Effect Of Bridge Piers On Local Scouring At Alue Buloh Bridge Nagan Raya Regency

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ABSTRACT Scouring that occurs in cross-section a river can be caused by morphological conditions of the river and the effect of bridge piers that obstruct the flow. Availability of piers and abutments can cause the stability of soil base granules to be disrupted, downflow, and horseshoe vortex that causes soil base granules around the bridge pier to be transported the flow that causes occurrence in local scouring. The problems of local scours also occurred in Krueng Ineng river, Alue Buloh Village, Nagan Raya Regency. Local scours on the bridge piers will cause a structural collapse which has the impact of decreasing the stability of the bridge structure currently. In this study, local scour analysis are using empirical equations with the Froehlich, Lacey and Colorado State University Method. The Results of the analysis with used the peak discharge ($Q_{p100}$) that occurs in the Krueng Seunagan watershed is 1513$m^3$/sec. Analysis with a flow depth of 3.06m, Froude number 0.29, pier width with lenticular shaped 4m, and D50, D95 (average grain size analysis ) 0.91mm and 4.35mm, show a maximum scour depth at the field of 1.65m and 1.68m occurs in point (station) 2 and 3 on segment 5. Analysis with the Froehlich, Lacey Method and the CSU Method shows a scour depth is 1.68m, 4.47m ($Q_{p10}$) and 2.43m. The closest measurement result in the field is the Froehlich Method. With this result, it might be input for local governments to plan appropriate handling for minimizing local scour in this study area.

KEYWORDS local scour; scour depth; lacey method; froehlich method; CSU method.

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1 INTRODUCTION

The problem with bridges on a cross section of the river is the structural damage under bridges such as foundations, piers, abutments, which in some cases will lead to the collapse of the bridges. The main structure at the bottom of the bridge is piers which are directly related to the water flow. Flowing water in the river is usually accompanied by scouring and sedimentation processes. The process of scouring that occurs can be caused by river morphological conditions and the existence of piers that obstruct the flow (Rizaldi et al. 2020).

The existence of obstacles such as structure under the bridge can cause changes in river morphology can cause aggradation and degradation. Aggradation at the riverbed can cause the river to experience sedimentation, and if the sediment is allowed to settle it can cause flooding because the river basin is reduced. Sediment that is constantly eroded due to the increased flow velocity will make the structure of the bridge above it unstable. While degradation cause the riverbed erosion is deepened, and erosion on the cliffs will cause the river to widen and causing meander deposition at the river (Purwantoro 2015). Local scouring usually occurs in a river channel obstructed by a bridge pier, it causing a vortex at the upstream bridge of piers make a water flow changes rapidly so that the acceleration of flow will cause the water level to rise (Ahmad et al. 2017).

The horizontal angle of attack of pier caused by bridge piers and abutments can also result in a disrupted material balance on the riverbed, establish of downstream and horseshoes vortex that causes the riverbed around the piers to be transported by the water flow, that resulting in local scouring around the piers. Local scouring on the bridge pier may have an impact on the structural stability of the bridge (Breusers and
Raudkivi 1991). At the obstruction of pier, in formation of vortex at the base of the pier as known as horseshoes vortex (Akan 2006).

Scouring occurs due to sedimentation, narrowing of river flow, and local scouring. Analysis of local scour is very complicated which is also influenced by river conditions and river geometric because the stream or river can also cause bridge stability problems. The scouring by contraction scour occurs due to changes the morphology of the river which is increasingly narrow where most of it is caused by the existence of water buildings (Rustiat 2007).

Different factors affect scouring around the bridge pier. Among them is the shape of the pier which will affect the flow pattern around the bridge pier and influence the creation and strength of the vortex (Farooq and Ghumman 2019). Rectangular pier shows the maximum scour depth of 6.3 cm and 2.6 cm which is minimum for rectangular piers. The scour depth increases due to increased intensity of flow parameters. The rectangular shape is considered as the best among the three shape piers which restrict the local scour by 50% from maximum scouring for rectangular pier (Roy 2017).

