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Planning for Normalization of the Apu River in the Post-Mining Area

Risal Gunawan[1]*, Rika Ernawati[2], Tedy Agung Cahyadi [3]
[1] Department of Mining Engineering, Universitas Pembangunan Nasional "Veteran" Yogyakarta, Indonesia.
*e-mail: risalgunawan92@gmail.com

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Abstract

Miners often leave traces such as irregular river channels, holes in the mining area without repair measures, the mining area is located in Boyolali Regency, precisely in the Apu River area. Apu River is one of the centers of Merapi sand mining which is quite large, mining activities have the potential to cause river overflows. For this reason, improvements need to be made. This study aims to plan a post-mining model in a river that has changed, the method in this study is to take water discharge directly with 5 sampling points and analyze the distribution of gumbell rainfall for 10 years and make a comparison, then a trapezoidal open channel plan is made and modeled in HEC-RAS software. Based on the results of taking river water discharge, it is known that the maximum river flow velocity is 0.57 m^3/second, while the results of the rainfall analysis are 2.77m^3/second. so that in repairing the cross-section using a higher water discharge. The method of repairing the river cross-section is the trapezoidal open channel method, the dimensions of the open channel are designed using a manning roughness of 0.30. The initial design depth of the channel was 1.35 m plus 0.60 m to avoid flood overflow, so that the channel depth became 1.95 m.

1. Introduction

Mining activities are feared to have a negative impact on the destruction of evacuation routes and the risk of natural disasters such as landslides and floods [1]. Miners often leave traces [2] such as irregular river channels, holes in the mining area without repair measures [25]. The mining area is located in Boyolali Regency, precisely in the Apu River area.

The Apu River is one of the centers of Merapi sand mining which is quite large, mining activities have the potential to cause river overflows [3]. Sand and stone mining in river areas disrupts the provision of clean water and changes river flow patterns [4,5]. For this reason, repairs need to be made, [6]. The existence of rivers plays an important role for the community, especially for household water sources and rice field irrigation, and other needs so that normalization is needed after mining [7]. Therefore, the sustainability of rivers needs to be maintained, especially river channels that are safe for the community, namely by making appropriate designs in mining areas [8].

This study aims to plan a post-mining model in a river that has changed [9] from former mining in the river channel to restore the function of the river that has been disturbed because it is closed from mining activities, by making higher embankments and repairing the cross-section, so that it can prevent the risk of flooding [2], by modeling the river channel [10,11] and repairing the cross-section [9]. The post-mining plan model considers areas by maintaining river flow patterns. The concept of post-mining area management in river areas is very important to be implemented to prevent flooding as part of the concept of good mining practice and requires support from various parties [12].

2. Methodology

The research was conducted at a mining location located on the Apu River, along ± 1 km of Selo District, Boyolali Regency. By taking water discharge at 5 sample points

Table 1. Measurements at various depths

No.	River Depth (m)	Measuring Depth	V average (m/s)
1.	0-0,6	0,6h	V=V0,6
2.	0,6-3,0	0,2h dan 0,8h	V=(V0,2+V0,8)/2
3.	3,0-6,0	0,2h, 0,6h dan 0,8h	V=(V02+V0,6+V0,8)/3
4.	> 6,0	0,2h,0,6h, 0,8h dan b	V=(Vs+3V0,2+3V0,6+3V0,8+Vb)/5

Source: Surya and Setiawan, [14].

2.1 Current meter

River water discharge sampling with the help of a current meter or also known as a current measuring instrument, is usually used to measure flow at low water. Current meter is the most widely used speed measuring instrument because it provides quite high accuracy. This tool is the most widely used speed measuring instrument because it provides quite high accuracy. Designing a digital current meter to measure water flow velocity for open channel rivers [13].

Current Meter Measurement Method:

1. Measure the width of the water to be measured by the current meter, then divide it into three parts, namely the left side, the middle part and the right side.
2. Measure the depth of the water and determine the depth points where the speed will be measured.
3. After the water depth is known, measurements at various depths are in accordance with Table 1.

