Study of Hydrograf Synthetic Unit Method of Nakayasu, Limantara and Snyder on Way Semah

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Abstract - Way Semah River is the longest river located in Pesawaran Regency. Way Semah Creek passes several villages such as Gedong Tataan, Kesugihan, Kagungan Ratu, Katon Country, Halangan Ratu, Negara Saka, and many other villages. The upstream area of the Way Way River is located on Mount Pesawaran, while the downstream of the Way Semah River goes to the river Way Sekampung. The purpose of this study is to find out the fluctuation picture of the rising and falling water flow in the Way Semah river, knowing the peak discharge and the length of flow time, in certain period. The purpose of this study is to analyze rainfall occurring in das way semah. know the fluctuation of the water flow with the hydrograph of nakayasu, Limantara, and Snyder methods, and comparH Limantara, strongly influenced by the slope of the river, the higher the elevation difference between the upstream and downstream of the river, the higher the Qp value, and the reverse is true, whereas for the Tp value is relatively the same. Keywords: Way Semah, HSU, Nakayasu, Limantara, Snyder

1. Introduction

Way Semah River is the longest river located in Pesawaran District. Way Semah's flow passes through several villages such as Gedong Tataan, Kesugihan, Kempungan Ratu, Katon Country, Ratu Hatu, Negarasa Saka, and many other villages. The upstream area of the Way River is located on Pesawaran Mountain, while the downstream of the Way Semah river to the river Way Sekampung is one of the subdases of the river Way Sekampung.Banjir that occurred on 29 - 04 - 2017, is a big flood. The floods inundated the settlements of residents in Kedondong sub-district up to the negrikaton and surrounding areas. The right type of flood control building in Sungai Semah River Basin should be adjusted to the amount of flood discharge occurring in a certain repeat period. This study, will analyze and calculate the flood discharge capacity that occurs using the HSU Nakayasu, Limantara and Snyder methods. Given the magnitude of the design debit on the Way Semah River, it can be beneficial for irrigation water supply, flood control and other needs.

2. Literature Review

2.1.Analysis of Hydrology

In general, hydrological analysis is an early part of development planning activities Water resources. The quantities obtained in the hydrological analysis are an important input in subsequent analysis. The dimensions and characteristics of hydraulic buildings as a means of utilizing water resources are highly dependent on the development objectives and information obtained from hydrological analysis.

2.2 Data of Rainfall

Rainfall data is data containing rainfall record from rain stations. Rain data can be from automatic or manual stations. Rain data from station automatically informs rain records every time continuously (continuous), this data is used for analysis of hourly rain distribution. From the available rainfall data it can be seen the height of the rain at the point being reviewed, which can then be used for rainfall flood analysis by using synthetic hydrograph.

2.3.Data Rainfall Fall Lost

Recorded rainfall data contains some empty data in some sta. Observation. Before the data is processed then first done charging the empty data. The missing data or data gaps of a raindrop post can, at any given moment, be filled with the help of data available on raindrop posts. For Method used is Method of Normal Ratio. The requirement to use this method is the average annual average rainfall of posters whose missing data should be known, as well as the annual high rainfall data and data on surrounding skirting posts. The height of rain on X scoreboard at the time of lost data can be estimated by the following formula:

$$d_c = \frac{1}{n}\left(d_c \frac{A_{nx}}{A_{na}} + d_b \frac{A_{nx}}{A_{nb}} + d_c \frac{A_{nx}}{A_{nc}} \ldots\ldots\ldots \right) \ldots\ldots\ldots\ldots\ldots\ldots (2.1)$$

with:

n = Many of the posters around the x used for search for data x

Anx = Average annual mean rainfall in x

Ani = The average annual mean rainfall in the posts about x used to search for missing data x.

2.4. Average Rainfall Distribution

To determine the mean rainfall the selected area from each rain station can be used several methods, such as Thiessen and Arithmetic Method.

