The benefits of river normalization of Guntur weir upstream to irrigation area service in Demak Regency Central Java Indonesia

A Y Imawan 1, S I Wahyudi 2* and N R Wahyudi3

1Master of Civil Engineering Student, Faculty of Engineering, Universitas Islam Sultan Agung, Semarang, Indonesia
2Professor of Civil Engineering Department, Faculty of Engineering, Universitas Islam Sultan Agung, Semarang, Indonesia
3Master of Ocean Engineering Student, Faculty of Ocean Engineering, Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia

*Corresponding authors: wahyudi@unissula.ac.id

Abstract. Guntur weir is located in Demak Regency, Central Java Province, Indonesia. The damage occurred in the upstream of Guntur Weir, mainly due to sedimentation. The cross-sectional area of the river becomes smaller so that when heavy rainfall, river water overflows and breaks the levees. These problems also disrupt water supply to irrigation channels where sedimentation covers the entrance of the Guntur Intake Weir. The purposes of this study are to determine the condition of the Guntur weir before and after the normalization work, the benefits of the Jagung river normalization work. This study was performed by analyzing hydrological data to find out the water balance, flood discharge, and the benefits analysis of the Jagung River normalization work. Based on the analysis using the HEC RAS application at Guntur Weir, an increase of Guntur Weir storage from 1002.5 m³ to 88280.525 m³. Flood discharge calculation using the HEC RAS application shows normalization work has benefits to reduce the potential flooding in the upstream of the Guntur Weir and also increase the ability of Guntur Weir to supply water needs for the Guntur Irrigation Area. The result used to adapt the operation Guntur Weir gate.

Introduction
The Guntur Irrigation had an area of 2,036 Ha in the last data and become 1,944 Ha area after updating to the current condition map. Guntur weir is located at coordinates 6° 43' 26" - 7° 09' 43" latitude South and 110° 27' 58" - 110° 48' 47.40" East Longitude, Demak Regency, Jawa Tengah, Indonesia. All Guntur irrigation areas are in Demak Regency [1]. Number of villages which entered the Guntur Irrigation Area are 12 villages consisting of 2 regions sub-districts namely Guntur sub-district with 5 villages and Karangtengah sub-district with 7 villages. According to Irrigation history, in 1912-1914 The Dutch East Indies Government built the Guntur Weir. Then In 1974 Indonesia government, by the Jratun Seluna Project,
Guntur Weir was rehabilitated by increasing the crest height ± 0.90 m and replacing the water gate. Then in 1982, the 10 gates were replaced with wooden sliding doors which were driven by electricity [2]. In 2008 by the Pemali Juana, Guntur Weir was rehabilitated again by increasing the height of the crest ± 0.48 m and replacing the sliding door which was originally from wood becomes steel door. Damage occurred in the Jragung river mainly due to sedimentation in the upstream of the Guntur Weir and the lack of awareness of the people who live along the river in disposing of the residual agricultural waste [3]. These problems also hampered the flow of water into the irrigation channel so that sediment covered the right and left Intake gates and extended to the Primary and Secondary channel. In 2018 the Jragung River normalization work was carried out by the Ministry of Public Work to overcome the problems in the Jragung River.

The purposes of this study are to determine the rainfall intensity, to analyze water needs, to know the volume of Guntur weir storage before and after implementing normalization work, and then to know its benefits. After normalizing the Jragung River, it expected to be more effective function for Guntur Irrigation Area.

**Research methods**

The research method is a step of work to be carried out to achieve a maximum, efficient, and effective result [4]. The stages of the data collecting and analysis of the benefits of normalization in the Jragung River are as follows:

![Research stages diagram](image)

**Figure 1.** Research stages.

**Result and discussion**
The hydrological analysis phase aims to analyze the water balance to determine the water ability of the Guntur Weir to supply the Irrigation Area. The analysis stages are to analyze the rainfall plan, calculation of rainfall intensity, analysis of flood discharge plans, analysis of the discharge and water requirements. One method used in the rainfall analysis plan is the Thiessen method [5]. The Thiessen polygon is required for calculation and is shown in Figure 2 below:

From the Thiessen polygon drawings, the Thiessen coefficient value can be calculated for each region. The results of the calculation of the Thiessen coefficient for each region are shown in table 1 below:

| Rainfall station | Area (Ha) | Percentage (%) |
|------------------|-----------|----------------|
| Sta Karangsari   | 1.06928   | 54.99          |

