Syntax Literate: Jurnal Ilmiah Indonesia p–ISSN: 2541-0849 e-ISSN: 2548-1398
Vol. 7, No. 12, Desember 2022

THE EFFECT OF SEDIMENT TRANSPORT FOR FLOOD DISCHARGE PREDICTION BASED ON AWLR AND RIVER BATHYMETRY

Angga Yoga Pranatan, Indratmo Soekarno, Arie Setiadi Moerwanto, Eka Oktariyanto Nugroho
Magister of Water Resources Management, Faculty of Civil Engineering and Environmental, Bandung of Institute of Technology, Bandung, Indonesia
Water Resources Engineering Research Group, Civil Engineering and Environmental, Civil Engineering Masters Study Program, Universitas Teknologi Bandung, Bandung, Indonesia
Center for Research and Development of Water Resources (SDA), Research and Development Agency of the Ministry of Public Works and Public Housing
Email: anggayogapranatan@gmail.com

Abstract

Rivers have very important benefits for the survival of the community. However, rivers can also cause problems if not managed properly, especially can cause flooding or sedimentation, one of which is the Sayung River. The Sayung River is a downstream river that empties into the north coast where sedimentation naturally occurs so that in a building plan or flood runoff on the Sayung River it is necessary to consider aspects of the planned flood discharge and sedimentation that occurs because it is something that cannot be separated. If the capacity of the river channel is not able to accommodate the flood discharge so the flood overflow causes disasters for the community. On this basis, the researchers developed a flood and sediment analysis in one frame using a quasi-unsteady flow hecras application by modifying the upstream boundary value, namely daily data for 8 years (AWLR data) to see sedimentation for 8 years and the 8th year given a bankful discharge and planned floods Q2, Q25, Q50 to determine the cross-sectional capacity of the Sayung River after sedimentation occurs, then at the downstream boundary in the form of tidal data (MSL:+ 1.30 m) because it empties into the sea. The analysis was carried out 4 times with an upstream limit of 1. use the data as is (validated with rainfall data by the sacramento method) and bankful discharge (+ 57.18 m3/s) in the 8th year, the sedimentation was + 378.977 m3and there is no embankment runoff. 2, use the baseflow and discharge data for Q2 (± 63.22 m3/s) in the 8th year, it is found that sedimentation of + 360.117 m3does not occur embankment runoff. 3, use baseflow and design flood discharge data for Q25 (+ 120.53 m3/s) there is embankment runoff at station + 5100 (upstream) with runoff height 8cm.4, use baseflow data and planned flood discharge Q50 (+141.31 m3/s) there was embankment runoff at station +5100 with a runoff height of + 25cm.

Keywords: Sayung river; flood discharge; sedimentation.

Introduction

The Sayung River is a river under the authority of the Pemali – Juana River Basin Authority (BBWS) which is located in the administrative area of Semarang City and Demak

How to cite:	Angga Yoga Pranatan, Indratmo Soekarno, Arie Setiadi Moerwanto, Eka Oktariyanto Nugroho (2022) The Effect of Sediment Transport For Flood Discharge Prediction Based on Awlr and River Bathymetry, (7) 12, http://dx.doi.org/10.36418/syntax-literate.v7i12.11301
E-ISSN:	2548-1398
Published by:	Ridwan Institute

Regency. The Sayung River has a length of 18.9 km with a downstream limit on the north coast and an upstream limit in the form of the Pucang Gading Weir which functions to divide the flow of the Penggaron River into 3 rivers (Sayung River (free flow) – Babon River (free flow) – East Flood Canal River (Operational gate), (Center for Research and Development of Water Resources, 2007) In the downstream area of the Sayung River, there is a national vital object in the form of the Pantura highway, which at certain times is flooded for days, thus hampering the stability of the national economy. The factors that led to flooding in the downstream area of the Sayung River include (Bina Marga, 2020): 1) Sea tides. 2) Elevasi area lower than the water level (land subsidence). 3) Narrowing of the river channel so that the cross section of the river cannot accommodate flood discharge.

Part of the development of irrigation activities according to Law no. 11 of 1974 concerning Irrigation (amended by Law No. 11 of 2020 concerning Job Creation), one of which is to safeguard and or control the destructive power of water in the surrounding areas. The Ministry of PUPR has carried out a process of controlling the factors that caused the disaster, including : 1) Directorate General of Highways, Construction of a sea wall which functions as a toll road on the sea coast between the Jakarta Flood Canal (BKT) river and the Sayung River, also equipped with a retention pond on the upstream side of the embankment to accommodate regional rain and household or industrial waste. 2) BBWS Pemali -Juana, Maintenance of the Sayung River and Babon River channels from the estuary as far as ± 4 km upstream which is expected to increase flood discharge capacity, improve drainage channels, build retention ponds and raise Babon River embankments.

To build a complete control, the Directorate General of Highways and BBWS Pemali-Juana must work together to carry out mutually integrated development with the one aim of no more flood inundation caused by tidal floods or rain discharge floods with other supporting buildings. The objectives to be achieved in this research are to conduct flood and sediment simulations using Hec-Ras Quasi-UnsteadyFlow with AWLR (Automatic Water Level Recorder) data which was developed into several flood plan schemes over a period of 8 years.

Research Method

The research methodology of this study consisted of several stages from problem identification, literature study, primary secondary data collection, data analysis, calibration to obtaining results in a study conclusion. In detail, the research methodology is described as follows:

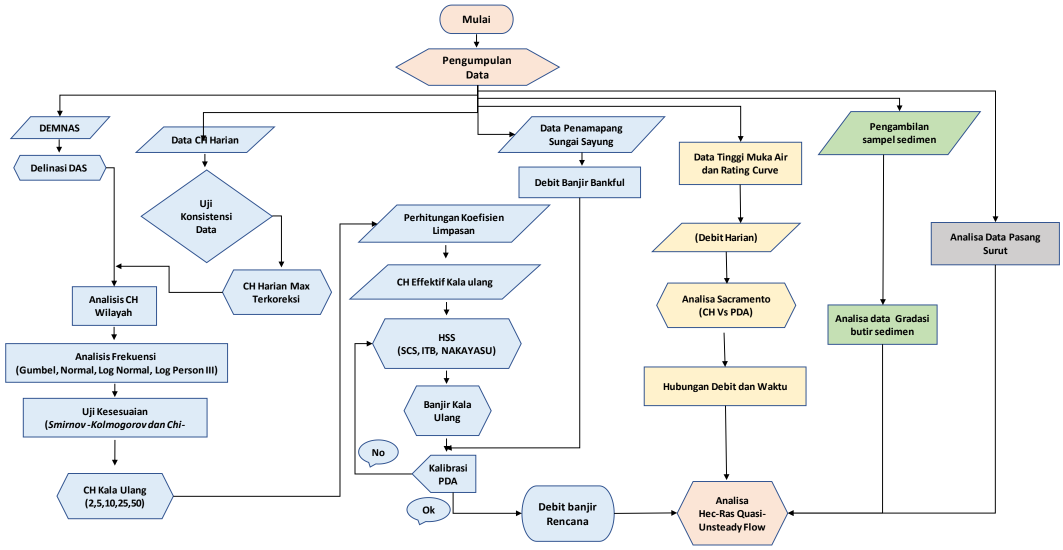

Figure 1. Research Steps

The steps taken are:

1. Look for return period flood discharge using the closest rainfall data using the HSS method, then compare it with the planned flood discharge from AWLR data and analyze it using frequency analysis. The design flood discharge used is data that is similar to the HSS method and AWLR data.
2. Analyze the daily discharge of AWLR and CH data using Sacramento analysis, then perform a simulation or a combination of the planned flood discharge and baseflow discharge.
3. Perform analysis of tidal values and gradation grain size values for modeling constraints.

Modeling is done using the Hec-ras application with data input

1. DEMNAS map
2. River geometry data (transverse and longitudinal)
3. Design flood discharge (Q2,Q10,Q25,Q50)
4. Baseflow debit data

Results and Discussions

A. Topographic Analysis Results

The data needed for topographical analysis is DEM data and land cover data from DEMNAS. The data is processed using the ARGIS application with output such as drainage basin, river length, ballast coefficient for regional rainfall (Thiessen Polygon Method), area of land use (runoff coefficient calculation), etc. These data will be needed to be able to describe the study location and support hydrological analysis, such as the following:

1. Drainage basin delineation

The Study on Flood and Sediment Control on the Sayung River in Demak City is a study on the 18.9 km long Sayung River (red line) with a catchment area of 60.4 acres. From the results of the DAS delineation, the fact is that the Sayung River has the influence of discharge from upstream, namely the Penggaron River with a river length of 17.4 km (light blue line) with a catchment area of 122 km^2 (red) The Penggaon River has an outlet in the form of the Pucang Gading Weir, which divides the discharge of the Penggaron River into 3 parts into the Sayung River, Babon River and BKT River. In this study, the upstream boundary in the form of planned flood discharge and base flow is only calculated from the influence of the Penggaron watershed (AWLR data on Pucang Gading Dam).

