ISSN 2810-0182 (Online)
ACITYA WISESA (Journal of Multidisciplinary Research)
Vol. 1, Issue 3, 2022
https://journal.jfpublisher.com/index.php/jmr

HEC-RAS Simulation of Flood Management in Seruyan River

(A Case Study of Mekar Indah Village, East Seruyan Hilir and UPT Tanggul Harapan Pematang Limau Village, Seruyan Hilir)

Iwan Zulianto[1*], Noor Syarifuddin Yusuf[1], Nomeritae[2] Herry Redin[1] Vera Amelia[1] Misrita[1]
iwanzul@yahoo.co.id
[1]Post-Graduate of Natural Resources and Environmental Management
[2]Engineering Faculty of Palangka Raya University

Abstract

In 2020 and 2021, there was a big flood in (Technical Implementation Unit) UPT Tanggul Harapan, Pematang Limau Village, Seruyan Hilir District and Mekar Indah Village, Seruyan Hilir Timur District and it forced some people to flee their homes. The overflowing of Seruyan River is caused by high intensity of rain and river flooding from the headwaters of Seruyan. This condition occurred because of Mekar Indah Village and UPT. Tanggul Harapan is in a downstream location. The main objective of this research is to find out the effective way of controlling floods in the Seruyan River. The calculation result of flood peak volume is obtained by using the synthesis of hydrograph units using the SCS and Snyder methods. The results of this research indicated that the design of periodic re-rain for 50 years prior to the handling of floods in the area of UPT Tanggul Harapan occurred flooding of 94.96% of the entire area of UPT Tanggul Harapan. Meanwhile, in Mekar Indah Village occurred 40.72%, after simulating flood handling in making an embankment along 20111 m, elevation 5 m above sea level, top width of the embankment 5 m and 4 units of floodgates. It indicated a significant change in the flood area in UPT Tanggul Harapan to only 1.23%, while in Mekar Indah Village it is 0.80%. The simulation result indicated that flood management by making embankment is able to reduce the flood area by 93.19% in UPT Tanggul Harapan and 39.92% in Mekar Indah Village.

Keywords: *Flood Controlling, Flood Routing, HEC-HMS 4.10, HEC-RAS 6.2*

INTRODUCTION

During a period of two consecutive years, Seruyan district have been affected by the floods and in mid-2020 it was the worst flood in the last 30 years. Most of the sub-districts in Seruyan district were affected by flooding, including the national road, Sudirman road in Km 122, Asam Baru Village, Danau Seluluk sub-district. When the flood disaster hitting, the people living around the UPT. Tanggul Harapan had to evacuate from their houses to an evacuation site on the side of district road provided by the local government. Based on interview results of some local people, flood in 2020 occurred for quite a long time, which was almost 4 months, from September 2020 to early January 2021. In mid-2021, flooding again hit the Seruyan district area and around 7 sub-districts were affected, most of which were on the banks of the river. The flood inundated agricultural land at UPT Tanggul Harapan which caused in a failed planting plan this season. Therefore, the flood that occurred deeply affected social and economic life. The attempt in accelerating flood handling and ease the burden on people's lives, the Seruyan district government issued SK (Decree). The disaster emergency response was also provided in assistance of flood-affected communities at UPT Tanggul Harapan.

Flood routing is conducted to predict quantity of outflow and the approximate time of flood would affect in the downstream of river by using inflow data from the upstream area. The result of flood routing is used to attempt in early anticipating before the flood affected, such as normalize the river or build a flood control structure (Soedodo Hardjoamodjodjo; Sukandi Sukartaatmadja, 2008). The hydrological method used to analyze river discharge by estimating the amount of planned flood discharge is the unit hydrograph method. According to Sri Harto statement that the unit hydrograph is a direct run off hydrograph produced from rain evenly throughout DAS (Watershed Area) with a fixed intensity and in a set time unit (Harto, 1993).

