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RESEARCH PAPER

Application of eco-drainage system in reducing the potential for flooding in the District of Sampang

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Abstract. Kamoning River watershed is one of the watersheds in Sampang. Sampang City experienced flooding almost every year caused by the overflow of the River Kamoning. One of the causes of flooding in that city is the high rainfall and a lack of rainwater catchment areas in the upper and middle Kamoning River watershed. To overcome these problems, it is necessary to use a system of flood discharge reduction eco drainage in the upstream and in the middle of Kamoning River watershed. This study used two scenarios of eco-drainage system: first is to change the land use in combination with the creation of retention ponds, the second scenario is to change the land use in combination with the creation of infiltration wells. From the analysis of large unknown, designed-flood discharge of 50 year-return period of Kamoning River basin is 289.361 m^3/ sec. By using the first scenario, the designed-flood discharge can be reduced by 199.59 m^3/s or 31.02%, while large designed-flood discharge can be reduced by 205.20 m^3/s or 29.08% using second scenario. Efforts to reduce the discharge flood in Sampang can be effectively conducted by using the scenario 1.

Keywords: Eco drainage; flood; Kamoning River watershed

1. Introduction

Kamoning River is one of the great rivers in Sampang. The river has been providing some benefits to the people living around the river. However, during the rainy season, the river that primarily provided benefits to the community might turn to be a disaster. Floods occur almost every year in the district of Sampang because the river was unable to accommodate the huge number of rain water.

One of solutions to reduce flood which were occurred in the region is through water resources conservation (Arsyad, 2006). The main purpose of water resource conservation is protecting the existence of power support land, capacity, and function of water

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resources is carried out through the preservation, management, control and utilization of water resources with reference to the prescribed rules on water resources.

One of the concepts of conservation of water resources is eco-drainage (Suripin, 2004). This water resource conservation provides the benefits of problems that include the conservation methods of vegetative by increasing vegetation as water catchment areas. The conservation mechanically is created by making the pond rainwater on the upper and middle regions Kamoning River watershed.

2. Materials and methods

Data and data analisis

The research is in Kamoning River watershed located in Sampang. The data used in this research is secondary data obtained from the relevant agencies that have relation to department of irrigation. Secondary data gathered in this research consists of daily rainfall data from rainfall recording stations are included in the scope of Kamoning River watershed which Karang Penang station, Robatal, Kedungdung, Omben and Sampang station. Rainfall data used in this research using the last 10 years of data from 2006 to 2015, and land use data.

Data analysis aims to get a huge flood discharge design with a return period of 50 years as the basis for the plan in an effort to reduce the flood discharge at Kamoning River watershed. Stages of the analysis performed in this research are to analyze the rainfall average maximum by using polygons Thiessen, to analyzes the design rainfall using the log Pearson type III, to test the suitability of Smirnov Kolmogorov and chi square calculating flood discharge design return period of 50 years with HSS Nakayasu methods.

Reduction flood discharge

Reduction of flood discharge in this research was carried out through eco-drainage system using several scenarios. The scenarios considered eco-drainage systems that can reduce flood discharge in Kamoning River watershed. The drainage system scenarios in this research are two. Those two scenarios are selected to obtain feasible and effective scenario that able to reduce flood discharge in Kamoning River watershed.

Scenario 1, the change of land use of 30% combined with the creation of a retention pond. Effect of land on the incidence of flooding is so large that one of the efforts to reduce the potential for flooding is by changing patterns of land use in the region Kamoning River watershed. Relationship with the land use change is the reduction of flood discharge runoff coefficient of each type of land use. As for the calculation of retention ponds to the needs of the pitcher using the method of flood routing through the reservoir spillway building (Syamsiah et al., 1994). The results of the pitcher needs will be implemented with the creation of retention ponds located in the upstream region and the central region Kamoning River watershed. The effort to reduce flood discharge is called the conservation of mechanical methods. Besides, as a flood control reservoir also serves as a catchment area which will enhance the soil water content results (Subagyono et.al, 2004).

