Risk And Mitigation Analysis of Tidal Flooding Disaster in Medan Belawan Sub-Distric, Medan City

Ngakan Putu Purnaditya¹, Elfina Rozita², Dwinanti Rika Marthanthy³

¹Civil Engineering Department, Engineering Faculty, Universitas Sultan Ageng Tirtayasa
²National Board for Disaster Management (BNPB)
³Civil Engineering Department, Engineering Faculty, Universitas Indonesia

Email: purnaditya@untirta.ac.id

ABSTRACT

Medan Belawan is one of sub-district in Medan City North Sumatera which is the coastal area. The area is particularly vulnerable to coastal hazard that of all people living near coastal line. The most influential of disaster is tidal flood. Tidal flood almost occurs every year with the total inundation area is 26.25 Km², for example from 2010 until 2017 recorded that the tidal flood inundated around 0.5 m to 2 m in average. There were 98 113 people and 3000-4000 houses, schools, public health facility (puskesmas), highway, fishponds, and international harbor affected. The disaster is not only threatening the community life but also disturbance their sustainable livelihood especially people with low socio-economic condition. This paper provides risk index analysis of the flood and propose the disaster risk reduction measures to reduce the impact of risk. Regarding the analysis, Medan Belawan Sub-district was categorized into high-risk area to the tidal flood, so that its need disaster risk reduction measures. Disaster risk reduction aims to protect affected communities, reduce damage and losses when the disaster happens and make sure sustainable livelihood. Mitigation is one of disaster risk reduction effort that can be divided into structural and non-structural. In structural measure, one of solution is building the impervious seawall which is designed based on increasing of sea level rise due to some factors such as tidal, wave, wind, climate change, land subsidence, and flood which is caused by rainfall with the high intensity. Overall basic design of seawall can build in Medan Belawan Coastal Area is around 4.95 m for its height and will be in residential area that is directly bounded by the sea. In the other hand non-structural approach can be implemented if people permanently live in that area. They can do some adaptation activities to reduce negative impacts and if possible, for taking any advantages of its positive impacts. People can modify their settlements, public facilities and livelihood. Some area in Medan Belawan sub-district also have mangrove forest, there is around 747 hectares. Combination both of approaches aim to reduce the disaster risk.

Keywords: Disaster Risk Index, Tidal Flooding, Mitigation, Seawall, Adaptation, Reforestation
1. Background

Tidal flooding is one of natural water related disaster which occurs in coastal area. Tidal flooding is the flood which enhanced by tide activity and cause damage of building and many public facilities. Furthermore, this disaster can inhibit community and industry activities [1]. Technically, tidal flooding will occur in coastal area which has land elevation lower than or equal with maximum sea level water. One of place in Indonesia which often occur tidal flooding is Medan Belawan Sub-district, Medan City North Sumatera.

Because of the primary trigger of tidal flooding is tide activity, so the effect of rainfall to that flood is not significantly except for estuary. Medan Belawan Sub-district is a flanked area between Belawan River estuary and Deli River estuary so in this case, the authors think there is an effect from raising of estuary’s water level due to rainfall.

Taking from many sources, especially online newsletter like as Antara News, Metro TV News, Antara Sumut News, etc there are the record of tidal flooding occurrence in Medan Belawan Sub-district from 2010 until 2017. In that timeline, the most severe events occurred in 2016 with 1 m until 2 m water depth. If we take the average from year to year 0,3 m until 1 m water depth is possible. Because of this condition (tidal flooding), 3000 until 4000 houses, schools, public health facility (puskesmas), highway, fishponds, and international harbor have been sunken.

There are some research related to tidal flood and physical characteristic of wave in Medan Belawan coastal area. It starts from Frederick et al., (2016) who made map disaster for tidal flooding in Medan Belawan Sub-district. The method which used were comparing between land elevation with maximum sea level water. Based on result of that research, we can say that all of villages in Medan Belawan Sub-district are vulnerable from tidal flooding. In other hand, Putri & Tarigan, n.d. have been analyzed the forecast of wave in Medan Belawan statistically based on wind velocity data. They used Jonswap method to analyze it. Some of data from them will be cited by this research.

The aim of this research to analyze level of risk for tidal flooding in Medan Belawan and analyze of structural-nonstructural mitigation as disaster risk reduction measures. There are some limitations in this research such as level of risk is analyzed for sub-district level only, all geotechnical data is assumed, and morphology of estuary is assumed. Despite of that limitation, hopefully, this research can give enlightenment about disaster risk assessment and disaster risk reduction measures for tidal flooding in Medan Belawan sub-district.

2. Theoretical Considerations

Conceptual Framework

Conceptual framework, in this case as tidal flooding is made as foundation thinking for integrating primary trigger, level of risk and mitigation. For tidal flooding case, we can make conceptual framework (adopted from Andy Prasetyo Utomo) as Figure 1.

