

## Flood Prediction Based on Hydrological and Topographic Conditions Using Hec HMS 4.5 and Hec Ras 5.0.3 in The Toli-Toli, Indonesia

Riki Chandra Wijaya\*

Civil Engineering Department, University of Lampung, Lampung, Indonesia  
Email: riki.chandra@eng.unila.ac.id

Umboro Lasminto

Civil Engineering Department, Institute of Technology Sepuluh Nopember, Surabaya, Indonesia

### Abstract

*Floods in the Toli-toli area often occur due to the continued reduction in infiltration land. Flood events from year to year have a bigger impact and cause a lot of losses. The impact of this flood needs to be analyzed and its magnitude predicted so that the potential for flooding can be estimated. Flood handling can be addressed early on so that when a flood the losses are not so great. Flood prediction can be done by hydrological analysis using HEC HMS 4.5 and continued hydraulics using HEC RAS 5.0.3. Based on the incidence of rain over the last 10 years, it is known that the return period of rain in the Toli-toli area varies from a period of 2 years, 5 years, 10 years, and 15 years. Based on the calculation results, it is known that the flood in the Toli-toli area in the 2-year return period has a depth of 0.66 meters with a flood inundation area as shown in Figure 7 of this article. In overcoming this flood, efforts should be made to handle it with several alternatives such as increasing infiltration land, normalizing rivers, and so on.*

**Keyword:** Flood prediction, Toli-toli, hydrological, topographic.

### Abstrak

*Banjir di wilayah Toli-toli sering terjadi akibat terus berkurangnya lahan resapan. Peristiwa banjir dari tahun ke tahun memberikan dampak yang lebih besar dan menimbulkan banyak kerugian. Dampak banjir ini perlu dianalisis dan diprediksi besarnya sehingga potensi banjir dapat diperkirakan. Penanganan banjir dapat diatasi sejak dini sehingga ketika terjadi banjir kerugian yang ditimbulkan tidak begitu besar. Prediksi banjir dapat dilakukan dengan analisis hidrologi menggunakan HEC HMS 4.5 dan dilanjutkan hidrolika menggunakan HEC RAS 5.0.3. Berdasarkan kejadian hujan selama 10 tahun terakhir, diketahui periode ulang hujan di wilayah Toli-toli bervariasi mulai dari periode 2 tahun, 5 tahun, 10 tahun, dan 15 tahun. Berdasarkan hasil perhitungan diketahui banjir di wilayah Toli-toli periode ulang 2 tahun mempunyai kedalaman 0,66 meter dengan luas genangan banjir seperti terlihat pada Gambar 7 artikel ini. Dalam mengatasi banjir ini perlu dilakukan upaya penanganan dengan beberapa alternatif seperti memperbanyak lahan resapan, normalisasi sungai, dan lain sebagainya.*

**Kata Kunci:** Prediksi banjir, Toli-toli, hidrologi, topografi

### 1. Introduction

Changes in land use in a watershed will hurt harm all aspects of hydrology (Roy dan Islam, 2019). The reduction in infiltration land can cause a very high increase in runoff discharge (Butler and Davies, 2014). The increasing quantity of surface water can cause potential flooding in some areas in the watershed (Dong, at. Al., 2019). Flash floods or the so-called rapid flow of surface water, it is very dangerous and very deadly (Javier and Smith, 2010). In some areas affected by this flash flood, it was noted that the losses caused were very large and caused many casualties (Peng, at. Al., 2018).

The increase in runoff discharge can be detrimental for the downstream area (Zhang and Singh, 2005). This will be very large if the downstream area is very densely populated or in urban areas (Zischg, at. Al., 2021). The current climate change will cause so many changes in hydrological conditions that occur so that humans must adapt to this (Zhang and Singh, 2006). The current runoff discharge occurs in large quantities so that the potential for landslides and river erosion is very likely to occur (Xiao, at. Al., 2019).

One of the areas affected by flash floods is the Indonesian Toli-Toli area. Toli-toli is one of the districts in Central Sulawesi, Indonesia. This district has an

\* Penulis Korespondensi: riki.chandra@eng.unila.ac.id

area of 4,079.77 km<sup>2</sup> and a population of 220,411 in 2020 (Wikipedia online, 2021). On Sunday, October 24, 2021, there has been a flash flood in the Toli-toli area which is very dangerous and has caused a lot of material and moral losses (Sangalu online, 2021).

This change in hydrological conditions needs to be anticipated so that when the flood arrives, the community will be able to adjust (Shabani, at. Al., 2021). This global climate change certainly needs to do the latest hydrological studies so that all impacts that occur can be estimated, and that the community can anticipate them immediately (Xiong, at. Al., 2018). Therefore, this research is very helpful in estimating the impact of floods that occurred in the Toli-toli area, Indonesia.

