Analysis of Floodwater Level and Periodic Maintenance of Celeng River, Bantul

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Abstract. Flooding in the Celeng River usually occurs after high-intensity rains. The Celeng River cannot accommodate any water from the hills around Imogiri and Dlingo. Channel modeling was carried out using HEC-RAS 5.0.7 simulations to determine the river capacity and floodwater level as a control design for periodic maintenance planning. The results of HEC-RAS 5.0.7 modeling in the existing conditions show that there were floods at several points. The usual effort is to make retaining walls. The river morphology, which is changed by the construction of the retaining wall, will accelerate the water rate so that the volume of water in the downstream part is high and will only move the flood to another place. This destructive to the environment, so flood mitigation using bio-engineering methods is proposed to answer the problem.

1. Introduction
Flood hydrometeorological disasters often occur in several regions in Indonesia. Floods cause economic losses, loss of property, and loss of lives [1]. Factors that influence flooding are rain, land use in watersheds, and wrong river development planning [2]. The flood-prone areas studied in this paper are the Celeng Watershed. Flooding in the Celeng Watershed, Imogiri, Bantul was caused by the overflowing of the Celeng River. Celeng River is one of the rivers in the Progo-Opak-Serang River Basin. The Celeng River is located east of the Opak River, and the lower part of the Celeng River is located right at the confluence (combat) with the Oyo River. The Celeng Watershed has an area of 25.6 km² with a main river length of 13.3 km. When it rains, the water flow will be concentrated into the main river. When the capacity of the main river is insufficient, the water will overflow. The type of flood in the Celeng River is that the water will rise, and if the rain intensity decreases, the water will immediately recede.

A previous study was conducted regarding the flood discharge in the Celeng River, including the research on flood-prone zones using geographic information system imagery and remote sensing that obtained a peak discharge of 108,78 m³/second [3]. To minimize potential losses due to floods and landslides, the Ministry of Public Works and Public Housing through the Serayu Opak River Basin Office conducts operations and maintenance of river areas. The Scheme of Celeng River is shown in Figure 1.
The development of research using HEC-RAS was conducted to analyzing the river character, predict a threat, and solve the problem of floods [4, 5, 6]. Periodic maintenance is carried out in the construction of the retaining walls, and this happens massively. The physical structure of the retaining wall harms the ecosystem. In terms of ecology, retaining walls along the river border will eliminate the flora and fauna habitat so that the flora and fauna diversity decreases. The construction of retaining walls will cause changes quickly, and fauna, especially amphibians, will be disturbed and become extinct. It is different if the changes that occur are natural, flora fauna will adjust accordingly. The quality of river water will decline due to many external disturbances, especially from people who build houses on top of the retaining wall and dump their garbage directly into the river. The mindset needs to change, and efforts need to be directed to environmental restoration and ecological engineering. River development changes river morphology and needs to build a healthy river ecosystem, which has a sustainable positive impact on the area concerned [7].

2. Methodology

2.1. Data collection
Primary data were obtained from field surveys on February 18, 2020, and interviews. Interviews were conducted with related parties, especially the Operation and Maintenance Unit III of the Serayu Opak River Basin and residents around the Celeng River. Secondary data in land use, rainfall, and cross-section were obtained from the Serayu Opak River Basin.

2.2. Hydrological analysis
Conducting hydrological analysis starting from recapitulating rainfall data, calculating regional rainfall with the Thiessen Method, calculating statistical parameters, calculating the frequency distribution (Gumbel, Normal, Log-Normal, and Log Pearson Type III methods), conducting data suitability tests, calculating land use using The Method Soil Conservation Service (SCS)-Curve Number (CN), estimates hourly rain by the Alternating Block Method (ABM), and performs Nakayasu Synthetic Unit Hydrograph Analysis to obtain the design flood discharge [8].

2.3. HEC-RAS 5.0.7 modeling
Modeling the channel on HEC-RAS 5.0.7 according to the geometry data obtained and the calculated design flood discharge, then performing a hydraulic analysis from the simulation results of HEC-RAS 5.0.7.
2.4. Periodic maintenance of the Celeng River
The proposed periodic maintenance is periodic maintenance with the concept of bio-engineering to reduce problems arising from physical infrastructure development without considering ecological aspects. The flowchart of the methodology is shown in Figure 2.

3. Result and Discussion

3.1. Hydrological Analysis
Calculation of regional rain using the Thiessen Method with hydrological data for ten years, from 2009-2018 at Barongan, Terong, and Siluk Stations. The determination of regional rain using the Thiessen Method was carried out using the ArcGIS application in the ArcMap module. The results of the Thiessen Polygon in the Celeng River Basin are shown in Figure 3. The results of the Thiessen Polygon calculation are shown in Table 1.

Figure 3. Thiessen Polygon in the Celeng Watershed analyzed BBWS SO data using ArcGis
Table 1. Recap the Thiessen Polygon calculation at Celeng Watershed

| Year | Average rainfall (mm) |
|------|-----------------------|
| 2009 | 37.71                 |
| 2010 | 47.24                 |
| 2011 | 60.26                 |
| 2012 | 48.82                 |
| 2013 | 80.92                 |
| 2014 | 57.60                 |
| 2015 | 92.70                 |
| 2016 | 99.13                 |
| 2017 | 207.10                |
| 2018 | 80.19                 |

The calculation of the frequency distribution of return rainfall using the Log Pearson Type III distribution according to the statistical parameter recap is shown in Table 2.