Disaster Risk Index

Disaster Risk is a function from hazard \(H\), vulnerability \(V\), and capacity \(C\) or in mathematical statement, we can write as [3]

\[
Risk = f(H, V, C).
\]

To figure out the risk index, we can calculate based on index of component of function (1) in this empirical equation [3]

\[
Risk = H \frac{V}{C}.
\]

To analyze each part of equation (2), the authors use national regulation, Peraturan Kepala BNPB No. 2 Tahun 2012 about risk assessment, with secondary data which most of them according to Medan City in Figures, 2016.

Hazard Index

Hazard index estimated by historical occurrence. For tidal flooding, there are two important components that become primary measurement. That components are probability of hazard and exposure recorded data.
Measurement of vulnerability index is more complicated than hazard index because in this analysis distinguished to four sub-indices as follows:
1. Demography vulnerability
2. Economic vulnerability
3. Physical vulnerability
4. Environmental vulnerability

As explained before, all of index calculated by Perka BNPB, No. 2 Tahun 2012 procedures. Therefore, we can compile vulnerability index scoring parameter in Table 2. In Medan Belawan sub district lived around 98.11 thousand people who most of them as fisher who manage fishpond along coastal area. To determined total score of vulnerability index, Perka BNPB, No. 2 Tahun 2012 has been inform that vulnerability index can be calculated as

$$V = 0.4V_1 + 0.1V_2 + 0.25V_3 + 0.25V_4.$$  (3)

In this equation $V_i$ until $V_4$ parameter denote demography vulnerability, environmental vulnerability, physical vulnerability, and economical vulnerability.

**Capacity Index**

Capacity terms mean as the resilient level of sub-district and communities to take overcoming disaster. Usually, to get and calculated capacity index, interviewing communities and other stakeholders are very necessary. Table 3 shows basic parameters for calculate capacity index. In this case, authors use the middle score for capacity index because of unavailability information about interview result.

<table>
<thead>
<tr>
<th>Type of Index</th>
<th>Sub-Index</th>
<th>Parameter</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hazard Index</td>
<td>Hazard based on depth of pond</td>
<td>Depth of pond &lt; 0.76 m</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Depth of pond between 0.76 m - 1.5 m</td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Depth of pond &gt; 1.5 m</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>Hazard based on duration of pond</td>
<td>Duration of pond &lt; 1 day</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Duration of pond 1 to 2 days</td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Duration of pond &gt; 2 days</td>
<td>High</td>
</tr>
</tbody>
</table>

**Tidal Forecasting**

Based on the trigger, tidal wave is raised by interaction force between earth, moon, and...
sun. Therefore, tidal wave has repetitive characteristics, even because of this characteristics, tidal wave can be forecasted by Fourier Series [4]. The aim of tidal forecasting is to determine values of Mean Sea Level (MSL), both of average on Low Water Level (LWL) and Maximum Water Level (MWL).

In this research, to determine MSL, MLWL an MHWL, authors use admiralty method. According to previous explanation, tidal wave has repetitive characteristics, therefore the analysis can use the monthly tides record data. In this case, the most important data are daily and hourly record data.

**Wave Forecasting**

Wave has a significant role to tidal flooding because, wave is most trigger of wave set-up. Wave set-up is water level raising because of wave. In fact, measurement of wave level periodically is very difficult work because we have to set-up the equipment in deep sea, and it has many risks especially damage on equipment. For fix this problem, usually we can forecast the wave in deep sea from wind velocity data that measured in land (3 m above zero point of water level). We can use the method written on Coastal Engineering Manual. The steps of wave forecasting based on wind data are follows:

![Table 2. Vulnerability Index Scoring Parameter](Adopted from Perka BNPB, No. 2 Tahun 2012, with adjustment)
1. Find the wind velocity in 10 m above zero point of water level using equation [5]

\[ U_{10} = U_z \left(\frac{10}{z}\right)^{1/7}. \]  

(4)

\( U_z \) is inland wind velocity (usually measured on 3 m above zero point of water level). Therefore, \( z \) is elevation of measurement.

2. Convert the result of step 1 as wind velocity in deep sea using \( R_L \) and \( R_T \) factor using equation [5]

\[ U = U_{10} R_L R_T. \]  

(5)

\( R_L \) is conversion factor for location of measurement and then \( R_T \) is conversion of difference temperature between in land and in deep sea.

3. Calculate effective fetch, \( F_{eff} \). Fetch is yaitu distance of wave from the land where wind speed and direction are constant. Fetch measured in every 6° until 42° where 0° is wind direction [6], [7]. Use equation

\[ F_{eff} = \frac{\sum X_i \cos \alpha}{\sum \cos \alpha} \]  

(6)

to calculate the value of \( F_{eff} \). \( X_i \) is the distance between point of measurement in shoreline to closest land area in every 6° until 42°.

