APPLICATION OF A RAINFALL-RUNOFF MODEL FOR ASSESSING THE EFFECT OF LAND USE CHANGE ON FLOOD CHARACTERISTICS IN SERANG REGENCY, BANTEN

I A Rakhmatika[1*]

[1]Universitas Gadjah Mada

ABSTRACT
A flood in Serang Regency is predicted to occur due to changes in land use in the Ciujung River Basin. Land cover conditions in upstream areas affect flooding in downstream areas. A study is needed to evaluate the runoff from the Ciujung River Basin that reaches the flood-prone area in Serang Regency. This research aims to identify the effect of land-use change on floods in the Serang Regency and identify sub-watersheds that have a dominant influence on floods. The effect of the land-use change was analyzed by determining the composite curve number (CN) values in 2010 and 2019. Composite CN values were used for simulating flood hydrographs with 5, 20, 50, 100, and 1000 return periods using a simple semi-distributed rainfall-runoff hydrological model. The results showed that all sub-watersheds experienced an increase in composite CN values. The upper middle sub-watershed has a dominant influence on floods in normal conditions ranging from 9.2%-19.6%, in wet conditions ranging from 2.4%-6.5%. Implementing the spatial pattern of the Banten Provincial Plan 2010-2030 can reduce the composite CN value and the peak discharge of flood by around 7.3%-13.3% for normal conditions, in wet conditions down by about 1.7%-4.1% for each return period.

Keywords: Flood; Hydrological Model; Effect of Landuse

1. INTRODUCTION
The Ciujung River passes Serang District, one of the main rivers in the Cidanau Ciujung Cidurian River Area, with an irrigation area of 1818.55 km2. Serang Regency is the downstream area of the Ciujung River Basin. Based on the rainfall trend recorded at the Pamarayan Rainfall Post located in Serang District, it has not changed significantly. Flooding in Serang Regency is predicted due to changes in land use in the Ciujung River Basin.

Heriyanto (2018) analyzed the land-use changes in the Ciujung watershed from 2000 to 2015 showed that land-use changes in primary dryland forests decreased by -1.55%. Secondary dryland forests decreased by -5.67%, plantation forests fell by -6.06%, settlements rose by +54.34%, shrubs fell by -84.5%, open land fell by -61.02%, and rice fields fell by -31.49% [1].

Ismoyojati (2018) analyzed the land-use changes to the flood characteristics of Bima City. In this study, changes in land use caused an increase in CN values, and an increase in CN values increased flood discharge and runoff volumes in the Padalo sub-watershed and the Malayu sub-watershed [2]. Ilmi (2019) analyzed land-use changes in the Dodokan watershed of West Nusa Tenggara Province. In the study, decreasing forest and shrub areas also increasing settlements caused an increase in the value of the River Regime

[1*] Corresponding author's email: intanrakhmatika19@mail.ugm.ac.id
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Coefficient and flood events, the increase in plantation area caused the value of the Water Deposit Coefficient to increase, and the Annual Flow Coefficient to decrease [3].
Based on this, upstream areas' land cover conditions affect flooding in downstream areas. Land use conditions can determine the large volume of runoff. A study is needed to model the magnitude of the runoff that reaches the Serang Regency flood-prone area because the watershed size is large. This study used a simple semi-distributed hydrological model to simulate the rainfall-runoff process within the watershed. This study identified sub-watersheds influencing floods and watershed management for flood mitigation in the Serang District.
This study intends to show the effect of land-use changes on floods in the Serang Regencyand identify sub-watersheds that have a dominant influence on floods in Serang District. This research is expected to be considered by the Serang Regency Government in preparing flood control and mitigation plans.

2. RESEACH METHOD

The scope and stages of the analysis in this study follow the procedure as shown in Table 1.

Table 1. Research procedure.