2.2 Rainfall

Rainfall data is needed as basic data for consideration of direct measurement data to improve river cross-sections [15]. The rainfall and temperature data used in this study are data from 2012 to 2021 from BPS Boyolali data [16]. Data processing is carried out using the Gumbell method, which is a method based on normal distribution (extreme price distribution). Rainfall greatly affects river channels, because the amount of rainfall will affect the amount of water that must be accommodated. The planned rainfall is the maximum rainfall that may occur during the life of the drainage facility. Rainfall analysis is carried out to obtain rainfall in a certain rainfall recurrence period and short-term rainfall intensity, in this case the intensity of one hour of rainfall. Determination of planned rainfall with the Gumbell distribution (Suripin, 2004) [19] can be calculated using the following formula:

$$Xt = \bar{x} + k\ x\ Sd \quad \text{.......} \quad (1)$$

$$k = \frac{(Yt - \overline{Yn})}{Sn}$$

Description:

Xt = Maximum planned daily rainfall (mm/day) with a certain rainfall return period (PUH).
$\overline{x}$ = Average rainfall (mm/day).
k = Reduced variate factor.
Sd = Standard Deviasi.
Sn = Standard deviation of the variate reduction, depending on the amount of data (n).
Yt = Variate reduction value.
$\overline{Yn}$= The average value of the variate reduction, depending on the amount of data (n).

Reduced Mean ($\bar{Y}n$) can be calculated using the following formula:

$$\overline{Yn} = -In\left[-In\left\{\frac{(n+1)-m}{n+1}\right\}\right] \quad \text{.......} (2)$$

Description:

n = Number of samples.
m = Sample order (1,2,3…) from largest to smallest value.

Reduced Variate (*Yt*) can be calculated using the following formula:

$$Yt = -In\left\{-In\left(\frac{T-1}{T}\right)\right\} \quad \text{.......(3)}$$

Description:
T = Repeat period.

Standard Deviation (*Sd*) can be calculated using the following formula:

$$d = \sqrt{\frac{\Sigma_{i=1}^{n}(x-\overline{x})^2}{n-1}} \quad \text{.......(4)}$$

Reduced Standard Deviation (*Sn*) can be calculated using the following formula:

$$Sn = \sqrt{\frac{\Sigma_{i=1}^{n}(Yn-\overline{Yn})^2}{n-1}} \quad \text{.......(5)}$$

2.3 Rainfall Return Period

Rainfall will show a tendency to repeat. This can be seen from the data that the analysis covers a long period. In relation to this, in rainfall analysis, the term return period is known, which means the possibility/probability of a certain level of rainfall recurring. In designing water structures or in this case river drainage facilities, one of the design criteria is the planned rainfall, namely rainfall with a certain return period or the possibility of occurring once in a certain period of time. The calculation can be done using the following equation:

$$Rh = 1 - \left(1 - \frac{1}{Tr}\right)^n \% \quad \text{.......(6)}$$

Description:
Rh = Hydrological Risk (%)
Tr = Rainfall Return Period (years)
n = Mine Age (years)

The rainfall recurrence period is presented in table 2:

Table 2. Planned Rainfall Return Period

Description	Rainfall Recurrence Period
Open Area	0-5
Mining Facilities	2-5
Mine Slopes and Stockpiles	5 -10
Main Well	10-25
Mine Circumference Drainage	25
River Flow Diversion	100

Source: Sosrodarsono, et all. 1983 [17]

Rainfall Intensity

Rainfall intensity is the amount of rain per unit of time, expressed in mm/hour. Rainfall intensity is obtained from calculations using the Mononobe formula. The value of rainfall intensity will then be used in calculating the water discharge entering the river channel. The calculation can be done using the following equation:

$$I = \frac{R_{24}}{24}\left(\frac{24}{t}\right)^{\frac{2}{3}} \quad \text{.......(7)}$$

Description:
I = Rainfall intensity (mm/hour).
T = Rain duration or constant time (hours).
R_{24} = Maximum rainfall (mm).

Rainfall frequency analysis is needed to determine the type of distribution that has the following statistical parameters:
Average rainfall ($\bar{x}$)

$$\bar{x} = \frac{\Sigma xi}{n} \qquad (8)$$

Description:
Σxi = Rainfall Amount
n = Amount of data

The following is a classification of rainfall in table 3:

Table 3. Classification of Rainfall Based on Rainfall Intensity

No.	Rainfall Classification	Rainfall (mm)	
		1 hour	24 hours
1	Very Light Rain	< 1	< 5
2	Light Rain	1 – 5	5 – 20
3	Normal Rain	5 – 10	20 – 50
4	Heavy Rain	10 – 20	50 –100
5	Very Heavy Rain	>20	> 100

Source: Aldrian et all 2011 [18]

2.4 Rainfall Catchment Area
A rain catchment area is an area that is the boundary where rainfall that falls in the area will be collected at the lowest place in the research area. In the division of rain catchment areas, direct observation in the field and observation on the rain map are carried out. The classification of rainfall can be seen in Table 3. topography of the mining area. Direct observation in the field aims to determine the direction of the overflow flow and the problems caused by the overflow flow, so that later a drainage system can be designed that can overcome existing problems

2.5 Run-off Water
Run-off water (surface run-off) is part of the rainfall that flows above the ground surface that will enter the ditches and gutters which then join into tributaries and finally become rivers flowing towards lakes or the sea. This flow occurs because rainwater that reaches the ground surface is not infiltrated due to the intensity of rain exceeding the infiltration capacity or other factors, such as slope, shape and compactness of the land surface and vegetation.

