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# COASTAL VULNERABILITY INDEX ANALYSIS IN THE ANYER BEACH SERANG DISTRICT, BANTEN

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***Abstract --*** *Anyer Beach is one of the famous tourist destinations. In addition to tourist destinations, the Anyer beach also has residential and industrial areas. In managing coastal areas, a study of vulnerability is needed due to threats from sea level rise, abrasion/erosion and also high waves that can damage infrastructure and cause losses. The research method is to collect data of hydro-oceanography, coastal vulnerability index calculates (Coastal Vulnerability Index). The coastal vulnerability index is a relative ranking method based on the index scale physical parameters such as geomorphology, shoreline change, elevation, sea level rise, mean tidal, wave height. On the results of the analysis of the criteria of vulnerability based on the parameters of geomorphology in the category of vulnerable with scores of 4, shoreline change in the category of vulnerable with a score of 4, the elevation in the category of extremely vulnerable with scores of 5, sea level rise into the medium category with a score of 3, mean tidal in the category less susceptible with a score of 2, the wave height is very vulnerable in the category with a score of 5. The variable that most influences the vulnerability of Anyer Beach is elevation and wave height.*

***Keywords:*** *Coastal vulnerability index; Anyer beach; Wave Height; Shoreline Change*

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## INTRODUCTION

Anyer Beach is one of the famous tourist destinations. In addition to tourist destinations, the Anyer beach also has residential and industrial areas. In managing coastal areas, a study of vulnerability is needed due to threats from sea level rise, abrasion/erosion and also high waves that can damage infrastructure and cause losses (Nguyen et al., 2016). The potential of the coastal area as one of the regions that have high economic value, because the coast is one of the natural sources for fisheries, the population increases and tourism activities are concentrated in the coastal area (Louinenak et al., 2015). Therefore, the study of the vulnerability of Anyer Beach needs to be done as a basis for the local government in considering the development of the region, especially Anyer Beach.

Studies related to coastal vulnerability have been carried out in other countries such as Australia (Lewis et al. 2018), Spain (Ojeda-Zújaret al., 2008), Greece (Alexandrakis et al., 2009), Turkey (Özyurt & Ergin, 2010), and India (Kumar et al., 2010), as well as several researchers in Indonesia (Rositasari et al., 2011; Kasim, 2011).

Coastal Vulnerability Index (CVI) is a straightforward method that can be used to determine the vulnerability index of coastal areas. This method takes into account vulnerabilities based on seven variables, namely: 1. Geomorphology, 2. Changes in Coastline, 3. Elevation, 4. Increase in Relative Sea Levels, 5. Average Tidal Rides, 6. Wave Height (Gornitz et al., 1997).

In its development, each variable can be determined using geographic information systems, especially for geomorphological and elevation variables, as Louinenak et al. (2015) did, for the calculation of CVI Doreri Beach, Manokwari, and Kasim (2011) in their research. While for tidal riding variables, the average still refers to the SPM 1983 using the Least square or admiralty method. For sea level rise in several studies using data/information from the satellite image of Altimeter TOPEX/POSEIDON map (Louinenak et al., 2015). The shoreline change is also an important variable in determining coastal vulnerability. The method used one of them is using a one-line model as done by Sebayang & Kurniadi (2015) on Tanjung Pasir Beach in Tangerang Regency. In its development, to determine coastline changes can also be done with geographic information systems by utilizing maps from google earth in a certain period.

## MATERIAL AND METHOD

### Coastal Vulnerability Index (CVI)

Research on coastal vulnerability to sea level rise have been carried using several different methods. Gornitz (1997) perform database creation and analysis of coastal vulnerability using methods Coastal Vulnerability Index (CVI) with seven variable geology and physical processes in the coastal areas of west America. Pendleton et al., (2004) analyzed CVI uses six variables on a local scale in the area of the Cape Hatteras National Seashore (CAHA). CVI approach provides benefits for policymakers and decision-makers in determining appropriate management program in a coastal region that has the highest level of vulnerability to the impacts of sea level rise.