2.4.1.MetodeTheissen

In Thiessen method it is assumed that rainfall data from a place of observation can be used for the drainage area around the place. Calculation method by making polygon and cut perpendicular to the middle of the connecting line of two rain systems, thus each RN burner station is located in a closed polygon region An. Comparison of polygon area for stations of magnitude An /

A. The calculation formula by Theissen Polygon is as

follows:

$$R = \frac{A_1R_1 + A_2R_2 + A_3R_3 + \ldots\ldots A_nR_n}{A_1 + A_2 + A_3 + \ldots + A_n} \ldots\ldots\ldots\ldots (2.2)$$

with:

R = Average rainfall area

R1, R2, ..., Rn = Rainfall at each rainfall post point

A1, A2, ..., An A1, A2, ..., An = Area of Influence of rain

station post each station

2.4.2.MetodeAritmetik

How to find the average rainfall in a flow area by means of Arithmetic Mean is one very simple way. This method is used in flat areas and many rainfall stations, assuming that in the area the nature of the rainfall is uniform (uniform distribution).

$$R = \frac{R_1 + R_2 + R_3 + \ldots\ldots R_n}{n} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.3)$$

with:

R = Average area rainfall (mm)

R1, R2, .., Rn = Rainfall in each rainfall post point

N = Number of rainfall heading

2.4.3. Test Consistency

In a typical series of rain observations there is an inconsistency. Test Consistency of data conducted on annual rainfall data intended to determine the existence of irregularities of rain data, so it can be concluded whether the data is feasible to be used in the calculation of hydrological analysis or not. Mismatch data can be caused by various things, including:

1.The change or disturbance of the environment around the place where the rain register station is installed, for example, obstructed by trees, located adjacent to tall buildings and so on.

2. Changing recording and burning systems.

3. Climatechange

4. Station location change.

This situation can be considered and corrected at the same time by describing an orthogonal graph called Mass Curve, a curve that compares the cumulative annual rainfall data of the station tested with the cumulative annual mean rainfall of the other stations.

The test to be used in this study is the Curve Test Dual Mass that aims to find out where the inconsistency of a row of data. The basis of this test is using Mass Curve. The way of improvement if there is data that is inconsistent with the formula as follows:

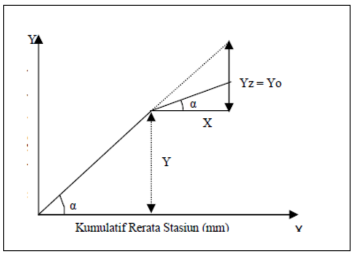

Figure 1. curve test

The way the calculation is as follows:

Tg α = Y / X = Yz / Xo

Tg αo = Yo / Xo

Hz = (Tg α / Tg αo). Ho

with:

Hz = Rainfall data that has been corrected

Ho = Yearly observed rainfall data

Tg α = Tilt after corrected

Tg αo = Initial slope

2.5. Rain Distribution of Hours of Time

In planning a water construct to estimate the hydrograph of the design flood by means of unit hydrograph (hydrograph unit) it is necessary to know first the spreading of hourly rain with a certain interval. In this study there is no observation data of hourly rain distribution so for the calculation used Mononobe formula, as follows:

$$R_T = \frac{R_{24}}{t}\left(\frac{t}{T}\right)^{2/3} \quad \text{.................................} \quad (2.4)$$

with:

RT = Mean rain intensity in T hour (mm / day)

R24 = effective rainfall in 1 day (mm)

t = rainfall concentration time (hours)

T = Start time of rain

Based on observations, rainfall in Indonesia is estimated for 6 hours / day. Then the calculation is:

$$R_T = \frac{R_{24}}{t}\left(\frac{t}{T}\right)^{2/3} = 0.55R24 \text{ ....} (2.5)$$

then the same way can be calculated for the next RT. After obtaining the distribution of rain-hour then can be calculated the ratio of rain distribution as follows:

$$Rt = t \cdot R_T - (t-1) \cdot R_{(T-1)} \text{ ....} (2.6)$$

with:

Rt = Rainfall at hour t

RT = mean rainfall intensity in T hour (mm / h)

t = rain time from start to hour t

R (t-1) = Average rainfall from start to hour to (t-1)

T = Start time of rain

Thus becoming :
R1 = 1. R1 - (1-1). R (1-1)
R1 = 2. R1 - (2-1). R (2-1)
R1 = 3. R1 - (3-1). R (3-1)
R1 = 4. R1 - (4-1). R (4-1)
R1 = 5. R1 - (5-1). R (5-1)
R1 = 6. R1 - (6-1). R (6-1)

2.6. Coeficient of Streaming

Analyze Net rainfall hourly Net rainfall is the total part that results in direct run-off. Assuming that the rain transpormation process becomes direct overflow following the linear and time invariant process, the net rainfall Rn can be expressed as follows:

$R_n = c \cdot R$ ……….................. (2.7)

with:
Rn = net rainfall
R = rainfall / rain intensity
C = flow coefficient

Characteristics of River Flow Area

Detailed information on DPS characteristics along with other parameters that affect its limitations. To illustrate the characteristics of irrigation areas is usually used an analysis based on:

1. Flow Area
2.Kerapatan Sungai

The shape of the usual stream area is expressed in the shape / shape coefficient (F) formulated as follows:

$$F = \frac{A}{L^2} \quad \text{..............................} \quad (2.8)$$

with:
F = coefficient of pattern
A = area of drainage (km2)
L = length of main river (km)

A large F value signifies the width of a large drainage area, indicating a long short-term flood with peaked peak discharge, and vice versa. The river density commonly expressed in the river density index is formulated as follows:

I = L / A ....(2.9)

with,
I = river density index
L = the total length of the river and its tributaries (km)
A = area of drainage (km2)

On the down curve ($t_p < t < t_{0,3}$) $Q_d > 0{,}3\ Q_p$

2.7. Synthetic Hydrograph (HSU) Nakayasu

The Nakayasu Synthetic Unit Hydrograph (HSU) is a way to get hydrograph flood design in a watershed. To create a flood hydrograph on the river, it is necessary to find the characteristics or parameters of the drainage region. The characteristics are:

a. Time from start of rain to hydrograph peak (time to peak magnitute).
b.Time of time from heavy rainpoint to hydrograph time (time log).
c. Hydrograph time-out (time base of hydrograph).
d. Area of drainage area.
e. The length of the main river channel (lenght of the longest channel).

Synonyms of Nakayasu Synthesized Unit Hydrograph:

$$Qp = \frac{C\ A\ Ro}{3{,}6\,(0{,}3\ Tp + T_{0,3})}\ (m^3 / dt) \qquad \text{.................(2.10)}$$

Where :
Qp = flood peak discharge (m3 / sec)
Ro = rain unit (mm)
Tp = time log from the start of the rain to the peak of the flood (hour).
T0,3 = time required by the discharge decrease, from peak discharge to 30% of peak discharge (hours). The formulas used in HSU Nakayasu are:
Flood Peak Discharge
Tp = tg + (0.8tt) > 75 ………………………..(2.11)
Tg = 0,4 +(0,0058L) untuk L > 15 Km………(2.12)
= 0.21L ^0,7 untuk L < 15 Km………….(2.13)
t0.3 = α x tg…………………………............. (2.14)
α =

$$\alpha = \frac{0{,}47\,(AL)^{0{,}25}}{Tg} \qquad \text{…………(2.15)}$$

Where :
Qp = flood peak discharge (m3 / sec),
A = area of river drainage (km2),
Re = effective rainfall (mm),
tp = time from start of flood to flood peak (hour),
t0,3 = time from flood peak to 0.3 x peak flood discharge (hour),
tg = lag time in the river stream (hour),
tr = the time unit of rainfall (hours),
α = coefficient of watershed characteristics,
L = length of main river (km).
On the rising curve (0 <t <tp)

$$Qa = Qp\,\left(\frac{1}{Tp}\right)^{2,4...} \qquad \text{.................(2.16)}$$

