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Analysis of α Parameters: Nakayasu Synthetic Hydrograf and Collins Method in Optimizing the Dimensional Planning of Water Buildings

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ABSTRACT

The limited availability of hydrograph data is an obstacle to waterworks planning. This obstacle makes synthetic unit hydrograph (HSS) models provide considerable benefits for waterworks planning. Ideally, each watershed has a unit hydrograph with its own unique characteristics.
Observations of hydrograph characteristics in each watershed and all watersheds in South Sulawesi Province have many differences. Modeling is carried out based on the Alpha equation with the influence parameters of the watershed area (A), river length (L), slope of the riverbed (S), form factor (FD), and concentration time (tg).
The data used is the data of the hydrograph observation unit in 2011–2017, which is then calculated with the HSS Nakayasu Method and Collins Method. From the calculation of the HSS Nakayasu and Collins Methods, each peak discharge (QP) is obtained, which has the smallest difference between the two of them. With these results, the α parameter value of 0.60 is obtained. The value of the α parameter obtained is in accordance with the actual river characteristics of the Janeberang watershed, so it can optimize the planning of water building dimensions.

Keywords: Alpha Parameters, Watershed Area, River Length, Slope, Form Factor

INTRODUCTION

When organizing the water resources sector, one of the many things that needs to be taken into account is being aware of the potential for flooding in the area. A flood discharge value is required for planning, and it serves as the foundation for creating water buildings. Planning considerations include the building's strength, efficiency, and economic worth (Safarina et al., 1997). Because of this, it is crucial to understand hydrological data, which is the primary source of information needed to do hydrological analysis and construct water structures including river management, irrigation systems, and flood control buildings. Hydrological analysis is a crucial component that must be considered in order to plan water constructions with accuracy and care (Asdak, 1995).

A watershed's design flood discharge can be predicted using a variety of techniques, including the Rational Method and the very intricate mathematical method of rainfall flow diversion (Sutapa, 2005). Sujono (1998) stated that the unit hydrograph method is one of the approaches that is frequently utilized in Indonesia.

Hydrograph analysis is a technique that turns rainfall into runoff in a rainfall-runoff model, allowing observed river flows and unmeasured watersheds to be estimated. An empirical equation derived from one region to numerous additional regions served as the basis for the earliest rainfall models in use (Sri Harto, 1993).

Hydrographs are a useful tool for displaying how watersheds (DAS) respond overall to specific inputs that are consistent with their characteristics. The flow hydrograph is always affected by the amount and timing of input (Sri Harto, 1993). Because they can determine the diversity of physical properties of a watershed and represent the time distribution of surface flow at a measurement location, flow hydrographs are an essential tool for solving hydrology-related problems (Nugroho, 2001).

The unit hydrograph is a hydrograph showing direct runoff produced by rainfall that falls uniformly over the watershed at a constant intensity during a predetermined period of time (Sri Harto, 1993). The watershed's response to the idea of hydrology is represented by the unit hydrograph. The interaction between the flow hydrograph and the physical characteristics of the watershed shapes the nature of the response in the watershed. A typical hydrograph for a watershed is the unit hydrograph. The unit hydrograph is a direct flow hydrograph produced by one unit of extra rainfall that is dispersed uniformly and at a constant intensity over a predetermined period of time throughout the watershed (Nugroho, 2001).

The issue with the watershed system's process of turning rainfall into floods is that it consistently produces inconsistent results. A method in the form of flood hydrographs is offered to solve this issue. If measurable flood hydrographs are available, the process of generating unit hydrographs from them can be used to depict the flood hydrographs; if not, empirical formulas, such as the Synthetic Unit Hydrograph (HSS), a hydrograph based on watershed parameters, can be used. A watershed needs extensive rainfall data from a rainfall recording post since outflow and rainfall data are frequently sparse (Suprapti et al., 2024).

Hydrologists have developed a number of techniques, such as the Synthetic Unit Hydrograph Method, based on the type, quantity, and applicability of the data for each technique (Snyder, Nakayasu, Gama I, Limantara) (Manyuk, 2000). An artificial hydrograph that is used to simulate a unit hydrograph based on the features of a watershed is called a synthetic unit hydrograph. acquiring knowledge about the unit hydrograph as it is approached by the synthetic unit hydrograph technique and estimating the use of the unit hydrograph idea in a planning without direct observational data on the watershed's flood hydrographs (Agus & Hadihardaja, 2011).

If data is available, the approach of generating unit hydrographs using measured flood hydrographs and applying empirical formulas—that is, the synthetic unit hydrograph, a hydrograph based on synthetic watershed parameters—can be used to show flood hydrographs. The Nakayasu Synthetic Unit Hydrograph is one of the synthetic unit hydrographs that is frequently utilized in flood discharge computations in Indonesia (Limantara, 2009).

A well-liked technique in the field of water resource planning, the Nakayasu Synthetic Unit Hydrograph method is particularly useful for analyzing unmeasured watershed flood output (Dewi et al., 2016). Although Nakayasu's Synthetic Unit Hydrograph (HSS) approach is being used more and more, there are actually a number of challenges that arise, particularly when figuring out the value of α, which indicates the features of the watershed (DAS). Namely the watershed area (A), the length of the main river (L), the conveyance coefficient (C), the average slope of the river (s), the basic roughness coefficient (n), the length of the river from the watershed to the outlet (Lc), and the alpha parameter (α) itself (Priyantoro, 2009). Nakayasu's Synthetic Unit Hydrograph (HSS) frequently yields less exact and reliable results because of its historical research in the Japanese region, which differs from the Indonesian region in many ways. The Nakayasu Synthetic Unit Hydrograph (HSS)'s α value will have a significant impact on the outcomes.

RESEARCH METHODS

Every research activity is typically conducted using a "research method" that enables all necessary procedures to be accomplished as scheduled and the research to be concluded at the decision-making stage (Noor, 2008; Savira & Suharsono, 2013). The location of the research carried out is geographically located in the Jeneberang River Basin, located at 119° 23' 50" East - 119° 56' 10" East and 05° 10' 00" LS - 05° 26' 00" LS, with a main river length of 78.75 kilometers. The Jeneberang River Basin is fed by one supporting river (tributary), the Jenelata

River (220 km^2). Major cities that are covered by this watershed besides Makassar (Ujung Pandang) are Malino City, Bili-bili City, and Sungguminasa City. Jeneberang Watershed is one of the National Priority Watersheds as stated in the joint Decree of the Minister of Home Affairs, Minister of Forestry, and Minister of Public Works No. 19 of 1984, No. 059/Kpts-II/1985, and No. 124/Kpts/1984, which in its management needs special attention (Kamila et al., 2019).

Figure 1: Research Location

The hydrograph of the observation unit in each watershed is calculated by means of Collins with the following calculation steps:

1) The stage hydrograph is converted into a discharge hydrograph by calibration.
2) The base flow is separated from the hydrograph by one of the empirical methods: the straight line method (Sri Harto, 1993).
3) Effective rainfall that causes flooding is analyzed using the Infiltration Index (Phi Index)
4) An arbitrary unit hydrograph is established by setting its coordinates to a certain magnitude.
5) The initial unit hydrograph (trial and error) is multiplied by all but the largest effective rainfall.
6) The direct runoff hydrograph obtained above is subtracted from the measured direct runoff hydrograph, from which the direct runoff hydrograph generated by the maximum rainfall is obtained, the second unit hydrograph (trial and error).
7) The second unit hydrograph is compared with the initial unit hydrograph. If there is still a large difference (according to the specified error benchmark), then the fifth and sixth stages are repeated again based on the final unit hydrograph (Krisnayanti, Frans, & Halema, 2019).
8) And so on until the smallest possible difference is obtained between the final unit hydrograph and the previous unit hydrograph.

Each watershed unit was hydrographed. Hydrograph unit observation for all watersheds, obtained by averaging the ordinate hydrograph unit observation at the same hour, the peak discharge, and the time to reach the peak discharge, with the following stages:

1) Calculate the average peak time and average peak debit.
2) Calculate dimensionless observed unit hydrographs (t/TP and Q/Qp) for each watershed.
3) Calculating the dimensionless average observed in the in the unit hydrograph.
4) Calculating the average observed unit hydrograph

The functional formula for peak time contains the physical factors L (main river length), A (watershed area), S (main river slope), FD (shape factor), and Tg (concentration time), or $\alpha = f$ (A, L, S, FD, Tg), because these parameters greatly affect the value of the Alpha parameter (α). Factors that affect the model will be determined based on the magnitude of the coefficient of determination (Krisnayanti et al., 2019). Modeling analysis is carried out using regression with several alternatives based on the independent variables used (five, four, three, two, and one independent variable).

RESULTS AND DISCUSSION

In modeling the shape of the watershed for the Jeneberang river basin, which is distributed in 10 districts, there are 58 watersheds. To model the shape of the watershed using ArcGIS 10.7 software using data taken from the Digital Elevation Model (DEM) data. The Digital Elevation Model (DEM) data used in this research is sourced from the Indonesian Geospatial Agency.

The forms of watersheds in the Jeneberang river basin area have different topographic characteristics according to their conditions. Topographic data is obtained from the Digital Elevation Model (DEM), which is then processed with ArcGIS 10.7 software so that this software will automatically form the regency boundaries up to the watershed boundaries.

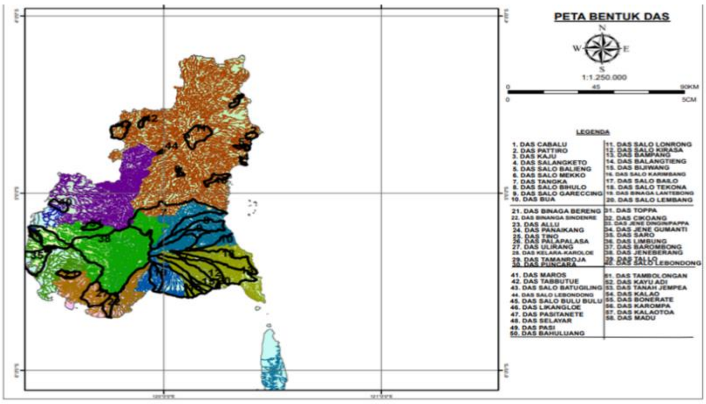
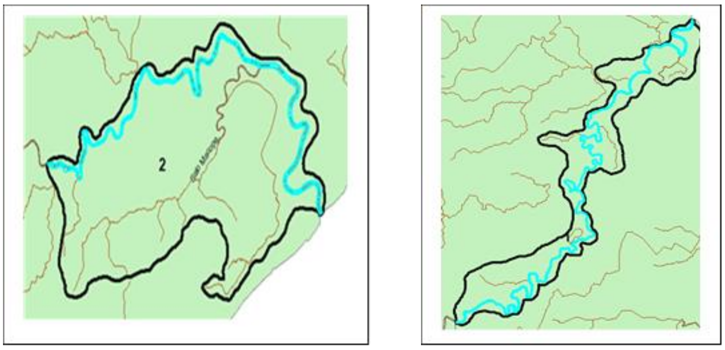


Figure 2: The shape of the river basin in the Jeneberang river area
Source: Data processing ArcGIS 10.7 software

Each watershed's shape is mostly determined by the features of the river and the shape of the river channel (DASThe river's flow is significantly influenced by the watershed's (DAS) shape, specifically the speed of the flow's center. From the Digital Elevation Model (DEM) data, which is then digitized using ArcGIS 10.7 software, the watershed boundaries and river flow patterns in the Jeneberang river basin area are obtained.



(a) Radial Shape (b) Elongated shape

Figure 3: The shape of the watershed in the Jenebarang watershed area
Source: ArcGIS 10.7 software results

The data obtained in each sub-watershed is in the form of observation flood hydrograph data in each sub-watershed, where the observation unit hydrograph (observation unit hydrograph) of each watershed is analyzed using the Collins method.

Collins Method

Calibration is done using the Collins of Observation Hydrograph (HSO) approach. Calibration is used to plan flood discharge studies and verify that the parameters used to calculate the Nakayasu synthetic unit hydrograph are accurate. The Collins method of analysis uses rainfall data and hourly discharge data. The discharge data used is the hydrograph observation unit data for 2011–2017, as follows:

Table 1. Recapitulation of Collins observation method hydrograph calculation

HSO-1		HSO-2		HSO-3		HSO-4		HSO-5		HSO-6	
2011	Hour of	2012	Hour of	2013	Hour of	2014	Hour of	2015	Hour of	2016	Hour of
0,0000	0	0,0000	0	0,0000	0	0,0000	0	0,0000	0	0,0000	0
60,947	1	33,032	1	20,594	1	4,678	1	14,083	1	23,623	1
24,530	2	30,206	2	61,209	2	11,474	2	21,294	2	39,058	2
1,191	3	18,016	3	2,748	3	15,264	3	39,426	3	14,583	3
0,0000	4	5,415	4	0,615	4	16,284	4	11,866	4	9,765	4
	5	0,0000	5	1,513	5	14,303	5	0,0000	5	0,0000	5
			6	0,0000	6	8,604			6	0,0000	6
					7	7,678					7
					8	8,381					8

The average hydrograph of the observation unit from the analysis results is as follows:

Table 2. Hydrograph of the average observation unit

HSO	Peak Time (TP)	Peak discharge (Qp)	Base Time (Tb)
HSO-1	1	60,947	2
HSO-2	1	33,032	3
HSO-3	2	61,209	4
HSO-4	4	16,284	5
HSO-5	3	39,426	3
HSO-6	2	39,058	3
HSO-7	4	21,095	6
Rerata	2,43	38,72	3,71429

Nakayasu HSS Design Flood Discharge Calculation

To calculate the flood discharge plan using the Nakayasu Synthetic Unit Hydrograph method with river length data of 33 km and a watershed area of 312.01 km^2.

The measured flood discharge was compared to the peak discharge in the Nakayasu HSS at the measured rainfall using the value trial method. This was done to get the QP (peak discharge) values that differed the least in the Janeberang watershed area.

Calculations are carried out using the Collins method to obtain the QP (peak discharge) value.

Table 3. Calculation Results of the Plan Flood Discharge of the Collins Method and Nakayasu HSS Method

T	Qt m³/s/mm	T	Qt m³/s/mm
Hour	Collins	Hour	Nakayasu
0,00	0,0000	0,00	0,0000
0,44	6,468	1,00	2,1860
0,86	13,345	2,00	11,540
0,95	13,531	3,00	30,536
2,12	24,764	3,24	36,720
3,29	36,620	4,00	18,990
4,45	13,280	4,63	11,016
5,73	5,74	5,00	8,884
6,70	5,59	6,71	3,304
7,89	0,0000	7,00	2,915
		8,00	1,889
		10,00	0,794

The following HSS Nakayasu and Collins Method curves are presented, which have the intersection of the two methods.

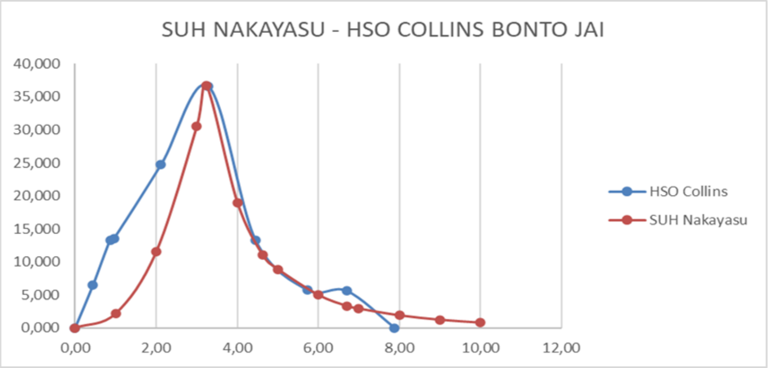


Figure 4: Nakayasu curve – Collins

From the results of the trial-and-error value of α, the value of α is obtained in accordance with the Collins method, which is 0.60. Furthermore, for the other 9 observation posts (Daraha, Jenelata, Jonggoa, Kampili, Mancini Sombala, KD-1, Malino, Limbunga, and Panaikang), the same stages are carried out for the calculation of the Nakayasu Synthetic Unit Hydrograph.

CONCLUSION

1. The Collins and Nakayasu HSS methods produce a value of α = 0.60, which has the smallest difference in Qp.
2. With the value of α obtained, it has an impact on the value of the resulting plan flood discharge that affects the calculation of water building planning.
3. Nakayasu Synthetic Unit The hydrograph shows the factors that affect the value (Alpha): watershed area (A), river length (L), river slope (S), watershed shape (FD), and time from rain center to peak discharge (Tg).

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