## 2. Method

Hydrology is a cycle consisting of evaporation, precipitation, surface runoff, infiltration, evapotranspiration, groundwater flow, and other events that support the occurrence of rain (Njogu and Waita, 2021). In this hydrological analysis, the main data needed is rainfall data that affects the Toli-Toli Regency area. Based on the survey data, it is known that the nearest station is the Sultan Bantilan Meteorological Station which is located at the coordinates of latitude: 1.12114 and longitude: 120.79433. Rainfall data for the last 10 years is used in this study. The rainfall data is then determined by the maximum daily value in each year. Rainfall data will be processed statistically by determining the average value, standard deviation, coefficient of skewness or skewness, coefficient of kurtosis using the equation (Subramanya, 1995):

$$\bar{x} = \frac{\sum x}{n} \quad \text{determine the average value}$$

$$Std(x) = \sqrt{\frac{(x - \bar{x})^2}{n - 1}}$$

determine the standard deviation

$$Cs = \frac{n \sum (x - \bar{x})^3}{(n - 1)(n - 2)(std(x))^3}$$

determine the coefficient of skewness

$$Ck = \frac{n^2 \sum (x - \bar{x})^4}{(n - 1)(n - 2)(n - 3)(std(x))^4}$$

determine the coefficient of kurtosis

Furthermore, the appropriate method of calculating the return period of rain is determined. Based on the results of the analysis, it is known that one of the appropriate methods in calculating the return period of rain is the Gumbel analysis method (Guo and Markus, 2011). Gumbel analysis can be used using the equation:

Gumbel equation that is often used in practice is.

$$x_T = \bar{x} + K \sigma_{n-1}$$

Where:

$\sigma_{n-1}$  = standard deviation of the number of samples

$$N = \sqrt{\frac{\sum (x - \bar{x})^2}{N - 1}}$$

$$K = \text{frequeution factors} = \frac{y_T - \bar{y}_n}{S_n}$$

$y_T$  = variasi reduksi =

$$- \left[ \ln \ln \frac{T}{T - 1} \right] = - \left[ 0.834 + 2.303 \log \log \frac{T}{T - 1} \right]$$

$S_n$  = from table

$\bar{y}_n$  = from table

After determining the maximum rain return period for 2 years, 5 years, 10 years, and 15 years. The rainfall data for the return period is then analyzed for hourly rainfall forecasts using the equation (Chow and Te, 1994):

$$R_t = R_0 \left( \frac{5}{T} \right)^{2/3}$$

Where:

$R_t$  = the average rain from the beginning to the T hour

T = rainy time from the beginning to the T hour

$R_{24}$  = daily effective rain (net rain causing runoff)

Furthermore, to determine the amount of rainfall at hour T, the following equation can be used (Chow and Te, 1994):

$$R_T = t \cdot R_t - (t - 1) R_{(t-1)} \quad \begin{matrix} R_0 = \frac{R_{24}}{5} \\ R_0 = \frac{R_{24}}{5} \end{matrix}$$

Where:

$R_T$  = amount of precipitation in hours to T

t = rainy time from start to hour to T

$R_t$  = average rainfall from start to hour to T

$R_{(t-1)}$  = the average rainfall from the beginning to the hour to (t-1)

Furthermore, the rain data is inputted into the hydrological model for further analysis of the surface runoff that occurs (USACE, 2000). several other methods are used to support the hydrological analysis carried out such as analysis of land-use change (SCS Curve Number), flow concentration time, and so on (Chow and Te, 1994).

## 3. Result and Discussion

The watershed that affects the Toli-toli district is the watershed which has an area of around 98.4 km<sup>2</sup>. The watershed is illustrated in the following **Figure 1**.

The area of the watershed is divided into several parts, each of which has an area as shown in the following **Table 1**.

Based on the results of Gumbel's analysis and calculated hourly rainfall estimates based on the return period of rain as in the following **Table 2**.

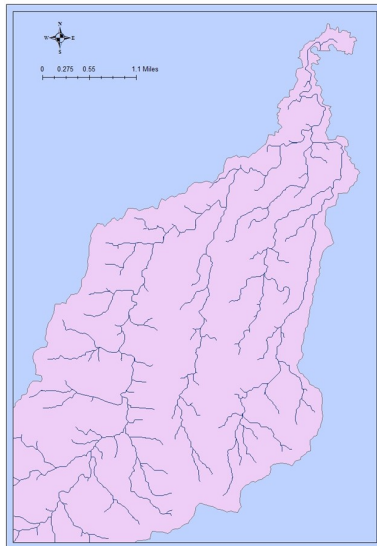


Figure 1. The watershed of Toli-toli

Table 1. Area of subbasin

Subbasin Name	Area (Km <sup>2</sup> )
Subbasin-13	4.6
Subbasin-12	3.6
Subbasin-2	4.8
Subbasin-1	2.8
Subbasin-3	2.6
Subbasin-4	2.44
Subbasin-9	2.76
Subbasin-5	1.58
Subbasin-6	0.94
Subbasin-7	1.5
Subbasin-10	2.76
Subbasin-8	1.96
Subbasin-11	1.59

The rain pattern for 10 years in the Toli-toli watershed can be shown in the graph (Figure 2).

