

Analysis of Scour Depth at River Bends Due to a Combination of Groin and Gabion Structures

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Abstract

This research aims to determine the scour depth based on the relationship between the flow discharge (Q_1) and the simulation time (t_1), between the flow discharge variable (Q_2) and the simulation time (t_2) and between the flow discharge variable (Q_3) and the simulation time (t_3).

This study was conducted at a bend in the Musi River in Bailangu Village, Musi Banyuasin Regency, and with model simulations carried out at the Hydraulics Laboratory of universitas Bina Darma.

The results in the first simulation, which utilized only a groin with a discharge of $Q_1 = 0.726 \text{ m}^3/\text{sec}$, the maximum scour observed was -4.5 cm. The coefficient of determination (R^2) was 0.8539, indicating that 85% of the data variation could be explained by the model; the correlation coefficient (R) was 0.73 (73%), signifying a strong relationship between the variables of scour depth (dg) and flow discharge (Q). The second simulation, employing a combination of a groin and gabions with a discharge of $Q_2 = 0.888 \text{ m}^3/\text{sec}$, resulted in a maximum scour (dg_{max}) of -5.0 cm. The coefficient of determination (R^2) was 0.8713, meaning 87% of the data variation could be explained by the model; the correlation coefficient (R) was 0.759164 (76%), indicating a strong relationship between the variables of scour depth (dg) and flow discharge (Q).

Keywords: Groin, Gabion structure, discharge, scour depth

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I. INTRODUCTION

A river is a naturally formed open channel or drainage way that functions as a conduit for water. An interesting aspect of rivers to observe is the occurrence of morphological changes. These changes arise either naturally or as a result of various interventions along the river—such as the construction of dams and bridges—or due to unavoidable natural features like river bends.

According to Triatmodjo (2003), a river or open channel is a waterway in which water flows with a free surface. In open channels—such as rivers (natural channels)—flow variables are highly irregular in terms of both space and time. These variables include the channel's cross-section, roughness, bed slope, bends, and discharge rate. Sosrodarsono (1994) defines a river as a naturally formed, elongated channel on the Earth's surface that conveys rainwater and is continuously subjected to the flow of water.

Aristi (2012) notes that at channel meanders (bends), there are longitudinal velocity components aligned with the flow direction and transverse velocity components perpendicular to the flow direction—directed either toward the inner or outer bank of the bend. The superposition of these two velocity components results in helical flow (a screw-like flow pattern). Centrifugal force at the bend generates a transverse current which, combined with the main current, creates helical flow. Specifically, the centrifugal force at the bend induces a transverse current that interacts with the main current to form helical flow. The magnitude of this transverse current velocity ranges from 10% to 15% of the main flow velocity. Consequently, in meandering rivers, erosion occurs on the outer bank of the bend, while deposition takes place on the inner bank (Aristi, 2012).

In addition to centrifugal force, there is helical flow, which results in higher flow velocities along the outer bank of a bend compared to the inner bank. This phenomenon causes damage to existing infrastructure, erosion of the riverbank on the outer side of the bend, and sediment deposition on the inner side. If this process continues over time, it leads to changes in river morphology. River meandering is a highly complex phenomenon influenced by parameters such as bed sediment, river geometry, and flow discharge. (M. Galib Ishak et al., 2008)

Mudjiatko (2000) stated that water flowing through a bend experiences centrifugal force—a force that drives the water outward toward the outer bank. Centrifugal force acts when there is no transverse mass transfer of water. The vertical distribution of flow velocity—where surface velocity exceeds velocity near the riverbed—

influences the distribution of this centrifugal force; consequently, the centrifugal force is greater at the surface than near the bed. Helical flow is a spiral movement of river water that causes erosion on the outer bank and deposition on the inner bank. The magnitude of the transverse current velocity ranges from 10% to 15% of the main flow velocity; notably, near the surface, the transverse current moves toward the inner side of the bend. Forces at the bend generate transverse river currents which, combined with the main flow, create helical flow. (Vita Dwi Febriani et al., 2015)

II. MATERIAL AND METHODS

This study was conducted at a bend in the Musi River in Bailangu Village, Musi Banyuasin Regency, as shown in Figure 1, and with model simulations carried out at the Hydraulics Laboratory of Bina Darma University (Figure 2).