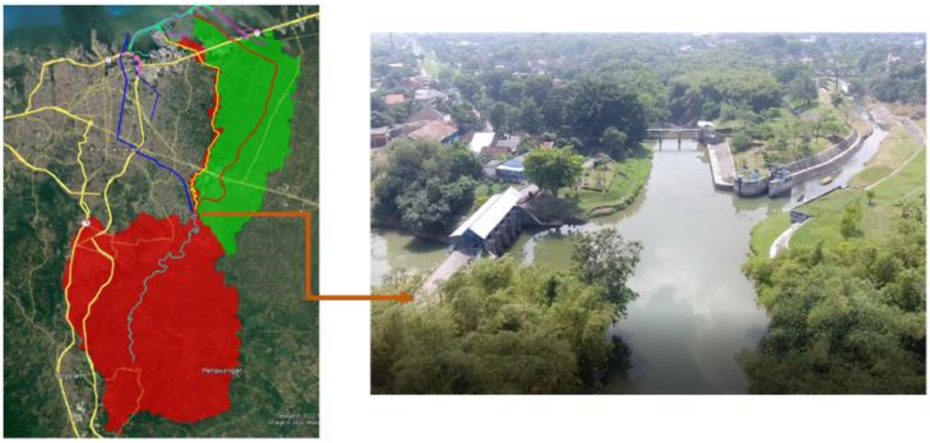

Figure 2. Results of the Delination of the Sayung River and Penggaron River Watersheds

2. **Watershed Runoff Coefficient**

Using the argis application, Dem data and land cover can be delineated and get the following results:

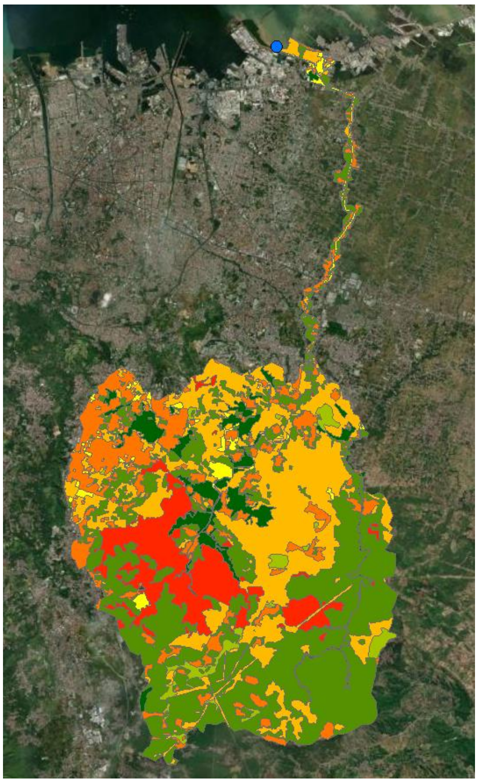

Figure 3. Land Cover Analysis Results

From the land use map, the area of each land use was obtained, using Table 1. Runoff coefficient data obtained from Penggaron watersheds as follows:

Table 1
Result of Penggaron Watershed Runoff Coefficient Value

Tata guna lahan	Luas	C	C*Luas
Padang Rumput	2.44	0.50	1.22
Perkebunan/Kebun	47.92	0.80	38.33
Permukiman dan Tempat Kegiatan	16.73	0.55	9.20
Sawah	6.16	0.75	4.62
Sawah Tadah Hujan	2.72	0.80	2.18
Semak Belukar	13.16	0.80	10.53
Tegalan/Ladang	33.53	0.85	28.50
	122.65	0.77	94.58

3. Thiessen Polygon Analysis

Thiessen polygon analysis was carried out to determine the extent of influence on the Pucang Gading rain station, Brumbung Rain Station, Tambak Roto Rain Station and Maritime Rain Station. From this analysis the delineation results were obtained as follows:

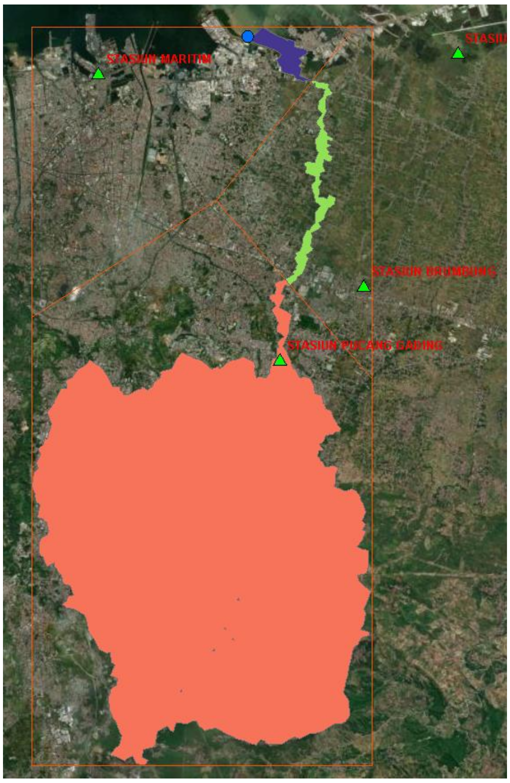

Figure 4. Thiessen Polygon Analysis Results

It can be concluded from the results of the delineation analysis that the area of influence of the Penggaron Watershed is influenced by the following Pucang Gading Rain Station:

B. Hydrological Analysis Results

The intended hydrological analysis is the process of obtaining the upstream boundary of the modeling in the form of a design flood discharge at a certain return period. To obtain a design discharge for the Sayung River, there are several stages of calculation, including:

1. Look for rain plans using the frequency analysis method.
2. Finding the planned flood discharge with the HSS method
3. Looking for the division of the planned flood discharge due to the existence of the Pucang Gading Dam and the operational pattern of the BKT River gate

Details of the calculation process can be seen as follows (Natakusumah DK, 2014):

1. Rain Data Testing

From the results of the delineation it can be seen that the Penggaron Watershed is affected by the Pucang Gading Rain Station which has rainfall data for 20 years from 1996 – 2015.

a) Rainfall Analysis

The basis for calculating regional rainfall in the Penggaron Watershed and River uses the Thiessen Polygon method with several reference rain stations and obtains the influence rain is stations of pucang gading.

1) Outlier Test

Outliers test are performed to see whether the data being analyzed falls within the acceptable upper and lower ranges. Examination of outliers on the rain data is carried out for the upper and lower outliers. If there are outliers during the inspection, then the outlier data must be removed before the data set is used for further hydrological analysis.

Table 2
Outlier Test Sta. Pucang Gading

No.	Tahun	Curah Hujan (mm)	No.	Curah Hujan Xi (mm)	Probabilitas	Log Xi	Log Xi - Log X_{rt}	(Log Xi - Log $X_{rt})^2$	(Log Xi - Log $X_{rt})^3$
1	1996	**99**	1	120	**4.76**	**2.079**	0.079	0.006	0.000
2	1997	**95**	2	116	**9.52**	**2.064**	0.064	0.004	0.000
3	1998	**99**	3	110	**14.29**	**2.041**	0.041	0.002	0.000
4	1999	**97**	4	106	**19.05**	**2.025**	0.025	0.001	0.000
5	2000	**104**	5	105	**23.81**	**2.021**	0.021	0.000	0.000
6	2001	**100**	6	104	**28.57**	**2.017**	0.017	0.000	0.000
7	2002	**101**	7	101	**33.33**	**2.004**	0.004	0.000	0.000
8	2003	**98**	8	100	**38.10**	**2.000**	0.000	0.000	0.000
9	2004	**100**	9	100	**42.86**	**2.000**	0.000	0.000	0.000
10	2005	**97**	10	100	**47.62**	**2.000**	0.000	0.000	0.000
11	2006	**116**	11	100	**52.38**	**2.000**	0.000	0.000	0.000
12	2007	**110**	12	99	**57.14**	**1.996**	-0.005	0.000	0.000
13	2008	**100**	13	99	**61.90**	**1.996**	-0.005	0.000	0.000
14	2009	**85**	14	98	**66.67**	**1.991**	-0.009	0.000	0.000
15	2010	**87**	15	97	**71.43**	**1.987**	-0.014	0.000	0.000
16	2011	**120**	16	97	**76.19**	**1.987**	-0.014	0.000	0.000
17	2012	**100**	17	95	**80.95**	**1.978**	-0.023	0.001	0.000
18	2013	**90**	18	90	**85.71**	**1.954**	-0.046	0.002	0.000
19	2014	**106**	19	87	**90.48**	**1.940**	-0.061	0.004	0.000
20	2015	**105**	20	85	**95.24**	**1.929**	-0.071	0.005	0.000
			Sum	2009	**1000**	**40**	0.000	0.025	0.000
				Rerata			**2.000**		
				Standar Deviasi (Stdev)			**0.036437303**		
				Skewness (Cs)			**0.173533306**		
				Jumlah Data (n)			**20**		
				Kn			**2.385**		
				Batas Atas		**122.291**		**Diterima**	
				Batas Bawah		**81.957**		**Diterima**	

2) Double Mass Curve Test

Double mass curve test shows that the cumulative rainfall points coincide with the trend line, where the line forms an angle close to 45° with a value of R.