4. Calculate wind stress factor \( U_A \) for every wind velocity using equation [5]

\[ U_A = 0.71 U^{1.23}. \]  

(7)

5. Estimate wave height (\( H \)) and wave period (\( T \)) in deep sea using Coastal Engineering Manual Method. Consider both of condition Fetch Limited and Time Duration Limited to choose final value (choose smaller value between that condition). To analyze this step, use equations

\[ t_{x,u} = 77.23 \left( \frac{F_{eff} \times 1000}{u^{0.34} g^{0.33}} \right)^{0.67}, \]  

(8)

\[ C_d = 0.001 (1.1 + 0.035 U^2), \]  

(9)

\[ u_\ast = \sqrt{C_d U}, \]  

(10)

\[ \frac{g H_o}{u_\ast^2} = 4.13 \times 10^{-2} \left( \frac{g F_{eff} 1000}{u_\ast^2} \right)^{0.7}, \]  

(11)

\[ \frac{g T_p}{u_\ast} = 0.751 \left( \frac{g F_{eff} 1000}{u_\ast^2} \right)^{0.3}. \]  

(12)

**Statistical Analysis**

Eventually, after we determine wave height and wave period in every timeline of data, we have to conduct that result to statistical analyze. The objective of this step is determining the wave design in many returns period. Usually, the statistical method for this analyze are using Fisher Tippet I distribution. Fisher Tippet I distribution is one of method which developing relationship between wave height design and statistical parameter into regression equation [6]. In this distribution we can use equations

\[ \hat{H}_{sm} = \hat{A} y_m + \hat{B}, \]  

(13)

then \( y_m \) is figured out by

\[ y_m = -\ln \{-\ln F(H_s \leq H_{sm})\}, \]  

(14)

and

\[ F(H_s \leq H_{sm}) = 1 - \frac{m - 0.44}{N_T + 0.12} \]  

(15)

Wave height design in many returns period is calculated by equation

\[ H_{sr} = \hat{A} y_r + \hat{B}. \]  

(16)

whereby,

\[ y_r = -\ln \{-\ln \left( 1 - \frac{1}{L_T} \right)\}, \]  

(17)

\[ \hat{A} = \frac{N \sum y_m H_{sm} - \sum y_m \sum H_{sm}}{N \sum y_m^2 - (\sum y_m)^2}. \]  

(18)
Wave Deformation

Wave which spread from deep sea could be deformed because of depth difference and bathymetry. Wave refraction is wave deformation because of bathymetry formation. Wave propagation from deep sea will form perpendicular with depth contours. Figure 2 provides the refraction process illustration.

![Figure 2. Wave Refraction Process](source)

We can estimate the value of refraction coefficient in equation [6]

\[
\sin \alpha_{i+1} = \frac{C_{i+1}}{C_i} \sin \alpha_i. 
\]

(20)

\[
K_r = \sqrt{\frac{\cos \alpha_i}{\cos \alpha_{i+1}}} 
\]

(21)

Where, \(\alpha\) is the angle that formed between wave angle and bathymetry profile.

If the wave propagates from deep sea to transition or shallow sea, then in any certain location in that sea, the wave will be break [6]. Breaking wave condition depends on slope of bathymetry profile, \(m\). There are some equations which correlate depth of breaking wave \(d_b\) and breaking wave height \(H_b\) such as [6], [7]

\[
d_b = \frac{1}{b - (a. H_b / g. T^2)} 
\]

(22)

\[
a = 43.75(1 - e^{-19.5m}). 
\]

(23)

\[
b = \frac{1.56}{(1 + e^{-19.5m})}. 
\]

(24)

Wave Set-Up and Wind Set-Up

Wave set-up is sea water level rising because of the wave. This phenomenon estimated from equation

\[
S_w = 0.19 \left[ 1 - 2.82 \left( \frac{H_b}{gT^2} \right) \right] H_b. 
\]

(25)

In other hand, wind set-up is sea water level rising because of the storm wind. This phenomena estimated from equation

\[
\Delta h = F_{eff} c \left( \frac{U \sin \alpha}{2gd} \right)^2. 
\]

(26)

Flood Forecasting

Hydrological analysis runs through watershed area. In this case, Medan Belawan Sub-district located between two watershed, Belawan and Deli Watershed. There are maximum daily rainfall data from three rain monitoring station around the watershed, such as Pancur Batu, Bulu Cina and Polonia. They are the fundamental equation on Thiessen Polygon Method analysis. This analysis results the maximum daily rainfall data for each of watershed. The polygons formed by the perpendicular bisectors of the lines joining nearby stations (Figure 3). In regard to find out the representative rainfall of the watershed, executing the equation [8], [9]

\[
P = \frac{P_1 A_1 + P_2 A_2 + P_3 A_3 + \ldots + P_n A_n}{A_1 + A_2 + A_3 + \ldots + A_n}. 
\]

(27)

is necessary. The term of \(P_n\) is rainfall weight at all of rainfall station and \(A_n\) is the area that the rainfall station represents to.