Stage of analysis	Data	Methods	Objectives and results
Delineation of watershed boundaries	Digital Elevation Model (DEM)	HEC-GeoHMS	Determination of sub-watersheds and parameters
Rainfall area	Daily rainfall	Polygon Thiessen	Determines average rainfall in all sub-watersheds
Design rainfall	Maximum rainfall	Frequency analysis	Determining the amount of extreme rainfall within the return period
Rainfall hyetograph	Design rainfall	Alternating Block Method (ABM)	Rainfall hyetograph used for simulated rainfall-runoff simulations
Design flood	Sub-watershed area and river length	Nakayasu synthetic unit hydrograph	Flood hydrograph used for rainfall-runoff simulations
Determination of composite CN	Soil type and land use data	HEC-GeoHMS	Set composite CN values for all sub-watersheds
Calibration of watershed parameters	Discharge and rainfall in the flood event	Trial and Error	Set representative parameters for all sub-watersheds
Flood hydrograph simulations	Calibrated sub-watershed parameters, designed rainfall	HEC-HMS	Flood hydrograph for each return period
Evaluation of simulation results	Simulation results	Comparison of flood hydrograph changes	Knowing the change in time to peak, peak discharge, and runoff volume
Study of flood characteristics in the study area	Simulation results		It knows the sub-watersheds that have a dominant influence on the floods of Serang District

Flood management recommendations	Simulation results and characteristics of flood hydrographs		Its recommendations for dealing with the Serang District flood problem

2.1 Site Description

Serang Regency geographically is between 5°50' - 6°21' LS and 105°7' 106°22' E. Serang Regency is bordered by various regions, including the Java Sea, Tangerang Regency, Pandeglang Regency, Lebak Regency, Serang Municipality, and Sunda Straits as shown in Figure 1.

Figure 1. Study area (base map from ArcMap 10.2).

2.2 Semi-Distributed Model

The distributed rainfall-runoff model has been simplified into the semi-distributed rainfall-runoff model. The semi-distributed rainfall-runoff model describes the sub-watershed as a unit of the area almost identical to the watershed. Within the scoop of sub-watershed, hydrological phenomena are seen. Based on their topographical similarity, this model divides the sub-watershed into many sub-watersheds [4]. One example of a semi-distributed rainfall-runoff model application is HEC-HMS. This software is commonly used for flood events simulation. Modeling inputs use the help of the HEC-GeoHMS tool, an extension of ArcGIS. HEC-GeoHMS output can be directly imported into HEC-HMS [5]. The advantage of the HEC-HMS is that it has used the concept of Geographic Information System (GIS), and there are facilities such as calibration, simulation of distribution models, event flow, and continuous flow models. The modeling component of the rainfall-runoff transformation using HEC-HMS is shown in Table 2.

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Table 2. Modeling components of rainfall-runoff transformation using HEC-HMS.

Components	Description
Basin model	Elements contained in a watershed such as sub-watersheds, outlet points, rivers, and reservoirs
Meteorologic model	Rainfall and evaporation
Control specification	Simulation start and end time
Time series data	Time sequence of rainfall and discharge data
Paired data	It consists of storage-discharge function, unit hydrograph curve, and elevation-storage function

3. RESULT AND DISCUSSION

3.1 Watershed Delineation

Determining watershed boundaries or the delineation of watershed boundaries is a process of determining areas that contribute to flowing rainfall as inputs, becoming runoff at the outlet (flood-prone area). The watershed delineation process uses a digital elevation model or DEM data. DEM data is used to determine the topographic shape of an area so that hydrological characteristics are obtained, which are the basis for the watershed delineation process [6]. The results of the watershed delineation are shown in Figure 2.

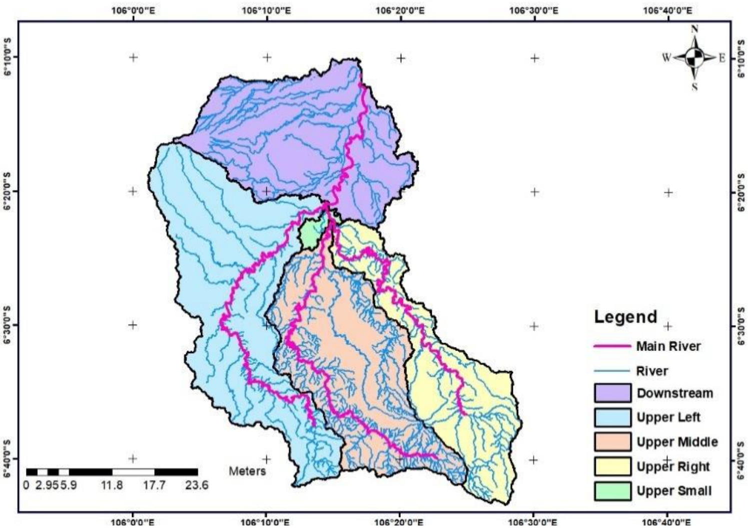

Figure 2. Ciujung watershed delineation (base map from Geospatial Information Agency https://tanahair.indonesia.go.id/)

Sub-watershed parameters for the Ciujung watershed are shown in Table 3.