The calculation of the value of the vulnerability index score is based on the originality of the concept of vulnerability index values in the CVI method, which is at the root of the multiplication of each variable weight value divided by the number of variables as in Equ (1).

$$CVI = \sqrt{\frac{axbxcxdxexf}{6}} \quad (1)$$

where CVI is a value (score) Coastal Vulnerability Index. a, b, c, d, e, and f is the weighting variables consecutively geomorphology, shoreline change, the slope of the beach, the mean wave height, mean tidal range, and rate of change of sea level (Kasim, 2012).

Determining Scores for each of the variables and calculations Coastal Vulnerability Index (CVI) that is used referring USGS research Gornitz et al., (1997) and Pendleton et al., (2005) on show in Table 1.

Table 1. Determination of Scores for CVI

| No | Variable | Not Vulnerable | Less Vulnerable | Medium Vulnerability | Vulnerable | Very Vulnerable |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 |
| 1 | Geomorphology (a) | High cliffs | notched beach, medium studded, | Low cliffs, alluvial plains | Beach building, beaches, estuaries, lagoons | barrier beach, sandy beaches, muddy, mangrove, delta |
| 2 | Coastline Changes (m/year) | >20 | 1,0 – 2,0 | +1 – (-1) | -1 – (-2) | < -2,0 |
| | (b) | Accretion | Accretion | Stabil | Abrasion | Abrasion |
| 3 | Elevation (m) (c) | >30 | 20,1-30,0 | 10,1-20,0 | 5,1-10,1 | 0,0-5,0 |
| 4 | Relative Sea Level Increase (mm/year) (d) | <1,8 | 1,8-2,5 | 2,5-3,0 | 3,0-3,4 | >3,4 |
| 5 | Average Tidal Rides (m) (e) | <1,0 | 1,0-2,0 | 2,0-4,0 | 4,0-6,0 | >6,0 |
| 6 | Wave Height (m) (f) | <0,55 | 0,55-0,85 | 0,85-1,05 | 1,05-1,25 | >1,25 |

### Parameter Coastal Vulnerability

The vulnerability of coastal areas is an increase in the process of destruction in coastal areas caused by various factors such as human activities and natural elements. Based on research Gornitz (1997) and Pendleton et al. (2004) are the parameters that affect coastal vulnerability variable geology (geomorphology, shoreline change, and elevation) and physical process variables (sea level rise, riding tidal and wave height). In this study, the coastal parameter used is based upon the parameters proposed by Gornitz (1997) and Pendleton et al. (2005).

1. Geomorphology

Geomorphology is defined as the study of the shape of the surface of the earth and the aspects that influence (Noor, 2010). Geomorphology studies the shape of the landscape or landform. Associated with the impact of rising sea levels, types of landforms need to know to identify the endurance or resistance of a section of the beach erosion and accretion due to sea level rise (Pendleton et al., (2005).

2. Coastline Changes

The coastline can be changed by various factors, both natural and human factors.

Changes in the shoreline are mostly done by human activities such as land clearing, exploitation of minerals in the coastal plains that could alter the balance of the shoreline through an excessive supply of sediment load (Tarigan, 2007).

3. Elevation

Elevation coastal area refers to the size of height in certain areas that are above the average sea level. The study of coastal elevation is significant to learn in depth to identify and estimate the land area that is threatened by the impact of sea level rise in the future (Kumar et al., 2010).

4. Sea Level Rise

Sea level rise is a danger that many studied in climate change issues. This danger is the result of two main variables, namely thermal expansion or contraction in the sea and the effects of melting a mass of water contained or trapped in icebergs and snow cover around the poles (BAPPENAS, 2010). Sea level rise globally, of course, will affect coastal areas both in Indonesia and in the world. The island nations like Indonesia will much feel the impact of sea level rise.