The 10-year rainfall pattern in the Toli-toli watershed looks very irregular and seems extreme at certain times. The land use conditions in the Toli-toli watershed are mostly forest and grassland. Initial loss, constant loss, and impervious are determined based on land use conditions in the Toli-toli watershed. Based on the conditions of the Toli-toli watershed, the coefficient values are set as in the following Table 3.

Increase watertight conditions in each subbasin indicates how much catchment area is available. The surface runoff will gather in the river to then flow towards the downstream area. The travel time of this flow is indicated by the time of concentration value in each subbasin. The time of concentration and time lag values are shown in the following Table 4.

Several analyzes were then carried out to determine the time lag in each river and perform other hydrological

Table 2. The return period of rainfall

Time (hour)	Rainfall (mm)			
	2	5	10	15
1	11.27	39.59	69.53	78.24
2	3.11	10.92	19.18	21.58
3	1.94	6.83	11.99	13.49
4	1.55	5.46	9.59	10.79
5	1.55	5.46	9.59	10.79

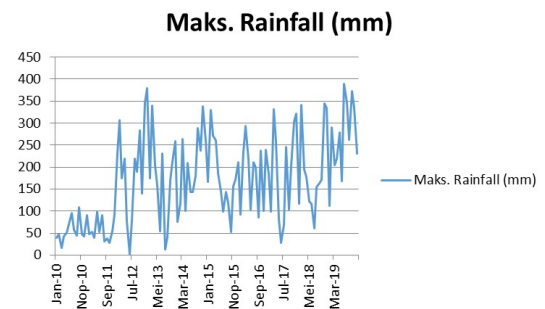


Figure 2. Maximum rainfall in the watershed at 10 years

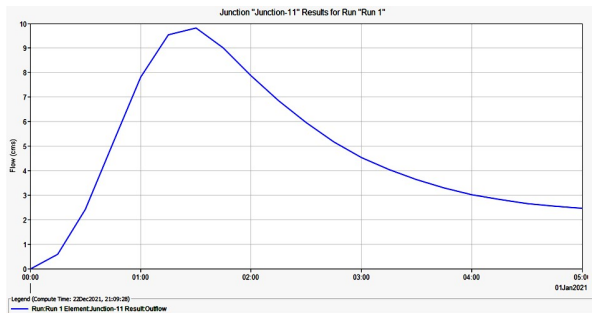
Table 3. Initial loss and impervious in the subbasin

Subbasin Name	Initial Loss (mm)	Constant Loss (mm/hour)	Impervious (%)
Subbasin-13	460	230	15
Subbasin-12	360	180	15
Subbasin-2	480	240	15
Subbasin-1	280	140	15
Subbasin-3	260	130	15
Subbasin-4	244	122	15
Subbasin-9	276	138	15
Subbasin-5	158	79	15
Subbasin-6	94	47	15
Subbasin-7	150	75	15
Subbasin-10	276	138	15
Subbasin-8	196	98	15
Subbasin-11	159	79.5	15

Table 4. Time of concentration and time lag in the subbasin

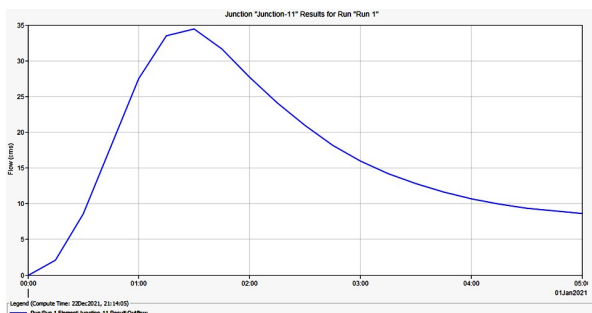
Subbasin Name	Time of Concentration (Hour)	Time Lag (Hour)
Subbasin-13	0.11390	0.068340
Subbasin-12	0.09431	0.056585
Subbasin-2	0.11769	0.070616
Subbasin-1	0.07772	0.046630
Subbasin-3	0.07341	0.044043
Subbasin-4	0.06990	0.041941
Subbasin-9	0.07686	0.046116
Subbasin-5	0.05002	0.030013
Subbasin-6	0.03354	0.020121
Subbasin-7	0.04806	0.028836
Subbasin-10	0.01692	0.010149
Subbasin-8	0.00999	0.005994
Subbasin-11	0.00728	0.004370

analyzes to obtain the discharge value and hydrograph shape at the control point. Based on this hydrological analysis, the outflow discharge from the Toli-toli watershed is obtained as shown in the following **Figure 3**.