The correlation between the scour depth and parameter scour data will represent the flood flow, bottom sediment characteristics, river geometry, and scour rate (Melville 2008). In studying the phenomenon of local scour, many researchers have done it both experimentally and theoretically by considering the parameters that affect the local scour. Three types of scouring due to the influence of the bridge pier are general scour, local scour and contraction scour. Factors affecting the scour depth that occur around bridge pier are river flow velocity, flow depth, sediment roughness, pier size and shape (Piers, Akib, and Rahman 2013). The Colorado State University (CSU) method is the most widely used equation in America where is using to predict the maximum scour depth for live-bed conditions and clear water condition (Administration 2012).

Alue Buloh– Latong bridge that provides access between two villages has experienced local scouring. The problem at this location is the scouring of the riverbed around the bridge. This study aims to obtain the magnitude of design flow discharge in rivers with periods of 50 years and 100 years. Then the design flow discharge data is used to predict the depth of scour that occurs around the bridge pier at the research location. Scour depth analysis in this study used the empirical method with the Froehlich method, Lacey Method and the Colorado State University (CSU) method. So that later it will be an input for the Regional Government in planning the handling of local scour according to the study location.

2 METHODS

2.1 Location Research

The location of this research is only in areas experiencing local scouring problems under the bridge in Alue Buloh area of Seunagan District, Nagan Raya Regency, which is one of the access between Alue Buloh Village and Latong Village (Figure 1).

Figure 1. Location of Study In Alue Buloh

2.2 Procedures and Analysis

Primary data obtained through observation in the field and secondary data from related institutions to support research. The primary data include the shape and dimensions of the pier, the distance between the piers, pier length, depth of flow, the angle of attack of flow, and sediment samples. For secondary data in the form of topographic map
data, river cross-section, and rain data to get the design of flood discharge.

The methodology was arranged to simplify the implementation of research. The flowchart of research implementation can be seen in Figure 2. The steps in processing this research data follow the flowchart of research. The data processing steps carried out in this study are based on research flowchart:

1. Field survey;
2. Obtain field data: pier dimensions, pier shapes, sediment samples, depth of flow, velocity of flow, and riverbed elevation.
   Field data measurements were carried out in January - April 2020, the type of flow used was uniform flow.
3. Measurement of water flow velocity in rivers with a buoy, because there is no current meter:
   a. Set one point on the side of the river with a wooden peg marked on another point across the river in the form of a perpendicular to the direction of flow;
   b. Determine the distance L 20 meters perpendicular to the flow;
   c. Wash the buoy by pressing the stopwatch button at the start.;
   d. When the buoy crosses the second line the stopwatch is pressed again, so that the T flow time is obtained;
   e. Flow velocity can be calculated by the length of the distance divided by time or L / T (m/sec). Keep in mind that this method will get the flow velocity at the surface only, and then measurement must be done several times given the uneven distribution of surface flow.
4. Measurement of grain size analysis:
   a. Sediment samples were taken as many as 9 points (on the left, middle and right of the river) when the conditions of river flow were quiet;
   b. Sediment sample was tested with a sieve analysis to obtain the percentage of sediment passed through a sieve;
   c. Make a filter analysis chart, the correlation between a sieve diameter and percentage of sediment escaped;
   d. The grain size used is the average grain size D_{50} and D_{95} from the graph.
5. Measurement of river bed elevation:
   a. specify a point in the upper reaches of the river as a datum point in the river;
   b. Divide into several river sta directions and from each river sta divided into several segments with their respective distances;
   c. Measure base elevation in each segment with the theodolite and draw a cross-section of river.
6. Analysis of design flood discharge using the Synthetic Hydrograph Nakayasu method.
   Soewarno (1995), the Synthetic Hydrograph Nakayasu is a way to obtain the design of a flood hydrograph in a watershed. To get the magnitude of the design flood hydrograph is needed parameter data that covers the watershed area. The Nakayasu Synthetic Unit Hydrograph Equation is as follows (Yuliansyah, Aprizal, and Nurhasanah 2017).

\[
Q_p = \frac{1}{3.6} \left( \frac{A \cdot Re}{0.3 \cdot T_p + T_{0.3}} \right)
\]