Table 3. Sub-watershed parameters.

Sub-watersheds	Area (km^2)	River Length (km)
Downstream	455.20	48
Upper Left	578.60	81
Upper Middle	449.31	72
Upper Right	319.26	87
Upper Small	16.17	11
Total	1818.553	

3.2 Rainfall Area

Three methods can be used to measure rainfall area: the algebraic method, polygon Thiessen, and isohyet. In this study, the Polygon Thiessen method was used. This method is determined by making polygons between rainfall posts to predict the rainfall area [7]. The coefficient of polygon Thiessen for the Ciujung watershed is shown in Table 4.

Table 4. Thiessen polygon coefficient of Ciujung watershed.

Sub-watersheds	Rainfall Stations						Total
	Pamarayan	Pasir Ona	Ciboleger	Bojong Manik	Banjar Irigasi	Sampang Peundeuy	
Downstream	0.74	0.26	0.00	0.00	0.00	0.00	1
Upper Left	0.00	0.23	0.00	0.00	0.77	0.00	1
Upper Middle	0.00	0.01	0.37	0.02	0.20	0.32	1
Upper Right	0.00	0.25	0.12	0.21	0.00	0.41	1
Upper Small	0.00	1.00	0.00	0.00	0.00	0.00	1

3.3 Design Rainfall

The alternating block method (ABM) is one of the methods to derive a hyetograph that can be obtained from the intensity-duration-frequency (IDF) curve. Rainfall is obtained by multiplying the intensity of rainfall by the duration of rain [8]. The approach to obtain the rainfall duration can use the time of concentration. The design rainfall for the Ciujung watershed is shown in Table 5.

Table 5. Design Rainfall.

Return Periods	Design Rainfall (mm)				
	Downstream	Upper Right	Upper Middle	Upper Left	Upper Small
5	108.94	136.41	63.81	107.20	127.97
20	150.39	162.23	89.45	134.15	171.89
50	181.43	175.47	107.95	152.67	202.36
100	207.53	184.25	123.12	167.41	226.78
1000	315.24	208.30	182.94	222.59	319.07

3.4 Nakayasu Syinthetic Unit Hydrograph

The hydrograph of Nakayasu in the existing condition is obtained by calculating the time of concentration, time unit of rainfall, time to the peak of the flood, decrease in peak discharge, and peak discharge. After those calculations, the tables and graphs of the Nakayasu flood hydrograph of the existing condition for every return period are obtained

[9]. The Nakayasu synthetic unit hydrographs and parameters are shown in Figure 3 and Table 6.

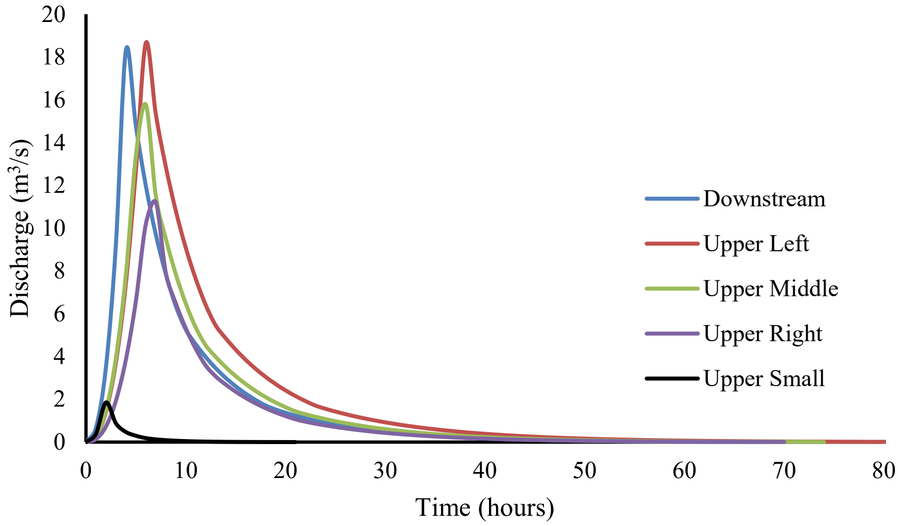

Figure 3. Nakayasu synthetic unit hydrograph of each sub-watershed.