Table 4. Run-off Coefficient Value

Slope	Land Use	Run-off Coefficient
Slope < 3%	Rice fields and swamps	0,2
	Forests and plantations	0,3
	Settlements	0,4
A bit tilted (3 – 15%)	Settlements	0,5
	Light vegetation	0,6
	Bare land	0,7
Steep Slope (>15 %)	Forests	0,6
	Settlements	0,7
	Light vegetation	0,8
	Mining areas	0,9

Source: Aldrian et all, 2011 [18]

The calculation of run-off water discharge is carried out using the following rational formula (see also Table 4):

Q_{Maks} = 0,278 x C x I x A …………………………………………...………….(9)

Description:
Q_{maks} = Maximum run-off discharge (m^3/ second).
C = Run-off coefficient (Table 4).
I = Rainfall intensity (mm/hour).
A = Area of rain catchment area (Km^2).

2.6 Trapezoidal Open Channel

An open channel is a natural or artificial channel that has a free surface at atmospheric pressure where water flows with a free water surface. Flow behavior is known as fluid mechanics. One classification of flow through an open channel is called uniform, namely if various types of flow such as depth, wet cross-section, velocity and discharge at each cross-section along the flow are constant as in this study, the open channel used in this study is a trapezoidal shape because it will channel rainwater runoff with a large discharge, the nature of the flow continues to flow with small fluctuations adjusted in the research area, the area of free land is available. Calculation of open channel dimensions using the Manning formula as follows:

$$Q = \frac{1}{n} \, x \, S^{\frac{2}{3}} \, x \, R^{\frac{2}{3}} \, x \, A \quad \ldots\ldots(10)$$

Description:
Q = water discharge (m^3/secon)
R = Hydraulic spokes (m)
S = Channel slope (%)
A = Wet cross-sectional area (m^2)
N = Manning's roughness coefficient [19].

The Manning hardness table according to Chow in 1959 in Sanusi and Pratiwi 2019 [20] is presented in Table 5.

2.7 HEC_RAS Software

Hydrologic Engineering Centre-River Analysis System (HEC_RAS) is a software designed to be used as a flood discharge forecasting tool in rivers. The software is able to predict the time and magnitude of peak discharge and runoff volume in a river quickly and does not require overly complicated input data. This model only requires input data such as discharge data, rainfall data, watershed area and a few parameters that facilitate regionalization to simulate flow at nodes where discharge measuring instruments are not available [21. In the HEC_RAS software, it basically studies the condition of river water which is influenced by hydrology and hydraulics and further river handling as needed. In general, this software provides the following functions:

1. File Management
2. Data input and editing
3. Hydraulic Analysis
4. Output of tables, graphs and images [22]

Table 5. Typical values of Manning's hardness coefficient n,

No.	Channel Type	*value n*		
		Minimum	Normal	Maksimum
1	Concrete			
	Straight and free from dirt culverts	0,010	0,011	0,013
	Culverts with curves and minimal dirt/disturbances	0,011	0,013	0,014
	Polished concrete	0,011	0,012	0,014
	Well controlled drains	0,013	0,015	0,017
2	Straight and uniform land			
	Clean new	0,016	0,018	0,020
	Clean and weathered	0,018	0,022	0,025
	Gravel	0,022	0,025	0,030
	Short grass, few weeds	0,022	0,027	0,033
3	Natural channels			
	Clean straight	0,025	0,030	0,033
	Clean, winding	0,033	0,040	0,045
	Many weeds	0,050	0,070	0,08
	Short-grass floodplain	0,025	0,030	0,35
	Channel in thickets	0,035	0,040	0,07

3. Results and discussions

3.1. River Water Discharge Taking

The study was conducted in the Apu River with 5 sampling locations starting from Station 01 (downstream) to station 05 (upstream) which have different water discharges at each station in this study to take water discharge using Current Meter type Flowatch FL-03 and meters to determine the length of the river profile, the results of observations in the field can be seen that the depth in this research area is on average below 1 meter so that in this study using the average depth is used with the formula V = V0.6.

From the results of river water discharge measurements each month for four months, the following are the average results of monthly measurements for each station:

a) Station 1 the average results of river water discharge velocity measurements at station 1 can be presented in Table 6.

