A Study on the Geometric Developmental Characteristics of Riffle-Pool-Bar system

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1. Introduction

Natural rivers commonly display a channel shape that has a repetitive pattern of faster and slower flow rates and at the meander to build up bar as known as the riffle-pool-bar system (RPBS). RPBS are observed from mountain headwaters to valley lowland settings, straight to meandering river reaches (Fig.1). However, we have a limited understanding of how RPBS form, including the channel shape and mechanisms.

Observations and laboratories were used to address these knowledge gaps. First, we measured the developed RPBSs in three rivers (Dan, Jialing, Jing Rivers) in China and in the laboratories to obtain the necessary information (latitude, longitude, elevation, current speed, depth, river width, etc.). Second, we quantified the planar and vertical morphology of the RPBS by the knowledge of irregular geometry. Finally, we relate these two quantified indices to the energy dissipation rate and resistance of the RPBS in an attempt to explain the formation mechanism.

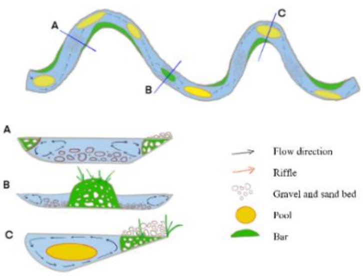

Figure 1. The primary, secondary and tertiary nature of the riffle-pool-bar system

2. Materials and Methods

2.1 Field Investigation

Field measurements obtained the latitude, longitude, elevations of riverbed, the water surface, the velocity and depth of flow of sampled cross sections of each RPBS. There were 18 RBPSs in the Dan River, 9 RBPSs in the Jialing River, and 10 RBPSs in the Jing River (Fig.2). In total, the parameters of 391 cross sections in RBPSs were obtained in the field work.

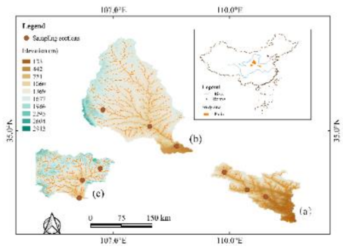

Figure 2. Sampled river sections. (a) is the Dan River basin; (b) is the Jing River basin; and (c) is the Jialing River basin

2.2 Flume Experiment

The experiment was divided into two runs, which were with a fixed channel and without a fixed channel in the flat original channel. Each run included the experiments of 15 groups of steady flows (0.1-1.5 L/S) and 6 groups of unsteady flows, respectively. For each group of experiment, the riverbed was refilled before the experiment, which ensured the initial riverbed conditions were consistent with all groups (Fig.3).

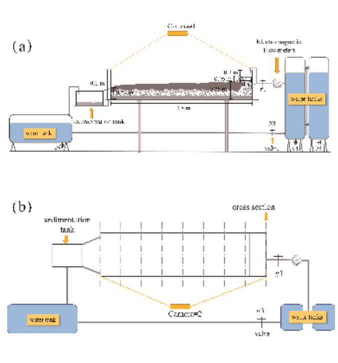

Figure 3. (a) the side view; (b) the top view.

2.3 Developmental degree

1) Coefficient of plane development degree

The plane development degree *RPB* of the RPBS was calculated by Formula (1). The larger the value of RBP is, the shorter the system is, and the smaller the value is, the narrower and longer the system is.

$$RPB = 0.447ZK_1 + 0.485ZK_2 + 0.448ZK_3 + 0.485ZK_4 + 0.360ZK_5 \quad (1)$$

Where,

Index	Equation	Mean
K_1	$4A/P^2$	Circularity ratio
K_2	A/A'	Compactness ratio
K_3	L'/L	Percentage elongation
K_4	A/L^2	Shape ratio
K_5	$2\pi/P$	Mean curvature

In the table: A is the area of the system, m^2; P is the perimeter of the system, m; A' is the minimum circumscribed area of the system, m^2, and the A' is calculated by the length and width of the minimum external rectangle. L is the major axis of the system, m; L' is the minor axis of the system, m. $ZK_1, ZK_2, ZK_3, ZK_4, ZK_5$ are standardized by K_1, K_2, K_3, K_4, K_5.

2) Coefficient of longitudinal development degree

The vertical development degree was defined after the riverbed shape is stable (Equation 2), SP is close to 0 for flat-bed; when the RP<0.05 for bed surface with sand ridge or single system; If RPBS was well developed, SP>0.05, and may reach or exceed 0.2.

$$RPB = 0.447ZK_1 + 0.485ZK_2 + 0.448ZK_3 + 0.485ZK_4 + 0.360ZK_5 \quad (2)$$

Where AB, BC, CD, DE, EF and FG are the length of curve, and AG is that of straight line.

3. Results

In the both runs with the sediment tractive force and the fluid shear stress trending to a decrease along the flume, all of the RPBSs gradually become stable (Fig.4).

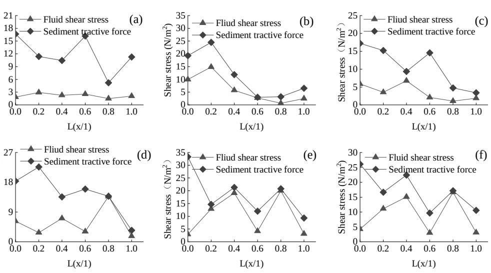

Figure 4. Fluid shear stress and sediment tractive force in the flume experiment.

The change of n in the two steps could clearly indicate the change of riverbed morphology during the experiment (Fig. 5).

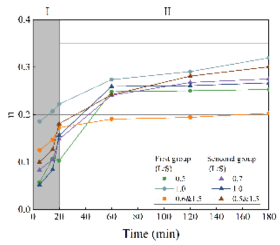

Figure 5. Variation of roughness with time for different discharges.

The developed systems were positively correlated with RP, which indicated that the better the systems developed, the higher the self-dissipation rates within the systems, and the more stable they were (Fig.6)

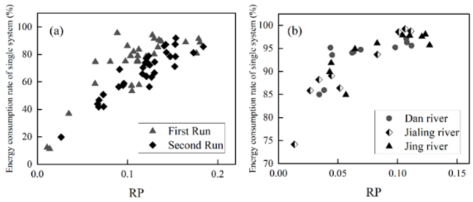

Figure 6. Relationship between the RP and the energy consumption rate of each system

It showed that the integrated resistance increased with the development of RPBS, and the longer and narrower the RPBS was developed, the larger the resistance in the system (Table 1).

Table 1. Relationship between resistance and development degree coefficients

	Model	R^2
Indoor	$\chi = 1.0151 + 0.5049 * RP - 24.2462 * RBP$	0.716
Field	$\chi = 0.54 + 0.2579 * RP - 8.6029 * RBP$	0.729

4. Conclusion

1. The formation process of RPBS could be divided into two steps.

2. RPBS developed well has the high energy dissipation rate, which is more stable.

3. The morphological structure of RPBS has the characteristics of increasing resistance, and increasing the intensity of turbulence and self-consumption of flow energy.