Figure 2. Polygon Thiessen Guntur Weir.
From the above table, the percentage comparison results are obtained between the area of the polygon of the rain station and the total area of the River Basin [6]. After obtaining the Thiessen coefficient for each region, it can be calculated the average monthly rainfall. The results of the calculation of average monthly rainfall are shown in table 2 below:

Table 2. Average monthly rainfall.

| Station  | Polygon thicsson | Description | Jan | Feb | Mar | Apr | Mei | Jun | Jul | Aug | Sep | Oct | Nov | Des |
|----------|------------------|-------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Sta. Karangsari | 54.99 | X | 461.89 | 423.67 | 296.17 | 192.11 | 78.83 | 48.00 | 31.56 | 13.28 | 40.00 | 159.44 | 227.06 | 322.83 |
| Sd | 223.53 | 183.10 | 134.36 | 95.42 | 73.87 | 55.34 | 38.89 | 25.13 | 63.72 | 112.36 | 87.81 | 92.51 |
| R5 monthly | 273.68 | 269.50 | 183.04 | 111.77 | 16.63 | 1.40 | 0.00 | 0.00 | 0.00 | 64.83 | 153.12 | 244.94 |
| R5 daily | 8.83 | 9.62 | 5.90 | 3.73 | 0.54 | 0.05 | 0.00 | 0.00 | 2.09 | 5.10 | 7.90 |
| Sta. Guntur | 45.01 | X | 365.06 | 362.33 | 260.61 | 212.33 | 96.67 | 75.89 | 36.39 | 16.33 | 44.83 | 167.61 | 235.33 | 308.17 |
| Sd | 173.76 | 198.15 | 85.84 | 104.81 | 53.54 | 75.06 | 38.89 | 27.17 | 77.35 | 122.92 | 109.34 | 100.73 |
| R5 monthly | 218.75 | 195.49 | 188.34 | 124.08 | 51.59 | 12.68 | 3.64 | 0.00 | 0.00 | 64.11 | 143.27 | 223.35 |
| R5 daily | 7.06 | 6.98 | 6.08 | 4.14 | 1.66 | 0.42 | 0.12 | 0.00 | 0.00 | 2.07 | 4.78 | 7.20 |
| Result | 100.00 | X | 418.30 | 396.06 | 280.16 | 201.21 | 86.86 | 60.55 | 33.73 | 14.65 | 42.18 | 163.12 | 230.78 | 316.23 |
| Sd | 201.13 | 189.88 | 112.52 | 99.65 | 64.72 | 64.22 | 38.89 | 26.05 | 69.85 | 117.12 | 97.50 | 96.21 |
| R5 monthly | 248.96 | 236.19 | 185.42 | 117.31 | 32.26 | 6.48 | 1.64 | 0.00 | 0.00 | 64.51 | 148.68 | 235.22 |
| R5 daily | 8.03 | 8.44 | 5.98 | 3.91 | 1.04 | 0.22 | 0.05 | 0.00 | 0.00 | 2.08 | 4.96 | 7.59 |

From the above table, the percentage comparison results are obtained between the area of the polygon of the rain station and the total area of the River Basin [6]. After obtaining the Thiessen coefficient for each region, it can be calculated the average monthly rainfall. The results of the calculation of average monthly rainfall are shown in table 2 below:

From the calculation of average monthly rainfall using the Thiessen Polygon method above, it is necessary to analyze the distribution using statistical methods [7]. There are 4 distributions in the calculation of rainfall statistical parameters namely Normal, Gumbel, Log Normal and Log Pearson III. Table 2 present the statistical parameters and selected by some distribution model in table 3.

According to the table 3, the formula selected is the Normal Distribution. The next step is to do the distribution test with the Chi-Square and Smirnov-Kolmogorov test to find out whether the distribution is acceptable or not. From the Chi-Square and Smirnov-Kolmogorov test results obtained that the distribution of data can be accepted. The calculation of flood debit plan is calculated using the FSR Jawa Sumatra method. Calculation of flood debit plan can be seen in table 4 below:
Table 3. Selection of distribution types.