Unit hydrographs can be made if there are some data, such as AWLR (Automatic Water Level Recorder) recordings, Automatic Rain Recorder (ARR) data, daily rainfall data, and hourly rain data. However, these data are not always available. Therefore, a synthetic unit hydrograph method was developed to counter such problems. Sri Harto also stated that if the HSS (Synthetic Unit Hydrograph) flood can be analyzed with many methods, such as the HSS *Nakayasu*, HSS Gamma I, HSS Snyder, HSS *Limantara*, and HSS SCS (Soil Conservation Service) (Harto, 1993). In this research, researchers used HSS SCS and HSS Snyder from the HEC-HMS 4.10 application. While for analyzing in flood routing, the researchers used the HEC-RAS 6.2 application.

There are some problem statements of this research, such as what is the result of the flood discharge exceeding the cross-sectional capacity of the river, and what is effectiveness in using alternative methods in handling and controlling floods to anticipate annual flooding in Seruyan Regency, especially at UPT Tanggul

Harapan, Pematang Limau Village, Seruyan Hilir District and Mekar Indah Village, East Seruyan Hilir District.

The researchers limited this research to avoid discussion outside the scope of this research. There are some limitations of this research, such as (1) research location, the researchers only focused on flood simulation location in UPT Tanggul Harapan, Pematang Limau Village, Seruyan Hilir District and Mekar Indah Village, East Seruyan Hilir District; (2) Synthetic Unit Hydrograph HSS SCS and HSS Snyder from the HEC-HMS 4.10 application; (3) Hydraulics analysis used HEC-RAS 6.2 application to analyze flood routing; (4) Rainfall data used rainfall post stations located closest to the Seruyan watershed; (5) Excluding erosion, sedimentation and river tides in this research; and (6) Excluding land cover map changes in this research.

Based on the problem statements of this research, the researchers can determine the objectives of this research, such as (1) to analyze and simulate flood overflow in 2D used the HEC-RAS 6.2 model; and (2) to find out the effectiveness in using alternative methods in handling and controlling floods to anticipate annual flooding in Seruyan Regency, especially at UPT Tanggul Harapan, Pematang Limau Village, Seruyan Hilir District and Mekar Indah Village, East Seruyan Hilir District.

LITERATURE REVIEW

Flood Control System

Loss reduction due to flood disaster had been conducted by government. There were various methods or systems that have been used in managing the increase of river water discharge volume. Therefore, intending to minimize the losses suffered by the community due to floods, one thing that can be applied is to deal with the source causing the flood, namely the management of river areas through disaster risk management (Sari, 2021).

Flooding has been recognized as one of the worst disasters. It is one of the most frequent and expensive natural disasters in the world. Hundreds of million people around the world have been affected by flood (Ratih Indri Hapsari, 2016). The highly changing climate also has an impact on floods, such as the rising rainfall that causes of flooding. Flooding will occur when the watershed system receives an unusually high rainfall intensity or prolonged incidence of rainfall so that the flow rate exceeds the channel and water capacity is difficult to flow in urban areas (Sudirman, 2019).

The modern concept of flood risk assessment is based on combination of flood hazard, probability and potential negative consequences of floods for human health, economic activities, the environment and cultural heritage (Lubomir Solin, 2013). Structural flood control is principally conducted by building structures or water structures that can increase the capacity of the river cross-sectional flow or reduce flood flow.

Every region needs to make a good and efficient flood control system, taking into account the existing conditions and development of future water resources utilization. Flood control system planning should take into account all aspects from upstream to downstream of the river to produce a good planning document. Aspects of review and assessment of flood control plans include technical, economic, social, cultural, legal, institutional and environmental aspects (Kodoatie, 2013). The flood control alternatives chosen must be adapted to the existing situation, conditions and policies, especially policies regarding this disaster management program. These alternatives include preventing flooding to a certain height with embankments or lowering the flood water level by normalizing the drain. There are some of systems to flood control (Novitasari, 2010), such following below:

1. River Flow Normalization
   River Flow Normalization is attempting to increase river flow capacity, such as straightening river bends, deepening riverbeds, widening river banks, reducing the roughness coefficient, controlling flow direction, and scouring on river flows.
2. Embankment and Flood Walls Construction
   One of the oldest and most widely used system to protect land from flooding is the construction of a barrier to prevent flood overflow. Basically, the embankment and flood wall are an elongated dam that is built parallel to the river flow and this is not made crosswise following the river flow. In general, the embankments and flood walls must appropriate the same structural criteria as ordinary dams.
3. Flood Channel Construction
   Flood Channel Construction has two function in flood reduction, there are (1) to create a wide shallow reservoir to accommodate some of the flood water, especially in the main river channel downstream of the branching; and (2) to provide additional watersheds from upstream in order to increase the velocity of the river flow and lower the water level forecast to a certain distance upstream of the river tributaries.
4. Retarding Basin
   Retarding Basin usually built by utilizing the area on the floodplain or swamp on the left and right of the downstream river. Retarding basin is useful for temporarily accommodating part of the flood discharge and securing the downstream area, which if the flood in the river has receded, the water from the reservoir can be flowed back into the river.

HEC-HMS and HEC-RAS Application

In this research, researchers conducted a hydrological analysis using the HEC-HMS 4.10 application. HEC-HMS is an application to calculate rain transformation and routing process in a watershed system (Triatmojo, 2008). This application can be used to calculate run-off volume, direct run-off, baseflow and channel flow. This app was developed by the Hydrologic Engineering Center (HEC) of the United States Army Corps of Engineers. Meanwhile for the hydraulics analysis, the researchers used the HEC-RAS 6.2 application (Soemarto, 1987). HEC-RAS is an application program for modeling one-dimensional flow in rivers. The River Analysis system (RAS) was developed by the Hydrologic Engineering Center (HEC). HEC-RAS is a one-dimensional model of permanent and non-permanent flow (Shadiq, 2008).

In a simplistic meaning, HEC-HMS is a tool to convert rainfall data that falls into run-off that comes out of the watershed. If we want to know the flood flow in the river, then we can use HEC-RAS. We use HEC-HMS to calculate the discharge based on rainfall data, while we use HEC-RAS to calculate the water level along the river channel based on the incoming water discharge. The difference between the two is that HEC-HMS provides flood discharge at watershed control points, while HEC-RAS provides information on flood water levels in rivers. The study conducted by Anto, (2019) From the analysis of the cross-sectional capacity of the Jatiroto River using HEC-RAS was found that several points experienced flood. The worst flooding occurred at River Sta.12.5 with a height of 1.61 meters. The inflow data is taken 2-yearly rain discharge data and calculating for the outflow discharge value through *muskingum* method that measuring the inflow value, namely the outflow value is same as the initial value (Ikhsan et al., 2018). This statement also supported by Catharina (2020) in Badeng river that the inflow of 6.86 m3/s and the outflow of 7.32 m3/s with parameters obtained from the calculation, namely C0 = 0.780, C1 = 0.815, C2 = -0.595 , the value of X = 0.08 and the value of the constant K = 0.138 hours. The value of the constant K is the time lag between the Inflow discharge and Outflow discharge, which is 8.28 minutes. This shows an indication of the occurrence of flash floods downstream of Badeng River because the outflow value is bigger than inflow value. Another research from Arif Budiyanto (2017), found that the calculation of surface runoff using the SCS-UH method only considers the type of land cover, soil hydrological group and rainfall. The characteristics of the Luk Ulo watershed that flows downstream have a CN value between 62 - 63. These results indicate that the Luk Ulo watershed is classified as a good watershed, indicated by non-significant changes in surface runoff when it rains.

RESEARCH METHODOLOGY

The Analysis of Seruyan Flood Management in Seruyan District: A Case Study of Mekar Indah Village, East Seruyan Hilir and UPT. Tanggul Harapan Pematang Limau Village, Seruyan Hilir, this research needs some of data as following table below:

Table 1. The List of Data Required in Research

No.	Data Required	Data Time Range	Location	Data Source
1	Rainfall Data	10 years	Seruyan District	The Ministry of Public Works and Housing / Indonesian Agency for Meteorological, Climatological and Geophysics
2	Seruyan Watershed Delineation from Topographical Data (DTM)		Seruyan River	DEMNAS (National Digital Elevation Model and Bathymetry) and ALOS PALSAR
3	Land Covering Map		Seruyan River	The Ministry of Environment and Forestry
4	River Geometry Data		Seruyan River	The Ministry of Public Works and Housing/ BWS (River Basin Hall) Kalimantan II
5	Flow Depth Data		Seruyan River	On-the-ground Measurements

The flow of research is shown in the image below:

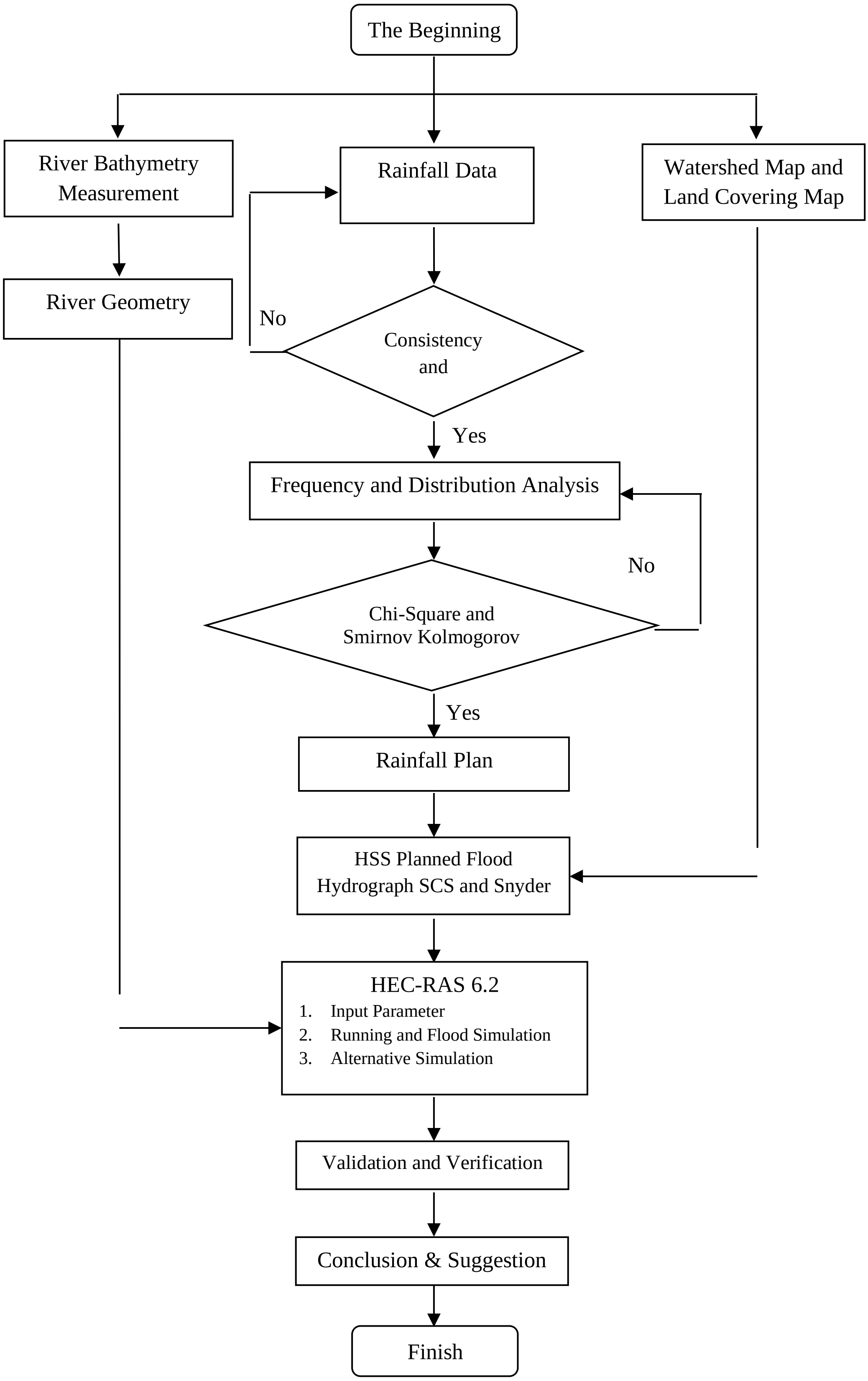

Figure 1. Research Flowchart

RESULTS AND DISCUSSION

Hydrological Analysis

1. Collecting and Analyzing of Rainfall Data

Rainfall data was taken through the BMKG (Indonesian Agency for Meteorological, Climatological and Geophysics) website and the Ministry of PUPR (The Ministry of Public Works and Housing) website regarding hydrological data. The data used in this research is rainfall data for the past 10 years, that is data from 2012 to 2021. While the rainfall analysis method in this research used Thiessen Polygon method. The following describes the maximum daily rainfall data for 10 years and its Thiessen coefficient.

Table 2. Maximum Daily Rainfall Data for each Wet Station

Wet Station	Koef.	Year									
	This Ser	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
STA Asam Baru	0,176	184	123	135	79	111	174	169	151	130	120
STA Baung	0.2177	172	104	84	78	163	148	186	134	176	96
STA Beringin Angin	0,0015	171	123	140	143	165	185	167	176	114	124
STA Kuala Pembuang	0,1043	180	124	74	94	182	103	140	156	171	143
STA Meteorologi Hasan	0,0167	125	103	162	124	166	116	164	153,2	100,2	153
STA Meteorologi Iskandar	0	173	146	68	82	122	124	183	100,1	108,4	137,8
STA Nanga Bulik	0	110	167	162	74	98	108	176	107	164	131
STA Nanga Ella Hilir	0,1677	138	96	94	70	138	121	174	183	102	100
STA Rantau Pulut	0,3126	175	163	116	91	159	169	166	113	152	107
STA Semitau	0,0035	133	120	95	86	116	128	122	158	218	102
Regional Rain		169,26	126,60	105,04	83,46	150,27	149,37	169,33	141,41	146,26	110,25

Table 3. Rainfall in the Seruyan watershed

Year	Daily Rainfall max. (mm)
2012	169.26
2013	126.60
2014	105.04
2015	83.46
2016	150.27
2017	149.37
2018	169.33
2019	141.41
2020	146.26
2021	110.25

2. Calculating Rain Statistical Parameters for the Seruyan Watershed

Table 4. Rain Statistical Parameters for the Seruyan Watershed

m	P = m/(n+1)	Year	Rain (mm)	Rain Log (mm)	Rain Ln (mm)
1	0.091	2018	169.33	2.23	5.132
2	0.182	2012	169.26	2.23	5.131
3	0.273	2016	150.27	2.18	5.012
4	0.364	2017	149.37	2.17	5.006
5	0.455	2020	146.26	2.17	4.985
6	0.545	2019	141.41	2.15	4.952
7	0.636	2013	126.60	2.10	4.841
8	0.727	2021	110.25	2.04	4.703
9	0.818	2014	105.04	2.02	4.654
10	0.909	2015	83.46	1.92	4.424
Description:					
		Data Total (n) =	10	10	10
		Average value (*Mean*) =	135.12	2.12	4.88
		Standard Deviation (Sd) =	28.28	0.10	0.23
		Skewness Coefficient (Cs) =	-0.57	-0.94	-0.94
		Kurtosis Coefficient (Ck) =	-0.53	0.24	0.24
		Coefficient of Variation (Cv) =	0.21	0.05	0.05
		Median =	143.83	2.16	4.97

3. Calculating Rainfall Data Consistency Test with the RAPS (Rescaled Adjusted Partial Sums) Method

Table 5. Daily Rainfall Data Consistency Test used the RAPS Method

No.	Rain	Sk*	[Sk*]	Dy2	Sk**	[Sk**]
1	169,33	34,20	34,20	116,98	1,27	1,27
2	169,26	34,14	34,14	116,52	1,27	1,27
3	150,27	15,15	15,15	22,95	0,56	0,56
4	149,37	14,25	14,25	20,30	0,53	0,53
5	146,26	11,13	11,13	12,40	0,42	0,42
6	141,41	6,28	6,28	3,95	0,23	0,23
7	126,60	-8,52	8,52	7,27	-0,32	0,32
8	110,25	-24,87	24,87	61,87	-0,93	0,93
9	105,04	-30,09	30,09	90,52	-1,12	1,12
10	83,46	-51,66	51,66	266,91	-1,93	1,93
Description:						
n		=	10,00			
Dy		=	26,83			
Sk**max		=	1,27			
Sk**min		=	-1,93			
Q = [Sk**max]		=	1,93			
R = Sk**max - Sk**min		=	3,20			
Q/ √n		=	0,61	< p90% =	1,05	Consistent
R/ √n		=	1,01	< p90% =	1,21	Consistent

4. Frequency Distribution Conformity Test Check

Finding the rainfall data appropriate with the selected theoretical distribution then further test is needed. Analyzing the suitability test used Chi Square Test Method and Smirnov-Kolmogorov Test.

Table 6. Chi-Square Test-Gumbel Method

Interval	Ef	Of	Ef - Of	(Ef-Of)2 / Ef
> 149.868	2.50	3.00	0.50	0.10
130.479-149.868	2.50	3.00	0.50	0.10
115.197-130.479	2.50	1.00	1.50	0.90
<115.197	2.50	3.00	0.50	0.10
Total		10.00		
GUMBEL Distribution Accepted		Chi-Square =		1.200
		DK =		1.000
		Chi-Critic =		3.841

Table 7. Distribution Suitability Test of SMIRNOV-KOLMOGOROV in Seruyan Watershed

m	Rain (mm)	P = m/(N+1)	NORMAL		LOG-NORMAL		GUMBEL		LOG-PEARSON III	
			P(x >= Xm)	Do	P(x >= Xm)	Do	P(x >= Xm)	Do	P(x >= Xm)	Do
1	169.33	0.091	0.113	0.022	0.140	0.049	0.112	0.021	0.111	0.020
2	169.26	0.182	0.114	0.068	0.140	0.041	0.112	0.069	0.112	0.070
3	150.27	0.273	0.302	0.029	0.293	0.020	0.251	0.022	0.334	0.061
4	149.37	0.364	0.313	0.050	0.303	0.061	0.260	0.104	0.346	0.018
5	146.26	0.455	0.354	0.100	0.336	0.118	0.294	0.161	0.389	0.065
6	141.41	0.545	0.421	0.124	0.393	0.152	0.353	0.192	0.457	0.088
7	126.60	0.636	0.632	0.004	0.589	0.047	0.580	0.057	0.653	0.017
8	118.39	0.727	0.738	0.010	0.701	0.026	0.719	0.008	0.746	0.019
9	105.04	0.818	0.869	0.050	0.856	0.038	0.906	0.088	0.861	0.043
10	83.46	0.909	0.971	0.062	0.982	0.073	0.998	0.089	0.962	0.053
DCritic= 0.369				0.124 Accepted		0.152 Accepted		0.192 Accepted		0.088 Accepted

Description:
m = Rating
P = Field Odds
Do= Difference between Field Odds and Theoretical Odds

According to the Chi-Square Test, the best distribution is GUMBEL with Chi-Critic Value = 3.841 and Chi2 value = 1.20, based on the Smirnov-Kolmogorov Test. The best distribution of LOG-PEARSON III with Maximum Delta Value = 0.088 and Criticism Value = 0.369 of the two methods for the daily return period used as the design is the LOG-PEARSON III method.

5. Calculating Design Rain for 2, 5, 10, 25 and 50 years

Table 8. Seruyan Watershed Designing Rainfall

T Year Periodically	Designing Rainfall (mm)
2	136.89
5	160.61
10	171.47
25	181.58
50	187.29

6. Calculating Synthetic Unit Hydrograph

Calculating the synthetic unit hydrograph using 2 methods, these are the SCS method and the Snyder method with HEC-HMS. Based on the two methods, the largest discharge value was chosen to be used as a hydraulics calculation.

Table 9. Recapitulation of Debit Calculation Design

Periodic Year	**SCS Method (m^3/second)**	**Snyder Method (m^3/second)**
2	1864.43	1815.02
5	2491.54	2418.01
10	2763.94	2688.70
25	3018.74	2936.05
50	3163.94	3077.38

Based on Government Regulation no. 38 Article 42/2011 concerning Rivers, the flood discharge used for flood control planning is the 50 years periodically. Then based on the results of the calculation between the SCS method HSS and the Snyder method that will be used is the 50 years periodically SCS method.