5. Tidal

Tides (abbreviated to tide) is the rise and fall of sea level periodically generated by the force of attraction of celestial bodies, especially the moon and sun on the water mass of the earth. Knowledge of the tidal conditions in Indonesia is significant for a variety of activities related to the sea and beaches such as shipping, coastal resource management or national defense. To determine the condition of the tide in a body of water that can be predicted with reasonable accuracy the measurement data required at least 15 days or 30 days for 19 years. The tidal waters of the coast is a tide that extends from the open sea/off (Pariwono, 1989).

6. Wave

Wave is one of the phenomena that are in the sea which can be seen directly. According to Pond and Pickard (1983), the wave is a phenomenon of rising and fall of sea level, where the energy moves from a region of the formation of the wave towards the shore. One factor that could generate waves is the wind. Philip (1957) in Holthuijsen (2007) states that when the surface of flat water, the presence of wind will cause turbulence on the surface of the water pressure. Factors influencing wave generation is the wind speed, the wind blew the length (duration) in one direction and fetched (distance unimpeded taken by the wind for blowing in one direction).

**Research Location**

Serang Anyer beach is located at latitude -06º03 ' Latitude and Longitude 105º56 ' BT and is situated in the district of Serang District Anyer Banten province is 38 km from the center of the city of Serang, the location of the study is shown in Fig. 1.


Figure 1. Location Map Anyer

The methodology for obtaining the Coastal Vulnerability Index (CVI) value for a coastal area can be seen in Fig. 2.

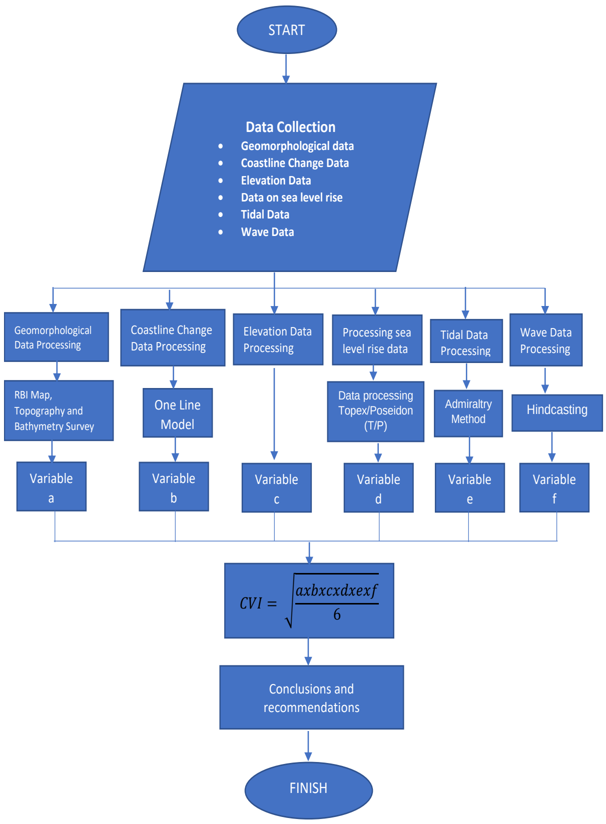


Figure 2. CVI Study Flow Chart

**Data Collection**

Data needed in this research include primary data and secondary data. Primary data is data obtained from the field or research sites. While secondary information is data that can be directly collected from the government agencies concerned. The secondary data acquisition method in this final task is done by literature method is a method used to obtain the data by collecting, identifying and processing the data.

The secondary data acquisition method in this final task is done by literature method is a method used to obtain the data by collecting, identifying and processing the data. Data processing is used to obtain the value of each parameter coastal vulnerability to sea level rise. The parameters are then given the value for later united into coastal vulnerability index using the equation Coastal Vulnerability Index (CVI) of Gornitz (1997) and Pendleton et al. (2004).

