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Analysis of Rain Intensity Calculation Based on Rainfall Data from the Rain Station in Amuntai City, Hulu Sungai Utara District

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ABSTRACT

Flood management in South Kalimantan has been crucial in addressing the devastating floods that occurred in 2021. The event, which spanned around 4000 km^2, was exacerbated by land cover changes and continuous rainfall. Understanding the factors contributing to flooding is essential for developing effective mitigation and management measures. Utilizing methodologies like calculating rainfall intensity, analyzing rainfall patterns, and employing models like IDF curves and nomographs can enhance flood prevention efforts and develop more effective strategies to mitigate the impact of floods. This research aims to calculate the flood debit plan using an empirical method. This study employs the Library Study Method and conducts a rainfall analysis to determine the Flood Debit Value of the State River Flow Area Plan (DAS), utilizing the Rational Method, the Der Weduwen Method, and the Haspers Method. The highest annual effective rainfall data for the study area was found for 2.5, 10, 25, and 50 years. The Flood Debit Value of the Plan (Qbr) was found using the following logical methods: 419.14 m^3/s, 533.75 m^3/s, 562.75 m^2/s, 603.32 m^3/s, and 649.62 m^3/s. The rational method yielded the largest flood debit plan, which can serve as guidelines or a reference for future planning of water buildings for flood control in the State River. This is based on the analysis of the calculation of flood debit plans based on the maximum annual rainfall and effective rainfall of the area of river flow (DAS) in the State River streets, Pandan river district, Pandan (Alabio), Hulu Sungai Utara

INTRODUCTION

The flooding that occurred in South Kalimantan in 2021 was a significant event that affected various sub-districts and regencies in the region. The floods submerged settlements, farms, and agropolitan areas, impacting the lives and livelihoods of the local population. (Farida, 2024; Saputra, 2023) The inundated area spanned across multiple sub-provincial and district areas, totaling around 4000 km2, highlighting the extensive reach of the disaster. (Lestari, 2024) The flood event in January 2021 was particularly severe, hitting ten regencies and cities in South Kalimantan, causing widespread damage and displacement. (Farida, 2024) This flood was recorded as the most serious in the province's history, underlining its unprecedented nature and the challenges it posed. (Pratama et al., 2021).

The flooding was exacerbated by factors such as land cover changes in the Barito watershed, which led to land degradation and contributed to the occurrence of the floods (Adi and Savitri, 2022). Additionally, continuous rainfall over several days in January 2021 played a crucial role in the disaster, affecting various locations in South Kalimantan (Novitasari and Kurdi, 2022). The extreme rainfall that triggered the floods was part of a larger hydro-meteorological context, involving topography, tides, and precipitation patterns in the region (Kuntoro et al., 2022; Pratama et al., 2021).

The flood event in South Kalimantan in 2021 was considered one of the most significant in recent decades, causing substantial losses and highlighting the urgent need for effective flood management strategies in the region (Kuntoro et al., 2022). The impact of floods on the region's social and economic fabric is profound, with floods causing increasing social and economic losses over the years (Mauro et al., 2022). Understanding the factors contributing to flooding, such as land use changes, precipitation patterns, and hydro-meteorological aspects, is crucial for developing effective flood mitigation and management measures in flood-prone regions like South Kalimantan.

Understanding the correlation between rainfall intensity and flood events is crucial, as demonstrated in studies estimating flood inundation depth along roads based on rainfall intensity. This information can guide flood prevention strategies, such as adjusting side ditches to minimize flood risks (Suharyanto, 2021). Rainfall Area intensity-duration-frequency (IDF) curves are valuable tools for evaluating hydrologic responses during extreme rainfall conditions, aiding in flood risk management and mitigation efforts (Luo et al., 2015). Additionally, the stochastic generation of hourly rainfall series can provide vital information for flood planning and decision-making, underscoring the significance of comprehending rainfall intensity distributions in flood prevention (Syafrina, 2018).

In flood management, calculating planned flood discharge involves determining average regional rainfall, conducting alignment tests to select appropriate methods, and calculating rain intensity, all of which are critical steps in flood prevention strategies (Ikhwanudin, 2024). Furthermore, the application of flood nomographs for flood forecasting in urban areas using real-time rainfall data offers a straightforward yet effective technique for flood prediction and mitigation (Lee et al., 2018).

