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GOVERNMENT'S EFFORTS TO MINIMIZE THE THREAT OF COASTLINE CHANGES ON THE NORTH COAST OF BENGKALIS ISLAND

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Abstract

This study aims to analyse the changes in the coastline that will occur using geographic information system technology and formulate anticipatory efforts from the government to overcome the threat of abrasion on the north coast of Bengkalis Island, Riau Province. Bengkalis is a Regency located on the north coast of Riau Province, where the coastal area is very vulnerable to maritime disasters. This is evidenced by tidal waves or high tides that regularly occur at the end of the year in the north coastal area of the Bengkalis Regency. There are hundreds of houses and shopping centre shops submerged by the tide; this is causes harm to the community. In addition, the threat of abrasion, which causes changes to the coastline toward settlements, continues to increase every year; this problem threatens the country's sovereignty because the worst possibility is to eliminate the island. This study found that coastal abrasion that occurred on the coast of Bengkalis Island reached 39 meters a year, and the average rate of change of the coastline was 14 meters a year. Without serious handling and countermeasures from the government, this will become a big problem.

Keywords: *Geographic Information Systems, Government Efforts, Coastline Change.*

INTRODUCTION

Indonesia is an archipelagic country with 17,504 islands and 95,181 km of coastline, making Indonesia, commonly referred to as Nusantara, with the longest coastline in the world after Canada, and 71% of Indonesia's territory is territorial waters (Ministry of Maritime Affairs and Fisheries RI). Coastal areas in Indonesia are widely used for human life, such as residential areas, tourism areas, aquaculture areas, industrial areas, port areas, etc. Currently, coastal areas are not only the centre of economic growth but have been used as a strategic and anticipatory sector to face changes in the development paradigm and future economic orientation.[1]

[1] Dahuri, R., J. Rais., S.P. Ginting., M.J. Sitepu, *Pengelolaan Sumberdaya Wilayah Pesisir dan Lautan Secara Terpadu*, (Jakarta: PT. Pradnya Paramita, 2008).

As the largest archipelagic country in the world, besides the potential for abundant natural resources, Indonesia is also a country that has a very high potential for disasters due to its geographical conditions. Especially in the coastal areas of Indonesia with dynamic environmental characteristics, sensitive and vulnerable to coastal disasters. Marfa revealed that the coastal areas of Indonesia are very prone to disasters. There are various kinds of coastal disasters such as earthquakes, tsunamis, extreme waves, dangerous sea waves, volcanic eruptions, floods, sea-level rise, landslides, coastal erosion, hurricanes and so on.[2]

Global Warming is one of the causes of several maritime disasters in Indonesia. Global warming is a term that refers to an increase in the average temperature above the earth's surface. The Intergovernmental Panel on Climate Change (IPCC) predicts that global temperatures will likely increase by 1.1°C to 6.4°C in the next 90 years. The increase in global temperature will cause ice melting at the north and south poles, resulting in the expansion of seawater masses and sea-level rise.[3] Rising sea levels cause the expansion of inundated coastal areas. Based on the IPCC report, there will be an increase in sea level by 2.8-3.6 mm a year. This sea-level change directly impacts climate change and has been predicted globally and regionally for decades. The impacts of sea-level sea-level rise include increased frequency and intensity of floods, changes in ocean currents, widespread damage to mangroves and widespread threats to the socio-economic activities of coastal communities.[4]

The coastal area is dynamic, which means beach space (shape and location) changes rapidly in reaction to humans' natural processes and activities.[5] As an archipelagic country, Indonesia certainly has great potential for the maritime disasters described above. One of them is the abrasion that occurred in Riau Province abrasion; abrasion caused by rising global temperatures has occurred in several coastal areas in Riau. The government has made much progress in identifying potential disasters and dealing with them. One of them is by identifying regional vulnerabilities and making prediction maps. Prediction can be done using geographic information system technology. Geographic information systems can be used for spatial analysis modellingling using measurement data and satellites. Spatial analysismodellingeling can provide objective information on the potential impacts of disasters and areas with high potential exposures. In this case, the geographic information system (GIS) is the key to strengthening the geospatial function in determining an area's location, routes, and zones for compiling disaster mitigation maps, disaster-prone zones, and community evacuation locations. By identifying an area's vulnerability, it is hoped that the government can create scenarios for anticipating and adapting to disasters that will occur. In maritime disasters, the data that can be managed are tidal data and satellite image data extracted into future coastline predictions