Table 2. The results of the Log Pearson Type III distribution in the Celeng Watershed

| Return period | Rainfall data of Log Pearson Type III (mm) |
|---------------|--------------------------------------------|
| 2             | 66.65                                      |
| 5             | 104.25                                     |
| 10            | 138.23                                     |
| 25            | 194.16                                     |
| 50            | 247.06                                     |
| 100           | 311.40                                     |

The validity of the rainfall distribution data during the return period of the Log Pearson Type III method was tested using the Kolmogorov Smirnov test. The maximum delta value is smaller than delta critical, 0.20<0.41, so the rainfall distribution data for the return period of the Log Pearson Type III method is acceptable. Land Use Analysis was carried out using The Soil Conservation Service (SCS) method. From the analysis, the Curve Number (CN) value of the calculation results is 74.46, and the potential retention value of groundwater (S) is 87.10. The effective rain, which is affected by groundwater’s potential retention, is shown in Table 3.

Table 3. The results of the calculation of effective rain in the Celeng Watershed.

| Return period | Effective rain (mm) |
|---------------|---------------------|
| 2             | 17.7                |
| 5             | 43.3                |
| 10            | 70.2                |
| 25            | 118.3               |
| 50            | 166.4               |
| 100           | 226.7               |

Effective rain is converted into hourly rain with the Alternating Block Method (ABM) so that hourly rain is generated every time it returns, used as input for design flood analysis. In this study, the flood
design was calculated using the Nakayasu synthetic unit hydrograph method. From the recap results, the $\alpha$ used is three because the difference in rain volume is closest to the ideal rain unit of 1 mm, it is 1.64%. The design flood discharge is recapitulated each time, and the maximum flood discharge is generated each time. The design discharge each time is shown in Table 4.

Table 4. The results of the calculation of periodical discharge

| Return period | Max discharge (m$^3$/second) |
|---------------|-----------------------------|
| 2             | 21.26                       |
| 5             | 51.99                       |
| 10            | 89.64                       |
| 25            | 142.01                      |
| 50            | 199.69                      |
| 100           | 272.02                      |

3.2. HEC-RAS 5.0.7 Modeling
Research on the Celeng River on this occasion took a look at the starting point of STA 0+000 to the endpoint of 2+500, as shown in Figure 3. This location is one of the worst flooded areas in 2019, Wukirsari and Imogiri Village to be precise Paduresan. The river geometry data in the form of cross-sections were obtained by PT Wijaya Karya. The Scheme of Celeng River modeling in HEC-RAS is shown in Figure 4. After running the existing HEC-RAS 5.0.7, the results are shown in Figure 5 and Figure 6.

Figure 4. Scheme of Celeng River System in HEC-RAS 5.0.7
Figure 5. Cross-section STA 0+000 in upstream of Celeng River

Figure 6. Cross-section STA 1+500 in middle of Celeng River

From the two sample points, it can be seen that flood occurs at the first and second points. Illustrates that the Celeng River's capacity cannot accommodate the flood discharge designed for the ten year return period.

3.3. Celeng River Periodic Maintenance
The study took samples at STA 2 + 079, namely on a landslide river border during heavy rain. The modeling results when the location was carried out the construction of the retaining wall with the appearance adjustment is shown in Figure 7.

Figure 7. Cross-section STA 2+079 modeling using the retaining wall.
Water does not overflow, but the concept of maintaining which is carried out is short-term maintenance that only responds to community demands so that floods and landslides can be handled immediately. Retaining walls makes people feel safe and interested in building buildings in the riparian zone, the large trees on the riparian zone are felled, and after the house is built, the culture of throwing trash in the river will occur.

The recommended periodic maintenance is eco-engineering. Celeng River is a small river because it has an area of 25.6 km² of Watershed (DAS), the boundary area of the riparian zone determined is 50 m [9]. Checking the capacity of a natural channel with a border of 50 m to the right and 50 meters to the left measured from the riverbank using HEC-RAS 5.0.7 is shown in Figure 8.

![Figure 8. Cross-section STA 2+079 modeling using the natural channel](image)

To strengthen river bodies, rivers are using bio-engineering. One of the bio-engineering methods is with the rods tied and fixed longitudinally with wooden stakes to prevent landslides from occurring on cliffs. The plant stalks are covered with soil to accelerate vegetation growth. River bodies with normal water levels in retaining walls and rivers with bio-engineering are shown in Figure 9 and Figure 10.

![Figure 9. Retaining wall in a normal water level](image)
Figure 10. Bio-engineering at the normal water level.

Retaining wall only at the hydraulic side, water will flow and be wasted as quickly as possible (such as the drainage regime), natural river retention is lost, and changes are sudden, causing a decrease to the extinction of river organisms. Also, settlement growth around the river will be fast and difficult to control, so that the river will be difficult to develop in the future.

River borders with cliffs with bio-engineering require attention in handling vegetation. However, bio-engineering considers ecology and human interests sustainably. Silting due to sedimentation at natural boundaries is low, excess water flows optimally so that the possibility of flooding is lower, hydraulic conditions are better, biodiversity is maintained, existing vegetation as a barrier reduces erosion, settlement growth is easily controlled so that rivers can be developed for example as tourist attractions. Apart from that, a riparian zone filled with vegetation will be a place for water to infiltrate so that water is not wasted.

4. Conclusions and Recommendations
Based on the results of the analysis of the flood water level, it can be concluded that the capacity of the Celeng River has not been able to accommodate the flood discharge design for the 10-year return period (89.64 m³/second). It is necessary to repair the cross-section, but from the observation of periodic maintenance carried out, retaining walls’ construction has made the watershed increasingly critical. Based on this, more comprehensive maintenance of the Celeng River is needed. Determination of riparian zone boundaries and sustainable maintenance, namely eco-systemic and eco-hydraulic maintenance by considering the chain of damage starting from watershed damage, one of which is the application of bio-engineering which involves the Celeng River community and the government as a policymaker so that existing proposals can be realized.

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