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Local Scouring Visualization of Bed Channel Surface in Hydraulic Structure Using Surfer

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Abstract. Water flowing in the river causes a scouring event that occurs at the bed channel. The existence of scouring will increase along with changes in the geometry of the river and obstacles such as the weir which are followed by local scouring around the weir. Local scouring often occurs downstream end of weir sill which weakens its construction. Scouring measurement was conducted to monitor the pattern of scouring that occurs. By using Surfer software, the scouring visualization through the Data Grid and 3D Surface can be seen. In this research, scour monitoring in the laboratory using open channels (flume) and MDO weir with fine aggregate material as the basis of the channel. The retrieval of scouring data was performed after installing fine aggregate and three times variations of flow discharge, then the data were processed using Surfer. The first flow used water level +3.50 with the material carried at 3.77%. The second flow used water level +4.50 with the material carried at 11.16%. The third flow used water level +5.70 with the material carried at 25.46%. So with the continuous method, the total material carried at 36.27% is equivalent to 12575.77 cm^3.

Keywords: local scouring, end sill, MDO, surfer.

INTRODUCTION

A river is a watercourse with an open water face. [1]. The majority of precipitation that falls to the earth goes to lower areas and finally spills into lakes or the ocean after encountering diverse opposition from strong forces. [2]. Humans benefit greatly from rivers' functions as raw water sources, irrigation systems, renewable energy sources, modes of transportation, tourist attractions, drainage channels, and other things.

The water flowing in the river causes the bed channel to erode. Scouring is a natural phenomenon caused by erosion of the flow of water at the base and cliffs of the alluvial channel or the process of decreasing or deepening the riverbed under the elevation of the natural surface (datum) because of the interaction between the flow and the riverbed material [3]. The existence of scouring will increase with changes in river geometry and obstacles in the form of hydraulic structure followed by local scouring around the structure [4]. Local scouring was caused by changes in flow characteristics such as flow patterns turning into spiral flows or turbulence, and changes in flow speed, causing changes in sediment transport.[5].

The water flow in the weir reservoir creates a large amount of speed and energy because of increasing upstream water level by damming. The principle of the stilling basin is when the elevation of the upstream water level is higher than the elevation of the downstream water level causing a hydraulic jump [6]. The hydraulic jump can be useful to reduce energy due to water flow, but stilling basin is needed to protect the riverbed. In addition, the hydraulic jump that occurs downstream of the structure often results in waves or vortexes. The coils can cause scouring of the bed channel.

Based on the flow pattern that occurs downstream of the weir, the biggest cause of weir damage is due to hydraulic factors, especially the influence of local scouring the downstream of end sill. Local scouring frequently has a pattern of rapid changes in flow. Damage to the bed channel structure will come from the impact of scouring, which could impair the stability of the water structure. [7]. Surfer is one of the data processing software according to known parameters that produce output in the form of contour map visualization and grid-based three-dimensional modeling. Surfer provides wider gridding control with its ability to process irregular XYZ tabular data into a customizable visual form of the grid. This informative display makes it easy for users to interpret data so that a quality publication map is obtained quickly [8].

Previous studies have utilized Surfer to analyze topographic measurement data as well as a contour to apply digital technology in the field of mapping. A similar study in processing data using Surfer was performed by Ari Nugroho [9] to illustrate an integrated, informative, and editable topographical digital map of Pulau Panjang, Banten. Agustan [10] proposed Surfer can be used to measure the increase in building heights in residential or urban environments. Junaidi [11] proposed the sedimentation pattern of the Muara Batang Arau can be modeled in three dimensions with Surfer and is very helpful in volumetric analysis. Didit Puji Riyanto [12] proposed discharge simulation affects to the amount of loss percentage of bed channel surface volume which is calculated by Surfer.

In this study, grid data and 3D Surface tools were used as outputs in scouring analysis using Surfer. Surfer software is highly interactive for use in scouring visualization in this study. The Data Grid displays the scouring conditions shown on the color scale and the Surface 3D displays the scour isometry that occurs according to existing XYZ data.

