JURNAL geografi

https://jurnal.unimed.ac.id/2012/index.php/geo/article/view/34651
https://doi.org/10.24114/jg.v14i2.34651 - (Vol 14, No 2 - 2022)
available at http://jurnal.unimed.ac.id/2012/index.php/geo
e-issn (2549-7057) & p-issn (2085-8167)

The Estimation of Flood-Affected Area in the Downstream of Code River, Yogyakarta

Suhadi Purwantara*, Arif Ashari, Dyah Respati Suryo Sumunar, Nurul Khotimah
Department of Geography Education, Faculty of Social Sciences, Universitas Negeri Yogyakarta, Indonesia

ARTICLE INFO

Article History:
Received: May 20, 2022
Revision: August 22, 2022
Accepted: August 23, 2022

Keywords:
Disaster
Floods
Estimated Flood-Affected Areas
Code River
Yogyakarta

Corresponding Author
E-mail: suhadi_p@uny.ac.id

ABSTRACT

The rapid development of settlements and sediment deposition has increasingly narrowed the drainage in the Code River. This condition causes floods and wider distribution of the affected areas. This research aims to estimate the maximum amount of rain, predict the probability of flood, and predict flood-prone areas in the Code River. Data were collected by observation, remote sensing image interpretations, literature studies, and documentation. Data analysis was performed using Log Pearson Type III for design rainfall analysis, Weibull formula for flood probability analysis, and rational method for planning maximum discharge analysis. Flood modeling is carried out by the iteration method. The results show: (1) the maximum amount of rain based on the calculated design rainfall with a return period of 5 to 40 years is R5 = 106.83 mm, R10 = 116.67 mm, R20 = 127.30 mm, R40 = 134.25 mm, (2) the probability of flood that is predicted from the maximum discharge caused by the design rainfall at each return period is Q5 = 82.45 m^3/sec, Q10 = 89.42 m^3/sec, Q20 = 96.95 m^3/sec, Q40 = 101.86 m^3/sec. (3) Inundation of the flood target area in the 5-year return period covers an area of 0.4456 km^2, the 10-year return period covers 0.5209 km^2, the 20-year return period covers 0.6023 km^2, the 40-year return period covers 0.6555 km^2. This paper presents information on the potential for a flood at various return periods to increase preparedness and reduce risks due to flood disasters.

INTRODUCTION

The Indonesian archipelago always faces the threat of various natural disasters from time to time due to its position at the junction of three large plates, complex geomorphological conditions, and tropical climate impacts (Sunarto & Rahayu, 2006; Verstappen, 2010, 2013). Daerah Istimewa Yogyakarta (DIY) is one of the provinces-level regions in Indonesia which offers various natural hazards. Various disasters have provided a severe threat in the last 15 years, including the Merapi Volcano eruption, earthquakes, landslides, and floods. Landslides and floods are disasters that occur regularly. A flood is a disaster that requires more attention due to its routine occurrences, which is almost every year, and its significant impacts. Data from the Indonesian National Disaster Management Agency shows that the flood in DIY may cause physical losses worth 97 billion rupiah and economic losses of 1.1 trillion rupiahs. The flood-affected population reached 2,964,112 or 80,56% of the total population of Yogyakarta Province in that year (Amri et al., 2016; BPS-Statistics of DI Yogyakarta, 2016).

Flood occurs as the drainage cannot accommodate the large volume of runoff. In some urban areas in Yogyakarta, flood often occurs due to too small drainage channels as well as the morphometrical characteristics of the track (Nurhadi et al., 2016). This condition is a global phenomenon, not only in Yogyakarta but also in various cities around the world, including Europe (Bathrellos et al., 2016; Guerreiro et al., 2017; Mel et al., 2020), America (Ress et al., 2020), Asia (Pambudi, 2022; Rafiq et al., 2016; M. Yang et al., 2020), and Africa (Asiedu, 2020; Oruonye, 2016). Code Watershed is one area in the regions of Yogyakarta that often experience floods (Nurhadi et al., 2016). The flood hit the area because the runoff water volume exceeds the river channel's capacity. The high rainfall in the rainy season causes a large amount of discharge in these rivers. Data from BPS Sleman Regency shows that in 2020 the maximum precipitation in the upstream area of the Code watershed reached 650 mm in January and 646 mm in December. Also, the lack of space for rainwater infiltration currently contributes to floods. The reduction in infiltration space is due to unwell-planned development. As a result, many built-up areas do not function as infiltration spaces and disturb the hydrological balance (Feng et al., 2021; Purwantara et al., 2020; Wing et al., 2022).

The reduction in infiltration spaces is due to population growth and an increase in settlement land needs. The population growth rate in DIY during 2010-2020 reached 1.18% per year, with the highest population growth rates in the Sleman and Bantul Regencies (BPS-Statistics of DI Yogyakarta, 2020). The rapid population growth has triggered agricultural land conversion into settlements, industrial areas, offices, and educational complexes. Code Watershed is an area that has undergone many land-use changes due to high population growth, especially in the upstream region of Sleman Regency. The Code River originates from the Merapi Volcano, crossing the Sleman Regency, Yogyakarta City, and Bantul Regency. Geologically, the Code watershed is mainly composed of young Merapi volcanic deposits with high permeability and porosity. Geomorphologically, the river flow starts from the volcanic cone and ends in the fluvial-volcanic plain area. Vegetation covers such as forests and shrubs dominate the upstream region.

Meanwhile, the middle and downstream areas are dominated by human activities for built-up land in urban and agricultural areas. The seasonal weather pattern in the downstream area that experiences flooding is the same as the catchment area in general, namely the dry and rainy seasons, which alternate for half a year, influenced by the monsoon. Due to the characteristics of the physical environment and human activities in this area, many land-use changes become the most decisive factor, which increases the flood potential since abundant rainwater enters the Code River valley directly due to the lack of water absorption.