![Figure 3. Thiessen Polygon Method](source)
must run first before calculating the rainfall for planning and design. In statistic science there is known some methods that can be used to hydrological analysis, such as normal, log normal, log Pearson III and Gumbel distribution [9] which is the analysis use maximum daily rainfall data at Medan Belawan Sub-district. This research took Gumbel distribution in analysis as the subject to the extreme value. Gumbel distribution follows the equation

\[ X_r = x + KS_x, \]  

\[ K = \frac{y_r - \bar{y}_n}{S_n} \]  

as the fundamental procedure in analysis. The term of \( x \) and \( S_x \) are the mean value and deviation standard of rainfall data in sequence. In another hand, \( K \) deals with the reduce mean \( \bar{y}_n \), reduce deviation standard \( S_n \) and reduce variate \( y_r \) as the Gumbel’s frequency factor [9], [10].

The unit quantity of effective rainfall is taken as 1 mm or 1 cm and the outflow hydrograph is expressed by the discharge ordinate. Nature of hydrograph depend on rainfall and watershed characters. In this case it will be use Synthetic Unit Hydrograph Nakayasu. The ordinate can be calculated by steps below [8], [11]:

1. Rising limb \((0 < t < T_p)\)

\[ Q_t = Q_p \left( \frac{t}{T_p} \right)^{2.4}. \]  

2. Recession limb \((T_p < t < T_p + T_{0.3})\)

\[ Q_t = Q_p 0.3^{\frac{t-T_p}{T_{0.3}}}. \]  

3. Recession limb \((T_p + T_{0.3} < t < T_p + T_{0.3} + 1.5T_{0.3})\)

\[ Q_t = Q_p 0.3^{\frac{t-T_p+0.5T_{0.3}}{1.5T_{0.3}}}. \]  

4. Recession limb \((t > T_p + T_{0.3} + 1.5T_{0.3})\)

\[ Q_t = Q_p 0.3^{\frac{t-T_p+1.5T_{0.3}}{2T_{0.3}}}. \]  

3. Result and Discussion

Disaster Risk Index Analysis

As explained in Figure 1, we must know the level of risk of tidal flooding disaster in Medan Belawan. In this case, authors using Perka BNPB, No. 2 Tahun 2012 as a guidance. From table 1, table 2 and table 3, we get each index for hazard, vulnerability, and capacity.

There is each index as result of analysis as follows:

1. Hazard index: 5
2. Vulnerability index: 3.64
3. Capacity index: 2.2

Therefore, we can calculate the estimate of risk index based on equation 2 and yield 8.27 as risk index.

Tidal Analysis

From the result (risk index: 8.27) we can say that the tidal flooding disaster risk in Medan Belawan Sub-District is categorized as high risk. To reduce that risk (from Figure 1), there are two approaches in mitigation, structural and non-structural mitigation. In structural mitigation, in this case seawall designed, we must consider sea level design first. To estimate sea level design, consider the condition below:

1. Mean high water level (MHWL)
2. Wave set-up
3. Wind set-up
4. Estuary water level
5. Land subsidence
6. Climate change

MHWL analysis runs from tides analysis using admiralty method. Table 4 is result of admiralty method to estimate each tides components based on tides record data.
Wave Forecasting

The next step to estimate water level design is, wave forecasting. From wind velocity data, we conducted distribution analysis of wind, wave forecasting and then find wave set-up and wind set-up. Distribution analysis results the information about most dominant of wind direction in Medan Belawan coastal area from wind rose. Figure 4 describes the spread of wind direction and velocity as the wind rose. This wind rose generated from WR-Plot software.

![Figure 4. Wind Rose](image)

From wind rose in Figure 4, we can say that there are 3 directions of wind. Further, we only choice one of them based on wind frequency. This result exposes on the Table 5. Although wind direction from north is more frequent based on description in wind rose, but most of maximum wind velocity are from northeast direction, so finally we use this direction in next analysis if needed.

<table>
<thead>
<tr>
<th>Wave Components</th>
<th>Tides Components</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A$ (cm)</td>
<td>$H_{o}$</td>
</tr>
<tr>
<td>149,94</td>
<td>60,44</td>
</tr>
<tr>
<td>127,86</td>
<td>36,93</td>
</tr>
<tr>
<td>150 cm</td>
<td>1,35 m</td>
</tr>
<tr>
<td>272 cm</td>
<td>2,72 m</td>
</tr>
<tr>
<td>255 cm</td>
<td>2,35 m</td>
</tr>
<tr>
<td>65 cm</td>
<td>0,65 m</td>
</tr>
<tr>
<td>28 cm</td>
<td>0,28 m</td>
</tr>
</tbody>
</table>

Table 4. Result of Admiralty Method

### Table 5. Maximum Wind Velocity and Direction

Table 5 became the primary information for wave forecasting analysis. It starts from wind velocity in which measured in land converted into wind velocity in deep sea. Using equation 5 to convert into wind velocity, we conduct it in Medan Belawan coastal area from wind rose. From wind rose in Figure 4, we can choose wind direction and velocity as the wind rose. This wind rose generated from WR-Plot software.

