Journal of Civil Engineering Research 2014, 4(3A): 245-250
DOI: 10.5923/c.jce.201402.42

Assessment of Flood Index of Asahan River, North Sumatra, Indonesia

Rumilla Harahap[1,*], Ahmad Perwira Mulia Tarigan[2], Zulkifli Nasution[3]

[1]Faculty of Engineering, Universitas Negeri Medan, Medan, Indonesia
[2]Departement of Civil Engineering, Universitas Sumatera Utara, Medan, Indonesia
[3]Department of Agroecotechnology, Universitas Sumatera Utara, Medan, Indonesia

Abstract Frequent flooding in Asahan river is one of the hydrological events. This study was made to get the index value of the Middle, downstream and upstream watershed flood discharge accordance Asahan river conditions through analysis of rain. The study was conducted using primary data through surveys taken around the river and secondary data drawn from periodic reports issued by the relevant agencies. Rainfall data, discharge, land use was analyzed by the method of Gumbel and Log Pearson. The calculation of flood discharge is done by using the Rational method and Nakayasu. The study shows that the ability of the river is the return period of the flood discharge area design of 617.72 km ^{2}Annual is 2.89 km long river in the upstream region contained the maximum flood discharge on the 4th hour of 40.585 m^3/s while began to rise in 2nd hour of 13. 226 m^3/s. For the central region of the ability of the river is 150.30 m ^{3}/s, for 4 Hour with a return period of 25 years, area 34.22 km ^{2}and 49 km long flood discharge index 1.3. Ability to lower river is 210 852 m ^{3}/s for 4 hour with return period of 25 years, extensive shelf 178.51 km ^{2}and 49 km. The study also found that the flood period average index is 0.33 for 5 years, while the maximum flood discharge is 1447.229 m^3/s. To flood discharge index was obtained for the 1.43 is 105.22 m^3/s to 34.22 km^2 wide. The benefit of this study is to reduce the pool of flooding potential along the Asahan.

Keywords Asahan River, Hydrology Study and Flood Index

1. Introduction

Asahan river is placed in Asahan district, North Sumatra Province, Indonesia. This river has two tributaries namely Piasa rivers and Silau River. The riverside areas of the Asahan river are used for residential, agricultural and industrial activities. The main problem of Asahan river is flash flood during rainy season causing economic losses to the people significantly and also damaging watershed areas, and therefore the management of river watershed of this river is very crucial to study in relation to plan a better management strategy. This is because watershed has an important role in dampening fluctuations of runoff after precipitation and stabilize or maintains the flow in the dry and rainy seasons [1]. Hydrological the rivers watershed management is a task to manage biophysics of the earth to achieve the maximum water discharge evenly throughout the year [2].

A paucity studies have been conducted on river discharges and its watershed in Indonesia. Studies on the conservation of river watershed are very important in relation to conserve public interested and ecology [3]. This study is possibly conducted using a hydrological data, where one of the important data is rainfall. According to Suradi and Fouri [4], the rainfall data of highly fluctuating intensity was often simplified by using an average value that diminishes intensity fluctuation results. The other common problems are the accuracy of data, up-to-dateness, completeness, timely, meaningful and commensurate [5]. Therefore, the data needs to be validated prior to utilize. One of the important outcomes from this analysis is a flood index which will be useful in the river management.

Generally the equal distribution of rainfall is commonly happening in small watersheds, but rarely occurs in large watersheds due to the intensity of rainfall in entire watershed is different. Study on the Asahan discharge was reported by Harahap [6], however, study on river flood index of this river has not been reported. Hence, the objective of the present study was to assess of flood index of Asahan River in North Sumatra, Indonesia.

2. Data and Method

The study was conducted in Asahan River which is situated at eastern part of North Sumatra, Indonesia ($02^0$03'-$03^0$26'N, $99^0$01'-$100^0$00'E). The river is bordered by Deli Serdang District in north, Labuhan Batu District in the south, Simalungun District in the west and Malacca Strait in

* Corresponding author:
rumi_harahap@yahoo.com (Rumilla Harahap)
Published online at http://journal.sapub.org/jce

east. The rainfall data were collected from five meteorological stations; (1) Terusan Tengah, (2) Pulau Maria/Pulau Kemuning, (3) Simpang Kawat, (4) Ujung Seribu and (5) Balige. (Figure 1)

The hydrologic and hydraulic simulations were conducted using hydro-climatology and water discharge data of headwater of Asahan River. In addition, the topography, land use and river networks maps were also utilized in the study. The maximum of rainfall frequency was analyzed using two models; (1) Log Pearson distribution model, and (2) Gumber distribution model. The Chi quire and Smirnov-Kolmogrov tests were employed to determine the suitable model of distribution. In addition, the flood discharges was examined using Nakayasu method, then the flood discharge was calculated based on Fig. 2.