Where: \(Q_p\) = design flood discharge (m³/s); \(Re\) = unit rain (mm); \(T_p\) = time lag (the beginning of the rain to the peak of the flood) (hour); \(T_{0.3}\) = time required for a discharge decrease, from peak discharge to 30% of peak discharge (hour).

\[
t_g = 0.4 + 0.058L \rightarrow \text{for } L > 15\text{km}
\]
\[
T_p = T_g + 0.8, T_r
\]
\[
t_g = 0.21L^{0.7} \rightarrow \text{for } L < 15\text{km}
\]
\[
T_r = 0.5t_g
\]
\[
T_{0.3} = a \cdot t_g
\]

The synthetic unit hydrograph curve equation:

For \(t < T_p\):

\[
Qt = Q_p \frac{t}{T_p}
\]

For \(t < T_p + T_{0.3}\):

\[
Qt = Q_p \times 0.3^{(t/T_p/T_{0.3})}
\]

For \(t < T_p + T_{0.3} + 1.5T_{0.3}\):

\[
Qt = Q_p \times 0.3^{((t/T_p/(0.5/T_{0.3})/(1.5/T_{0.3}))}
\]

\[t_g = 0.4 + 0.058L \rightarrow \text{for } L > 15\text{km}
\]
\[T_r = 0.5T_g
\]
\[T_{0.3} = a \cdot t_g
\]
for \( t > T_p+T_{0.3} +1.5T_{0.3} \):

\[
Q_t = Q_p * 0.3^{((t \cdot T_p + (1.5T_{0.3} + 2T_{0.3})))}
\]

(10)

Where: \( T_r \) = duration of effective rain; \( T_g \) = concentration time (hour); \( t \) = time (hour); \( L \) = length of river channel (km); \( Q_t \) = Runoff before and after reaching peak discharge (m\(^3\)/sec).

7. Then determine the depth of scouring with the CSU Method, Lacey Method, and Froehlich Method.

The CSU equation is the most widely used equation in America and used to predict the maximum of scour depths for both live-bed and clear-water scour conditions (Garde, R and Kothyari, U 1998).

\[
d_s = 2.0K_{1}K_{2}K_{3}K_{4}F_{R}^{0.45}y_{0.35}
\]

(11)

\[
K_{2} = (\cos \theta + \sin \theta b \frac{1}{L})^{0.65}
\]

(12)

\[
K_{4} = 0.4 \left( \frac{V_{R}}{V_{c50}} \right)^{0.15}
\]

(13)

\[
V_{R} = \left( \frac{V_{c50} - V_{i50}}{V_{c50} - V_{i95}} \right)
\]

(14)

\[
V_{c50} = K_u y_{0.3} D_{50}^{1/3}
\]

(15)

\[
V_{c50} = 0.645 \left( \frac{D_{50}}{b} \right)^{0.053} V_{c50}
\]

(16)

\[
V_{c95} = 0.645 \left( \frac{D_{95}}{b} \right)^{0.053} V_{c95}
\]

(17)

\[
V_{i95} = K_u y_{0.3} D_{50}^{1/3}
\]

(18)

Where: \( d_s \) = scour depth (m); \( K_{1} \) = correction factor for pier nose shape (are shown in Table 1); \( K_{2} \) = correction factor for angle of attack of flow (are shown in Table 2); \( K_{3} \) = correction factor for bed condition (are shown in Table 3); \( K_{4} \) = correction factor for armoring of bed material. Correction factor \( K_{4} = 1.0 \) if \( D_{50} < 2 \) mm or \( D_{95} < 20 \) mm for the bed material. If \( D_{50} > 2 \) mm and \( D_{95} > 20 \) mm, then \( K_{4} \) decreases the scour depths for armoring of the bed material (Mueller and Jones, 1999); \( V_{p} \) = velocity ratio, \( V_{c} = \) average velocity in the main channel at the cross-section just upstream of the bridge; \( V_{i50} = \) approach velocity required to initiate scour at the pier for grain size \( D_{50} \), \( V_{i95} = \) approach velocity required to initiate scour at the pier for grain size \( D_{95} \), \( V_{c50} = \) critical velocity for \( D_{50} \) bed material size, \( V_{c95} = \) critical velocity for \( D_{95} \) bed material size; \( K_u = 6.19 \) m\(^{1/2}\)/s = 11.17 ft\(^{1/2}\)/s, and \( y_3 = \) depth of flow from upstream of the pier; \( Fr = \) Froude number; \( y_3 = \) flow depth directly upstream of pier (m); \( \theta_p = \) pier angle of an attack; \( L = \) pier length (m); \( b = \) pier width (m).