**Data Processing**

Data processing is used to obtain the value of each parameter coastal vulnerability to sea level rise. The parameters are then given the value for later united into coastal vulnerability index using the equation Coastal Vulnerability Index (CVI) of Gornitz (1997) and Pendleton et al. (2004).

1. Data Geomorphology

Data necessary to identify the class of geomorphology can be obtained from Map Rupa Bumi Indonesia (RBI) Geospatial Information Agency (BIG). RBI types of data used is the data used land (land use) with a scale of 1:25000. These maps are then scanned (scan) to obtain a digital map to *.jpg format. Before processing, the map is corrected in advance using Global Mapper 9. Correction program is intended that the map has the exact coordinates. The corrected map is then digitized to obtain land use data in the form of fresh water, swamp, sand, scrub/shrub, swamp, grass/clearing, settlement, ponds, fields, gardens, and irrigated fields.

2. Coastline Changes

Changes in the shoreline can be obtained by using one line model is a simple model (Sebayang & Kurniadi, 2015), also known as line method (Dalrino & Sofyan, 2015). This method is used in a one-line model to describe the movement of a single contour of the shoreline wave responses were converted from the wind speed. The existence of a protective structure such as mangroves and revetment is not considered in this model. The parameters are then given the value for later united into coastal vulnerability index using the equation Coastal Vulnerability Index (CVI) of Gornitz (1997) and Pendleton et al. (2005).

3. Elevation Data

Digital Elevation Model (DEM) is a model to describe the shape of the earth's surface topography that can be visualized in 3D. Elevation data used in this research is data Global Digital Elevation Model (GDEM) derived from ASTER satellite. Data coverage GDEM almost the entire surface of the earth and has a pretty good spatial resolution of 30 meters with an accuracy of 20 meters (ASTER GDEM, 2009). GDEM data is then processed by software Global Mapper 9 to determine the area of interest. Then, doing data processing using ArcGIS 9.3 software. Processing GDEM to generate parameter elevation, where the elevation values are then classified according to the vulnerability index as determined by Gornitz (1991).

4. Data of Sea Level Rise

Satellite altimetry Topex/Poseidon (T/P) and Jason 1-Jason 2 satellite whose mission is to study the dynamics of the global ocean and the phenomenon of the tide. The resulting data were formatted Network Common Data Form (netCDF) using a grid system measuring $0,25^{o}x0,25^{o}$ or less measuring 27,8 x 27,8 km with worldwide coverage.

Data processing trend of sea level rise begins to extract the data format netCDF using Ocean Data View (ODV) into data in text format on the desired area. Data in text format are then interpolated by software interpolation surfer 9. This data is done to fill the data gaps. Interpolating the spatial size of the grid in the cell that is adapted to the size of 1km x 1km. Furthermore, the interpolation is truncated (Cropping) according to the study area and in export data into formatted *.xyz using Global Mapper 9. The final process to include the value of the cell closest to the shoreline then be overlaid with cell shoreline and the digitization process by using Surfer 9.

5. Data Tidal

Analysis of tidal conducted to obtain the components of the preparation of ups and downs that are then used to predict the tidal water level fluctuations, which are then used to determine the elevation - significant elevation (benchmark) for the measurement of altitude (elevation) on land and water depth. Calculation of Tidal Using methods Admiralty.

Forecasting Waves with using Admiralty method has several advantages compared to methods Doodson Rooster. If using Admiralty method is as follows.

