

Analysis of Flood Peaks Using The Mean Annual Flood Method

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Manuscript received 30 Nov 2021; revised 3 Dec 2021; accepted 10 Jan 2022. Date of publication 10 April 2022

Abstract

The Kedang Pahu river is one of the tributaries of the Mahakam river. The research plan is located in Damai District, West Kutai Regency, East Kalimantan province. Recently, the Damai District and Damai Seberang areas have flooded activities that have caused the surrounding settlements to flood into residential areas and block existing road access. Planning analysis and knowing the annual flood elevation is essential. The analysis uses the method of calculating the mean annual flood (MAF) to search for the average annual flood discharge data and the search for the average annual elevation. Data validation using a simple linear regression method produces a correlation coefficient of 58.67%, or R-value = 0.5867. The analysis results in the value of Q1 or the 1st year period, the mean annual flood rate of the average annual flood discharge is 2576.0695 m³/second and the value associated with the magnifying factor (GF) is the average annual flood discharge rate of Q5=3014,00 m³/sec, Q10 = 3529.22 m³/sec, Q20 = 4095.95 m/sec, Q50 = 5049.10 m³/sec, Q100 = 5847.68 m³/sec, Q200 = 6852.34 m³/sec, Q500 = 8423.75 m³/sec & Q1000 = 9917.87 m³/sec. The analysis results at HEC-RAS 5.07 based on manning analysis showed the elevation values were Q1=18.47m, Q5=18.85m, Q10=18.86m, Q20=19.18m, Q50=19.74m & Q100=19.99m. Researchers only show elevations up to Q100 or the 100th year because of limited data and the reviewed data accuracy.

Keywords: Mean Annual Flood, MAF, Flood, Growth Factor.

1. Introduction

The Kedang Pahu river has had flooding activities and flood-impacted local residential areas, especially in Damai District and Damai Seberang. Recently, the Damai District and Damai Seberang areas have flooded, actions that have caused the surrounding settlements to flood into residential areas and block existing road access. For the mitigation, a researcher has the strategy for flood analysis. The analysis uses the method of calculating the mean annual flood (MAF) to search for the assumption average annual flood discharge data and the search for the yearly average elevation. The analysis value can have more responsibilities and positively impact sustainability and mitigation in Damai District and Damai Seberang areas [1]. Mean annual flood is the amount of water that causes flooding that comes on time from a spring or watershed. Maximum peak flood discharge is the ultimate peak flood discharge in one year. Flood peak discharge in each river profile is the most critical data for planning, repairs, and river arrangements [2] [3].

Meanwhile, to use the MAF method, one must pay attention to the availability of the data obtained. In the hydrology book [4], there are three selection methods based on data availability [5]. The estimated average annual flood peak discharge or moderate annual flood based on the availability of data from the watershed has the following conditions:

1. If discharge data is available, at least ten-time series data records are available, then MAF is calculated based on annual peak flood discharge serial data.
2. If debit data are available, less than ten years of time series data, then MAF is calculated based on the method of peak flooding above the threshold (peak over a threshold = POT)
3. If there is no debit data available from the watershed, then the MAF is determined by regression equation based on data on the watershed area (AREA), the annual mean of rainfall, most significant rain in one day (APBAR), river slope (SIMS), an index of the area of inundation such as area of lakes, puddles, reservoirs (LAKE) [5] [6].

This study aims to determine the average annual peak flood discharge to find a return period for peak flood discharge based on the growth factor value, knowing the return period of the flood discharge of the Kedang Pahu river [7]. Based on the aims and objectives of the research, there are several benefits given to the sustainability of research results, including [1]:



1. Have a complete overview of the average annual peak flood discharge on the Kedang Pahu river.
2. Have high responsiveness if you already have limits or guidelines for flood risk mitigation from analyzing the average annual peak flood discharge.
3. Can find out the flood elevation through analysis of the average annual peak flood discharge

The population object in this study is the community and industry domiciled around the Damai District. The most significant population in this study is Damai District and Damai Seberang Community, housing around the Kedang Pahu River [8] [9]. The primary role of population objects in research is to provide input and will be in direct contact with the impact of the research result. Observations are located as follows:

Location	: West Kutai, East Kalimantan. Indonesia.
Zone UTM	: 50 South
WGS	: 84
Coordinate global	: 0° 27' 20.453" S ; 115° 41' 56.683" W
Total watershed area	: 3626.24 km ²
River length from estuary to observation	: 103.86 km



Fig 1. Damai District & Seberang Regency in West Kutai, East Kalimantan

2. Method

I have general and technical guidelines for creating research flows in my study. I prefer the technical research flow process. Because in the flow of technical analysis [10], we can find out the research system as a whole, starting from data collection to the data processing process to have the final result.

