The effect of diameter and distance between vegetation in the riverbank to flood discharge by Eco-hydraulic in the Lawe Alas River, Southeast Aceh, Indonesia

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Abstract. One of the eco-hydraulic methods used to reduce flooding and erosion in rivers is by vegetation along the riverbanks. The main problem in the Lawe Alas River is repeated flooding in the downstream areas that need to be addressed upstream. The purpose of this study is to design the proper vegetation diameter and the distance between plants that can reduce the velocity and flow of the river. The method of study in this research consists of conducting field surveys, measuring river discharge, and calculating vegetation diameter on riverbanks to reduce velocity and discharge based on the equation proposed by Merten. The planned diameter of vegetation with diameter is 0.1 m – 1.1 m, and the distance between vegetation 1 m - 11 m. The results showed that the maximum discharge capacity of the Lawe Alas River was 514,360 m³/s. For the return period of 50 years, 50 m from the riverbank design, vegetation with a diameter of 10 cm to 110 cm can reduce flooding in the resulting discharge 222,955 m³/s – 241,684 m³/s. Discharge is greater than 50 yearly flood discharge, which is 528,670 m³/s. In conditions without vegetation (diameter = 0) velocity = 1,725 m/s, the velocity produced by the design is 0,727 m/s – 0,789 m/s. Discharge and velocity are reduced by 54% - 58% so that the vegetation diameter of 10 cm is suitable for environmentally friendly designs on the riverbanks 50 m. In conclusion, all planned vegetation diameters can reduce discharge and velocity. Recommended vegetation is local vegetation, which is a tree that produces fruit that can be benefited to the community so that it can be planted and managed by local residents.

1. Introduction
Kutacane City is one of the cities in Aceh Province which when the rainy season is often hitting by flooding. Flood disasters often occur due to the overflow of river water. One of the rivers in Kutacane City is the Lawe Alas river. The Lawe Alas River is a large river that crosses the Gunung Leuser National Park, and this river is located along the Gayo Luces District, Southeast Aceh District, and South Aceh District so that the Lawe Alas River is in the Alas-Singkil River Area Unit (SWS). The Lawe Alas River is located at 03° 29' LU - 03° 59' LU and 97° 10' BT - 97° 45’ BT. The Lawe Alas River is often hit by floods, with the most affected areas being the Bambel District and Babul Makmur District. Based on information obtained from [1], land belonging to Bambel residents who were damaged and failed to harvest reached 20 hectares, due to flash floods, 15 houses were damaged, and hundreds of houses were submerged. To overcome the flooding, the local government built structural buildings, namely gabions on the banks of the river. The function of making the gabion is to maintain the banks of the river against the flow of water flow and business to keep the flow of water flow from the banks of rivers that damage cliffs (erosion) and as flood control.
The purpose of this study is to design an eco-hydraulic riverbank area to cope with flooding in the Lawe Alas River by optimizing the riverbank width and the selection of vegetation diameters that can reduce flood discharge. The scope of this research is to determine the eco-hydraulic river design that can accommodate 50-year flood discharge.

The methods study in this research consist of field survey, literary study, measurement cross hydrometric river, and eco-hydraulic study. The benefit of this research is to be able to know the condition of river discharge and the maximum capacity of river basins based on water level elevation. We can find out the eco-hydraulic river design that is right on the Lawe Alas River so the river design can reduce flood energy towards the downstream. The research location can see in figure 1.

![Figure 1. Map of the Lawe Alas-Singkil watershed.](image)

In this study, the Melchior method was used to calculate flood discharge because it has a watershed area of more than 100 km². Data needed are river hydrometry data, daily rainfall data, and topographic maps. River hydraulic data is obtaining from measurements for seven days in the field, such as measurements of river depth, river width, flow velocity, and river water level. Rainfall data were analyzed using statistical parameters which can then be determined the appropriate type of distribution between Normal distribution, Log-Normal, Gumbel, and Pearson Log.

2. Literature review

The flood is affected by the geomorphometric of watershed [2]. According to [3], flood control is generally carried out with pure hydraulic concepts, namely increasing physical or structural development such as embankment making, river diversion, dredging of river basins, making riverbanks, and others. Be aware that this is an improper step in applying the eco-hydraulics concept. Flood control with physical development causes a decrease in river retention, an increase in river slope, increasing flow, peak flow discharge and decreasing time to reach peak discharge resulting in an increase in flood retention in the downstream area of the river.