As one of the rivers originating from the top of the Merapi Volcano, the Code River receives abundant lahar deposition during the Merapi eruption period. Massive material deposition in the river valley has narrowed river channels, improving the potential of flooding. The distribution of flood-affected areas has been wider due to the potential for flooding. Therefore, the calculation of rainfall and the flood discharge amount is needed to determine how much of the potential flood and flood-affected areas are around the Code River. This information is badly needed to enhance various prevention efforts to reduce flood risks. In addition, the flood prediction-related information helps increase the preparedness of residents that lives and do activities around the Code River border.

Among all parts of the Code watershed, the downstream area in Jetis District, Bantul Regency, is the most frequently affected area by a flood. The problem is that the flood in the downstream area always causes significant losses as residents widely exploit this area. Based on the Indonesian Topographical Map of Bantul regency sheet and the Central Bureau of Statistics data of Bantul Regency, land in this area is widely used by the residents for agriculture and settlements. For this reason, the research examining the Code River flood prediction needs to focus on this area. This paper aims to present alternative information on the applied geography in estimating flood-affected areas in the downstream area of the Code River. Applied geography in this study includes three stages: analyzing the maximum amount of rain, predicting the flooding probability, and estimating the flood-prone areas in the Code River. This study analyzes urban floods in the volcanic foot plain area with specific watershed characteristics, and varied land uses. This study is expected to provide new insights regarding the estimation of potential flood areas on the longitudinal-shaped watershed

RESEARCH METHODS

Data collection and analysis

Based on the research objectives, there are two main tasks to accomplish in this research: predicting the amount of rainfall that will be a source of the flood and estimating the amount of discharge and the area affected by the flood. To achieve these goals, the collected data include rainfall, river basin area, and morphological and morphometric river valleys in the downstream area of the Code River. Data was collected through observations, interpretations of remote sensing images, literature studies, and documentation (Table 1).

Table 1. Types of data, data collection methods, and instruments

No	Types of Data	Data Collection Methods	Instruments/Data Sources
1	River valley morphology and morphometry	Observations	GPS, clinometer, geological compass
2	The slope of the riparian zone	Observations	GPS, clinometer, geological compass
3	Landuse in Code Watershed	Documentations	Topographical Map of Indonesia for Kaliurang, Pakem, Sleman, Bantul Sheet
		Interpretation of remote sensing images	Landsat imagery
4	Rain intensity	Documentations	Rainfall data for 25 years from the Provincial Public Works Office of DIY
5	Geological and geomorphological conditions of Code watershed	Literature review	Sutikno et al. (2007)

Data analysis in this research includes the study of the design rainfall and the maximum discharge. The design rainfall is the amount of full daily rain estimated to repeat itself at a certain return period. The design rainfall is calculated to determine the maximum discharge estimated based on long-term rainfall. In this case, the frequency of rainfall must be analyzed to get the amount of rain planned for a certain return period. Rainfall analysis was performed using the Log Pearson Type III statistical method, and the probability of occurrence was calculated using the Weibull formula. The Log Pearson Type III analysis method employed in this study has also been used in previous studies, such as (Griffits and Stedinger (2007; Farooq et al., 2018; Deraman et al., 2017).

The calculation phases include determining the rainfall and the flow coefficient. The measured rainfall average at a representative regional rain station in the study area was calculated to determine the regional rainfall. Based on this assumption, rain-influential areas should be created in areas with more than one rain station. The determination of the influential rain area utilized the Polygon Thiessen method. The obtained average rainfall data are then used to calculate the design rainfall. Meanwhile, the analysis of the maximum discharge plan was carried out by calculating the rational method (eq 1)

$$Q = 0.2778CIA \quad (1)$$

Modeling with an iteration process is employed to determine the flooded areas based on the calculated data. This process is a map calculation model that utilizes mathematical operations for its function. The results of the map calculations are used as input for the iteration process. The process is based on a line by line, pixel by pixel, which is then applied to all the data used as input. Some examples of operations utilizing the iteration process include mapiter and mapiterprop followed by inputting the data, known as the start map. The formula is according to (Marfai and Chandra, 2018) (eq 2).

Iteration result = MapIterProp (start map, iterexpr, number of iterations. (2)

This process is continued with flow direction, which is an operation process that determines the natural flow direction of each pixel in the Digital Elevation Model (DEM). Then, the flow accumulation process is carried out, namely the cumulative operation of the number of pixels that naturally flow to the outlet based on the results of the flow direction process. The research procedure is shown in Figure 1.

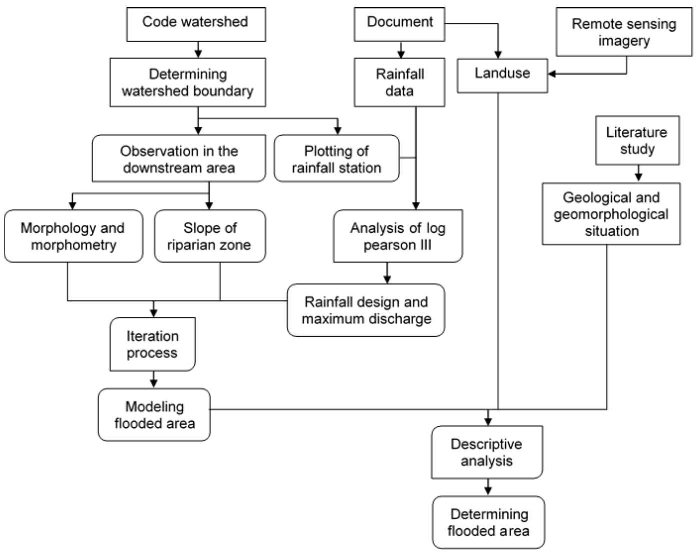

Figure 1. Research procedure

Research Area

This research was conducted in the downstream area of the Code River, Yogyakarta, which is located in Jetis District, Bantul Regency (Figure 2). Code watershed is part of Opak Watershed, stretching north-south from around the peak of Merapi Volcano in Pakem District, Sleman Regency, to the meeting with the Opak River in Jetis District, Bantul Regency. The altitude of the Code watershed ranges from 40 meters above the Code-Opak River confluence to about 2,900 meters above the peak of Mount Merapi. The Code watershed in the east is bordered by the Gajahwong watershed, while in the west, it is bordered by the Winongo watershed.