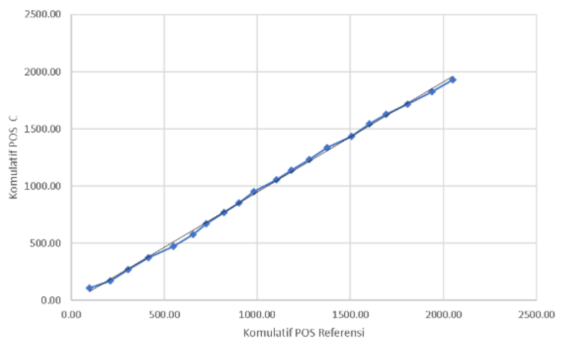

Figure 5. Sta Pucang Gading Double Mass Curve Test

b) Regional Planning Rainfall Analysis

The results of the analysis of the area and weight of the Thiessen polygons are then used to calculate the annual maximum rainfall on the percentage of influence of rain stations on the watershed.

Table 3
Maximum Daily Rainfall Thiessen Penggaron Watershed

Tahun	Hujan Harian Maksimum Tahunan (mm)	
	Pucang Gading 100.00%	Rata - rata
1996	108.07	108.07
1997	63.52	63.52
1998	99.00	99.00
1999	105.08	105.08
2000	99.00	99.00
2001	100.00	100.00
2002	95.00	95.00
2003	98.00	98.00
2004	85.00	85.00
2005	97.00	97.00
2006	106.00	106.00
2007	80.54	80.54
2008	96.00	96.00
2009	102.00	102.00
2010	103.00	103.00
2011	106.00	106.00
2012	85.00	85.00
2013	90.00	90.00
2014	109.00	109.00
2015	105.00	105.00

c) Planned Rainfall Analysis

The method used to analyze the planned rainfall is frequency and probability distribution analysis using the Normal, Log Normal, Gumbel and Log Person III frequency distribution methods. The results of the analysis can be seen below.

How to cite:	Angga Yoga Pranatan, Indratmo Soekarno, Arie Setiadi Moerwanto, Eka Oktariyanto Nugroho (2022) The Effect of Sediment Transport For Flood Discharge Prediction Based on Awlr and River Bathymetry, (7) 12, http://dx.doi.org/10.36418/syntax-literate.v7i12.11301
E-ISSN:	2548-1398
Published by:	Ridwan Institute

Table 4
Frequency Analysis Calculation Results (DAS Penggaron)

No.	Periode Ulang	Hujan Rencana (mm)			
		Normal	Gumbel	Log Normal	Log Pearson III
		Excel	Excel	Excel	Excel
1	2	96.611	94.961	95.909	99.819
2	5	105.988	106.866	106.846	109.128
3	10	110.900	114.748	113.064	110.884
4	25	115.700	124.708	119.490	111.189
5	50	119.496	132.096	124.829	110.242
6	100	122.622	139.430	129.404	108.268
7	200	125.412	146.737	133.631	105.735
8	1000	131.106	163.663	142.686	99.105

From the results of the frequency analysis, a distribution suitability test is carried out and a calibration is carried out based on the area of the watershed before becoming the basis for calculating the flood discharge for the HSS method plan.

d) Distribution Suitability Test

This distribution suitability test is carried out to find out whether the frequency analysis carried out can be accepted or rejected. At the same time as a reference which method will be used for the basis of calculating the planned flood discharge by looking at the lowest error rate from the suitability test of the Chi-Square and Smirnov-Kolmogorov methods. Following are the results of the distribution suitability test.

Table 5
Suitability Distribution Test for Penggaron Watershed

No.	Periode Ulang	Hujan Rencana (mm)			
		Normal	Gumbel	Log Normal	Log Pearson III
		Excel	Excel	Excel	Excel
1	2	96.611	94.961	95.909	99.819
2	5	105.988	106.866	106.846	109.128
3	10	110.900	114.748	113.064	110.884
4	25	115.700	124.708	119.490	111.189
5	50	119.496	132.096	124.829	110.242
6	100	122.622	139.430	129.404	108.268
7	200	125.412	146.737	133.631	105.735
8	1000	131.106	163.663	142.686	99.105
Uji Smirnov Kolmogorov		0.157	0.230	0.112	0.156
		0.290	0.290	0.290	0.290
		Memenuhi	Memenuhi	Memenuhi	Memenuhi
Uji Chi Square		6.000	11.000	5.500	2.5000
		7.815	7.815	7.815	7.815
		Memenuhi	Tidak Memenuhi	Memenuhi	Memenuhi

From the results of the suitability distribution test, the normal log method can be taken and then used for adjusting the watershed area factor and analyzing the planned flood discharge

e) Area reduction factor (AFR)

The expected planned rainfall is that there will be evenly distributed rain in the watershed area, so that an area reduction factor (ARF) is needed with conditions based on the area of the watershed as follows (SNI 2451, 2016):

Table 6
Area Reduction Factor (ARF).

LUAS DAS : A (Km2)	ARF
1 -10	0.99
10 - 30	0.97
30-30000	1.152 - 0.1233 Log A

Based on the results of the calculation of the frequency analysis of the Normal Log method, it is necessary to multiply the AFR value by: Panggaron DAS is 0.89 because it has a watershed area of 122.3 km^2. So that when it rains again, the plan is:

Table 7
Rain Plans for the Penggaron Watershed

No.	Periode Ulang	Hujan Rencana (mm) Log Normal	Hujan Rencana (mm) x ARF
1.00	2.00	95.91	85.80
2.00	5.00	106.85	95.58
3.00	10.00	113.06	101.15
4.00	25.00	119.49	106.90
5.00	50.00	124.83	111.67
6.00	100.00	129.40	115.77
7.00	200.00	133.63	119.55
8.00	1000.00	142.69	127.65

f) Effective Rainfall

The effective rain meant is rain that will have an effect on the planned flood discharge or rainwater that actually affects the flood discharge on the Sayung River or Penggaron River. There are 2 factors that will be discussed and are very influential in calculating the planned flood discharge, there are distribution of hourly rain, and runoff coefficient. For more details will be discussed as follows (Natakusumah, D.K., Waluyo, H., & Harlan, D., 2011):

Distribution of Hourly Rainfall

Hourly rain distribution pattern uses the PSA-007 method issued by the Ministry of Public Works and Public Housing (PUPR, 2017). For analysis of hourly rainfall distribution on the Penggaron River, a 6 hour distribution was used because at the study site it was very rare to have rain of more than 6 hours. The following are the results of the planned rain analysis using the PSA 007 rain distribution method for 6 hours.

Table 8
Hours Rain Distribution (Penggaron Watershed)

Distribusi Hujan		85.800	95.585	101.147	106.896	111.672	115.765	119.547	127.647
Kum	Jam	**2**	**5**	**10**	**25**	**50**	**100**	**200**	**1000**
0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.05	0.050	4.290	4.779	5.057	5.345	5.584	5.788	5.977	6.382
0.15	0.100	8.580	9.558	10.115	10.690	11.167	11.577	11.955	12.765
0.75	0.600	51.480	57.351	60.688	64.138	67.003	69.459	71.728	76.588
0.91	0.160	13.728	15.294	16.184	17.103	17.868	18.522	19.127	20.424
0.97	0.060	5.148	5.735	6.069	6.414	6.700	6.946	7.173	7.659
1	0.030	2.574	2.868	3.034	3.207	3.350	3.473	3.586	3.829

Runoff Coefficient

The planned flood discharge / effective rain value (rainwater entering the river) has a very close relationship with the function of land use in a watershed and has a value that changes over time (Chow, V.T, 1959). In this study the infiltration approach uses runoff coefficient tables with the following calculation results:

Table 9
Effective rain (2 years) Penggaron watershed

Total	85.800	19.641	66.159
Jam	**Rtot (mm)**	**Infil (mm)**	**Reff (mm)**
0	0.000	0.0000	0.0000
1	4.290	0.9821	3.3080
2	8.580	1.9641	6.6159
3	51.480	11.7846	39.6956
4	13.728	3.1426	10.5855
5	5.148	1.1785	3.9696
6	2.574	0.5892	1.9848
7	0.000	0.0000	0.0000
8	0.000	0.0000	0.0000
9	0.000	0.0000	0.0000
10	0.000	0.0000	0.0000
11	0.000	0.0000	0.0000
12	0.000	0.0000	0.0000