Table 6. Average river water discharge sampling at station 1

Station	Profile No.	h (m) depth	Reading (m/sec)	L (m)	H (m)	River Width (m)
1	h1	0,6	0,3	1	0,15	4,10
	h2	0,6	0,7	2,1	0,21	4,10
	h3	0,6	0,3	1	0,14	4,10

b) Station 2 the average results of river water discharge velocity measurements at station 2 can be presented in Table 7.

Table 7. Average river water discharge sampling at station 2

Station	Profile No.	h (m) depth	Reading (m/sec)	L (m)	H (m)	River Width (m)
2	h1	0,6	0,3	1	0,15	3,8
	h2	0,6	0,7	2	0,21	3,8
	h3	0,6	0,2	0,8	0,16	3,8

c) Station 3 the average results of river water discharge velocity measurements at station 3 can be presented in Table 8.

Table 8. Average river water discharge sampling at station 3

Station	Profile No.	h (m) depth	Reading (m/sec)	L (m)	H (m)	River Width (m)
3	h1	0,6	0,4	0,9	0,19	3,47
	h2	0,6	0,8	1,8	0,24	3,47
	h3	0,6	0,3	0,7	0,19	3,47

d) Station 4 the average results of river water discharge velocity measurements at station 4 can be presented in Table 9.

Table 9. Average river water discharge sampling at station 4

Station	Profile No.	h (m) depth	Reading (m/sec)	L (m)	H (m)	River Width (m)
4	h1	0,6	0,5	0,8	0,17	3,31
	h2	0,6	0,9	1,6	0,21	3,31
	h3	0,6	0,3	0,91	0,14	3,31

e) Station 5 the average results of river water discharge velocity measurements at station 5 can be presented in Table 10.

Table 10. Average river water discharge sampling at station 5

station	Profile No.	h (m) depth	Reading (m/sec)	L (m)	H (m)	River Width (m)
5	h1	0,6	0,5	0,5	0,16	1,61
	h2	0,6	0,7	0,6	0,23	1,61
	h3	0,6	0,4	0,51	0,18	1,61

Field observations of the Apu River show a pure dendric river flow pattern. In general, this river flow pattern is controlled by homogeneous lithology, namely sandstone. Where this river flow pattern has a flow structure that is controlled by the type of rock. The research area is ± 1 km long with 5 sampling points. The dendritic flow pattern is one of the river flow patterns with branches that resemble lines in the cross-section of a leaf. Basically, this flow pattern is controlled by homogeneous lithology, where this river flow pattern has a flow structure that is controlled by the type of rock. From the results of research and analysis, it is known that the maximum river flow velocity at station 04 is 0.57 m / sec and the minimum is at station 2, namely 0.40 m / sec. The following is a picture of the water discharge in the Apu River in Figure 1.