In conclusion, by utilizing methodologies such as calculating rainfall intensity, analyzing rainfall patterns, and employing models like IDF curves and nomographs, stakeholders can enhance their flood prevention efforts and develop more effective strategies to mitigate the impact of floods.

METHODS

This study employs the Library Study Method and conducts a rainfall analysis to determine the Flood Debit Value of the State River Flow Area Plan (DAS), utilizing the Rational Method, the Der Weduwen Method, and the Haspers Method.

Research Location

Pandan River Street, Alabio, Hulu Sungai Utara district, South Kalimantan, covers 8,300 km of this research.

Figure 1. Research Location

Data Collection and Analysis

We carry out Rain Intensity Calculation (I) in a series of stages, as detailed below:

1. A field survey; The field survey, conducted by directly reviewing the study object to obtain up-to-date data at the research site, includes important things, among others:
   a) Understanding the environment surrounding the research object is crucial.
   b) Understand the type of activity that is occurring;
   c) Stay up-to-date with the latest information in the field.
2. Primary data collection The field review provides this data in the following ways, among others:
   a) Understanding where the station recording or precipitation detector is located.
   b) Be aware of the geographical conditions and the presence of the area, region, or DAS in question.
3. We collect secondary data from institutions, services, or other stakeholders directly related to the research objects.
   a) The Meteorological Agency Climatology and Geophysics (BMKG) Hulu North River District, through the Station in Amuntai City, collected annual rainfall data from 2004 to 2015. This data came from observations of the rainfall detector area/area study in Hulu Sungai Utara District (HSU). Hydrological analysis was then performed to obtain the average rainfall flat area/region/DDAS, which was then used to calculate the maximum rainfall plan based on the period of re-planning (T plan: 2, 5, 10, 25 years).
   b) The landscape is designed for land management in the research area.

RESULTS AND DISCUSSION

Maximum Annual Rainfall Data

Tabel 1. Data on Annual Rainfall City of Amuntai (2004 – 2015)

No	Year	Maximum Annual Rainfall (mm)	Month
1	2004	325	December
2	2005	359	February
3	2006	378	July
4	2007	308	April
5	2008	349	Januar
6	2009	296	December
7	2010	412	March
8	2011	384	February
9	2012	355	December
10	2013	310	February
11	2014	308	March
12	2015	318	April

The research site has been collecting maximum daily rainfall data for the observation period 2004–2015, which spans the last 12 years. Next, we need to estimate the planned maximum daily rainfall of various recurring periods (T plan), specifically the parameter (R.24 or XT plan), and measure the required dispersion or deviation.

It is a fact that not all hydrological variables lie or are equal to their average values, but it is possible that there are values greater or smaller than their average. *(Sosrodarsono,1993)*. By measuring dispersion, or by statistically parametrically calculating values, one can determine the magnitude of the dispersion. $\boldsymbol{(Xi - \bar{X}), (Xi - \bar{X})^2}$ and $\boldsymbol{(Xi - \bar{X})^3}$ used for Gumbel and Normal distributions, while $\boldsymbol{(logXi - log\,\bar{X}), (logXi - log\bar{X})^2}$ and $\boldsymbol{(logXi - log\,\bar{X})^3}$ for distribution of Normal Log and Pearson Log Type III.

Table 2. Statistics Big Calculation

No	Year	Xi	$(Xi - \bar{X})$	$(Xi - \bar{X})^2$	$(Xi - \bar{X})^3$	$(Xi - \bar{X})^4$
1	2009	296	-45,83	2100,39	-96260,82	4411633,53
2	2007	308	-33,83	114,47	-38717,38	2273367,06
3	2014	308	-33,83	114,47	-38717,38	2273367,06
4	2013	310	-31,83	1013,14	-32248,53	969642,76
5	2015	318	-23,83	567,87	-13532,31	322475,08
6	2004	325	-16,38	268,30	-4394,83	71987,25
7	2008	349	-7,17	51,41	-368,60	2642,87
8	2012	355	-13,17	187,69	-2389,98	30084,52
9	2005	359	-17,17	294,81	-5061,87	86912,29
10	2006	378	36,17	1308,27	4320,09	1711567,51
11	2011	384	42,17	1778,31	74991,29	3162382,54
12	2010	412	70,17	4923,83	345505,07	24147494,28
Sum		*4102*	-	*12722,96*	*193124,75*	*37923556,75*