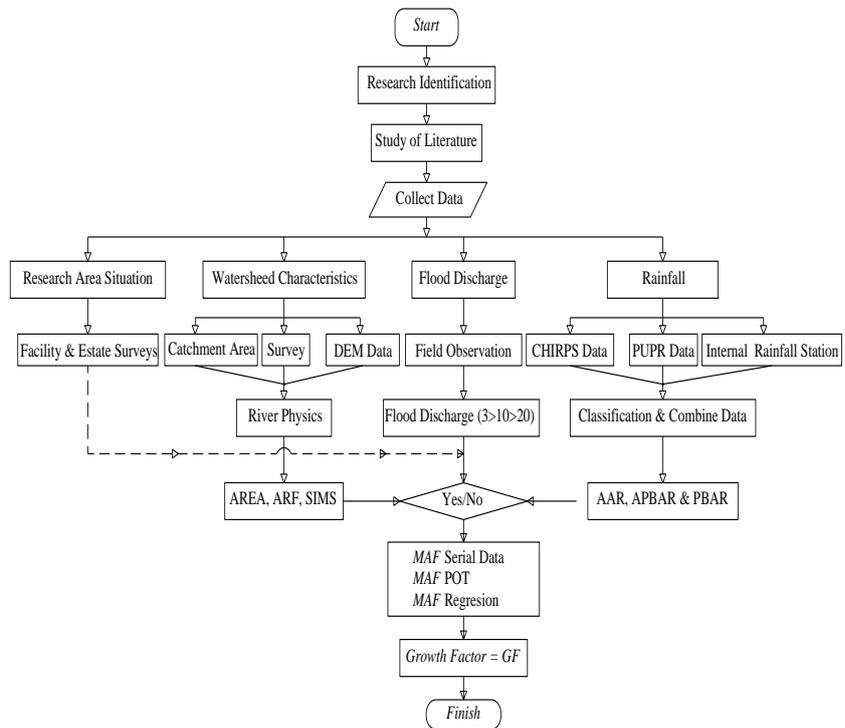


Fig 2. Damai District & Seberang Regency in West Kutai, East Kalimantan

To choose the method of calculating the annual mean flood (MAF) based on hydraulic guidelines [11] [12], a flow chart is available that will guide in choosing the method of analyzing the frequency of peak flood discharge according to the availability of the data obtained. The chart is as follows:

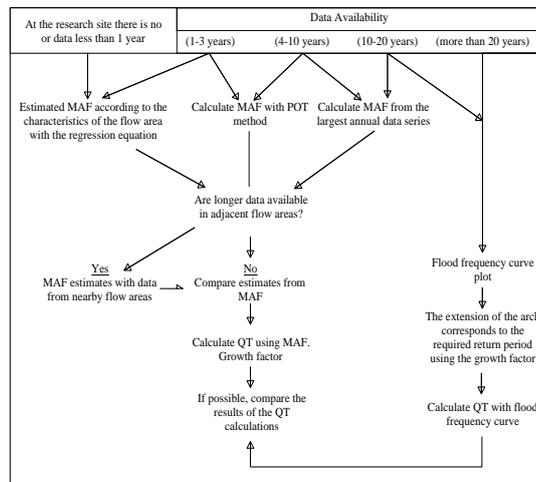


Fig 3. The Flow of the Selection of the Method of Analyzing the Frequency of Peak Flood Discharge

Before creating and analyzing data, good data validation is needed to fit the data. Whether the data relationship from one variable to another variable. Data validation is necessary because it can be used with good and right as a data quality threshold [13]. Data validation has a relationship with one to two variables, even more than two variables. One data validation method related to one or even more than two variables is a simple linear regression method [7]. The results are the correlation coefficient (R) and the coefficient of determination (R²). The correlation coefficient value will relate to the strength of the data relationship. The power of the data can be described as follows:

R = 1	: Perfect positive relationship
0,6 < R < 1	: Positive direct relationship good
0 < R < 0,6	: A direct relationship was weakly positive
R = 0	: There is no linear relationship
-0,6 ≤ R < 0	: Weak negative direct relationship
-1,0 < R < -0,6	: Negative direct relationship good
R = -1	: A perfect negative relationship