[2] Marfai, M.A.; Yulianto, F.; Hizabron, D.R.; Ward, P. dan Aerts, *Preliminary Assessment and Modeling The Effects of climate change on Potential Coastal Flood Damage in Jakarta. Joint research report,* (Vree Univ Amsterdam dan Fakultas Geografi, Universitas Gadjah Mada, 2009).

[3] M. Djazim Syaifullah, *Suhu Permukaan Laut Perairan Indonesia Dan Hubungannya Dengan Pemanasan Global,* (Jakarta Pusat: BPPT, 2015), hlm. 1-2.

[4] Anggraeni Damayanti, *Analisis Dampak Perubahan Iklim Berdasarkan Kenaikan Muka Air Laut Terhadap Wilayah Kota Surabaya,* (Surabaya: Institut Teknologi Sepuluh November, 2016), hlm. 1.

[5] Solihuddin, T. 2010. Morfodinamika delta Cimanuk, Jawa Barat berdasarkan analisis citra landsat. J. Ilmiah Geomatika, 16(1):77-85.

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using the Digital Shoreline Analysis System (DSAS) method. This study aims to analyse the changes of coastline changes and formulate government efforts to minimise the threats on the t of Bengkalis Island, Riau Province.

RESEARCH METHODS

The research location selected in this study is along the north coast of Bengkalis Island. Bengkalis Island is one of the islands in Bengkalis Regency, Riau Province. The map of the research location is presented in the following figure;