Hydraulic Analysis

1. 2-D Flow Simulation before Flood Handling

In this research, the flood routing analysis used HEC-RAS 6.2, while for the simulation and unsteady flow analysis used data for the Q50th watershed Seruyan = 3060.19 m3/sc, the Q50th flow of the Kalua watershed = 339.43 m3/sc and the Q50th discharge of the Pukun watershed = 438.89 m3/ sc.

Based on the simulation at UPT. Tanggul Harapan, the flood area reached 2540.99 Ha or 94.42% and the flood area in Mekar Indah Village reached 1189.13 Ha or 40.72%. The flood depth varies between 0 – 3.1 m, with the highest flood water level 3.56 m above sea level. The following is a picture of the flood area at UPT. Tanggul Harapan and Mekar Indah Village.

Figure 2. The flood area at UPT. Tanggul Harapan and Mekar Indah Village

2. 2-D Flow Simulation with Flood Handling

Furthermore, simulations were conducted with flood management, an embankment along 20111 m with an elevation of 5 m above sea level, 7 m above sea level and 4 units of floodgates, the results showed a significant change in the flood area at UPT Tanggul Harapan only to 33.03 Ha or 1.23%, while in Mekar Indah Village is 23.43 Ha or 0.80%. The following below is a picture of the flood area at UPT. Tanggul Harapan and in Mekar Indah Village after flood handling.

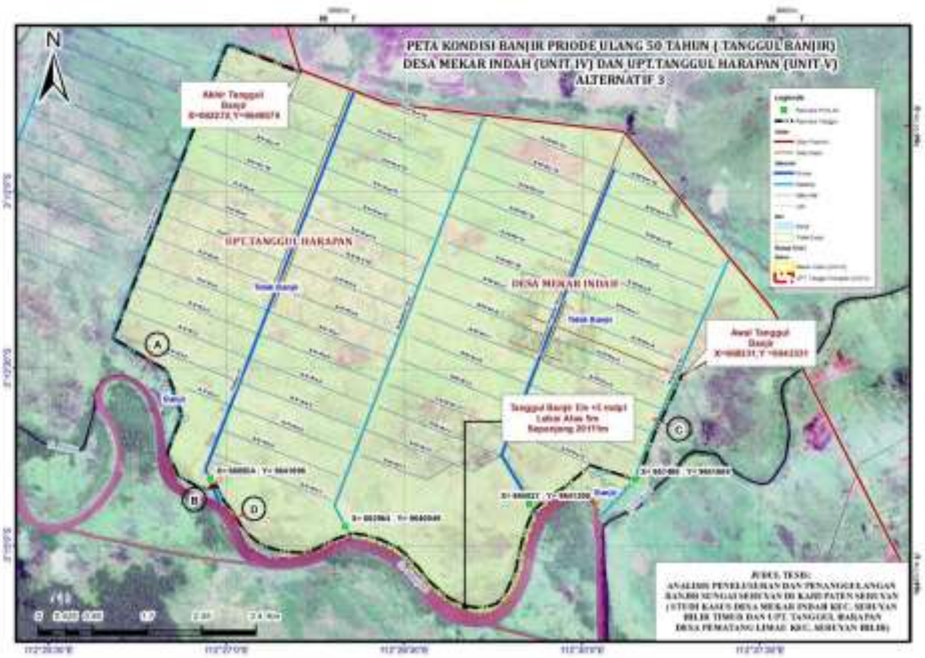

Figure 3. Flood Area in Mekar Indah Village and UPT. Tanggul Harapan by building Flood Embankment and Sluice Gate

CONCLUSION AND SUGGESTION

Conclusion

Based on the results of research on the Seruyan River Flood Routing Analysis in Seruyan District, it can be concluded that the cross section of the Seruyan River at the research point is no longer able to accommodate the flood discharge at the 50 years periodically. Meanwhile, the Flood management of Seruyan river are the construction of a 20111 m long embankment with an elevation of 5 m above sea level, a width of 5 m above sea level and 4 sluice gates, with a planned flow rate of Q Seruyan River 3060.19 m3/second, Q River Kalua 339.43 m3/second and Q Pukun River 438.89 m3/sec for 50 years periodically. Based on the results of the HEC-RAS simulation, it is known that it is able to reduce the flood area by 93.19% in UPT Tanggul Harapan and 39.92% in Mekar Indah Village.