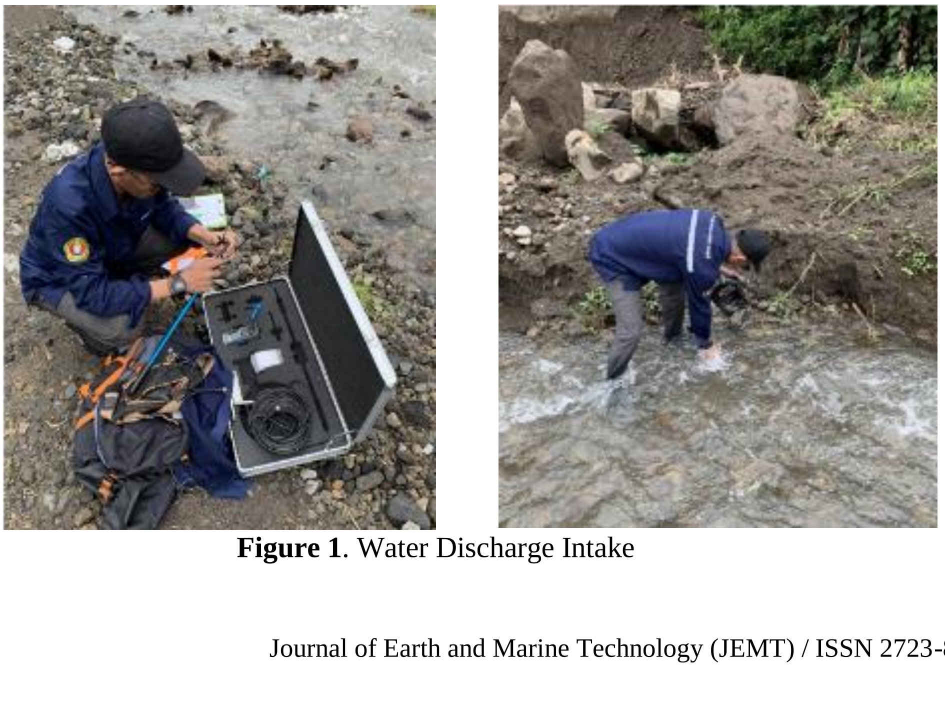


Figure 1. Water Discharge Intake

3.2. Rainfall Analysis

Rainfall is used as the basis for calculating all components in the river flow system, rainfall data using the Gumbell distribution formula from daily rainfall data for 10 years (2013-2022) is based on the distribution of maximum rainfall with a value of 16.50 mm/day. Rainfall data is presented in Table 11:

3.3. Calculation of Planned Rainfall Variables

The results of the calculation of planned rainfall with a value of 16,50 mm/day in a 10-year rainfall recurrence period. The results of the Gumbell distribution calculation are used to determine the intensity of rain using the Mononobe formula.

Table 11. Rainfall Data for Boyolali Regency

Year	Month (mm/month)												Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
2013	476	215	236	175	121	122	0	0	0	90	275	674	2384
2013	799	411	336	367	304	182	191	85	0	285	195	494	3649
2014	373	409	240	243	159	86	0	0	0	13	126	246	1895
2015	400	356	351	269	230	130	124	147	222	273	288	375	3165
2016	439	418	277	256	160	78	17	0	74	173	421	301	2614
2017	410	430	251	96	39	57	0	0	9	7	294	211	1804
2018	441	426	285	255	139	0	0	0	0	2	372	300	2220
2019	435	414	294	260	160	13	5	19	6	201	219	300	2326
2020	454	409	291	250	159	169	13	20	126	136	283	258	2568
2022	465	420	434	450	403	420	155	248	240	279	150	279	3943
Average	469	391	299	263	187	126	50	52	68	146	262	344	2657

Source: BPS Boyolali Regency, (2014-2023)

The planned rainfall is calculated as the average maximum rainfall, 16.50 mm/day Reduced Mean (Yn) 4.95, average Reduced Mean $(\overline{(Yn)})$ 0.50, Standard Deviation (SD) 4.00, Reduced Standard Deviation (Sn) 1.00.

3.4. Rainfall Intensity

Rainfall intensity is the height or depth of rainwater per unit of time. The general nature of rain is that the shorter the rain lasts, the higher the intensity tends to be and the greater the recurrence period, the higher the intensity. The relationship between intensity, duration of rain, and frequency of rain is usually expressed in the Intensity-Duration-Frequency Curve (IDF).

The magnitude of 1-hour rainfall intensity is calculated using the Partial series method, namely rainfall data in one hour and finding its threshold value, then the calculation is continued using the Gumbell Distribution. Rainfall intensity is used to calculate runoff water discharge. Calculation of rainfall intensity using the Mononobe formula The R24 price is the planned daily rainfall obtained from the calculation, which is 20.51 mm/day and the t value = 5 hours. Using the Mononobe formula, the following is presented in table 12 the calculation of rainfall intensity.

Table 12. Calculation of rainfall intensity.

CH	Time	Xt	Rain Intensity					
Average	duration of rain		1	2	3	4	5	24
(mm/day)	(hours)	(mm/day)	(mm/hr)					
	1,00		0,85	1,36	1,78	2,15	2,50	7,11
	2,00		0,54	0,85	1,12	1,36	1,57	4,48
16,50	3,00	20,51	0,41	0,65	0,85	1,04	1,20	3,42
	4,00		0,34	0,54	0,71	0,85	0,99	2,82
	5,00		0,29	0,46	0,61	0,74	0,85	2,43

Based on the results, the calculation then obtained the value of the intensity, namely 2.43 mm/day with the rain conditions categorized as light rain, slightly wet when exposed to rain.

3.5. Run-off Water Discharge

Run-off water discharge can be known from the intensity of rain which can be used to calculate the discharge of rainwater run-off. To find out the discharge of run-off water, the area of the rainwater catchment area is needed which is carried out by observation at the research location. In the rainwater catchment area, the area has a condition without vegetation so that it has a coefficient value of 0.9 with an area of 4.56 km^2. The total water discharge can be known through the addition of the runoff water discharge and rainwater discharge of 2.77 m^3/second. The following are the Results of the Discharge Calculation in table 13.