Table 6. Nakayasu synthetic unit hydrograph parameters for each sub-watershed.

Parameters	Unit	Sub-watersheds				
		Downstream	Upper Right	Upper Middle	Upper Left	Upper Small
Area	km^2	455.20	319.26	578.61	449.31	16.17
River Length	km	48.08	86.99	80.63	71.66	11.09
Peak Discharge	m^3/s	18.29	11.17	18.54	15.79	1.93
Time to Peak	hours	3.99	6.25	5.88	5.36	1.95
Alpha		1.79	1.11	1.36	1.38	1.52
T0.3	hours	5.72	6.07	6.91	6.30	1.72

3.5 Curve Number Analysis

Ideally, a flood hydrograph was developed from rainfall and flow data measured at the same time. Loss or runoff volume is calculated using SCS CN (Soil Conservation Service Curve Number). The value of the curve number depends on several factors regarding existing basin conditions: soil type, vegetation cover type, land use, hydrological conditions, previous soil moisture, antecedent moisture conditions (AMC), and basin climate. SCS method estimates cumulative excess rainfall [10]. Orthic Acrisols dominate the watershed. This type of soil has a reddish to yellow or yellowish color. The texture of this soil is generally loam clay. This soil is a soil hydrological group D. Comparison of CN II composite, and CN III composite values are shown in Figures 4 and 5.

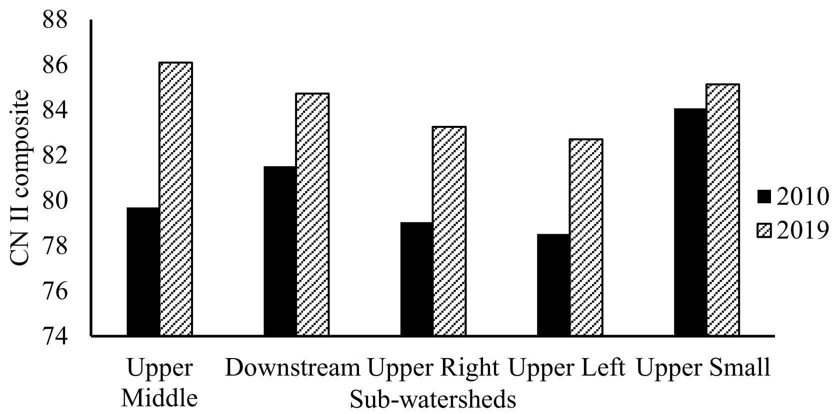

Figure 4. Comparison CN II composite.

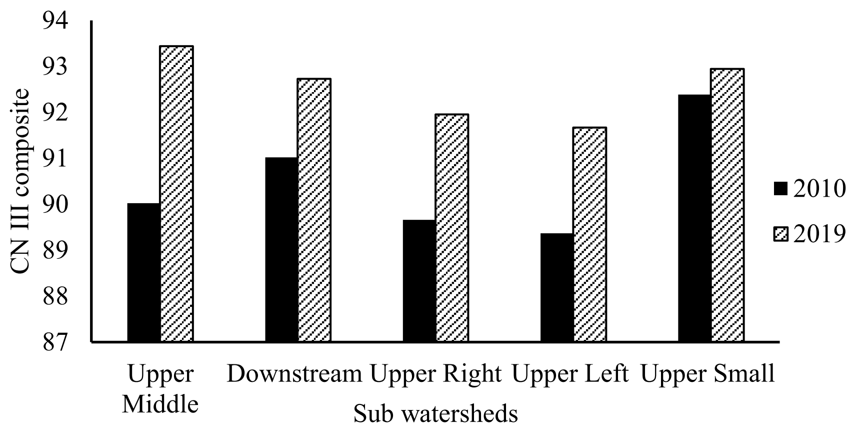

Figure 5. Comparison CN III composite.