Scenario 2, change the land use of 30% combined with the creation of infiltration wells making the recharge well as one of the efforts in the conservation of ground water. Recharge wells can be conducted in a residential area or in every house so it does not require a large area. The function of absorption wells than as a backup water supply as well as reduce the discharge of runoff so that rainwater does not directly into water bodies.

3. Result and discussion

Analysis of rainfall mean

From the calculation of daily rainfall data, maximum value of the average rainfall per year using Thiessen polygon method is obtained. Table 1 shows the results of analysis of the maximum average rainfall. Rainfall averages Thiessen polygon method area can be calculated with the following equation Soemarto (1999):

$$\bar{d} = \sum_{i=1}^{n} \frac{A_i d_i}{A_i} \tag{1}$$

Where $\bar{d}$ is rainfall average, d is the raifall in specific area, A is size of spesific area, n is number of station.

Table 1. The maximum average precipitation

Year	Station					R Max
	Robatal	Karang Penang	Sampang	Omben	Kedungdung	
	0.284	0.228	0.137	0.169	0.182	
2006	42.00	59.00	51.00	141.00	60.00	67.15
2007	88.00	142.00	132.00	88.00	43.00	98.13
2008	75.00	131.00	80.00	53.00	75.00	84.72
2009	35.00	131.00	64.00	115.00	30.00	73.48
2010	45.00	73.00	89.00	48.00	65.00	61.56
2011	43.00	47.00	67.00	36.00	69.00	50.75
2012	42.00	48.00	80.00	44.00	33.00	47.27
2013	78.00	162.00	82.00	49.00	82.00	93.50
2014	48.00	47.00	58.00	68.00	80.00	58.36
2015	42.00	57.00	73.00	98.00	75.00	65.16

Analysis of rainfall design

Rainfall design is the largest rainfall that may occur in an area with a certain chance. The purpose of the design rainfall analysis is to obtain large rainfall with a certain repetitive period. The re-calculated period in this research is a 50-year period using the Log Person Type III Distribution method. The reason for using this method is because it can be used for all data distribution without having to meet the requirements of coefficient of skewness and coefficient of kurtosis Soemarto (1999). With the standard deviation value of 0.11 and the coefficient of 0.11 then the calculated slope of the design rainfall. From the calculation results, it is obtained a large rainfall draft period 50 years return of 114.49 mm. Table 2 demonstrates the result of rainfall design of log type III person method.

Table 2. The calculation method of design with rain Log Pearson Type III

Tr(year)	R average (Log)	Std Dev. (Log)	Skewness (Cs)	Opportunity (%)	K	Rainfall Plan	
						Log	mm
2	1.83	0.11	0.11	50	-0.019	1.83	67.81
5	1.83	0.11	0.11	20	0.835	1.92	83.65
10	1.83	0.11	0.11	10	1.293	1.97	93.60
25	1.83	0.11	0.11	4	1.789	2.02	105.73
50	1.83	0.11	0.11	2	2.113	2.06	114.49
100	1.83	0.11	0.11	1	2.408	2.09	123.10

Distribution compatibility test

Distribution compatibility test is used to test the suitability of the distribution of the distribution data qualify for planning data (Soewarno, 1995). Testing suitability of the distribution is conducted in two ways: Kolmogorov-Smirnov test and Chi Square test. Based on the calculations obtained from Kolmogorov-Smirnov test, the Δ_{max} is 0.084. While the critical value Δ_{table} for Kolmogorov-Smirnov test obtained $\Delta_{critical}$ (N = 10) with α equal to 20% is 0.32, α equal to 10% is 0.37, α equal to 5% is 0.41 and α equal to 1% is 0.49. While the results of the calculation values obtained chi square χ^2_{Hit} = 2.00 while Chi-Square table based on dk = 10 and α = 5%, the value of χ^2_{table} = 3.841 and α = 1%, the value of χ^2_{table} = 6.635. So we can say that the data meet the suitability test conducted distribution.

Analysis of design flood discharge method HSS Nakayasu

Design flood discharge is the largest annual flood discharge with a certain probability of occurrence or discharge with a certain probability of repetition period. Nakayasu of Japan has been investigating hydrographs unit in several rivers in Japan. The Nakayasu Synthetic Unit Hydrograph Method is often used in dam planning and river improvement in Indonesia. This is due to the Nakayasu hydrograph arch having characteristics similar to the situation in Indonesia, i.e. floods reach the peak with an instant and then slowly down.

