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STUDY ON MITIGATION OF COASTAL VULNERABILITY TO SEA LEVEL RISE AROUND THE EAST COAST OF NORTH SUMATERA

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Abstract

The east coast of North Sumatera is a relatively sloping coastal area, so it will be vulnerable to the threat of phenomena due to sea level rise. The level of vulnerability of the coastal areas of the east coast of North Sumatra is categorized into low, medium, and high. The results of the vulnerability assessment show that the level of vulnerability is dominant in the east coast of North Sumatra. The distribution of coastlines with a low level of coastal vulnerability is 14 km (35.90%), the medium category is 15 km (38.46%), and the high category is 10 km (25.64%). Vulnerability to the phenomenon of sea level rise, needs to be anticipated as early as possible, because the east coast of North Sumatra is very strategic and has abundant Marine and Fishery Resources with fishery potential of 565,200 tons/year. This study aims to determine the level of vulnerability of villages on the East Coast of North Sumatra to sea level rise. The targets of this research include: Identifying vulnerable areas on the east coast of North Sumatra to sea level rise, in terms of physical and socio-economic factors and will provide a map of vulnerability to sea level rise and deliver disaster management models due to vulnerability to sea level rise to the east coast of North Sumatra.

Keywords: Coastal Zone, Mitigation, Area Vulnerability, Sea Level

1) INTRODUCTION

Indonesia is an archipelagic country consisting of 17,508 islands, with a coastline of 81,000 km and a sea area of 62% of its territorial area and the coastal area is the most densely populated area. There are about 140 million people or 60% of the population living in coastal areas [10]. This condition makes many areas in Indonesia strongly influenced by natural phenomena from the sea such as climate change and sea level rise, especially coastal areas because they are directly adjacent to the sea [4], [5]. The coastal area is an environmental area that is abundant in biological and non-biological resources. The intensity of the use of this area is also high, including settlements, aquaculture, agriculture and tourism. The high intensity of use and the lack of awareness in nature conservation will have a negative impact on the physical and social conditions of this area, thus affecting its vulnerability. The impact of population development in the area is the conversion of mangrove forests into settlements, aquaculture, agriculture, marine infrastructure, and fish landing sites, ports, and industries [3].

According to the Forestry Service of North Sumatra Province, the area of mangrove forest on the east coast of North Sumatra has become increasingly critical. This condition is exacerbated by the tendency of rising sea levels caused by factors: climate change, extreme waves, and the impact of global warming, although until now it is not known how much influence global warming has on sea level rise.

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Climate change triggered by global warming can result in the threat of extreme waves, which will later lead to disaster vulnerability in coastal areas, especially for the east coast of North Sumatra which is relatively flat and densely populated. Several actions can be taken for disaster management, including prevention, mitigation, preparedness, and emergency management [18], [19]. The emphasis of pre-disaster actions that can be taken is disaster mitigation measures. Specifically, disaster mitigation in coastal areas is an effort to reduce disaster risk structurally or physically through natural and/or artificial physical development as well as non-structural or non-physical through increasing the ability to face disaster threats in coastal areas and small islands [18],[19].

One important factor that must be analyzed in disaster mitigation efforts is the assessment of the area's vulnerability to disasters that will occur. Vulnerability is aimed at identifying the impact of disasters in the form of casualties and short-term economic losses consisting of the destruction of residential infrastructure, facilities and infrastructure and other buildings, as well as long-term economic losses in the form of disruption of the economy due to trauma or damage to other natural resources. Vulnerability analysis is emphasized on the physical condition of the area and the impact of the socio-economic conditions of the local community [9].

