Analysis of Flood Flow of Ketibung Catchment Area Using HSS Nakayasu, Limantara and Snyder Methods

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Abstract. Ketibung catchement area administratively located at Southern Lampung and Eastern Lampung districts. Ketibung river upstream is Ketibung dam that administratively located at Talang Baru village Sidomulyo districts Eastern Lampung district. Ketibung river has a variatif wide from upstream to downstream, river's wides at the upstream approximately ± 8,5 m, wides at the middle stream approximately ± 6,8 m and at the downstream approximately ± 7,2 m, with the catchement area extensive approximately 315 km2. At these areas hidrology data are not avaliable, to decrease unit hidrograf, synthetic hidrograf unit is made according to physical characteristic of Ketibung catchement area. Using HSS Nakayasu, Limantara and Snyder methods that will be used as flow at river infrastructures planning for the flood management. From these three methods, for the biggest design flood is using Snyder method (Q25 : 653,72 m³/second), for Limantara Method (Q25:416,45 m³/second) and Nakayasu (Q25 : 519,40 m³/second). For HSS Limantara, the top time is happened at (TP:4,91) with top flow (Qp:7,813 m³/second), while HSS Nakayasu has the same top time at (TP:4,91) with top flow (Qp:11,5 m³/second) and HSS Snyder top time happened at (Tp;5,39) with top flow (Qp:10,80 m³/second).
Keywords : Ketibung catchement area, HSS Nakayasu plan debit, HSS Limantara, HSS Snyder

1. Introduction

1.1 Background

Rainfall, river length, river slop and area in a catchment area are some factors that can effect flood. Administratively Ketibung catchment area located between South Lampung and East Lampung. Ketibung river has variatif widths from upstream to downstream, river width at upstream are about 8,5 m, width at middlestream are about 6,8 m and at downstream are about 7,2 m, with river length of 46 km and catchment area of 315 km². To reduce the risk of damage because of flood, flood management is neeeded. Flood management planning in a catchment area can be done if design flood flow is known. Hidrograf unit is a method that can be used to calculate flood flow. But because of data insufficient that are needed to reduce hidrograf to unit are very difficult to obtain, there for analysis of synthetic hidrograf unit is needed. The Research of Ketibung river Flood flow is using Hydrograf Synthetic Unit (HSU) Nakayasu, Limantara and Synder.

1.2 Problem Formulation

For flood flow planning at Ketibung river that using data limitation, calculation using Hydrograf Synthetic Unit method are needed.

1.3 Problem Limitations

1. Hidrology analysis using maximum daily for 10 – 20 years from 3 stations.
2. Hydrograf Synthetic Unit that are usedis HSS Nakayasu method, HSS Limantara, dan Snyder.
3. Datas that are used in design flood analysis are secondary datas from rain posts that has influence at Ketibung cachment area.
4. Desain flood flow that are used are Q5, Q10, Q25.

1.4 Purpose

a. The purpose for this research is to obtain design flood scale that can be used for water building planning around Ketibung catchment areas.

b. The purpose for this research is to obtain comparison of flood flow calculation result between Nakayasu method, Limantara method, dan Snyder method that are drawn ini Hidrograf Synthetic unit graphic.

1.5 Hydrology Analysis

Hydrology analysis in general term are one part of water resource development planning. The definition is that informations and scales that are used in hydrology analysis are important input for the next analysis. Size and building character as the means in water resource utilization are depends on the purpose of the development adn infomations that are gain from hydrology analysis.

1.6 Average rainfall Distribution

To get an idea of the distribution of rain across the selected Rainwater Stream area that is considered to represent the condition of the study area. The selected rainfall station are the stations that re within catchment areas coverage. To determine the average rainfall area of each rain station can be used several methods Thiessen and Arithmetic Method. Parameter Statistics In the analysis of hydrological data required numerical measures that characterize the data. The parameters used in the analysis of the data arrangement of a variable are called statistical parameters (Triatmodjo, 2008).

The statistical parameters used in the analysis of hydrological data are: average count, standard, coefficient of variation, slopness (coefficient of skewness) and kurtosis coefficient. The opportunity distribution function used is: Normal distribution, Gumbel distribution, Normal Log distribution, Pearson Log distribution III.

