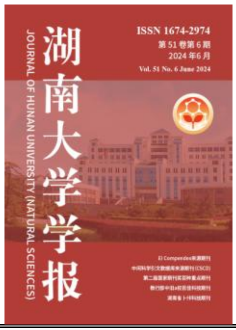

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Limiting Parameter for Modifying the Snyder Synthetic Unit Hydrograph

Riman[1]*, M. Bisri[2]*, Pitojo Tri Juwono[2], Aniek Masrevaniah[2]

[1] Doctoral Student, Department of Water Resources Engineering, Faculty of Engineering, University of Brawijaya, Jl. MT Haryono No. 167, Malang, Indonesia

[2] Department of Water Resources Engineering, Faculty of Engineering, University of Brawijaya, Jl. MT Haryono No. 167, Malang, Indonesia

* Corresponding authors: riman.sipil@gmail.com, mbisri@ub.ac.id

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Abstract: Synthetic unit hydrograph (SUH) is a method for estimating the use of the unit hydrograph concept in a design that does not involve direct measurement of flood hydrographs. Snyder is a synthetic unit hydrographs that is often used in Indonesia. There are two non-physical parameters in the Snyder SUH model that are functions of watershed characteristics, such as Ct and Cp. The use of this method under Indonesian conditions is still difficult because the determination of the coefficients requires a calibration process for each area. This research aimed to investigate which parameters influence the coefficient Cp (coefficient that is depended on the watershed characteristic), Ct (coefficient that is depended on the basin slope), Tp (time to peak of hydrograph), Tb (time base of hydrograph), and Qp (peak discharge of hydrograph) in the Snyder SUH model for parts of Indonesia's watersheds. This research was conducted in 10 watersheds spread throughout some provinces of Indonesia. ARR (automatic rainfall recorder) and AWLR (automatic water level recorder) must complete the selected watersheds. The methodology consists of collecting characteristic watershed data and investigating the factors that influence each parameter using variance analysis (Anova). The result shows that the parameter estimate of Ct to Tp = f(Ct, L, and Lc) with R^2 is 72.8%, that of Ct to Tp = f(Ct, L, and Lc) with R^2 is 73.5%, that of Ct to Tp = f(L, Lc, Lb, Wr, and S) with R^2 = 90.2%, that of Qp to Cp = f(Cp, A, and Tp) with R^2 = 96.8%, that of Qp to Tp = f(Cp, A, and Tp) with R^2 is 95.6%, that of Cp to Qp = f(Tp, A, Ai, K, and L) with R^2 = 99.0%, and that of Tb to Qp with R^2 is 73.5%.
Keywords: synthetic unit hydrograph, flood, Snyder.

修正斯奈德綜合單位過程線的限制參數

摘要：綜合單位過程線是一種在不涉及直接測量洪水過程線的設計中估算單位過程線概念使用情況的方法。斯奈德是印尼經常使用的合成單位流程線。斯奈德綜合單位過程線模型中有兩個非物理參數是流域特徵的函數，例如 Ct 和 Cp。在印尼的條件下使用這種方法仍然很困難，因為係數的確定需要對每個區域進行校準過程。本研究旨在探討哪些參數影響係數 Cp（取決於流域特徵的係數）、Ct（取決於流域坡度的係數）、Tp（水文峰值時間）、Tb（水文時間基準） 以及印尼部分流域斯奈德綜合單位過程線模型中的 Qp（水文峰值流量）。這項研究是在印尼部分省份的 10 個流域進行的。自動雨量記錄器和自動水位記錄器必須完成選定的流域。該方法包括收集特徵分水嶺資料並使用變異數分析(方差分析)調查影響每個

參數的因素。結果表明，Ct 到 Tp = f(Ct, L, Lc) 與 R2 的參數估計值為 72.8%，Ct 到 Tp = f(Ct, L, Lc)與 R2 的參數估計值為 73.5%，Ct 至 Tp = f(L、Lc、Lb、Wr 和 S)，其中 R2 = 90.2%，Qp 至 Cp = f(Cp、A 和 Tp)，其中 R2 = 96.8%，Qp 至 Tp = f(Cp, A, Tp)與 R2 的比值為 95.6%，Cp 到 Qp = f(Tp, A, Ai, K, 和 L) 與 R2 = 99.0%，Tb 到 Qp 與 R2 的比值為 73.5 %。

关键词：合成单位过程线，洪水，斯奈德。

1. Introduction

In the stages of planning, design, development, and management of water resources, especially related to the infrastructure of water resources such as dams, reservoirs, small dams, weirs, drainage channels, embankments, and other water structures, hydrological analysis plays an essential role mainly in design floods for determining the dimension, capacity, and design lifetime of water resources that will be developed [1-4].

The transformation of rainfall into discharge is a very complex problem, and it has not ever been completed by researchers and hydrologists, mainly in arranging models [5]. The complexity of a problem relates to some factors influenced in determining the flow characteristic, which is the result of rainfall transformation as a factor of rainfall that becomes input, and the watershed system is the result of transformation media. Because the influenced factors are very complex, not all the parameters allegedly related to the transformation process and modeling of rainfall flow [6].

As an effort to anticipate the problem, there are more arranged models for analyzing the transformation of rainfall to discharge that relate to the demands of water structure design and evaluation mainly the model based on the synthetic unit hydrograph [7] based on Rational, Seduxen, Hampers, and Melchior models for small watersheds. The synthetic unit hydrograph model is a transformation of rainfall to discharge that is based on unit hydrograph theory. However, a unit hydrograph is a hydrograph produced by the unit rainfall due to the rain evenly in the watershed for a certain duration using the watershed parameters as the model compiler. Synthetic unit hydrography is a method for estimating the usage of the unit hydrograph concept in a design that does not involve direct measurements of food hydrographs [8-9].

The Snyder synthetic unit hydrograph (SUH) is a conceptual SUH model, which is popular enough in Indonesia. Snyder SUH was developed based on the watershed characteristics in the Appalachian highlands in the USA by F.F. Snyder born in 1938. The Snyder SUH model is not necessarily suitable for a watershed in Indonesia. This is due to the difference in characteristics, conditions [10-11], and rainfall patterns between the watersheds in Indonesia and the area of the model development.

In the future, this research will focus on the modification of the Snyder SUH in the influenced factors [12] to the parameters of Tb, Tp, Qp, Ct, and Cp by evaluating a few gauged watersheds in Indonesia fitted with watershed characteristics in Indonesia as the objects of hydrograph parameter development. Therefore, it can produce the model development of Snyder SUH with the best performance and can become guidelines for determining flood design procedures in ungagged watersheds in Indonesia.

2. Materials and Methods

2.1. Research Location

The research locations were some watersheds in Indonesia that were completed with the Automatic Water Level Recorder (AWLR) and Automatic Rainfall Recorder (ARR) with complete and long enough data recording, as presented in Fig. 1 and Table 1.

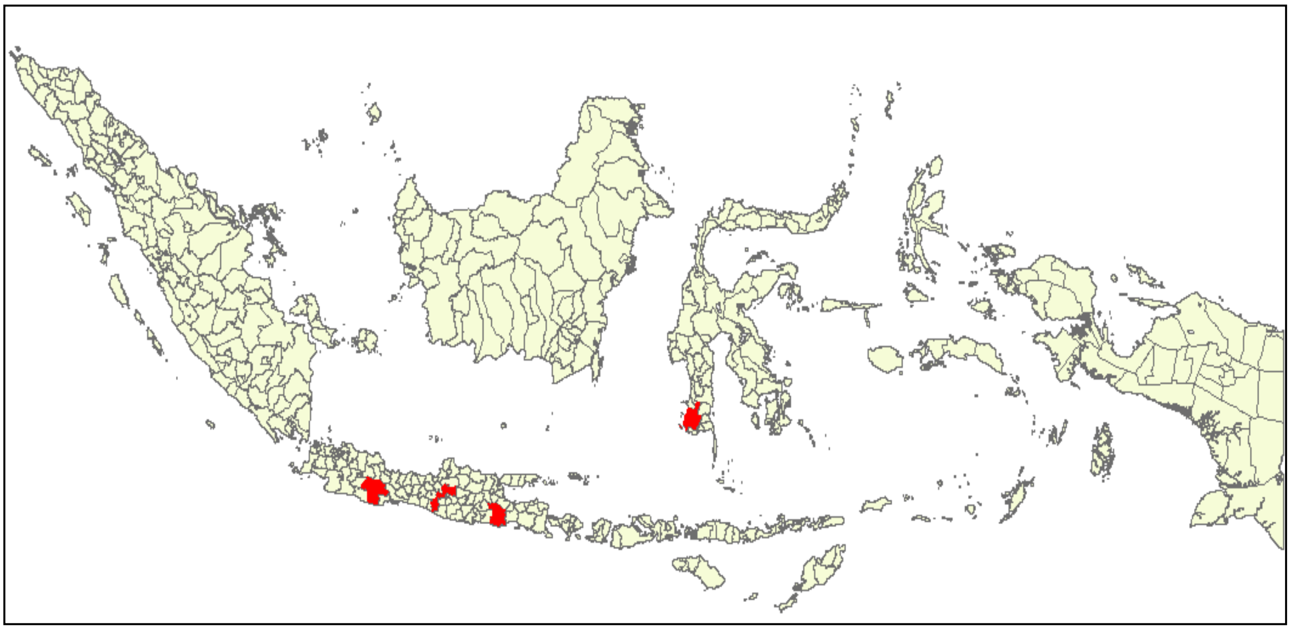


Fig. 1 Watershed map of the research locations (The authors)

Table 1 Location of the research watershed, AWLR, and ARR (Own study; the authors)

No.	Research Location	Watershed	AWLR	ARR
1	Jawa Barat	Pataruman,WS Citanduy	AWLR Pataruman	St. Cibereum, St. Pataruman, St. Cihonje, St. Kawali, St. Cineam, and St. Pagerageung
2	Jawa Timur	Lesti, WS Brantas	AWLR Tawang Rejeni	St. Poncokusumo, and St. Dampit
3	Jawa Timur	Gadang WS Brantas	AWLR Gadang	St. Jabung, and St. Malang
4	Jawa Timur	Dungus, WS B. Solo	AWLR Dungus	St. Ahmad Yani, and St. Jatirogo
5	Jawa Tengah	Girimargo, WS Pemali Juana	AWLR Kunthi	St. Kunthi
6	Jawa Tengah	Jurug WS B.Solo	AWLR Jurug	St. Klaten, St. Jatipuro, and St. Gunungan
7	Daerah Istimewa Yogyakarta	Code, WS Serayu Opak	AWLR Kaloran	St. Prumpung, St. Kemput, and St. Angin-angin
8	Sulawesi Selatan	Sombala, WS Pompengan Jeneberang	AWLR Sombala	St. Janelata, St. Bonto Jai, and St. Jonggoa
9	Sulawesi Selatan	Kampili WS Pompengan Jeneberang	AWLR Kampili	St. Janelata, St. Bonto Jai, and St. Jonggoa
10	Sulawesi Selatan	Jonggoa WS Pompengan Jeneberang	AWLR Jonggoa	St. Jonggoa, and St. Daraha

2.2. Methodology

Performing identification of data in an institution that prepares sufficient quantities and qualified data initiated this research. Based on the identification result, there is carried out initial data collecting for performing the preliminary studies in the performance analysis form of Snyder SUH (Synthetic Unit Hydrograph) at the research locations. This research result will become the guidelines for determining the number of watersheds that will be used in the research. Then, there will be verification based on the results of hydrology data collection. To identify the parameters influenced for modifying the Snyder SUH, there is carried out the stages as follows:

(1) To find the relationships between input variables to determine the characteristics of multi-collinearity between variables using correlation analysis. If the correlation between variables is high, it means that both variables influence each other, so determining only one regression variable is enough.

(2) To determine the relationship between each input and output variable. A variable with high

correlation can be used as the input variable of the model.

2.3. Snyder SUH

Snyder developed a formulation using empirical coefficients that related the uncertainty of a unit hydrograph with the specific characteristic of the watershed and analyzed an amount of watershed hydrographs in the Appalachian Mountain Region (USA) by the watershed area between 25 km^2 and 25,000 km^2.

The unit hydrograph is sufficiently accurate for rainfall depth (d) = 1 cm, and the three other uncertain ones are Qp (m^3/s), Tb (hours), and Tr (hours). Uncertainty about the hydrograph is related to A (watershed area, km^2), L (length of main river, km), and Lc (the length of river until the point which is the nearest with the weight point of the catchment area, km).

Based on the uncertainty, Snyder developed the following formulations:

$$t_p = C_t\,(L_c \times L)^{0.3} \quad (1)$$

$$t_r = \frac{t_p}{5{,}5} \quad (2)$$

$$Q_p = 2{,}78\,\frac{C_p \times A}{t_p} \quad (3)$$

$$T_b = \frac{72+3T_p}{24} \quad (4)$$

However, the coefficients of Ct and Cp must be empirically determined because the dimensions change between areas. Ct is a coefficient that is dependent on the slope-basin (0.75–3.00), and Ct can be used using the approach proposed by Taylor and Schawarz as follows:

$$C_t = \frac{0{,}6}{\sqrt{s}} \quad (5)$$

C_p is a coefficient that is dependent on the watershed characteristic (0.40–0.80).

The modified Snyder formulation is more frequently used. The change in the exponential of 0.30 is changed with n as follows:

$$tp = Ct\,(Lc \times L)^n \quad (6)$$

- *Tr* in Equation 2 changes to *te*, which represents the duration of effective rainfall (*tr* = 1 h). The duration of effective rainfall (*te*) is influenced by time lag; this relation can be seen in the following equation:

$$t_e = \frac{t_p}{5{,}5} \quad (7)$$

- The relationships between t_e, t_p, t_r, and T_p are expressed as follows:

If $t_e > t_r$:

$$t_p' = t_p + 0.25\%\,(t_r - t_e) \quad (8)$$

Thus, the time to peak is obtained as follows:

$$T_p = t_p' + 0{,}50\,t_r \quad (9)$$

If $$Tp = tp + 0{,}50\,tr \quad (10)$$

So, $$q_p = 0{,}278\,\frac{C_p}{t_p} \quad (11)$$

$$Qp = qp \times A \text{ (for 1 mm/hour rainfall)} \quad (12)$$

where:
te - duration of effective rainfall (hour)
tr - duration of 1-h effective rainfall (hour)
tp - time lag (hour)
Tp - time to peak (hour)
N - coefficient of proportional (0.10 – 0.38)
Qp - peak discharge (m^3/s/mm)
Qp - unit hydrograph peak (m^3/s/mm/km2)
S - average slope of the watershed
H - rainfall depth = 1 mm

The other functions used in this study are as follows:

$$T_p = C_t \left\{\frac{L \times L_c}{S}\right\}^n \quad (13)$$

$$T_b = 5 + (T_p + t_r/2) \quad (14)$$

Snyder only built an empirical formula for the peak discharge (Qp) and time to peak (Tp) of a hydrograph. To obtain the hydrograph curve, time is needed to calibrate the parameters. To accelerate the process, the Alexeyev formulation that gives the unit hydrograph form is used. The form of unit hydrograph that is determined by Alexeyev formulation is as follows:

$$Q = f(t) \quad (15)$$

$$Y = \frac{Q}{Q_p} \quad (16)$$

$$x = \frac{t}{t_p} \quad (17)$$

$$Y = 10^{-a\frac{(1-x)^2}{x}} \quad (18)$$

$$a = 1.32\,\lambda^2 + 0.15\,\lambda + 0.045 \quad (19)$$

$$\lambda = \frac{Q_p T_p}{h.A} \quad (20)$$

Fig. 2 presents the Snyder SUH with the Alexeyev formulation. Fig. 3 presents the flow chart of the research.

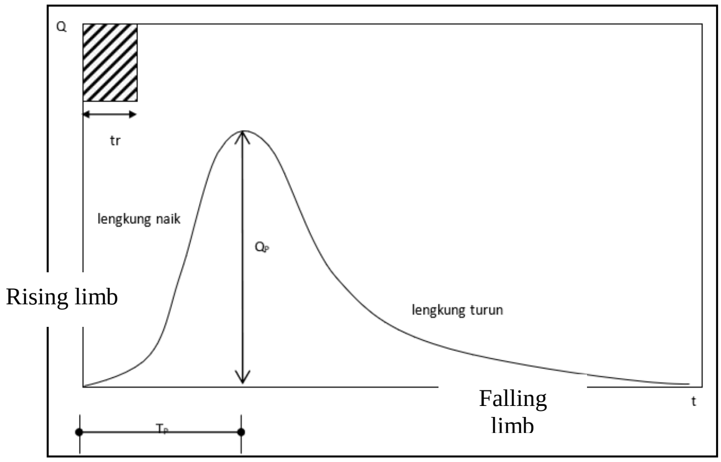
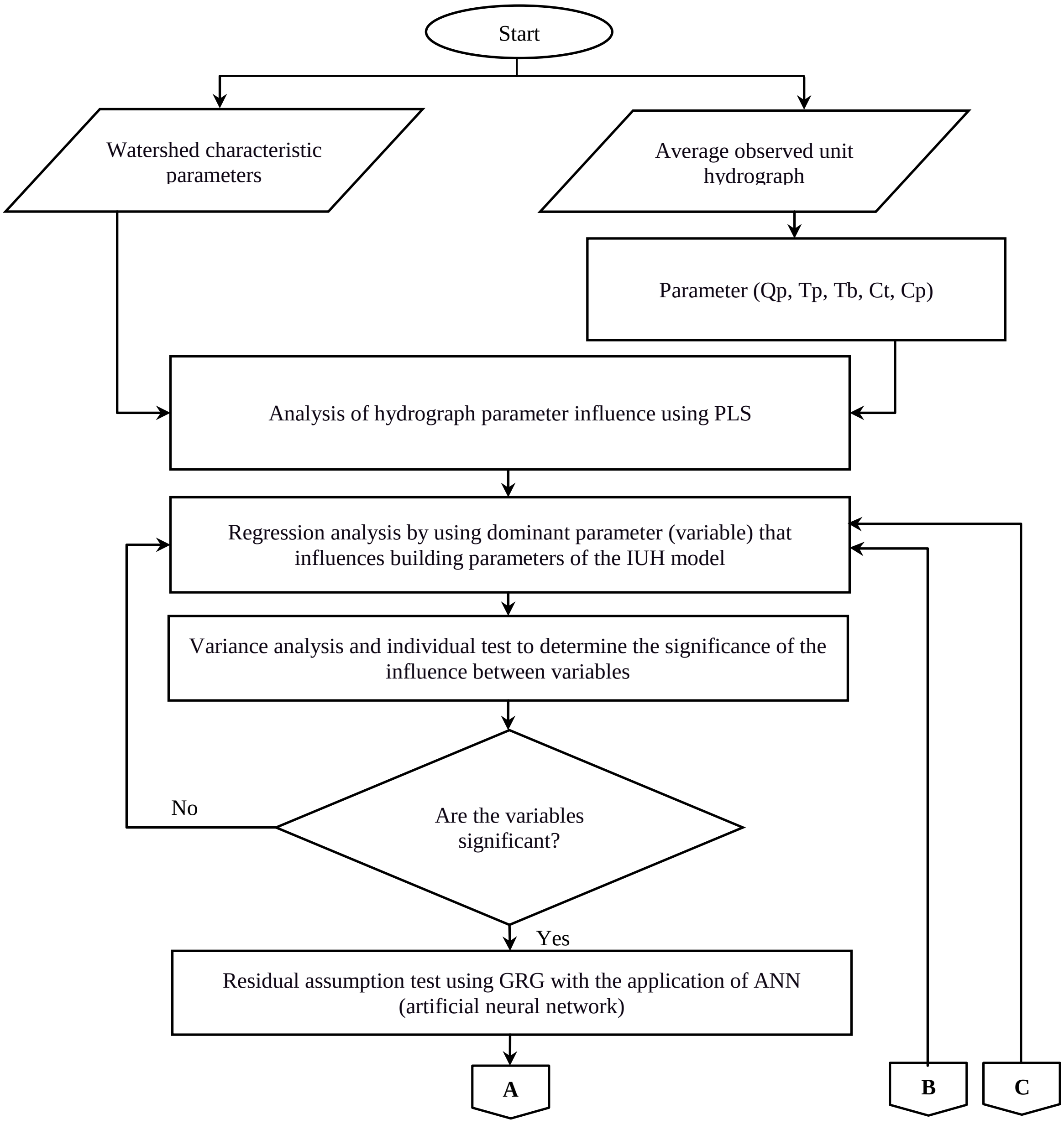


Fig. 2 The Snyder SUH based on Alexeyev formulation [8]



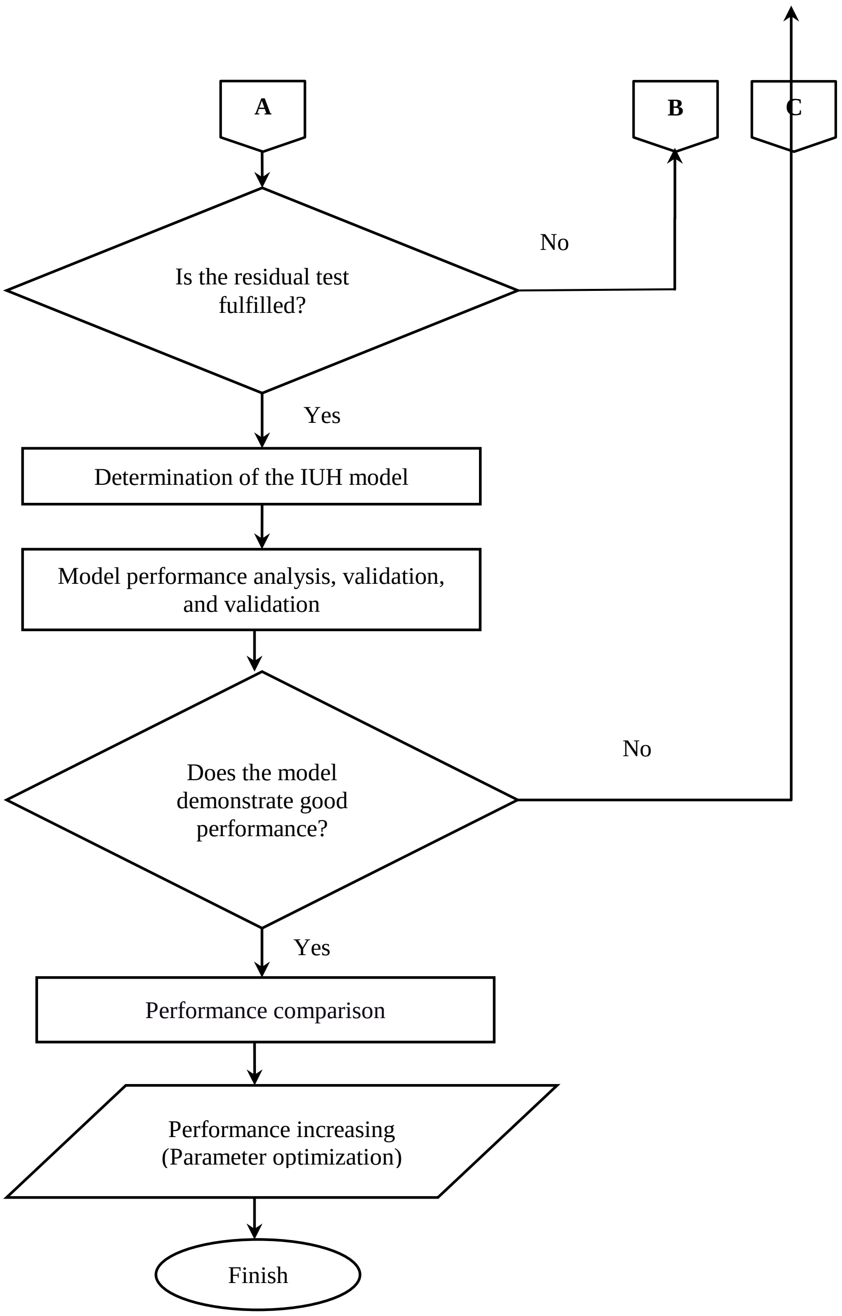


Fig. 3 Flowchart of research (The authors)

3. Results and Discussion

3.1. Characteristic Data for the Watershed

Table 2 presents the characteristic data of the watershed, including peak discharge (Qp), time base (Tb), time to peak (Tp), watershed area (A), length of the main river (L), and the length of the river until the point nearest to the weight point in the catchment area (Lc).

Table 2 Data of watershed characteristic (The authors)

No.	Watershed	Qp	Tb	Tp	A	L	Lc
1	DAS Girimargo	3.42	26.35	3.10	90.08	24.95	5.45
2	DAS Gadang	45.89	26.67	4.00	809.73	45.40	10.27
3	DAS Pataruman	55.59	32.78	5.70	1376.75	106.58	32.99
4	DAS Daraha	2.76	8.53	3.10	26.02	11.94	6.32
5	DAS Jonggoa	11.13	11.16	2.70	128.62	25.81	10.48
6	DAS Jenelata	7.80	25.62	4.20	222.95	36.08	13.89
7	DAS Kampili	29.28	22.99	5.40	630.43	63.53	26.62
8	DAS Code	3.16	16.78	3.30	40.62	36.62	16.27

Continuation of Table 2

9	DAS Sombala	22.62	27.00	5.40	666.69	80.23	37.09
10	DAS Jurug	98.78	19.80	6.60	3284.91	111.37	24.21
11	DAS Dungus	97.75	31.43	8.20	3725.05	104.89	33.66
12	Brantas Lesti Tw. Renjeni	19.23	25.40	4.94	382.51	40.07	19.03
13	Brantas Brantas Konto 1	16.39	12.70	3.00	186.00	33.50	16.02
14	Brantas Widas Lengkong	21.43	39.70	6.83	1257.98	64.74	30.16
15	B. Solo K. Madiun Sekayu	33.89	30.10	5.42	1002.60	45.62	21.55
16	Ciliwung Ciliwung Sugutamu	8.46	28.80	5.19	253.54	72.14	33.46
17	B. Solo K. Keduang Ngadipiro	17.20	25.90	5.29	375.57	44.52	21.05
18	DAS Lesti	22.22	25.33	4.00	380.86	46.04	12.92
19	DAS Bonto Jai	35.25	5.60	2.80	277.96	39.45	17.39
20	Brantas Brantas Gadang	34.79	23.30	5.67	731.37	35.23	16.82
21	Progo Progo Kranggan	20.63	21.00	4.30	431.94	36.50	17.40

Explanation: Qp - peak discharge (m^3/s); Tp - time to peak (hour); Tb - time base (hour); A - watershed area (km^2); L - length of main river (km); Lc - length of river until the point nearest with the weight point on the catchment area (km); Ai - downstream watershed area (km^2); Lb - length of main river until from axis point to outlet (km); M - width of river (m); Wr - run-off width to average river; S - river slope; K - watershed perimeter (m)

3.2. Parameter Estimation of Ct as a Function of Tp

Parameter estimate in this case shows the influence of Ct on Tp based on the Tp formulation, which is a function of Ct, L, and Lc:

$$T_p = C_t.(L.L_c)^{\,n} \quad (21)$$

Table 3 presents the estimated parameter for Ct as a function of Tp (eq. 21). Table 4 presents the correlation of the parameter estimate of Ct as a function of Tp; however, the variance analysis of Ct as a function of Tp is presented in Table 5.

Table 3 Parameter estimates for Ct. of Tp function (The authors)

Parameter	Estimate	Std. error	95% confidence interval	
			Lower bound	Upper bound
Ct	.792	.264	.230	1.354
b_1	.261	.045	.165	.358

Table 4 Correlations of parameter estimates for Ct of the Tp function (The authors)

	Ct	b_1
Ct	1.000	-.993
b1	-.993	1.000

Table 5 ANOVA[a] for the Ct of the Tp function (The authors)

Source	Sum of squares	df	Mean squares
Regression	426.692	2	213.346
Residual	10.307	15	.687
Uncorrected Total	436.999	17	
Corrected Total	37.892	16	

Dependent variable: time to peak (Tp)

R squared = 1 (residual sum of squares)/(corrected sum of squares) = .728

The parameter estimate of Ct in the formulation of Tp (eq. 21) produces determination coefficient: R^2 = 72.8%, meaning that the 72.8% parameter of Ct influences Tp in eq. 21.

3.3. Parameter Estimate of Ct as a Function of Tp

Parameter estimate in this case shows the influence of Ct on Tp based on the formulation of Tp, where Tp is a function of Ct, L, and Lc as follows:

$$T_p = C_t.(L^{b1}.L_c^{\,b2})^n \quad (22)$$

Table 6 presents the parameter estimate of Ct as a function of Tp. Table 7 presents the correlation of the parameter estimate for Ct as a function of Tp (eq. 22); however, the variance analysis for Ct as a function of Tp is presented in Table 8.

Table 6 Parameter estimates for Ct of the Tp function (The authors)

Parameter	Estimate	Std. error	95% confidence interval	
			Lower bound	Upper bound
Ct	.748	.262	.186	1.310
b_1	1.047	.451	.081	2.014
b_2	.512	.491	-.542	1.566

Table 7 Correlations of parameter estimates for Ct of the Tp function (The authors)

	Ct	b_1	b_2
Ct	1.000	-.552	-.011
b_1	-.552	1.000	-.825
b_2	-.011	-.825	1.000

Table 8 ANOVA[a] for the Ct of the Tp function (The authors)

Source	Sum of squares	df	Mean squares
Regression	426.940	3	142.313
Residual	10.059	14	.719
Uncorrected Total	436.999	17	
Corrected Total	37.892	16	

Dependent variable: time to peak (Tp)

R squared = 1 (residual sum of squares)/(Corrected sum of squares) = .735

The parameter estimate of Ct in Eq. Tp (eq. 22) produces determination coefficient: R^2 = 73.5%, meaning that 73.5% of the Ct parameter influences Tp in eq. 22.

3.4. Parameter Estimation of Ct as a Function of Tp

Parameter estimate in this case indicates the influence of Ct on Tp based on the formulation of Tp as a function of L, Lc, Lb, Wr, and S as follows:

$$T_p = C_t.L^{b1}.L_c^{\,b2}.L_b^{\,b3}\,.\,Wr^{b4}.\,(S^{0.5})^{b5} \quad (23)$$

Table 9 presents the parameter estimate for Ct as a function of Tp (eq. 23). Table 10 presents the correlation of the parameter estimate of Ct as a function of Tp (eq. 23); however, the variance analysis for Ct as a function of Tp (eq. 23) is presented in Table 11.

Table 9 Parameter estimates for Ct of the Tp function (The authors)

Parameter	Estimate	Std. error	95% confidence interval	
			Lower bound	Upper bound
Ct	.599	.180	.203	.996
b_1	.316	.407	-.581	1.212
b_2	.362	.119	.100	.623
b_3	-.300	.317	-.999	.398
b_4	.141	.058	.015	.268
b_5	-.237	.145	-.555	.082

Table 10 Correlations of parameter estimates for Ct of the Tp function (The authors)

	Ct	b_1	b_2	b_3	b_4	b_5
Ct	1.000	-.572	-.102	.518	.305	-.062
b_1	-.572	1.000	-.248	-.944	-.432	.639
b_2	-.102	-.248	1.000	-.015	.097	-.251
b_3	.518	-.944	-.015	1.000	.333	-.537
b_4	.305	-.432	.097	.333	1.000	-.057
b_5	-.062	.639	-.251	-.537	-.057	1.000

Table 11 ANOVA[a] for the Ct of the Tp function (The authors)

Source	Sum of squares	df	Mean squares
Regression	433.288	6	72.215
Residual	3.711	11	.337
Uncorrected Total	436.999	17	
Corrected Total	37.892	16	

Dependent variable: time to peak (Tp)
R squared = 1 (residual sum of squares)/(corrected sum of squares) = .902

The parameter estimate of Ct as a function of Tp (eq. 23) produces the determination coefficient: R^2 = 90.2%, meaning that 90.2% of the Ct parameter influences Tp (eq. 23).

3.5. Parameter Estimation of Qp as a Function of Cp

Parameter estimate in this case indicates the influence of Qp on Cp based on e formulation Qp, which is a function of Cp, A, and Tp as follows:

$$Qp = 2.78*Cp.\ A / Tp \quad (24)$$

Table 12 presents the parameter estimate for Qp as a function of Cp. Table 13 presents the variance of Qp as a function of Cp (eq. 24).

Table 12 Parameter estimates for Cp in the Qp function (The authors)

Parameter	Estimate	Std. error	95% confidence interval	
			Lower bound	Upper bound
Cp	.074	.002	.069	.079

Table 13 ANOVA[a] for Cp in the Qp function (The authors)

Source	Sum of squares	df	Mean squares
Regression	28245.027	1	28245.027
Residual	460.277	16	28.767
Uncorrected Total	28705.304	17	
Corrected Total	14304.878	16	

Dependent variable: time to peak (Qp)
R squared = 1 (residual sum of squares)/(corrected sum of squares) = .968

The parameter estimate of Qp in the formulation of Cp (eq. 24) produces the determination coefficient: R^2 = 96.8%, meaning that the 96.8% parameter of Qp influences Cp in eq. 24.

3.6. Parameter Estimation of Qp as a Function of Cp

Parameter estimate in this case indicates the influence of Qp on Cp based on the formulation of Qp, which is a function of Cp, A, and Tp as follows:

$$Qp = 2.78\ Cp.\ A / Tp \quad (25)$$

To be fitted to data conditions, the formulation becomes as follows:

$$Qp = Cp.\ A^{b1}.\ Tp^{\ b2}$$

Table 14 presents the parameter estimate of Qp from the function of Cp (eq. 25). Table 15 presents the correlation of the parameter estimate for Qp from the function of Cp (eq. 25); however, the variance analysis for Qp as a function of Cp (eq. 25) is presented in Table 16.

Table 14 Parameter estimates for Cp in the Qp function (The authors)

Parameter	Estimate	Std. error	95% confidence interval	
			Lower bound	Upper bound
Cp	.294	.092	.101	.487
b1	1.042	.085	.864	1.220
b2	-1.359	.276	-1.940	-.779

Table 15 Correlations of parameter estimates for Cp in the Qp function (The authors)

	Cp	b1	b2
Cp	1.000	-.631	.188
b1	-.631	1.000	-.879
b2	.188	-.879	1.000

Table 16 ANOVA[a] for Qp in the Cp function (The authors)

Source	Sum of squares	df	Mean squares
Regression	31434.976	3	10478.325
Residual	642.560	18	35.698
Uncorrected total	32077.536	21	
Corrected total	14493.592	20	

Dependent variable: peak discharge (Qp)
R squared = 1 (residual sum of squares)/(corrected sum of squares) = .956

The parameter estimate of Qp in the formulation of Cp (eq. 25) produces the determination coefficient: R^2 = 95.6%, meaning that the 95.6% Qp parameter influences Cp (eq. 25).

3.7. Parameter Estimation of Cp as Function of Qp

Parameter estimate in this case indicates the influence of Cp on Qp based on the formulation Qp, which is a function of Tp, A, Ai, K, and L as follows:

$$Qp = Cp.\ A^{b1}\ .\ Tp^{b2}.\ Ai^{b3}\ .\ K^{b4}\ .\ L^{b5} \quad (26)$$

Table 17 presents the estimated parameter for Cp from the function of Qp (eq. 26). Table 18 presents the correlation of the parameter estimate for Cp as a function of Qp (eq. 26); however, the variance analysis for Cp from the function of Qp (eq. 26) is presented in Table 19.

Table 17 Parameter estimates for Cp in the Qp function (The authors)

Parameter	Estimate	Std. error	95% confidence interval	
			Lower bound	Upper bound
Cp	.272	.147	-.051	.595
b_1	.865	.240	.336	1.393
b_2	-1.754	.324	-2.468	-1.040
b_3	-.073	.168	-.443	.297
b_4	.439	.117	.182	.696
b_5	-.045	.131	-.335	.244

Table 18 Correlations of parameter estimates for Cp in the Qp function (The authors)

	Cp	b_1	b_2	b_3	b_4	b_5
Cp	1.000	-.804	.486	.800	.308	-.597
b_1	-.804	1.000	-.617	-.927	-.318	.161
b_2	.486	-.617	1.000	.650	-.388	-.121
b_3	.800	-.927	.650	1.000	.101	-.268
b_4	.308	-.318	-.388	.101	1.000	-.316
b_5	-.597	.161	-.121	-.268	-.316	1.000

Table 19 ANOVA[a] for Cp in the Qp function (The authors)

Source	Sum of squares	df	Mean squares
Regression	28556.547	6	4759.425
Residual	148.757	11	13.523
Uncorrected Total	28705.304	17	
Corrected Total	14304.878	16	

Dependent variable: peak discharge (Qp)
R squared = 1 (residual sum of squares)/(corrected sum of squares) = .990

The parameter estimate of Cp in the formulation of Qp (eq. 26) produces the determination coefficient: R^2 = 99.0%, meaning that 99.0% of the Cp parameter influences Qp (eq. 26).

3.8. Parameter Estimation of Tb as Function of Qp

Parameter estimate in this case indicates the influence of Tb from the function of Qp based on the formulation of Tb as a function of Qp and L as follows:

$$Tb = bo. A^{b1} . Qp.^{b2}. L^{b3} \quad (27)$$

Table 20 presents the parameter estimate for Tb as a function of Qp (eq. 27), and Table 21 presents the correlation of the parameter estimate for Tb from the function of Qp (eq. 26); however, the variance analysis for Tb from the function of Qp (eq. 27) is presented in Table 22.

Table 20 Parameter estimates for Tb of the Qp function (The authors)

Parameter	Estimate	Std. error	95% confidence interval	
			Lower bound	Upper bound
b_1	.584	.117	.337	.830
b_2	-.598	.120	-.850	-.346
b_3	.040	.154	-.284	.365
b_0	3.390	1.371	.497	6.283

Table 21 Correlations of parameter estimates for Tb of the Qp function (The authors)

	b_1	b_2	b_3	b_0
b_1	1.000	-.837	-.551	-.244
b_2	-.837	1.000	.124	.442
b_3	-.551	.124	1.000	-.618
b_0	-.244	.442	-.618	1.000

Table 22 ANOVA[a] for Tb of the Qp function (The authors)

Source	Sum of squares	df	Mean squares
Regression	12326.023	4	3081.506
Residual	372.460	17	21.909
Uncorrected Total	12698.483	21	
Corrected Total	1407.504	20	

Dependent variable: time base (Tb)
a. R squared = 1 (residual sum of squares)/(corrected sum of squares) = .735

The parameter estimate of Tb in the formulation of Qp (eq. 27) produces the determination coefficient: R^2 = 73.5%, meaning that 73.5% of the Tb parameter influences Qp (eq. 27).

4. Conclusion

The Snyder SUH model is not necessarily suitable for watersheds in Indonesia. It is due to this difference in the characteristics, conditions, and rainfall patterns between the watersheds in Indonesia and the areas in which the model was developed.

Based on the analysis result of the parameters that influenced Snyder's SUH, it can be concluded as follows:

a. The parameter estimate of Ct to Tp = f(Ct, L, and Lc) produces the determination coefficient (R^2) = 72.8%.

b. The parameter estimate of Ct to Tp = f(Ct, L, and Lc) produces the determination coefficient (R^2) = 73.5%.

c. The parameter estimate of Ct to Tp = f(L, Lc, Lb, Wr, and S) yields the determination coefficient (R^2) = 90.2%.

d. The parameter estimate of Cp to Qp = f(Cp, A, and Tp) produces the determination coefficient (R^2) = 96.8%.

e. The parameter estimate of Qp to Tp = f(Cp, A, and Tp) produces the determination coefficient (R^2) = 95.6%.

f. The parameter estimate of Cp from the function Qp = f(Tp, A, Ai, K, and L) produces the determination coefficient (R^2) = 99.0%.

g. The parameter estimate of Tb from the function of Qp = f(A, L and Qp) produces the determination coefficient (R^2) = 73.5%.

In the future, this research will focus on the modification of the Snyder synthetic unit hydrograph in the influenced factors [12] to the parameters of Tb, Tp, Qp, Ct, and Cp by evaluating a few gauged watersheds in Indonesia that are fitted with watershed characteristics in Indonesia as the objects of hydrograph parameter development.

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