From Figures 3 and 4, it can be seen that almost all sub-watersheds experienced an increase in composite curve number value. In the upper middle sub-watershed, the land use distribution in 2010 was dominated by plantations with a value of CN 81, covering an area of 202.57 km^2. In 2019 land use changed, dominated by shrubs with a value of CN 89, covering an area of 207.89 km^2. In the upper left sub-watershed, the land use distribution in 2010 was dominated by plantations with a value of CN 81, covering an area of 498.1 km^2. In 2019, it remained dominated by plantations with CN 91 covering an area of 200.80 km^2, increasing the area of shrubs with a value of CN 89 covering an area of 144.86 km^{2,} and rice fields with a value of CN 89 covering an area of 118.31 km^2. In the upper left sub-watershed, the land use distribution in 2010 was dominated by plantations with a value of CN 81, covering an area of 498.1 km^2. In 2019, it remained dominated by plantations with CN 91 covering an area of 200.80 km^2, increasing the area of shrubs with a value of CN 89 covering an area of 144.86 km^2 and rice fields with a value of CN 89 covering an area of 118.31 km^2. In the upper small sub-watershed, the land use distribution in 2010 was dominated by plantations with a value of CN 81, covering an area of 387.80 km^2. In 2019, it remained dominated by plantations with a value of CN 81 covering an area of 197.10 km^2, and there was an increase in rice field area with a value of CN 89 covering an area of 163.07 km^2.

In the downstream sub-watershed, the land use distribution in 2010 was dominated by plantations with a value of CN 81, covering an area of 11.66 km^2. In 2019, dominated by plantations with CN 81 covering an area of 8.85 km^2 and increasing the rice field areas with a value of CN 89 covering an area of 4.23 km^2 and settlements with a value of CN 92 covering an area of 2.34 km^2.

3.6 Model Calibration

A calibration process is carried out with the available input and output data to determine the values that can represent the actual condition of the watershed. As a result of the calibration process, watershed parameter values are obtained, which can be used as a basis for simulating rainfall-runoff transformation. The calibration process is carried out until the simulation results are close to the observation results. The difference between the simulation and the observation results or peak error is less than 10%[11], unavailability data of rating curve on AWLR outlet Pamarayan. Measured discharge data and rating curve are only available on AWLR Bojongmanik. Calibration using AWLR Bojongmanik discharge data on 12 March 2019. Bojongmanik subwatershed calibration results and initial abstraction results in normal and wet conditions are shown in Figure 6 and Tables 7,8,9, and 10.

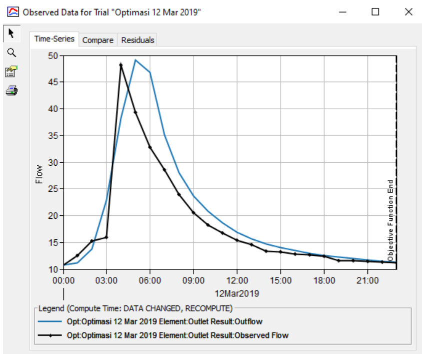

Figure 6. Bojongmanik sub-watershed calibration results.

Table 8. Initial abstraction calibration result

Parameter	Initial Value	Calibration
Initial Abstraction	0.2 S	0.18 S

Table 9. Initial abstraction in normal condition.

Year	Initial Abstraction (mm)				
	Upper Middle	Downstream	Upper Right	Upper Left	Upper Small
2010	11.43	10.18	11.90	12.27	8.50
2019	7.24	8.09	9.03	9.38	7.83
Changes (%)	-57.87	-25.75	-31.83	-30.83	-8.52

Table 10. Initial abstraction in wet condition.

Year	Initial Abstraction (mm)				
	Upper Middle	Downstream	Upper Right	Upper Left	Upper Small
2010	4.97	4.42	5.17	5.34	3.70
2019	3.15	3.52	3.92	4.08	3.41
Changes (%)	-57.87	-25.75	-31.83	-30.83	-8.52

3.7 Flood Hydrograph Simulation

One application that can be used to model flood hydrographs is HEC-HMS. The rainfall-runoff transformation model HEC-HMS is supported by a geographic information system (GIS). HEC-GeoHMS is one of the extensions of the Arc-GIS application. Various features in HEC-GeoHMS can be used to prepare hydrological modeling in the HEC-HMS application [5]. Simulation hydrographs are shown in Figures 6,7,8, and 9.