Geologically, the Code watershed area is composed of quaternary rocks from Merapi Volcano, namely young Merapi Volcano sediments (Qmi) and old Merapi Volcano sediments (Qmo). Geomorphologically, the Code Watershed is part of Merapi Volcano's morphological system, consisting of volcanic cones, slopes, foothills, foot plains, and fluvial plains (Sutikno et al., 2007). The relief characteristics and varying altitudes affect the timing and volume of discharge in the Code watershed area (Figure 3).

Most orographic rains are produced on the upper slopes of Merapi Volcano, while the volcanic slopes to the fluvial-volcanic plains of the Merapi Volcano offer the potential for moderate rain. Land uses vary greatly, including vacant land, scrub, forest, mixed garden, moor, paddy fields, and settlements. Besides depending on human cultivation, variations in land use are also influenced by relief and climate. The spatial distribution of the impervious surface that exacerbates flood is shown in Figure 4.

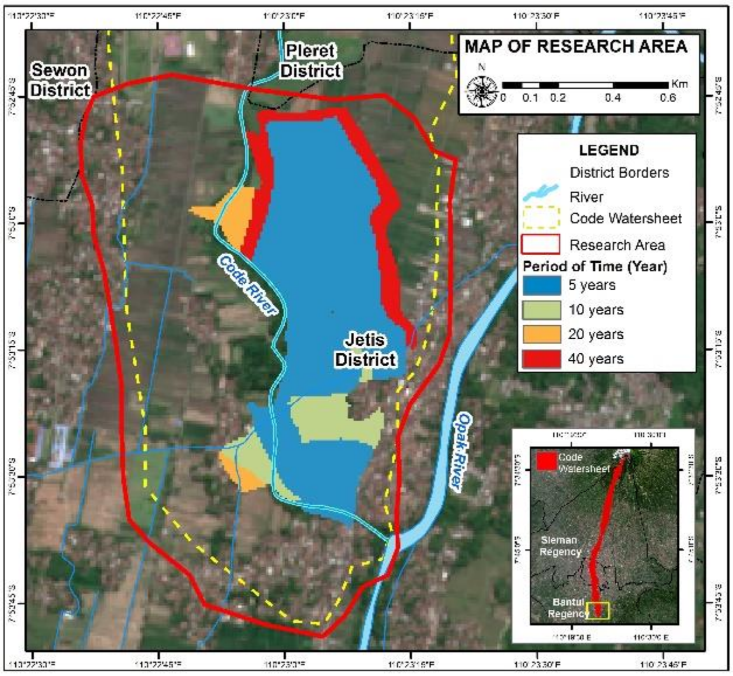

Figure 2. Study area

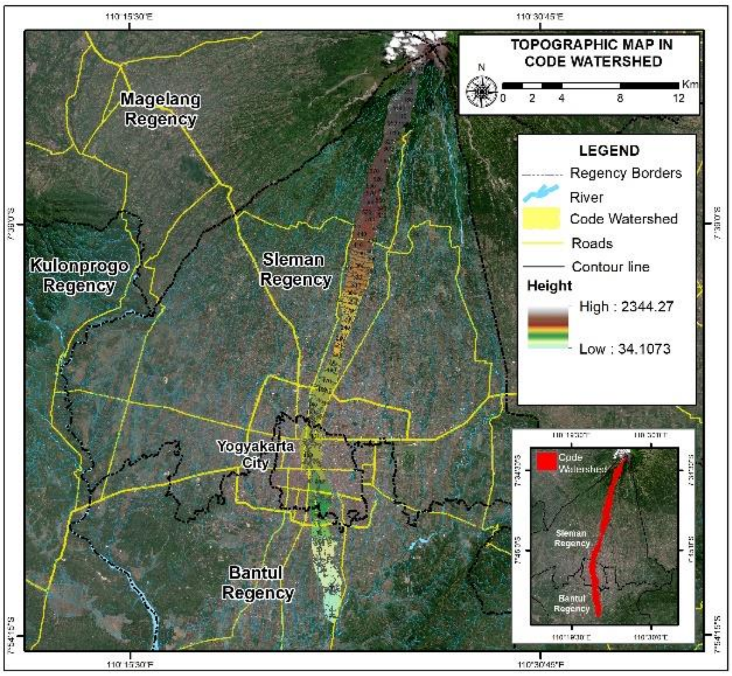

Figure 3. The relief characteristics and altitudes of Code Watershed

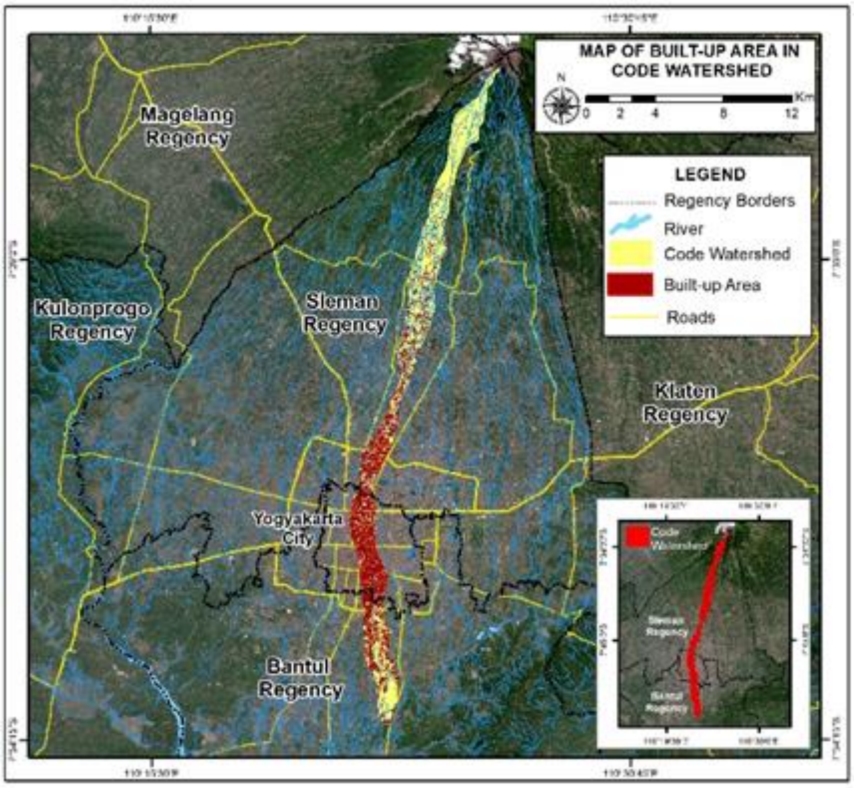

Figure 4. The spatial distribution of the impervious surface in Code Watershed

RESULTS AND DISCUSSION

The estimation of maximum rainfall that occurs on the Code River

Rainfall in the catchment area determines the amount of flood discharge in a particular site. The amount of rainfall in the Code watershed is calculated based on the rain data recorded at six stations representing the research area, namely Jangkang, Pakem, Beran, Colombo, Sewon, and Jetis stations. The location of all rainfall stations is shown in Figure 5.

Rainfall data were obtained from the Bureau of Public Works, Yogyakarta Special Province. This research utilizes rainfall data for 20 years, 1998-2017. By determining the rainfall in the research area, the amount of rain intensity can be calculated to estimate the planned discharge. Based on the analysis of rainfall data for 20 years in the Code watershed, the highest average maximum daily rainfall is 152 mm, and the lowest average maximum daily rainfall is 70 mm (Table 2).

Table 2. The Maximum Daily Rainfall Average of Code Watershed in the Period of 1998-2017

Rank	Rainfall (mm)
1	152
2	138
3	128
4	114
5	112
6	104
7	100
8	95
9	92
10	89
11	85
12	84
13	82
14	82
15	81
16	78
17	78
18	75
19	70
20	70

Source: Calculation result (2018).

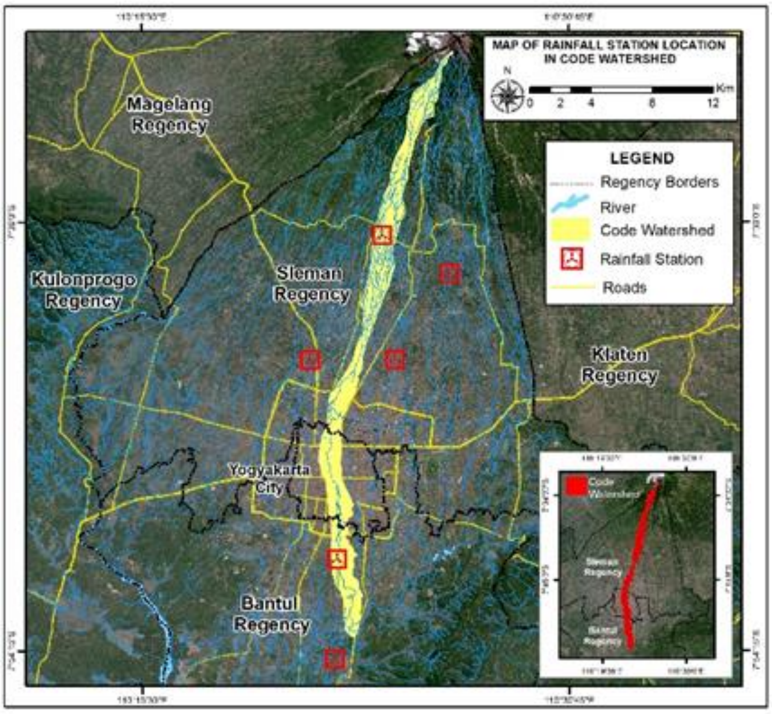

Figure. 5 The spatial distribution of the impervious surface in Code Watershed