2) LITERATURE REVIEW

Global warming followed by climate change has become a new disaster in the world. Unlike tsunamis, volcanic eruptions, and earthquakes, which have a large but temporary impact, global warming has a slow but definite and permanent impact. Global warming has led to the melting of polar ice caps. Rising sea water temperatures cause sea water to expand so that sea levels rise (Adi & Wahyudi, 2018). One of the impacts of climate change that can be clearly seen is rising sea levels. Rising sea levels cause land area to decrease and coastlines to decline. This causes when high tide occurs, sea water enters settlements and other land uses and disrupts residents' activities [1]. Climate change can cause floods and tidal waves. Floods and tidal waves are events that inundate water on land widely, especially for tidal floods. Trewartha and Horn (1995) state that climate change is climate variations that occur over a period of more than 30 years. Climate change has the potential to cause flooding through increased rainfall, increased flow of Glacier Rivers, and increased sea levels due to melting of polar ice caps or in Indonesian terms known as rob [21].

Handling Sea Level Rise

Tidal floods and other phenomena that occur as a result of rising sea levels mentioned above have a direct or indirect impact on changes in people's welfare. These impacts are generally a loss of income or an increase in the amount of expenditure to adapt, for example the cost of house reconstruction, the cost of buying clean water, and so on [21].

According to Marfai [13], the handling of tidal flooding must be handled seriously, the government must limit activities that can exacerbate tidal flooding. The activities that must be supervised are divided into several parts, namely as follows:

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a. The permitted activities are the construction of green open spaces, polders, retention ponds, pump house stations, embankments, river weirs, drainage channels and other urban infrastructure.

b. Activities that may be carried out, however, are subject to several conditions, namely development activities that do not damage the local drainage system and can adapt to rob problems, as well as the development of non-green open spaces that can increase surface water infiltration into the ground.

c. The activities that are allowed to be limited are settlement development activities taking into account the sustainability of the area and the carrying capacity of the environment.

d. Prohibited activities are activities and or development that threatens damage and or reduces the quality of environmental sanitation.

e. The determination of the boundaries of the tidal plains is carried out by the authorized agency.

However, adaptation efforts to sea level rise can be done in two ways, namely physical and non-physical efforts. Physical efforts can be in the form of natural and artificial protection. Meanwhile, non-physical efforts can be carried out by making disaster-prone maps, public information and counseling, training and disaster mitigation simulations. Physical effort is an effort to protect by building infrastructure to protect against sea level rise, both tidal and tidal flooding. Physical efforts with natural protection methods can be done by planting mangroves, coral reefs, or forests. While physical efforts with natural methods can be done by building current breakers, weirs, sea walls, embankments, construction of protection and houses on stilts [2].

Tidal Flood Rob

Floods can be divided into several groups based on natural factors. The three factors are tides or tidal floods and high rainfall intensity, sending floods. Here are the types of floods.

a. Rob flood comes from a flood whose water comes from sea water. This tidal flood is a flood disaster caused by the tide of sea water, so that the tidal water inundates the land. This tidal flood disaster is also often known as a puddle flood, this tidal flood disaster will often hit or have occurred in areas where the surface is lower than the sea level itself.

b. Delivery flood is a flood that is sent from a higher area to a lower area. The reason is because of the lack of water infiltration in the higher area which causes water to flow to a lower place. The solution is to make a lot of infiltration places.

Losses due to the tides of the sea

Tidal floods will cause damage to infrastructure. The building will experience damage or decrease in quality because it cannot survive the puddle of sea water that enters the mainland. Settlements, roads, rice fields, ponds, industries and roads are affected by tidal flooding. Damage to infrastructure causes huge losses to the community. Community activities are

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disrupted due to damage to infrastructure. Seawater that is too long to pool on the surface of the soil will affect soil fertility and soil properties. Pooling of sea water can increase the salinity of the soil in the inundation area. This will result in a decrease in soil fertility so that it can no longer be used as agricultural cultivation land. Rice fields that experience flooding become unproductive and have an impact on decreasing agricultural productivity. Inundation of sea water also has a negative impact on water resources in areas affected by tidal flooding. As a result of high tide water will enter rivers or water channels that are directly related to the sea [21].