1.7 Matched Test

Matched Test The matching test is intended to assess whether a particular distribution type frequency curve can represent the distribution of observational data. The matching test was performed by Smirnov- Kolmogorov test (Triatmodjo, 2008).

1.8 Flood Flow Planning

Flood flow planning is the highest flow that could be occured at the corresponded river. There are several methods to calculate flood flow. The method used in a location is more determined by the availability of data. The commonly used method is the flood hydrograph method and the rational method. (Suripin, 2003).

1.9 Hydrograph Unit

Hydrograph Unit is adalah presentation between one element of the flow with time. Hidrograf units are direct run off hydrograph generated by effective rainfall that occurs evenly across the watershed and with fixed intensity within a set time unit.

1.10 Nakayasu Flood Hydrograph

To analyze the design flood discharge it must first be made the flood hydrograph on the river in question The parameters affecting the hydrograph unit are :

1. Grace period from start of rain to peak hydrograph (*time to peak magnitude*)
2. The grace period from the point of rain to the point of hydrograph weight (*time lag*)
3. Hydrograph time limit (*time base of hidrograf*)
4. Area of drainage area
5. length of the longest channel
6. run-off coefficient

Calculation of hydrograph units in this study used "*Shynthetic UnitHydrografh DR. Nakayasu*" method

$$Qp = C * \frac{1}{36} * A * \frac{Ro}{(0.3 * Tp + T_{0.3})} \quad ....(1)$$

To determine Tp and T0.3 used the formula:

$Tp = Tg + 0.8 * Tr$

$T0.3 = \alpha * Tg$

Tg is calculated by formula :

Tg = 0.40 + 0.058 * L, for L > 15 km

Tg = 0.21 * L0.70, for L < 15 km
Price α has the following criteria :
1. For the regular flow region the price α = 2
2. For the slow rising parts of the hydrodgraph and the chart rapidly decreases the price of α = 1.5
3. For fast hydrograph riding section and slow down part of the price α = 3
To determine the parameters used formula approach as follows :
T0.3 = 0.47 (A*L)0.25
T0.3 = α * Tg
From the two equations above then the value of α can be searched by the following equation:

$$\alpha = \frac{0.47 * (A * L)^{0.25}}{Tg} \qquad ....(2)$$

However, it is not possible to take a varied α price to get hydrograph in accordance with the results of observation. The unit hydrograph equation is as follows :
1. On the ascending curve (*rising line*) 0 < t < Tp 2.4 Tp

$$Qt = Qp * \left[\frac{t}{Tp}\right]^{2.4} \qquad ....(3)$$

2. On the descending curve (*recession line*)
- Tp < t < (Tp + T0.3)

$$Qt = Qp * 0.30^{\left[\frac{t - Tp}{T_{0.3}}\right]}$$

$$(Tp + T_{0.3}) \leq t \leq (Tp + T_{0.3} + 1.5\ T_{0.3})$$

$$Qt = Qp * 0.3^{\left[\frac{t - Tp + 0.5 * T_{0.3}}{1.5 * T_{0.3}}\right]}$$

$$t \geq (Tp + T_{0.3} + 1.5\ T_{0.3})$$

$$Qt = Qp * 0.30^{\left[\frac{t - Tp + 1.5 * T_{0.3}}{2 * T_{0.3}}\right]} \qquad ....(4)$$

1.11 Syntentic Hydrograph Unit (HSS) Limantara
There are 5 Cachment area parameter that are used in HSS Limantara, they are :
- Catchment Area wide (A)
- Main river Length (L)
- River length measured from nearest point with catchment area heavy point DAS (Lc)
- River slop (s)
- Roughness coefficient (n)
Top flow equation
Qp = 0,042 x A 0,451 x A 0,497 x Lc - 0,131 x n 0,168
Ascending curve equation :
Qn = Qp [(t/TP)]1,107
Descending curve equation :
QT = Qp x 10 0.175 (Tp-t)
1.12 Syntentic Hydrograph Unit (HSS) Snyder
Syntentic Hydrograph Unit model are

$$Tp = 0{,}75.Ct.(L.Lc)\ 0{,}3$$

$$Tr = \frac{tp}{5{,}5}$$

$$Tr = 2{,}75\frac{Cp.A}{Tp} \qquad \text{.....................(5)}$$

Where :
Tp : time log
Qp : top flow (m3/second)
Tb : Base time (hour)