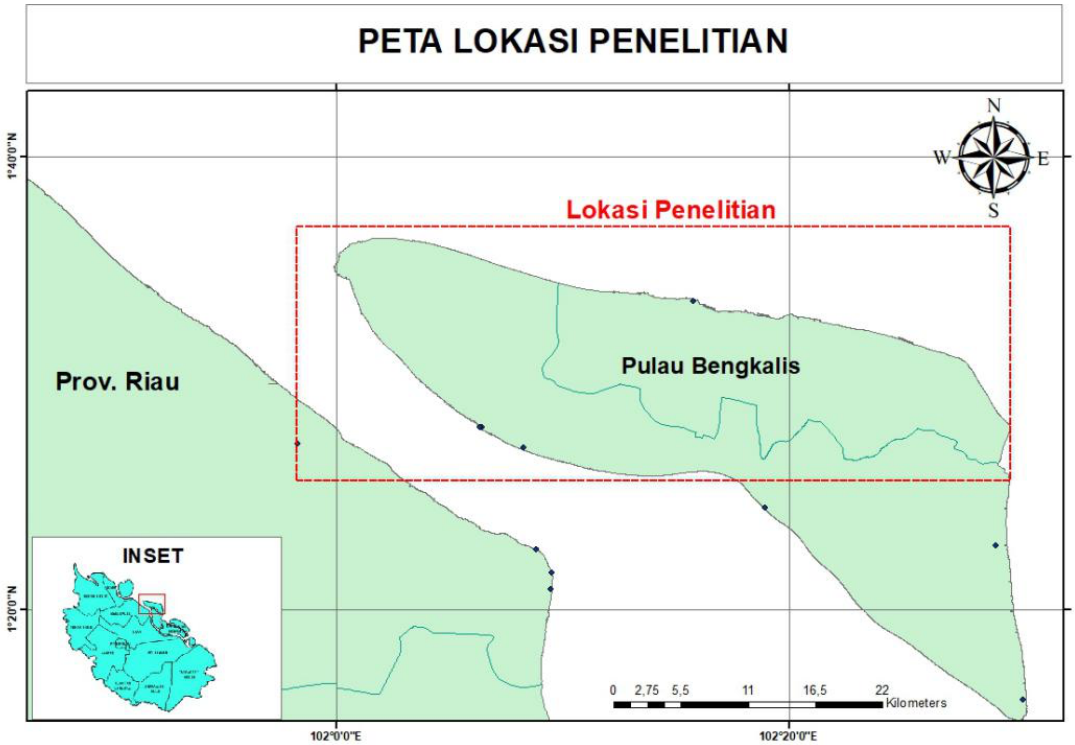

Figure 1. Research Location Map

The method used in this study is quantitative. The data used in this study are primary data and secondary data. The primary data used in this study are Landsat 5,7 and 8 satellite image data from different periods (1992, 2002, 2012, and 2022). The primary data is obtained by downloading satellite images through the website http://eartheexplorer.usgs.gov/. Next, secondary data as a support in the form of tidal prediction data that can be obtained through the website https://hdc.pushidrosal.id/e-navigasi/ based on the adjustment of the time of taking satellite imagery; for satellite imagery data which tidal data is not available, it is assumed that satellite imagery is taken at low tide. This study's other secondary data is the Indonesian topographic map (ITM). Data retrieval of Indonesian topographic maps is done by downloading data on the Geospatial info website www.info-geospatial.com. The downloaded Indonesian Earth Map is a map with the boundaries of the Districts and Regencies in Indonesia.

The Landsat satellite image data is carried out with the help of ENVI 5.3 software for radiometric correction. The calculation of coastline changes is obtained through ArcGIS 10.5 software which is processed and analysed to determine coastline changes in the study area. Tidal data is used to analyse sea level rise due to climate change and the increase in temperature on the earth's surface. Tidal data was processed using the

admiralty method and obtained the MSL (Mean Sea Level) value which can be used to predict a sea-level rise in the next few years. Analysis of Coastline Changes on the north coast of Bengkalis Island using the Digital Shoreline Analysis System (DSAS) method. The type of data used in this research is secondary data.

Landsat data analysis and interpretation consist of image cropping, image recovery, enhancement, geometric correction, digitisation, and overlaying. Image cropping is done to focus on the research area with consideration for saving memory storage in the computer. Image recovery is carried out to improve the quality of satellite images that are not good due to damage to the satellite or due to atmospheric disturbances. Image recovery is done by performing gap-fill correction and radiometric correction.

Image processing begins with the geometric correction pre-processing using the polynomial method with resampling type nearest neighbour using the coordinate transformation system WGS 1984 S UTM Zone 48N. Furthermore, radiometric correction is carried out to reduce the influence of the atmosphere, which can reduce image quality using the Dark Object Subtraction (DOS) method referring to the Ardiansyah equation.[6]

Corrected Digital Number = Digital Number - Refractive (Minimum Value)

ENVI 5.3 software was used for land and ocean delineation of Landsat TM and ETM+ images using the Modified Normalized Difference Water Index (MNDWI) formula from Xu.[7] MNDWI is a fairly efficient method to emphasise the difference between waters and urban areas, with the following formula;

$$\text{MNDWI} = \text{Green} - \text{MIRGreen} + \text{MIR}$$

While on the Landsat 8 OLI satellite imagery using the formula from Ko et al.[8], namely:

$$\text{MNDWI} = \text{Green} - \text{MIRGreen} + \text{SWIR}$$

In the research flow, there are several processes or stages. This process begins with data collection to get the final analysis results of coastline changes. To explain the research flow more specifically, look figure below:

[6] Ardiansyah, A., Subiyanto, S., & Sukmono, A. (2015). I*dentifikasi lahan sawah menggunakan NDVI dan PCA pada citra landsat 8 (Studi Kasus: Kabupaten Demak, Jawa Tengah)*. Jurnal Geodesi Undip, 4(4), 316-324.

[7] Xu, H. (2006). *Modification of normalised difference water index (NDWI) to enhance open water features in remotely sensed imagery.* International Journal of Remote Sensing, 27(14).

[8] Ko, B. C., Kim, H. H., & Nam, J. Y. (2015). *Classification of potential water bodies using Landsat 8 OLI and a combination of two boosted random forest classifiers.* Sensors, 15(6), 13763–13777.