Table 10
Effective Rain (10th) Penggaron Watershed

Total	101.147	23.154	77.993
Jam	**Rtot (mm)**	**Infil (mm)**	**Reff (mm)**
0	0.000	0.0000	0.0000
1	5.057	1.1577	3.8997
2	10.115	2.3154	7.7993
3	60.688	13.8925	46.7959
4	16.184	3.7047	12.4789
5	6.069	1.3893	4.6796
6	3.034	0.6946	2.3398
7	0.000	0.0000	0.0000
8	0.000	0.0000	0.0000
9	0.000	0.0000	0.0000
10	0.000	0.0000	0.0000
11	0.000	0.0000	0.0000
12	0.000	0.0000	0.0000

Table 11
Effective Rain (25th) Penggaron Watershed

Total	106.896	24.470	82.426
Jam	**Rtot (mm)**	**Infil (mm)**	**Reff (mm)**
0	0.000	0.0000	0.0000
1	5.345	1.2235	4.1213
2	10.690	2.4470	8.2426
3	64.138	14.6821	49.4557
4	17.103	3.9152	13.1882
5	6.414	1.4682	4.9456
6	3.207	0.7341	2.4728
7	0.000	0.0000	0.0000
8	0.000	0.0000	0.0000
9	0.000	0.0000	0.0000
10	0.000	0.0000	0.0000
11	0.000	0.0000	0.0000
12	0.000	0.0000	0.0000

Table 12
Effective Rain (50th) Penggaron Watershed

Total	111.672	25.564	86.109
Jam	**Rtot (mm)**	**Infil (mm)**	**Reff (mm)**
0	0.000	0.0000	0.0000
1	5.584	1.2782	4.3054

2	11.167	2.5564	8.6109
3	67.003	15.3381	51.6653
4	17.868	4.0902	13.7774
5	6.700	1.5338	5.1665
6	3.350	0.7669	2.5833
7	0.000	0.0000	0.0000
8	0.000	0.0000	0.0000
9	0.000	0.0000	0.0000
10	0.000	0.0000	0.0000
11	0.000	0.0000	0.0000
12	0.000	0.0000	0.0000

Table 13. Effective Rain (100th) Penggaron Watershed

Total	**115.765**	**26.501**	**89.265**
Jam	**Rtot (mm)**	**Infil (mm)**	**Reff (mm)**
0	0.000	0.0000	0.0000
1	5.788	1.3250	4.4632
2	11.577	2.6501	8.9265
3	69.459	15.9003	53.5590
4	18.522	4.2401	14.2824
5	6.946	1.5900	5.3559
6	3.473	0.7950	2.6779
7	0.000	0.0000	0.0000
8	0.000	0.0000	0.0000
9	0.000	0.0000	0.0000
10	0.000	0.0000	0.0000
11	0.000	0.0000	0.0000
12	0.000	0.0000	0.0000

Table 14. Effective Rain (200th) Penggaron Watershed

Total	**119.547**	**27.366**	**92.181**
Jam	**Rtot (mm)**	**Infil (mm)**	**Reff (mm)**
0	0.000	0.0000	0.0000
1	5.977	1.3683	4.6090
2	11.955	2.7366	9.2181
3	71.728	16.4196	55.3083
4	19.127	4.3786	14.7489
5	7.173	1.6420	5.5308
6	3.586	0.8210	2.7654
7	0.000	0.0000	0.0000
8	0.000	0.0000	0.0000
9	0.000	0.0000	0.0000
10	0.000	0.0000	0.0000

11	0.000	0.0000	0.0000
12	0.000	0.0000	0.0000

Description :
1) Rtot = Total rain (At a certain return period)
2) Infil = Infiltration (seepage of water into shallow soil)
3) Reff = Effective Rain (rain which is believed to affect the flood discharge value)

g) Flood Discharge Prediction

flood discharge of the Sayung River is the Penggaron Watershed flood discharge which is flows into the Sayung River (after being divided into the Babon River and the BKT River) plus the Sayung River Basin itself. Or it can be described in the schematic below.

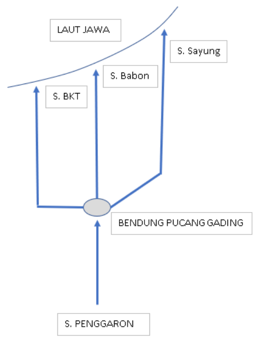

Figure 6. River Flow Scheme

To get the results of a flood discharge plan that can implement real conditions, to get a flood discharge plan for the Sayung River, it is necessary to take the following steps:
1) Looking for the flood discharge plan for the Penggaron watershed using the HSS method
2) Looking for flood discharge plans for the Sayung River, Babon River, BKT River in relation to the existence of the Pucang Gading Dam and the operating pattern of the gate on the BKT River.
3) Finding the planned flood discharge of the Sayung River using AWLR data with the frequency analysis method, as a calibration of the flood discharge of the Sayung River upstream plan.

The detailed calculation of these steps will be explained as follows:
1) Penggaron River Flood Discharge Prediction

The design flood discharge analysis used is the Synthetic Unit Hydrograph (HSS) method of Nakayasu, SCS, ITB, (DK Natakusumah, W Hatmoko, D Harlan, 2011) with the following results:

Table 15
Table of Planned Flood Discharge for Panggaron Watershed

Tr	Nakayasu (Alpha=2.0)	SCS	ITB-1a	ITB-2a	ITB-1b	ITB-2b
2	391.05	311.01	302.30	388.07	312.91	400.58
5	435.64	398.74	336.77	432.33	348.59	446.26
10	461.00	459.23	356.37	457.49	368.88	472.23
25	487.20	528.80	376.63	483.49	389.85	499.07

50	508.97	597.40	446.01	572.56	461.66	591.00
100	527.62	660.06	407.88	523.61	422.19	540.47
200	544.86	721.22	421.20	540.71	435.98	558.13
1000	581.78	868.60	449.74	577.35	465.52	595.95

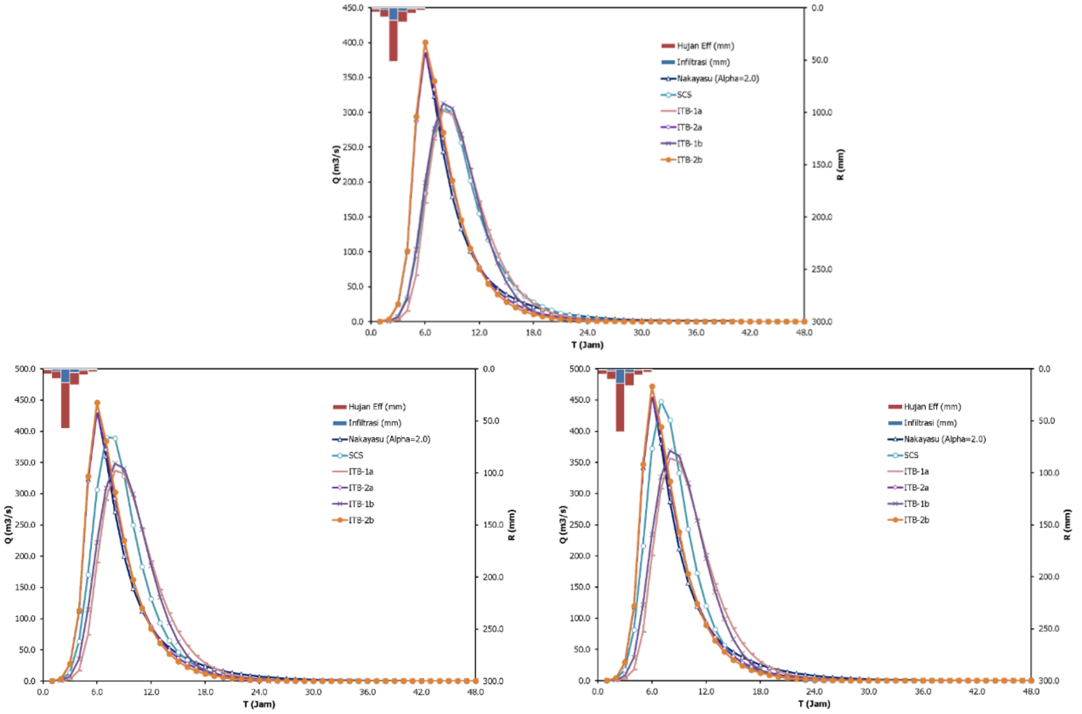

Figure 7. HSS DAS Penggaron (Q2), (Q5), and (Q10)