Fig 4. Correlation Coefficient Value

After the data validation process, the researcher selects the analytical calculation method from the flow chart as a guide for choosing the calculation method; the researcher tends to lead to the calculation using the regression method. The regression method in the study of the mean annual flood (MAF) has several data needed to fulfill theoretical calculations such as:

AREA	:	Catchment Area
APBAR	:	Most considerable yearly average precipitation in one day
PBAR	:	The annual average value of the most significant rainfall is I (one) day; from the Isohyet map, the maximum precipitation is one day which is the most influential annual average rainfall data for each rain post.
ARF	:	Area reduction factor whose magnitude depends on the area of the watershed
SIMS	:	River slope coefficient
LAKE	:	Lake Index

of the required data collection, the data can be entered into the implementation of the MAF formula; the MAF formula is:

$$\bar{X} = (8,00)(10^{-6})(\text{AREA})^y (\text{APBAR})^{2,445} (\text{SIMS})^{0,117}(1+\text{LAKE})^{-0,85}$$

Predicting or estimating flood discharge based on high data availability water level is very different from the calculation of the design discharge. So it is necessary to know the existing discharge height based on the results of an in-depth survey in the field to realize accurate data or for further data validation. The formula for finding elevation based on river discharge that has been recorded in the area uses the following formula:

$$Q_{\text{med}} = \frac{1}{n} R^{\frac{2}{3}} S^{\frac{1}{n}} A$$

Qmed	:	Debit
n	:	Manning
S	:	Water level slope
R	:	Hydrolic radius
A	:	Cross section area of river

In this calculation, the researcher has a limit or distance between the error threshold in the analysis. The formula for the mathematical model is as follows:

$$\frac{\bar{X}}{1,59} < \bar{X} < (1,59) \bar{X}$$

\bar{X} : Mean annual flood value

3. Results and Discussion

Results and analysis describe the effects of data analysis and interpretation of research results, which include a description of the research subject. The results of the research that will be discussed are how the researcher sorts the data, processes the data, and informs or describe the results of the study, which will later answer the research problem straightforward or easy to understand

3.1 Watershed Characteristics, Slope Data (SIMS) & Lake Index (LAKE)

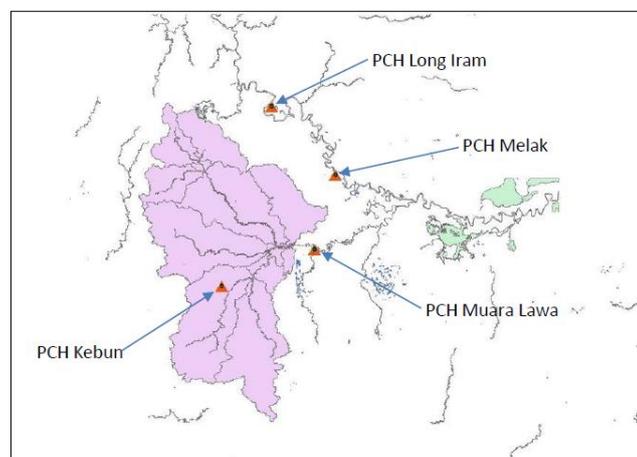


Fig 5. Catchment Area and Precipitation Post

The picture above illustrates the results of the analysis of searching for watershed data and entering the position of the rain post around the research area. Apart from the results of the watershed analysis, it can be used to determine the characteristics of the watershed; the data can also be used as rain catchment area data. In this analysis, data were obtained from the rain catchment area of 3626.24km².

In addition to looking for watershed data and catchment area, planning the discharge or carrying capacity of the volume of the river that is passed must take into account the slope of the riverbed observed, starting from the riverbed the highest river to the lowest riverbed—elevation relationship in search. The river’s gradient will also be related to the river’s length, starting from the point of the highest point to the lowest point or point of concentration of observations for research. The river length is described through DEM data and tracked shapefile data through ArcMap; then, the data is converted to AutoCAD as the basis for sorting data. The data length is 103,865m, and the slope coefficient (SIMS) is 0.42523541 [14].

LAKE index or multiplier value of the coefficient of influence of lake or reservoir area or adjacent swamps directly affects river discharge. This value can be described through shapefile data that has been selected and surveyed via ArcMap; Then, the data is summed based on the area obtained. The index is obtained through the total available lake area and research watershed. This is meant as a multiplier for calculations analysis, and the analysis results get a total LAKE area of 3,820,335 m² or 3.82 km².