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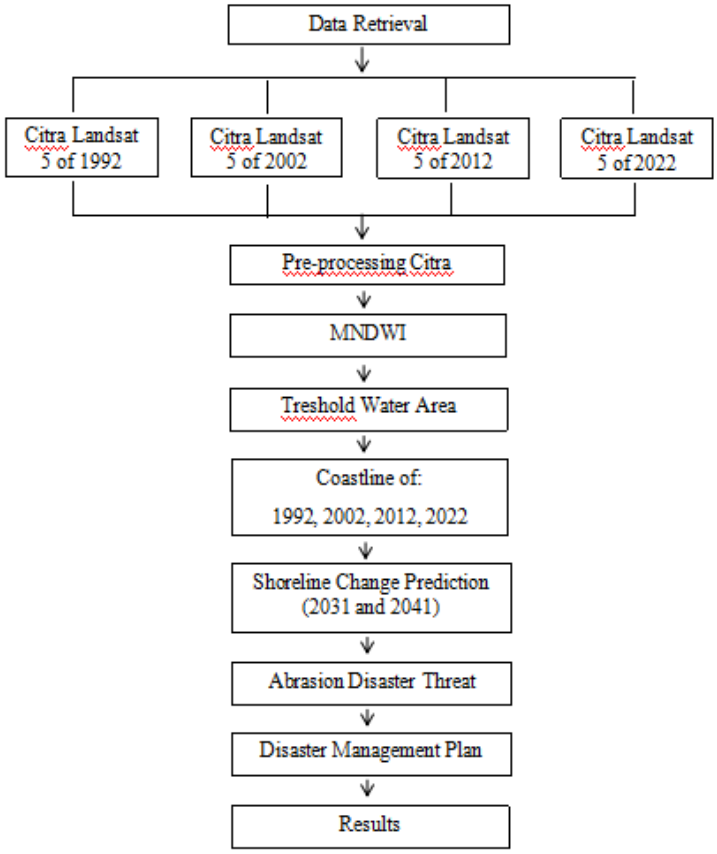

Figure 2. Research Flowchart

RESULT AND DISCUSSION

Threat Analysis of Coastline Changes in the North Coast of Bengkalis with GIS

Bengkalis is the initial Regency of three new Regencies (Rokan Hilir Regency, Siak Regency and Meranti Islands Regency) in Dumai City, Riau Province. In the book on initiating an incentive policy by Filip Uni, it is stated that the Bengkalis Regency is located on the eastern coast of Sumatra Island between 2030' North Latitude - 0056' North Latitude and 100052' East Longitude - 102031' East Longitude. The area of Bengkalis Regency is 7,773.93 km², consisting of islands and oceans. There are 16 main islands beside another small island in the Bengkalis Regency area. From this geographical location, this district is an archipelagic district that is geographically directly opposite the Malacca Strait.

Based on the analysis results using the Digital Shoreline Analysis System (DSAS) method, changes in the northern coastline of Bengkalis Island, Riau Province, tend to be significant from year to year. The coastline along the north coast of Bengkalis Island, from year to year, experiences abrasion. This can be seen from the change line in 1992, 2002, 2012, and 2022. The northern coastal area of Bengkalis Island is one of the outermost boundaries of the Republic of Indonesia, Indonesia, which borders the sea with Malaysia. The geographical location of the northern coast of Bengkalis Island, which is directly opposite the Malacca Strait, makes the coastline very dynamic. With large currents facing the strait directly, abrasion along the northern coast of Bengkalis Island is unavoidable.