The simulation results show that the upper small sub-watershed has a large enough percentage of changes for peak discharge and runoff volume under normal and wet conditions. However, the upper small sub-watershed does not have a dominant influence on the flood because it has 0.9% of the watershed area. The upper middle sub-watershed greatly influences floods because, in addition to having a reasonably large percentage of changes, the upper middle sub-watershed has 24.7% of the watershed area.

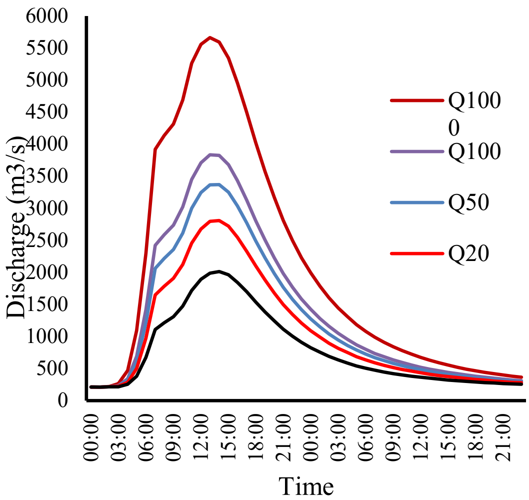

Figure 7. Flood hydrograph simulation at Serang Regency flood-prone area in normal condition using land use data in 2011.

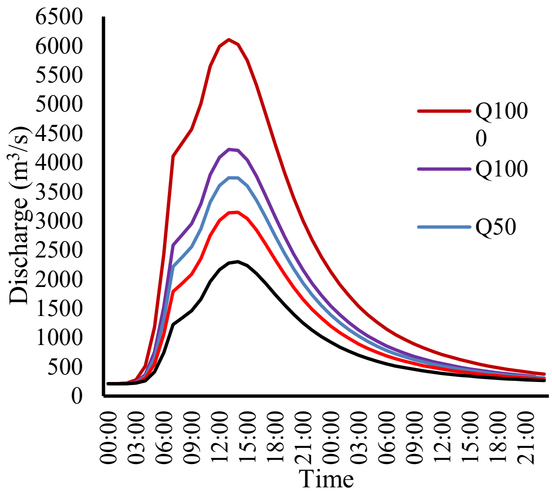

Figure 8. Flood hydrograph simulation at Serang Regency flood-prone area in normal condition using land use data in 2019.

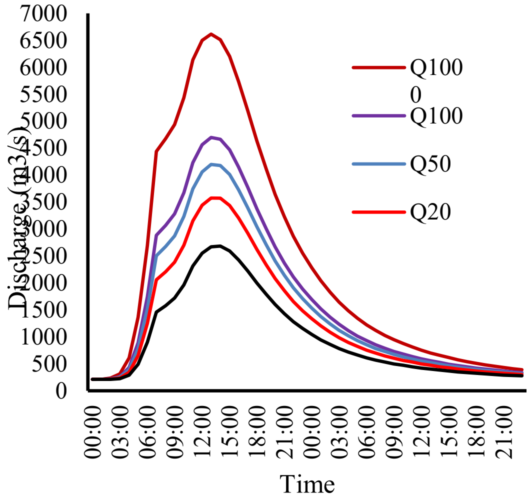

Figure 9. Flood hydrograph simulation at Serang Regency flood-prone area in wet condition using land use data in 2011.