Table 13. Discharge Calculation

Description		Value	Unit
Rainfall Catchment Area	A	4,56	Km^2
Rainfall Intensity	I	2,43	mm/hour
Run-off Coefficient Value	C	0,9	
Runoff water discharge	Q_{max}	2,77	m^3/second

3.6. Open Channel Design

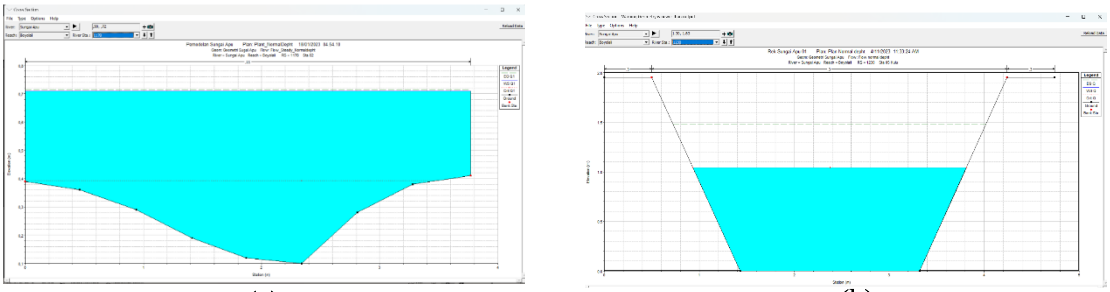
Open channels are one of the components of the river flow system that functions as a place for river water to flow, both from runoff and groundwater, open channels are made based on the location of the rain catchment area. Open channels have various types of cross-sections that are commonly used in mining areas, namely trapezoidal shapes that have a good tiered shape for water flow and trapezoidal cross-sections tend to be easy to form. The depth of the channel is added 0.6m to avoid flooding, so that the depth of the channel becomes 1.95m to anticipate the occurrence of water overflow and sedimentation that occurs in open channels. The design of open channels uses maximum water discharge where the results of field measurements are 0.57 m3/second while the results of the analysis of runoff water discharge are known to be 2.77 m^3/second.

So that the open channel planning uses 2.77 m^3/second, the calculation results using equation (10) are known as the channel wall slope (α) 60°, Water depth (h) 1.35 m, Channel depth (d) 1.95 m, Channel base width (B) 1.55m, Upper channel base width (b) 3.11 m Channel wall length (*a*) 1.55 m.

3.7. River Channel Modelling

Normalization is done by enlarging the dimensions of the river cross-section in the part of the river where overflow occurs, the size of the river cross-section is made in such a way that overflow does not occur. Trapezoidal open channels by enlarging the dimensions of the main channel, then modeling is carried out in the HEC_RAS software [23]. The normalization carried out on the Apu River so that it can flow discharge is by dredging and raising the embankment. In addition, the irregular river cross-section is made into a trapezoid [24]. The river normalization system is an effort applied to post-mining locations to prevent or release water so that flooding does not occur [21]. The selection of the cross-sectional shape of the open channel is based on the type of soil or rock where the channel will be made, the water discharge to be flowed and the type of construction to be made on the walls or bottom of the channel [11]. The elevation at station 05 as the upstream has a height of 1230 meters above sea level, station 01 has an elevation of 1169 meters above sea level as the downstream station. From the results of cross-sectional improvements and HEC_RAS software analysis, it was found that with a flood elevation of 0.87 m at each station. The Apu River is predominantly composed of gravel and gravel, so that in the HEC_RAS modeling, the Manning hardness coefficient n, 0.30 was used. The channel flow in the research area has a flow depth that does not change or is constant over time so that using steady flow data functions to calculate the permanent flow water surface profile, the distance between station 01 (downstream) to the next station is ± 250 m to station 05 (upstream).

The results of the Hydraulic Analysis with modeling in the HEC_RAS software, obtained a comparison of the cross-section before and after the planned normalization. which is presented in Figure 2 as follows:



(a) (b)

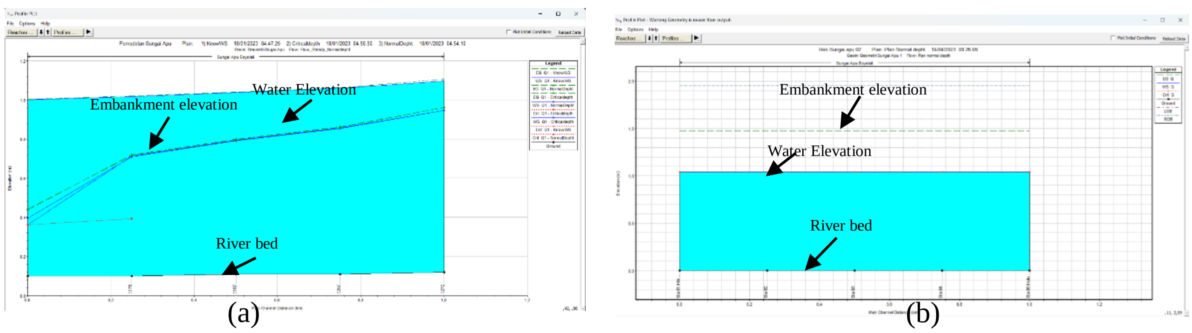
Figure 2. River Normalization Before (a) and After Normalization (b)