According to [4], the negative effect of structural development is the condition of the watershed will lose the habitat of flora and fauna around the river environment and change the characteristics of the shape of the river. What is including in pure eco-hydraulic? According to [5], pure hydraulics means that the problem-solving in the area of water is only essential on the hydrology function of the water area, without considering the negative impact and its relation to the existing ecological components [6]. According to the pure hydraulic concept, the river is only seeing as a hydraulic channel that discharges excess water towards the sea. This concept concludes that all rivers should be straightened or grounded so that water can quickly flow downstream.

With the rate of development of environmental awareness and the enormous negative impact of pure hydraulic engineering as mentioned above, a new interdisciplinary engineering pattern has been developed by including ecological considerations in solving water problems. This interdisciplinary
economic approach is seeing as a new approach that can be accepted from both ecological and hydro-
civil engineering people and has high sustainability.

According to Pertiwi [4], vegetation planted on the banks of the river will reduce the velocity of
water to the ground. By reducing the velocity of water in the river, the problem of flooding in the
downstream area can reduce, and the natural conditions of the river can be maintained.

The development of this research has been entirely publishing in [4, 7-10]. According to [11], in
natural rivers shaped close to the trapezoid, where on the banks of the vegetation are dense vegetation,
there will be a wide interaction area and the process of losing energy due to the friction of the velocity
between the faces. With this interaction area, a lower velocity reduction will occur. As a consequence,
the water level will rise, and the flowrate capacity will decrease (for the same water level). The method
of calculating the influence of vegetation in the riverbank area on water velocity and discharge is basing
on the equation proposed by Merten in 1989 [7-11].

1. Coefficient of resistance

\[
\frac{1}{\sqrt{\lambda}} = -2.03 \log \left( 12.27 \frac{R}{K_s} \right)
\]  

(1)

2. Roughness Value

\[ K_s = Cb + 1.5dp \]  

(2)

with:
C = vegetation composition coefficient,
b = riverbank width (m), and
dp = vegetation diameter (m).

3. Vegetation composition coefficient

\[ C = 1.2 - 0.3(B/1000) + 0.06(B/1000)^{1.5} \]  

(3)

\[ B = \left[ \frac{\alpha_x}{\alpha_y} - 1 \right] \left( \frac{\alpha_x}{\alpha_y} \right) \]  

(4)

with:
B = vegetation parameter,
\( \alpha_x \) = transverse vegetation distance (m), and
\( \alpha_y \) = distance between vegetation in longitudinal direction (m).

4. Water velocity according to Darcy – Weisbach

\[ V = \left( \frac{1}{\lambda} 8gRI \right)^{0.5} \]  

(5)

with:
\( \lambda \) = resistance coefficient,
g = gravity speed (m/dt^2), and
R = hydraulic radius (m).
I = river slope

3. Methodology

3.1. Field measurements
The research location is in the Badar Subdistrict area of Kutacane City, Aceh Province, with the primary
location of the research being the upstream area of the Lawe Alas River. The study conducted in
September 2018 to November 2018 which included the results of direct measurements in the field,
namely river depth measurements aimed at obtaining a cross-sectional shape of the river which can then calculate the cross-sectional area of the river. The width of the river is divided into several pieces and measured the depth of each stake using a weighted rope. Measurements of water level measurements measured by using wood placed at the edge of the river every day for seven days and the flow rate calculated for each different water level elevation. Flow velocity is measured using a float from the bridge. On the bridge the width of the river is measured:

1) measured the height of the bridge to the surface of the river;
2) tie afloat on a 50 m long rope;
3) the buoy place in the cross I (above the bridge) and is allowed to drift along the 50 m (cross II) rope;
4) measured t (float time) using a stopwatch; and
5) this work is done repeatedly until three times, and the time and results recorded.

River hydraulic data is obtained from measurements for 7 days in the field such as measurements of river depth, river width, flow velocity, and river water level, as presented in figure 2.

