focused on coastline retreat due to abrasion. The decline of the coastline in Sayung, Demak, which has begun to be felt since 1995, was due to the lack of existing coastal protective structures. The mangrove planting that is done is not enough to withstand the abrasion process and the flooding that occurs. The relocation of residents carried out by the government has not been able to overcome the economic problems of the Sayung community, which partly derive their livelihood from ponds or the sea. After doing the modeling, the author concludes that there are two alternatives that can be done, namely by handling abrasion without returning the lost land by building a seawall along the coastline of the abrasion area accompanied by planting a parallel mangrove forest so that the defense against abrasion becomes stronger. Next is the handling of abrasion without the return of lost land, namely reclamation in areas lost due to abrasion. Reclamation is carried out from land using dry sand (sand from land) to minimize disruption to marine ecosystems and residents in the area around the project. During reclamation, relocate residents who reside at the project site and provide employment for the residents. Relocation is done to simplify the work of reclamation and provide comfort for the victims of abrasion.

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