Figure 1: Map of the study area

2.1. Laboratory Modeling

The laboratory model was constructed as shown in Figure 3.2 to calibrate or compare numerical calculation results against a fixed-bed baseline. Laboratory Experimental Setup



Figure 2: Laboratory scale model



Figure 3: Model simulation

The experimental equipment and procedures are as follows:

1. A rectangular channel model (50 cm wide, 30 cm high, and 600 cm long) with a 90° bend, constructed with brick walls.
2. A point gauge for measuring water surface elevation. Measurements are taken across the channel's transverse section at the bend during the simulation run.

3. A stopwatch to measure the time required to collect the flow discharge at the channel outlet. For this purpose, the water discharge is collected, and both the collection time and volume are measured. Based on the time and volume data, the average flow velocity in the channel can be determined.
4. Laser Doppler (a laser-based flow velocity measuring device) and a current meter to measure flow velocity distribution (vertically and horizontally) in both straight sections and at the bend. These instruments are movable, allowing for the measurement of vertical velocity distribution, particularly at the bend.
5. Water source (pump). Water is supplied via a previously calibrated pump. Simulation runs are conducted using various discharge rates.

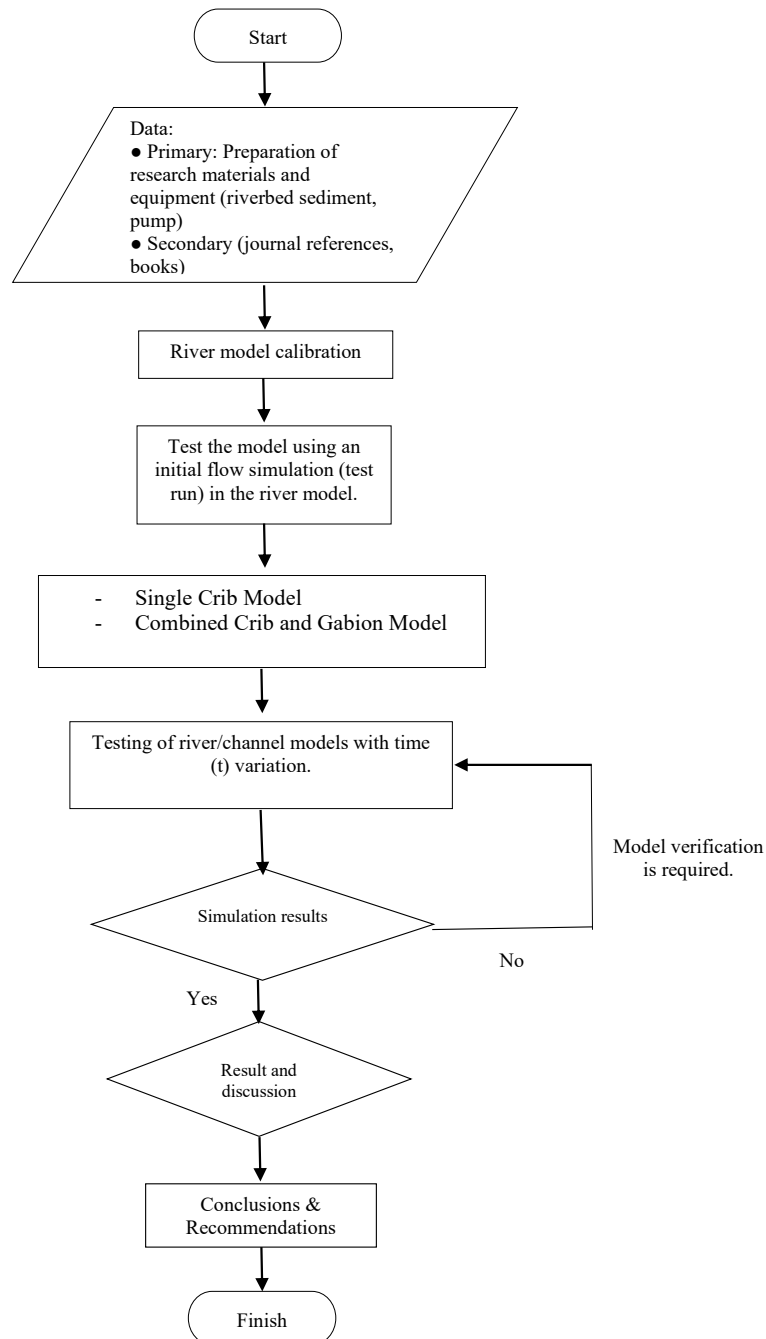


Figure 4: Research flowchart

III. RESULTS AND DISCUSSION

3.1 Model Scale Analysis

The dimensional analysis in this study employs Langhaar's method; this approach is considered more suitable because it involves relatively few parameters and is typically used for relatively simple problems. Dimensionless numbers are derived directly from the relationships between the existing parameters. However, this method would encounter difficulties in complex problems involving a large number of parameters.

