The Effects Of The Watershed Characteristics On Ogan River Flood Discharge

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The Effects Of The Watershed Characteristics On Ogan River Flood Discharge

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Abstract: Ogan River watershed is one of the watersheds in South Sumatra Province which has a total catchment area of 923.565 km^2 with a length of ± 6,042 km. The Ogan River watershed is divided into several sub-watersheds based on the topographic conditions. This study specifically examines the condition of the Ogan River flood discharge in the Peninjauan Village, Subdistrict of Peninjauan, which has a catchment Area of 3168.95 km^2 with a river length of ± 158.1 km. At some points of the Ogan River in the Peninjauan Village, siltation occurred so that during the rainy season the river overflows and causes flooding every year. Regency due to the changes of land use. This study used the rain data from the nearest rain post, Ogan River watershed map, land use map and the software to get spatial data. The analysis of planned flood discharge used Synthetic Unit Hydrograph (SUH) Gamma 1 with various land use changes. The results indicate that land use change from forest to settlement increases peak discharge.

Index Terms: Watershed Characteristics, Land Use, Hydrograph, Gamma 1, Peninjauan

1 INTRODUCTION

Awatershed is an area that is delineated by hills based on the topography in which the watershed is a basin of the ongoing hydrological processes that carry rainwater flowing on the surface towards the river and its tributaries up to the outlet. Flooding is a common problem at some areas in Indonesia. When a flood occurs in a watershed, it can cause social and economic impacts in the region. Flooding is affected by the surface runoff that flows into the river. The magnitude of runoff is greatly influenced by the magnitude of flow discharges that occur in the river. Flooding is caused by an occurrence of an imbalance in the environmental system in the process of flowing the water on the surface (run off) and it is also affected by runoff of river water which is caused by the inability of the river to accommodate the discharge of the flowing water [1] The determination of the discharge value and runoff volume of a watershed is very important in designing a hydraulic structure. The Synthetic Unit Hydrograph Method is a simple method for determining the form of runoff hydrographs. To determine the hydrological response that occurs in the Komering watershed, the SCS, Snyder, ITB 1 and ITB 2 methods were used. The results obtained revealed that all methods used showed hydrographic shapes and runoff values that were close to each other [2]. The magnitude of runoff value is greatly influenced by the changes in vegetation. To calculate the amount of runoff value due to the influence of vegetation changes, the Guansihe Hydrological (GSH) model was used as a physical model to simulate runoff responses to land use changes in the Guansihe watershed located in the upper reaches of the Yangtse River Basin in southwest China. The simulation results showed a very significant change in runoff value due to various land conversion scenarios [3] The magnitude of a runoff is greatly influenced by the factors in land use change coupled with the extreme weather changes.

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To find out the hydrological response that is a consequence of land use changes, many studies have been done in various watersheds. To disclose the runoff models that occur due to changes in land use is to analyze by using a model of land and water assessment tools (SWAT). This SWAT modeling predicts changes in runoff, surface runoff, groundwater and the magnitude of evapotranspiration due to changes in land use. The results show that the changes in land use have a linear relationship to the magnitude of the runoff [4]. One of the rivers in South Sumatra Province that has affected the flooding in some of its watersheds is the Ogan River. Ogan River is one of the Musi River tributaries that has a catchment area of 9,235.65 Km2 with a total river length of ± 6,042 Km. The Ogan River watershed is divided into several sub-watersheds based on its topographic conditions. There are several sub-watersheds that experience flooding each year due to Ogan River discharge runoff caused by silting. As population growth increases, the need for water use also increases, however the declining watershed conditions result in reduced water resources [4], [8]. Thus, it requires intensive regulation and management [4], [9]. This study was conducted to analyze the magnitude of the discharge in the Ogan River Basin at Peninjauan Village control point by using the Gamma 1 Synthetic Unit Hydrograph method with various conditions of land use changes. Meanwhile the secondary data of land coverage was obtained from the BPDAS-HL Ministry of Environment and Forestry of 2016, 2017 and 2018.

2 STUDY AREA

Regency is located between 103^0 49' 57.7" East Longitude, 4^0 13' 58.57" South Latitude up to 104^0 31' 03.41" East Longitude, and 3^0 47' 50.31", the borders of the region are as follows:

- The North side borders with Muara Enim Regency.
- The South side borders with Ogan Komering Ulu Selatan Regency.
- The West side borders with Muara Enim Regency and Pagar Alam Municipality.
- The East side borders with Ogan Komering Ulu Timur Regency.

Fig 1. *The Map Ogan Watershed*

The study was carried out at upper Ogan River Basin at the Peninjauan as an outlet runoff point in the area of 3168.95 km2 (Based on GIS analysis).

3 MATERIALS AND METHODS

This study was intended to obtain a design flood discharge with various return periods by simulating the rainfall runoff process in the form of hydrograph at an outlet with a watershed area of 3168.95 km^2.

3.1 Analysis of design rainfall

The average maximum rainfall representing the rain of the region can be determined by using the Thiessen polygon method with the equation:

$$\overline{P} = \sum_{i=1}^{n} \alpha_i P_i = \frac{A_A P_A + A_B P_B + A_C P_C}{A_A + A_B + A_C} \quad (1)$$

After the daily rainfall is obtained, it can be continued by analyzing the frequency and selecting the type of probability distribution [10]. To find out the goodness of fit of probability distribution, probability smirnov kolmogorof test was used.

3.2 Analysis of GIS (Georaphic Information System)

Geographic Information System is information used to enter, process and analyze to produce geo-referenced data or in the form of geospatial data that are commonly used to facilitate the planning and management of land use, natural resources, environment, transportation, urban facilities and other services [11]. To get geospatial data in order to calculate the flood discharge plan, Arch. GIS software version 10.3 was used with the following steps:

a. Delineation of maps obtained, including map of earth's appearance, river network maps, land use maps, topographic maps so that the catchment area of the study area was obtained;
b. After the watershed was determined as the study area, it could be analyzed to determine the characteristics of the watershed;
c. The watershed characteristics obtained were used in analyzing the flood discharge with the Gamma 1 synthetic unit hydrograph;
d. Flood discharge analysis was carried out starting from the existing land use condition, then comparing the magnitude of the discharge with the land use condition against that of the previous year.

3.2 Analysis of design flood discharge

Analysis of the flood discharge was carried out using the Gamma 1 synthetic unit hydrograph in which some watershed parameters were very influential in the process of transforming rain into flow. Gamma 1 parameters used in the calculation to get the hydrograph form include source factor (SF, source factor); source frequency (SN); width factor (WF); area of upstream watershed (RUA); symmetry factor (SIM); number of river confluences (JN); drainage network density (D). There are several variables used in the Gamma 1 synthetic unit hydrograph analysis, including:

a. Rise time (TR)
$TR = 0.43 ((L / 100). SF)3 + 1.0665 SIM + 1.2775$ (2)

b. Peak discharge (Qp)
$QP = 0.1836 A^{0.5886} JN^{0.2381} TR^{\wedge -0.4008}$ (3)

c. Base time (TB)
$TB = 27.4132 TR^{0.1457} S^{-0.0986} SN^{0.7344} RUA^{0.2574}$ (4)

d. Storage coefficient (K)
$K = 0.5617 A^{0.1798} S^{-0.1446} SF^{-1.0897} D^{0.0452}$ (5)

e. Basic flow (QB)
$QB = 0.4715 A^{0.6444} D^{0.943}$ (6)

4 ANALYSIS AND DISCUSSION

The area of the sub-watershed of Ogan River was determined through GIS analysis. Figure 2 shows the area of interest. GIS analysis is used to know The morphometric from Ogan Watershed, such as Area, upstream, length of main river and the others. The analysis of the design flood discharge is done by using the Gamma 1 HSS method that requires several variables from the characteristics of the watershed concerned that can be seen in table 1.

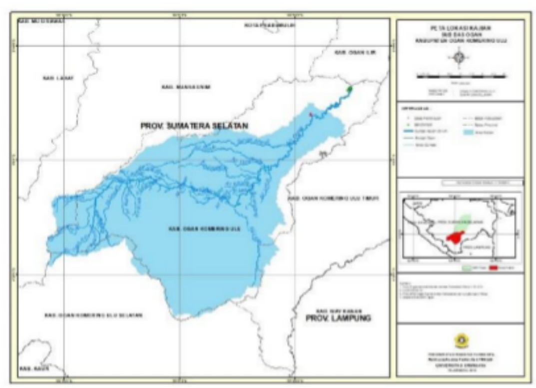

Fig 2. *The Map of Area of Interest*

TABLE 1
Gamma 1 HSS Parameters

Parameters	*Symbols*	*Results*

Area of Watershed	*A*	*3168.950*	*km²*
Area of upstream watershed	*Au*	*2074.660*	*km²*
Length of the main river	*L*	*158.100*	*km*
Length of orde 1 river	L_1	*613.200*	*km*
The length of the river of all levels	L_n	*701.420*	*km*
Length of 0.75L (OB along river)		*118.575*	*km*
Length of 0.25L (OA along river)		*39.525*	*km*
Number of confluences	*JN*	*83*	
Widht of watershed of 0,75 L (bb')	W_U	*11.220*	*km*
Widht of watershed of 0,25 L (aa')	W_L	*33.660*	*km*
Number of Order 1 River	*P1*	*48*	
Number of River of other orders	*Pn*	*16*	
Number of Rivers of all orders		*64*	
Average River Slope	*S*	*0.00040*	

Then the parameters above were used to simulate the flood hydrograph by determining the hydrograph shape parameters as in table 2

TABLE 2
Parameters of the hydrograph form

Parameters	*Symbols*	*Results*
Source Factor	*SF*	*0.874*
Source Frequency	*SN*	*3.000*
Density of drain network	*D*	*0.221*
Width Factor	*WF*	*0.333*
Comparison of upstream and downstream watershed area	*RUA*	*0.655*
*SIM = RUA * WF*	*SIM*	*0.218*

Based on the above parameters, the amount of rise time (TR), peak discharge (Qp), base time (TB), pool coefficient (K) and base flow (QB) can determined. With the obtained variables above, the form of hydrograph that connects between the time and the rain discharge that falls per 1 mm thickness of rain can be obtained as explained by the following hydrograph form:

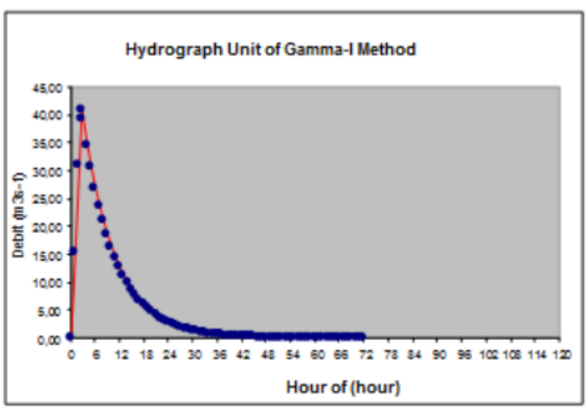

Fig 3. *HSS Gamma 1 Hydrograph Unit*

After obtaining the hydrograph unit, then the plan flood discharge was analyzed by connecting the value of the flow coefficient (c) and the effective rain against the plan rainfall that has been determined. This study compared the scale of plan discharge with the land use changes that occurred over three years, namely 2016, 2017 and 2018. The secondary data in the form of the land use obtained were analyzed with Arc GIS software version 10.3 to obtain the extent of each land use in order to obtain the drainage coefficient (c) in the following table.

TABLE 3
Changes in land use

No	*Land Cover*	*2016*	*2017*	*2018*
1	*Mixed Dry Land Farming*	*1,914.49*	*1,914.41*	*1,900.84*
2	*Secondary Dry Land Forest*	*505.01*	*504.71*	*506.70*
3	*Shrubs*	*245.24*	*245.24*	*251.41*
4	*Plantation*	*246.89*	*246.89*	*246.89*
5	*Dry Land Agriculture*	*127.89*	*127.72*	*125.51*
6	*Open Land*	*4.12*	*3.96*	*35.20*
7	*Primary Dry Land Forest*	*40.98*	*40.88*	*31.10*
8	*Settlement*	*28.37*	*29.73*	*16.00*
9	*Rice fields*	*17.09*	*15.77*	*17.57*
10	*Body of water*	*12.46*	*12.46*	*12.46*
11	*Savana*	*10.11*	*10.11*	*10.11*
12	*Plantation Forest*	*6.71*	*6.70*	*6.70*
13	*Transmigration*	*7.58*	*7.58*	*6.64*
14	*Mining*	*2.01*	*2.78*	*1.80*
	Total Area	*3,168.95*	*3,168.95*	*3,168.95*

Changes in land use above were simulated in the flood discharge analysis to obtain the hydrograph form and the magnitude of the plan flood discharge with various return periods by determining the value of the drainage coefficient each year.

TABLE 4
Flow coefficient (C)

No	*Land Cover 2016*	*Total Area (km²)*	*Value of C*	*C * A*	*C average*
1	*Mixed Dry*	*1,914.49*	*0.1*	*191.45*	
2	*Secondary*	*505.01*	*0.03*	*15.15*	
3	*Plantation*	*246.89*	*0.4*	*98.76*	
4	*Shrubs*	*245.24*	*0.07*	*17.17*	
5	*Dry Land*	*127.89*	*0.1*	*12.79*	
6	*Primary Dry*	*40.98*	*0.03*	*1.23*	
7	*Settlement*	*28.37*	*0.6*	*17.02*	*0.115114*
8	*Rice fields*	*17.09*	*0.15*	*2.56*	
9	*Body of*	*12.46*	*0.05*	*0.62*	
10	*Savana*	*10.11*	*0.1*	*1.01*	
11	*Transmigrati*	*7.58*	*0.6*	*4.55*	
12	*Plantation*	*6.71*	*0.05*	*0.34*	
13	*Open Land*	*4.12*	*0.35*	*1.44*	
14	*Mining*	*2.01*	*0.35*	*0.70*	
	Total Area	*3,168.95*		*364.79*	

The composite C value obtained is multiplied by the plan rainfall value to get the effective rain value used to determine the plan flood discharge for each period that occurs in the studied watershed as shown in table 3 and The magnitude of the plan flood discharge is shown in table 4. Based on the data in the table 3, the magnitude of plan flood discharge against the land use conditions in 2016-2018 can be determined by obtaining the hydrograph form in Figure 4. The objective of this study was to disclose the magnitude of the flood discharge of return periods that occurred due to changes in land use in 2016, 2017 and 2018. With the same steps, the plan flood discharges for 2017 and 2018 have been analyzed. The comparison is shown in table 5.

TABLE 5
Hourly rain ratios

Kala Ulang (Tr)	(tahun)	2	5	10	25	50	100	200	500	1000
$R_{Rancangan}$	(mm)	116.9	142.3	162.0	190.8	215.5	243.3	274.7	323.0	365.4
C		0.116	0.116	0.116	0.116	0.116	0.116	0.116	0.116	0.116
R_n	(mm)	13.512	16.449	18.722	22.049	24.903	28.118	31.755	37.332	42.233
Jam ke-		Nisbah (%)								
1	0.03	0.410	0.500	0.569	0.670	0.756	0.854	0.965	1.134	1.283
2	0.05	0.632	0.770	0.876	1.032	1.165	1.316	1.486	1.747	1.976
3	0.11	1.534	1.867	2.126	2.503	2.827	3.192	3.605	4.238	4.795
4	0.44	5.902	7.185	8.178	9.631	10.878	12.282	13.870	16.306	18.447
5	0.08	1.076	1.310	1.491	1.756	1.983	2.239	2.529	2.973	3.363
6	0.06	0.857	1.043	1.187	1.398	1.579	1.783	2.013	2.367	2.678
7	0.05	0.723	0.881	1.002	1.180	1.333	1.505	1.700	1.999	2.261
8	0.04	0.565	0.688	0.783	0.923	1.042	1.177	1.329	1.562	1.767
9	0.04	0.514	0.626	0.712	0.839	0.947	1.069	1.208	1.420	1.606
10	0.03	0.473	0.575	0.655	0.771	0.871	0.984	1.111	1.306	1.477
11	0.03	0.439	0.534	0.608	0.716	0.809	0.913	1.031	1.212	1.372
12	0.03	0.386	0.470	0.535	0.630	0.712	0.804	0.908	1.067	1.207

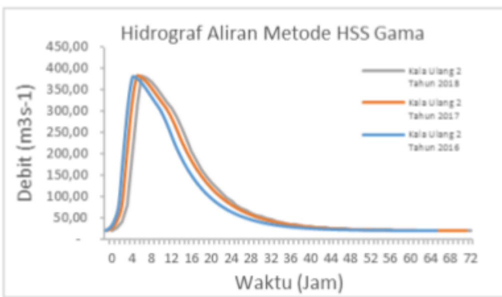

***Fig 4**. Flood hydrograph*

TABLE 6
Flood discharge plan for 2016 land use impacts

No	Kala Ulang (Tahun)	Q Maks (m3/dt)
1	2	381.63
2	5	460.10
3	10	520.86
4	25	609.77
5	50	686.06
6	100	771.97

TABLE 7
The design flood discharges as the effects of land use in 2016, 2017 and 2018

No.	Return Periods (Year)	Qmax (m3/dt) 2016	2017	2018
1	2	380.17	380.96	381.63
2	5	458.33	459.29	460.10
3	10	518.84	519.93	520.86
4	25	607.40	608.68	609.77
5	50	683.39	684.83	686.06
6	100	768.95	770.58	771.97

5 CONCLUSION

This study shows that the conditions and changes in land use on the magnitude of the discharges generated, the worse the land use change that occurs, the greater the runoff value of a watershed which is shown in the hydrograph shape changes produced. The results of this study indicate that land use change from forest to settlement increases peak discharge.

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