The rainfall data which have been ranked are then used to calculate the design rainfall. The results of calculating the return period and the probability of design rainfall utilizing the Weibull formula is plotted on the Gumbel probability paper as presented in Table 3. The parameters used in the calculation of the frequency analysis are the average score (mean / X), standard deviation (Sd), Skewness coefficient (Cs), Kurtosis coefficient (Ck), and coefficient of variation (Cv). The five statistical parameters are utilized for performing frequency analysis. The results of statistical parameters calculation for frequency analysis are presented in Table 4. Furthermore, the skewness coefficient (Cs) and the kurtosis coefficient (Ck) are used to determine the test distribution of rain patterns, as shown in Table 5.

Table 3. Return Period and Maximum Probability of Daily Rain in the Code Watershed

Rank	Rainfall (mm)	Return Period (Year)	Proba bility
1	152	21,00	4,76
2	138	10,50	9,52
3	128	7,00	14,28
4	114	5,25	19,05
5	112	4,20	23,81
6	104	3,50	28,57
7	100	3,00	33,33
8	95	2,62	38,09
9	92	2,33	42,91
10	89	2,10	47,62
11	85	1,91	52,36
12	84	1,75	57,14
13	82	1,61	62,11
14	82	1,50	66,66
15	81	1,40	71,42
16	78	1,31	76,19
17	78	1,23	80,95
18	75	1,16	90,00
19	70	1,10	90,48
20	70	1,05	95,24

Source: Calculation result (2018)

Table 4. Statistical parameter for frequency analysis

Parameters	Score
Average score (mean/X)	95,45
Standard deviation (Sd)	21,57
Koefisien Skewness (Cs)	0,100
Kurtosis coefficient (Ck)	0,048
Coefficient of variation (Cv)	0,240

Source: Calculation result (2018).

Table 5. Results of Rain Pattern Distribution Test

Types of distribution	Requirements	Calculations	Conclusion
Normal	Cs = 0 Ck = 3	Cs = 0,100 Ck = 0,048	Do not meet the requirement
Gumbel	Cs = 1,139 Ck = 5,403	Cs = 0,100 Ck = 0,048	Do not meet the requirement
Log Pearson Type III	Cs = 0<Cs<9	Cs = 0,100	Meet the requirement
Log-Normal	Cs = 3Cv = 0,720	Cs = 0,100	Do not meet the requirement

Source: Calculation result (2018)

The rain pattern distribution test (Table 5) indicates that the appropriate distribution model is Log Pearson Type III because the consequence of Cs = 0.100 is considered the closest to the required score, namely Cs = 0 <Cs <9. This is the basis for using the Log Pearson Type III distribution analysis method in calculating the thickness of the design rainfall in the research area. The formula used is presented in eq. Three below.

$$Log\ X_T = Log\ X + K.S \quad (3)$$

Where: K is a standardized variable whose amount depends on the slope coefficient, and S is the standard deviation.