METHODOLOGY

The research method used is a quantitative method of experimentation in the Hydraulic Laboratory of Politeknik Pekerjaan Umum with a grid system analyzed descriptively. The objects in this study used samples of the stilling basin model on an open channel (flume). The research flow chart is coherently described in FIGURE 1.

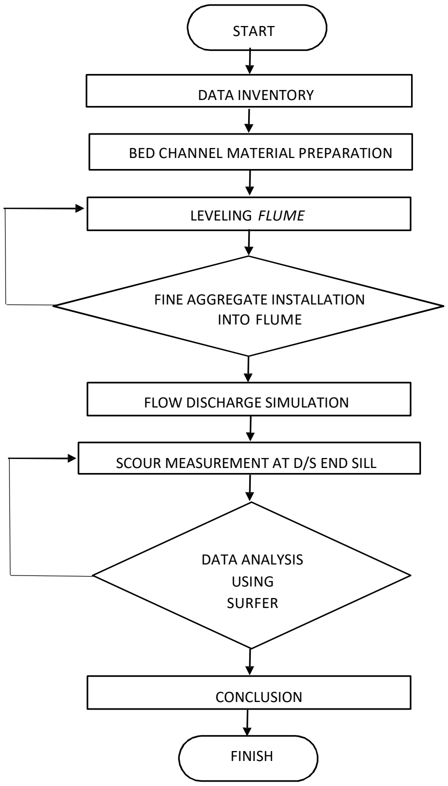

FIGURE 1. Research Flowchart

Data Inventory

Data inventory was conducted by looking for references to previous research, including journals, scientific papers, and final projects. Apart from research journals, references are also obtained through books related to research. The data used in this study used secondary data and uses assumptions under certain conditions. Due to this research, all analyzes are based on empirical theories which are then modeled on a laboratory scale.

Making Bed Channel

The making of bed channel in this study used fine aggregate that had been sifted with several layers of fine aggregate retained on a 1.18 mm sieve. The selection of fine aggregate on selected model sizes are 0.6 mm (No. 30) and 1.18 mm (No. 16). The two types of fine aggregate granules are then mixed to produce movable granules. The fine aggregate used is volcanic fine aggregate which is sieved using the Sieve Analysis tool for Grain Size Analysis. The material for riprap also uses volcanic fine aggregate with a grain size of 2.36 mm (No. 6) [12].

Available fine aggregate is stored in the Building Materials Laboratory to facilitate access to work because the laboratory contains material and concrete test equipment. Fine aggregate is taken as needed using a shovel and put into a bucket. Furthermore, the fine aggregate is transported using an *angkong* or fine aggregate wheelbarrow to the Sieve Shaker as shown in FIGURE 2.

FIGURE 2. Fine Aggregate Material Sieving Process Using Sieve Shaker

Sieve analysis is an experiment to filter soil samples through a set of sieves to determine the grain size distribution of soil with the largest hole at the top. Before sifting fine aggregate, a sieve must be prepared first. The sieve size used a standard ISO 565/3310-1 to sieve fine aggregate in the order shown in TABLE 1. The bottom sieve sequence used a pan and the topmost order uses a cover. After the filter was installed according to the standard, then the fine aggregate was inserted from the topmost sieve arrangement using a small shovel with sufficient volume.

TABLE 1. Fine Aggregate Sieve Size

Sieve Size	Sieve Size (mm)
3/8”	9,5
No. 4	4,75
No.6	2,36
No. 16	1,18
No. 30	0,60
No. 50	0,300
No. 100	0,150
No. 200	0,750

After the sieve set was closed using a cover, then the sieve set was placed on the sieve shaker and tied tightly. The power button was turned on and waits for five minutes for the fine aggregate to completely separate from the largest to the smallest size. After that remove the sieve set and separate it according to the required sieve number as shown in Figure 3, the size of the unneeded granules was separated to be used for other purposes. Fine aggregate grains of 0.06 mm and 1.18 mm were mixed and put into containers, which are then called mixed fine aggregate. Fine aggregate grains of 2.36 mm are also put in different containers.