In determining the type of tidal using admiralty, it has first prescribed parameters tidal among others S0, M2, S2, N2, K2, K1, O1, P1, M4, MS4. By using the parameters of the calculation results, it can be determined the value of F (Formzahl) where F is the value that will be used to determine the type of ups and downs that have occurred.

$$F = \frac{K1+O1}{M2+S2} \quad (2)$$

where:
0<F<0,25 : Tidal Semi Pure Diural
0.25<F<1,5 : Tidal Mixed Semi Diural
1,5<F<3 : Tidal Mixed Diural
F < 3,0 : Tidal Diural Pure

While the water level determination is done by using the following formula:

HHWL= S0 + 1.2 (M2 +S2 + N2 + K1 + O1) (3)
LLWL = S0 – 1.2 (M2 + S2 + N2 + K1 + O1) (4)

6. Data Wave

Wave data obtained by performing Hindcasting. Hindcasting is one way of wave forecasting by processing wind data based on conditions/circumstances meteorology in the past (CERC, 1984). Wave model simulation was carried out at the coastal area as the basis for the assessment of coastal vulnerability (Rojali & Nandiasa, 2016).

The object wave which will forecast the ocean waves in a body of water and raised by the wind, which propagates towards the shore and burst in tandem with the more shallow waters to get to the beach. Of forecasting, waves will generate data on wave height and period of each wind data. The data required in the form of wave forecasting wind data on average hourly converted into wind stress factor (Ua), effective fetch length and duration of the wind which will blow in the plot as a graphic wave forecasting.

## RESULT AND DISCUSSION

### Geomorphology

Anyer beach is located at the sea mouth Sunda Banten is located at latitude 6º 03' latitude and 105º 56' east longitude. The beach has a long coastline and wide, facing the Sunda Strait. Judging from the morphology Anyer beach is a region of undulating and along the coast, there are many coral reefs. Vegetation land at Anyer the beach is generally in the form of shrubs and palm trees as depicted in Fig. 3.

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Figure 3. It looks land Anyer beach are coconut trees and shrubs

Alongside Anyer beach is occupied by coral limestone; a coral colony with little pieces of shells of mollusks marine origin, yellowish white to gray, hard, hollow with a very rough surface. Along the beach side very much occupied by rocks were very rude. At the time of low tide at Anyer Beach, then gravel, gravel, sand, and rocks, as shown in Fig. 4, shards dominant coral and Mollusca shells origin of the high seas will be seen along the coast.

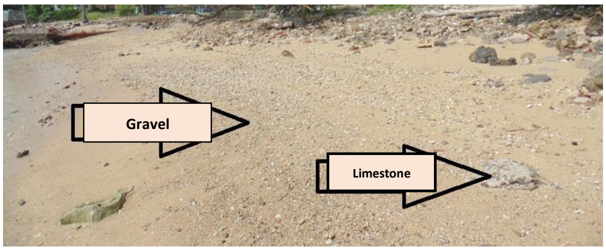

Figure 4. Appears gravel, limestone on the beachside Anyer

Based on observations and surveys directly to the study site, the vulnerability index of parameter geomorphology along the coast of Anyer that serve as the study site including vulnerable category with a score of 4.

Category vulnerable expanses of alluvial plains (irrigated rice, rainfed lowland, upland/fields, and orchards/plantations) wider. In addition to alluvial plains, the coast of Anyer also occupied by residential buildings coast residents, lodging and recreation areas that are too close to the beach.

### Coastline Changes

Changes in Anyer beach coastline belongs to a class of vulnerability Vulnerable with a score of 4, where the rate of average change in Anyer beach coastline of -1.212 m/year. Variations of the longest coastlines are at coordinates 6°6'34,62 latitude and 105°52'47,88 BT amounting to -2.473 m/year, whereas the change of the shortest coast, is at coordinates 6°6'14,28 LS and 105°52'52.27 BT amounting to -0.619 m/year. Changes in Anyer beach coastline belongs to a class of vulnerability, as shown in Fig. 5. Red line shows the coastline in 2000, while the green line is the coastline in 2014.

Figure 5. Changes in Anyer Beach Coastline In the Year 2000-2014

Reduction of the beach area (abrasion) is caused by current and wave. The main factors that determine the abrasion are mainly caused by the dominant wave of the tidal flow. Abrasion will take place rapidly in coastal areas facing directly with the direction of the currents and waves, compared with parallel or unidirectional beach. Fig. 6 shown grids for Landsat processing in Anyer beach.