2.1. Procedure

$$Q_p = \frac{C \cdot A \cdot R_0}{3{,}6\,(0{,}3\,T_p + T_{0{,}3})}\ ; \quad T_p = t_g + 0{,}8\,t_r\ ;$$

$t_g = 0{,}21 \times L^{0{,}7}$ (L < 15 km)

$t_g = 0{,}4 + 0{,}058 \times L$ (L > 15 km) $T_{0{,}3} = \alpha \times t_g$

Where, Qp= flood peak discharge (m^3/s), C= coefficient of drainage, R_o= rain unit (mm), A= watershed area (km^2), Tp= interval period from the beginning of the rain until the flood peak (hour), $T_{0.3}$= the times required to decrease flood discharge up to 30% of the peak discharge (hour), tg= concentration time (hour), tr= time rain unit (1 hour), α= parameter of hydrograph, the value ranged between 1.5 to 3.5 and L= river length (m).

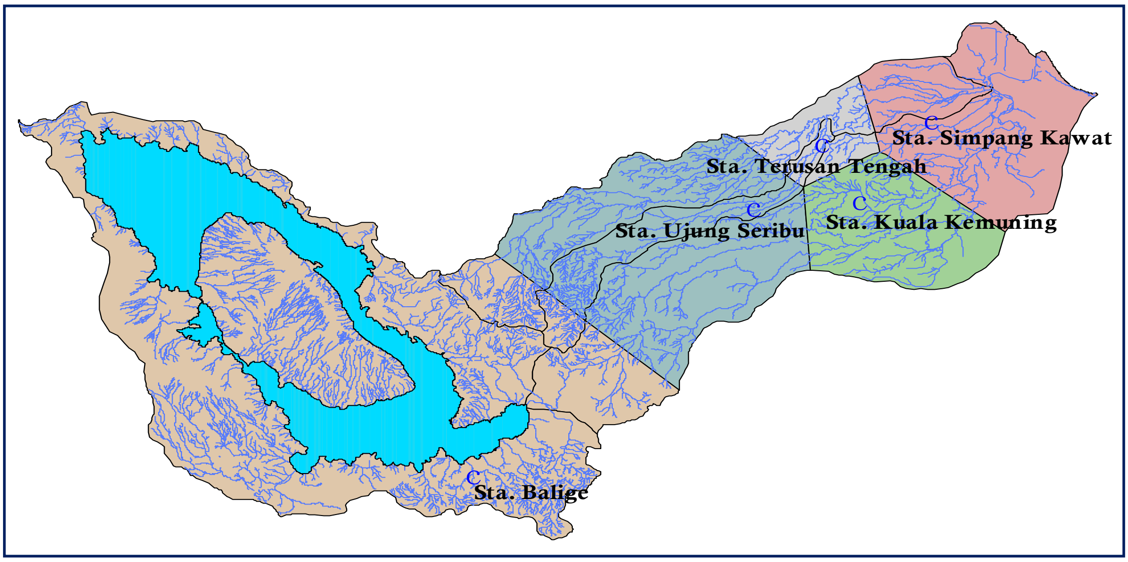

Figure 1. Station spread rain in the watershed Asahan

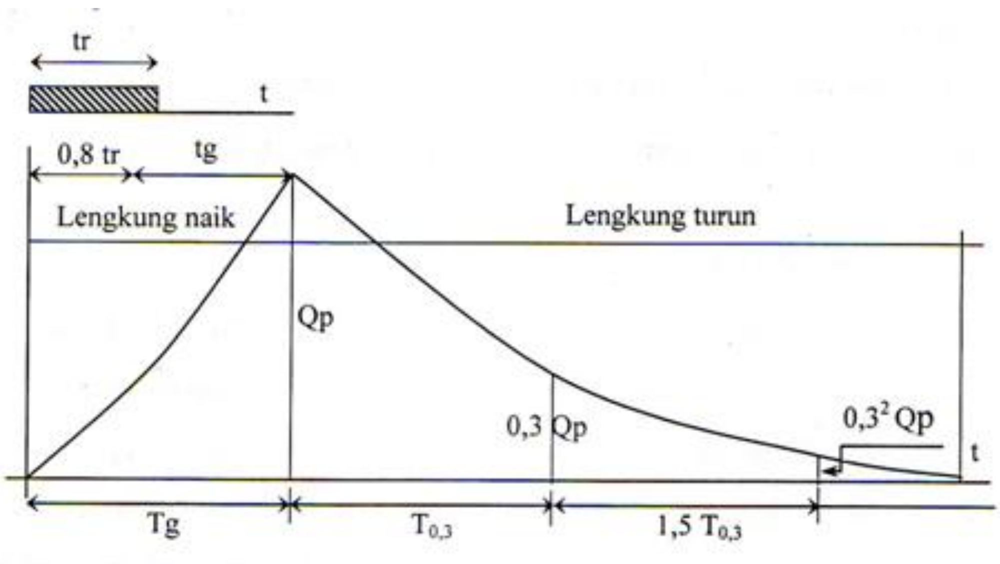

Figure 2. Nakayasu method

The Nakayasu hydrograph formula as follow:

Curved up, $0 \le t \le Tp$, where $Qt = \left(\frac{t}{Tp}\right)^{2,4} x\ Qp$

Curved down, $Tp < t \le (Tp + T_{0,3})$,

where $Qt = Qp\ x\ 0{,}3^{\left[\frac{t - Tp}{T_{0,3}}\right]}$,

$(Tp + T_{0,3}) \le t \le (Tp + T_{0,3} + 1{,}5T_{0,3})$,

for $Qt = Qp\ x\ 0{,}3^{\left[\frac{t - Tp + 0{,}5T_{0,3}}{1{,}5T_{0,3}}\right]}$,

and $t > (Tp + T_{0,3} + 1{,}5T_{0,3})$,

where $Qt = Qp\ x\ 0{,}3^{\left[\frac{t - Tp + 1{,}5T_{0,3}}{2T_{0,3}}\right]}$

The time series data of runoff discharge from 2001 to 2012 will be used to estimate the water stock for watershed of Asahan River. Inflow discharge index is defined as the ratio between the flood discharge that occurs reduced with minimum discharge at interval period between the maximum with the minimum discharges as the formula:

$$IQ = \frac{Qt - Qmin}{Qmax - Qmin}$$

Where, I_Q = inflow discharge index, Q_t = flood discharge, Q_{min} = minimum discharge causes flooding, and Q_{maks} = maximum discharge causes flooding.

3. Results and Discussion

The results of the analysis of rainfall and return period is calculated based on the Gumbel method. Rainfall tends to increase in 25-year return period frequency factor K for the Gumbel distribution method greatly affect the greater the frequency factor, the greater rainfall. Significant difference from the results of rainfall. This difference can be clearly seen in Fig. 3 where the Gumbel method based rainfall tends to be greater in the long period of re-precipitation compared with those obtained by other methods. Results Normal precipitation Method and Method of Log Pearson tend to be almost equal to the return period is short (<10 years). The results of the calculation of the Asahan River region flood discharge design is listed in Table 1 with Synthetic Unit Hydrograph calculations based on Nakayasu method. Results of the calculation of 5th Annual flood discharge obtained maximum flood discharge on the 4th Hour by 103.295m^3/dt is also is listed in Table 1.

The dominant factor that cause flooding is the rain characteristics. High intensity rainfall which can cause watershed runoff hydrograph that would cause flooding of the river in its path. Analysis of the results of the maximum flood discharge results in frequent damage to buildings in the surrounding area. Predicted flood discharge plan is based on rainfall data from rainfall recording stations around the catchment area in river Asahan. Distribution Asahan river flood discharge can be seen in Fig. 4.