Ct and Cp are coefficients that depend on unit and catchment are characteristics (Wilson, 1993). The coefficients Ct and Cp must be determined empirically, since the magnitude varies between regions with the other regions. In the metric system the magnitude of Ct is between 0.75 and 3.00, whereas Cp is between 0.90 to 1.40 (Soemarto, 1995). The value of Ct and Cp is obtained by Snyder for a number of catchment area in the Appalachian plateau of the United States, where if the Cp value is close to the largest value, the value of Ct will be close to the smallest value, and vice versa (Wilson 1993).

2. Research Methodology

2.1 Flowchart

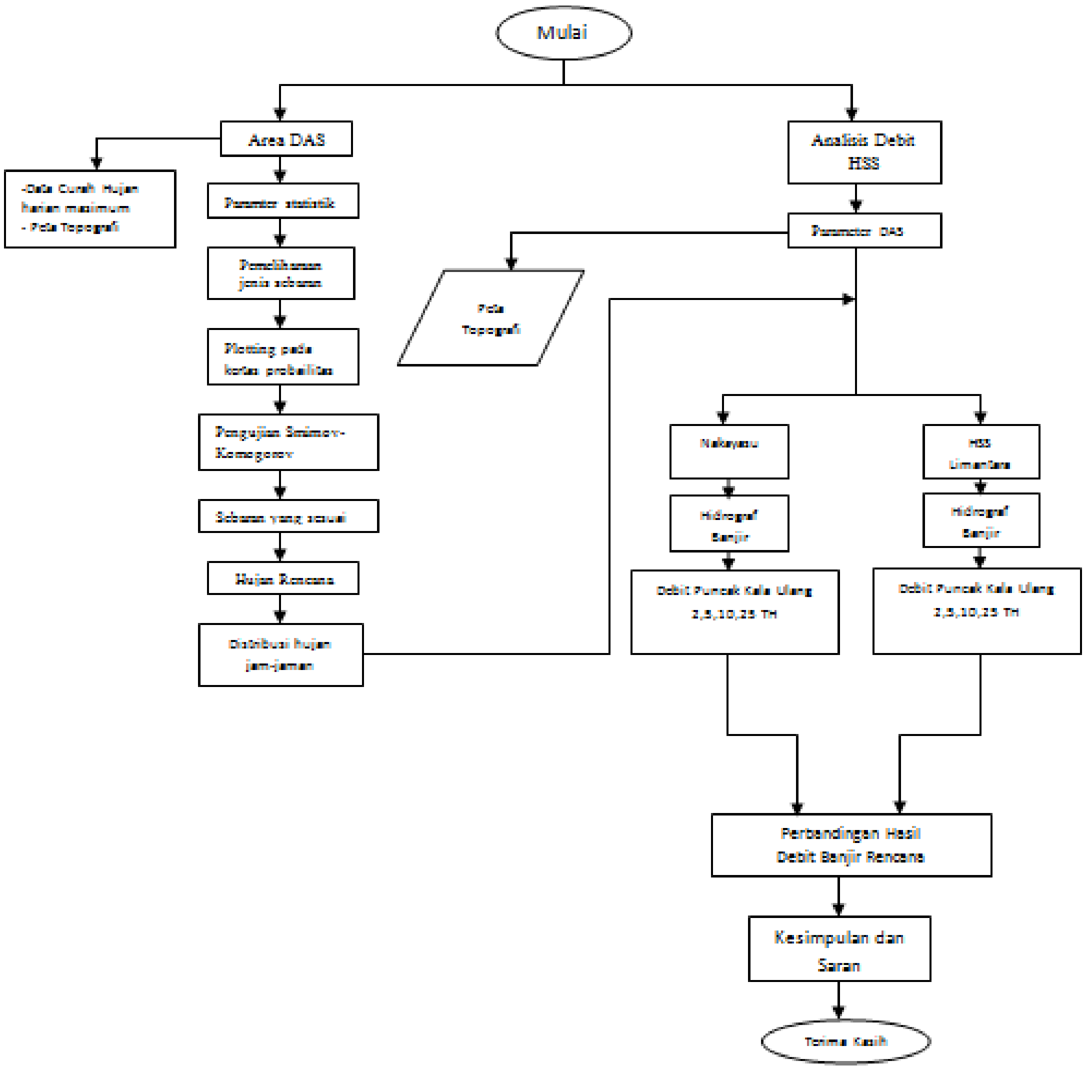

Figure 1. Flowchart

3. Results Analysis

Design rainfall analysis The maximum daily rainfall data used in this analysis is sourced from the Mesuji Sekampung River Basin Region with the 1995 – 2016 recording period. The observation station used is a station located within the study site. The stations in the Ketibung catchment area are Central Station, Jabung Station, Ketibung Station.

Tabel 1. Daily Rain Daily Maximum station of Rainfall River Basin Ketibung

No	TAHUN	STA R.127	STA R.019	STA R.233
1	1995	95,5	96,4	96,0
2	1996	92,00	96,00	47,50
3	1997	76,00	96,40	78,00
4	1998	96,00	112,20	70,60
5	1999	91,00	109,80	78,60
6	2000	111,50	94,20	47,80
7	2001	137,00	82,20	88,50
8	2002	191,00	73,00	43,10
9	2003	68,00	116,80	92,40
10	2004	96,00	95,30	90,50
11	2005	81,00	94,20	77,00
12	2006	65,50	90,40	90,60
13	2009	75,00	79,00	47,00
14	2010	191,50	97,00	51,00
15	2011	95,70	98,00	270,00
16	2012	84,16	66,00	65,00
17	2013	83,17	20,00	46,00
18	2014	75,50	52,75	30,00
19	2015	90,10	187,00	65,00
20	2016	81,00	175,00	33,00