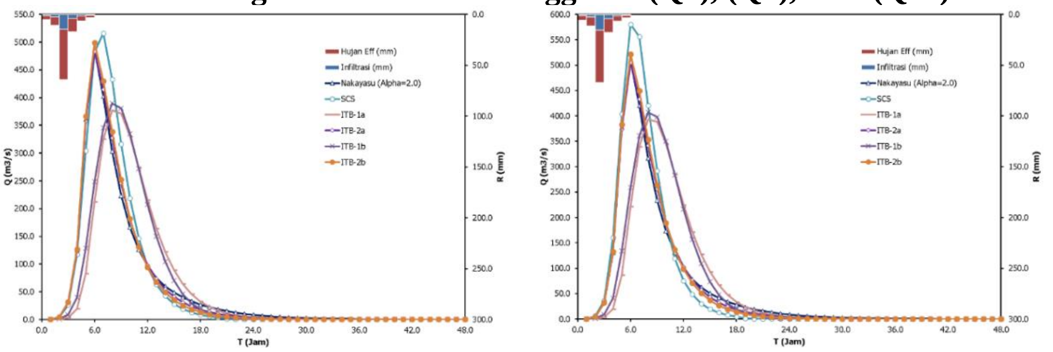

Figure 8. HSS DAS Penggaron (Q25) and (Q50)

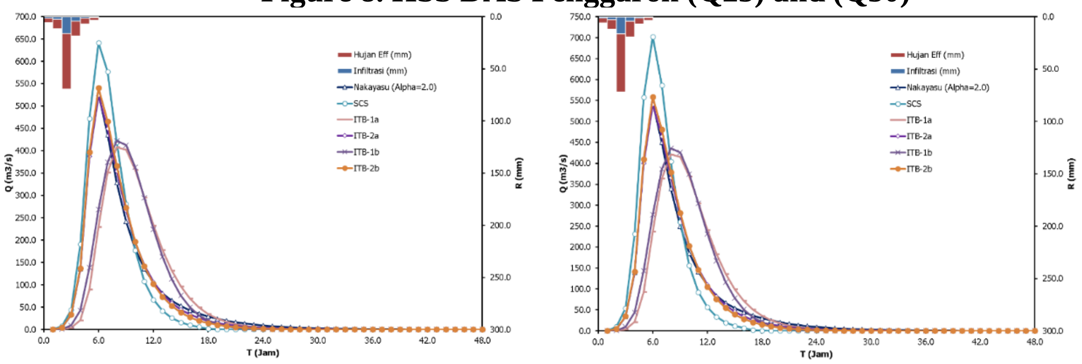

Figure 9. HSS DAS Penggaron (Q100) and (Q200)

The flood discharge planned for the Penggaron Watershed cannot yet become the upstream limit of the study because it is necessary to understand the systematic operation pattern of the Pucang Gading Dam to determine the discharge flowing into the BKT River and the Babon River so that the flood discharge value for the Sayung River plan can be obtained as the upstream limit of the study.

2) Systematic Flow of Pucang Gading Weir

The Pucang Gading Weir is an outlet of the Penggaron River which divides the Penggaron River discharge into 3 rivers. The Sayung River and the Babon River have a fixed inlet weir that is free-flowing (equipped with a rating curve, you can see in the image below) while the BKT River has an inlet in the form of a gate that has a standard operation (Center for Research and Development of Water Resources, 2007).

Figure 10. BKT River - Babon River - Sayung River (Left - Center - Right)

Pucang gading weir have a automatic water level recorder to so that the history of daily debits can be known because Sayung river dan babon river have rating curve data as as depicted in this Figure.

ELEVATION (m)	DISCHARGE (m3/s)
22.00	0
22.25	0.438
23.02	10.871
23.48	24.673
23.9	39.298
24.22	53.398
24.53	67.396
25.07	97.865
25.33	116.535
25.5	135.742

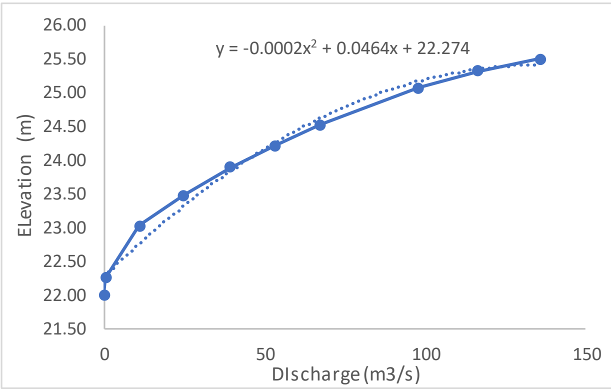

Figure 11. Sayung River Rating Curve

ELEVATION (m)	DISCHARGE (m3/s)
22.44	3.621
22.67	9.24
22.91	18.453
23.18	31.478
23.45	47.601
23.64	70.53
23.74	97.123
23.98	129.496
24.21	168.428
24.4	212.938
24.66	263.578
24.89	322.957
25.16	386.994

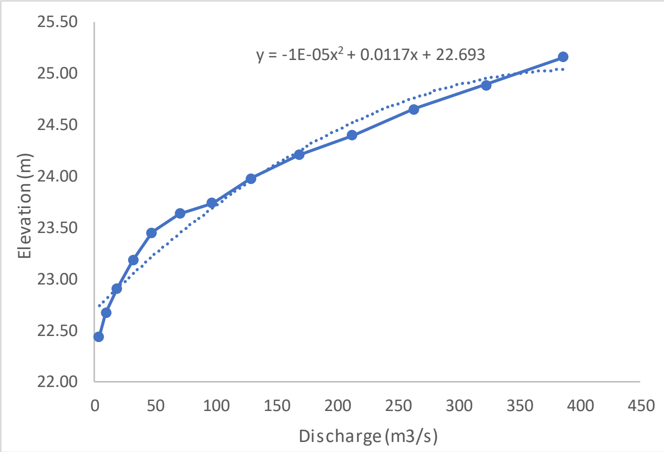

Figure 12. Babon River Rating Curve

From the Rating Curve data, it is used to process AWLR data in the form of water level into a discharge value so that the proportion of the flow flowing in the Sayung River and Babon River can be known as depicted in this Table.

Table 16
Percentage of Sayung River and Babon River Streams

Tanggal Bulan Tahun	Elevasi Muka Air (M)	Debit (M3/S)			Persentase		Rata2 - %	
		Sayung	Babon	Total	Sayung	Babon	Sayung	Babon
01/01/2021	+23.28	17.313	39.605	56.919	30%	70%	31%	69%
02/01/2021	+23.25	16.504	37.016	53.520	31%	69%		
03/01/2021	+24.31	56.925	186.431	243.356	23%	77%		
04/01/2021	+23.68	29.965	83.256	113.222	26%	74%		
26/07/2021	+23.07	12.060	23.484	35.544	34%	66%		
27/07/2021	+23.06	11.833	22.833	34.666	34%	66%		
28/07/2021	+23.07	12.060	23.484	35.544	34%	66%		
29/07/2021	+23.04	11.387	21.563	32.950	35%	65%		
30/07/2021	+23.04	11.387	21.563	32.950	35%	65%		
31/07/2021	+24.02	43.446	133.707	177.154	25%	75%		
01/08/2021	+23.31	18.142	42.290	60.432	30%	70%		
02/08/2021	+23.07	12.060	23.484	35.544	34%	66%		
03/08/2021	+23.07	12.060	23.484	35.544	34%	66%		

From these data, the percentage of the flow of the Sayung River is ± 31% and the Babon River is ± 69%, this data does not take into account the operational pattern of the BKT River which is operated at a certain elevation so that it will reduce the flow rate in the Sayung River and Babon River. The following is the operation pattern of the BKT River gate:

The BKT River has 6 gates which are operated only if the Penggaron River discharge is high enough with the operating conditions being divided into 3 stages (BBWS. Pemali Juana, 2022).

1. Stages 1 = at an elevation of 24.16 m
2. Stages 2 = at an elevation of 24.34 m
3. Stages 3= at an elevation of 24.56 m

Table17
BKT Door Operation Pattern

NO	Operasional	PINTU (Bukaan Pintu (m) dan Debit (m3/s))												TOTAL DEBIT
		A (Bukaan)	Debit	B (Bukaan)	Debit	C (Bukaan)	Debit	D (Bukaan)	Debit	E (Bukaan)	Debit	F (Bukaan)	Debit	
1	Siaga 1			1.5	21.37	1.5	21.4	1.5	21.37	1.5	21.37			85.48
2	Siaga 2			1.5	21.85	2	27.4	2	27.42	1.5	21.85			98.54
3	Siaga 3	1	15.75	1.5	22.32	2	28	2	28.01	1.5	22.32	1	15.75	132.16

Table 18. Distribution of the Sayung River - Babon River - BKT River Debt

Siaga 1

Sungai	Elevasi (m)	Debit (m3/s)	Efek BKT	Debit'ok
Babon	24.16	158.04608	58.57443	99.47165
Sayung	24.16	49.7257984	26.90557	22.82023
TOTAL		207.771878	85.48	122.2919
			41.1%	

Siaga 2

Sungai	Elevasi (m)	Debit (m3/s)	Efek BKT	Debit'ok
Babon	24.34	192.39458	67.52368	124.8709
Sayung	24.34	58.4236684	31.01632	27.40735
TOTAL		250.818248	98.54	152.2782
			39.3%	

Siaga 3

Sungai	Elevasi (m)	Debit (m3/s)	Efek BKT	Debit'ok
Babon	24.56	239.04448	90.5615	148.483
Sayung	24.56	70.0082304	41.5985	28.40973
TOTAL		309.05271	132.16	176.8927
			42.8%	

Description :

1) Elevation (m): condition when the BKT gate is operated, before the water level reaches that point the BKT gate is completely closed.
2) Debit (m^3/s) : total discharge from Penggaron River (not yet divided into 3)
3) BKT effect: discharge (m^3/s) enters the BKT River
4) Debit'ok : discharge (m^3/s) existing flowing into the Sayung River and Babon River.