2.8 Flood Discharge Design

In determining the amount of flood discharge plan is done by transforming the rainfall data into input data.

$$Qd = 0{,}3\ Qp \wedge \left(\frac{t - Tp}{T_{0,3}}\right)\text{.................}$$

$$0{,}3\ Qp > Qd > 0{,}3^2\ Qp$$

$$Qd = 0{,}3\ Qp \wedge \left(\frac{(t - Tp) + (0{,}5 . T_{0,3})}{1{,}5\ T_{0,3}}\right)\text{..}$$

$$0{,}3^2\ Qp > Qd$$

$$Qd = 0{,}3\ Qp \wedge \frac{(t - Tp) + (0{,}5 . T_{0,3})}{2\ T_{0,3}}\text{)...} \qquad \text{...........(2.17)}$$

Synthetic Hydrograph (HSU) Limantara is referred to as the typical HSU of Indonesia considering the location of the research conducted on the watersheds in Indonesia.HSU is made, based on studies that have been conducted using 5 supporting data, the studied watershed has an area <5000 km2 Limasan HSU Model Parameter watershed used in HSU Limantara there are 5 kinds, that is:
- Watershed Area (A)
- The length of the main river (L)
- The length of the river is measured to the point closest to the watershed (Lc)
- The slope of the river (s)
- coarse coefficient (n)

Limantara HSU can be applied to watersheds that have similar characteristics with watersheds in the study sites. The specifications of HSU Limantara techniques are presented in the following table:

Table 1 Technical Specification of HSU Limantara

Description	Notation	Unit	Range
Width of River Basin	A	Km2	0,325 – 1667,500
The length of the main river	L	Km	1,16 – 62,48
Distance of outlet	Lc	Km	0,50 – 29,386
The main river slope of	S	-	0,00040 – 0,12700
Rough coefficient	N	-	0,035 – 0,070
Bobot Luas hutan	Af	%	0,00 - 100

The peak discharge demo of HSU Limantara

$$Qp = 0,042 \times A^{0,451} \times L^{0,497} \times Lc^{-0,131} \times n^{0,168} \quad ....(2.18)$$

with:
Qp = peak discharge of unit hydrograph flood (m3 / dt / mm)
A = broad watershed (km2)
L = length of main river (km)
Lc = long river daro outlet to the point closest to the watershed
s = the slope of the main river
n = coefficient of roughness of watershed
0.042 = coefficient for unit conversion (m0,25 / dt)
The equation of the curve rises

$$Qn = Qp \left[\left(\frac{t}{Tp}\right)\right]^{1,107} \quad ....(2.19)$$

with:
Qn = discharge at the equation of the rising curve (m3 / dt / mm)
Qp = peak discharge hydrograph unit (m3 / dt / mm)
t = hydrograph time (clock)
Tp = hydrograph rise time or time reaches the top of the hydrograph (clock)
The equation of the curve falls

$$Qt = Qp \times 10^{0,175\,(Tp-t)} \quad ....(2.20)$$

with:
Qt = the discharge at the equation of the down curve (m3 / dt / mm)
Qp = peak discharge hydrograph unit (m3 / dt / mm)
Tp = hydrograph rise time or time reaches the top of the hydrograph (clock)
t = hydrograph time (clock)
0.175 = coefficient for unit conversion (dt-1)

Synthetic Hydrograph (HSU) Snyder. To obtain a unit hydrograph as described in the above procedure, good data is available, ie AWLR data, debit measurement data, daily rain data, and rain hour data. The problem is that for various reasons this data is very difficult to obtain or not available .