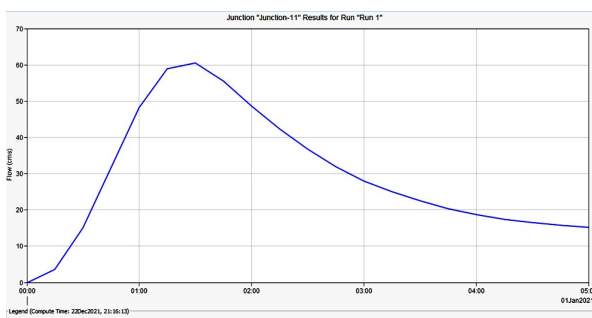
**Figure 3. 2 year return period flow discharge**

In the 2-year return period, the peak discharge reaches  $9.8 \text{ m}^3/\text{s}$ . As for the 5-year return period, it can be seen in the following hydrograph (**Figure 4**).



**Figure 4. 5 year return period flow discharge**

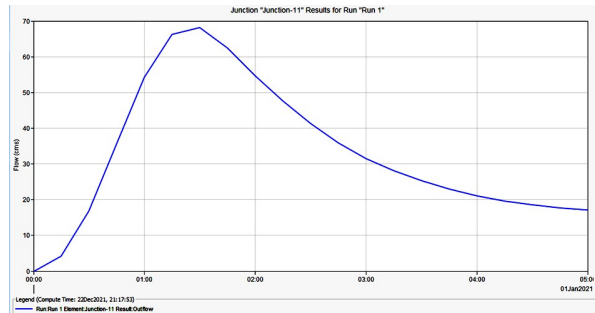
In the 5-year return period, the peak discharge reaches  $34.5 \text{ m}^3/\text{s}$ . As for the 10 year return period, it can be seen in the following hydrograph (**Figure 5**).



**Figure 5. 10 year return period flow discharge**

In the 10 year return period, the peak discharge reaches  $60.5 \text{ m}^3/\text{s}$ . As for the 15 year return period, it can be seen in the following hydrograph (**Figure 6**).

In the 15 year return period, the peak discharge reaches  $68.1 \text{ m}^3/\text{s}$ . The largest maximum water quantity in this 15 year return period must of course be adjusted to the



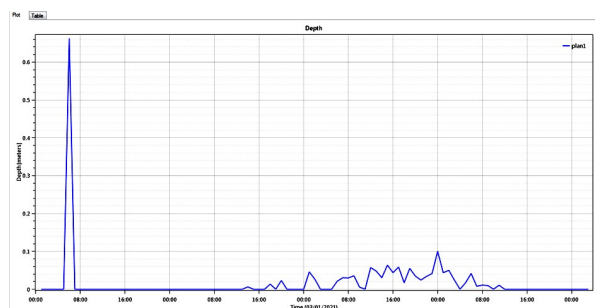
**Figure 6. 15 year return period flow discharge**



**Figure 7. Flood Inundation Area on the Toli-toli River in a 2-Year Period**

existing river capacity. Based on the results of hydraulic analysis on the cross-section of the Toli-toli river, it can be seen that there is a very large overflow of water every time it rains. The overflow can be seen as in the following image (**Figure 7**).

The picture above is the condition at 2 year return period which looks like an overflow occurs. Based on this condition, it can be seen that at the lowest return period the river has overflowed, of course at higher return times the overflow will be even greater. The depth of the water can be seen in the graph below (**Figure 8**).



**Figure 8. Prediction of water depth at flow rate return period of 2 years**

Based on the graph above, it can be seen that the depth of the flood in the 2-year return period is around 0.66 meters. This shows that flood awareness for the river

border needs to be increased. To overcome this condition, it is necessary to anticipate immediately by making some improvements to the cross-section of the river or other hydrological conditions the upstream.

#### 4. Conclusion

1. It is predicted that the overflow of river water will certainly occur during the smallest return period of rain. The capacity of the river is no longer able to channel runoff discharge in the watershed. In the 2-year return period, the river has overflowed and has the potential to flood, this will certainly be greater in the 5-year, 10-year, and 15-year return periods. Thus, flooding in the Toli-toli area is an unavoidable event (Wijaya and Lasminto, 2016).
2. It is recommended that in dealing with flooding in the Toli-toli area, it is necessary to immediately normalize the river, enlarge the infiltration area upstream to downstream, as well as several other engineering techniques to reduce runoff discharge or increase the river's storage capacity (Chao and Wang, 2017).

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