### Table 1. Correction Factors \( K_{1} \) For Pier Shape

<table>
<thead>
<tr>
<th>No</th>
<th>Shape of pier nose</th>
<th>( K_{1} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Square nose</td>
<td>1.1</td>
</tr>
<tr>
<td>2</td>
<td>Cylinder</td>
<td>1.0</td>
</tr>
<tr>
<td>3</td>
<td>Round nose</td>
<td>1.0</td>
</tr>
<tr>
<td>4</td>
<td>Circular cylinder</td>
<td>1.0</td>
</tr>
<tr>
<td>5</td>
<td>Sharp nose</td>
<td>0.9</td>
</tr>
</tbody>
</table>

### Table 2. Correction Factors \( K_{2} \) For Pier Angle

<table>
<thead>
<tr>
<th>No</th>
<th>Pier angle</th>
<th>( L/b = 4 )</th>
<th>( L/b = 8 )</th>
<th>( L/b = 12 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>2</td>
<td>15</td>
<td>1.5</td>
<td>2.0</td>
<td>2.5</td>
</tr>
<tr>
<td>3</td>
<td>30</td>
<td>2.0</td>
<td>2.75</td>
<td>3.5</td>
</tr>
<tr>
<td>4</td>
<td>45</td>
<td>2.3</td>
<td>3.3</td>
<td>4.3</td>
</tr>
<tr>
<td>5</td>
<td>90</td>
<td>2.5</td>
<td>3.9</td>
<td>5.0</td>
</tr>
</tbody>
</table>

There are several methods that can be used to calculate the depth of scours that occur on the riverbed around the piers, such as: Laursen and Toch Method, Lacey Method, Colorado State University Method (CSU), Breuser and Raudkivi Method, Simon Method and Senturk and the Froehlich Method.
The equation developed by Dr. David Froehlich (1987), that depth of scour as a function of Froude number, pier width, flow angle of attack, pier type and grain size (Froehlich 2013). The form of the equation is:

\[
d_s = 0.32 \cdot b \cdot K \cdot \frac{b}{b'} \cdot 0.02 \cdot \frac{y}{b}^{0.46} \cdot Fr^{0.2} \cdot \frac{b}{d_{50}}^{0.08} + 1.0
\]

(19)

\[b' = b \cdot \cos\beta + L \cdot \sin\beta\]

Chow (1988), that due to the earth’s attraction to flow is expressed by the ratio of inertia to the earth’s attraction force (g).

\[Fr = \frac{\sqrt{\frac{V}{g \cdot h}}}{v\cdot g \cdot h}
\]

(20)

Where: \(ds\) = scour depth (m); \(Fr\) = Froude number; \(y\) = depth of flow (m); \(b\) = width of the pier; \(\Theta\) = flow angle; \(L\) = length of pier (m); \(d_{50}\) = grain size (m); \(K\) = coefficient of pier type (\(K = 1.3\) for square piers, \(K = 1.0\) for round or round-ended piers, \(K = 0.7\) for acute-pointed piers); \(V\) = flow velocity (m/s); \(h\) = depth of flow (m).

Lacey (1930) introduced the formula for the prediction of the maximum scour depth around piers and abutment-like structures (Rahman and Haque 2003).

\[d_s = 0.47 \cdot \frac{Q}{f} \cdot 0.33\]

(21)

where \(ds\) = scour depth measured from the initial bed level, \(h\) = approach flow depth, \(Q\) = regime discharge, \(f\) = Lacey clay factor which is a function of basic material = 1.76 x \(\sqrt{\text{grain size}}\) \(d_{50}\), and \(d_{50}\) = grain size diameter (mm).