To overcome this problem, we developed a way to get unit hydrograph without using the above data (SriHarto, 1993). One such way was developed by F.F. Snyder from the United States in 1938 utilizing watershed parameters to obtain synthetic unit hydrographs.

A number of watersheds studied by Snyder are in the Appalachian highlands with a watershed ranging from 30 to 30,000 km2 (Chow, et al., 1988). Snyder develops models with coefficients -the empirical coefficients connecting the unit hydrograph elements with watershed characteristics. It is based on the idea that the diversity of rains becomes the flow of both the translational effect and its expression can be explained influenced by its watershed system (SriHarto, 1993). The unit hydrograph is determined by elements such as Qp (m3 / sec), Tb (clock), and tp (hours) and tr (hours). The hydrograph elements are related to:

A = broad watershed (km2)

L = length of main river flow (km)

Lc = the length of the main river is measured from the measurement point (discharge) to the point on the main river closest to the watershed (km)

Snyder with parameters (characteristics) unit hydrograph on a region. Espey, Altman and Graves in 1977 (in Chow, et al, 1988) developed a set of common equations for constructing unit hydrographs by examining 41 watersheds with an area ranging from 0.014 to 15 mil2. The locations of the 41 watersheds covered 16 locations in Texas, 9 locations in North Carolina, 6 locations in Kentucky, 4 locations in Indiana, 2 locations respectively in Colorado and Mississippi, and 1 location respectively in Tennessee and Pennsylvania. USCE gives the time coefficient (Ct) of the Snyder equation as follows:

Tabel 2. Tabel ct Persamaan snyder

Watershed type (condition)	C_t
Mountains	1,20
Hill Areas (Kaki Bukit)	0,72
Valley Area	0,35
Urban Areas	0,08

Dengan unsur-unsur tersebut di atas Snyder membuat model hidrograf satuan sintetis sebagai berikut (Gray, 1970; Chow, et al, 1988; Bedient and Huber,1992)

Tp = 0,75.Ct.(L.Lc) 0,3……………….. (2.21)

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

$$Qp = 2,75 \frac{Cp.A}{Tp}$$ ……………….. (2.22)

Where :

tp = time lag (clock)

Qp = peak discharge (m3 / sec)

Tb = base time (hours)

qpR = discharge per unit area (m3 / second / km2)

To speed up the work is given the formula Alexejev, which gives the form hydrograph unit. Alexejev's equations are as follows (Soemarto, 1995)

1. $Q = f(t)$
2. $Y = \frac{Q}{Q_p}$
3. $X = \frac{t}{T_p}$
4. $Y = 10^{-a\frac{(1-x)^2}{x}}$ ....(2.23)

With equation :

$$\lambda = \frac{Q_p \, . \, T_p}{h \, . \, A}$$

h = rainfall height = 1 mm

$$a = 1{,}32 \, . \lambda^2 + 0{,}15\lambda + 0{,}04 \qquad \text{.............(2.24)}$$

Snyder with parameters (characteristics) unit hydrograph on a region. Espey, Altman and Graves in 1977 (in Chow, et al, 1988) developed a set of common equations for constructing unit hydrographs by examining 41 watersheds with an area ranging from 0.014 to 15 mil2. The locations of the 41 watersheds covered 16 locations in Texas, 9 locations in North Carolina, 6 locations in Kentucky, 4 locations in Indiana, 2 locations respectively in Colorado and Mississippi, and 1 location respectively in Tennessee and Pennsylvania. The resulting equation:

$$T_p = 3{,}1 . L^{0{,}23} . S^{-0{,}25} . I^{-0{,}18} . \varphi^{1{,}57}$$
$$Q_p = 31{,}62 \times 10^3 . A^{0{,}96} . T_p^{-1{,}07}$$
$$T_b = 125{,}89 \times 10^3 . A . Q_p^{-0{,}95}$$
$$W_{50} = 16{,}22 \times 10^3 . A^{0{,}93} . Q_p^{-0{,}92}$$
$$W_{75} = 3{,}24 \times 10^3 . A^{0{,}79} . Q_p^{-0{,}78} \qquad \text{.............(2.25)}$$