From the calculations that have been done with the conditions mentioned above, then selected distrubusi Log Pearson Type III. To ensure the selection of the distribution it is necessary to compare the results of statistical calculations by plotting the data on the probability paper and the Smirnov- Kolmogorov test.

Tabel 2. Review of Conformity of Distribution Type Based on Statistical Parameters

Jenis Sebaran	Syarat	Hasil Hitungan
Sebaran Normal	Cs ≈ 0	-1,513
	Ck ≈ 3	4,761
Sebaran Log Normal	Cs ≈ 3 Cv	-1,513
	Cs/Cv ≈ 3	0,083
Sebaran Log Person III	yang tidak termasuk sebaran diatas	

(Sumber: Perhitungan)

3.1 Matching Test

Selection of Distribution Types Based on Statistical Parameters The data parameters used to be able to determine the exact type of distribution are divided into 5 major sections of measurement, namely: the measurement of central tendency (mean) or the average of the count, standard deviation, skewness (skewness coefficient) coefficient of variation, and coefficient of keresingan (kurtosis coefficient). The determination of the appropriate distribution type of data is done by matching the statistical parameters with the terms of each type of distribution. From the calculations that have been done with the conditions mentioned above, then selected distrubusi Log Pearson Type III. To ensure the selection of the distribution it is necessary to compare the results of statistical calculations by plotting the data on the probability paper and the Smirnov- Kolmogorov test. The test method used is Smirnov-Kolmogorov and Chi Quadrat

3.2 Smirnov-Kolmogorov Method

Based on the available data, the value of n is 20, so that the critical price obtained Smirnov-Kolmogorov with the degree of confidence 0.05 is 0.29. Smirnov-Kolmogorov test results can be seen in the tables below