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Coastline changes are a continuous process through various processes. It can be from erosion (abrasion) or addition (accretion) coast, caused by sediment movement, wave action and land use. The wave that occurs due to shifting the base plate of the sea or a tsunami sweeps over the land, thus changing the mainland coast and covering the land on the coast. Land change on the beach results from a pile of sediment carried by waves and eroded coastal sediments by waves or ocean currents. The shoreline change study is important as a reference in developing coastal areas and ports, tourism and activities, fishing and aquaculture.[9]

The coastline changes from 1992, 2002, 2012 and 2022, as shown in (figure 1), can be seen as continuous abrasion. Almost all of the northern coastal areas of Bengkalis Island from 1992-to 2022 experienced abrasion. Of course, this is very dangerous and has the potential to bring the threat of maritime disasters in the region. Several factors trigger abrasion that occurs along the north coast of Bengkalis Island. The damage to the coastline due to abrasion is triggered by the disruption of the natural balance of the coastal area caused by several factors, including; currents, waves, coastal topography, types of coastal sediments and sea-level rise.

This was also expressed by Prokopim of the Bengkalis Regency Government (2022), that the trigger for abrasion on Bengkalis Island is caused by an increase in sea level caused by melting ice in the polar regions as a result of global warming and the loss of mangrove vegetation (mangroves) on the coast. As is known, mangroves planted on the coast, their roots can withstand the waves to prevent beach erosion.

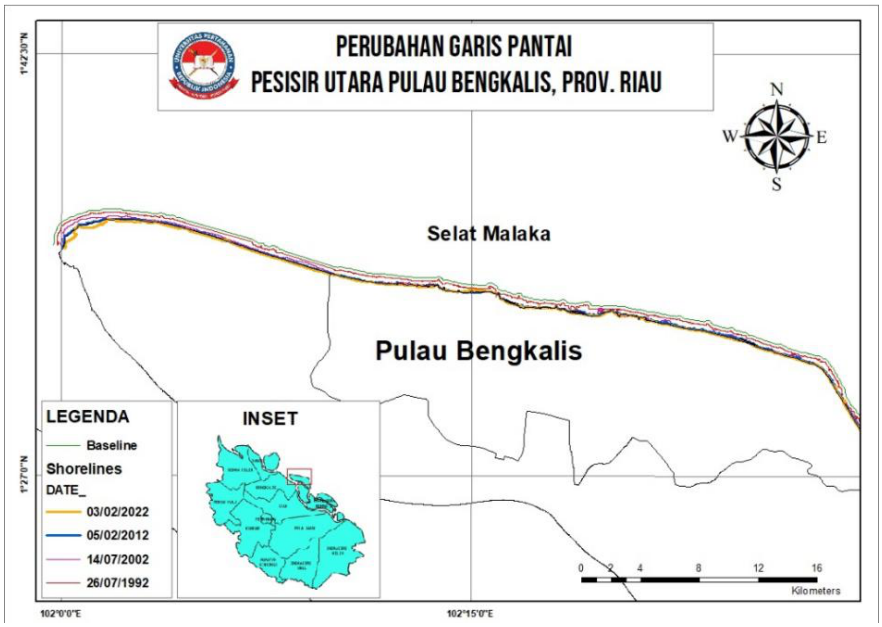

Figure 3. Bengkalis Island Coastline Change Map, Prov. Riau

The results of coastline changes analysis are then used to make predictions (forecasts) which are carried out using ArcGIS 10.5 software with the Digital Shoreline Analysis System (DSAS) method. The results of the coastline prediction obtained are shown in Figure 2. Based on the map, it is known that the prediction of the coastline in the next 20

[9] Darwin P Luwis, *Analisis Perubahan Garis Pantai Dengan Menggunakan Citra Penginderaan Jauh (Studi Kasus Di Kecamatan Talawi Kabupaten Batubara)*, (Medan: Universitas Negeri Medan, 2012), hlm. 2.

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years, the north coast of Bengkalis Island will experience abrasion. The highest abrasion occurred on the west coast of the island of Bengkalis.

Figure 4. Coastline Changes Prediction Map of the North Coast of Bengkalis Island, Prov. Riau In 2042

Apart from the coastline changes prediction map of the North Coast of Bengkalis Island in 2042, it was also found that the distance of the change in the coastline of the North Coast of Bengkalis Island by using the Net Shoreline Movement (NSM) value was obtained. Net Shoreline Movement (NSM) measures the distance of shoreline change between the oldest and newest shorelines. The results of the NSM value from 128 transects showed that the lowest abrasion was on transect 128, which was on the southern part of the skip pambangBambang beach by 1.7 meters. Meanwhile, the highest abrasion is on transect 4, the western part of the Sesame Panjang beach, with more than 1-kilometre abrasion. The graph of the rate of change of the coastline is shown in the following figure.