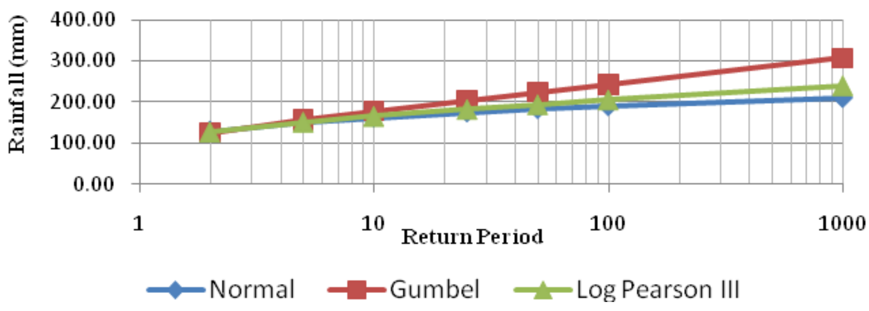

Figure 3. The relationship between the design rainfall and return period

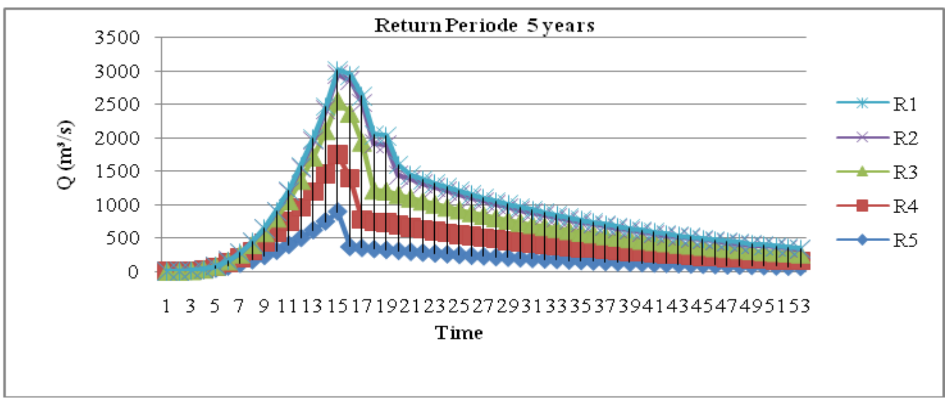

Figure 4. Distribution debit banjir sungai Asahan

Table 1. Design of flood discharge 5 Year Period

Hour	UH	**Rain in Hours**					**flood discharge**
(Hour)	(m^3/s)	R1 21.03 mm/Hour	R2 24.27 mm/Hour	R3 27.40 mm/Hour	R4 16.38 mm/Hour	R5 3.74 mm/Hour	Q m^3/s
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
0	0.000	0.000					0.000
1	0.095	2.001	0.000				2.001
2	0.502	10.560	2.309	0.000			12.868
3	1.329	27.943	12.185	2.607	0.000		42.735
4	2.650	55.736	32.242	13.758	1.558	0.000	103.295
5	4.527	95.218	64.310	36.407	8.225	0.356	204.516
6	7.012	147.487	109.867	72.617	21.764	1.878	353.612
7	10.151	213.513	170.177	124.058	43.410	4.971	556.128
8	13.986	294.175	246.361	192.158	74.160	9.915	816.769
9	18.555	390.276	339.432	278.183	114.869	16.938	1139.698
10	23.893	502.562	450.318	383.276	166.294	26.236	1528.685
11	30.034	631.731	579.879	508.484	229.117	37.981	1987.191
12	37.009	778.439	728.920	654.780	303.965	52.329	2518.432

To get the index flood predetermined classification of extensive inundation adjusted to the classification of the flood discharge that caused widespread inundation is to obtain two classifications, namely: widespread inundation between average and maximum, middle watershed inflow discharge index can be seen in Table 2.