Figure 6. Processing of Landsat in Anyer Beach

### Elevation

Elevation can affect the extent of seawater inundation caused by sea level rise. Elevation of the beach is one of the parameters to determine the potential for flooding. In the event of a tidal wave morphology of the beach with ramps can cause the water will go into the land relatively far that the overflowing water is very spacious. In the image shows that the coast of Anyer that serve as the location of vulnerability analysis belong to a class susceptible and very vulnerable based on the parameters of elevation.

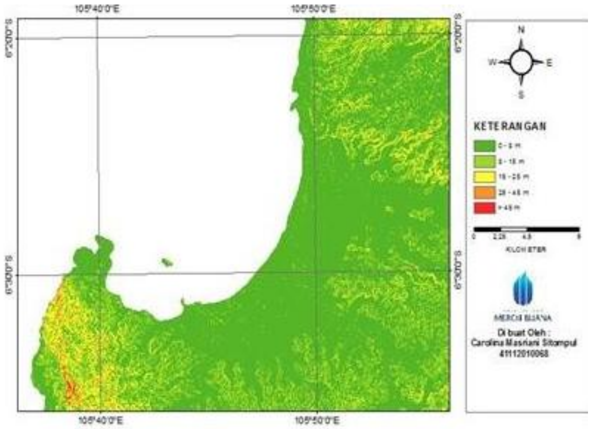

Figure 7. Crop elevation Anyer

Anyer coast is a region with elevations ranging from 0 to 8 meters as shown in Fig. 7. Therefore coast of Anyer including categories that tend to be particularly vulnerable to a score of 5 to rising sea levels.

### Sea Level Rise

Fig. 8 is a picture of relative sea level rise (mm/year) in the waters around the world the results of satellite data processing Topex/Poseidon (T/P), Jason-1 and Jason 2.

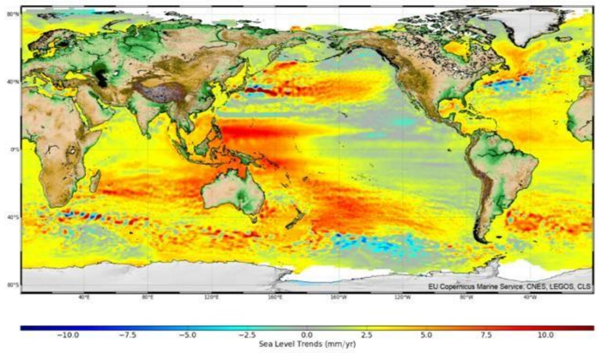

Figure 8. waters of the sea level rise

Based on the data in the image above sea level rise in Anyer Beach Serang, Banten ranged between 2,5 mm/year. According to Gornitz (1997) relative sea level rise 2,5 mm/yr to 3,0 mm/year, including into the medium category with a score of 3. The relative sea level rise indicates how the effects of sea level rise to a part of the coastline.

### Mean Tidal

The average value of riding the ups and downs of significant importance in coastal vulnerability, which contribute to the stable tidal flooding coastal areas. Tidal movements cause sea levels are always changing every moment. Vulnerability index value based on parameters riding the tides on Anyer Beach Serang, Banten, including less susceptible to class or obtain a score of 2, where the average riding the ups and downs of 1,367 m as shown in Fig. 9.