3.2 Rainfall & River Water Level Overview

The selection of rainfall data based on rainfall posts near or located in the catchment area of a watershed is very effective and can be used as a calculation benchmark. In this study, several locations of rainfall posts can be used and studied. Still, the researchers chose the rainfall post located in the watershed area where the rainfall data has been collected or collected by the team field supervisor. For now, data is available through statistical information on the maximum rainfall that has been recorded in the garden rainfall post. Post garden rainfall data records numbers. The highest daily rainfall in 2010-2021 is 273mm/day. The daily maximum rainfall activity in 2010-2021 can be seen below.

Table 1. Daily Maximum Rainfall Data

	Daily Maximum Rainfall (Month/Years)										
	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
JAN	92.00	87.00	85.00	61.50	118.00	100.00	98.00	70.00	89.67	80.00	118.00
FEB	99.00	121.00	80.00	69.50	151.00	135.33	41.23	84.00	195.00	117.50	123.00
MAR	103.00	80.00	110.00	105.00	43.50	119.00	69.00	99.00	82.33	273.00	139.00
APR	76.00	68.00	64.00	80.00	90.00	86.50	70.23	102.50	75.00	134.00	66.00
MEI	62.00	42.00	42.00	80.00	74.00	94.67	83.00	62.50	74.00	110.00	-
JUN	63.00	62.00	24.00	70.00	225.00	60.25	68.00	42.50	68.00	72.17	-
JUL	48.00	45.00	47.00	35.00	63.00	60.00	105.43	74.00	22.83	74.00	-
AGST	37.00	29.00	19.00	61.00	11.67	38.93	84.00	30.00	40.00	82.00	-
SEPT	38.00	38.00	67.00	31.00	26.00	63.00	49.25	64.00	39.00	42.00	-
OKT	65.00	65.00	69.00	126.67	44.00	96.50	72.00	94.00	60.00	93.00	-
NOV	79.00	74.00	104.80	45.00	91.00	98.00	157.00	120.00	57.00	121.00	-
DES	77.00	77.00	32.00	193.00	84.00	48.00	132.67	103.00	77.00	105.00	-

Source: Research Data

In addition to rainfall data, there is also flood discharge data recorded [15]. The recording is done at the point of the review location. As a comparison later, the recorded river discharge data can be used as material for consideration and data validation. The following discharge data that have been recorded by researchers and field supervisors can be illustrated through tables and curve drawings:

Table 2. River Flood Water Level

Kriteria	2019		2020		2021	
	MAB (R)	MAB (T)	MAB (R)	MAB (T)	MAB (R)	MAB (T)
Jan	-	-	+12.807	+16.157	+14.237	+18.737
Feb	-	-	+15.687	+19.487	+14.997	+19.137
Mar	-	-	+13.757	+20.777	+13.897	+17.237
Apr	-	-	+15.257	+20.057	-	-
Mei	-	-	+16.937	+20.387	-	-
Jun	-	-	+13.907	+18.057	-	-
Jul	-	-	+13.307	+15.717	-	-
Agust	-	-	+12.907	+14.297	-	-
Sept	-	-	+12.857	+14.837	-	-
Okt	-	-	+12.907	+18.887	-	-
Nov	-	-	+13.537	+18.657	-	-
Des	+13.207	+16.207	+13.857	+18.457	-	-

Source: Research Data

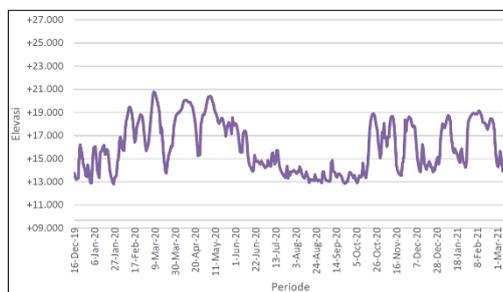


Fig 6. Flood Activity Curve

3.3 Validation Data

Data validation was carried out using a simple linear regression model that aims to find a straight-line correlation between two variables. This is the rainfall with discharge observed by the researcher. The calculation of a simple linear regression model requires discharge and precipitation. Using the Manning formula, delete the flood data found by researchers through flood elevation data converted into flood elevation data debit value. Manning's formula requires several watershed characteristics and can be calculated by math. Some of these characteristics are the crew roughness value (n), centralized distance flow (Centroid Stream Distance), and river slope value (S). The results of data validation produce R values 0.5867 and R² 0.3442.

3.4 Analysis

The mean annual flood review analysis has a different dependence on data validation. This dependence is based on criteria that have been obtained by watershed characteristics that have been reviewed [16]. After the study is received, the next step is to multiply by a growth factor—analysis using excel data and HEC-RAS 5.07.

Table 3. Mean Annual Flood Analysis

Catchment Area	VALUE
A =	3626.24
X Factor	
$(8)(10^{-6})$	0.000008
AREA	
$v(1.02-0.0275 \cdot \text{LOG A})$	0.9221149
A^v	1915.2615
ARF	
$1.152-0.1233 \cdot \text{LOG A}$	0.713119
APBAR	
Maximum rainfall/PBAR	273 mm/day
$(\text{PBAR} \times \text{ARF})^2 \cdot 445$	395729.83
SIMS	
$((\text{Elv A} - \text{Elv B}) / L)^{0.117}$	0.4252354
LAKE	
Indeks	0.0010535
LAKE Index < 0.25Ok
$(1+\text{index})^{-0.85}$	1.00
HASIL	
\bar{X}	2576.070 m ³ /sec

Source: Research Data

Based on the growth factor table can be described in table 4 below. This refers to the discharge magnification multiplier, in which the multiplier enters into the classification of magnifying factors more than > 1500km² area (A). The results of the growth factor analysis can be seen in the table below [17] [18]:

Table 4. Growth Factor Analysis Results

No.	Y	Time Period (Tahun)	C	m ³ /sec
1	1.50	5	1.17	3,014.00
2	2.25	10	1.37	3,529.22
3	2.97	20	1.59	4,095.95
4	3.90	50	1.96	5,049.10
5	4.60	100	2.27	5,847.68
6	5.30	200	2.66	6,852.34
7	6.21	500	3.27	8,423.75
8	6.91	1000	3.85	9,917.87

Source: Research Data

This analysis has limitations if there are inaccuracies in estimating the data peak flood discharge for DPS in the absence of river flow data. As for the flood discharge range using the formula [19], The calculation can be seen below:

$$\frac{\bar{X}}{1,59} < \bar{X} < (1,59) \bar{X} = 1620.169 \text{ m}^3/\text{sec} \leq 2576.0695 \text{ m}^3/\text{sec} \leq 4095.951 \text{ m}^3/\text{sec}$$

The data analysis results obtained the mean annual flood elevation data. Each magnifying factor has the mean yearly flood elevation so that this data can be inputted into the ras 5.07 for further analysis [20].

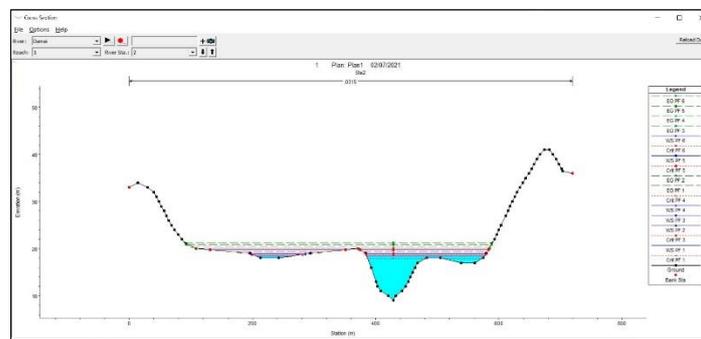


Fig 7. Elevation of Mean Annual Flood with Growth Factor

4. Conclusion

Based on the research analysis results, the researchers made the following conclusions the final result and the essence of the whole research. The abstract correlation-based study between the objectives, benefits, and results that have been analyzed. Conclusion as follow :

1. The average peak flood discharge can be determined based on the analysis of the annual moderate flood with the selected regression method, and the final result of the release is 2576.07m³/s at a flood height of 18.47m and a distance value of 1620.169m³/s for the minor discharge and 4095.951 m³/s for the most powerful shot.

2. Average peak flood discharge, which has been multiplied by a magnifying factor (Growth factor) with a planned 1st anniversary period, 5th year, 10th year, 20th year, 50th year, 100th year, 200th year, 500th year & 1000th year obtained with a value of Q1: 2576.07 m/s, Q5: 3014.00 m³/s, Q10: 3529.22 m³/s, Q20: 4095.95 m/s, Q50: 5049.10 m/s, Q100: 5847.68 m/s, Q200: 6852.34 m³/s, Q500: 8423.75 m/s & Q1000: 9917.87 m/s
3. Average peak flood discharge with a magnifying factor that has been adjusted to plan return period has limited data accuracy or correlation coefficient of 58.67% with a weak positive direct relationship statement specifically for evaluation of the Kedang Pahu river. So the return discharge from the peak flood discharges, the average that has been multiplied by the magnifying factor, can be used as a reference and research guidelines in the Kedang Pahu river.

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