### Table 3. Correction Factors K3 For Bad Condition

<table>
<thead>
<tr>
<th>Bed condition</th>
<th>Dune height</th>
<th>(K_3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clear water scour</td>
<td>Not applicable</td>
<td>1,1</td>
</tr>
<tr>
<td>Plane bed and antidune flow</td>
<td>Not applicable</td>
<td>1,1</td>
</tr>
<tr>
<td>Small dunes</td>
<td>0,6 – 3,0 m</td>
<td>1,1</td>
</tr>
<tr>
<td>Medium dunes</td>
<td>3,0 – 9,1 m</td>
<td>1,1 – 1,2</td>
</tr>
<tr>
<td>Large dunes</td>
<td>&gt;9,1 m</td>
<td>1,5</td>
</tr>
</tbody>
</table>

3.1 Measurement of Pier Dimension

This measurement is carried out to determine the dimensions of the piers that will be used in research. From measurements in the field, pier dimension data obtained such as pier width, the distance between piers, and pier shape (are shown in Table 4). Map of the situation at the study area are shown in Figure 3.
### 3.2 Measurement of Riverbed Elevation

Based on measurements in the field, obtained data from river bed elevation measurements as shown in Figure 3 below.

![Figure 3. Cross-section of The Riverbed Elevation Data River Station](image)

The results analysis of the sediment grain that has been carried out (figure 4) obtained the average values of sediment grain size for $D_{50}$ is 0.91 mm and $D_{95}$ is 4.35 mm.

![Figure 4. Sediment Grain Size Analysis](image)

### 3.3 Analysis of Design Flood Discharge

In this study, the debit that used in the calculation of the scour depth is the peak discharge from Synthetic Unit Hydrograph Nakayasu method. The rainfall plan can use the Log Pearson Type III distribution is acceptable. Repeat Periode Year Design Rain And Parameter of The Krueng Sednagan River Basin as shown in Table 6.

![Table 6. Repeat Periode Year Design Rain And Parameter of The Krueng Sednagan River Basin](image)

<table>
<thead>
<tr>
<th>Parameters of Nakayasu</th>
<th>Data and Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Q_p 50$</td>
<td>195,130</td>
</tr>
<tr>
<td>$Q_p 100$</td>
<td>299,230</td>
</tr>
<tr>
<td>Watershed Area</td>
<td>995.86 km²</td>
</tr>
<tr>
<td>length of the longest channel</td>
<td>152.92 km</td>
</tr>
<tr>
<td>$T_g = 0.40 + 0.058 * L$</td>
<td>7,749 hours</td>
</tr>
<tr>
<td>$T_p = T_g + 0.8 * T_r$</td>
<td>12,399 hours</td>
</tr>
<tr>
<td>$T_r = 0.75 * T_g$</td>
<td>5,812 hours</td>
</tr>
<tr>
<td>$T_{0.3} = \alpha * T_g$</td>
<td>15,499 hours</td>
</tr>
<tr>
<td>$Q_p = \frac{1}{3.6} \left( \frac{A\cdot Re}{0.3T_p + T_{0.3}} \right)$</td>
<td>14,394 m³/det</td>
</tr>
</tbody>
</table>

