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Rainfall Analysis for Estimation of Peak Discharge and Soil Erosion on the Catchment Area of Musi Hydro-Power Plant, Bengkulu Indonesia

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Abstract. This research aims to determine peak of discharge and soil erosion occurring in catchment area of Musi Hydro-Power Plant, Bengkulu, Indonesia based on analyzing rainfall characteristics. The research was conducted from October to December, 2012 in the catchment area of 60.357,21 Ha. The area lies on 102°22'18.98"-102°38'38.93" Lat., and on 3°16'28.873" -3°33'57.441" Long. Melchior method of rainfall analysis was applied for analyzing hydrological characteristics of peak discharge (Qp) with the specific time return. Potential soil erosion occurring in PLTA Musi Catchment Area was using *USLE* method determining by indices of rain erosivity, soil erodibility, length and slope, crop management, and soil conservation practices. Sediment Delivery Ratio (SDR), analyzing method of sedimentary ratio, is calculated to estimate the total amount of sediment based on calculation of total erosion occurring in the Catchment Area. Result of the research revealed that the peak of discharge for the catchment area of Musi Hydro-Power Plant, Bengkulu Province was 204,131 m^3/second, and the time of concentration (Tc) was of 12,565 hours in the watershed area of 60.357,21 Ha for over 2 years at all the time. In addition, the total amount of erosion that occurred in the area of Musi Hydro-Power Plant, Bengkulu Province reached 1.737.884,27 tons/year which is twice over the tolerable soil erosion that equal to 811.804,475 tons/year. The amount of sediment released to the Musi river within the catchment, further, was of 137.292,857 tons/year is double over the tolerable value of sediment that equal to 64.132,55 tons/year, unfortunately.

Keywords: *Rainfall, Peak of Discharge, Soil Erosion and Sedimentation*

1. INTRODUCTION

Catchment area of Musi Hydro-Power Plant is very important especially as life support communities in the District of Rejang Lebong Kepahiang, Bengkulu, Indonesia. Along with the increased activity in the upstream population led to the need for greater land so the impact on land use changes in the watershed Musi Hulu. Based on data for watershed land use Musi Hulu in 2003 by the Ministry of Public Works, refer to Central River Region VIII Sumatra, land cover of the area was of 30% primary forest, of 7% secondary forest, 23.5% intensive horticulture cultivation, 6% coffee plantation, settlement of 1%, and of 33.5% shrubs. Whereas in 2007, land use change was of 8% primary forest, of 19% of secondary forest, of 46% intensive horticultural cultivation, of 3% bare land 3%, of 5% coffee plantations, of 2.5% settlements, of 3% rice, and of 13.5 shrubs and bush.

Land use changes in the watershed particularly in the catchment area of the Musi Hydro-Power Plant from forest to other uses, cause of capacity on the upstream as water harvesting area reduced, at the same time, run off over the area increased. Increasing runoff can accelerate soil erosion and sedimentation in the catchment area, and the flood discharge will occur at rainy season, and then, will be followed by drought in

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the dry season. This is because all the water in the rainy season rapidly flows downstream due to high surface runoff, so the stored water in the upstream becomes greatly reduced (Sumarto, 1987 in Farianto, 2012). Herefore, to solve these problems, we need to study how large peak flows, erosion, and sedimentation in the catchment of Musi upstream so that they can provide additional information for the public and relevant agencies in the context of river basin management more effective and efficient, hopefully.

2. RESEARCH METHOD

3.1. Research Sites

The research was conducted in the sub-watershed of Musi upstream, District of Kepahiang and of Rejang Lebong, Bengkulu, Sumatera, Indonesia. Site review of research can be seen in Figure 1.