![Figure 4. Wind Rose](image)

Next analysis calculating wave height ($H_{o}$) and wave period ($T_{p}$) based on final conversion of wind velocity using equation 8 to 12. There are 2 approaches to analyze it, fetch limited approach and time duration limited approach. In fetch limited approach analysis, authors calculate the value of effective fetch using equation 6. Consider the statement of Table 5, effective fetch in which

### Table 6. Conversion Result of Wind Velocity

Table 6 describes the result of conversion wind velocity. The value in $U$ column is held the final conversion (the conversion including calculate wind stress factor), therefore it’s become prediction wind velocity in deep sea.

<table>
<thead>
<tr>
<th>Num</th>
<th>Year</th>
<th>Velocity ($U_{z}$)</th>
<th>$U_{10}$</th>
<th>Correction Factor</th>
<th>$U$</th>
<th>Wind Direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2006</td>
<td>22,11,31</td>
<td>13,43</td>
<td>0,68,10</td>
<td>20,99</td>
<td>NE</td>
</tr>
<tr>
<td>2</td>
<td>2007</td>
<td>20,10,28</td>
<td>12,21</td>
<td>1,10,11</td>
<td>19,49</td>
<td>NE</td>
</tr>
<tr>
<td>3</td>
<td>2008</td>
<td>46,23,64</td>
<td>28,08</td>
<td>0,97,11</td>
<td>42,99</td>
<td>NE</td>
</tr>
<tr>
<td>4</td>
<td>2009</td>
<td>40,20,56</td>
<td>24,42</td>
<td>0,91,11</td>
<td>36,22</td>
<td>NE</td>
</tr>
<tr>
<td>5</td>
<td>2010</td>
<td>25,12,85</td>
<td>15,26</td>
<td>1,03,11</td>
<td>23,85</td>
<td>NE</td>
</tr>
<tr>
<td>6</td>
<td>2011</td>
<td>18,9,25</td>
<td>10,99</td>
<td>1,13,11</td>
<td>17,86</td>
<td>NE</td>
</tr>
<tr>
<td>7</td>
<td>2012</td>
<td>25,12,85</td>
<td>15,26</td>
<td>1,03,11</td>
<td>23,85</td>
<td>E</td>
</tr>
<tr>
<td>8</td>
<td>2013</td>
<td>28,14,39</td>
<td>17,09</td>
<td>0,99,11</td>
<td>24,61</td>
<td>N</td>
</tr>
<tr>
<td>9</td>
<td>2014</td>
<td>15,42,16</td>
<td>18,31</td>
<td>0,97,11</td>
<td>27,49</td>
<td>N</td>
</tr>
</tbody>
</table>

Table 6. Conversion Result of Wind Velocity

...
is only analyzed for northeast direction. Figure 5 describes spread of fetch in northeast direction in every 6 degrees to 42 degrees. For estimate effective fetch value, use equation 6 to calculate it and the result described on Table 7.

$F_{eff}$ used for calculating wave height and wave period in fetch limited condition. In time duration limited approach, we must take the value of maximum average duration of wave occurs, because of limitation information about this, so in this analysis, assumed 4 hours for wave duration as duration limited value. Table 8 is the result of this analysis. Analysis distinguished in fetch limited and time duration limited condition. As a result, we must select the condition in which give smaller value and for this case time duration limited approach is selected. Based on this result we can make the graph of relationship between wave height and wave period (Figure 6).

$$\begin{array}{|c|c|c|c|}
\hline
\alpha (^{\circ}) & \cos \alpha & X_{i} (\text{Km}) & X_{i} \cos \alpha \\
\hline
42 & 0.7431 & 0 & 0 \\
36 & 0.8090 & 280 & 226,52 \\
30 & 0.8660 & 594 & 514,42 \\
24 & 0.9135 & 376 & 343,49 \\
18 & 0.9511 & 285 & 271,05 \\
12 & 0.9781 & 284 & 277,79 \\
6 & 0.9945 & 256 & 254,6 \\
0 & 1 & 225 & 225 \\
6 & 0.9945 & 221 & 219,79 \\
12 & 0.9781 & 205 & 200,52 \\
18 & 0.9511 & 214 & 203,53 \\
24 & 0.9135 & 226 & 206,46 \\
30 & 0.8660 & 233 & 201,78 \\
36 & 0.8090 & 227 & 183,65 \\
42 & 0.7431 & 241 & 179,1 \\
\hline
\end{array}$$