Hourly rain distribution

To calculate the design flood discharge by means of hydrograph unit requires the distribution of hourly rain with a certain interval. In general, rainfall data available on meteorological stations is daily rainfall data, meaning cumulative rainfall data is recorded for 24 hours. If rainfall data is not available, the hour-time rain distribution pattern can be conducted by using the hourly rain distribution, which is Mononobe formula:

$$RT = t.Rt - [(t-1)Rt - 1] \quad (2)$$

From the calculation result, the value of rain hour distribution can be seen in Table 3.

Runoff coefficient

Runoff coefficient is a variable that is based on regional conditions and characteristics of the flow of the rain that fell in the area. Runoff coefficient (c) is the number that shows a comparison between the magnitudes of water overflow against the magnitude of the rainfall. This runoff coefficient number is one indicator to determine whether the watershed has undergone physical disorders (Asdak, 2001).

Tabel 3. The distribution of hourly rain

Hours to	Rt (mm)	RT (mm)	The ratio of %
0.50	1.000	0.500	50.00
1.00	0.630	0.130	13.00
1.50	0.481	0.091	9.12
2.00	0.397	0.073	7.26
2.50	0.342	0.061	6.13
3.00	0.303	0.054	5.36
3.50	0.273	0.048	4.79
4.00	0.250	0.044	4.35

The determination of the value of the coefficient stream an area comprising several land use is conducted by taking the average runoff coefficient of each land use by calculating the weight of each piece in accordance with the area it represents. Type of land use in the watershed of the river Kamoning can be seen in the Table 4.

Table 4. Runoff coefficient of Kamoning River watershed

Type of land use	Area (ha)	C	C x A
Lake/dam	3.188	0.05	0,16
productive forest	547.596	0.20	109.52
garden	1,287.641	0.30	386.29
Farm/vacant land	18,125.167	0.40	7,250.07
The settlement	5,457.114	0.50	2,728.56
Pond	244.661	0.05	12.23
Marsh/swamp forest	81.531	0.15	12.23
paddy field irrigation	2,635.906	0.45	1,186.16
Rice field rainwater	5,818.764	0.50	2,909.38
River	121.759	0.05	6.09
	34,323.327	0.425	14,600.69
$C_{composit}$		0.425	

As for how the calculations by using the following formula (Suhardjono, 1984):

$$C = \frac{\sum_{i=1}^{n} C_i . A_i}{\sum_{i=1}^{n} A_i} \tag{3}$$

Where C is runoff coefficient and A is size of area in ha, n is number of area. Using equation (3) can be calculated quantity of runoff coefficient (C) on the Kamoning River watershed.

Based on the results of the calculation which is presented in Table 4, the coefficient of runoff obtained large by 0.425.

Effective rainfall

Effective rainfall is part of total rainfall which resulted runoff. Assuming that the process of transformation of rain becomes runoff directly follow a linear process and did not change by time, then rain net (Rn) can be expressed as follows:

$$Rn = C \times R \quad (4)$$

Where Rn is rain net, C is runoff coefficient and R is rainfall (mm). Using equation (4), on the Table 5, then it is obtained effective rainfall value of 48.7 mm.

Table 5. Calculation of effective rainfall

Hours	A rainy hour ratio times (%)	Effective rain every hour a 50 year re-period
0.50	0.50	24.351
1.00	0.13	6.329
1.50	0.09	4.440
2.00	0.07	3.535
2.50	0.06	2.985
3.00	0.05	2.609
3.50	0.05	2.333
4.00	0.04	2.120
Rain design (mm)		114.49
Runoff coefficient		0.425
Effective rainfall (mm)		48.70

Design flood discharge estimation

Further analysis to calculate the design flood discharge in River Kamoning watershed is by using Synthetic Nakayasu Hidrograf Unit. In calculating the magnitude of the design flood, discharge flow base was combined with the flood discharge. In the area of research, the basic flow is considered 0 m^3/sec, since the location of the research area is dry.