FIGURE 3. Granules Separation According to Size

In this process, no weighing and drying are carried out first because the purpose of using this tool is to find the size of the granules that match the scale of the model. The results of the sieve are used to fill the flume which results in the required amount of weight is not yet known, so the fine aggregate sieved is quite a lot. In addition, fine aggregate will also be watered, so the drying process is not needed. However, in the process of sieving using a relatively dry fine aggregate so that the distribution of fine aggregate can be well netted.

Leveling Flume

The steps to set the flume level is done by adjusting the position of the balance or level of the flume floor using a waterpass shown in FIGURE 4. The rise or fall of the flume position was regulated by a hydraulic jack located at the bottom of the flume. The Nivo position must be in the middle which indicates the flume is level. When the flume was level, the next step was to plan the elevation and location of the weir to match the hydraulic design calculations. The elevation plan and the location of the weir were drawn using whiteboard marker ink or BG-12 markers. The various lines drawn are the elevation of the design water level, the bed channel elevation, and the bed slope channel protector, the flow monitoring area that is upstream along 66.6 cm or equivalent to 20 m of real size, as well as the position of the scouring pattern observation point located downstream of the end sill.

FIGURE 4. Leveling Flume

The observation point of the scouring pattern was at points A to K drawn on the flume wall. Each alphabet has three points which when viewed from the direction of the flow are located on the right side (point 1), the middle side (point 2), and the left side (point 3). The points were then named A1, A2, A3, ..., K1, K2, and K3 with a total of 33 points. Alphabets A to E were located on the transition slope from the end sill to an elevation ± 0.00. The distance range between alphabets A to B is 6 cm or 2 meters under real conditions. This is intended so that the scouring pattern that occurs downstream of the end sill can be recorded completely at a relatively close distance. Then the distance was widened from the alphabet F to K, with the distance F to G is 12 cm or 4 meters under real conditions. This tenuous distance was intended so that the data obtained can represent the pattern of scouring at the bed channel before and after being given the bed channel protector. The total length of the observed scour pattern is 90 cm or 30 m under real conditions (look at FIGURE 5 and FIGURE 6).

If the position of the observation point had been drawn on the flume wall, the next step was to draw the same point and install a reference line that was on the upper side of the flume to facilitate the process of measuring the depth of the scouring pattern. The reference line is made using mattress thread. The first line was made, which was a position above point A that connects points A1 and A3, then the mattress thread is tied and glued together with tape. The next stage is to do the same at points K1 and K3. Lines A and K are then divided into 3 points, two points on the left-right side and one point in the middle. Then connect the points to form a net that is rectangular in size. After that, other points (B to J) were made based on the references that have been drawn.

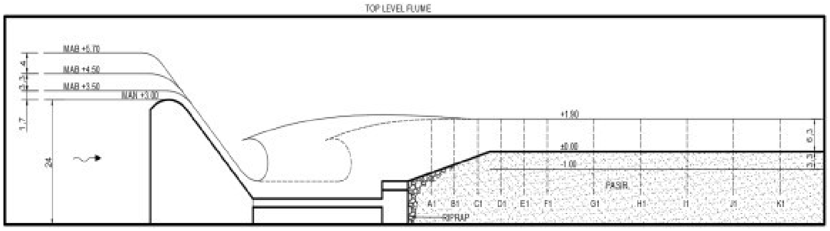

FIGURE 5. Flume Longitudinal Section [12]

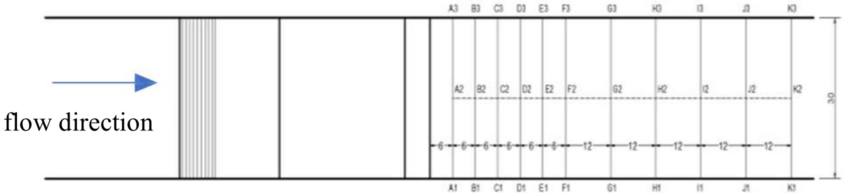

FIGURE 6. Flume Top View [12]

Fine Aggregates Installation into Flume

Fine aggregate that had been sieved and mixed was first stored in containers, picked up, and put into the flume. The fine aggregate of the mixture is inserted until it reaches the bed channel elevation which is ± 0.00. The fine aggregate is reduced and does not reach the bed channel elevation on the slope downstream of the end sill. It is intended to fill the remainder with riprap material as the bed channel protector. When detailed, then points A to D are filled with riprap at the top and fine aggregates at the bottom. Meanwhile, point E to the end of the flume was filled with mixed fine aggregate.