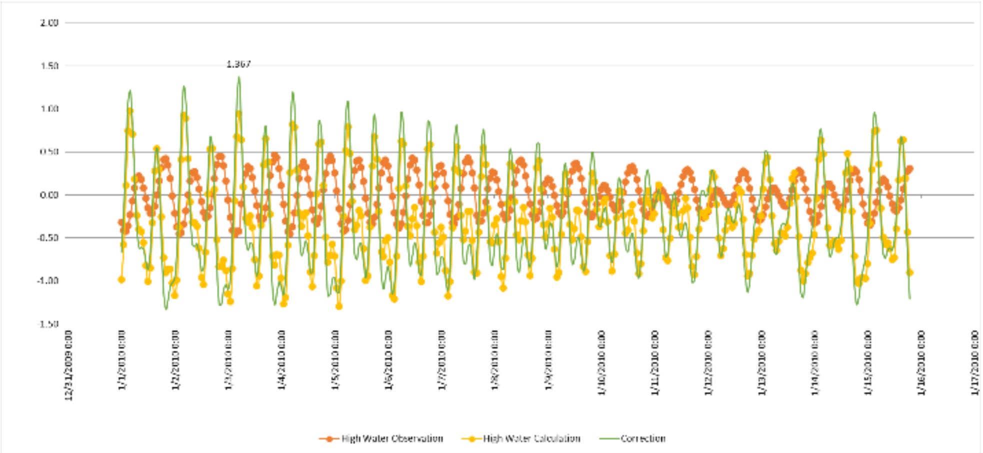


Figure 9. Graph Tidal Anyer Beach

**Wave Height**

Waves are the main parameters in the process of erosion or sedimentation. The amount depends on the energy that knocked down by the waves before the rupture. High marks waves in coastal vulnerability may affect shoreline change and geomorphological conditions of the area. Besides, the wave height of the danger associated with inundation and sediment the beach (Pendleton et al.,2005).

Table 2. Maximum wave data in Anyer beach of the Year 2010 s / d 2014.

| YEAR | JAN | FEB | MAR | APR | MEI | JUN | JUL | AUG | SEP | OCT | NOV | DEC | Max Wave |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2010 | 1.4 | 1.2 | 0.8 | 1 | 1.1 | 0.8 | 1.1 | 1 | 1 | 0.9 | 1.4 | 1.4 | 1.40 |
| 2011 | 1.5 | 1.2 | 1.1 | 1.3 | 1 | 1 | 0.8 | 1 | 0.9 | 1 | 0.8 | 0.9 | 1.50 |
| 2012 | 1.2 | 1.7 | 1.2 | 1.5 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.9 | 0.8 | 1 | 1.70 |
| 2013 | 1 | 1.5 | 1.6 | 1.8 | 1.1 | 1.1 | 1.3 | 1.1 | 0.9 | 1 | 1 | 1.1 | 1.80 |
| 2014 | 1 | 1.1 | 1.1 | 0.7 | 1.1 | 1.1 | 1 | 1 | 1.3 | 0.8 | 0.9 | 0.9 | 1.30 |

the above data obtained maximum wave is the direction of 180° (South) 1,8 meters occurred in April 2013, as shown in Table 2 and Fig. 10.

Data from the maximum wave height at Anyer beach included in the class is very vulnerable with a score of 5.