Using the data characteristics of the Kamoning River watershed with the watershed of 343.23 km^2, length of river = 58.10 km, the effective rain unit (R_0) = 1 mm, the hydrograph parameter (α) = 3. From the results of calculation of estimation of discharge design with a length of river (L) > 15 km, then retrieved the value of tg = 3.77, rainy duration effectivity (tr) = 3.77, grace period from the beginning of the rain to flood peak (Tp) = 6.79, the time needed by a decrease in discharge from the discharge peaks of up to 30% of the peak discharge (T_0, 3) = 11.31 hours. Next, calculate flood peak discharge with equation (5), obtained a value of 7.144 m^3/sec.

$$Q_p = \frac{A.R_0}{3.6(0.3T_p + T_{0.3})} \quad (5)$$

Where $Q_p$is flood peak discharge (m³/sec), A is watershed area (km²), Ro is unit rain (mm), Tp is time to peak (hour), $T_{0.3}$ is time to 30% of peak discharge. As for picture time arch synthetic unit hydrograph of Nakayasu unit can be seen on the Figure 1. Where, tg is concentration (hour), tr is rain time unit, taken in an hour, α is hydrograph parameter.

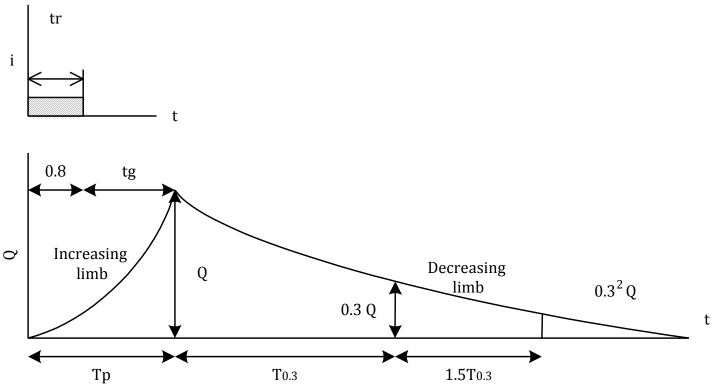

Figure 1. Hidrografsynthetic unit Nakayasu (Soemarto, 1999)

Next calculate the curved time ordinate synthetic unit hydrograph Nakayasu to produce ordinate curved up and down, the result of the calculation time ordinate synthetic unit hydrograph Nakayasu arch can be seen in Table 6. While the graphic results of ordinate time curved synthetic unit hydrograph Nakayasu is seen in Figure 2.

Table 6. Time curve ordinate synthetic unit hydrograph Nakayasu

The characteristics of the	The Notation	The beginning of the (hours)		the end of the (hours)	
		the end	value	the end	value
Curve Up	Qa	0	0	Tp	6,786
Curved down phase 1	Qd1	Tp	6,786	$Tp + T_{0,3}$	18,095
Curved down phase 2	Qd2	$Tp + T_{0,3}$	18,095	$Tp + T_{0,3} + 1{,}5.T_{0,3}$	35,059
Curved down phase 3	Qd3	$Tp + T_{0,3} + 1{,}5.T_{0,3}$	35,059	~	~

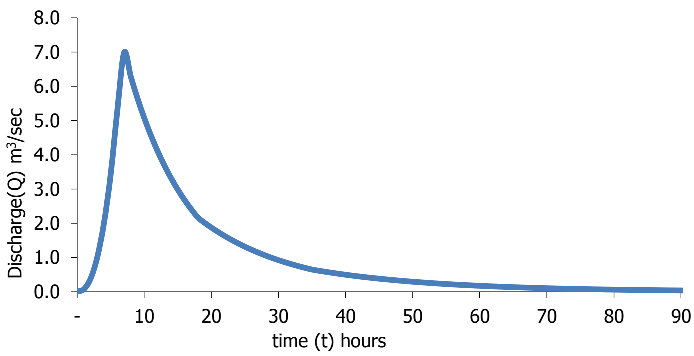

Figure 2. Ordinate synthetic unit hydrograph Nakayasu Kamoning River watershed from the analysis