$F_{eff}$ 259.62 Km

Table 7. Analysis of Effective Fetch

$\begin{array}{|c|c|c|c|c|c|c|c|}
\hline
\text{Year} & \text{Wind Velocity (m/s)} & \text{Wind Direction} & \text{Fetch Limited} & \text{Time Duration Limited} \\
\hline
2008 & 42.99 & NE & 49692 & 12,757 & 15,000 & 14,047 & 37,623 & 6,702 & 8,032 \\
2009 & 38.25 & NE & 49692 & 13,553 & 12,442 & 13,055 & 49,167 & 3,149 & 2,250 \\
2011 & 17.66 & NE & 62222 & 17,284 & 5,150 & 9,739 & 34,034 & 1,773 & 4,780 \\
2012 & 19.49 & N & 100173 & 22,593 & 8,544 & 42,901 & 36,600 & 2,054 & 5,063 \\
2013 & 23.65 & E & 52689 & 14,613 & 6,976 & 10,596 & 29,371 & 2,722 & 5,655 \\
\hline
\end{array}$

Table 8. Wave Height and Period Forecast Result

Figure 6. The Graph of Relationship Between Wave Height and Wave Period

Statistical Analysis
The result of Table 8 will be transform become wave height and period data. This data is analyzed statistically using Fisher Tippet I distribution. Using equation 13 to 19 we got the result of wave height in some return periods. Table 9 contains the prediction of wave height in some return period according to Fisher Tippet I analysis.

<table>
<thead>
<tr>
<th>Return Period, (T_r)</th>
<th>(Y_r)</th>
<th>(H_{sr})</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>0.367</td>
<td>2.956</td>
</tr>
<tr>
<td>5</td>
<td>1.500</td>
<td>4.384</td>
</tr>
<tr>
<td>10</td>
<td>2.250</td>
<td>5.330</td>
</tr>
<tr>
<td>25</td>
<td>3.199</td>
<td>6.525</td>
</tr>
<tr>
<td>50</td>
<td>3.902</td>
<td>7.411</td>
</tr>
<tr>
<td>100</td>
<td>4.600</td>
<td>8.291</td>
</tr>
</tbody>
</table>

Table 9. Wave Height in Some Return Periods

Wave Deformation
The aim of wave deformation analysis is to conduct wave height value when it starts to brake. Using method in equation 21 to 23, we yield 6.37 m wave height in 8.19 m depth of water. For near shore (in depth of water is 0.50 m), we yield wave height is 0.42 m. This value will be used in wave force calculation. This value is based of figuring out in return period of wave height, in this case, authors select 25 years in return period (\(H_{1/25}\)).

Wind Set-Up and Wave Set-Up
This is the final coastal hydrodynamic analysis before we conduct design of seawall. Using equation 24 and 25 in sequence, we got the value of wave set-up is 0.86 m and in other hand the value of wind set-up is 0.28 m.

Hydrological Analysis in Estuary
Medan Belawan Sub-distric located in estuary area which is between Belawan and Deli sub-watershed. In the north side stream Belawan River and Deli River in the south side. The analysis of Thiessen Polygon results maximum daily rainfall data (Table 10 and 11) for both of watershed.

<table>
<thead>
<tr>
<th>Year</th>
<th>(R_{max})</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003</td>
<td>113.803</td>
</tr>
<tr>
<td>2004</td>
<td>77.948</td>
</tr>
<tr>
<td>2005</td>
<td>155.683</td>
</tr>
<tr>
<td>2006</td>
<td>210.442</td>
</tr>
<tr>
<td>2007</td>
<td>162.7</td>
</tr>
<tr>
<td>2008</td>
<td>107.593</td>
</tr>
<tr>
<td>2009</td>
<td>87.213</td>
</tr>
<tr>
<td>2010</td>
<td>148.855</td>
</tr>
<tr>
<td>2011</td>
<td>178.483</td>
</tr>
</tbody>
</table>

Table 10. Maximum daily rainfall data of Belawan Watershed

Table 11. Maximum daily rainfall data of Deli Watershed

In this case Gumbel Method is proper method to calculate rainfall return period. The Result of the frequency analysis appears on Table 12 and Table 13.

<table>
<thead>
<tr>
<th>Return Periods</th>
<th>(Y_{sr})</th>
<th>(Y_{ns})</th>
<th>(S_n)</th>
<th>(R_{24}) (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>0.3668</td>
<td>0.4982</td>
<td>0.946</td>
<td>135.9316/785</td>
</tr>
<tr>
<td>5</td>
<td>1.5004</td>
<td>0.946</td>
<td>167.5802/57</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>2.251</td>
<td>0.946</td>
<td>221.810/45/12</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>3.1993</td>
<td>0.946</td>
<td>297.0/87/38</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>3.9028</td>
<td>0.946</td>
<td>325.937/47</td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>4.6012</td>
<td>0.946</td>
<td>325.937/47</td>
<td></td>
</tr>
</tbody>
</table>