Using the equation above, the design rainfall for the return periods of 5, 10, 20, and 40 years is calculated. The design rainfall in the Code Watershed for each return period determined using the Log Pearson Type III distribution is presented in Table 6.

Table 6. Design rainfall in the Code Watershed for Each Return Period determined using Type III Pearson Log Distribution

Return Period (years)	Probability(%)	Design rainfall (mm)
5	20	106,83
10	10	116,67
20	5	127,30
40	2,5	134,25

Source: Calculation result (2018).

After calculating the design rainfall, the concentration-time and the estimation of the flow coefficient are calculated. Concentration time is required for rainwater to flow from upstream to downstream or watershed outlets. The condition of the slope in the study area and the length of the river influences the concentration time. The concentration-time can be calculated with eq. 4 as follows.

$$tc = 0{,}0195\ (L/\sqrt{S})\ 0{,}77 \quad (4)$$

Where tc is the concentration-time (hours), L is the length of the river from upstream to downstream (m), and S is the slope of the land.

The calculation result shows that the concentration time is 3 hours. This indicates that the time required for rainwater to flow in the Code watershed from upstream to downstream is 3 hours. The flow coefficient (C) is the ratio of flow thickness to rain thickness. At the same time, the physical characteristics, especially the type of land use, will determine the value of C. The more land is covered by buildings or hardening, the greater the C value. The value of C in the study area with several land-use types is determined by employing weighted average methods. The value of the flow coefficient (C) is 0.31.

The maximum discharge in the research area is calculated using a rational method. The parameters used in the rational formula include flow coefficient (C), rain intensity (I), and catchment area (A). The maximum discharge is the largest in the area due to rain that falls on a certain return period. The maximum discharge calculation is performed at return periods of 5, 10, 20, and 40 years. The duration of rain with a certain intensity is the same as the time of concentration. Therefore, the value of the rain intensity used to calculate the maximum discharge of the Code

Watershed is the value of rain intensity within a certain period. The results of the calculation of the maximum debit for each return period are presented in Table 7.

Table 7. Maximum Discharge of Code Watershed based on Return Period

Return Period (years)	R (max)	I (mm/hour)	C	A (km²)	Q (m³/second)
5	106,83	19,40	0,31	49,34	82,45
10	116,67	21,04	0,31	49,34	89,42
20	127,30	22,81	0,31	49,34	96,95
40	134,25	23,97	0,31	49,34	101,86

Source: Calculation result (2018).

The Code watershed is an area occupied by a large population with a complex form of land use. The downstream part of the code river is productive agricultural land and the urban area of Yogyakarta, which functions as the center of government and business. The flood that always occurs yearly causes many losses to agricultural production and residential areas. For this reason, flood requires attention and management. Flood analysis and forecasting have become the first step in flood management (Kumar, 2019). In flood mitigation and policies, research on the return period of the flood is needed instead of the usual flood peak analysis (Ewea et al., 2020; Morrison & Smith, 2001; Mouri et al., 2013; Nadarajah & Shiau, 2005; Zhang et al., 2016).

Rainfall, especially extreme rain that occurs in a short period, becomes a key factor in analyzing the return period of a flood. Landslides and floods are disasters that frequently occur with short and extreme rains (Afungang & Bateira, 2017). This is because high rainfall is a source of river discharge which causes overflow and flood inundation. Using historical weather, the experts analyze a river or creek's estimated flow rate or release (Deraman et al., 2017). Afungang and Bateira (2017) found seven events of extreme rain in 43 years, namely between 95 mm / day and 129.3 mm / day. These extreme rains trigger landslides and floods with return periods ranging from 7.3 to 68.9 years. Compared to this research, analysis of rainfall data in the Code Watershed in the 1998-2017 range found bigger numbers, namely 138 and 152 mm / day. Therefore, concerning the characteristics of this rain, the flood due to extreme rain may potentially occur in a short period in the Code watershed. The rain trend in the Code watershed also tends to increase. Referring to (Avia, 2019), the average annual rainfall in the Code watershed area during the 1991-2000 period ranged from 2000-2200 mm, it increased to 2200-2400 in 2001-2020 and continued to the next period until 2016. Meanwhile (Supari et al., 2012) explain that extreme rain events in Java Island with low frequency and intensity generally occur in coastal areas while high frequency and intensity occur in mountainous areas. This is not included in the entire area of Code watershed.

The Log Pearson Type III analysis method employed in this research has also been widely used in various previous studies. (Griffits and Stedinger, 2007) explain that Log Pearson Type III is commonly used in hydrology, especially after the adoption of this method by the U.S. federal agency. For example, (Farooq et al., 2018) use Log Pearson Type III to analyze flood return periods over 5, 10, 25, 50, and 100 years based on rainfall data for 30 years between 1980 and 2016. This research used the same method but for analysis in a shorter period based on the availability of rain data.

The prediction of the amount of flood probability and flood-prone areas of Code River

In estimating the amount of flood probability, it is necessary to consider the channel capacity, inundation discharge, and inundation volume. The channel capacity refers to whether or not the existing channel can accommodate the input discharge. If the channel can adjust the input discharge, flood or inundation will not occur, on the contrary, if the channel cannot fully accommodate the existing input discharge, there will be flood and inundation in the area. River capacity is a form of river cross-section. The river cross section is the main factor in determining whether the study area is flooded. The maximum channel capacity in this study was taken at several points in the downstream area of the Code River. Based on the calculation of channel area and discharge, the channel in the Code River has a cross-sectional area of 43.4 m^2 with a maximum discharge of 41.23 m^3/sec.