Design of flood discharge

Flood discharge the draft is an annual with a possibility of a specific return period, or debit cards with a possibility of a certain return period. Nakayasu of Japan has been investigating hydrograph unit on several rivers in Japan (Soemarto, 1999). From the results of synthetic hydrograph unit of Nakayasu ordinate arch next time calculating flood discharge design return period of 50 years using Equation (6).

$$Q_k = \sum_{m=1}^{n \leq m} R_m U_{n-m+1} \tag{6}$$

Where Q_k is value of flow at the and of time interval to k in m3/sec, U is sample data, R pulse data. As for picture time arch synthetic hydrograph unit of Nakayasu unit can be seen on the Figure 1.

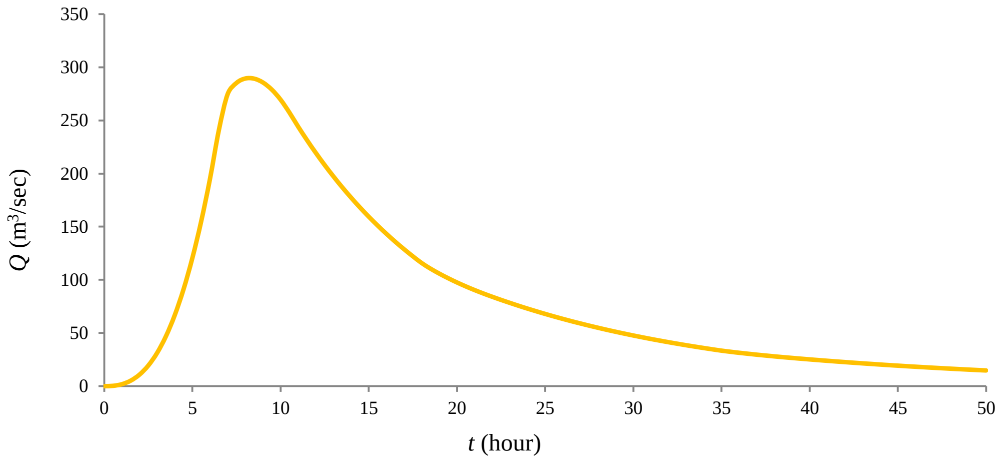

Figure 3. Graph flood discharge the draft 50-year return period HSS method Nakayasu in Kamoning River watershed

3.1. Reduction of flood discharge

Scenario 1

In scenario 1 to reduce the flood discharge using a change of land use by 30% combined with the creation of the retention pond. Kamoning River watershed with an area of 34,323.327 ha, more than 50% of the breadth of its land allocation in the form of agricultural fields or dry land. A large allotment of land converted into forest be scenario by 30%. Changes of land function in Kamoning watershed is divided into 2 zones. First zone is Kamoning River watershed upstream of zones with a total area of 11,703.327 ha. As for types of land uses that will be transformed into a forest, among other: land of gardens with an area of 451.701 ha, fields/vacant lot covering an area of 7,229.907 ha, and rained rice fields an area of 2,294.717 ha. Second zone is Kamoning river watershed of Central Zone with an area of 16,808.739 ha. As for types of land uses that will be transformed into a forest, among other: land of gardens with an area of 802.632 ha, fields/vacant lot covering an area of 9,684.829 ha, and rained rice fields an area of 2,695.298 ha.

Based on the calculation obtained, the coefficient of runoff after changes in land use by 0.382. From the result of change of coefficient value of drainage, then recalculated the flood discharge design of synthetic hydrograph unit Nakyasu method with coefficient of drainage value after the change of land function. From the calculation results obtained, the flood discharge design draft 50 years return period of synthetic unit Nakayasu method after the land use change is 259.60 m^3/sec.

Next step is calculating the reduction of flood discharge using retention ponds. Calculations for the needs of the pitcher using the method of flood routing through the reservoir spillway building. The results of the pitcher needs will be implemented with the creation of retention ponds located in the upstream region and the central region Kamoning River watershed. Assuming that the spillway elevation data = 1, spillway width = 50 m, spacious bin = 170 ha ≈ 1.7 million m^2, bin initial = 0 m^3, the initial depth = 0 m. From the results of the search calculation above flood spillway, spillway above obtained maximum discharge of 199.59 m^3/sec. From the calculations, the large percentage of the reduction of flood discharge design using the scenario 1, which is 31.02%. The resulting graph inflow and outflow rate fluctuations over the spillway design flood discharge of 50 years return period can be seen in Figure 4.