Table 12. Frequency Analysis Using Gumbel Method

<table>
<thead>
<tr>
<th>Return Periods</th>
<th>(Y_{sr})</th>
<th>(Y_{ns})</th>
<th>(S_n)</th>
<th>(R_{24}) (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>0.3668</td>
<td>0.4982</td>
<td>0.946</td>
<td>105.563/23</td>
</tr>
<tr>
<td>5</td>
<td>1.5004</td>
<td>0.946</td>
<td>142.10/63/22</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>2.251</td>
<td>0.946</td>
<td>166.27/253/8</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>3.1993</td>
<td>0.946</td>
<td>196.8/13/96/8</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>3.9028</td>
<td>0.946</td>
<td>219.6/67/18</td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>4.6012</td>
<td>0.946</td>
<td>241.93/79/9</td>
<td></td>
</tr>
</tbody>
</table>

Table 13. Frequency Analysis Using Gumbel Method

Synthetic unit hydrograph methods are popular and play a significant role in water resources design especially in the analysis of flood discharge of ungagged watersheds. There is Nakayasu Synthetic unit hydrograph that
will be used to analyze flood for planning. It uses watershed and river data such as area of the watershed and river length. Belawan watershed has area around 417.63 km² and length of the Belawan river around 74 km and Deli watershed has area around 459.86 km² and length of Deli River around 73 km. The Nakayasu hydrograph for Belawan and Deli watershed figures on Figure 7 and Figure 8 sequentially.

![Image](image1)

**Figure 7. Flood Discharge of Belawan Watershed**

![Image](image2)

**Figure 8. Flood Discharge of Deli Watershed**

For design requirement which use 25 years return period data to calculate level of flood at Belawan and Deli Estuary Area. Level of flood was calculated by Manning Equation, and it result level of flood around 2.95 m at Deli Estuary area and 3.45 m. Finally, it was chosen the highest value for design which is 3.45 m.

**Structural Mitigation Approach**

The previous paragraphs explains that to reduce tidal flooding risk in Medan Belawan, we could make two approaches, structural and non-structural. In structural approach, we propose an idea to build seawall in communities’ region. In this text, authors conducted design of cantilever seawall. In design of seawall, the seawall must consider 3 conditions in safety factor value analysis [12]:

1. Stable in risk of overturning.
2. Stable in risk of sliding.
3. Stable in risk of uplift pressure.

To achieve the seawall design, at least there are some analyses throught to. The first analysis is sea water level design. **Table 14** explains the components of sea water level design. Both value of land subsidence and climate changes assumed hypothetically.

To analyze in seawall configuration design, we must decide the typical of wave force. In this text authors use Saintflou formula [13] to figure out the wave force. According to **Figure 9**, there are some configuration forces:

1. \( p_1 \): wave pressure at the still water level, corresponding to wave crest.
2. \( p_2 \): water pressure at the base of the vertical wall.
3. \( p_3 \): wave pressure at still water level, corresponding to wave through.

In other hand, there are supplementary pressure from lateral soil pressure (active), \( p_4 \) and lateral pressure from seismic (assumed 40% of self weight), \( p_5 \). Other assumption in this analyze is neglecting the lateral soil pressure (passive).

**Table 14. Analysis of Seawater Level Design and Seawall Height Design**

<table>
<thead>
<tr>
<th>Num</th>
<th>Parameter</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>MHWL</td>
<td>m</td>
<td>2.35</td>
</tr>
<tr>
<td>2</td>
<td>Wave Set-Up</td>
<td>m</td>
<td>0.86</td>
</tr>
<tr>
<td>3</td>
<td>Wind Set-Up</td>
<td>m</td>
<td>0.28</td>
</tr>
<tr>
<td>4</td>
<td>Estuary Water Level</td>
<td>m</td>
<td>0.53</td>
</tr>
<tr>
<td>5</td>
<td>Land Subsidance</td>
<td>m</td>
<td>0.30</td>
</tr>
<tr>
<td>6</td>
<td>Climate Changes</td>
<td>m</td>
<td>0.11</td>
</tr>
<tr>
<td>7</td>
<td>Freeboard</td>
<td>m</td>
<td>0.50</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4.43</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4.93</td>
</tr>
</tbody>
</table>

In analyzing the design of seawall, the maximum wave pressure is added on the seawall design. This wave pressure is the maximum wave pressure obtained from the wave force analysis. According to **Figure 9**, the wave pressure added is as follows:

1. \( p_1 \): wave pressure at the still water level, corresponding to wave crest.
2. \( p_2 \): water pressure at the base of the vertical wall.
3. \( p_3 \): wave pressure at still water level, corresponding to wave through.
4. \( p_4 \): supplementary pressure from lateral soil pressure (active).
5. \( p_5 \): lateral pressure from seismic (assumed 40% of self weight).

Other assumption in this analyze is neglecting the lateral soil pressure (passive).

![Image](image3)

**Figure 9. Saintflou Approach to Analyze Water Pressure**
Eventually, after this analysis (water pressure, lateral soil pressure, seismic pressure and bearing capacity), the configuration of seawall is obtained as described in Figure 10. From Figure 10, there are impermeable rocks because authors involving seismic force in design. If seismic force doesn't involve in design and analysis, the impermeable rock isn't necessary. The final condition after structural mitigation can be described as Figure 16.