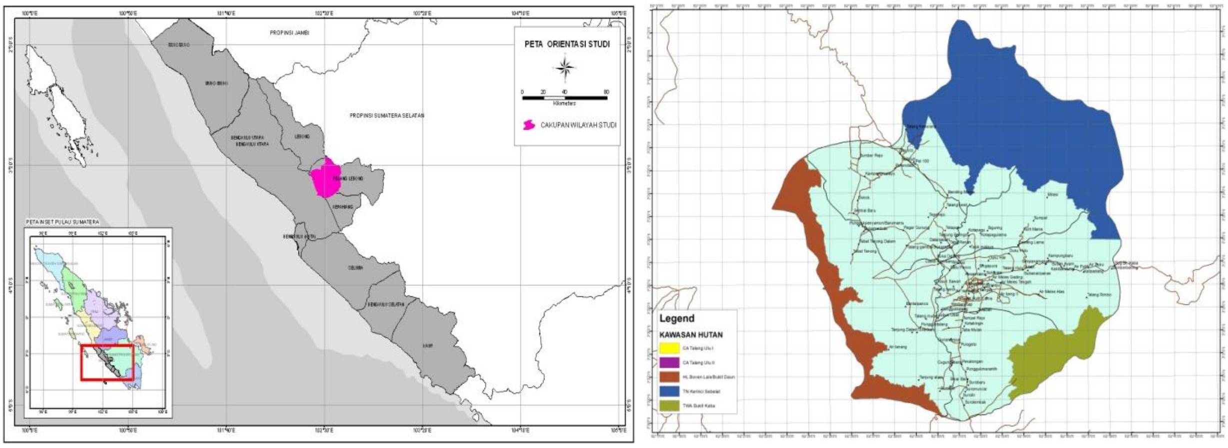

Fig.1. Site Research Map of Musi Hulu Sub-Watersheed, Bengkulu, Indonesia

3.2. Data

Primary data collection method used in this study were performed with a descriptive survey approach, namely in the field of soil sampling for calculation of erosion and sedimentation, such as soil organic matter contents, soil textures, soil structures, and hydraulic conductivities. Secondary data used in this study include; daily rainfall data for the last 25 years, soil map, topographycal map, land use map.

3.3. Data Processing

Concentration of peak discharge followed Melchior method, expressed by the following equation :

$$T_c = 0,186.L.Q^{-0,2}.I^{-0,4} \quad (1)$$

Where: T_c is time of concentration in hours, L is length of the river in Km, Q is peak discharge m3 / d
I is the average slope of the river.

When the watershed has an area of over 100 km^2 (10,000 ha), the amount of discharge is expressed by the following equation:

$$Qn = \alpha\ \beta\ qno\ A \quad (2)$$

Where : Qn is maximum flood discharge (m3/sec) with the possibility of unfulfilled n%, α is coefficient of runoff, β is coefficient of rain the area reduction, qn is rainfall in $m^3/d.km^2$ with a certain return period, A is area of the watershed (km^2).

To estimate the amount of erosion that occurs in the watershed, USLE method was applied with the formula:

$$E=R.K.L.S.C.P \quad (3)$$

Where: E is estimated total amount of erosion (ton / ha / year), R is rainfall erosivity index, K is soil erodibility index, L.S is length-slope factor, C is Factor land cover crops or crop management, P is factor land conservation practices.

The amount of sediment yield estimates by Asdak (2007) may be determined by the following equation :

$$Y = E\ (SDR)\ Ws \quad (4)$$

Where: Y is the result of sediment per unit area, E is total erosion, Ws is area of the river area drainage, and SDR is sediment discharge ratio.

3. Result And Discussion

3.1 Analysis of Peak Discharge

From the calculation of the value of α is taken, βqn, and Qc Tc of the same for each peak discharge calculation is as follows :

For over 2 years old when taken α = 0.193, is 1.752 m^3/sec.km^2, βqn then obtained Qp is 204.131 m^3/second.

3.2 Soil Erosion

3.2.1 Rain Erosivity Index (R)

Following Bols formula based on average monthly amount of rainfall, of rain days, and of maximum for a particular railfall for calculating rainfall erosivity index (R), the monthly erosivity indices showed in Table 1.

Table 1. Erosivities Indices in The Catchment Area of The Musi Hydro-Power Plant.

No	Month	Rain (cm)	Days	Max P (cm)	EI_{30}
1	January	23,41	17,96	4,50	158,54
2	February	20,95	15,42	4,57	150,21
3	March	26,01	19,56	4,84	179,94
4	April	21,56	17,25	4,71	149,88
5	May	20,13	15,08	5,03	152,12
6	June	13,26	12,32	3,41	82,14
7	July	13,95	13,04	3,46	85,80
8	August	17,08	13,28	3,84	114,73
9	September	20,78	14,44	4,53	152,61
10	October	22,25	16,84	4,53	154,24
11	November	24,44	18,68	4,26	159,26
12	December	32,19	19,63	5,34	244,80
Value of R = Total EI_{30}					1784,27

Sources:Calculation Results

3.2.2 Factors Erodibility Land (K)

Once the value of Texture Soil Ingredients Organic, Soil Structure and Permeability Soil is known, it can be determined the value Erodibility Soil (K) using Nomograph based on each land unit, then taken K values averaged to obtain the value of K at 0.088**.**

3.2.3 Length-Slope factor (L.S)

The catchment area of the Musi Hydro-Power Plant lies on the hilly to mountainous area of Bukit Barisan range, Sumatera. So, slope-length of topography should be considered indeft in calculation of the potential erosion. Analysis of slope-length factor of the catchment area shown in: Table 2.