Parametric calculation of statistics is as follows:

1. Average value $(\bar{X})$

$$\bar{x} = \frac{\sum_{i=1}^{n} Xi}{n} = 4102/12 = 341{,}83$$

2. Deviation Standard (Sx)

$$Sx = \sqrt{\frac{\sum_{i=1}^{n}(Xi - \bar{X})^2}{n-1}} = \sqrt{\frac{12722{,}96}{12-1}} = \sqrt{1156{,}63} = 34{,}01$$

3. Skewness Coefficient *(Cs)*

$$Cs = \frac{n\sum_{i=1}^{n}(Xi - \bar{X})^3}{(n-1)\,(n-2)\,S^3} = \frac{12\,x\,\,193124{,}75}{(12-1)(12-2)\,x\,34{,}01^3} = 0{,}535$$

4. *Curtosis* coefficient *(Ck)*

$$Ck = \frac{n^2\sum_{i=1}^{n}(Xi - \bar{X})^4}{(n-1)\,(n-2)\,(n-3)S^4} = \frac{12^2\,x\,37923556{,}75}{(12-1)\,(12-2)\,(12-3)x34{,}01^4} = 4{,}12$$

5. Variation coefficient *(Cv)*

$$Cv = \frac{Sx}{\bar{X}} = \frac{34{,}01}{341{,}83} = 0{,}099$$

Table 3. Logarithmic Statistical Scale Calculation

No	Year	Xi	Log Xi	$(logXi - log\bar{X})$	$(logXi - log\bar{X})^2$	$(logXi - log\bar{X})^3$	$(logXi - Log\ \bar{X})^4$
1	2009	296	2,471	-0,119	0,01416	-0.001685	0,000200
2	2007	308	2,488	-0,041	0,00168	-0,000069	0,000003
3	2014	308	2,488	-0,041	0,00168	-0,000069	0,000003
4	2013	310	2,491	-0.038	0,00144	-0,000055	0,000002
5	2010	318	2,502	-0,027	0,00073	-0,000020	0,000001
6	2004	325	2,511	-0,018	0,00032	-0,000006	0,00
7	2008	349	2,543	-0,014	0,00020	-0,000003	0,00
8	2012	355	2,550	0,021	0,00044	0,000009	0,00
9	2005	359	2,555	0,026	0,00068	0,000018	0,00
10	2006	378	2,557	0,029	0,00084	0,000002	0,000001
11	2011	384	2,584	0,055	0,00302	0.000166	0,000009
12	2015	412	2,614	0,085	0,00722	0,000614	0,000052
Sum		-	*30,354*	-	*0,03241*	*-0,001095*	*0,000271*

Logarithmic Statistical Large Parametric Calculation as follows:

1. Average value $(\bar{X})$

$$log\ \bar{X} = \frac{\sum_{i=1}^{n} logXi}{n} = 30,354/_{12} = 2,529$$

2. Deviation Standard (Sx)

$$Log\ \ Sx = \sqrt{\frac{\sum_{i=1}^{n}(logXi - log\bar{X})^2}{n-1}} = \sqrt{\frac{0,03241}{12-1}} = \sqrt{0,00295} = 0,054$$

3. Skewness coefficient *(Cs)*

$$Cs = \frac{n\sum_{i=1}^{n}(logXi - log\ \bar{X})^3}{(n-1)\ (n-2) log\ \ Sx^3} = \frac{12\ x\ -0,001095}{(12-1)(12-2)x0,054\ ^3} = -\ 0,758$$

4. Curtosis coefficient *(Ck)*

$$Ck = \frac{n^2\sum_{i=1}^{n}(logXi - log\ \bar{X})^4}{(n-1)\ (n-2)\ (n-3) logSx^4} = \frac{12^2\ x\ \ 0,000271}{(12-1)\ (12-2)\ (12-3)x0,054^4} = 4,636$$