Referring to the operating pattern of the BKT gate and understanding the discharge value of the Babon River, the flood discharge planned for the Sayung River is the flood discharge of the Penggaron watershed - the flood discharge of the Babon River - the operating pattern of the BKT River gate, or can be seen in the following table:

Table 19
Sayung River Flood Discharge Prediction

Debit Sungai Sayung						
Q2	Q5	Q10	Q25	Q50	Q100	Q200
0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.41	0.79	1.06	1.72	2.20	2.77	3.64
2.34	4.50	6.03	9.81	12.28	15.21	19.24
11.18	21.08	27.75	43.33	53.41	64.97	53.56
30.83	56.03	72.87	67.98	89.29	113.58	144.05
59.23	57.68	79.80	120.31	141.31	160.47	179.34
54.12	81.67	99.65	120.53	129.14	134.09	133.60
55.86	79.49	87.31	87.27	86.45	84.11	77.86
52.43	60.36	59.78	50.86	47.75	53.09	44.96
49.52	50.04	46.78	61.92	57.47	51.99	43.78
63.22	56.23	51.93	39.94	35.37	31.03	25.53
48.25	39.98	35.62	25.36	22.21	19.20	14.83
36.59	28.15	24.00	16.57	14.23	11.41	8.73
27.43	19.61	16.52	10.78	8.84	7.08	5.13
20.49	13.91	11.59	6.98	5.57	4.37	2.92
15.08	10.05	7.94	4.45	3.56	2.59	1.56
11.28	7.14	5.51	2.95	2.18	1.47	0.46
8.55	5.05	3.78	1.86	1.26	0.43	0.14
6.58	3.61	2.64	1.10	0.37	0.14	0.04
4.91	2.56	1.79	0.33	0.12	0.04	0.00
3.69	1.84	1.21	0.11	0.03	0.00	0.00
2.80	1.26	0.73	0.03	0.00	0.00	0.00
2.07	0.83	0.22	0.00	0.00	0.00	0.00
1.59	0.25	0.07	0.00	0.00	0.00	0.00
1.19	0.08	0.02	0.00	0.00	0.00	0.00
0.87	0.02	0.00	0.00	0.00	0.00	0.00
0.60	0.00	0.00	0.00	0.00	0.00	0.00

Flood discharge prediction for the Sayung River has been calibrated with an analysis of the planned flood discharge using AWLR data for 8 years which was analyzed using the frequency analysis method. Methods that have similary with HSS method will be used as a reference for the upstream boundary of this study.

C. Tidal Analysis Results

(Prayogo, 2021) The data used for tidal analysis using the Least Square method is hourly data for 15 days from 18 May 2022 to 31 May 2022. The data can be seen in the image below.

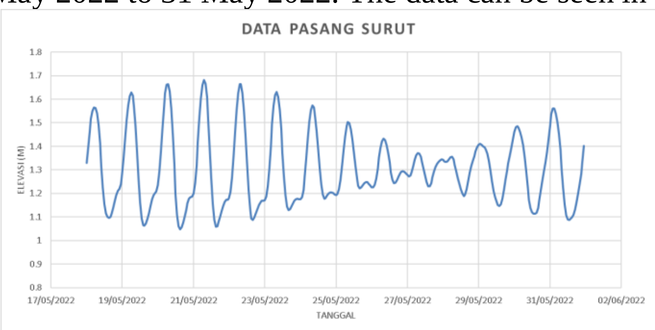

Figure 13. Tidal Data

Formzal value is 2.29 or mixed tidal type (dominant diurnal) with HHWL, MHWL, MSL, etc. values as follows.

Table 20
Important Tidal Values

No	Muka Air Penting	Symbol	Calculation	Elevasi Penting Least Square
1	Higher High Water Level	HHWL	Z0+(M2+S2+K2+K1+O1+P1)	2.30
2	Mean High Water Level	MHWL	Z0+(M2+K1+O1)	1.82
3	Mean Sea Level	MSL	Z0	1.30
4	Mean Low Water Level	MLWL	Z0-(M2+K1+O1)	0.79
5	Chart Datum Level	CDL	Z0-(M2+S2+K1+O1)	0.66
6	Lower Low Water Level	LLWL	Z0-(M2+S2+K2+K1+O1+P1)	0.31

D. Flood and Sediment Analysis

Analysis of Flood and Sediment Control on the Sayung River in Demak City using the Hec-Ras 6.2 Quasi-unsteady flow application in one run with the following modeling scheme:

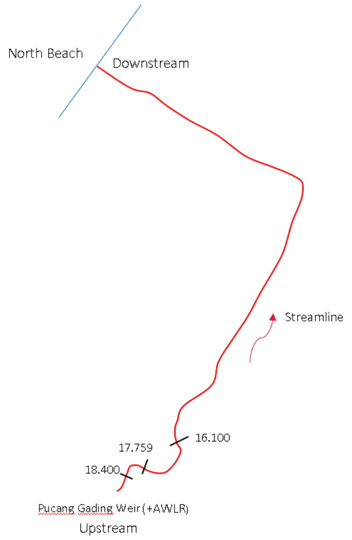

Figure 14. Sayung River scheme

From the schematic it is explained:

1. Sayung River Length: 18.9 km (supplemented with longitudinal and transverse river geometry data, measurement data for 2017 and as built drawings for 2022). (BBWS. Pemali Juana, 2017)
2. River slope:
   a) upstream : 0.0068 %
   b) downstream : 0.025 %

3. River transverse building:
   a) Checkdam at station 16.100
   b) Checkdam at station 17,759
   c) Groundsill at station 18,400

On this occasion, primary data was also collected in the form of instantaneous discharge data and sediment data at stations 8,400, 12,700 and 14,500 with the following data results:

Table 21
Sayung River Sediment Data

Item	Diameter (mm)	Hilir (%)	Tengah (%)	Hulu (%)
Clay	0.00	18.00	13.00	
VFM	0.01	26.00	18.00	
FM	0.02	33.00	20.00	
MM	0.03	42.00	24.00	
CM	0.06	47.00	27.00	8.00
VFS	0.13	59.00	33.00	11.00
FS	0.25	67.00	47.00	18.00
MS	0.50	82.00	62.00	28.00
CS	1.00	91.00	71.00	35.00
VCS	2.00	95.00	79.00	45.00
VFG	4.00	96.00	91.00	59.00
FG	8.00	99.00	99.00	88.00
MG	16.00	100.00	100.00	100.00

From the data that has been obtained, it can be concluded that the flood and sediment modeling analysis of the Sayung River will be carried out with the following limitations:

1. Sediment analysis was carried out using the Quasi-Unsteady Flow model
   a) Upstream boundary : Daily discharge from AWLR data
   b) Downstream boundary : Tidal data
   c) Sediment boundary conditions is the equilibrium load and sedimen grain size data

   The implementation scheme is to simulate the results of calculating the daily debit of AWLR data using sacramento method with the rule:
2. Modeling (using hecras) the results of calculating the daily discharge for 8 years (actual data).
3. Modeling (using hecras) the results of calculating the daily discharge for 8 years modified by lowering the flood discharge value to base flow and simulating the planned flood discharge Q2, Q5, Q25, Q50 to see capacity of the river after baseflow sedimentation occurred for 8 years.
   a) Model Calibration

      The calibration of the model in question is the calibration of the river geometry data that is modeled whether it can or can describe the current or future conditions of the Sayung River. The calibration is carried out by comparing the bangful conditions in the existing conditions when sampling the instantaneous discharge with the geometric conditions in the modeling (Kusuma, M.S.B and Nugroho.E.O., 2022). The steps taken include:
      1) Look for the manning value of the existing condition and then use the manning value in the modeling. (obtained the manning value there are 3 values in 1 section (middle: 0013, right armrest: 0.031, left armrest: 0.027)
      2) Look for debits and elevations on bankful conditions.

3) Run the unsteady flow hec-ras model then compare the bankful condition of the model results with the existing condition.
4) Perform river section calibration or manning values until modeling and existing conditions have an accuracy value of 95%.