**Table 5. Sediment Grain Size Analysis**

<table>
<thead>
<tr>
<th>Diameter Sieve (mm)</th>
<th>soil retained on each sieve (gram)</th>
<th>% soil retained on each sieve</th>
<th>soil retained finer</th>
<th>% Finer</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.75</td>
<td>1.46</td>
<td>2.73</td>
<td>194.54</td>
<td>97.27</td>
</tr>
<tr>
<td>2.36</td>
<td>27.14</td>
<td>13.57</td>
<td>167.40</td>
<td>83.70</td>
</tr>
<tr>
<td>1.18</td>
<td>39.14</td>
<td>19.57</td>
<td>128.26</td>
<td>64.13</td>
</tr>
<tr>
<td>0.6</td>
<td>60.68</td>
<td>30.34</td>
<td>67.58</td>
<td>33.70</td>
</tr>
<tr>
<td>0.3</td>
<td>47.49</td>
<td>23.74</td>
<td>20.09</td>
<td>10.05</td>
</tr>
<tr>
<td>0.15</td>
<td>17.57</td>
<td>8.78</td>
<td>2.53</td>
<td>1.26</td>
</tr>
<tr>
<td>0.075</td>
<td>2.53</td>
<td>1.26</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>
The longest river length of the Krueng Seunagan watershed is 132.92 km, the area of the Krueng Seunagan watershed is 995.86 km$^2$ and the unit discharge into the rain ($R_{50}$) is 195,130 mm. Parameters of the Krueng Seunagan River Basin are shown in Table 6 and Hydrograph Nakayasu can be shown in figure 5. From Figure 5 below, the peak discharge that occurs in the Krueng Seunagan watershed using the HSS Nakayasu method is $Q_{p50}$ 1354.5 m$^3$/sec and $Q_{p100}$ 1513 m$^3$/sec.

### Table 7. Parameters Data For Analysis of Scouring Depth with CSU Method

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Values Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>B (width of the pier)</td>
<td>4.0</td>
</tr>
<tr>
<td>L (pier length)</td>
<td>10.0</td>
</tr>
<tr>
<td>y (depth of flow)</td>
<td>2.28</td>
</tr>
<tr>
<td>V (flow velocity)</td>
<td>1.56</td>
</tr>
<tr>
<td>K1 (correction factor for pier nose shape)</td>
<td>0.7</td>
</tr>
<tr>
<td>K2 (correction factor for angle of attack of flow)</td>
<td>0</td>
</tr>
<tr>
<td>K3 (correction factor for bed condition)</td>
<td>1.1</td>
</tr>
<tr>
<td>$D_{50}$ (grain size diameter)</td>
<td>0.91</td>
</tr>
<tr>
<td>$D_{95}$ (grain size diameter)</td>
<td>4.35</td>
</tr>
<tr>
<td>FR (Froude number)</td>
<td>0.29</td>
</tr>
</tbody>
</table>

3.4 Analysis of Scouring Depth With Empirical Method

Calculation of local scour in this study used the Colorado State University method, Froehlich method, and Lacey method.

#### 3.4.1 Local Scour with the Colorado State University Method

Then determine the depth of scouring using Equations Colorado State University (CSU) method, obtained data as shown in the table 7:

$$K_2 = (\cos \theta + \sin \theta) \cdot y$$

$$V_{c50} = K_4 \cdot y_{50}$$

$$V_{c50} = 6.19 \cdot 3.06^{1/6} \cdot 0.91^{1/5} \cdot 3.06^{1/6} \cdot 0.43 = 7.228$$

$$V_{c95} = 6.19 \cdot 3.06^{1/6} \cdot 4.35^{1/3} \cdot 3.06^{1/6} \cdot 0.49 = 12.175$$

$$V_{i50} = 0.645 \left( \frac{D_{50}}{b} \right)^{0.053} \cdot V_{c50}$$

$$V_{i50} = 0.645 \left( \frac{0.91}{4} \right)^{0.053} \cdot 7.228 = 4.31$$

$$V_{i95} = 0.645 \left( \frac{D_{95}}{b} \right)^{0.053} \cdot V_{c95}$$

$$V_{i95} = 0.645 \left( \frac{4.35}{4} \right)^{0.053} \cdot 12.175 = 7.888$$

$$V_R = \frac{V_{c50} \cdot V_{i50}}{V_{c50} \cdot V_{i95}} = \frac{1.36 \cdot 4.31}{7.228 \cdot 7.888} = 4.46$$

$$K_4 = 0.4 \left( \frac{V_R}{0.15} \right)^{0.15} = 0.4 \cdot 4.46^{0.15} \cdot 0.501$$

$$d_s = 2.0 \cdot K_1 \cdot K_2 \cdot K_3 \cdot K_4 \cdot \left( \frac{D_{50}}{b} \right)^{0.43} \cdot 0.35$$

