STUDY OF LUSI RIVER FLOOD DISCHARGE IN CENTRAL JAVA PROVINCE

Pontjo Witjaksono Arief Rachmanto
Pemali Juana River Basin Organization, Ministry of Public Works, INDONESIA
Email: arief_pontjo73@yahoo.co.id

ABSTRACT

Lusi is one of the big rivers of Serang Lusi Juana (Seluna) River System that contributes to flood event on the downstream part of the system. To cope with the flood problem occurred in Seluna River System. Kedungombo Dam has been constructed on the upstream part of Serang River. However, flood flow from Lusi River, which covers 2.100 km^2 of catchment area, cannot be controlled.

By calculating the Lusi River design flood discharge, the flood discharge contribution of Lusi River to the Seluna River System can be predicted. Design flood hydrograph of Lusi River is determined using the synthetic unit hydrograph approach due to inadequate data. The synthetic unit hydrograph of Gama I is used in this study. To distribute design daily rainfall into hourly rainfall units to be applied in flood hydrograph calculation, hypothetic rainfall distribution is used by employing the Alternating Block Method (ABM) and Tadashi Tanimoto methods for several floods returning period.

Design flood discharge applied for the calculation is the results of the ABM Rainfall distribution based on the two-daily rainfall data. The results of design flood discharge under this method show 748m^3/s for return period of 2 years, 1036m^3/s for return period of 50 years, 1097 m^3/s for return period of 100 years and 1158 m^3/s for return period of 200 years. 96% of Lusi River design flood gives contribution to the Seluna River System which is approximately 1200m^3/s gained from Q_{200} design flood discharge in Klambu barrage

KeyWords: Flood discharge, synthetic unit hydrograph, hypothetical rainfall distribution, design discharge.

1 INTRODUCTION

Flood frequently occurred against Serang Lusi Juana (Seluna) River System in Central Java, even every year, particularly in the downstream river has caused loss in assets or goods. Some flood preventions have been conducted including Kedungombo Dam built on the upstream of Serang River and development of drainage system, SWD1 on the downstream of Serang River. Scheme of Seluna River system is provided in Figure 1.

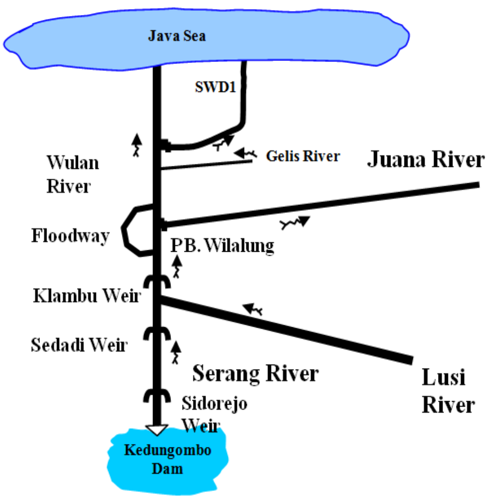

Figure 1. Seluna River System scheme.

Besides flood control structures, an attempt in river normalization has been implemented. However, flood still attacks persistently. The unsolved problem that should get concern here is flood discharge contribution incurred by Lusi River which is one of Serang River branches. Up to now, contribution of Lusi River is lack of concern, whereas it cannot be separated from Seluna River system.

2 METHODOLOGICAL APPROACH

2.1 Research Site

Research site is Lusi watershed located between $7^0 15^' 65^'$ - $6^0 98^' 35^'$ LS, $110^0 82'26''$-$111^0 92'32''$BT, and belongs to Blora and Grobogan Regency, Central Java Province

2.2 Data Availability

The available data consists of watershed map, rainfall data of 15 stations collected from 1991 to 2003, while flow discharge data are unavailable. Location of each rainfall station is shown in Figure 2 and Table 1.

Figure 2. Location of rainfall stations.

2.3 RESEARCH STEPS

2.3.1 Evaluating Data

Evaluation is applied to data length and quality, the real situation of each rainfall station, and data collection procedure. Reliable data are used for determining the selected rainfall station for the subsequent analysis.