Tabel 3. *Smirnov-Kolmogorov Test*

No.	Tahun	X	Log X	G	m	$S_n(X)$	Pr	Px (X)	D
									$\mid P_X(X) - S_n(X) \mid$
1	2015	164,78	2,2169	1,6867	1,0000	0,0476	-0,1941	1,0019	-0,9543
2	2016	151,68	2,1809	1,4639	2,0000	0,0952	-0,0966	1,0010	-0,9057
3	2011	109,59	2,0398	0,5898	3,0000	0,1429	0,2857	0,9971	-0,8543
4	2003	108,12	2,0339	0,5534	4,0000	0,1905	0,3415	0,9966	-0,8061
5	1998	105,17	2,0219	0,4790	5,0000	0,2381	0,3776	0,9962	-0,7581
6	1999	103,42	2,0146	0,4338	6,0000	0,2857	0,4009	0,9960	-0,7103
7	2010	99,89	1,9995	0,3403	7,0000	0,3333	0,4490	0,9955	-0,6622
8	1995	94,36	1,9748	0,1872	8,0000	0,3810	0,5280	0,9947	-0,6138
9	2004	93,07	1,9688	0,1504	9,0000	0,4286	0,5294	0,9947	-0,5661
10	1997	91,16	1,9598	0,0946	10,0000	0,4762	0,5474	0,9945	-0,5183
11	2000	90,16	1,9550	0,0649	11,0000	0,5238	0,5570	0,9944	-0,4706
12	1996	89,84	1,9535	0,0553	12,0000	0,5714	0,6847	0,9932	-0,4217
13	2005	89,75	1,9530	0,0526	13,0000	0,6190	0,6851	0,9931	-0,3741
14	2006	86,37	1,9363	-0,0508	14,0000	0,6667	0,7011	0,9930	-0,3263
15	2001	85,99	1,9345	-0,0625	15,0000	0,7143	0,7974	0,9920	-0,2777
16	2002	79,77	1,9018	-0,2645	16,0000	0,7619	0,8138	0,9919	-0,2300
17	2009	74,50	1,8722	-0,4483	17,0000	0,8095	0,8286	0,9917	-0,1822
18	2012	66,23	1,8211	-0,7646	18,0000	0,8571	0,8541	0,9915	-0,1343
19	2014	51,92	1,7154	-1,4193	19,0000	0,9048	0,9070	0,9909	-0,0862
20	2013	27,37	1,4372	-3,1419	20,0000	0,9524	1,0461	0,9895	-0,0372
Sumber : Hasil Perhitungan								D Maks.	**-0,0372**

Average Log x : 1,9445
Standard Deviation (S) : 0,1615
D Maks. : -0,037
Then the theoretical distribution used to determine the distribution equation is acceptable.

3.3 Chi Kuadrat Distribution test Method

Tabel 4. *Chi Kuadrat*

No.	Nilai Batas Sub Kelas					Jumlah Data		$(OF - EF)^2$	$(OF - EF)^2 / EF$
						OF	EF		
1	X		<		68,147	3	4	1,000	0,250
2	68,147	<	X	<	85,803	3	4	1,000	0,250
3	85,803	<	X	<	103,481	8	4	16,000	4,000
4	103,481	<	X	<	119,542	4	4	0,000	0,000
5	X		>		119,542	2	4	4,000	1,000
Jumlah :						20	20	22,000	5,500

(Sumber: Perhitungan)

X2Cr value of analysis <X2Cr table 4.10 (5,50 <5,991), then to calculate the rainfall plan can use the Pearson Type III Log distribution is acceptable.

Tabel 5 Repeat periode T year Design Rain

Kala Ulang	X (mm)
2	96,279
5	119,542
10	128,334
20	133,905
25	135,048
50	138,071
100	140,055

Sumber: Perhitungan)

3.4 Flood Debit Analysis Plan HSS Nakayasu

The steps and formulas used in the work with the Nakayasu HSS method are as follows :
Calculate the concentration time (Tg) Tg= 0,21 L0,7
0,4 + (0,058*L) = 3,07 hours
Calculate rain unit time (Tr)
Tr= 0,75 Tg
0,75 x (3,07) = 2,30 hours
Calculate rain unit time from rain surface to the top flood (Tp)
Tp= Tg + 0,8 Tr
3,07 + 0,8 x (2,30) = 4,91 hours
Calculate the time needed for flow formulas and flow until become 30% from top flow (T0,3)
T0,3= α x Tg
2 x 3,07 = 6,14 hours