Disaster Risk and Vulnerability

This high intensity rain that flushed all parts of Indonesia can cause flooding if this flood-prone area can be flooded very quickly. The degree of damage caused by the tidal flood in each area may vary depending on the carrying capacity of the area or the capacity of coastal and marine ecosystems. The occurrence of environmental changes caused by tides or tidal flooding, will have a great influence on the community, especially those who live around the coast [13]

Mitigation of Tidal Flood Disaster

a. Structural Mitigation

Disaster mitigation in coastal areas and small islands can be carried out structurally, namely by carrying out technical efforts, both natural and artificial, such as making breakwaters and planting mangroves for tsunami mitigation, building embankments, diversion canals, gates. Flood control water, normalization of rivers and polder systems in flood-prone areas, groynes in eroded coastal areas and construction of disaster-resistant structures [2].

b. Nonstructural Mitigation

Non-structural mitigation is a non-technical effort that involves adjusting and regulating human activities so that they are in line and in accordance with structural mitigation efforts and other efforts. Non-structural mitigation includes, among others, making land use policies, policies on standardization of disaster-resistant buildings, policies on exploration and economic activities of coastal communities, public awareness, as well as counseling and socialization on disaster mitigation.

Flood and Rob Handling

The concept of tidal flood prevention includes:

- Limiting the inflow of tidal waves towards the mainland
- Create a temporary reservoir for water from land that should be wasted downstream
- Pumping this stored water downstream periodically
- Enlarging the capacity of existing rivers and drainage

Physical development carried out include:

- Making embankments separating land and fishpond areas
- Make longstorage/carriage channel parallel to this ROB separator embankment

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- Procurement of pumps and pump housings to make water that is stored in longstorage periodically
- Making river embankments and/or raising river parapets that are still not high enough
- Normalizing the river
- Making drain collectors at several locations that require it and procuring pumps if needed in order to make the water stored in the drain collectors into rivers/seas

In addition to the physical work mentioned above, it is also necessary to normalize rivers that have experienced sedimentation.

Disaster Management as a Climate Change Disaster Management Effort

Disaster management is all activities that cover aspects of planning and disaster management, before, during and after a disaster, known as the disaster management cycle, which aims to prevent loss of life, reduce human suffering, provide information to the public and the authorities regarding disaster management. Risks, and reduce damage to key infrastructure, property and loss of economic resources (Rachmat, 2006).

a. Disaster Risk

Disaster risk is the potential loss caused by a disaster in an area and a certain period of time which can be in the form of death, injury, illness, threatened life, loss of sense of security, displacement, damage or loss of property, and disruption of community activities [5]. Disaster risk is the product of the multiplication of vulnerability, vulnerability.

b. Mitigation in Disaster Management

Mitigation is a series of efforts to reduce disaster risk, both through physical development as well as awareness and capacity building to face disaster threats (Law No. 24 of 2007). The series of disaster mitigation efforts in general is an interrelated cycle of main activities which include analysis of hazards (hazards), disaster mitigation, development of early warning systems, response/emergency response, and rehabilitation and reconstruction [9].

Geographic Information System (GIS) Technology as a Tool in Disaster Mitigation

Geographic Information System is a system that is applied to obtain, store, analyze and manage data related to attributes, which spatially refers to the state of the earth [12]. The development of Geographic Information Systems (GIS) can support development activities and regional and urban planning. Geographic Information System (GIS) provides the right platform for data acquisition and information management in disaster mitigation. Satellite imagery and digital elevation are used as layers in mitigation GIS and combined with different geodata and thematic data [17].

The GIS database is used to convey information at least about the location of the disaster, type of disaster, time of occurrence, analysis of spatial and temporal relationships of disaster events [12]. In this case related to climate change disasters causing the vulnerability of several coastal

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areas to sink, GIS can also identify and analyze the risk of these disasters. In this case, the basic conception of GIS can also be applied to this case.

3) METHODS

This study uses a modified vulnerability model according to Cutter [6], where the factors that affect the level of vulnerability to sea level rise are grouped into two groups of vulnerability variables, namely: physical variables, and socio-economic variables. Then it is analyzed to get the overall vulnerability of the place (regional vulnerability). Waves and tides are indicators of vulnerability in terms of the threat of sea level rise, the higher the sea level rise due to these two factors, and the more vulnerable the submerged area is. Meanwhile, other factors are indicators of vulnerability in terms of assets (existing conditions in the research area).