| Number | Distribution       | Requirements          | Results  | Explanation |
|--------|--------------------|-----------------------|----------|-------------|
| 1      | Normal             | $Cs \sim 0 \pm 0.3$   | 0.3194   | Fulfill     |
|        |                    | $Ck \sim 3.00$       | 1.8116   | Fulfill     |
| 2      | Gumbel             | $Cs = 1.14$          | 0.3194   | Not Fulfill |
|        |                    | $Ck = 5.4$           | 1.8116   | Not Fulfill |
|        |                    | $Cs = Cv^3 + 3 Cv = 0.21$ | -0.0033 | Not Fulfill |
| 3      | Log Normal         | $Ck = Cv^3 + 6Cv^2 + 15Cv + 16Cv^2 + 3 = 3.05$ | 0.1272   | Not Fulfill |
|        |                    | $Cs \neq 0$          | -0.0033  | Fulfill     |
| 4      | Log Pearson Type III |                    |          |             |

Table 4. Calculation of designed flood discharge using the FSR Jawa Sumatra method.

| T years | GF | A km² | V | PBAR mm | ARF | APBAR mm | H km | L km | MSL | SIMS | MAF m³/sec | Qt m³/sec |
|---------|----|-------|---|---------|-----|----------|------|------|-----|------|------------|----------|
| 5       |    | 1.275 | 264.22 | 0.95 | 203.95 | 1.12 | 228.86 | 0.83 | 71.67 | 64.50 | 0.013 | 329.54 | 420        |
| 10      |    | 1.550 | 264.22 | 0.95 | 203.95 | 1.12 | 228.86 | 0.83 | 71.67 | 64.50 | 0.013 | 329.54 | 511        |
| 20      |    | 1.860 | 264.22 | 0.95 | 203.95 | 1.12 | 228.86 | 0.83 | 71.67 | 64.50 | 0.013 | 329.54 | 613        |
| 50      |    | 2.325 | 264.22 | 0.95 | 203.95 | 1.12 | 228.86 | 0.83 | 71.67 | 64.50 | 0.013 | 329.54 | 766        |
| 100     |    | 2.750 | 264.22 | 0.95 | 203.95 | 1.12 | 228.86 | 0.83 | 71.67 | 64.50 | 0.013 | 329.54 | 906        |

From the results of the analysis using the FSR Jawa Sumatra method as the table above, the flood discharge results with a return period of ± 50 years is equal to 766 m³/ sec. After the flood discharge plan is obtained, the next step is the analysis of water requirements, in this analysis the calculation uses the Penman method to calculate potential evapotranspiration, which will be used later to calculate water needs. After that the calculation of effective rainfall is carried out which will also be used to calculate water needs [8]. The results of the calculation of water demand are obtained from the analysis of cropping patterns. The next calculation is the calculation of the mainstay debit which will later be entered into the water balance. Water balance is obtained by comparing water availability and water demand [9]. If there is a surplus, it means that the water demand is smaller than the water availability. and if the deficit means that the water demand is greater than the water availability.

Table 5. Calculation of water balance in the Jragung catchment area.

| Description                     | Unite | October | November | December | January | February | March |
|--------------------------------|-------|---------|----------|----------|---------|----------|-------|
|                                |       | I       | I        | I        | I       | I        | I     |
| Discharge Needs                | m³/dt | 0.94    | 1.45     | 2.74     | 2.65    | 1.91     | 2.11  |
| For Irrigation Water           |       | 2.12    | 1.63     | 0.69     | 1.30    | 2.53     | 2.32  |
| Jragung Discharge              | m³/dt | 0.66    | 1.52     | 2.44     | 4.57    | 5.60     | 6.62  |
| Reliability                    | %     | 70.50   | 100.00   | 88.83    | 100.00  | 100.00   | 100.00|
|                                |       | I       | I        | I        | I       | I        | I     |
|                                | April | 1       | 2        | 3        | 1       | 2        | 1     |
|                                | May   | 2.41    | 2.53     | 2.92     | 2.43    | 1.28     | 1.68  |
|                                | June  | 2.03    | 1.07     | 1.20     | 1.58    | 0.00     | 0.00  |
| Discharge Needs                | m³/dt |         |          |          |         |          |       |
| For Irrigation Water           |       | 2.41    | 2.53     | 2.92     | 2.43    | 1.28     | 1.68  |