2.3.2 Analyzing Catchment Rainfall

After determining the consistence of rainfall data towards selected stations, rainfall parameter in a watershed can be analyzed. Average rainfall can be obtained by averaging point rainfalls at each station using Thiessen Polygon method. According to the calculated rainfall of watershed and rainfall duration which is derived from Kirpich formula, daily rainfall and two-daily rainfall can be determined that will be used in frequency analysis.

2.3.3 Frequency Analysis

Frequency analysis is carried out using software developed from Macro, a feature in Microsoft Office Excel. The used rainfall data are daily and two-daily rainfall within 13 years. In order to cope with insufficient rainfall data, frequency analysis is accomplished by taking maximum data of every year (partial series) and specifying the threshold value. Data having value above the threshold will be used for analysis. The threshold value is 44 mm in compliance with maximum rainfall data occurred in 2002. Number of data based on partial series is determined in such a way so that it will be lower than five times of length of annual rainfall data (Sri Harto, 1991).

2.3.4 Watershed Parameter

In order to design flood hydrograph of the river system which has lack of observation data, watershed characteristic or parameter should be identified (Soemarto, 1987). Due to unavailability observation data of Lusi River, design flood hydrograph is determined using the synthetic unit hydrograph approach. The synthetic unit hydrograph of Gama I (Gama I SUH) is employed in this study. Though it was developed from hydrological behavior of 30 watersheds in Java Island, lately it was proved appropriate for the other regions in Indonesia (Sri Harto, 2000).

Table 1. Rainfall station data

No.	Code	Station	Latitude (^{0}LS)	Longitude (^{0}BT)	Location			Data Length (years)
					Village	Subdistrict	District	
1	Rb 4a	Sembung	7^{0}01'60''	111^{0}18'26''	Sembung	Tunjungan	Blora	13
2	Rb 4f	Lawungan	7^{0}00'78''	111^{0}20'76''	Lawungan	Lawungan	Blora	3
3	Rb 6	Kedungjenar	7^{0}02'10''	111^{0}21'66''	Kedungjenar	Kota	Blora	13
4	Rb 22	Gayam	7^{0}10'09''	111^{0}25'25''	Gayam	Gayam	Blora	1
5	Rb 23	Jiken	7^{0}08'95''	111^{0}27'33''	Jiken	Jiken	Blora	13
6	Rb 26	Japah	7^{0}00'10''	111^{0}12'32''	Japah	Japah	Blora	13
7	Rb 3	Todanan	7^{0}01'72''	111^{0}11'09''	Todanan	Todanan	Blora	5
8	Rb 9	Kunduran	7^{0}09'25''	111^{0}09'05''	Lawungan	Lawungan	Blora	3
9	Rb 7	Kidang jepon	7^{0}01'25''	111^{0}25'26''	Kidang jepon	Kdg. jepon	Blora	9
10	SE 211	Tambakselo	7^{0}01'72''	110^{0}84'04''	Tambakselo	Tambakselo	Grobogan	5
11	SE 213	Tawangharjo	7^{0}09'72''	110^{0}67'65''	Tawangharjo	Twg.harjo	Grobogan	2
12	SE 214	Pojok	7^{0}10'03''	110^{0}69'20''	Pojok	Pojok	Grobogan	4
13	SE 216	Nglangon	7^{0}11'21''	110^{0}78'04''	Nglangon	Nglangon	Grobogan	1
14	SE 217	Simo	7^{0}11'72''	111^{0}84'04''	Simo	Simo	Grobogan	2
15	SE 217a	Butak	7^{0}11'35''	111^{0}00'24''	Butak	Kradenan	Grobogan	13

Watershed parameter analysis is carried out by using Map Info Software. The required parameter comprises source factor, frequency source, width source, upstream watershed area, symmetry factor, number of river junction, and density of drainage network.