Data collection

The data needed in this study were collected and selected based on the following considerations: data availability, being able to represent the research variables in question, and being measurable. This data consists of spatial data and statistical data (tabulation), including wave data, tidal data, slope, elevation, and land cover data, population data, data on personnel and health facilities, fisherman data.

Data processing

After the data has been collected, data processing is carried out using Geographic Information System (GIS) technology both as a tool and data processing and map presentation. In addition to using GIS technology to perform data processing, this research also uses tidal data processing based on least squares (least square method). There are two groups of variables used, namely physical and socio-economic groups. In order to be spatially integrated, the two groups of data must be processed and spatialized first.

Vulnerability Analysis

Vulnerability analysis was carried out using the method of overlapping and determining the vulnerability index. Overlapping is carried out after all data has been transformed into spatial data and has criteria and is mapped based on the selected sub-variables to produce a certain sub-variable vulnerability map. The result is a map of the vulnerability of the study area according to the predetermined variables, namely the Physical Vulnerability Map and the Socio-Economic Vulnerability Map. Vulnerability Map of the Research Area, based on the Site Vulnerability Index (SVI). After obtaining the Vulnerability Map of the Research Area, it is classified into five classes of vulnerabilities based on their vulnerability index from the most vulnerable to the least vulnerable.

Sensitivity Analysis

To find out the contribution of each sub variable to vulnerability, a Map Removal Sensitivity Analysis (MRSA) sensitivity analysis was carried out, namely an analysis to measure, evaluate the sensitivity of vulnerability factors. The most sensitive sub-variable showed the highest contribution compared to other sub-variables. MRSA sensitivity analysis was carried out by

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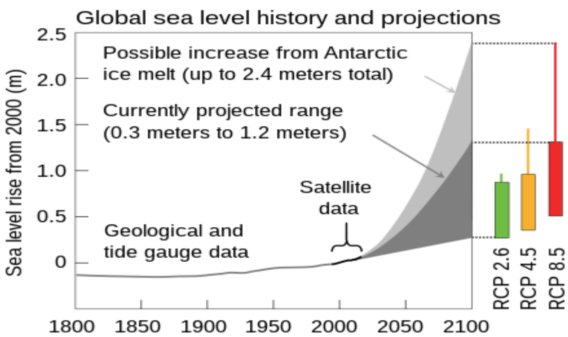
eliminating the sub variables used one by one and calculating the index variation for each reduction, the aim was to evaluate the sensitivity of the vulnerability map of each sub variable. The calculation of the variation in index (S) is carried out for each of the research areas in question.

4) ANALYZE AND RESULT

Global sea level rise

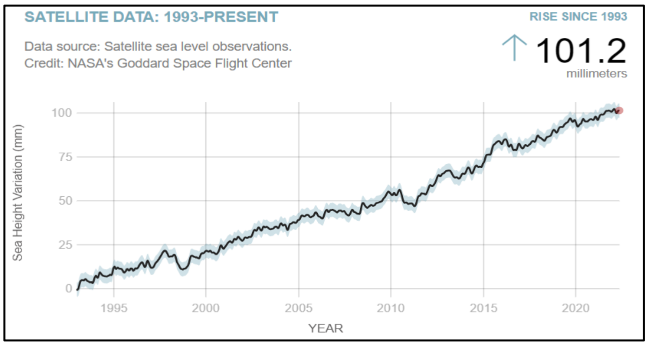
Global sea level rise is caused by two main factors: thermal expansion (seawater warms and expands), and the contribution of ice sheets (for example, from glaciers, land-based, ice sheets, and sea ice) due to increased melting. By 2100, thermal expansion and glacial melting are expected to cause sea levels to rise 0.26 to 0.98 meters (m), based on climate models and considering high and low emission scenarios: RCP2.6 and RCP8.5.(ref) However, the contribution of the ice sheet Greenland and West Antarctica could increase the rate of sea level rise.