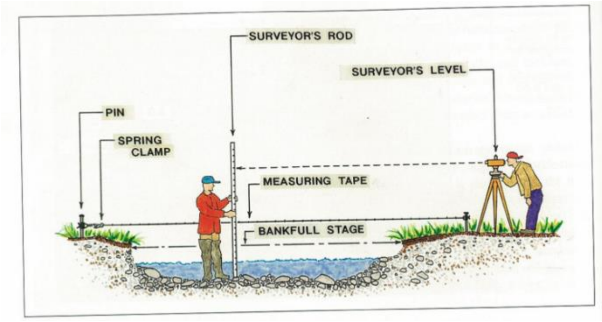

Figure 15. Bankful Condition (Rosgen, Dave, 1942)

Table 22
Bankful calibration

DATA OBSERVASI						Q Bankful (M3/S)-HECRAS	AKURASI	ELEVASI W.S		
LOKASI	STATION	A (M2)	P (M2)	V (m/s)	Q Bankful (M3/S)			Observasi	Hec-Ras	Akurasi
HILIR	8400	25.69	13.73	2.12	54.46	53.44	98.12%	+2.21	+2.26	97.79%
TENGAH	12700	12.15	9.51	4.66	56.62	55.85	98.64%	+6.50	+6.74	96.44%
HULU	14500	11.43	7.71	5.02	57.38	55.9	97.42%	+7.99	+8.10	98.64%

Because the accuracy value between field observation values and modeling conditions is quite accurate, the preparation of upstream and downstream boundary data is sufficient to represent the existing conditions and hydraulics and sedimentation modeling can be carried out for various current and future conditions. To ensure that the bankful value that is obtained is correct, bankful value analysis is also carried out by analyzing the first runoff that occurs in the Sayung River cross section and then looking at the bankful debit value.

Table 23. Bankful discharge on first runoff

HEC-RAS Plan: Plan 16 River: sayung Reach: Reach 1 Profile: 09APR20

Reach	River Sta	Profile	ROB Elev	LOB Elev	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope
			(m)	(m)	(m3/s)	(m)	(m)	(m)	(m)	(m/m)
Reach 1	1100	09APR2022 0900	1.90	1.99	56.96	-1.70	1.31		1.33	0.000010
Reach 1	1000	09APR2022 0900	1.65	1.75	57.03	-1.72	1.31		1.32	0.000010
Reach 1	900	09APR2022 0900	1.72	1.73	57.11	-1.74	1.31		1.32	0.000009
Reach 1	800	09APR2022 0900	1.31	1.31	57.18	-1.77	1.31		1.32	0.000009
Reach 1	700	09APR2022 0900	1.47	1.44	57.26	-1.79	1.31		1.32	0.000009
Reach 1	600	09APR2022 0900	2.08	1.75	57.34	-1.82	1.30		1.32	0.000009
Reach 1	500	09APR2022 0900	1.96	1.66	57.41	-1.84	1.30		1.32	0.000009
Reach 1	400	09APR2022 0900	1.81	1.72	57.49	-1.87	1.30		1.32	0.000010
Reach 1	300	09APR2022 0900	1.65	1.74	57.57	-1.89	1.30		1.32	0.000008
Reach 1	200	09APR2022 0900	1.76	1.62	57.66	-1.92	1.30		1.32	0.000008
Reach 1	100	09APR2022 0900	1.76	2.06	57.74	-1.94	1.30		1.31	0.000007
Reach 1	0	09APR2022 0900	1.56	1.79	57.83	-1.95	1.30	-1.22	1.31	0.000006

As seen in the table of results from the hec-ras test, it can be seen that the first runoff occurred at station $\pm$ 800 at an elevation of $\pm$ 1.31m with a discharge value of $\pm$ 57.18 m^3/s which has results not far from the bankful value using the Rosgen method, so the modeling parameters are in accordance with the existing ones.

b) Flood and Sediment Modeling

The sequence of modeling that will be carried out is:

(1) Modeling uses Hec-ras Quasi-Unsteady Flow using actual data from the results of the calibration daily discharge analysis using the sacramento method.

(2) Modeling uses Hec-ras Quasi-Unsteady Flow using modified Sacramento data to baseflow discharge, then in year 8 given flood discharge Q2, Q25, Q50.

Condition results from daily discharge analysis using Sacramento with data correlation with CH 81.32% for 8 years from 2014 – 2021

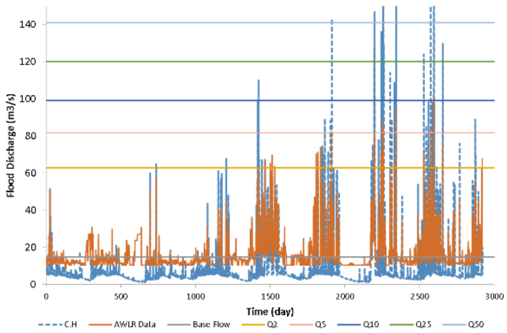

Figure 16. Database (calibration AWLR & Rainfall with sacramento method)

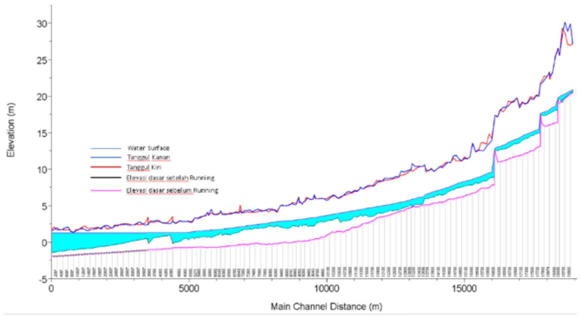

Figure 17. Bankful Sedimentation and debit simulation

Deskription :

1) Upstream boundary: calibrated daily discharge data with sacramento
2) Downstream boundary : MSL $\pm$1.3m
3) The discharge shown in the figure is a bankful debit $\pm$57.18 m^3/s.
4) The total sediment that occurred was $\pm$ 378,977 m^3

The next condition is the modification of the daily discharge to a baseflow discharge for 8 years and the 8th year is given a Q2 flood discharge to determine the cross-sectional capacity.

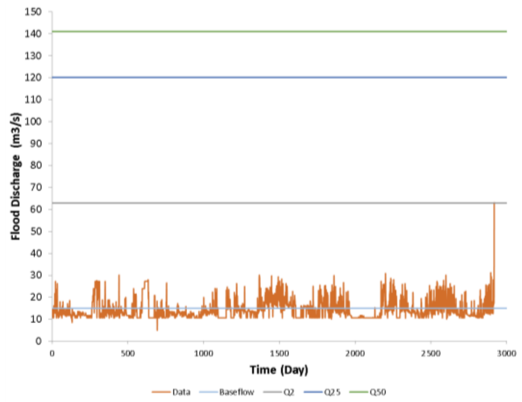

Figure 18. Modified AWLR data to baseflow and discharge Q2 data.

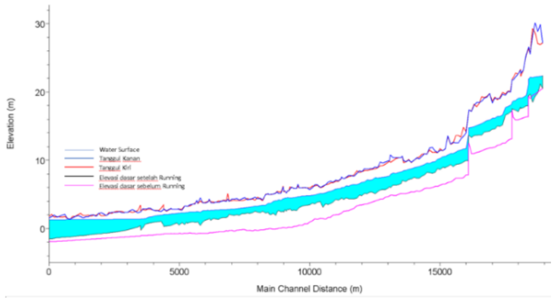

Figure 19. Results of modeling base flow and discharge Q2

Deskription :

In this condition, there is almost no difference when compared to running conditions as is. The difference is the location of the sedimentation that occurs, the conditions under which there is more sedimentation downstream (this is because at certain times there is a high discharge that carries sediment further downstream). The total sedimentation that occurs in this analysis is $\underline{+}$ 360.117 m^3.

The next condition is the modification of the daily discharge to a baseflow discharge for 8 years and the 8th year is given a Q25 flood discharge to determine the river capacity.

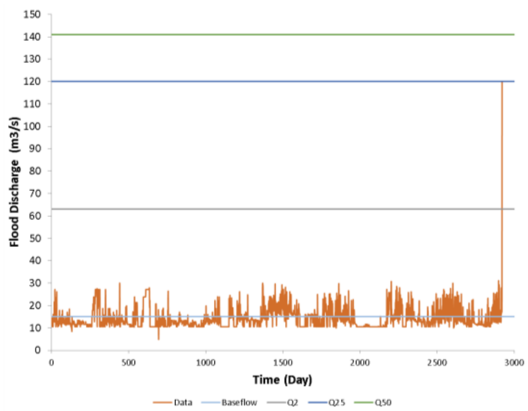

Figure 20. Modified AWLR data to baseflow and discharge Q25 data.