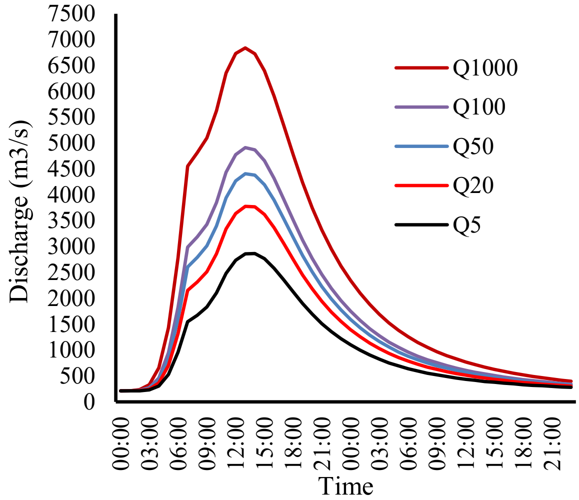

Figure 10. Flood hydrograph simulation at Serang Regency flood-prone area in wet condition using land use data in 2019.

The peak discharge and runoff volume changes in normal and wet conditions are shown in Tables 11,12,13, and 14.

Table 11. Changes in the peak discharge of normal condition.

Sub-watersheds	Area (km^2)	Peak Discharge Changes (%)				
		Q5	Q20	Q50	Q100	Q1000
Upper Right	17.56	10.5	9.1	8.5	8.2	7.3
Upper Left	31.82	13.6	11.6	10.4	9.7	7.6
Upper Small	0.89	2.7	2.1	1.7	1.6	1.1
Upper Middle	24.71	25.7	21.1	18.5	16.8	12.2
Downstream	25.03	9.4	7.3	7.0	6.3	4.2
Serang Regency Outlet	100.00	12.5	10.7	9.8	9.1	7.1

Table 12. Changes in the runoff volume of normal condition.

Sub-watersheds	Area (km^2)	Runoff Volume Changes (%)				
		Q5	Q20	Q50	Q100	Q1000
Upper Right	17.56	10.8	9.4	8.8	8.5	7.6
Upper Left	31.82	13.3	11.1	10.0	9.3	7.3
Upper Small	0.89	2.5	1.9	1.7	1.5	1.1
Upper Middle	24.71	26.6	21.0	18.3	16.5	12.1

Downstream	25.03	9.6	7.4	6.3	5.6	3.9
Serang Regency Outlet	100.00	10.2	9.1	8.4	7.9	6.5

Table 13. Changes in the peak discharge of wet condition.

Sub-watersheds	Area (km^2)	Peak Discharge Changes (%)				
		Q5	Q20	Q50	Q100	Q1000
Upper Right	17.56	4.5	3.7	3.5	3.3	2.9
Upper Left	31.82	8.4	6.9	6.1	5.2	4.2
Upper Small	0.89	6.0	4.2	3.4	3.0	1.9
Upper Middle	24.71	10.1	7.6	6.4	5.7	3.8
Downstream	25.03	5.4	4.0	3.4	2.9	1.9
Serang Regency Outlet	100.00	6.6	5.4	4.8	4.4	3.3

Table 14. Changes in the runof

Sub-watersheds	Area (km^2)	Runoff Volume Changes (%)				
		Q5	Q20	Q50	Q100	Q1000
Upper Right	17.56	4.9	4.2	3.9	3.4	3.3
Upper Left	31.82	8.3	6.9	6.1	5.2	4.4
Upper Small	0.89	6.2	4.8	4.1	3.6	2.7
Upper Middle	24.71	10.5	7.8	6.6	5.1	4.1
Downstream	25.03	5.0	3.7	3.2	2.6	1.9
Serang Regency Outlet	100.00	5.5	4.7	4.2	3.8	3.0

3.8 Flood Management Recommendation

Flood management is an effort to harmonize and integrate water resource conservation, water resource use, and water damage control (flooding). Technically, flood control can be carried out by structural or non-structural methods. Flood control structure methods can be done by building flood control buildings such as dams, retention ponds, check dams, and retarding basins [12].

Non-structural methods can be carried out by watershed management and land use arrangements. From the analysis of the upper middle sub-watershed, which is the sub-watershed that most affects floods in Serang Regency, alternatives can be found to regulate the composition of land use that is suitable to reduce the amount of flood discharge. The land use composition has been regulated in Banten Provincial By-law No. 5 of 2017 concerning the Banten Provincial RTRW for 2010-2030. A comparison of land use areas in 2010,2019 and 2030 are shown in Table 15. Furthermore, a comparison of curve number composite values in 2019 and 2030 is shown in Table 16.

Table 15. Comparison of land use area in 2010, 2019, and 2030 of upper middle sub-watershed.