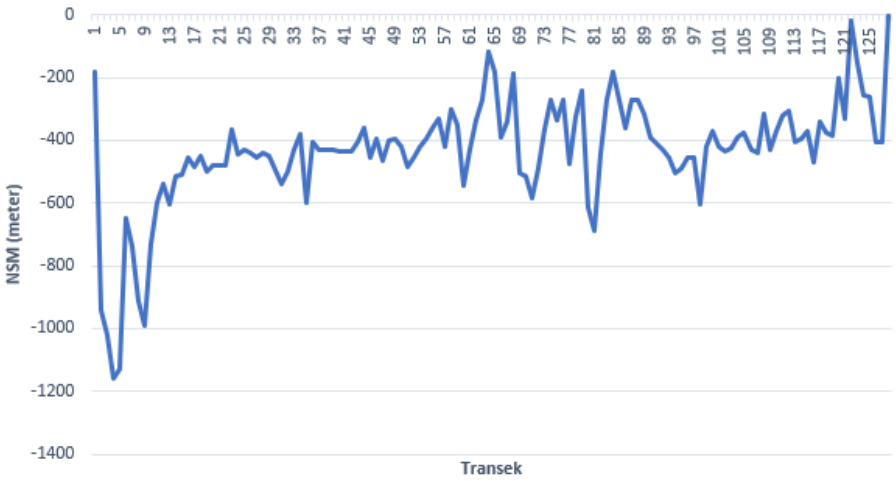

Figure 5. Coastline Change Distance (1992-2022)

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The line change rate on the North Coast of Bengkalis Island is obtained using the EPR Value (End Point Rate). End Point Rate is defined as the calculation of the rate of change of the coastline by dividing the distance between the longest coastline and the current coastline by the time. The formula used is as follows;

$$EPR = \frac{\text{Longest and Newest Shoreline Distance (m)}}{\text{Oldest and Most Recent Period (year)}}$$

The average shoreline change on the North Coast of Bengkalis Island is 14.8 meters a year. Furthermore, the results obtained from the EPR value of 128 transects showed that the lowest abrasion is on transect 128, the southern part of the Senekip Pambang beach, at 0.1 meters a year. The highest abrasion is on transect 4, which is on the west coast of Sesai Panjang, at 39 meters a year. The rate graph of the coastline change is shown in the following figure.

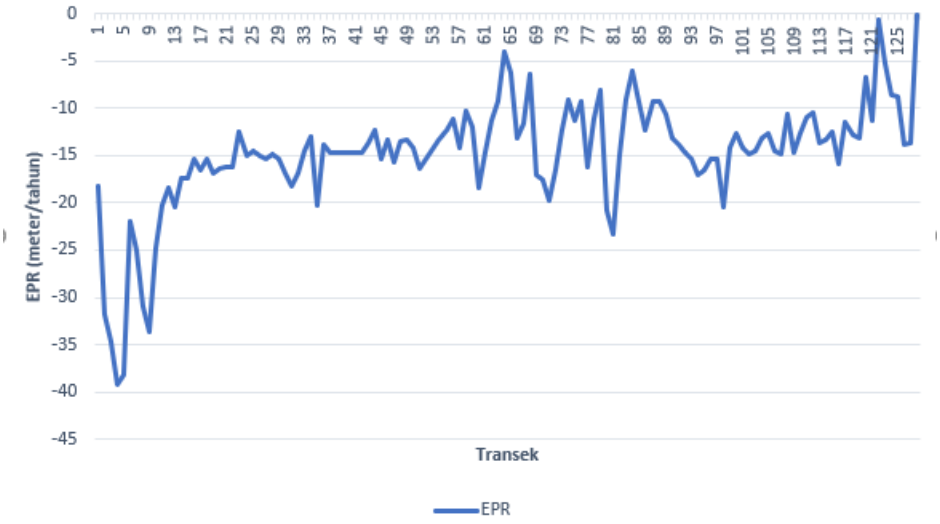

Figure 6. Coastline Change Rate (1992-2022)