$$d_s = 2.0 \cdot 0.7 \cdot 1.0 \cdot 0.501 \cdot 0.29 \cdot 0.43 \cdot 5.06 \cdot 0.35$$

$$d_s = 2.43 \text{ m}$$

The analysis of local scour depth by the empirical with the CSU Method of 2.43 m.
3.4.2 Local scour with the Froehlich method:
The calculation of scour depth with Froehlich method is obtain:

\[ b' = b \cos \beta + l \sin \beta = 4 \cos \beta + l \sin \beta = 4 \]

\[ d_s = 0.32b'K \left( \frac{b}{b'} \right)^{0.02} \left( \frac{V}{b} \right)^{0.46} \right) Fr^{-0.2} \left( \frac{b}{d_{50}} \right)^{0.08} + 1 = 1.68 m \]

The analysis of local scour depth by the empirical method is obtained the Froehlich Method of 1,68 m.

3.4.3 Local scour with the Lacey method:
The calculation of scour depth with the Lacey method is obtain:

\[ d_s = 0.32b'K \left( \frac{b}{b'} \right)^{0.02} \left( \frac{V}{b} \right)^{0.46} \right) Fr^{-0.2} \left( \frac{b}{d_{50}} \right)^{0.08} + 1 = 1.68 m \]

\[ d_s = 0.32 \left( \frac{4}{0.91} \right)^{0.02} \left( \frac{4}{4} \right)^{0.46} + 0.2 \]

\[ = 1.68 m \]

The analysis of local scour depth by the empirical method is obtained the Froehlich Method of 1,68 m.

3.4.3 Local scour with the Lacey method:
The calculation of scour depth with the Lacey method is obtain:

\[ d_s = 0.473Q_{50}^{0.33} = 0.473 \left( \frac{1354.5}{1.679} \right)^{0.33} = 4.3 m \]

\[ d_s = 0.473Q_{100}^{0.33} = 0.473 \left( \frac{1513}{1.679} \right)^{0.33} = 4.47 m \]

The analysis of local scour depth by the empirical method is obtained the Froehlich Method of 4,3m with Q_{50} and 4,47m with Q_{100}. The scour depth with the Lacey method is greater than the CSU and Froehlich methods, because this method only uses flood discharge design without using pier shape, pier dimensions and other parameters.

3.5 Analysis of Scouring Depth Around The Bridge Pier
The scour depth observed in this study is the scour depth that occurs around the is a river station P2, P3, and P4 where the pier position is a review point at S3, S4, S5, and S6. The results of the scour depth can be seen in the table 12:

<table>
<thead>
<tr>
<th>river sta</th>
<th>Froehlich</th>
<th>Colorado State University</th>
</tr>
</thead>
<tbody>
<tr>
<td>P2</td>
<td>1,48</td>
<td>1,52</td>
</tr>
<tr>
<td>P3</td>
<td>1,48</td>
<td>1,52</td>
</tr>
<tr>
<td>P4</td>
<td>1,47</td>
<td>1,52</td>
</tr>
</tbody>
</table>

From Table 12, the scour depth that occurs around bridge pier is located a river station P2 and P3 with the pier position is a review point at S5 with a maximum scour depth of 1,65 and 1,68 meters.

3 CONCLUSION
In this study, The peak discharge that occurs in the Seunagan Krueng watershed use the HSS Nakayasu method is Q_{50} 1354,5m^3/sec and Q_{100} 1513m^3/sec. The analysis of sediment grains obtained the average value of sediment grain size for D_{50} is 0,91 mm and D_{95} is 4,35 mm. The analysis of local scour depth by the empirical method is obtained: the Colorado State University (CSU) Method of 2,43 m, the Froehlich Method of 1,68 m and with Lacey Method of 4,3m and 4,47. Further research can be compared to scour depth analysis with Hecras 5.0.7 software and It is also necessary to research experiments in the laboratory using different piers shapes.

DISCLAIMER
The authors declare no conflict of interest.

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REFERENCES