Tp + T0.3 + 1.5 T0.3 = Tp + 2.5T0.3 = 20,25

Calculate the flood top flowMencari debit puncak banjir

$$Qp = \frac{C\,A\,Ro}{3{,}6\,(0{,}3\,Tp + T_{0,3})} = 11{,}5\ m^3/\ second$$

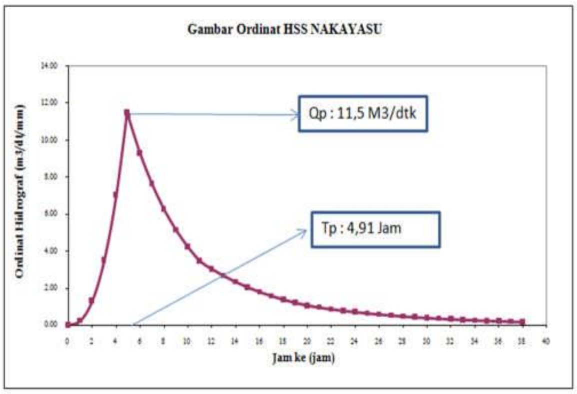

Figure 2. Graph Ordinat Nakayasu

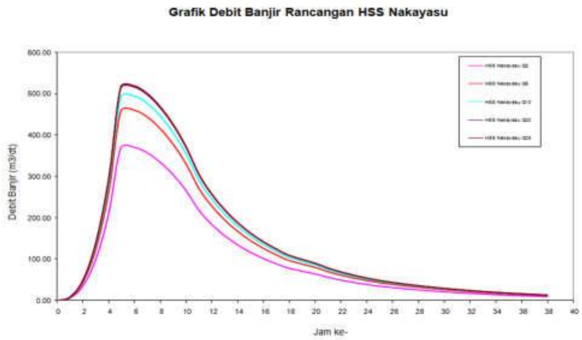

Figure 3. Hydrograph Flood Method HSS Nakayasu

From the figure of Ordinat HSS Nakayasu above can be obtained that the peak debit time Qp: 11.5 M^3 / s occurs at hours to Tp: 4.91 hours. Furthermore, for the results of hydrograph flood calculations for the return period 2, 5, 10, 20, and 25 can be seen in the following figure.

Tabel 6 Comparison of Flood Debit Plan of HSS Nakayasu Method

No.	Kala Ulang (tahun)	Debit Banjir (m^3/det)
1	2	370,38
2	5	459,80
3	10	493,59
4	20	515,01
5	25	519,40

(Sumber : Hasil Perhitungan)

3.5 HSS Limantara

The steps and formulas used in the work with the Limantara HSS method are as follows:

Top flow equation

Qp = 0,042 x A 0,451 x A 0,497 x Lc -0,131

x n 0,168

Qp = 0,042 x 3.15 x 0,451 x 3.15 x 0,497 x

3.15 x -0,131 x n 0,168

Qp = 7,813 m^3/second

Calculate ordinat Hidrograph Ascending curve equation :

Qn = Qp [(t/TP)]1,107

Qn = 7,813 (t/4,91)1,07

0 < t < 4,91

Descending curve equation :

QT = Qp x 10 0.175 (Tp-t)

QT = 7,813 x 10 0,175 (Tp-t)