Figure 1: Global sea level record and prediction



Sea level rise as an issue of global climate change is currently being monitored. Based on the results of observations made by NASA through satellite observations from 1993 to the present (Year 2022) it is noted that global sea level rise has reached 101.2 mm or 1.02 m.

Figure 2: Current sea level rise



(https://climate.nasa.gov**)**

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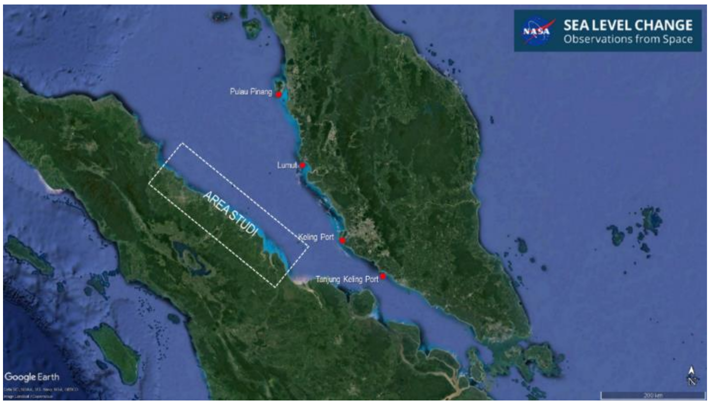
The east coast of North Sumatra faces the Malacca Strait. Judging from the impact of sea level rise for direct recording, the data is very minimal. Therefore, the description of global sea level rise through NASA stations uses data from the closest observation stations, namely Pulau Pinang Station (Malaysia), Lumut Station (Malaysia), Keling Harbor (Malaysia, Tanjung Keling (Malaysia) and Bitung (Indonesia).

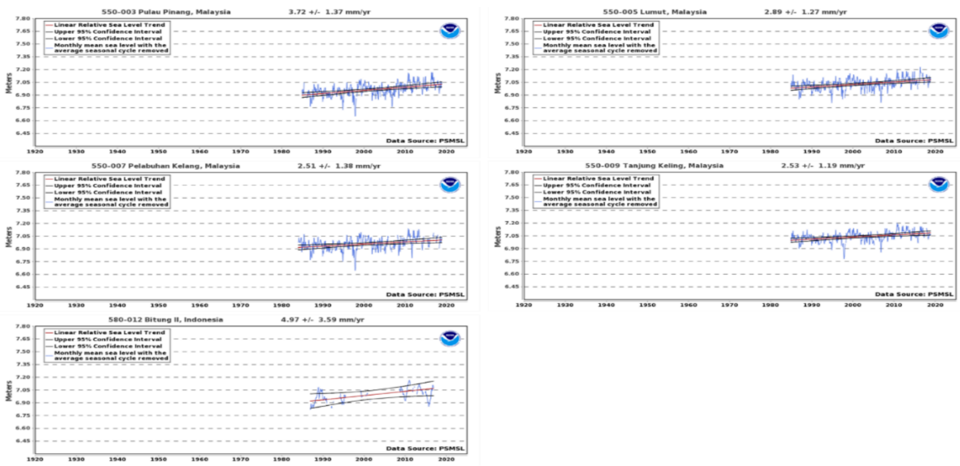
Figure 3: Global sea level rise observation point



(https://tidesandcurrents.noaa.gov)

The results of the recording of each station can illustrate that the sea level rise in the Malacca Strait reaches a maximum of 4.97 mm/year and is recorded at Bitung II station, Indonesia. To get an overview of sea level rise on the east coast of North Sumatra, data obtained from Pulau Pinang Station (Malaysia), Lumut (Malaysia), Kelang Harbor (Malaysia) and Tanjung Kelaing Port (Malaysia) can be used in this case sea level rise. each year a maximum of 3.72 mm/year.