![Figure 10. Configuration of Seawall](image)

**Non-Structural Mitigation Approach: Community Adaptation**

Adaptation is essential to reduce the damages and take advantages of new opportunities in-light of the rapid climate change already occurring and expected future impacts. Even though structural mitigation has implemented, but tidal flood still surges Medan Belawan sub-district area. Affected people need adaptation strategy to face tidal flood. They must adapt if the flood occurs and swamp their settlements. Adaptation is action or process to change the conditions, structures, and responsive activities to keep balancing along environmental fluctuation condition for short and prolonged period [14].

Cultural ecology scientist give description related to adaptation, that it is strategy of adapting that people can use to response any social and environmental phenomenon. There are some actions that community can implementation to adapt their house when tidal flood occurs:

1. They can adapt their house, raising the floor of house (Figure 11).
2. Establish tidal in front of the door.
3. Raising the floor of the house with assembled wood (Figure 12).
4. Elevate goods/furnishings; avoid furniture made from wood and prefer a plastic material.
5. Build drainage around the house.
7. Move to another place

![Figure 11. Raising the Floor of The House](image)

![Figure 12. Raised the Floor of the House with Assembled Wood](image)
Adaptation strategies to avoid fishpond damage are:
1. make the embankment
2. putting a smooth net around the pond
3. elevate of embankment
4. Mangrove planting also serves to reduce the impact of other tidal floods such as land loss and coastal abrasion.

On the other hand, it also can design house on stilts for new house (Figure 13) and raising the road by blowing and making concrete castings at the cost by themselves (Figure 14), and if possible local government can allocate their budget to empower coastal community to adapt with the tidal flood condition.

Figure 13. Establishing House on Stilts for New House

Figure 14. Raising the public road

In Sicanang Village there is mangrove forest reach 747 Ha which have some function including to reduce tidal flood impact. The aim of mangrove forest conservation are follows:
1. as a shelter for organisms.
2. as a stabilizer for the deposition of sludge.
3. as buffer area to protect land from wave, wind, and any pollutant from the sea. Mangrove forest as green belt whose phisyc, biological and chemical functions.
4. to reduce tidal flood impact

There are some requirements to cultivate mangrove along coastal area or riverside.
1. river mouth with width of 100 m the requirement of width of green line is 20 m.
2. river mouth with a width of 60-70m, the regulated mangrove thickness is 6 m.
3. estuary of river with width 50-60 m, requirement of width of green line is 5 m.
4. river mouth of a width of less than 5 m, the thickness of mangrove as the required green line is 3 m.
5. in a tsunami potential area that reaches a wave height of more than 10 m, according to the purpose and function of the protected area, the effective mangrove green line width is 400 meters (maximum) [15].

The mangrove green trails can be planted with a spacing of 1x1 m with mangrove vegetation types with the sequence of planting is Avicennia (Avicennia alba), Sonneratia (Sonneratia caseolaris), Rhizophora (Rhizophora apiculata), dan Bruguiera (Buguiera gymnorrhiza) (Figure 15).

Figure 15 Zoning Pattern Mangrove Forest from the Seaside towards the Mainland (Bengen, 2004)

Mitigation Zone Mapping
This part is final concept of mitigation zone. In determination of mitigation zone, we must consider land use existing, for example if we want to build seawall, we can’t build it in harbor zone because usually there are some
hydraulic structures like as jetties and it was directly bounded by the sea. Therefore, in this text, authors decide some consideration in mitigation zone mapping like as:

1. Seawall applies in communities’ region only.
2. Mitigation in community’s region is not only structural approach, but also non-structural.

Mangrove forest reforestation adopts in Sicanang village (Figure 17).

4. Conclusion
There are some conclusions including our limitation in this text:

1. Medan Belawan Sub-District has tidal flooding hazards which of all community living near coastal line.
2. Tidal flood risk index in high risk level.
3. Considering the condition of land use, the proper disaster mitigation are seawall as structural mitigation and adaptation including reforestation of mangrove forest as non-structural mitigation.
4. Zone mapping of mitigation distinguished into two region follows structural mitigation (urban area which nearby with belawan port) and non-structural mitigation as mangrove conservation in Sicanang village.
5. Structural mitigation exists coincide with non-structural mitigation in community adaptation pattern.

The largest limitation in this text is all geotechnical information is assumed, so in extend analysis (if needed), geotechnical information should be available. the unavailable longer rainfall data is also our limitation in this research.

5. References
[15] Karminasih, “Pemanfaatan Ekosistem Mangrove bagi Minimasi Dampak Bencana di Wilayah Pesisir The Use of Ecosystem Mangrove in Minimalize...
Figure 16. Description of Condition After Seawall Built on

Figure 17. Mitigation Zone Mapping in Medan Belawan Sub-Distric