FIGURE 7. Fine Aggregates Material Installation into Flume

The next process was leveling the fine aggregate surface so that the elevation was as planned. The tools used were a trowel and wooden board. This process is also known as fine aggregate leveling. Parts that have fine aggregate above the design line should be reduced or pressed using a wooden board. While the part that has a fine aggregate below the design line should be added with fine aggregate. This step should be done carefully because it is quite difficult to make the surface of the fine aggregate evenly.

FIGURE 8. Fine Aggregates Position Leveling

Flow Discharge Simulation

After the model and material were installed, the next step was to simulate the flow discharge. The water flow was simulated through several stages of water level, namely WL +3.50, +4.50, and +5.70. These three water levels were equivalent to prototype discharge as described in TABLE 2. This aims to create a discharge curve from the flow discharge that passes through the crest weir.

TABLE 2. Correlation of Elevation and Prototype Discharge [12]

No	Series Name	Elevation	Prototype Discharge (m^3/s)
1	Series A	+ 3.50	4.86
2	Series B	+ 4.50	31.40
3	Series C	+ 5.70	88.73

The first step was to turn on the water pump, then the valve was opened until the water level reaches the crest weir. After that, it was slowly opened until the first WL condition is +3.50 (discharge 4.86 m^3/s). The water level at this elevation was maintained for 5.5 minutes so that the downstream scouring pattern can be formed. While taking measurements of water level against models marked by several points. After completion and the valve is closed, a scour depth measurement is taken at the first WL condition.

The next step was to repeat the water flow simulation process with WL conditions +4.50 (discharge 31.40 m^3/s) to +5.70 (discharge 88.73 m^3/s). The measurement of scouring depth was carried out after each flow discharge simulation was completed with certain WL conditions. The pattern of scouring formed occurs due to several alternative flow discharges such as normal discharge, flood discharge, and rapid drawdown. Then the water level measurement is carried out on the weir profile will show a change in the type of flow that passes through the weir.

FIGURE 9. Water Level Measurement

Scouring Depth Measurement

The stages of scouring observation are carried out using a video recorder that will record the entire series of scouring events. In addition to the recording process, the results were noted manually. Here are the stages in the scouring pattern analysis:

1. Observation of scouring patterns downstream of end sill under standard design conditions
2. Scouring measurement of the depth and length from conditions downstream of the end sill
3. Processing data from scouring downstream of end sill using Surfer Software

The scour depth measurement was carried out every flow discharge simulation was completed and the water had begun to recede. The measurement starts from point 1 which was on the right side of the flow, followed by point 3 which is on the left side of the flow. The point at the end was measured first because the measurement was relatively easier using a ruler. After that, the measurement at point 2 was carried out. At this point, the measurement was made using the caliper inserted from the top of the flume towards the bed channel. The X and Y coordinates have been determined by creating auxiliary lines in the form of mattress thread nets located on the top of the flume. To find out the exact Z coordinates or point level 2, a laser pointer was used that can firelight at the same position between points 1 and 3. This is by the nature of the rays that can penetrate clear objects (flume glass) and propagate straight.

The rays hit the caliper and the scour depth can be read by lowering the measuring rod. After the beam hit the end of the main scale and the end of the measuring rod reached the fine aggregate surface, then the jaw locking bolt was rotated. The depth of scouring was known by reading the main scale and the vernier caliper scale. Measurements were carried out carefully at all existing points. After the depth of scouring was known, then the data is recorded in the table that has been provided.

FIGURE 10. Scouring Depth Measurement at Edge Side of Flume

FIGURE 11. Scouring Depth Measurement at Middle Side of Flume

Data Analyzing Using Surfer

Surfer is a software product of Golden Software, Inc. for contour map creation and three-dimensional modeling based on the grid. An advanced software interpolates a model that converts XYZ data into quality publication maps. Surfer will display the grid as a contour map of a 3D map, 3D wireframe, vector, image, shaded relief, and postal map.