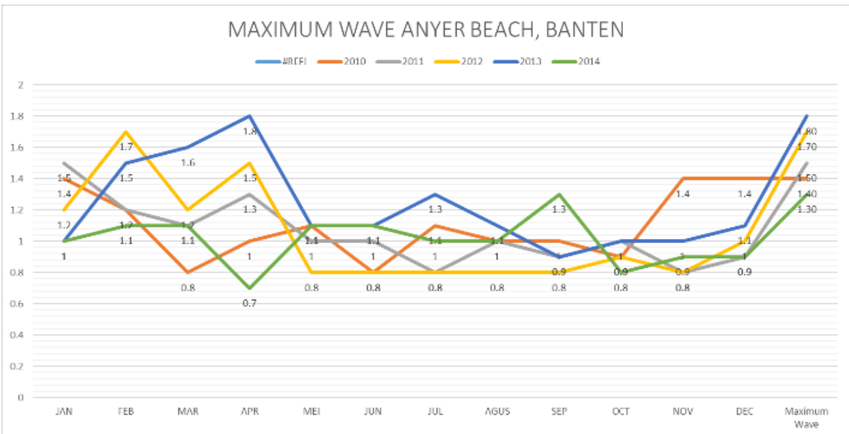


Figure 10. Graph Maximum wave at Anyer Beach Serang, Banten

**The vulnerability of Coastal Anyer Serang Banten**

Coastal vulnerability index can also be used as an indicator of vulnerability. The level of vulnerability is an important thing to know because it could affect the occurrence of disasters. Disaster will occur in vulnerable conditions. In the analysis results shown the vulnerability based on parameters Geomorphology, changes Coastline, Elevation/Tilt, Sea Level Rise, Stables average Tidal, Wave Height. Class divisions or the vulnerability is based on research conducted by Gornitz et al., (1997); Pendleton et al., (2005 ). Results of determination of the parameters in the Coastal Vulnerability Index Anyer Beach presented in Table 3, for each parameter. It shows parameters with very vulnerability criteria are elevation and wave height.

Table 3. Results of determination of the parameters in the Coastal Vulnerability Index Anyer Beach

| No. | Variables | Criteria | Score |
|---|---|---|---|
| 1 | Geomorphology (a) | Vulnerability | 4 |
| 2 | Coastline Changes (m/year) (b) | Vulnerability | 4 |
| 3 | Elevation (m) (c) | Very Vulnerability | 5 |
| 4 | Relative Sea Level Increase (mm/year) (d) | Medium Vulnerability | 3 |
| 5 | Average Tidal Rides (m) (e) | Less Vulnerable | 2 |
| 6 | Wave Height (m) (f) | Very Vulnerability | 5 |

The calculation of the value of the vulnerability index score is based on the originality of the concept of vulnerability index value calculation in the CVI method, which is the root of multiplying each weight value for the number of variables in the variable as follows:

$$CVI = \sqrt{\frac{axbxcxdxexf}{6}} \qquad (5)$$

Where :

a : Geomorphology

b : Changes in Coastline

c : Elevation / Tilt

d : Sea Level Rise

e : Stables Tidal average

f : High Waves

Class divisions or the vulnerability is based on research conducted by Gornitz and white (1990) in which the CVI (Coastal Vulnerability Index) > 33,0 included in the index of vulnerability is very vulnerable. Based on the processing and the analysis of CVI (Coastal Vulnerability Index) on the coast of Anyer of 20 are coastal vulnerability index values included in the vulnerable category based on the parameters of coastal vulnerability. Parameter geomorphology, shoreline change, elevation, sea level rise, riding tidal and wave height have a different score. Based on the results of the analysis showed that the parameters were very influential on a vulnerability in is elevation and wave height. In coastal vulnerability may affect shoreline change and geomorphological conditions in the area of Anyer Beach. Elevation between 0 to 5 meters and an average height of the sea level has risks that are particularly vulnerable to sea level rise. While the beach is very vulnerable is the beach with an elevation of more than 30 meters (Gornitz,1997).

## CONCLUSION

On the results of the analysis of the vulnerability criteria with geomorphological parameters included in the vulnerable category with a score of 4. The change in the category of coastline vulnerable to a score of 4. The elevation in the category of extremely vulnerable with scores of 5. Level rise seawater into the medium category with a score of 3. Riding the ups and downs in the category less susceptible, a score of 2. The wave height is very vulnerable in the category with a score of 5.

Based on the analysis of coastal vulnerability index for the reduction of abrasion note that the level of vulnerability in Anyer Beach categorized into vulnerable, with coastal vulnerability index of 20 is based on the physical parameters of coastal vulnerability. With coastal vulnerability index by 20 in Anyer beach for the reduction of abrasion can perform additional green line, limiting the number of buildings is too close to the coast of Anyer beach.

Parameters coastal vulnerability affecting vulnerability in Anyer beach is the most influential parameter elevation and wave height. Based on the results of the analysis in this study, the local government needs to pay attention to the height of the development location of the Anyer beach area, which elevation is safe from the threat of high waves.

## ACKNOWLEDGMENT

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