Table 2. Middle Index watershed inflow discharge

Return Period	Q_{maks}(m^3/s)	Q_{min}(m^3/s)	Q_t(m^3/s)	inflow discharge index
2	1116.92	0.23	35.66	0.03
5	2156.134	0.43	51.31	0.02
10	2772.894	0.70	61.87	0.02
25	3584.497	0.65	75.41	0.02
50	4195.37	0.76	85.58	0.02
100	4850.74	0.88	85.58	0.02
1000	7138.87	1.30	95.78	0.01

The calculations show that the peak discharge rate from Nakayasu method ranged from 10% to 20% of the discharge Rational. Based on the above results. it turns out that the flood peak discharge can be calculated from the Nakayasu Method by simply multiplying the peak flood discharge of the Rational Method with constant 0.1 to 0.2. The results of the previous description shows the relationship between the design rainfall Hour R1, R2, R3, R4 and R5. Thus increasing flood discharge varies depending on the length of the rainy obtained. Maybe there is a link between the watershed area, length of the river, and magnitude of peak flows. Significant in the calculation of the discharge by any method because of the length of the rain is one of the parameters in the calculation of the discharge process. The next step is the calculation of inflow discharge index, the index decreased inflow discharge a minimum flow with the boundary between the maximum with a minimum flow that has been in the can as shown in Table 3. In Table 3, middle river basin flood index to 34.22 km^2 wide and 49 miles long return period of 2 years at the maximum flood discharge of 77.06 m^3/s, indeks input flood of 1.56. While the 100-year return period the maximum flood discharge of 187.98 m^3/s, indeks flood input of 1.24 Calculation results show that the value of the index flood discharge the higher the index the smaller.

Downstream Asahan river flood events always happen several times in 1 year flood one of the reasons is because of its inability to hold the Asahan river with the rain water discharge, as shown in Table 4.

Table 3. Middle River Basin Flood Index for A = 34.22 km^2. L = 49 km

Retrun Period	Q_{maks} (m^3/s)	Q_{min} m^3/s)	Q_t (m^3/s)	Discharge Index Inflow
2	77.06	0.35	119.90	1.56
5	105.22	0.49	149.98	1.43
10	125.04	0.58	169.89	1.36
25	150.30	0.70	195.06	1.30
50	169.16	0.79	213.72	1.26
100	187.98	0.88	232.25	1.24
1000	250.64	1.17	293.48	1.17

Table 4. Maximum discharge downstream watershed

Return Period	Q_{maks} A (m^3/s)	Q_{maks} B (m^3/s)	Q_{maks} C (m^3/s)	Q_{maks} D (m^3/s)	Q_{maks} rerata
2	318.337	319.012	1059.831	401.968	524.787
5	434.689	435.620	1447.229	548.899	716.6093
10	516.568	517.664	1719.797	652.278	851.5768
25	620.908	622.226	2067.176	784.030	1023.585
50	698.841	700.324	2326.635	882.437	1152.059
100	776.568	778.216	2585.412	980.585	1280.195

A=141.37 km^2 B=141.67 km^2 C=470.66 km^2 D=178.51 km^2

From Table 4. Asahan river downstream watershed has an area of 141.37 km^2 2-year retrun period in the flood discharge downstream of the discharge obtained by 318 337 m^3/s. The area of 141.67 km^2 calculations flood return period of 2 years in the downstream area. in may flood at 319 012 m^3/s. Area of 470.66 km^2 for flood discharge obtained at 1,059,831 m^3/s. for 178.51 km^2 large flood discharge 401.968 m^3/s. so that the average flood discharge 524.787 m^3/s. The results of the calculation of flood discharge indicates that the average value of the maximum discharge downstream in the watershed there are wide, the more extensive the higher flood discharge. Based on the results obtained in 100 year return period flood peak discharge is 1280,195 m^3/ s.

Downstream Asahan river has a very important role in the regulation and flood control. In flood control, always required needed information in the form of characters flood flood discharge, length of time up to the top, long inundation and flood flow volume [7]. For the average incidence of flooding in the downstream can be seen in Fig. 5.

In Fig. 5, calculation of the average index in the downstream flooding, it is known that the incidence of flooding in downstream not because of high rainfall intensity alone but with lower levels of intensity that can occur due to the effects of flooding in the upstream. For the calculation of the index with the results of calculation of the index flood in downstream averages obtained at 0.3.

4. Conclusions

Ability Asahan river of middle Asahan river flood index to 34.22 km^2, wide 49 km long return period 2 years of maximum flood discharge was obtained for 77.06 m^3/s with Index input floods at 1.56. Return period of 100 years the maximum flood discharge obtained at 187.98 m^3/s with Index input floods of 1.24. Asahan River downstream area of 141.37 km^2, 2 year return period flood discharge of 318.337 m^3/s. Return period of 100 years the mean flood discharge is 1280,195 m^3/s. Appropriate conditions Asahan river, for a period of 5 years flood index average of 0.33, the maximum flood discharge 1447.229 m^3/s. Index inflow discharge at 1.43 with the maximum inflow discharge 105.22 m^3/s area of 34.22 km^2. Hydrology study on the pattern of rainfall as the cause of the flood discharge is an indicator of the index discharge that contributes to the flooding.