In the course of this study used excel data from scours that have been observed to be entered into the Surfer as contour coordinates to be used. Then through the surface plot which is a worksheet used to create a map or grid file will appear a 3D contour of the excel data that has been interpolated.

After that, the process of gridding or interpolation the point using the algorithm of choice in the surfer includes inverse distance, kriging, minimum curvature, nearest neighbor, polynomial regression, radial basis function, Shepard method, and triangulation with linear interpolation.

RESULT AND DISCUSSION

Measurement of the scour depth was carried out after running one of the water levels was completed. Crest weir was at an elevation of +3.00. Scouring observations were carried out on 4 conditions as shown in TABLE 3 that is the initial condition, after running discharge elevation +3.50, after running discharge elevation +4.50, and after running the discharge elevation +5.70. The method used in analyzing this scouring is by continuous method, namely the running process was carried out continuously from the initial running (condition A) to the end (condition D).

TABLE 3. Scour Observation at Each Condition

No	Series Name	Elevation	Description
1	Condition A	+ 3.00	Initial Conditions
2	Condition B	+ 3.50	After running elevation discharge + 3.50
3	Condition C	+ 4.50	After running elevation discharge + 4.50
4	Condition D	+ 5.70	After running elevation discharge + 5.70

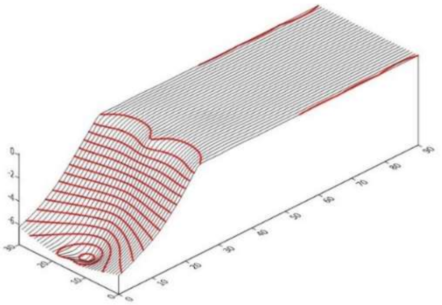

FIGURE 12. Bed Channel Surface Perspective of Condition A

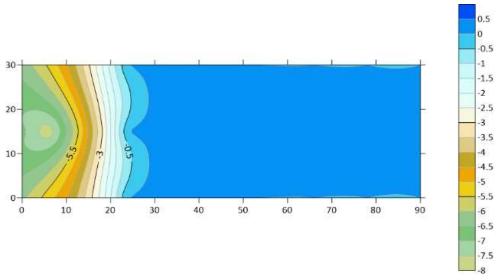

FIGURE 13. Bed Channel Surface Plan of Condition A

In condition A, the bed channel surface is depicted according to flume leveling and installing fine aggregate materials as in FIGURE 12 and FIGURE 13. No scouring has occurred due to the water flow.

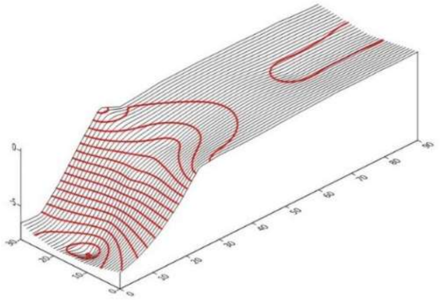

FIGURE 14. Scour Perspective of Condition B

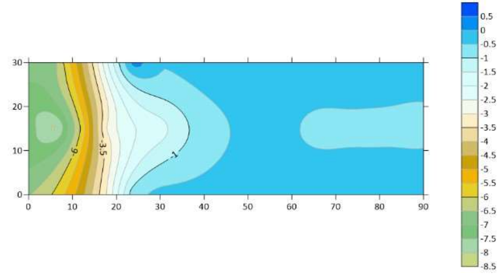

FIGURE 15. Bed Channel Surface Plan of Condition B

In condition B begins to erode on the slope and bottom of the most downstream channel as shown in FIGURE 14 and FIGURE 15. This shows the hydraulic jump start back at the elevation of the downstream water level resulting in scour hole on the bed channel surface.