Comparison of elevation before and after normalization can be presented in Table 14

Table 14. Comparison of Elevation Before and After Normalization

Station	Before Normalization			After Normalization		
	Flood elevation	Right Embankment Elevation	Left Embankment Elevation	Flood elevation	Right Embankment Elevation	Left Embankment Elevation
1	0,39	0,36	0,37	0,87	1,95	1,95
2	0,71	0,41	0,39	0,87	1,95	1,95
3	0,79	0,46	0,47	0,87	1,95	1,95
4	0,86	0,51	0,56	0,87	1,95	1,95
5	0,96	0,58	0,59	0,87	1,95	1,95

Table 14 shows a comparison of river cross-sections before river cross-section repair (normalization) at stations 1 to 5, before normalization the river water was higher than the embankment, causing flooding, so it was necessary to repair the embankment. The results of embankment repair and modeling in the HEC_RAS software obtained a flood elevation of 0.87 m at each station, for the left embankment elevation of 1.95 m and the right embankment 1.95 m from these results there was no overflow or flooding. The following is a plot of the river water level profile before and after normalization.



(a) (b)

Figure 3. Before normalization (a) after normalization (b)

The figure shows that before the river normalization in the Apu River, flooding occurred almost along the riverbank. However, after normalization, flooding can be avoided. Efforts that can be made to deal with problems in the Apu River are:

a) Reconstruction of the river cross section at the end of post-mining
b) Making channels in the form of trapezoids
c) Reforestation with hard plants is needed
d) Construction of retaining walls in several locations prone to landslides.

4. Conclusion

The river model in the post-mining area was repaired by repairing the river cross-section including, the slope of the channel wall *(α)* 60°, the water depth *(h)* 1.35 m, the depth of the channel *(d)* 1.95 m, the width of the channel base *(B)* 1.55 m, the width of the upper channel base *(b)* 3.11 m and the length of the channel wall *(a)* 1.55 m, from the repair of the cross-section can overcome flood overflows in the Apu River. The repair of the cross-section and HEC_RAS software modeling obtained a maximum water elevation of 0.87 m and a height of 1.95 m at each station.

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References:

[1] Desalegn, H., & Mulu, A. (2021). Mapping flood inundation areas using GIS and HEC-RAS model at Fetam River, Upper Abbay Basin, Ethiopia. *Scientific African*, 12, e00834. https://doi.org/10.1016/j.sciaf.2021.e00834

[2] Gunawan, R., Nurkhamim., and Izza F, R,. (2021). Overview Metode Perencanaan Pengelolaan Lahan Bekas Penambangan, *Prosiding Nasional Rekayasa Teknologi Industri dan Informasi XVI Tahun 2021*, Hal 345-350.

[3] Kusmiyati, A., (2019). Analisis Dampak Adanya Penambang Pasir Merapi Modern terhadap Penambang Pasir Tradisional Merapi. *Dspace UII*. https://dspace.uii.ac.id/bitstream/handle/123456789/14463/Anita%20Kusmiyati%20jurnal.pdf?sequence=1

[4] Adiansyah, S, J. (2021). Lingkungan Tambang. Yogyakarta: CV Budi Utama.

[5] Arif, I. (2021). *Good Mining Practice di Indonesia*. Jakarta: PT Gramedi Pustaka Utama.

[6] Hancock, G. R., Lowry, J. B. C., and Saynor, M. J. (2016). Early landscape evolution -A field and modelling assessment for a post-mining landform. *CATENA*, 147, 699-708. https://doi.org/10.1016/J.CATENA.2016.08.015.

[7] Lawing, H.Y. (2021). *Reklamsi Lahan Pasca Tambang*. Banyumas: CV Amerta Media.