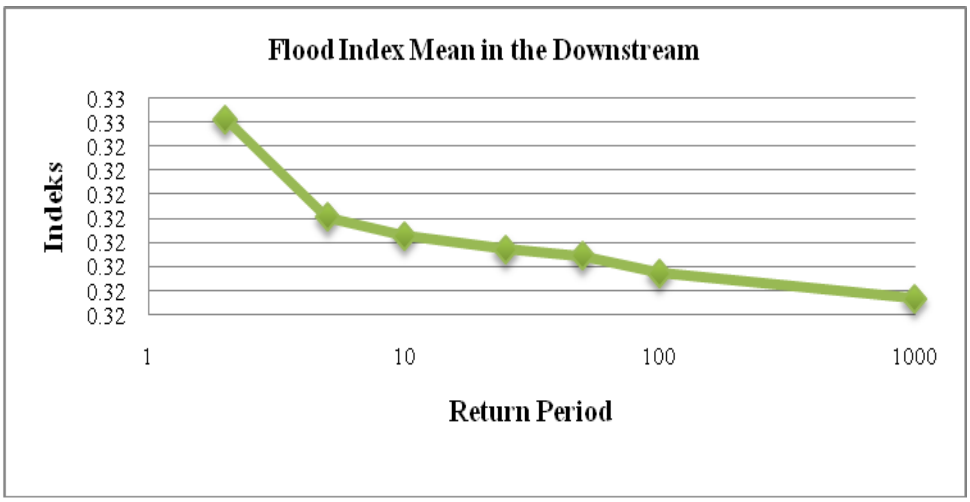

Figure 5. Flood Index Mean in the Downstream

ACKNOWLEDGEMENTS

The authors are grateful to Prof. Dr. Retno Widhiastuti as the chairman of the Doctoral Program PSL Universitas Sumatera Utara (USU) for the motivation and advice, so that almost the completion of my dissertation writing. Thanks also goes to the Dean of the faculty UNIMED Engineering Prof. Abdul Hamid K.M.Pd, the chairman research institutes Universitas negeri Medan (UNIMED) Prof. Dr. Manihar Situmorang.

REFERENCES

[1] Ichwana., Nasution I. and Sumono. 2013. Determining groundwater recharge from stream flow with seasonal recession method. Aceh International Journal of Science and Technology. 2 (1): 8-16

[2] Siswoyo. H. 2003.Optimasi Penggunaan Lahan dalam Pengelolaan DAS dengan Pendekatan Aspek Hidrologi berdasarkan teori Hidrograf Satuan. Tesis. ITB

[3] Harahap. R. 2009. Statistik Hidrologi Danau Toba Menuju Eksploitasi PLTA Si Gura-Gura Eksploitasi PLTA Si Gura-Gura Jurnal FT.UISU Vol 13/No1/ISSN 1410-4520 Medan

[4] Suradi. M., Fourie A. 2014. The Effect of Rainfall Patterns on the Mechanisms of Shallow Slope Failure. Aceh International Journal of Science and Technology. 3(1): 1-18.

[5] Maxwell. O. 2014. Hydrological Data Banking for Sustainable Development in Nigeria: An Overview. Aceh International Journal of Science and Technology. 2 *(2): 59-62*

[6] Harahap. R. 2012. Study Analysis of Flood Discaharge on the Aplication of Statistik in Rainfall for Utilization of Asahan River. Prosiding International Conference on REDSTAR; Medan 23 Juni 2012. Danau Toba International Hotel Medan ISBN 978-979-602-18199-0-6 ITM. hlm 66-84.

[7] Sobriyah dan Sudjarwadi, 2000, Penggabungan Metode O'Donnel dan Muskingun-Cunge Untuk Penelusuran Banjir Pada Aliran Sungai, Media Teknik, Fakultas Teknik UGM, No.4 th XXII, Edisi November.