Where:
L = total length of main river (feet)
S = the slope of the main river, defined as H / 0.8L, where H is the elevation difference A and B. A is the point on the bottom of the river at the upstream 0.2L from the edge of the river. B is a point on the bottom of the river at the bottom of the measuring point (feet per foot) I = the percentage of watertight area within a watershed (%), assumed to be equal to 5% of the undeveloped watershed. φ = the transport factor dimension, which is a function of the percentage of watertight area and roughness. (no units)
Tp = rise time measured from the start of the runoff to the peak of the unit hydrograph (min)
Qp = peak discharge hydrograph unit (cfs / min)
Tb = basic time hydrograph unit (min)
I = the percentage of watertight area within a watershed (%), assumed to be equal to 5% of the undeveloped watershed.
φ = the transport factor dimension, which is a function of the percentage of watertight area and roughness. (no units)
Tp = rise time measured from the start of the runoff to the peak of the unit hydrograph (min)
Qp = peak discharge hydrograph unit (cfs / min)
Tb = basic time hydrograph unit (min)
W50 = hydrograph width at 50% peak discharge (minutes)
W75 = hydrograph width at 75% reaching peak discharge (minutes).

3 Methodology

3.1. Physical Watershed Data

Watershed physical data, watershed, river length, slopes of watershed area, forest area, rainfall point location (PH) ,.

3.2. Rainfall Data Collection Method

In order to obtain the possible numbers of data discharges used in this study, the latest available 20-year rain data, the data is selected according to the physical condition of the watershed to determine the rainfall post points for which the data will be used. then the rainfall data is processed to obtain the maximum rainfall data on each rain heading taken data.

3.3. Determination of Rainfall Data Distribution

The design rainfall is the largest annual rainfall with a possibility of a certain repetition period. In the design rainfall analysis can be done in several ways, such as Normal, Log Normal, Pearson, Log Pearson type III, and Gumbel, Maximum rainfall data obtained from the data collection.

3.4. Testing Distribution

The distribution matching test is performed to determine whether the selected distribution matches the data distribution.

3.5. Synthetic Unit Data Hydrograph Processing

HSU is an appropriate method to calculate the flood discharge because the HSU calculation will produce the discharge value every hour and when the rain starts to fall, the peak flood time to the flooding event, compared with the empirical method.

3.6. Flowchart of study

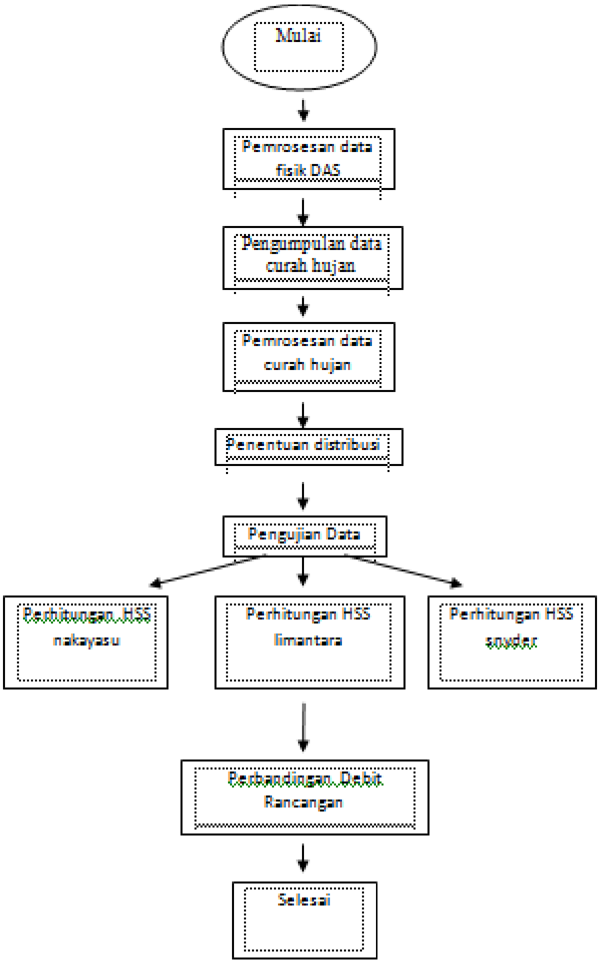

Figure 2. Flowchart of study

4. Result

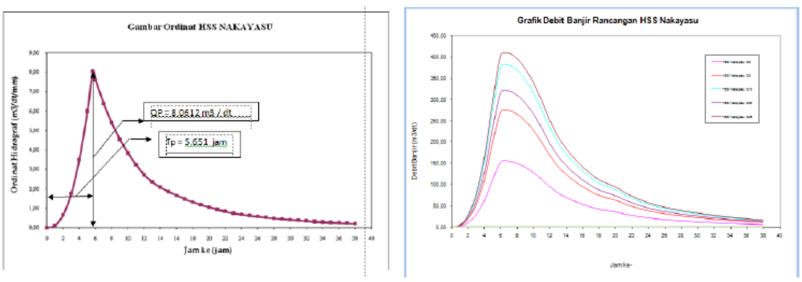

Figure 3. Ordinat HSU Nakayasu

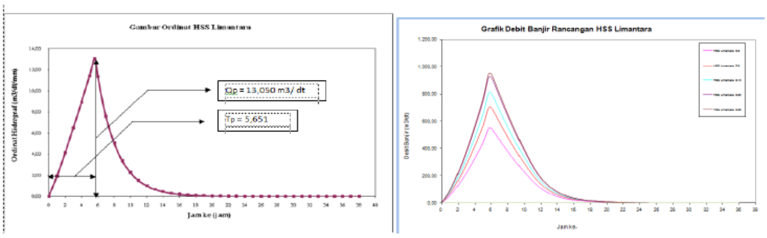

Figure 4. Ordinat HSU Limantara Dan Grafik debit banjir

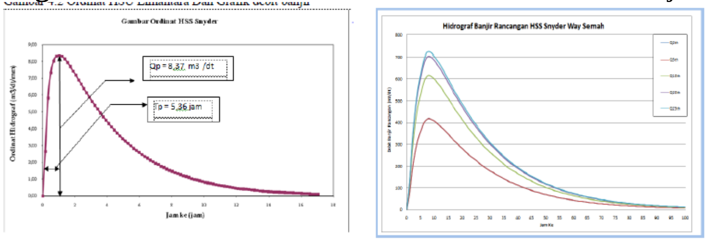

Figure 5. Ordinat HSU Snyder Dan Grafik debit banjir

From the results of Hintrograf Units of the Synthetic Method Nakayasu Method, Limantara And Snyder In Way Semah Basin can be concluded that.

1. The appropriate distribution used in Dah way semah is the distribution of pearson log type III, with 5 class divisions, the value c2count = 3.50 <c2cr = 5.991 and the Value D Max = -0.0370 <D Critical = 0.2940
2. The value of Qp on HSU Nakayasu = 8,061 m3 / dt and Tp Value = 5,651 Hours
3. Qp value on Limantara HSU = 13,050 m3 / dt and Tp Value = 5,651 Hour
4. The value of Qp on HSU Snyder = 8.37 m3 / dt and Tp Value = 5.36 Hours
5. The highest Qp value is obtained from HSU Limantara with a difference of more than 5m3 / s from the Nakayasu and Snyder hirdrograf. The value of Qp In the Limantara HSU, greatly influenced by the slope of the river, the higher the elevation difference between the upstream and downstream of the river, the higher the Qp value, and the reverse is true, whereas for the relatively equal Tp value.

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