Figure 4: Global Sea Level Rise of each observation point



(https://tidesandcurrents.noaa.gov)

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a. Hydro-oceanography of the east coast of North Sumatra

Hydro-oceanography of the east coast of North Sumatra in identifying the impact of inundation due to high tides and sea level rise. The initial data in this first year study used primary data that had been carried out by the research team and used the initial data of the first year in identifying inundation mitigation. Table 4.1 – Table 4.3 and Figure 4.4 – Figure 4.6 illustrates the sea level due to tides at three observation points, namely Belawan (Medan City), Tanjung Tiram (Coal District) and Panai (South Labuhan Batu).

Table 1: Higher High-Water Level due tide in Belawan

Uraian	Symbol	Calculation	TMA (m)
Higher High-Water Level	HHWL	Z0+(M2+S2+K2+K1+O1+P1)	2.768
Mean High Water Level	MHWL	Z0+(M2+K1+O1)	2.320
Mean Sea Level	MSL	Z0	1.499
Mean Low Water Level	MLWL	Z0-(M2+K1+O1)	0.677
Chart Datum Level	CDL	Z0-(M2+S2+K1+O1)	0.362
Lower Low Water Level	LLWL	Z0-(M2+S2+K2+K1+O1+P1)	0.229
Lowest Astronomical Tide	LAT	Z0-(all constituents)	0.082

Figure 5: Graph of tidal sea level chart in Belawan, Medan City

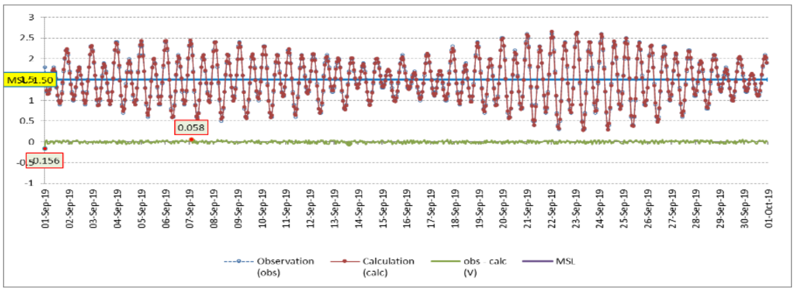

Table 2: Higher High-Water Level due tide in Tanjung Tiram, Batubara Regency

Uraian	Symbol	Calculation	TMA (m)
Higher High-Water Level	HHWL	Z0+(M2+S2+K2+K1+O1+P1)	3.077
Mean High Water Level	MHWL	Z0+(M2+K1+O1)	2.593
Mean Sea Level	MSL	Z0	1.598
Mean Low Water Level	MLWL	Z0-(M2+K1+O1)	0.603
Chart Datum Level	CDL	Z0-(M2+S2+K1+O1)	0.274
Lower Low Water Level	LLWL	Z0-(M2+S2+K2+K1+O1+P1)	0.119
Lowest Astronomical Tide	LAT	Z0-(all constituents)	-0.055

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Figure 6: Tidal sea level chart at Tanjung Tiram beach, Batubara Regency