$$dg = f(Q, v, h, \rho_w, g, t) \quad \dots \quad (3.1)$$

The steps for the dimensional analysis are as follows:

1. The problem formulation identifies the parameters influencing sedimentation (bedload) at the riverbed of the river in Bailangu Village, Musi Banyuasin Regency, as follows: flow discharge (Q), flow velocity (v), water depth (h), scour depth (dg), gravity (g), water density (ρ_w), and time (t).

2. These parameters are categorized as follows:

- a. Dependent parameter: dg
 - b. Parameters that vary during the experiment: Q, v, h, and t
 - c. Another parameter: g and ρ_w
3. The values of α_1 , β_1 , and γ_1 are determined via tabulation

Grup	1	2			3		Note
Parameter	Q	v	t	ρ	g		
M	3	0	0	1	0		α_1
L	0	1	1	-3	1		β_1
T	-1	0	1	0	-2		γ_1
	k1	k2	k3	k4	k5		ki

Equations related to the parameters

$$k_5 = 0$$

$$k_1 + k_2 + 2k_3 - 3k_5 + k_6 = 0$$

$$k_3 + k_4 - 2k_6 = 0$$

Eliminate k6

$$2k_5 + k_6 = 0 \quad k_6 = -2k_5$$

$$k_1 + k_2 + k_3 + 2k_5 = 0$$

$$2k_5 = -k_1 - k_2 - k_3$$

Determination of the dimensionless numbers:

ki	k1	k2	k3	k4	k5
Parameter	dg	h	t	ρ	g
π_1	1	0	-1	0	0
π_2	0	1	-1	0	0
π_3	0	1	-1	0	0
π_4	0	0	1	1	0,5