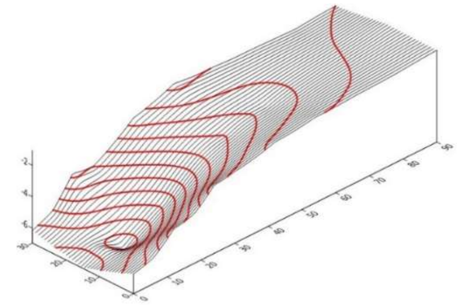

FIGURE 16. Scour Perspective of Condition C

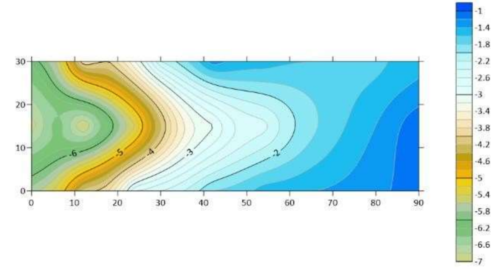

FIGURE 17. Bed Channel Surface Plan of Condition C

In condition C, scouring occurs a lot on the slope. Scouring begins to occur downstream near the stilling basin and then widens downstream along with the flow up to a certain distance shown in FIGURE 16. At FIGURE 17 there is a color variation that indicates the level of uniformity of scouring that occurs on the bed channel surface.

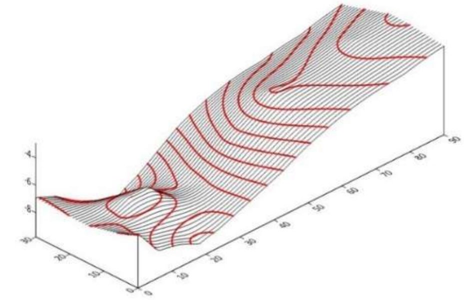

FIGURE 18. Scour Perspective of Condition D [12]

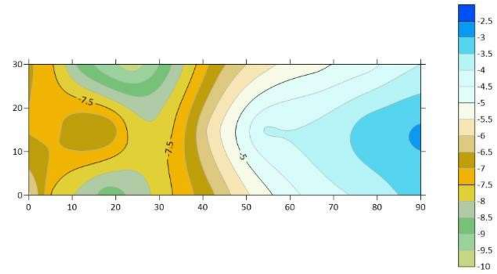

FIGURE 19. Bed Channel Surface Plan of Condition D [12]

In condition D the scouring that occurs deepens as the elevation of the water level rises. FIGURE 18 indicates that the increase in scouring depth occurs evenly at the slope and base of the most downstream channel. Variations in depth are shown in FIGURE 19 where the shape of the channel surface is increasingly sloping and eroded which is characterized by yellow discoloration and reduced blue color.

Based on the results of the running debit experiment and processed using Surfer, it can be seen the difference in the total initial volume with the lost volume. The percentage loss of channel base material from condition A to condition D is 36.27%. While the volume of material loss is 0.0125 m^3 (TABLE 4).

TABLE 4. Volume Loss [12]

No	Condition	Total Volume (cm^3)	Lost Volume (cm^3)	Loss Percentage (%)
1	Initial	34673.84		
2	Discharge Series A	33367.23	1306.61	3.77
3	Discharge Series B	29644.11	3723.12	11.16
4	Discharge Series C	22098.07	7546.04	25.46
		Total	12575.77	36.27

CONCLUSION

Scouring that occurs downstream end sill can weaken the weir structure. Scouring monitoring carried out on the scale of laboratory models shows the amount of scouring that occurs. By using Surfer, more interactive scouring monitoring and data visualization can be done quickly. Surface's 3D tool is used as a visualizer to get the scouring contours with an isometric look. The Data Grid center displays a scouring contour plan with depth levels indicated in terrain color variations.

At running discharge elevation +3.50 material loss gained 1306.61 cm^3 equivalent to 3.77%. For running discharge elevation +4.50 material loss obtained 3723.12 cm^3 equivalent to 11.16%. For running discharge elevation +5.70 material loss obtained 7546.04 cm^3 equivalent to 25.46%. So that the total volume loss of 12575.77 cm^3 is equivalent to 36.27%. The most extreme scouring depth occurs in condition D where the elevation of the water level is +5.70 and has previously gone through several flood conditions. The base surface of the channel becomes more sloping and is likely to erode the entire base of the channel as running continues.

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