2.3.5 Hypothetic Rainfall Distribution

Since there are no daily rainfall data in Lusi Watershed, hypothetic rainfall distribution method is applied for distributing design daily rainfall into hourly rainfall units. Two most used formulas of hypothetic rainfall distribution are Tadashi Tanimoto method and ABM (Alternating Black Method).

a) Tadashi Tanimoto method

Design rainfall resulted from frequency analysis is distributed into 8 hours of rainfall duration. The resulted percentages are 26%, 24%, 17%, 13%, 7%, 5,5%, 4% and 3,5% , successively (Subarkah, 1980).

b) Alternating Block Method (ABM)

Rainfall intensity is calculated by using Mononobe equation. Rainfall depth variation can be adjusted in such a way that maximum rainfall depth will be in the middle of rainfall duration, then the lower one is placed on the right of the maximum one, continued to to the left, and so forth in order (Chow et.al, 1988).

2.3.6 Design Flood Hydrograph

Design flood hydrograph of the reference point in the downstream of Lusi River connected to Serang River is determined. Flood hydrograph is obtained by multiplying effective rainfall depth per hours by unit hydrograph discharge with the assumption of rainfall return period as flood return period.

3 RESULTS AND DISSCUSSIONS

3.1 Rainfall Data Analysis

Lusi watershed has 15 rainfall stations, yet all station have been mostly damaged and deemed unfeasible to use. According to the evaluated data, there are only 5 rainfall stations providing the proper and feasible data. Those rainfall stations belong to daily rainfall stations equipped with manual rainfall recorder. They are in good condition and have no vacant rainfall data. However, one rainfall data series which is used for one particular station may have inconsistent characteristic. Those kinds of data cannot be analyzed directly (Sri Harto, 2000). Rainfall data input applies catchment rainfall parameter assumed to be able to represent entire rainfall over watershed. The selected stations based on data consistency test are SE 217a, Rb 26, Rb 4a, Rb 6, and Rb 23. The selected rainfall stations are listed in Table 2.

Consistency of daily rainfall data gained from five rainfall stations during 13 years should be tested. Data consistency analysis is conducted by using RAPS method (Rescaled Adjusted Partial Sums) towards annual rainfall data. The RAPS result shows that they are consistent. Regarding the consistency of annual rainfall data as consistency of daily rainfall data, those five stations are considered qualified for the subsequent analysis.

3.2 Catchment Rainfall Analysis

Catchment rainfall analysis is approached by using daily rainfall data and two-daily rainfall data. According to Kirpich formula, rainfall duration can be obtained which is approximately 40 hours. The Kirpich formula (1940 in Chow et al., 1988) is as follows.

$$t_c = 0{,}0663 L^{0{,}77} S^{-0{,}385} \qquad (1)$$

where t_c is time of concentration (hour), L is main river length (km), S is slope of river.

Table 2. The selected rainfall station data

No	Code	Station	Latitude (^{0}LS)	Longitude (^{0}BT)	Location			Data Length (years)
					Village	Subdistrict	District	
1	Rb 26	Japah	$7^0 00' 10''$	$111^0 12' 32''$	Japah	Japah	Blora	13
2	Rb 4a	Sembung	$7^0 01' 60''$	$111^0 18' 26''$	Sembung	Tunjungan	Blora	13
3	Rb 6	Kedungjenar	$7^0 02' 10''$	$111^0 21' 66''$	Kedungjenar	Kota	Blora	13
4	Rb 23	Jiken	$7^0 08' 95''$	$111^0 27' 33''$	Jiken	Jiken	Blora	13
5	SE 217a	Butak	$7^0 11' 35''$	$111^0 00' 24''$	Butak	Kradenan	Grobogan	13

3.3 Frequency Analysis Result

Frequency analysis result shows that theoretic rainfall distribution which is in accordance with rainfall distribution of Lusi watershed is distribution of Log Pearson III. Design rainfall resulted from frequency analysis against daily rainfall and two-daily rainfall data are provided in Table 3 and Table 4.