5. Variation coefficient *(Cv)*

$$Cv = \frac{\log Sx}{log\bar{x}} = \frac{0,054}{2,529} = 0,021$$

Table 4. Statistical Parametric Requirements for Selection of Frequency Distribution of Maximum Daily Rainfall Data

Distribution	Requirements	Calculation Results	Conclusion
Normal	$Cs \approx 0$	0,536	Rejected
	$Ck \approx 3$	4,120	Rejected
Log Normal	$Cs = Cv^2 + 3\ Cv \approx 3$	0,307	Rejected
Gumbel	$Cs \approx 1,139$	0,536	Rejected
	$Ck \approx 5,383$	4,120	Rejected
Log Pearson Type III	$Cs \neq 0$	- 0,758	Accepted
	$Cv \approx 0,05$	0.021	Accepted

In the table it appears that the distribution requirements Normal, Normal Log and Gumbel do not meet, then select the Pearson Log Distribution Type III that meets the requirements. Distribution Alignment Test (Goodness Of Fit Test).

Whether the chosen distribution method Log Pearson Type III already meets the data distribution requirements based on normal distribution, then the required Goodness Of Fit Test (Test of Data Distribution Alignment) includes the Chi-Squared test and the Smirnov-Kolmogorov test is seen in the following table:

Table 5. Chi Square Test Calculation or Chi Squared Test

Year	Maximum annual daily rainfall (log Xi)	Data sequence from the smallest (R.24 Maks)
2004	2,511	2,471
2005	2,555	2,488
2006	2,557	2,488
2007	2,488	2,491
2008	2,543	2,502
2009	2,471	2,511
2010	2,502	2,543
2011	2,584	2,550
2012	2,550	2,555
2013	2,491	2,557
2014	2,488	2,584
2015	2,614	2,614

Required parameters:

K = 1 + 3,22 log n , where n = number of data spreads = 12

= 1 + 3,22 log 12 = 1 + 3,22 x 1,079 = 4,474

$\approx 5{,}0\ Class$

DK : Degrees of Freedom

DK = K – (P + 1) , where P ; normal and binomial distribution values P = 1 and for the Poisson & Gumbel distribution P = 1.

DK = 4 – (1 +1) = 2 and degrees of confidence taken $(\alpha)\ :\ 5\% = 0{,}05$

Chi-Squared Value : Xh^2

$$Xh^2 = \sum \frac{(Ei-Oi)^2}{Ei},$$

Oi : Number of observation values in class- i

Ei : The number of theoretical values in class- i

$$Ei = n/K = 12/5 = 2{,}4$$

Probability or class limit:

$$\Delta X = (Xmax - X\min)/(K-1) =$$

$$(2{,}614 - 2{,}471)/(5-1) = 0{,}036$$

$$X_{awal} = X_{min} - (1/2\ \Delta X) = 2{,}471 - \left(0{,}036/2\right) = 2{,}453$$

Table 6. Calculation of Data Alignment Test with Smirnov – Kolmogorov

No	Year	R.24 Max (Log Xi)	P(x) = $\frac{m}{(n+1)}$	P (x <)	f(t) = $\frac{(logXi - log\bar{X})}{log\ Sx}$	P '(x) = $\frac{m}{(n-1)}$	P ' (x <)	D
1	2	3	4	5 = Nilai 1-4	6	7	8 = Nilai 1 - 7	9 = 5-8
1	2009	2,471	0,077	0,923	-2,203	0,091	0,909	0,014
2	2007	2,488	0,154	0,846	-0,759	0,182	0,818	0,029
3	2014	2,488	0,230	0,770	-0.759	0,273	0,727	0,043
4	2013	2,491	0,308	0,692	-0,704	0,364	0,636	0,056
5	2010	2,502	0,384	0,616	-0,500	0,454	0.546	0.070
6	2004	2,511	0,461	0,539	-0,333	0,545	0,455	0,084
7	2008	2,543	0,538	0,462	-0,259	0.636	0,364	0,098
8	2012	2,550	0,615	0,385	0,389	0,727	0,273	0,112
9	2005	2,555	0,692	0,308	0,481	0,818	0,182	0.126
10	2006	2,557	0,769	0,231	0,537	0,909	0.091	0.140
11	2011	2,584	0,846	0,154	1,018	1,000	0,0	0,154
12	2015	2,614	0,923	0,077	1,574	1,091	-0,091	**0,168**
Jumlah		30,354						
Log $\bar{X}$		2,529						

- m = data sorting number; n = amount of data
- Deviation Standard (log Sx) = 0,054
- Degrees of Confidence (signifikan) : (α) = 5% = 0,05
- Dmax = 0,168
- D Critical = 0,375 for n = 12

Condition: Dmax < Do Critical. Condition : 0.168 < 0.375, then the method of distribution of the Pearson Log Type III is acceptable..