t > 4,91

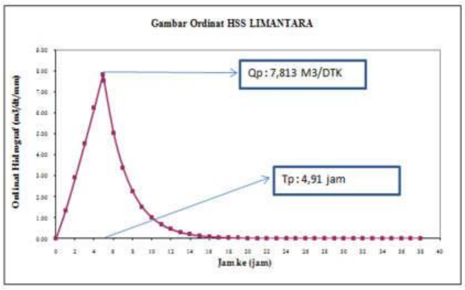

Figure 4. Ordinat HSS Limantara Picture

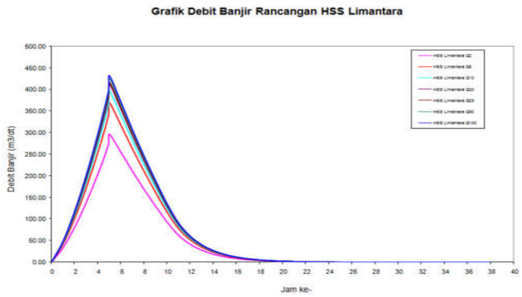

Figure 5. Flood Hydrograph HSS

From the Ordinate HSS Limantara Picture above can be obtained that the peak debit time Qp: 7.813 M³ / s occurs at hour to Tp: 4.91 hours. Furthermore, for the results of hydrograph flood calculations for the return period 2, 5, 10, 20, and 25 can be seen in the following figure.

Tabel 7 Comparison of Flood Debit Plan of Limantara HSS Method

No.	Kala Ulang	Debit Banjir
	(tahun)	(m^3/det)
1	2	296,99
2	5	368,67
3	10	395,76
4	20	412,93
5	25	416,45

3..6 HSS Snyder

The steps and formulas used in the work with HSS Snyder method are as follows :

Time from the center of gravity to the top of the hydrograph

Tr : 6 hours

Tp : Ct (L.Lc)n

Tp : 4,89 hours

Tp' : tp + 0,6 tr (tr taken 1 hour)

Tp': 5,39

T = 0,89 hour > Tr

Tp = 4,87 hours

Tp = t'p + 0,50 *Tr

Tp=5,37 hours

Qp= 0,03

Top discharge hydrograph

Qp = qp * A

Qp = 0,03 x 315

Qp = 10,80 m³/second

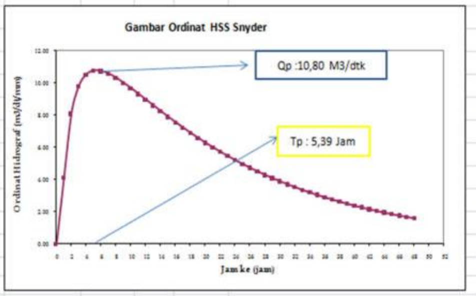

Figure 6. Picture Ordinat HSS Snyder

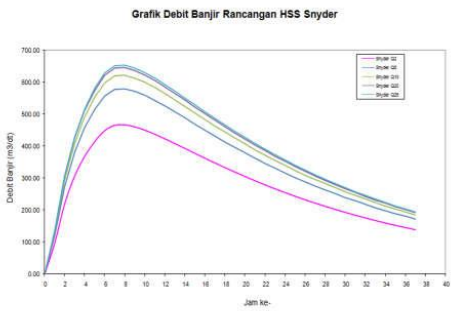

Figure 7. Flood Hidrograph HSS Snyder Method

From Figure Ordinat HSS Snyder above can be found that the peak debit time Qp: 10.80 M^3 / s occurs at hours to Tp: 5.39 hours. Furthermore, it can be seen the results of hydrograph flood calculations for return period 2, 5, 10, 20, and 25

Tabel 8 Comparison of design flood flow HSS Snyder Method

No.	Kala Ulang	Debit Banjir
	(tahun)	(m^3/det)
1	2	466,05
2	5	578,66
3	10	621,21
4	20	645,97
5	25	653,72

4. Conclusion

From the calculation result of the three methods, for the largest flood discharge plan using Snyder Method (Q25: 653,72 m3 / s) and for Limantara Method (Q25: 416,45m3 / s) and Nakayasu (Q25: 519,40 m3 /) The result is almost the same. For Limasan HSS the peak time occurs at hour (Tp: 4,91) with peak discharge (Qp: 7,813 m3 / s), while HSS Nakayasu peak time is same, occurs at hour (Tp: 4,91) with peak discharge (Qp: 11.5 m3 / sec) and HSS Snyder peak time occurs at hours (Tp: 5.39) with peak discharge (Qp: 10.80 m3 / s).

Tabel 9 Comparison of Design Flood Flow calculation

Repeat Period(Year)	Nakayasu Method	Limantara Method	Snyder Method
2	370,38	296,99	466,05
5	459,80	368,67	578,66
10	493,59	395,76	621,21
20	515,01	412,93	645,97
25	519,40	416,45	653,72