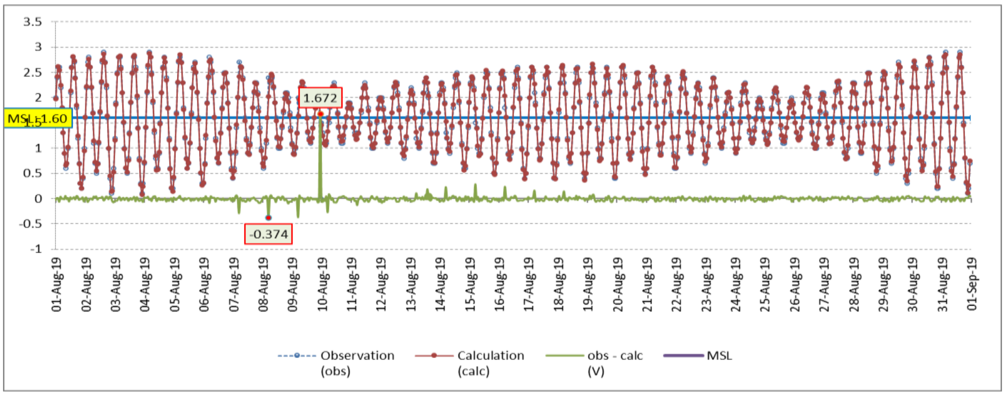
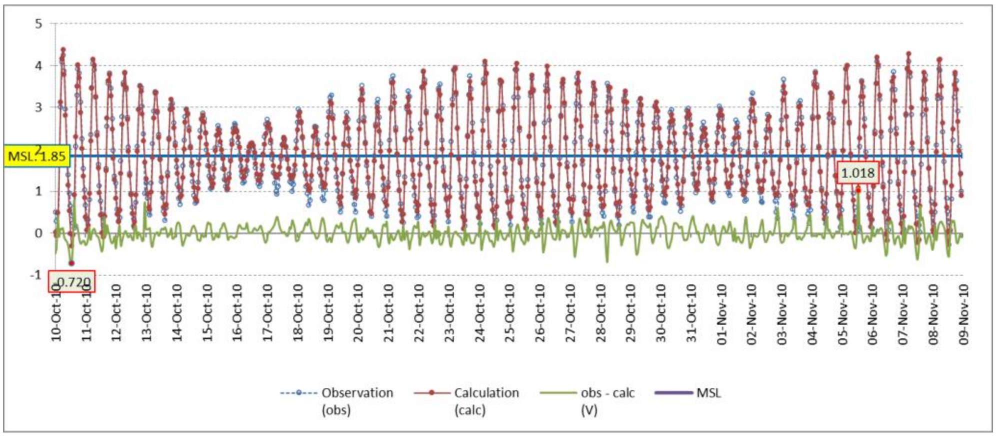


Table 3: Higher High-Water Level due to tides on the coast of South Labuhan Batu Regency

Uraian	Symbol	Calculation	TMA (m)
Higher High-Water Level	HHWL	Z0+(M2+S2+K2+K1+O1+P1)	4.377
Mean High Water Level	MHWL	Z0+(M2+K1+O1)	3.276
Mean Sea Level	MSL	Z0	1.848
Mean Low Water Level	MLWL	Z0-(M2+K1+O1)	0.419
Chart Datum Level	CDL	Z0-(M2+S2+K1+O1)	-0.346
Lower Low Water Level	LLWL	Z0-(M2+S2+K2+K1+O1+P1)	-0.682
Lowest Astronomical Tide	LAT	Z0-(all constituents)	-1.299

Gambar 7: Graph of tidal sea level Panai, South Labuhan Batu Regency



The results of the analysis show that the Higher High-Water Level (HHWL) due to high tides explains that the sea level on the east coast of North Sumatra reaches 2,768 m to 4,377 m. This means that the eastern region of North Sumatra is very vulnerable to inundation due to high tides.

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Figure 8: Graph of high tides on the east coast of North Sumatra

5) CONCLUSION

The east coast of North Sumatra is a coastal area with hydro-oceanographic characteristics of the Malacca Strait. One of its characteristics is the high tidal water level. The results of the analysis carried out using directly observed data obtained the highest sea level in Belawan 2.78 m, Tanjung Tiram, Batubara Regency 3.08 and Panai, Labuhan Batu Selatan Regency 4.38 m. The high tide level is the starting point for the East coast of North Sumatra which has the potential for catastrophic inundation due to high tides or known as ROB flooding.

The impact of the threat of flooding on the east coast of North Sumatra becomes a high risk in the future, when sea level rise due to global warming is getting bigger. This global threat is a concern in modelling coastal flood disaster mitigation. The average sea level rise in the Malacca Strait using 5 observation stations recorded a sea level rise of 3.79 mm/year. Potential inundation due to rising sea levels along the east coast of North Sumatra will be categorized as a flood disaster due to climate change.

From observations on the inundation model due to tidal flooding carried out in Belawan city. The results show an indication of 4 urban villages in Belawan City being areas at risk of flooding because they have a high risk index due to having a density of > 1000 people/Km2. The potential for flood risk is increasing, when social vulnerability, settlement density, physical, socio-economic and environmental also increase.

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