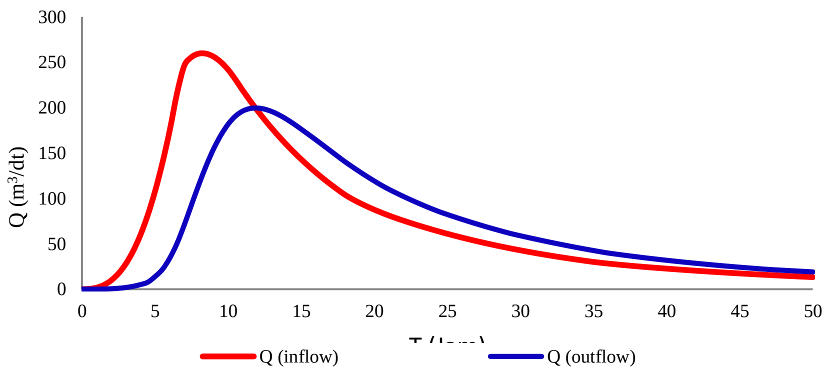

Figure 4. Fluctuation of inflow and outflow discharge above spillway with flood discharge of 50 year return period

Scenario 2

Scenario 2 is to change the land use of 30% combined with the creation of infiltration wells. From the calculation results obtained, scenario 1 large flood discharge design return period of 50 years after the change in land use amounted to 259.60 m3/sec.

Afterward, calculate the reduction of flood discharge design return period of 50 years after the change of land use by using the recharge wells. The data used in the calculation of infiltration wells, among others are follows: PUH is 50 Years, R24 is 114.49 mm, total population is 214,063 inhabitants, assuming the vast catchment area is 150 m^2,assumption per household is 5 people, number of house is 42,813 homes, runoff coefficient (C) = 95% (assuming 95% water and 5% rain accommodated lost due to evaporation and leakage), n = 0.012 (manning coefficient), L = 6.4 m, S = 0.4 (slope roofs), Ls = 25 m (length of flow path on the roof), V = 1 m^3/sec (speed of flow on the roof), K = 9.722 x 10-6 m/sec (medium grade soil permeability coefficient). From the calculations, the value of Q_{roof} is 0.00135 m^3/sec, $Q_{seepage}$ is 0.00008 m^3/sec, and $Q_{reduction}$ is 0.0013 m^3/

sec. The calculation of flood discharge reduction using recharge wells can be calculated using the equation:

$$Q_{\text{Recharge well}} = Q_{\text{reduction}} \text{ x Number of home} \quad (7)$$

From the calculation of recharge wells can reduce the flood discharge at 54.40 m^3/sec, so that the reduction of flood discharge design return period of 50 years using the second scenario of 205.20 m^3/sec, with a percentage reduction of flood discharge by 29 , 08%.

4. Conclusion and suggestions

Of the design flood discharge with Synthetic Hydrograph Unit Method Nakayasu with a return period of 50 years in Kamoning River basin of 289.361 m^3/sec. By using the scenario 1, which is a reduction in discharge using land use changes combined with the creation of retention ponds, flood discharge plan with a return period of 50 years in Kamoning River watershed can be reduced by 31.02% while the design flood discharge of the existing 50-year return period in the watershed Kamoning with great 289.361 m3 / sec can be reduced to 199.59 m^3/sec.

While using the second scenario, namely the reduction of flood discharge using land use changes combined with the manufacture of recharge wells, to reduce or mitigate flood discharge design of the existing 50-year return period in Kamoning River basin of 289.361 m^3/sec reduced to 205.20 m^3/sec or by 29.08%. From the analysis, efforts to reduce flood discharge a viable and effective in Kamoning River watershed is to use scenario 1 that changes in land use combined with the creation of a retention pond.

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