From the results of the analysis using the FSR Jawa Sumatra method as the table above, the flood discharge results with a return period of ± 50 years is equal to 766 m³/ sec. After the flood discharge plan is obtained, the next step is the analysis of water requirements, in this analysis the calculation uses the Penman method to calculate potential evapotranspiration, which will be used later to calculate water needs. After that the calculation of effective rainfall is carried out which will also be used to calculate water needs [8]. The results of the calculation of water demand are obtained from the analysis of cropping patterns. The next calculation is the calculation of the mainstay debit which will later be entered into the water balance. Water balance is obtained by comparing water availability and water demand [9]. If there is a surplus, it means that the water demand is smaller than the water availability. and if the deficit means that the water demand is greater than the water availability.
From the calculation of the above water balance table, it was found that the largest water availability deficit occurred in the August II period where the mainstay discharge only met water needs of 32.18% and there was a deficit of 67.82%. The next calculation is to calculate the volume of the Guntur Weir. The area of each cross can be seen in the image below:

![Figure 3. Water balance graph.](image)

| Jragung Discharge m³/dt | Reliability % |
|-------------------------|---------------|
| 9.55                    | 100.00        |
| 8.49                    | 100.00        |
| 5.25                    | 100.00        |
| 3.63                    | 100.00        |
| 2.88                    | 76.32         |
| 1.28                    | 55.98         |
| 1.14                    | 97.87         |
| 1.05                    | 45.82         |
| 0.55                    | 32.18         |
| 0.51                    | 100.00        |
| 0.39                    | 100.00        |
| 0.60                    | 100.00        |

![Figure 4. Cross section of River Basin area conditions, before normalization.](image)
After the basic elevation and water level elevation from the Jragung River are known in the upstream of the Guntur Weir when the conditions before and after the normalization, the volume of the reservoirs can be calculated. The first step is to make a number of pieces upstream of the Guntur Weir to calculate the cross-sectional area [10]. The figure 6 present HEC-RAS simulation after river normalization.

The next step is to calculate the cross-sectional calculation can be used to calculate the volume from the upstream part of the Guntur Weir. For the calculation of the cross-sectional area and volume of the Guntur Weir can be seen in the table below:
Table 6. Cross-sectional area calculation table.

| No | STA  | Area (m²) |
|----|------|-----------|
| 1  | P349 | Before Normalization 2.90 | After Normalization 98.07 |
| 2  | P340 | Before Normalization 0 | After Normalization 86.95 |
| 3  | P331 | Before Normalization 1.11 | After Normalization 73.11 |

Table 7. Table calculation volume of Guntur Weir.

| Distance                  | Volume (m³) |
|---------------------------|-------------|
| STA          Long (m)  | Before Normalization | After Normalization |
| P349 - P340  250       | 725         | 24517.5 |
| P340 - P349  250       | 0           | 21737.5 |
| P340 - P331  250       | 0           | 21737.5 |
| P331 - P340  250       | 277.5       | 20288.025 |
| Total        1000      | 1002.5      | 88280.525 |

The difference volume in Weir Reservoir between before and after Normalization is 87278.03 m³. Based on the analysis result can be used to irrigate Guntur Irrigation Area [11]. The recapitulation of the service ability of Guntur Weir can be seen in the table below:

Table 8. Calculation of capability of Guntur Weir service.

| No | Condition     | Storage Volume (m³) | Irrigation Need (m³/sec) | Service-ability (seconds) | Service-ability (hours) |
|----|---------------|---------------------|--------------------------|---------------------------|-------------------------|
| 1  | Before Normalization | 1002.5             | 1.07                     | 936.92                    | 0.260                   |
| 2  | After Normalization  | 88280.525          | 1.07                     | 82505.16                  | 22.92                   |

According to the table 8, it was found that the increase in service ability of the Guntur Weir after the normalization work was carried out increased from only 0.2 hours to 22.92 hours’ time services.

Conclusion

Based on the technical and benefit analysis of river normalization of Guntur Weir, it can be concluded on some following points:

1) Before the normalization, the storage volume of the Guntur Weir is 1002.5 m³. Then after normalization the storage volume of Guntur Weir is 88280.525 m³. So the difference storage volume of Guntur weir before and after normalization is 87278.03 m³.

2) The normalization work provides benefits for Guntur weir for increasing the availability of water for irrigation during the dry season. The ability after normalization, the Guntur Irrigation Area has increased 22.92 hours.

3) River normalization increases flood protection and aesthetic value of the Jragung River because after the normalization process a long of the river becomes wider and looks more beautiful than before.

4) The simulation result can be used to adapt the manual of Guntur weir gate operation.
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