Both the Chi Squared Test and the Smirnov Kolmogorov Test, the Pearson Log Distribution Method Type III can be used to calculate the Maximum Planned Rainfall.

Planned Maximum Daily Rainfall Analysis (R.24)

The results of the calculation of the planned rainfall using the distribution method of the Pearson Log Type III can be viewed in the Planned Rainfall Calculation Table with the pearson log Type III.

Table 7. Planned Rainfall Calculation with Pearson Log Type III

No	Year	Xi	Log Xi	$(logXi - log\bar{X})$	$(logXi - log\bar{X})^2$	$(logXi - log\bar{X})^3$
1	2009	296	2,471	-0,119	0,01416	-0,001685
2	2007	308	2,488	-0,041	0,00168	-0,000069
3	2014	308	2,488	--0,041	0,00168	-0,000069
4	2013	310	2,491	-0,038	0,00144	-0,000055
5	2010	318	2,502	-0.027	0,00073	-0.000020
6	2004	325	2,511	-0,018	0,00032	-0,000006
7	2008	349	2,543	-0,014	0.00020	-0,000003
8	2012	355	2,550	0,021	0,00044	0,000009
9	2005	359	2,555	0,026	0,00068	0,000018
10	2006	378	2,557	0,029	0,00084	0,000002
11	2011	384	2,584	0,055	0,00302	0,000166
12	2015	412	2,614	0,85	0,000722	0,000614
Sum		-	30,354	-	0,03241	-0,001095

Calculation of intensity, duration & frequency curves (IDF curves) with recurrence periods (when recurring) T plans: 2, 5, 10 and 25 years required to obtain settings or constants attached to the respective Talbot, Sherman and Ishiguro formulas so that IDP curve trends/trends for various recursion periods(T plans) can be described.

Table 8. Calculation of Rain Intensity with Talbot Formula

No	$t_c = t$	I	I.t	I^2	$I^{2.}$ t
1	5	684,23	3421,15	468170,69	2340853,46
2	10	430,94	4309,40	185709,28	1857092,80
3	20	271,41	5428,20	73663,39	1473267,76
4	30	207,10	6231,00	42890,41	1286712,30
5	40	170,94	6837,60	29220,48	1168819,34
6	60	130,43	7825,80	17011,98	1020719,09
7	80	107,06	8564,80	11461,84	916947,20
8	120	82,15	9858,00	6748,62	809834,40
9	180	62,68	11282,40	3928,78	707180,83
10	240	51,74	12417,60	2677,03	642486,62
$\sum =$ Sum		2198,68	76175,95	798592,09	12223913,80

Table 9. Calculation of Rain Intensity with Sherman Formula

No	$t_c = t$	I_5	*log I*	*log t*	*(log t log I)*	$(log\ t)^2$
1	5	684,23	2,835	0,698	1,979	0,487
2	10	430,94	2,634	1,0	2,634	1.0
3	20	271,41	2,433	1,301	3,165	1,693
4	30	207,10	2,316	1,477	3,421	2.181
5	40	170,93	2,233	1,602	3,577	2,566
6	60	130,43	2,115	1,778	3,760	3,161
7	80	107,06	2,030	1,903	3,863	3,621
8	120	82,15	1,915	2,079	3,981	4.322
9	180	62,68	1,797	2,255	4,052	5,085
10	240	51,74	1,714	2,380	4,079	5,664
$\sum =$ Sum		-	22,022	16,473	34,511	29,780