$$\pi_1 = dg/t$$

$$\pi_2 = h/t$$

$$\pi_3 = h/t$$

$$\pi_4 = 0.5gt = \sqrt{2g \times t}$$

$$(h/t) \times (\sqrt{2gt})$$

$$h/t \times (g^{1/2} t^{1/2}) \text{ is equivalent to } v = \sqrt{2gh}$$

$$f(dg/t; h/t; v) = 0 \quad (v \approx 0)$$

$$(dg/t) = f(h/t)$$

3.2 Discussion

3.2.1. Graph showing the relative relationship between (dg/t) and (h/t) with $Q = 0.726 \text{ m}^3/\text{sec}$

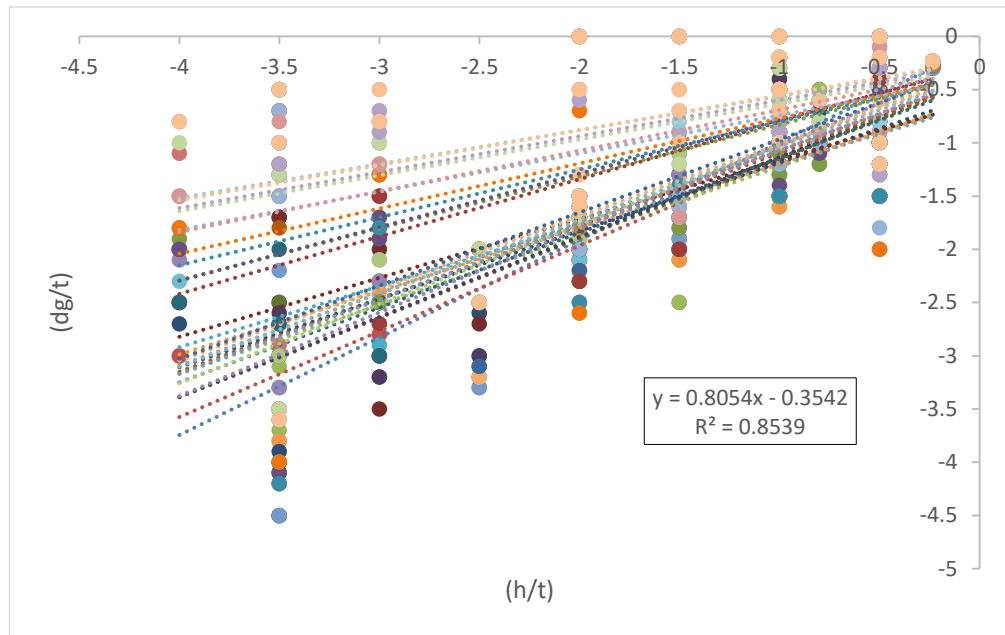


Figure 5: Scour pattern with $Q_1 = 0.726 \text{ m}^3/\text{s}$

Based on the analysis results shown in Figure 5—specifically for the first simulation where only a groyne was installed—the maximum scour observed was - 4.5 cm. The coefficient of determination (R^2) was 0.8539, meaning 85% of the data variation could be explained by the model; the correlation coefficient (R) was 0.73 (or 73%), indicating a strong relationship between the two variables: scour depth (dg) and flow discharge (Q).

3.2.2 Graph of the relative relationship between (dg/t) and (h/t)

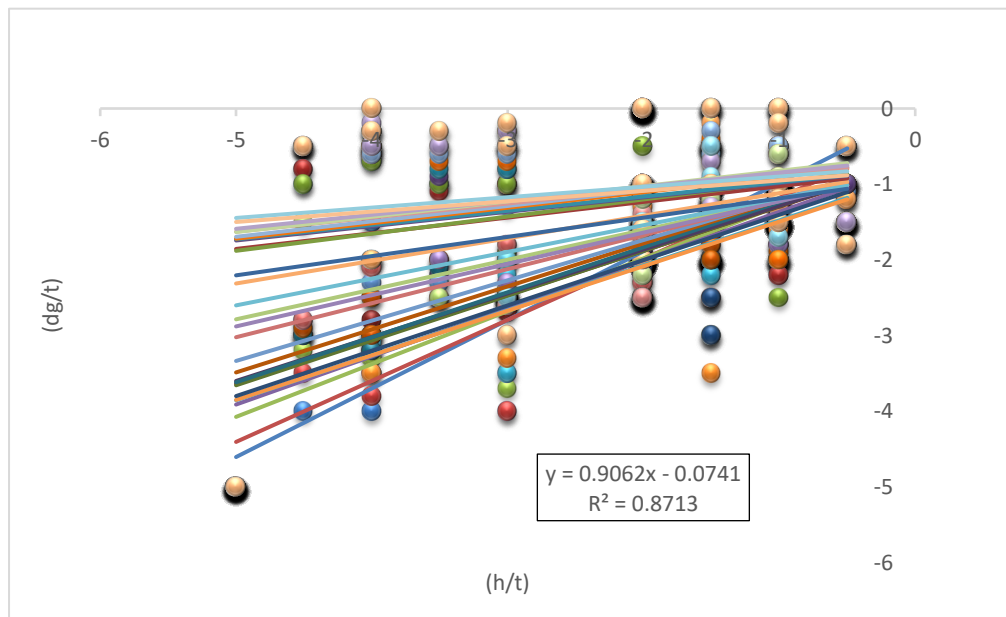


Figure 6: Relative scour pattern with $Q_2 = 0.888 \text{ m}^3/\text{sec}$

The analysis results are as shown in Figure 6; the second simulation, which utilized a combination of groin and gabions, produced a scour depth of 5.0 cm. The coefficient of determination (R^2) was 0.8713—indicating that 87% of the data variation could be explained by the model—while the correlation coefficient (R)

was 0.759164 (or 76%), signifying a strong relationship between the two variables: scour depth (dg) and flow discharge (Q).

IV. CONCLUSION

Based on the data analysis and discussion, the conclusions of this study are as follows:

1. In the first simulation, which utilized only a spur dike with a discharge of $Q_1 = 0.726 \text{ m}^3/\text{sec}$, the maximum scour observed was - 4.5 cm. The coefficient of determination (R^2) was 0.8539, indicating that 85% of the data variation could be explained by the model; the correlation coefficient (R) was 0.73 (or 73%), signifying a strong relationship between the variables of scour depth (dg) and flow discharge (Q).
2. In the second simulation, which employed a combination of a spur dike and gabions with a discharge of $Q_2 = 0.888 \text{ m}^3/\text{sec}$, the maximum scour ($dg_{\max}$) was -5.0 cm. The coefficient of determination (R^2) was 0.8713, indicating that 87% of the data variation could be explained by the model; the correlation coefficient (R) was 0.759164 (or 76%), signifying a strong relationship between the variables of scour depth (dg) and flow discharge (Q).

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