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Land Uses	CN	Area (km^2)		
		2010	2019	2030
Industry	93	0	0.01	0.00
Settlement	92	0.72	9.84	25.29
Water Body	100	0	3.90	5.44
Forest	77	149.37	56.03	56.52
Plantation	81	202.57	79.33	137.76
Open Land	80	0	0.00	26.82
Shrubs	89	0	207.89	0.00
Rice Fields	89	0	83.67	14.13
Agriculture	81	96.65	8.65	87.03

Table 16. Comparison of land use area in 2010, 2019, and 2030 of upper middle sub-watershed.

Land Uses	CN	Area (km^2)		
		2010	2019	2030
Tour Destination	92	0	0.00	14.45
National Park	77	0	0.00	81.87

Table 17. Comparison of composite curve number values in 2019 and 2030 of upper middle subwatershed.

Parameters	Composite curve number values
CN II composite 2019	86.10
CN II composite 2030	81.16

Comparison results of the 2019 and 2030 flood hydrograph simulation in normal and wet conditions are shown in Tables 17 and 18.

Table 18. Comparison of the results of the 2019 and the 2030 flood hydrograph simulation in normal condition.

	Parameters	Area (km^2)		Changes (%)
		2019	2030	
Q_5	Peak Discharge (m^3/s)	480.7	386.3	19.6
	Volume Runoff (MCM)	15.37	13.65	11.2
Q_{20}	Peak Discharge (m^3/s)	765.9	643.5	16.0

	Volume Runoff (MCM)	25.23	22.78	9.7
Q_{50}	Peak Discharge (m^3/s)	981.6	844.1	14.0
	Volume Runoff (MCM)	32.69	29.82	8.8
Q_{100}	Peak Discharge (m^3/s)	1162.4	1015.0	12.7
	Volume Runoff (MCM)	38.95	35.76	8.2
Q_{1000}	Peak Discharge (m^3/s)	1892.7	1719.2	9.2
	Volume Runoff (MCM)	64.23	60.19	6.3

Table 19. Comparison of the results of the 2019 and the 2030 flood hydrograph simulation in wet condition.

Parameters		Area (km^2)		Changes (%)
		2019	2019	
Q_5	Peak Discharge (m^3/s)	630.5	589.5	6.5
	Volume Runoff (MCM)	20.3	19.7	3.1
Q_{20}	Peak Discharge (m^3/s)	942.1	896.6	4.8
	Volume Runoff (MCM)	31.1	30.3	2.5
Q_{50}	Peak Discharge (m^3/s)	1170.2	1123.0	4.0
	Volume Runoff (MCM)	39.0	38.2	2.2
Q_{100}	Peak Discharge (m^3/s)	1358.8	1310.5	3.6
	Volume Runoff (MCM)	46.2	44.7	3.2
Q_{1000}	Peak Discharge (m^3/s)	2105.8	2055.8	2.4
	Volume Runoff (MCM)	71.7	70.7	1.4

4. CONCLUSION AND RECOMMENDATION

4.1 Conclusion

Land use changes between 2010 and 2019 resulted in an increase in composite CN values across the sub-watershed. The upper middle sub-watershed has a dominant influence on floods in Serang Regency because having a reasonably large percentage of peak discharge changes. In normal conditions ranging from 9.2%-19.6%, in wet conditions ranging from 2.4%-6.5% and the upper middle sub-watershed has a 24.7% of the total area. The land

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use composition has been regulated in Banten Provincial By-law No. 5 of 2017 concerning the Banten Provincial RTRW for 2010-2030. The land use composition based on the 2010-2030 Banten Provincial RTRW can reduce the composite of curve number value by 5.78% and reduce flood discharge by around 7.3%-13.3% for normal conditions, in wet conditions down by about 1.7%-4.1% for each return period.

4.2 Recommendation

a. The unavailability of the rating curve in AWLR Pamarayan and rainfall data resulted in no optimal analysis. In the future, an accurate water level-discharge relationship is needed to improve the hydrological analysis.
b. Determination of soil type dramatically affects the analysis of CN values, for the determination of soil type is expected to be obtained through sondir and boring soil tests at the research site so that the accuracy value is higher as well as updating the available data.

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