Table 3. Design rainfall based on frequency analysis (daily rainfall data)

No	T (year)	P_T (mm)
1	2	58.63
2	50	98. 01
3	100	106.89
4	200	116.19

Table 4. Design rainfall based on frequency analysis (two-daily rainfall data)

No	T (year)	P_T (mm)
1	2	93.35
2	50	119.05
3	100	123.72
4	200	128.33

3.4 Hypothetic Rainfall Distribution

Design rainfall obtained from frequency analysis is then distributed into hourly rainfall over 8-hours duration by using Tadashi Tanimoto formula, while for ABM, it is subjected to 24-hours distribution based on frequency analysis result against daily rainfall and 40-hours distribution based on frequency analysis result against two-daily rainfall. Deeming that rainfall duration is equal to time of concentration, rainfall distribution can be analyzed from the calculated concentration time using Kirpich equation.

3.5 Synthetic Unit Hydrograph

Parameter of watershed should be specified before determining synthetic unit hydrograph. It can be accomplished using Map Info Software as shown in Table 5. Synthetic unit hydrograph determined by Gama I SUH is necessary to validate. It is in accordance with the theory of unit hydrograph which is revealed that unit hydrograph is direct run-off resulted from effective rainfall over catchment area within constant time. Hence, direct run-off volume must be equal to volume of 1-mm effective rainfall over the catchment area.

Table 5. Lusi watershed parameter

Parameter	Value
Catchment area, *A* (km^2)	2100
Main River length, *L* (km)	166.49
Average slope, *S* (non-dimensional)	0.0017
Density of drainage network, *D* (km/km^2)	1.064
Relative upstream area, *RUA* (non-dimensional)	0.479
Widh factor, *WF* (non-dimensional)	0.569
Symmetry factor, *SIM* (non-dimensional)	0.272
Source factor, *SF* (non-dimensional)	0.570
Frekuensi Sumber, *SN* (non-dimensional)	0.684
Number of river junction, *JN* (non-dimensional)	1953
Time of rise, *TR* (hours)	12.00
Peak discharge, *QP* (m^3/s)	37.19
Time of base, *TB* (hours)	46.20
Reservoir coefficient, *K* (non-dimensional)	10.35
Phi Index, π (mm/hours)	8.60
Base flow, *BF* (m^3/s)	69.68

3.6 Design Flood Hydrograph

Flood hydrograph obtained from Tadashi Tanimoto, ABM (daily rainfall data), and ABM (two-daily rainfall data) approach are depicted in Figure 3, Figure 4, and Figure 5, while the design flood discharge are listed below (see Table 6).

Table 6. Design flood discharge

Rainfall Distribution Method	Q_2 (m^3/s)	Q_{50} (m^3/s)	Q_{100} (m^3/s)	Q_{200} (m^3/s)
Tadashi Tanimoto	534	1561	1799	2049
ABM (daily rainfall data)	495	998	1137	1282
ABM (two-daily rainfall data)	748	1036	1097	1158

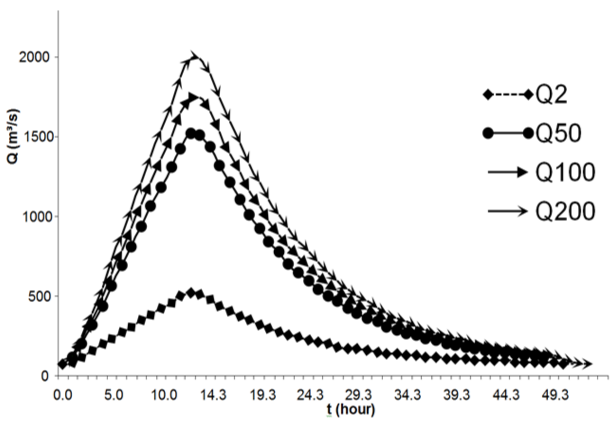

Figure 3. Flood hydrograph based on Tadashi Tanimoto equation.

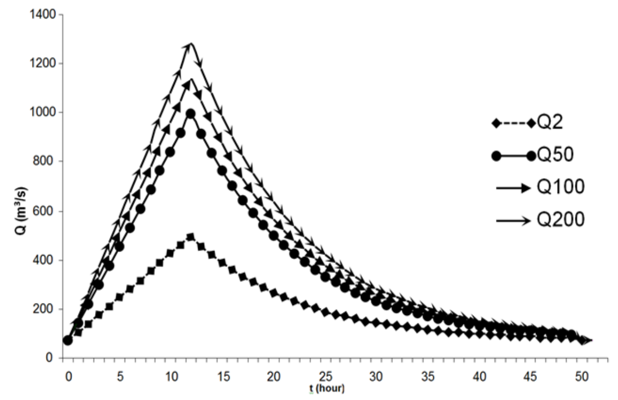

Figure 4. Flood hydrograph based on ABM (daily rainfall data).