Secondary data in the form of topographic maps of the Alas-Singkil River Area, Southeast Aceh Topographic Map, maximum daily rainfall data from 1980-2006 BPP Blang Keujereun station obtained from the Sumatra I-BWS, 2011 governance map obtained from the Sumatra-I Aceh BWS, serves to determine the value of the coefficient runoff (C) based on the land cover of the Alas River Basin.

River discharge is calculated for several different river water level elevations so that a curve rating obtained. From the rating curve, the amount of flood discharge can be calculated based on the flood water level that occurs. The planned flood discharge analysis is to find out the magnitude of the discharge that occurs in the return periods of 2, 5, 10.25, and 50 years — calculation of the planned flood discharge using the Melchior Method.
3.2. Eco-hydraulics analysis

The hydraulic analysis aims to determine eco-hydraulics planning, namely in the form of riverbank designs. The steps to be carried out in the hydraulic analysis in this study are as follows:

1) Plan the width of the riverbank 50 m;
2) Vegetation planned with a diameter of 0.1 m, 0.2 m, 0.3 m, 0.4 m, 0.5 m, 0.6 m, 0.7 m, 0.8 m, 0.9 m, 1 m and 1.1 m with longitudinal and transverse spacing between 1 m, 2 m, 3 m, 4 m, 5 m, 6 m, 7 m, 8 m, 9 m, 10 m and 11 m;
3) Calculate the roughness value of the channel using equation (2);
4) Calculation based on various vegetation diameters consisting of diameters of 10 cm, 20 cm, 30 cm, 40 cm, 50 cm, 60 cm, 70 cm, 80 cm, 90 cm, 100 cm and 110 cm;
5) Calculating the water velocity values for various vegetation diameters using equation (5);
6) Calculate the flood discharge after the influence of vegetation planting; and
7) Comparing flood discharge before and after vegetation planting.

![Flow direction diagram](image)

with: \( D \) = diameter vegetation
\( S_1 \) = the distance between vegetation in the transverse direction (ax)
\( S_2 \) = the distance between vegetation is elongated (ay)

Figure 3. Configuration of vegetation planting models on river banks.

4. Results and discussion

Based on measurements in the field, the total watershed area was obtained = 312.05 km\(^2\) river length = 89.7 km and Slope = 0.0245. The following is a table of results of velocity and river discharge measurements for a week.

| Tanggal    | Velocity (V) | Discharge (Q) |
|------------|--------------|---------------|
| 09-Nov 2018 | 0.76         | 514.36        |
| 10-Nov 2018 | 0.69         | 441.55        |
| 11-Nov 2018 | 0.61         | 388.13        |
| 12-Nov 2018 | 0.56         | 346.02        |
| 13-Nov 2018 | 0.50         | 297.70        |
| 14-Nov 2018 | 0.46         | 260.48        |
| 15-Nov 2018 | 0.43         | 236.75        |

The relationship figure of vegetation diameter to roughness; figure of vegetation diameter to velocity; and figure of vegetation diameter to steam flow (discharge) are presented in figure 4, 5, and 6. Based on figure 4, it can be following that when the vegetation diameter is 0, the roughness = 0 after the vegetation is planting, the higher the vegetation diameter, the greater the roughness. Based on figure 5 it can be seen that in conditions without vegetation (diameter = 0), velocity = 1.725 m/s while after improvement of the banks with vegetation planting 0.1 to 1.1 m, the velocity decreases to 0.727 - 0.789 m/s, which
indicates the occurrence decrease in velocity by 53 - 57%. Based on figure 6, at the time before the river bank structuring river discharge was 514.36 m$^3$/s, after the arrangement of the banks with vegetation river discharge decreased to 222.95 – 241.68 m$^3$/s, resulting in a decrease in discharge of 54 - 58% from before the riverbank was structured.