Bengkalis Local Government Efforts in Minimizing The Threats Of Coastline Change

The geographical shape of the Bengkalis Regency consists of islands with coastal areas around the coast. In addition to having the advantage of beautiful scenery and having high tourism potential because it is a coastal area, several potential disasters must be known and be wary in Bengkalis Regency. One of them is the threat of shoreline progress or abrasion that occurs on the Bengkalis coast, and it may be caused to threaten the boundaries of Indonesia's territory. The currents in Bengkalis waters have a very large and strong current flow pattern. This is due to the large influence of water flow from the South China Sea. Infield conditions, the current speed can range from 2-to 3 knots during high tide conditions. The north coast of Bengkalis Regency gets big influence from the Malacca Strait. This causes the current to flow very strong and large, but the existence of small islands to the east of the Bengkalis Regency can reduce the strength of the current flowing along the Malacca Strait. Overall, the wave conditions in Bengkalis Regency are 3-4 m.[10]

[10] Badan Perencanaan Pembangungan Daerah Kabupaten Bengkalis, *Masterplan Penanggulangan Abrasi Pantai Kabupaten Bengkalis tahun 2007*, (Bengkalis, 2007).

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Along the northern coast directly opposite the Malacca Strait and on the southern promontory of Bengkalis Island, abrasion reaches 2-7 m a year. From satellite image analysis data using spot six and the results of field observations, it was noted that the abrasion rate in Bengkalis Regency in 2011-2020 in 4 sub-districts where is Bantan, Bandar Laksamana, Rupert, and North Rupert sub-districts reached 30.95 meters a year.[11] The rate of abrasion in Bengkalis is certainly not reasonable, and if it is allowed to continue, it will be detrimental. Not only harming the people living in Bengkalis and harms the Indonesian government. If accumulated, the Bengkalis border body has moved to the mainland as much as 2 km. In addition, abrasion will also impact the loss of community settlements in coastal areas.

Monitoring and analysis of changes in the area and position of the coastline are very useful in providing information about which areas are experiencing abrasion and accretion in the analysed coastal area. From the study results, it was found that the causes of abrasion that occur on the coast, according to the Directorate of Coastal and Small Islands Utilization, are divided into 2two types, natural factors and human factors. Natural factors that can cause abrasion include the ebb and flow of seawater, wind over the ocean, ocean waves and destructive ocean currents. Of course, the natural factors that cause this abrasion cannot be avoided because the sea has its cycle. Because at a certain period, the wind will blow very hard to produce waves and large ocean currents, which can cause coastal erosion. While the human factor, several human behaviours contribute to the occurrence of coastal abrasion. One of them is the imbalance of marine ecosystems where there is massive exploitation by humans of the wealth of marine resources such as fish, coral reefs and another biota. So if there is a current or big wave, it will go directly to the beach, which can cause abrasion. One of them is the imbalance of marine ecosystems where there is massive exploitation by humans of the wealth of marine resources such as fish, coral reefs and another biota. So that if there is a large current or wave, it will directly lead to the beach, which can cause abrasion. One of them is the imbalance of marine ecosystems where there is massive exploitation by humans of the wealth of marine resources such as fish, coral reefs and another biota. So that if there is a large current or wave, it will directly lead to the beach, which can cause abrasion.

At the research location, which is along the north coast of Bengkalis Island, it was found that the abrasion that occurred was very unnatural. This was also confirmed by M. Azmir S.Hut.T., M.Sc. as Plt. Head of the Bengkalis Regency Environmental Service. He stated that the abrasion that occurred along the North Coast of Bengkalis Island could reach 1 kilometre, with a coastline change rate of more than 30 meters a year. This is the result of our research; that is, coastal abrasion occurs at 39 meters a year, and the average rate of change in the coastline is 14 meters a year. If this happens for a long time, it will become a threat of losing the island or changing the Indonesian borderline. In ms, with 40 community groups (1,781 people) an0 community groups (1,781 people) an0 community groups (1,781 people) and groups (1,781 people) and with the maritime abrasion disaster that occurs continuously in the Bengkalis Regency, The government has made several efforts to minimise the disaster. However, the efforts made cannot eliminate the threat of disaster, only minimising the loss and damage. The following are the efforts that the government has made in tackling the abrasion disaster on the north coast of Bengkalis Island:

[11] *Ibid.*

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a. Building Break Water

Breakwater is made from a pile of crushed stone with the size of the stone adjusted to the gentle slope of the building used. With this building, the waves that will hit the beach have broken somewhere a bit far from the beach, so the energy reaching the beach is quite small. Another advantage is the occurrence of sedimentation behind the building, allowing the growth of mangrove plants as natural reinforcement.[12]

b. Conducting a Mangrove Planting Program

The government carries out mangrove rehabilitation in Bengkalis Regency through the Economic Recovery Program (ERP) KLHK, BRGM, BPDAS-HL Indragiri Rokan and the Bengkalis Island Forest Rescue Unit (FRU) in 2020-2021, reaching an area of 1,369 Ha in 5 subs is 7,729,800 stems with 40 community groups (1,781 people) andnting are carried out to reduce the level of abrasion that occurs, filter seawater into the land, and reducing the threat of seawater intrusion.[13]

c. Raising Public Awareness

The rapid development of information technology is very helpful in disaster management. The role of information technology has made a very large contribution because it is connected so that the delivery of information is fast and integrated. Seeing the importance of the role of information technology, the Government created a website for the regional disaster management agency that the entire community of Bengkalis Regency could access. This website was built to provide various disaster information for the people of the Bengkalis Regency. Not only that, but through this website, the people of Bengkalis Regency can also find out more about the Bengkalis Regency Regional Disaster Management Agency and what activities have been, are being and will be carried out by the Bengkalis Regency Regional Disaster Management Agency.[14]

The Bengkalis Regency Government effort have succeeded in reducing the threat of abrasion is the construction of retaining or sheet piles and breakwaters at several points that are too severely affected by abrasion, such as in Bengkalis, Bantan, Bukit Batu, Rupat and North Rupat sub-districts which have coastal areas. In addition, natural rehabilitation efforts have also been successfully carried out by increasing the understanding and participation of people who care about the coastal environment to participate in activities ranging from nurseries, nurseries, and planting at several points of rehabilitation of mangrove areas. The result in the long term for the community is that before the tidal flood or abrasion occurs, the community can anticipate this and make adaptation scenarios. From observations, it was found that the lack of coordination among government institutions or agencies that have an important role in the rehabilitation of coastal areas made the formation of the Bengkalis District Mangove Working Group (DMWG) not run smoothly, so far efforts to improve coordination between sectors have

[12] M. Azmir, *Upaya Rehabilitasi dan Penanganan Abrasi Kabupaten Bengkalis*, (*Presented at* kegiatan KKDN prodi Keamanan Maritim, Universitas Pertahanan RI, 2022).

[13] *Ibid.*

[14] Badan Penanggulangan Bencana Daerah Kabupaten Bengkalis. https://bpbd.bengkaliskab.go.id diakses tanggal 12 Februari 2022.

also not been successful achieved.

CONCLUSION

As the largest archipelagic country globally, besides having a high potential for abundant natural resources, Indonesia is also a country with a very high potential for maritime disasters due to its geographical conditions. One of the maritime disaster is abration or coastline change. This study found that coastal abrasion that occurred on the coast of Bengkalis Island reached 39 meters a year, and the average rate of change of the coastline was 14 meters a year. Local government Bengkalis Regency has made several efforts to minimise the disaster, the first step by building breakwater, carrying out mangrove planting programs, and the last is to increase public awareness. This effort have succeeded in reducing the threat of abrasion is the construction of retaining or sheet piles and breakwaters at several points that are too severely affected by abrasion, such as in Bengkalis, Bantan, Bukit Batu, Rupat and North Rupat sub-districts which have coastal areas.

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