Overflow discharge shows the amount of input discharge the river cross-section cannot accommodate. The amount of discharge that exceeds the water level will become a flood or puddle. The overflow discharge is calculated by subtracting the release from the input by the channel capacity. The calculation is carried out using eq. 5 as follows.

$$S = Qp - Qs \quad (5)$$

Where S is the difference between the input discharge and the channel capacity, Qp is the input discharge (m^3 / sec), and Qs is the channel capacity (m^3/sec).

The discharge overflow inundation in the study area was also calculated based on the 5, 10, 20, 40, and year return period. The results of the overflow discharge calculation are presented in Table 8.

Table 8. Code Watershed Inundation Discharge Based on Several Return Periods

Return Period (years)	Probability (%)	Maximum discharge (m^3/sec)	Channel capacity (m^3/sec)	Puddle Discharge (m^3/sec)
5	20	82,45	41,23	41,22
10	10	89,42	41,23	48,19
20	4	96,95	41,23	55,72
40	2	101,87	41,23	60,64

Source: Calculation result (2018).

The inundation volume in the study area is calculated based on the flood discharge counted on the channel capacity in the Code River. Inundation volume is determined by multiplying the overflow discharge with the period. The period used in this calculation is a one-hour period to assess the inundation area from the flood overflow volume. The planned discharge that the channel capacity cannot accommodate will go down the slope and become a puddle in the form of volume, and then it is converted into a unit area so that the locations of flood in the study area can be identified. The results of the inundation volume calculation are presented in Table 9.

Table 9. The volume of inundation in Code Watershed for some return period

Return period (years)	Inundation Volume (m^3)
5	148409,40
10	173485,62
20	200496,20
40	2018303,42

Source: Calculation result (2018).

The final step in flood estimation is calculating the inundation area in the flood target area. The inundation area is assumed to be the volume of inundation in a basin. The importance of inundation in a basin equates to the formula of V = 1/3 (area of the base x height). Based on the assumption of calculating the inundation volume in the basin, the results show that every 33.3x104 m^3 of volume that becomes inundation represents 1 km^2 of the area that becomes the target of the flood.

The inundation area in the flood target area is calculated by converting the overflow discharge in each return period with the calculation of the inundation volume in the basin. The results of the inundation area calculation in the flood target areas are presented in Table 10. Meanwhile, the results of modeling the flood-affected areas are shown in Figure 10.

Table 10. Inundation Area in the Flood Target Area

Return Period (year)	Inundation Area (ha)
5	44,57
10	52,10
20	60,24
40	65,56

Source: Calculation result (2018)

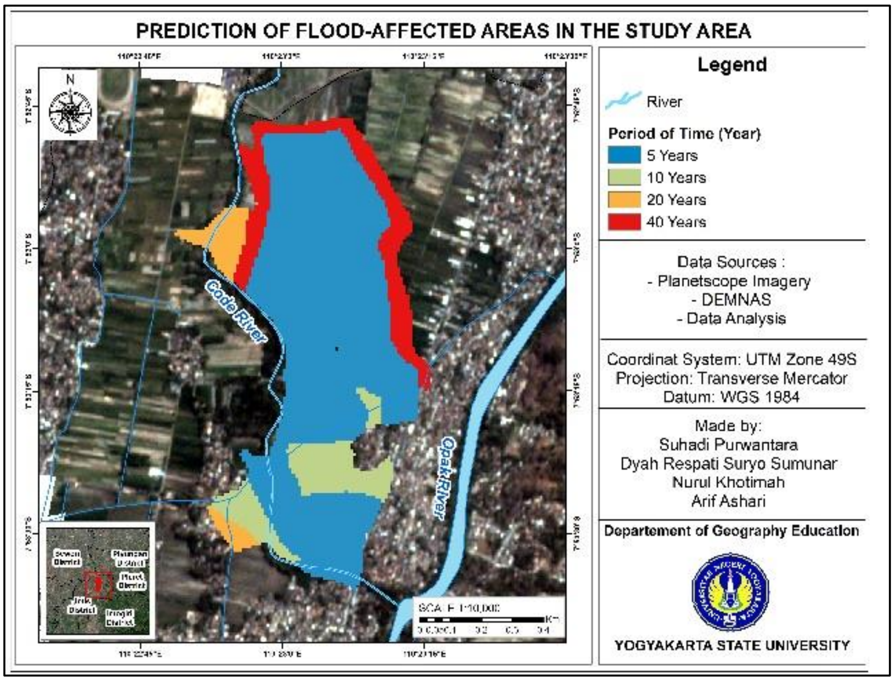

Figure 6. The modeling of the flood-affected areas in Code River

Compared to the previous study, this study has similarities and differences in predicting the probability of flooding. (Deraman et al., 2017), in their research, utilized rainfall data from 1985 to 2015 to analyze the frequency of floods and planned floods for areas along the river. The rain thickness data is used in the analysis to calculate statistical information such as mean, standard deviation, skewness, and recurrence interval. Based on this study, the probability of flood for 10, 50, 100, and 500 years is 10%, 2%, 1%, and 0.2%. This research also calculates statistical information in the rain pattern distribution tests, especially skewness. In summary, Pearson's log model as a statistical model is widely used to analyze flooding in urban areas (Diaf et al., 2020; Szulczewski & Jakubowski, 2018; X. Yang & Wang, 2017) by considering a process approach (Salazar-Galán et al., 2021) and producing several flood scenarios (Farooq et al., 2018; Tian & Wang, 2022). This study also showed several flood scenarios, as previous studies used the same method. The impact of land use change on urban flooding can also be identified, even climate change (Sun et al., 2021).

(Kumar, 2019) performed a flood return period analysis for 25, 50, 100, 500, and 1000 years. Based on this study, rainfall affects flood, but the characteristics of flood in a river area are also related to the lithology and morphology of the river valley. These results are similar to (Van Campenhaut et al., 2020) in Belgium. Compared to these two studies, this research does not analyze the effect of lithology on flood characteristics. However, this research attention to the morphological characteristics around the river boundaries to determine the potential flood areas at each return period. In addition, the lithology of the Code Watershed is also relatively homogeneous, namely, it is characterized by a very large proportion of Young Merapi Volcanic material and only a small amount of Old Merapi Volcanic material. Therefore, the lithology factor does not significantly influence the variability of the flood characteristics. In a future study, the effect of variations in land use on floods, as highlighted by (Mouri et al., 2013), is even more recommended.

CONCLUSION

The results of this research indicate that the maximum amount of rain that occurs in the Code River can be estimated using Log Pearson Type III, the collected design rainfall data for a five-year return period (R5) = 106.83 mm, ten-year return period (R10) = 116.67 mm, return 20 years (R25) = 127.30 mm, return 40 years (R50) = 134.25 mm. The probability of a flood in the Code River can be predicted from the amount of maximum discharge caused by design rainfall, for a 5-year return period, Q5 = 82.45 m^3 / second, Q10 = 89.42 m^3 / second, Q20 = 96.95 m^3 / second, Q40 = 101.86 m^3 / sec. The flood-prone areas in the Code River can be predicted from the inundation area of the flood target area, which indicates that floods will occur in all return periods, namely 5, 10, 20, and 40 years. Inundation of the flood target area in the 5-year return period covers an area of 44.57 ha, the 10-year return period covers 52.10 ha, the 20-year return period covers an area of 60.24 ha, and the 40-year return period covers an area of 65.56 ha.

In future research, more detailed rainfall data are needed, especially for daily rainfall intensity data, so estimating the maximum discharge and other calculations becomes easier. The analysis of rain intensity in similar research can utilize other than the Mononobe method because this method is used if short-term rainfall data is not available. In addition, in a similar study, the area of the river should be considered more to calculate the maximum discharge, especially using a rational method. The results of the calculation of the flow coefficient in the study area can be used to control land use which can encourage a greater flow coefficient. Active participation from the community to maintain and not damage the environment is badly needed, especially green lines to reduce surface runoff which can cause inundation in the study area and its surroundings. The results of this research can be used as a reference for consideration of regional development plans, especially in the case of disasters.

ACKNOWLEDGMENT

This paper is the result of research from a physical geography research group at the Faculty of Social Sciences, Yogyakarta State University. This research was conducted in 2018. This research is part of a research roadmap on hazard analysis, disaster risk, and disaster management, which a physical geography research group carried out.

REFERENCE LIST

Afungang, R., & Bateira, C. (2017). Statistical modelling of extreme rainfall return periods and associated hazard in the Bamenda Mountain N.W. Cameroon. Revista de Geografia e Ordenamento Do Territorio, 9, 5–19.

Amri, M. R., Yulianti, G., Yunus, R., Wiguna, S., Adi, A. W., Ichwana, A. N., Randongkir, R. E., & Septian, R. T. (2016). Risiko Bencana Indonesia (Disasters Risk of Indonesia). In BNPB.

Asiedu, J. B. (2020). URBAN AREAS : A LOOK AT THE CAUSES ement. Theoretical and Empirical Researches in Urban Management, 15(1), 24–41.

Avia, L. (2019). Change in rainfall per-decades over Java Island, Indonesia. IOP Conference Series: Earth and Environmental Science 374 012037.

Bathrellos, G. D., Karymbalis, E., Skilodimou, H. D., Gaki-Papanastassiou, K., & Baltas, E. A. (2016). Urban flood hazard assessment in the basin of Athens Metropolitan city, Greece. Environmental Earth Sciences, 75(4), 319. https://doi.org/10.1007/s12665-015-5157-1

BPS-Statistics of DI Yogyakarta Province. (2016). Daerah Istimewa Yogyakarta in Figures (Daerah Istimewa Yogyakarta dalam Angka). Statistical Agency of Indonesia.

BPS-Statistics of DI Yogyakarta Province. (2020). Daerah Istimewa Yogyakarta in Figures (Daerah Istimewa Yogyakarta dalam Angka). Statistical Agency of Indonesia.

Campenhaut, J. ., Houbrechts, G., Peeters, A., & Petit, F. (2020). Return period of characteristics discharges from the comparison between partial duration and annual series application to the Walloon Rivers (Belgium). Water, 12(792), 1–33.

Deraman, W. H. A. ., Mutalib, N. J. ., & Mukhtar, N. . (2017). Determination of return period for flood frequency analysis using normal and related distribution. IOP Conference Series: Journal of Physics Conference Series 890 012162.

Diaf, M., Hazzab, A., Yahiaoui, A., & Belkendil, A. (2020). Characterization and frequency analysis of flooding solid flow in semi-arid zone: case of Mekerra catchment in the north-west of Algeria. Applied Water Science, 10(2), 1–15. https://doi.org/10.1007/s13201-019-1132-4

Ewea, H. A., Al-Amri, N. S., & Elfeki, A. M. (2020). Analysis of maximum flood records in the arid environment of Saudi Arabia. Geomatics, Natural Hazards and Risk, 11(1), 1743–1759. https://doi.org/10.1080/19475705.2020.1810783

Farooq, M., Shafique, M., & Khattak, M. . (2018). Flood frequency analysis of River Swat using Log Pearson Type 3 generalized extreme value normal and gumbel max distribution methods. Asian Journal of Geosciences, 11(216), 1–10.

Feng, B., Zhang, Y., & Bourke, R. (2021). Urbanization impacts on flood risks based on urban growth data and coupled flood models. Natural Hazards, 106(1), 613–627. https://doi.org/10.1007/s11069-020-04480-0

Griffis, V., & Stedinger, J. . (2007). Log-Pearson Type 3 distribution and its application in flood frequency analysis. I: Distribution chacateristics. Journal of Hydrologic Engineering, 12, 482–491.

Guerreiro, S. B., Glenis, V., Dawson, R. J., & Kilsby, C. (2017). Pluvial flooding in European cities-A continental approach to urban flood modelling. Water, 9(4). https://doi.org/10.3390/w9040296

Kumar, R. (2019). Flood frequency analysis of the rapti River Basin using Log Pearson Type-III and Gumbel Extreme Value-1 Methods. Journal of Geological Society of India, 94, 480–484.