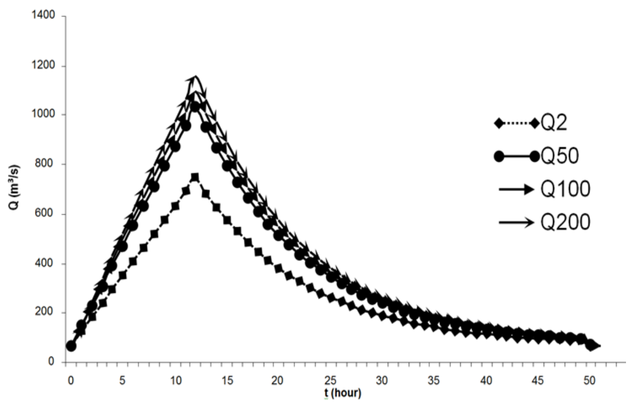

Figure 5. Flood hydrograph based on ABM (two-daily rainfall data).

3.7 Flood Management

Lusi River gives large contribution in downstream flooding. The design flood discharge result indicates that it contributes about 96% of total flood towards Klambu barrage downstream. Design flood discharge of Lusi River is 1.158 m^3/s for return period of 200 year, while design flood of Klambu barrage is 1.200 m^3/s. Klambu barrage is considered as control point since a junction point connected between Lusi River and Serang River has no gaging station.

If upstream flood discharge is assumed being confined approximately 50 % of total downstream flood, load of flood against Klambu barrage downstream can be reduced. Although flood control structure has been attempted with the existence of Kedungombo weir, downstream flooding still occurs, particularly at the downstream of Serang and Lusi River junction, whereas flood has apparently never been overtopped spillway at Kedungombo Dam. It indicates that flood discharge of Lusi River evidently has a quite large contribution in flooding, furthermore Lusi River that is branch of Serang River has a large catchment area.

In order to be able to hold temporary flood discharge, it is required to implemetn some additional flood control structures, for instance dam, or retarding basin at Lusi River reach. Consideration of placement of flood control structure is highly necessary, either in technical or non-technical aspect. However, this issue has not been disscussed on this study. Further research is necessary for the sake of better flood management in Seluna River system.

4 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusion

a) According to the Gama I SUH result, Lusi watershed with the area of 2100 km^2 tends to have large flood contribution. The values are about 748 m^3/s for 2-year flood, 1036 m^3/s for 50-year flood, 1097 m^3/s for 100-year flood, and 1158 m^3/s for 200-year flood by using ABM with two-daily rainfall analysis approach, while Tadashi Tanimoto method gives 534 m^3/s, 1561 m^3/s, 1799 m^3/s, and 2049 m^3/s, successively for return period of 2, 50, 100, and 200 year. ABM applying daily rainfall data analysis results flood contribution of 495 m^3/s, 998 m^3/s, 1137 m^3/s, and 1282 m^3/s, successively for 2, 50, 100, and 200-year flood.
b) Design flood analysis is carried out by using ABM approach with two-daily rainfall data since this method gives the closest result to the actual condition of Lusi watershed in which rainfall occurs in a long duration.
c) Since Lusi and Seluna River junction has not been equipped with rainfall gauge system, flood design discharge of Klambu barrage (Q_{200} = 1200 m^3/s) is used as control point implying that the flood contribution of Lusi and Seluna River junction is approximately 96%.

4.2 Recommendations

a) As known that flood occurring at downstream of Lusi River may affect Seluna River system, additional flood control structures, i.e dam, or retarding basin are necessary for holding temporary flood from Lusi River.
b) Besides hydrological analysis, hydraulic analysis is required to analyze for the further study.

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