Table 2. Results of calculation of roughness parameters, obstacle coefficient, velocity and discharge several variations diameter distance between vegetation for return period 50 years and riverbank 50 m.

| Vegetation Diameter (m) | Space Horizontal (m) | Space Vertical (m) | Vegetation Parameter (B) | Vegetation Parameter (C) | Roughness Coefficient (Ks) | Cross Section Area (m$^2$) | Hydraulic Radius (R) (m) | Roughness Coefficient (λ) (m/d) | Velocity (V) (m/d) | Discharge (Q) (m$^3$/d) |
|------------------------|----------------------|-------------------|---------------------------|--------------------------|---------------------------|----------------|----------------|----------------|----------------|------------------|
| 0                      | 0                    | 0                 | 0.00                      | 0.00                     | 0.00                      | 306,500        | 2.881          | 0.000          | 1.725          | 528.67           |
| 0.1                    | 1                    | 1                 | 810.00                    | 1.001                    | 50.187                    | 306,500        | 2.881          | 10.468         | 0.727          | 222.95           |
| 0.2                    | 2                    | 2                 | 810.00                    | 1.001                    | 50.337                    | 306,500        | 2.881          | 10.292         | 0.734          | 224.85           |
| 0.3                    | 3                    | 3                 | 810.00                    | 1.001                    | 50.487                    | 306,500        | 2.881          | 10.121         | 0.740          | 226.74           |
| 0.4                    | 4                    | 4                 | 810.00                    | 1.001                    | 50.637                    | 306,500        | 2.881          | 9.954          | 0.746          | 228.63           |
| 0.5                    | 5                    | 5                 | 810.00                    | 1.001                    | 50.787                    | 306,500        | 2.881          | 9.792          | 0.752          | 230.51           |
| 0.6                    | 6                    | 6                 | 810.00                    | 1.001                    | 50.937                    | 306,500        | 2.881          | 9.635          | 0.758          | 232.39           |
| 0.7                    | 7                    | 7                 | 810.00                    | 1.001                    | 51.087                    | 306,500        | 2.881          | 9.482          | 0.764          | 234.26           |
| 0.8                    | 8                    | 8                 | 810.00                    | 1.001                    | 51.237                    | 306,500        | 2.881          | 9.333          | 0.770          | 236.12           |
| 0.9                    | 9                    | 9                 | 810.00                    | 1.001                    | 51.387                    | 306,500        | 2.881          | 9.187          | 0.776          | 237.98           |
| 1                      | 10                   | 10                | 810.00                    | 1.001                    | 51.537                    | 306,500        | 2.881          | 9.046          | 0.782          | 239.83           |
| 1.1                    | 11                   | 11                | 810.00                    | 1.001                    | 51.687                    | 306,500        | 2.881          | 8.908          | 0.789          | 241.68           |

Figure 4. Relationship of Vegetation Diameter to Roughness.

Figure 5. Relationship of Vegetation Diameter to Velocity.
5. Conclusion

Sungai Lawe Alas until the outlet has a length of 89.7 km with an area of the watershed is 312.05 km². The width of the Lawe Alas River is 90 m, and the cross-sectional area is 306.5 m². Rating curve shows the maximum discharge that can be accommodated by the river is 514,360 m³/s. Vegetation diameter is 0, the roughness = 0, after the vegetation is planting, the higher the vegetation diameter, the greater the roughness. For return period of 50 years, 50 m of riverbank design, vegetation with a diameter of 1 m to 1.1 m can reduce flooding in the discharge produced by this design 222.95 m³/s – 241.68 m³/s. The discharge is higher than the annual 50 flood discharge, which is 528,670 m³/s. The discharge is reducing 54% - 58% from before there is an eco-hydraulic backing arrangement. The velocity produced by design is 0.727 m/s – 0.789 m/s. The velocity reduces by 53% - 57% from before there is an eco-hydraulic bank arrangement so that the vegetation diameter of 10 cm is feasible for eco-hydraulic design on the riverbank of 50 m. In conclusion, all planned vegetation diameters can reduce discharge and velocity, so vegetation planting on the riverbank should be recommended. Recommended vegetation is local vegetation, which is a tree that produces fruit that can be benefited by the community so that it can be planted and managed by local residents.

Recommendation

To get a more accurate value of velocity, we should use better equipment such as current meter. In planning eco-hydraulics, planning should not be applied only to one area or region that experiences flooding. Instead, the river must be considered one, in the sense that planning must be carried out thoroughly starting from upstream to downstream. In implementing real-time eco-hydraulic planning and implementation in the field, there is a need for public and government awareness, understanding, and participation regarding these eco-hydraulic functions and objectives.

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