Marfai, M. A., & Candra, R. F. . (2018). GIS Exercise Book: Coastal Monitoring and Hazard Modelling. BPFG UGM.

Mel, R. A., Viero, D. P., Carniello, L., & D'Alpaos, L. (2020). Optimal floodgate operation for river flood management: The case study of Padova (Italy). Journal of Hydrology: Regional Studies, 30, 100702. https://doi.org/10.1016/j.ejrh.2020.100702

Morrison, J. E., & Smith, J. a. (2001). Scaling properties of flood peaks. Extremes, 4, 5–22.

Mouri, G. ., Minoshima, V., Golosov, S., Chalov, S., Seto, S., Yoshimura, K., Nakamura, N., & Oki, T. (2013). Probability assessment of flood and sediment disasters in Japan using the Total Runoff-Integrating Pathways model. International Journal of Disaster Risk Reduction, 3, 31–43.

Nadarajah, S., & Shiau, J. T. (2005). Analysis of extreme food events for the pachang river, Taiwan. Water Resources Management, 19(4), 363–374. https://doi.org/10.1007/s11269-005-

2073-2

Nurhadi, Sumunar, D. R. S., & Khotimah, N. (2016). Analisis Kerentanan Banjir dan Penanggulangan Bencana di Daerah Aliran Sungai Code Kota Yogyakarta. Jurnal Penelitian Saintek, 21(2), 75–86. https://doi.org/10.21831/jps.v21i2.10553

Oruonye, E. (2016). Morphometry and Flood in Small Drainage Basin: Case Study of Mayogwoi River Basin in Jalingo, Taraba State Nigeria. Journal of Geography, Environment and Earth Science International, 5(1), 1–12. https://doi.org/10.9734/jgeesi/2016/23379

Pambudi, A. S. (2022). Problems of Local Floods and Their Relation To. Indonesian Journal of Applied Research, 3(1), 10–22. https://doi.org/10.30997/ijar.v3i1.178

Purwantara, S., Ashari, A., & Ibrahim, M. H. Bin. (2020). The characteristics of infiltration on the southern flank of Merapi Volcanic Plain, Yogyakarta, Indonesia. International Journal of GEOMATE, 19(74), 201–209. https://doi.org/10.21660/2020.74.52941

Rafiq, F., Ahmed, S., Ahmad, S., & Khan, A. A. (2016). Urban Floods in India. International Journal of Scientific & Engineering Research, 7(1), 721–734.

Ress, L. D., Hung, C. L. J., & James, L. A. (2020). Impacts of urban drainage systems on stormwater hydrology: Rocky Branch Watershed, Columbia, South Carolina. Journal of Flood Risk Management, 13(3), 1–13. https://doi.org/10.1111/jfr3.12643

Salazar-Galán, S., García-Bartual, R., Salinas, J. L., & Francés, F. (2021). A process-based flood frequency analysis within a trivariate statistical framework. Application to a semi-arid Mediterranean case study. Journal of Hydrology, 603(October). https://doi.org/10.1016/j.jhydrol.2021.127081

Sun, X., Li, R., Shan, X., Xu, H., & Wang, J. (2021). Assessment of climate change impacts and urban flood management schemes in central Shanghai. International Journal of Disaster Risk Reduction, 65(August 2020), 102563. https://doi.org/10.1016/j.ijdrr.2021.102563

Sunarto, & Rahayu, L. (2006). The Phenomenon of Natural Disaster in Indonesia (Fenomena Bencana Alam di Indonesia). Jurnal Kebencanaan Indonesia, 1(1), 1–5.

Supari, Sudibyakto, Ettema, J., & Aldrian, E. (2012). Spatiotemporal characteristics of extreme rainfall events over Java Island Indonesia. Indonesian Journal of Geography, 44(1), 62–68.

Sutikno, Santosa, L. W., Widiyanto, Kurniawan, A., & Purwanto, T. H. (2007). “The Merapi Kingdom”: Natural resources and carrying capacity (“Kerajaan Merapi”: Sumberdaya alam dan daya dukungnya). BPFG UGM.

Szulczewski, W., & Jakubowski, W. (2018). The Application of Mixture Distribution for the Estimation of Extreme Floods in Controlled Catchment Basins. Water Resources Management, 32(10), 3519–3534. https://doi.org/10.1007/s11269-018-2005-6

Tian, D., & Wang, L. (2022). BLP3-SP: A Bayesian Log-Pearson Type III Model with Spatial Priors for Reducing Uncertainty in Flood Frequency Analyses. Water (Switzerland), 14(6). https://doi.org/10.3390/w14060909

Verstappen, H. T. (2010). Indonesian Landforms and Plate Tectonics. Jurnal Geologi Indonesia, 5(3), 197–207.

Verstappen, H. T. (2013). Garis Besar Geomorfologi Indonesia (Suratman (ed.); 1st ed.). Gadjah Mada University Press.

Wing, O. E. J., Lehman, W., Bates, P. D., Sampson, C. C., Quinn, N., Smith, A. M., Neal, J. C., Porter, J. R., & Kousky, C. (2022). Inequitable patterns of U.S. flood risk in the Anthropocene. Nature Climate Change, 12(2), 156–162. https://doi.org/10.1038/s41558-021-01265-6

Yang, M., Sang, Y. F., Sivakumar, B., Ka Shun Chan, F., & Pan, X. (2020). Challenges in urban stormwater management in Chinese cities: A hydrologic perspective. Journal of Hydrology, 591, 125314. https://doi.org/10.1016/j.jhydrol.2020.125314

Yang, X., & Wang, W. (2017). Design tide hydrograph with a given risk threshold by a copula-based multivariate method. China Ocean Engineering, 31(4), 504–509. https://doi.org/10.1007/s13344-017-0057-7

Zhang, R., Wang, J., Ma, Y., Chen, G., Zeng, Q., & Zhou, C. (2016). Sedimentary microfacies and palaeogeomorphology as well as their controls on gas accumulation within the deep-buried Cretaceous in Kuqa Depression, Tarim Basin, China. Journal of Natural Gas Geoscience, 1(1), 45–59. https://doi.org/10.1016/j.jnggs.2016.04.003