Table 10. Calculation of Rain Intensity with Ishiguro Formula

No	$t_c = t$	I	$I\sqrt{t}$	I^2	$I^{2\cdot}\sqrt{t}$
1	5	684,23	1529,98	465437,77	1040750,50
2	10	430,94	1262,75	185709,28	587264,32
3	20	271,41	1211,95	73663,39	329432,69
4	30	207,10	1134,33	42890,41	23494,45
5	40	170,93	1081,06	29217,06	184784,94
6	60	130,43	1010,31	17011,98	131774,27
7	80	107,06	957,57	11461,85	102517,85
8	120	82,15	889,91	6748,62	73927,45
9	180	62,68	840,94	3928,78	52710,15
10	240	51,74	801,55	2677,03	41472,33
$\sum =$ Sum		2198,67	10720,35	838746,17	2568128,95

Formula Matching Comparison – Rain Intensity Formula

From the calculation of the intensity of the rain is made a resume or summary, so that it can be made a trend curve or curve tendency Rain intensity that is closest to the curve The precipitation intensity is calculated by the Mononobe formula as a comparison / comparison for the three rain intensity curves of the Talbot, Sherman and Ishiguro formula by looking at the summary or Average deviation = [M (ΔI)] of various variants according to re-period can be seen in the following table:

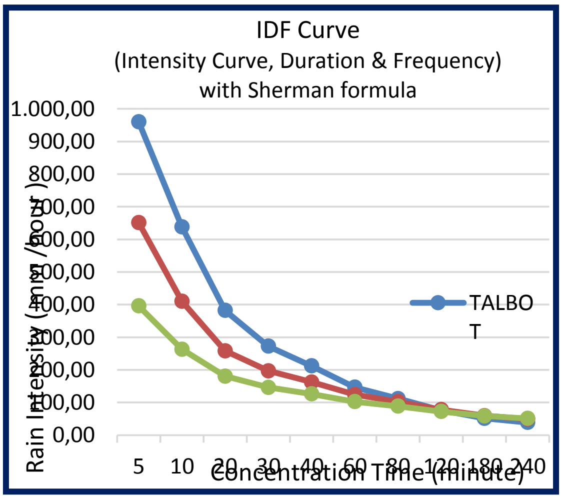

Figure 3. Graphic Data Measurement and Prediction of Rain Intensity with 3 (Three) Formulas: Talbot, Sherman and Ishiguro

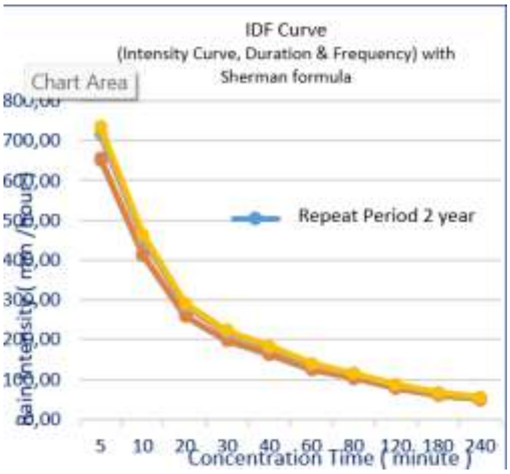

Figure 4. Intensity Curves / IDF Curves Using the Empirical Formula: Sherman with Various Re-Period Variants

Conclusion

We can conclude, based on the results and interpretation, that we have developed an empirical formula for calculating the rain intensity in Amuntai City, Hulu Sungai Utara district. This formula utilizes data from the maximum daily rainfall observed over a 12-year period (2004–2015), and compares it with the Mononobe and Sherman formulas, using the indicator of the default deviation of rain intensity, or average deviation = [M (ΔI)] = 6,354 mm / hours ≥ 0,00. The analysis results showed that the Sherman formula is closest to calculating rainfall intensity when compared to the Mononobe formula with a variety of specific re-periods starting from the T plan: 2, 5, 10 and 25 years are ($I_2 = \frac{1905,46}{t^{0,667}}$ *mm /hours*), ($I_5 = \frac{1923,09}{t^{0,667}}$ *mm / hours*), ($I_{10} = \frac{2089,30}{t^{0,667}}$ *mm / hours*) and ($I_{25} = \frac{2155,57}{t^{0,667}}$ *mm / hours*).

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