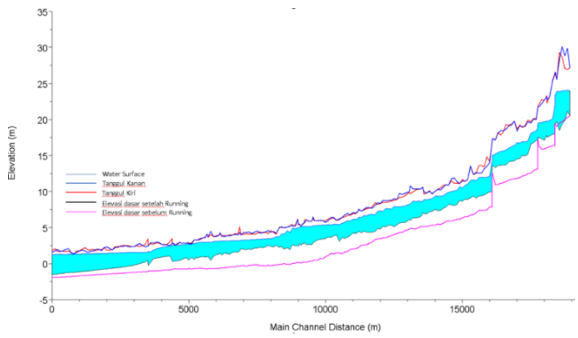

Figure 21. Results of modeling base flow and discharge Q25

Table 24. Baseflow and Q25 running results

HEC-RAS Plan: Plan 15 River: sayung Reach: Reach 1 Profile: 30Des201

Reach	River Sta	Profile	Q Total	ROB Elev	LOB Elev	W.S. Elev	Crit W.S.	E.(
			(m3/s)	(m)	(m)	(m)	(m)	
Reach 1	5600	30Des2017 0000	120.00	3.62	3.71	2.95		
Reach 1	5500	30Des2017 0000	120.00	3.54	3.58	2.94		
Reach 1	5400	30Des2017 0000	120.00	3.45	3.32	2.93		
Reach 1	5300	30Des2017 0000	120.00	3.25	3.22	2.85		
Reach 1	5271	30Des2017 0000	120.00	3.29	3.28	2.87		
Reach 1	5200	30Des2017 0000	120.00	3.27	3.29	2.77		
Reach 1	5100	30Des2017 0000	120.00	2.68	2.85	2.76		
Reach 1	5000	30Des2017 0000	120.00	2.79	2.81	2.68		
Reach 1	4972	30Des2017 0000	120.00	2.90	2.88	2.72		
Reach 1	4900	30Des2017 0000	120.00	2.83	2.82	2.70		
Reach 1	4800	30Des2017 0000	120.00	2.82	2.82	2.61		

Deskription :

The results of this test show that flood runoff occurs at the most upstream sta, which is sparse + 5.1 km from the downstream with a water level of + 2.76m on the right bank embankment height of + 2.68m or approximately + 8cm of runoff.

The next condition is the modification of the daily discharge to a baseflow discharge for 8 years and the 8th year is given a Q50 flood discharge to determine the river capacity.

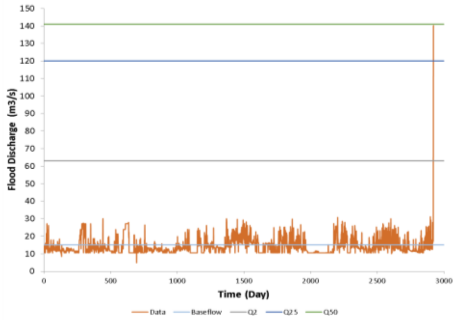

Figure 22. Modified AWLR data to baseflow and discharge Q5 data

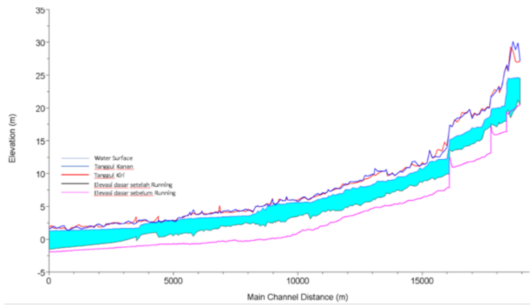

Figure 23. Results of modeling base flow and discharge Q50

Table 25. Baseflow and Q50 modeling results

Profile Output Table - Standard Table 1

File Options Std. Tables User Tables Locations Help

HEC-RAS Plan: Plan 15 River: sayung Reach: Reach 1 Profile: 30Des2017 0000

Reach	River Sta	Profile	Q Total	LOB Elev	ROB Elev	W.S. Elev	Crit W.S.	E.G. Elev
			(m3/s)	(m)	(m)	(m)	(m)	(m)
Reach 1	5600	30Des2017 0000	141.00	3.71	3.62	3.13		3.21
Reach 1	5500	30Des2017 0000	141.00	3.58	3.54	3.11		3.20
Reach 1	5400	30Des2017 0000	141.00	3.32	3.45	3.11		3.18
Reach 1	5300	30Des2017 0000	141.00	3.22	3.25	3.02		3.16
Reach 1	5271	30Des2017 0000	141.00	3.28	3.29	3.05		3.15
Reach 1	5200	30Des2017 0000	141.00	3.29	3.27	2.93		3.12
Reach 1	5100	30Des2017 0000	141.00	2.85	2.68	2.93		3.09
Reach 1	5000	30Des2017 0000	141.00	2.81	2.79	2.83		3.06
Reach 1	4972	30Des2017 0000	141.00	2.88	2.90	2.89		3.02
Reach 1	4900	30Des2017 0000	141.00	2.82	2.83	2.87		3.01
Reach 1	4800	30Des2017 0000	141.00	2.82	2.82	2.77		2.98
Reach 1	4700	30Des2017 0000	141.00	2.87	2.86	2.81		2.93
Reach 1	4682	30Des2017 0000	141.00	2.92	2.95	2.74		2.92

Deskription :

The results of this test show that flood runoff occurs at the most upstream sta, which is sparse ± 5.1 km from downstream with a water level of ± 2.93m on the right bank embankment height of ± 2.68m or approximately ± 25cm of runoff.

Conclusions

This method needs to be considered for flood analysis because flood analysis with high probabilities (Q25, Q50, dts) with unsteady flow is felt to be unable to represent the existing condition of the river in nature, because the river naturally occurs sedimentation and the running Hec-ras unsteady flow does not predict sedimentation conditions that occurred. In the observation of the simulation results for 8 years with the upstream base flow limit, it can be seen that the results of deposition in the cross section of the river tend to have a balanced deposition from downstream to upstream. The result is different from the upstream limit, which has a flood discharge almost every year, has sediment deposits that tend to be downstream because the flood discharge that occurs will carry sediment upstream to downstream.

It can be seen from the results of the analysis of the upstream boundary conditions as they are and the conditions modified to baseflow discharge, sediment deposits in what conditions are greatly influenced by the slope of the river channel. Seen at sta 13,000 with a steeper slope than the others has minimal sediment (sediments that occur more downstream due to a gentle slope). The lowest elevation of the Sayung River embankment is an elevation of 1.31m at STA 800, which means that the condition of this embankment will often be overturned by floods caused by tides (MSL: 1.3m, MHWL: 1.82, HHWL 2.3m). So even though there is no rain If there is a condition downstream of the Sayung River, flooding can occur which is caused by tides.

Looking at the results of the analysis, at least in 2030 if there is no raising of the embankment or maintenance of the river channel then if there is a flood discharge flow Q25 (120m3/s) there will be runoff on the embankment from downstream to upstream at Sta 5100 (runoff at Sta 5100 is 25cm high).

BIBLIOGRAPHY

Liu,Z., Sediment Transport, ed. 1, Aalborg University, 1998.

How to Calculate Flood Discharge with Synthetic Unit Hydrograph Method, Bandung. Google Scholar

General Procedure for Calculation of Synthetic Unit Hydrographs by the ITB Method, Bandung. Google Scholar

Course materials for River Engineering and Flood Control, Bandung. Google Scholar

Least Square Method for Analysis of Tidal Harmonic Constants on Gili Raja Island, Sumenep Madura Regency, UGM. Google Scholar

Open-Channel Hydraulics, New York: McGraw-Hill Book Company. Google Scholar

Gibson S, et. al., 2020,. Sediment Transport User's Manual Version 6.0, California, USACE. Google Scholar

Applied River Morphology , Amsterdam, Wildand hydrology. Google Scholar

Setiawan,B.,Soeharno,A.W.H.,Nugroho,E.O., Hassan, C., 2022, Sedimentation Study In the batu Merah (Check Dam Rinjani) Ambon City, Bandung.

Flood Control and ROB Project Planning Documents Semarang - Demak, Semarang.

Gate operational standards BKT river Documents, Semarang.

Semarang-Demak Toll Road Integrated with Sea Dike Project (Semarang-Sayung Section), Semarang. Google Scholar

PUPR, 2017, Technical Instructions for Calculation of Flood Discharge in Dams. Jakarta. Google Scholar

Investigation Survey and design optimization of the Pucang Gading weir, Bandung. Google Scholar

Procedure for Calculation of Planned Flood Discharge, 2016 (ARF). Google Scholar

Flood control method module, flood control training. Google Scholar

Copyright holder:
Angga Yoga Pranatan, Indratmo Soekarno, Arie Setiadi Moerwanto, Eka Oktariyanto Nugroho (2022)

First publication right:
Syntax Literate: Jurnal Ilmiah Indonesia

This article is licensed under: