Analysis of Flood Discharge due to Land Used Changes in Keramasan Watershed Palembang, Indonesia

by Yosi Marizan

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Yosi Marizan
Post Graduate Student of Civil and Environment Engineering Faculty,
Universitas Bina Darma
Indonesia
yosi.marizan@gmail.com

Achmad Syarifudin
Assoc. Prof. of Civil and Environment Engineering Faculty,
Universitas Bina Darma
Indonesia
achmad.syarifudin@binadarma.ac.id

***Abstract*— Changes in land use in the catchment area have a significant impact on flood discharge. This phenomenon also occurs in the Keramasan watershed. This study aims to determine the impact of land use changes on flood discharge. To calculate the flood discharge used the rational method. The data used in this study include rainfall data, land use data and topographic data. Rainfall data used is daily rainfall data recorded at BMKG Kenten Palembang. Daily rainfall is transformed into hourly rainfall intensity using the Mononobe method.**

The results of this study indicate that the increase in flood discharge due to changes in land use is approximated by the linear trend equation Y = a + b*X_1 + c*X_2 + d*X_3. Variable Y is flood discharge. The variables X_1, X_2, and X_3 are the area of rice fields, the area of agricultural land and the area of housing. The combination correlation coefficient is 0.96. Variables a, b, c, and d are –350.60, 33.63, -75.00, and 1.006. The partial correlation coefficient, RYX_1 is 0.57, RYX_2 = 0.57, and RYX_3 = 0.57.

Keywords*—*land uses changes, flood discharge, multi regression

I. Introduction

The Keramasan river has a watershed area of about 8,233 km2, with a river length of about 313 km, which flows from the south to the upper reaches of the river around Baturaja and empties into the Musi river in the Kertapati district of Palembang, better known as Muara Ogan. Changes in land use in watersheds (DAS) have a dominant influence on flood discharge (Jayadi 2000). Changes in land use in conservation areas to built areas can clearly cause floods, landslides and droughts. Floods are streams/puddles of water that cause economic losses or can even cause loss of life (Asdak 1995). This flow / puddle can occur due to overflows in the area to the right or left of the river due to the river channel not having sufficient capacity for the flow of the passing stream (Sudjarwadi 1987). This happens because during the rainy season, not much rainwater that falls on the catchment area can seep into the ground, but rather overflows as river water discharge. If the river discharge is too large and exceeds the river's cross-sectional capacity, it will cause flooding.

Increased flood discharge can also have an impact on the failure of flood control buildings (dams, weirs, embankments, drainage channels, etc.). This is because the flood control building is not able to withstand the force load due to the flood discharge which has increased due to changes in land use. Based on the above considerations, it is necessary to pay attention to the impact caused by changes in land use in the Keramasan watershed.

II. Research Methods

A. Frequency Analysis

The formula used to calculate the statistical parameters of rainfall is as follows.

Average value ($\overline{R}_1$)

$$\overline{R}i = \frac{1}{n}\sum_{i=1}^{n} Ri \quad (1)$$

Standar devation (Sd)

$$S = \left| \frac{\sum\left(R_1 - \overline{R}_1\right)^2}{(n-1)} \right|^{1/2} \quad (2)$$

Coefficient skewness (Cs)

$$C_S = \frac{n\sum_{i=1}\left(R_i - \overline{R}_i\right)^4}{(n-1)(n-2)S^3} \quad (3)$$

Sharpness coefficient (Ck)

$$C_K = \frac{n^2\sum_{i-1}\left(R_i - \overline{R}_i\right)^4}{(n-1)(n-2)(n-3)Sd^4} \quad (4)$$

Coefficient of Variation (Cv)

$$C_V = \frac{Sd}{\overline{R}_i} \quad (5)$$

with :

n = Number of data / length of data

R = Rainfall (mm)

$\overline{R}_1$ = Average rainfall (mm)

Sd = standard deviation / standard deviation

B. Rainfall Intensity Analysis

Rainfall intensity has a relationship between the duration of the rain and the frequency of rain which is usually given in the form of a curve called the IDF (Intensity Duration Frequency) curve. From this curve, it can be seen the amount of rain intensity with return periods of 5, 10, 25, 50 and 100 years. The following is the calculation of the rainfall intensity for the 5 year return period.

TABLE I. NUMBER PARAMETER GUMBEL DISTRIBUTION MAXIMUM RAINFALL

Return Period (Years)	**R_{24}(mm)**
5	125.984
10	145.140
25	169.341
50	187.294
100	205.118

$$I = \left(\frac{R_{24}}{24}\right)\left(\frac{24}{t}\right)^{\frac{2}{3}}$$

$$= \left(\frac{125{,}984}{24}\right)\left(\frac{24}{0{,}3247}\right)^{\frac{2}{3}}$$

$$= 257.1460 \text{ mm/jam}$$

Intensity calculations for 5, 10, 25, 50 and 100 year return periods in a 10-minute time span can be seen in Table II. below this:

TABLE II. RAIN INTENSITY WITH RETURN PERIOD AND RAIN DURATION

t		Return Period				
Minute	**Hours**	**5**	**10**	**25**	**50**	**100**
5	0.083	228.928	263.736	307.713	340.337	372.724
10	0.167	144.216	166.143	193.847	214.399	234.801
20	0.333	90.850	104.664	122.116	135.063	147.916
30	0.500	69.332	79.873	93.192	103.072	112.881
40	0.667	57.232	65.934	76.928	85.084	93.181
50	0.833	49.321	56.820	66.295	73.323	80.301
60	1.000	43.676	50.317	58.707	64.931	71.110
70	1.167	39.411	45.403	52.974	58.590	64.166
80	1.333	36.054	41.536	48.462	53.600	58.700
90	1.500	33.331	38.399	44.802	49.552	54.267
100	1.667	31.070	35.795	41.763	46.191	50.586
110	1.833	29.158	33.591	39.192	43.347	47.472
120	2.000	27.514	31.698	36.983	40.904	44.797
130	2.167	26.085	30.051	35.061	38.779	42.469
140	2.333	24.827	28.602	33.371	36.909	40.422
150	2.500	23.711	27.316	31.871	35.250	38.605
160	2.667	22.713	26.166	30.529	33.766	36.979
170	2.833	21.813	25.130	29.320	32.428	35.514
180	3.000	20.997	24.190	28.223	31.216	34.186
190	3.167	20.254	23.334	27.224	30.111	32.976
200	3.333	19.573	22.549	26.309	29.098	31.867
210	3.500	18.947	21.827	25.467	28.167	30.848
220	3.667	18.368	21.161	24.689	27.307	29.906
230	3.833	17.832	20.543	23.968	26.510	29.032
240	4.000	17.333	19.968	23.298	25.768	28.220
250	4.167	16.868	19.432	22.672	25.076	27.463
260	4.333	16.432	18.931	22.087	24.429	26.754
270	4.500	16.024	18.460	21.539	23.822	26.089
280	4.667	15.640	18.018	21.023	23.251	25.464
290	4.833	15.278	17.602	20.537	22.714	24.875
300	5.000	14.937	17.208	20.078	22.206	24.319
310	5.167	14.614	16.836	19.643	21.726	23.794
320	5.333	14.308	16.484	19.232	21.271	23.295
330	5.500	14.017	16.149	18.842	20.839	22.822
340	5.667	13.741	15.831	18.470	20.428	22.373
350	5.833	13.478	15.528	18.117	20.037	21.944
360	6.000	13.227	15.239	17.780	19.665	21.536

From the results of the calculation of the intensity of rain for each return period in a span of 10 minutes. So that IDF curves can be made. The following is the shape of the IDF curve from the rain intensity data that has been obtained which is shown in Figure 1.

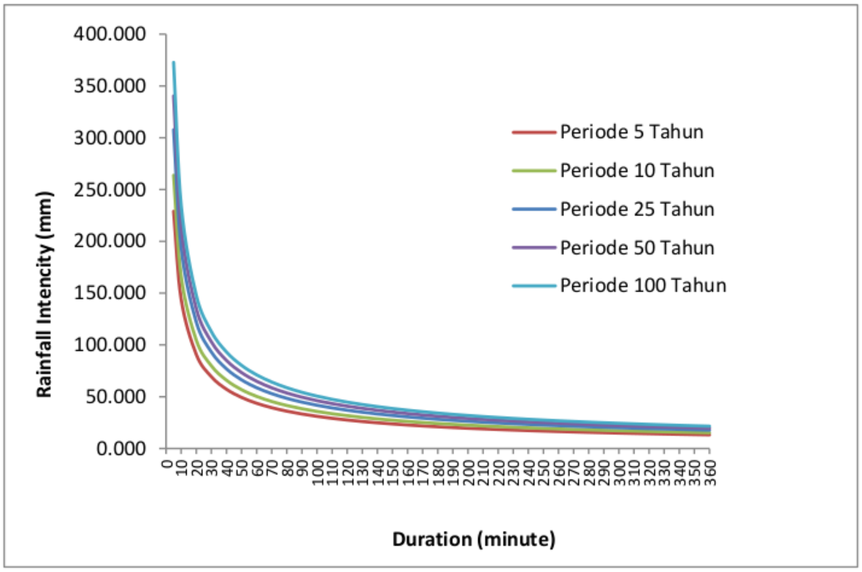

Fig. 1. Intensity Duration Frequency Curve

C. Hyetograph Rain Design Alternate Block Method (ABM)

The distribution of rain as a function of time that describes each variation in the depth of rain during the rain, which can be expressed in the form of a Hyetograph (Histogram). In this study, the design Hyetograph will use ABM (Alternative Block Method), which is a simple way to create a design Hyetograph from the IDF curve.

The calculation of the design rain hytograph using ABM (Alternati Block Method) for a 5 year return period can be seen in Table 2. and the graph obtained from the calculation results shown in Figure 2.

An explanation of the ABM (Alternati Block Method) calculation table for a 5 year return period, namely the duration of rain (column 1) is determined to be 360 minutes.

Column 4 is the multiplication between rain intensity (column 3) and duration.

Column 5 is the hourly rain depth whose value is obtained from the successive difference in the depth of rain (column 4).

Column 6 contains the hourly rainfall depth value which is represented by means of each row in column 5 (hourly rain depth) divided by the number and then multiplied by one hundred.

Column 7 is the Hyetograph expressed in percent.

Column 8 is the Hyetograph in millimeters (mm) which is obtained by multiplying column 7 (percent of the Hyetograph) with the annual return period design rainfall value divided by one hundred.

TABLE III. CALCULATION OF ALTERNATIVE BLOCK METHOD WITH 5 YEARS RETURN PERIOD

Rainfall Duration		Rainfall Intencity	Duration x Intencity	Rainfall depth		Hyetograph	
menit	jam	mm/jam	mm	mm	%	%	mm
10	0.167	144.216	24.036	24.036	30.285	0.935	1.17749
20	0.333	90.850	30.283	6.247	7.872	0.971	1.223906
30	0.500	69.332	34.666	4.382	5.522	1.012	1.275185
40	0.667	57.232	38.155	3.489	4.396	1.057	1.332197
50	0.833	49.321	41.101	2.946	3.712	1.108	1.396041
60	1.000	43.676	43.676	2.575	3.245	1.165	1.468129
70	1.167	39.411	45.979	2.303	2.902	1.231	1.550308
80	1.333	36.054	48.072	2.093	2.637	1.306	1.645046
90	1.500	33.331	49.997	1.925	2.425	1.394	1.755725
100	1.667	31.070	51.784	1.787	2.252	1.498	1.887124
110	1.833	29.158	53.455	1.672	2.106	1.624	2.046237
120	2.000	27.514	55.029	1.573	1.982	1.781	2.243785
130	2.167	26.085	56.517	1.488	1.875	1.982	2.497163
140	2.333	24.827	57.930	1.413	1.781	2.252	2.836835
150	2.500	23.711	59.278	1.348	1.698	2.637	3.322084
160	2.667	22.713	60.567	1.289	1.624	3.245	4.088071
170	2.833	21.813	61.803	1.236	1.558	4.396	5.53821
180	3.000	20.997	62.992	1.189	1.498	7.872	9.917208
190	3.167	20.254	64.138	1.146	1.443	30.285	38.15469
200	3.333	19.573	65.244	1.106	1.394	5.522	6.956689
210	3.500	18.947	66.313	1.070	1.348	3.712	4.676808
220	3.667	18.368	67.350	1.036	1.306	2.902	3.655624
230	3.833	17.832	68.355	1.005	1.267	2.425	3.055574
240	4.000	17.333	69.332	0.977	1.231	2.106	2.653484
250	4.167	16.868	70.282	0.950	1.197	1.875	2.362012
260	4.333	16.432	71.206	0.925	1.165	1.698	2.139326
270	4.500	16.024	72.108	0.901	1.136	1.558	1.962658
280	4.667	15.640	72.987	0.879	1.108	1.443	1.818462
290	4.833	15.278	73.846	0.859	1.082	1.348	1.698134
300	5.000	14.937	74.685	0.839	1.057	1.267	1.595921
310	5.167	14.614	75.506	0.821	1.034	1.197	1.50782
320	5.333	14.308	76.309	0.803	1.012	1.136	1.430951
330	5.500	14.017	77.096	0.787	0.991	1.082	1.363185
340	5.667	13.741	77.867	0.771	0.971	1.034	1.302912
350	5.833	13.478	78.623	0.756	0.953	0.991	1.248888
360	6.000	13.227	79.365	0.742	0.935	0.953	1.200137
				79.365	100		125.984

Then, with the above calculation results, the next step is to create an ABM (Alternative Block Method) Hyetograph. The following is shown in Figure 2.

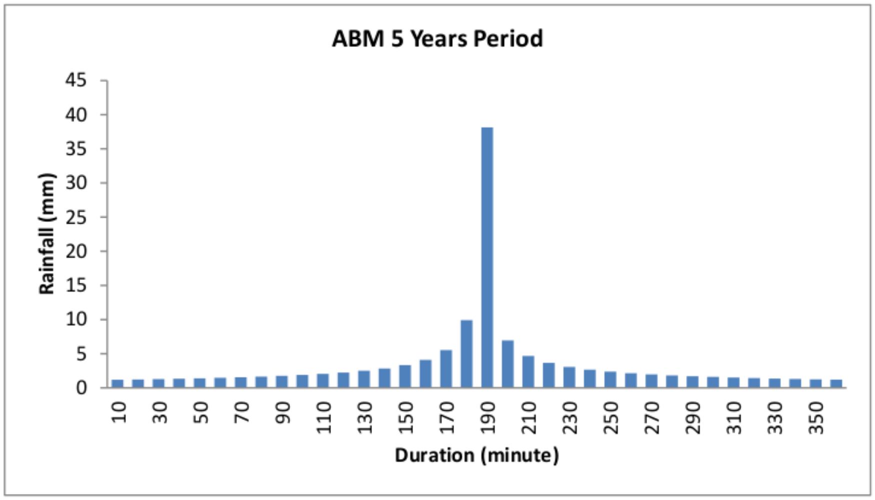

Fig. 2. Hyetograph with ABM Method 5 Years Return Period

III. Results and Discussion

A. Flood Discharge

Based on the hydrological analysis in the previous chapter, the planned flood discharge can be calculated based on the Gumbel method. The flood discharge in question can be seen in the following table for each specific return period

TABLE IV. FLOOD DISCHARGE

No.	R_{24} (mm)	Intencity (I) (mm/jam)	Q (m^3/det)
1	125,984	257,1460	35,47
2	145,140	296,2446	40,87
3	169,341	345,6414	47,69
4	187,294	382,2866	52,74
5	205,118	418,6661	57,76

B. Runoff Analysis

The runoff coefficient reflects the surface state of the flow area. The flow coefficient, C is the ratio of the volume of water that reaches the mouth of the watershed with the volume of water that falls above the watershed.

The value for the coefficient of drainage, C. Data obtained from Bappeda Palembang City, the area of land use for residential areas are:

High density area = 7.09 km2

The area of the catchment area = 7.37 km2

Trade area area = 4.73 km2

Based on table 4.27 the flow coefficient for residential areas with high density area is taken 0.90 and for the catchment area is taken 0.40 and for the trade area is taken 0.90. Then the value of Cw:

$$C_w = \frac{A_1C_1 + A_2C_2 + A_nC_n}{A_1 + A_2 + A_n}$$

$$C_w = \frac{(7.09 \times 0.9) + (7.37 \times 0.4) + (4.73 \times 0.9)}{7.09 + 7.37 + 4.73} = 0.708$$

The value of the runoff coefficient is obtained, Cw = 0.708 and in the calculation is taken Cw = 0.70.
Table 4. Flow coefficient C

TABLE V. COEFFICIENT C

Zona	Land Used	C
Urban	Residential Area:	
	- Low density	0,25-0,40
	- Medium density	0,40-0,70
	- High density	0,70-0,80
	- with infiltration well	0,20-0,30
	Trade Area	0,90-0,95
	Industrial area	0,80-0,90
	Parks, green lines, gardens, etc	0,20-0,30
Rural	Hills, slope<20%	0,40-0,60
	Gorge area, slope>20%	0,50-0,60
	Land with terraces	0,25-0,35
	rice fields	0,45-0,55

To calculate the surface runoff discharge by using the Rational formula. The runoff coefficient (C) is determined from land use.

C. *Flow Capacity (Discharge)*

To calculate the flow capacity (discharge) surface (Run Off) using the Rational Formula. It is known that the runoff coefficient (C) = 0.70, with a watershed area of 25.95 km2 then:

Q = 0.2778.C.I.A
= 0.2778 x 0.70 x 257.146 x 25.95
= 129.76 m3/s

For return periods of 2, 5, 10, 20 and 50, it can be seen in the following table:

TABLE VI. RUNOFF DISCHARGE CALCULATION RESULTS

Return Period (Years)	C	I (mm/jam)	A (km²)	Q (m³/det)
2	0,70	257.1460	25,95	36,04499
5	0,70	296.2446	25,95	41,52557
10	0,70	345.6414	25,95	48,44968
20	0,70	382.2866	25,95	53,58636
50	0.70	418.6661	25,95	58,68579

D. *Analysis of Land Function Changes on Flood Discharge*

From the results of multi-regression analysis, the relationship between land use area and flood discharge is as follows:

Years	Land Used Area (km^2)				Flood Discharge (Y)
	Paddy fields (X_1)	Dry fields, (X_2)	Settlements (X_3)	Others (X_4)	
2014	19,0948	7,6414	12,8256	30,8482	48,4496
2015	19,2066	7,6414	12,8127	30,8482	49,6365
2016	20,1282	7,9073	11,5263	30,8482	49,3889
2017	20,3284	7,6578	11,5756	30,8482	50,5528
2018	20,6822	7,8112	11,0686	30,8482	56,2529
2019	20,8012	7,7014	11,0592	30,8482	61,8408
2020	20,8287	7,6933	11,0398	30,8482	67,3679

Then a simple statistical analysis with a certain return period is obtained as follows:

Y	X_1	X_2	X_3	X_4	X_1^2	X_2^2	X_3^2	X_4^2
Discharge	Paddy Fields	Dry Fields	Settlements	Others				
48.44	12.83	7.64	19.09	30.85	164.6089	58.3696	364.4281	951.7225
49.63	12.81	7.64	19.21	30.85	164.0961	58.3696	369.0241	951.7225
49.38	11.53	7.91	20.13	30.85	132.9409	62.5681	405.2169	951.7225
50.55	11.58	7.66	20.33	30.85	134.0964	58.6756	413.3089	951.7225
56.25	11.07	7.81	20.68	30.85	122.5449	60.9961	427.6624	951.7225
61.84	11.06	7.7	20.8	30.85	122.3236	59.29	432.64	951.7225
67.36	11.04	7.69	20.83	30.85	121.8816	59.1361	433.8889	951.7225
383.4894	**81.92**	**54.05**	**141.07**	**215.95**	**962.4924**	**417.4051**	**2846.1693**	**6662.0575**

Y^2	YX_1	YX_2	YX_3	YX_4
2,346.43	621.4852	370.0816	924.7196	1494.374
2,463.14	635.7603	379.1732	953.3923	1531.0855
2,438.38	569.3514	390.5958	994.0194	1523.373
2,555.30	585.369	387.213	1027.6815	1559.4675
3,164.06	622.6875	439.3125	1163.25	1735.3125
3,824.19	683.9504	476.168	1286.272	1907.764
4,537.37	743.6544	517.9984	1403.1088	2078.056
21,333.10	31415.452	20727.602	54098.85	82814.536

E. Regression Equation

The form of the regression equation from the results of the analysis is:

$Y = \beta o + \beta 1\ X_1 + \beta 2\ X2 + \beta 3\ X3 + \beta 4 X4$

$Y = -350.6 + 33.64X1 - 75X2 + 1.537X3 + 1.006X4$

JKreg = 33.64 (81.92) + (-75) (54.05) + 1.537 (141.07) + 1.006 (215.95)

= 20601.744

JKres = JKY - JKreg

JKY = 383.4894– (20601.7442) / 7 = 322.856.28
JKres = 322.856.28 – 20.601.744 = 302254.5

F. Coefficient of Determination

R2 = 302254.5 – 322856.28 = 0.936

G. Total Correlation Coefficient:

Ryx1 = R2 = 0.969

H. Error Coefficient

Re2 = 1 – R2 = 1 – 0.936 = 0.064
Re = 0.25

I. Partial Correlation Coefficient

Ry1 = 81.92 / (962.4924) (21.333.10) = 0.57
Ry2 = 54.05 / (417.4051) (21.333.10) = 0.57
Ry3 = 141.07/ (2846.1693) (21.333.10) = 0.57

J. Correlation Coefficient Significance Test:

F_{Count} = 16.17

K. Test Criteria:

If $F_{Table} \leq F_{Count}$, then Ho is accepted
If $F_{Table} \geq F_{Count}$, then Ho is rejected
With a significant level = 0.05
F Table = F (1.α) (db numerator = m) (db denominator = n – m -1)
= F (1.0.05) (4) (7-4-1)
= F(0.95) (4) (2)
F_{Table} = 7.6

It turns out that $F_{Table} \leq F_{Count}$, it can be said that there is a significant effect of land use change on increasing flood discharge in the Keramasan watershed.

IV. Conclusion

1. The flood discharge calculated in this study is 48.45 m3/s with a return period of 10 years.
2. The percentage change due to the land use change is the equation Y = a+bX1+cX2+dX3 where the Y variable is flood discharge, while X1, X2, X3 and X4 are paddy fields, dry fields, settlements with their respective correlation coefficients. - partially are RYX1 = 0.57, RYX2 = 0.57, and RYX3 = 0.57.
3. Combined, the value of the Correlation Coefficient that occurs is 0.97 or 97%, an increase in discharge in the Keramasan watershed is due to the conversion of paddy fields, dry fields, and settlements.

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