[8] Liu, D., Feng, J., Li, H., Fu, Q., Li, M., Faiz, M. A., Ali, S., Li, T., & Khan, M. I. (2019). Spatiotemporal variation analysis of regional flood disaster resilience capability using an improved projection pursuit model based on the wind-driven optimization algorithm. *Journal of Cleaner Production*, *241*, 118406. https://doi.org/ 10.1016/J.JCLEPRO.2 019.118406

[9] Brenna, A., Marchi, L., Borga, M., Zaramella, M., & Surian, N. (2023). What drives major channel widening in mountain rivers during floods? The role of debris floods during a high-magnitude event. *Geomorphology*, *430*, 108650.https://doi.org/10.1016/j.geomorph.2023.108650

[10] Åberg, S. C., Korkka-Niemi, K., Rautio, A., & Åberg, A. K. 2022. The effect of river regulation on groundwater flow patterns and the hydrological conditions of an aapa mire in northern Finland. *Journal of Hydrology: Regional Studies*, *40*, 101044. https://doi.org/10.1016/J.EJRH.2022.101044

[11] Bargawa, W,S,. (2018). *Perencanaan Tambang (Edisi Kedelapan).* Yogyakarta: Kilau Book.

[12] Dyahwanti, N, I,. (2007). *Kajian Dampak Lingkungan Kegiatan Penambangan Pasir Pada Daerah Sabuk Hijau Gunung Sumbing di Kabupaten Temanggung.* Tesis, Universitas Diponegoro Semarang.

[13] Permana, R,.Kironoto, B, A. dan Istiarto.2015. A Study of Channel Water Current Velocity Meter with Horizontal and Vertical Axis Propeller Type. *Jurnal Potensi*. Vol.17 No.1. Hal 17-22.

[14] Surya, A,. and Setiawan, B,. 2021. Analisis Kecepatan Arus Air Menggunakan Current Meter Dan Karakteristik Sungai Tuan Haji Besar Muhammad Arsyad Al Banjari Kabupaten Banjar. *Jurnal Keilmuan Teknik Sipil*. Volume 4 Nomor 2 Hal 335-344.

[15] Akbar, M, A., Kusuma, G, J., Benggolo, R, S, G., dan Badhurahman, A,. 2023. Analisis Neraca Air Pascatambang Pada Tailing Storage Facility. Jurnal Teknologi Mineral dan Batubara. Vol 19 No 1. Hal 25-45. https://doi.org/10.3055 6/jtmb.Vol19.No1.2023.1330

[16] Anonim.2023. Badan Pusat Statistik Kabupaten Boyolali. *Badan Pusat Statistik*. Boyolali.

[17] Sosrodarsono ,S and Takeda, K.1983. *Hidrologi Untuk Pengairan*. Jakarta: PT. Pradnya Paramita.
[18] Aldrian, E,. Budiman, dan Karmini M,. (2011). *Adaptasi dan Mitigasi Perubahan Iklim di Indonesia. Pusat Perubahan Iklim dan Kualitas Udara*, Kedeputian Bidang Klimatologi, Badan Meteorologi, Klimatologi dan Geofisika. Jakarta.
[19] Suripin. 2004. *Sistem Drainase Perkotaan yang Berkelanjutan*. Yogyakarta. Andi Offset.
[20] Sanusi dan Pratiwi. 2019. Evaluasi Koefisien Manning Pada Berbagai Tipe Dasar Saluran. *Jurnal Penelitian dan Kajian Bidang Teknik.*
[21] Gunawan, G., 2018. Model Peramalan Banjir Air Bengkulu Menggunakan Aplikasi HEC_RASdan Sistem Informasi Geografis. *Seminar Nasional Inovasi, Teknologi dan Aplikasi (SeNITiA).*Hal 238-242.
[22] Wigati, R., Soedarsono., and Mutia,T,.2016. Analisis Banjir Menggunakan Software HEC_RAS4.1.0 (Studi Kasus Sub-Das Ciberang Hm 0+00 - Hm 34+00). *Jurnal Fondasi*. Vol. 5 No. 2 Hal. 51-61.
[23] Munassri, S., and Triki, A. (2021). On the unidirectional free-surface flow behavior in trapezoidal cross-sectional open-channels. *Ocean Engineering*, 223, 108656. https://doi.org/10.1016/J.OCEANENG.2021.108656
[24] Chendratama, E., Dian, P., Sriyana, A. W., & Pranoto, S.2013. Perencanaan Normalisasi Sungai Blukar Kabupaten Kendal. *Jurnal Karya Teknik Sipil*. Vol. 2, No. 2. Hal 228-240.
[25] Ainnia D, K., and Jirzanah,. (2021). Analisis Deep Ecology Arne Naess terhadap Aktivitas Penambangan Pasir (Studi Kasus: Penambangan Pasir Merapi di Sekitar Sungai Gendol Cangkringan Sleman Yogyakarta). *Jurnal Ilmu Lingkungan*. Vol 19 No 1. Hal. 98-106.