Table 2. Analysis of Slope (slope)

No	Slope Class	Area (ha)	Area	S %	S Factor
1	Flat (0-8%)	14.325,62	0,24	4,0	0,0095
2	Ramp (8-15%)	25.760,40	0,43	11,5	0,0491
3	Rather Steep(15-25%)	14.282,75	0,24	20,0	0,0473
4	Steep (25-45%)	3.069,67	0,05	35,0	0,0178
5	Very Steep(>45%)	2.931,53	0,05	72,5	0,0352
	Total	60.369,97			0,16

Sources: BPDAS Ketahun, 2012 and Calculation Results

3.2.4 Land Cover Crop Factor (C)

Land cover crop factor determined from land use multiplied by the index of crop management.

Table 3. Determine the average value C

No	Land Cover	Total	%Area	C	C x %Area
1	Young Thicket	514,35	0,009	0,001	0,000009
2	Old Thicket	2247,98	0,037	0,001	0,000037
3	Open Land	4632,29	0,077	1,000	0,077000
4	Mixed Garden	4448,04	0,074	0,200	0,014800
5	Young and Mixed Garden Grove	24564,92	0,407	0,100	0,040700
6	Forest	15931,45	0,264	0,001	0,000264
7	Field	4052,82	0,067	0,400	0,026800
8	Settlement	2893,05	0,048	1,000	0,048000
9	Rice Fields	912,79	0,015	0,010	0,000150
10	Rubber Society	85,32	0,001	0,200	0,000200
11	Young Shrub and Rubber	86,95	0,001	0,100	0,000100
	Total	60.369,97			0,208060

Sources: BPDAS Ketahun, 2012 and Calculation Results

3.2.5 Factors Soil Conservation Practices (P)

Land conservation measures factors determined from soil conservation index is determined from the interpretation of the types of crop land are evaluated with slope.

Table 4. Determine the average P value

No	Slope Class	Area (ha)	%Area	P	P x %Area
1	Flat (0-8%)	14.325,62	23,73	0,50	0,1186
2	Ramp (8-15%)	25.760,40	42,67	0,75	0,3200
3	Rather Steep(15-25%)	14.282,75	23,66	0,75	0,1774
4	Steep (25-45%)	3.069,67	5,08	0,90	0,0458
5	Very Steep(>45%)	2.931,53	4,86	0,90	0,0437
	Total	60.369,97			0,7056

Sources: BPDAS Ketahun, 2012 and Calculation Results

Erosion hazard is the ratio of the erosion that occurs comparing with tolerable erosion. Based on the calculation of the potential erosion on the catchment area of Musi hydropower was 13.45 tonnes/ha /year, and the the potential erosion for the whole area was 1.737.884,27 tons /year.

The tolerable erosion obtained based on Tolerance of Soil Erosion To Size (Thompson, 1957) in Sucipto (2008) was of 13.45 tonnes/ha/year, and the tolerable erosion for the whole area of 60.357,21 ha of the catchment area was of 811.804,475 tons /year. The magnitude of erosion index was at is 2.14; it means more than twice of torelable erosion.

3.3 Sedimentation Analysis

Based on the potential erosion in the catchment of Musi hydropower was 13,45 tonnes/ha/year with a catchment area of 60.357,21 ha, the Sediment Discharge Ratio (SDR) on this area was of 0.079. The value of the sedimentation in the catchment area of Musi hydropower amounted to 137.252,857 tonnes/year. The tolerable sediment based on the tolerable erosion of 811.804,475 tons/year and the SDR rate is 0.079, following calculation 811.804,475 tons/year x 0.079 was 64.132,55 tons/year of tolerable sediment. The total sediment was more than double comparing to tolerable sediment in this area.

4. CONCLUSIONS AND SUGGESTIONS

4.1 Conclusion

1) The maximum discharge occurring in the catchment area for various periods Musi hydropower repeated 2 years obtained at 204,131 m^3/second.

2) The potential soil erosion occurring in the catchment area of Musi hydropower plant reached 13.45 tons/ha/year or at 1,737,884.27 tons/year of the whole which more twice than the tolerable erosion of 811,804,475 tonnes/year.
3) The amount of sedimentation in the catchment area of Musi hydropower amounted to 137,252.857 tons/year which also more double than the tolerable sedimentation of 64,132.55 tons/year.

4.2 Suggestion

1) Rainfall data should be used in the calculations obtained from the rain at least 3 stations located in the catchment area for the results to be more accurate calculation.
2) To maintain the availability of water for hydroelectric energy sources Musi, the manager should evaluate the capacity of hydroelectric dams in order to accommodate the maximum discharge (excess water) that occurs during the rainy season, so that during the dry season (low rainfall) water being stored is expected to meet the needs of discharge electrical energy.
3) To reduce the rate of erosion and sedimentation, high erosion areas should be carried out replanting with plant density is high enough and the plantation areas are sloping land conservation efforts should be made by way of the creation of soil conservation terraces.

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