Suggestion

Based on the research result, the researchers provide the suggestions that it is necessary to build climatology posts or rainfall posts and AWLR (Automatic Water Level Recorder) posts along the Seruyan River watershed in each sub-district capital to make it easier to obtain hydrological data for further research, and it need to improve the data recording for existing rainfall posts. For the government, an in-depth and detailed research is required when there is development or investment that will reduce land cover in forest areas. The cooperation between all relevant elements is needed, especially the government, plantation owners, mine owners, and the community in tree planting efforts. The empowerment of local residents in disaster management issues, because considering the behaviour of nature that is constantly changing from time to time and also human behaviour that use rivers as life sustainability. Last, for the completeness and validity of the research, further detailed research is needed, such as the effect of sediment, the effect of mines, and the effect of oil palm plantations in watersheds.

REFERENCES

Anto, W. (2019). *Analisis dan Evaluasi Kapasitas Penampang Sungai Jatiroto dengan Menggunakan Program Hec-Ras 4.1* [Universitas Muhammadiyah Jember]. http://repository.unmuhjember.ac.id/7379/

Catharina Mirandha Noviandini, Z. E. (2020). PENELUSURAN BANJIR DI SUNGAI BADENG BANYUWANGI MENGGUNAKAN METODE MUSKINGUM. *Seminar Nasional Terapan Riset Inovatif (SENTRINOV)*, *6*(1), 650–657.

Harto, S. (1993). *Analisis Hidrologi*. Gramedia Pustaka Utama.

Ikhsan, M., Refiyanni, M., & Nazimi, D. (2018). Studi Penelusuran Aliran Pada Sungai Krueng Meureubo Kecamatan Meurebo Kabupaten Aceh Barat. *Jurnal Teknik Sipil Dan Teknologi Konstruksi*, *4*(1). https://doi.org/10.35308/jts-utu.v4i1.589

Kodoatie, R. J. (2013). *Rekayasa dan manajemen banjir kota*. ANDI.

Lubomir Solin, P. S. (2013). Flood risk assessment and management: Review of concepts, definitions and methods. *GEOGRAPHICAL JOURNAL*, *65*, 23–44.

Muchamad Arif Budiyanto. (2017). Penelurusan Banjir Sungai Luk Ulo Akibat Perubahan Tutupan Lahan. *Jurnal Geografi*, *14*(1), 26–39. http://journal.unnes.ac.id/sju/index.php/ujet

Noviandini, C. M., & Erwanto, Z. (2020). Penelusuran Banjir di Sungai Badeng Banyuwangi Menggunakan Metode Muskingum. *Indonesian Society of Applied Science (ISAS)*, *6*(1), 650–657.

Novitasari. (2010). *Bahan ajar : Rekayasa Hidrologi I*. Universitas Lambung Mangkurat Press.

Ratih Indri Hapsari, M. Z. (2016). View of Flood Disaster Management in Indonesia and the Key Solutions. *American Journal of Engineering Research (AJER)*, *5*(3), 140–151.

Sari, O. L. (2021). Effect of flood risk management methods on urban flooding: Article review. *TEKNIKA: JURNAL SAINS DAN TEKNOLOGI*, *17*(2), 301–308.

Shadiq. (2008). *Hidrolika Praktis dan Mudah*. Pustaka Banua.

Soedodo Hardjoamodjodjo; Sukandi Sukartaatmadja. (2008). *Teknik Pengawetan Tanah dan Air* (1st ed.). Graha Ilmu.

Soemarto. (1987). *Hidrologi Teknik*. Usaha Nasional.

Sudirman, et al. (2019). System of urban flood control: A Comparative Study between Kanagawa Prefecture and Makassar City. *IOP Conference Series: Earth and Environmental Science*.

Triatmojo, bambang. (2008). *Hidrologi Terapan* (1st ed.). Beta Offset.