River response by sediment transport after dam slit in mountain stream

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1. INTRODUCTION

One of methods to control sudden debris flow in the mountain areas is the construction of check dams. Approximately dams more than 85,000 (as of 2003, Sabo guide) are in the mountain stream to control natural disasters. Through check dam construct, people have kept security from the disasters, but it caused environmental problems such as coastal erosion, riverbed degradation and ecosystem discontinuity (Taguchi, 2009). Therefore the existing check dams are being repaired into open type shapes. A construction for slit check dam causes dramatic environmental changes and it is expected to restore river ecosystem. Nevertheless, it is not carried out enough research about ecosystem change or river restoration after check dam slit.

One check dam was slit with two passages on Wasada stream in Yamagata prefecture in July, 2010. We conducted investigations about physical condition such as velocity, particle size and bottom gradient and species diversity before dam slit, in 2009. The purpose of this paper is to compare river physical conditions and to verify river response with erosion before and after slit construction.

2. SUTDY AREA AND METHOD OF ANALYSIS

(1) Study areas

The check dam was constructed on second order's mountain stream in 1980. The stream has two small check dams and the slit dam is located on the downstream side. Accumulated sediments as average size of 27mm made mild bottom gradient on upstream reach of the dam before dam slit. At the same time with slit construction, a lot of sediment was removed, and channel converted into trapezoidal and straight channel (photo in Figure 1).

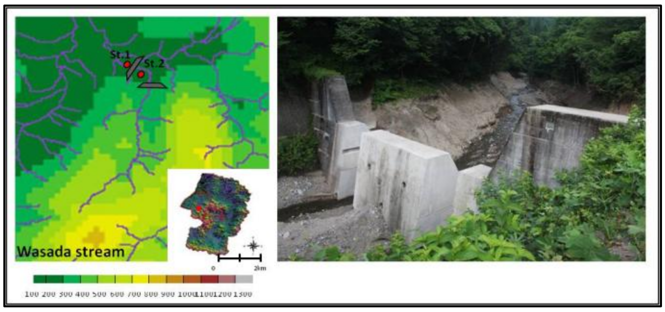

Figure 1. Two study areas on the Wasada stream, and photo immediately after dam slit

When data was collected three months later from dam construction, the channel flow through only one passage, and the other passage was clogged with coarser sediment and small tree branches.

(2) Method of Analysis

Physical conditions of velocity, particle size, bottom slope, cross-section and longitudinal section were obtained by field survey in October 2009 and 2010. In addition, survey of geomorphic river units was carried out with definitions about river unit of Frissel, et al (1986), Maddock (1999) using high accuracy GPS system in 2010. The river unit is immediately responded by several physical condition changes which are as above-mentioned. Therefore, firstly, river response can be easily explained through area of each river unit. We made a river unit map for post-dam slit using GPS data, and the other map for pre-dam slit made using a Google map, a sketched figure and photos in 2009. Next, the area of each unit was calculated by ArcGIS software. And then two maps of pre-dam slit and post-dam slit were compared by the area.

Erosion and deposition are an important and basic mechanism for river response. We calculated tractive force using shear stress (2.1) at 4 cross-sections which are 7.5m, 34m, 86m and 145m distance from dam in upstream reach of dam.

$$\tau_o = \rho g \frac{D_H}{4} \sin\theta \quad (2.1)$$

Where D_H is the hydraulic diameter and θ is the bed slope.

3. RESULTS AND DISCUSSION

After dam slit, significant change of physical parameters shown at upstream reach of dam. We focused river response of the upstream. River bottom gradient converted from - 0.032m/m to 0.096m/m, and particle size increased to cobble size (64-256 mm) at wetted bottom because of fine sediment transport (Table 1). Artificial digging immediately after slit construction is one reason of these dramatic changes. However we found downward erosion and bank erosion and little meandering since the artificial change was happened. Thalweg, which is a line drawn to join the deepest points along stream bed in its downward slope, has moved to left bank side. Depth of cross-section became deeper about 1.3 m ever since slit construction finished, and degradation is proceeding.

Key words: Check dam slit, Geomorphologic river unit, Sediment erosion, Boundary shear stress
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Table 1. A summary of data collection

Category	Site	Current velocity (m/s)	Gradient (m/m)	Geometric particle mean (mm)
Before slit	St.1	0.83	0.017	27mm
	St.2	0.59	-0.032	32mm
After slit (about 2.5m^3/s)	St.1	0.83	0.016	Bank: sand, slit Stream bottom: medium gravel(8-16mm) Wetted bottom: cobble(64-256mm)
	St.2	1.15	0.096	

Increased velocity causes sediment erosion on the bottom and both banks, and then it causes river unit change (Figure 2). The upstream reach of dam before slit looked like a small reservoir, and river units were very simple. River units, which are defined as slow flow such as pool or dammed pool, were dominated around 67%. Now, the units have converted into the units of high velocity such as step-pool, rapid and riffle, around 70%. In addition, kinds of river units have diversified. Diversity increasing of river units means that habitats for living things are abundant. Therefore it is to be expected species diversity increase by species restoration.

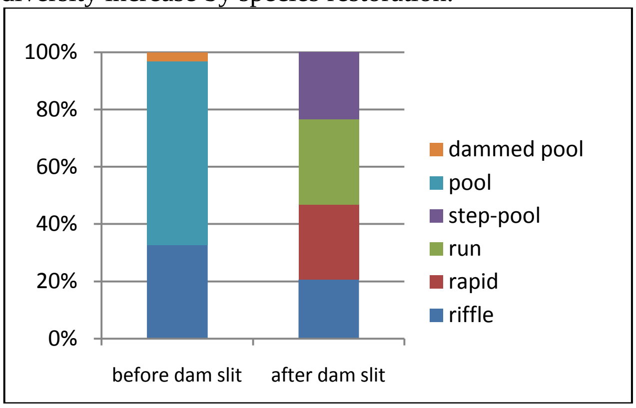

Figure 2. Area ratio of geomorphic river unit on upstream reach of dam before and after dam slit

Boundary shear stress shows a tendency to decrease when the distance from dam is far (figure 3). The shear stress calculated for a flow of 2.5 m^3/s is highest as 19.53 N/m^2 at cross-section of 34 m distance from dam. It means that a tractive force is sufficient to erode either fine, cohesive sediment (τ_{crit}=8 N/m^2 ; Chow(1959), Doyle(2003)). In addition, unconsolidated sediment still remains on the stream bottom and both banks. The banks are exposed to erode because the slope is fresh without vegetation cover. Therefore, dynamic river response will be happened by high discharge of either snow melt, rainy season.

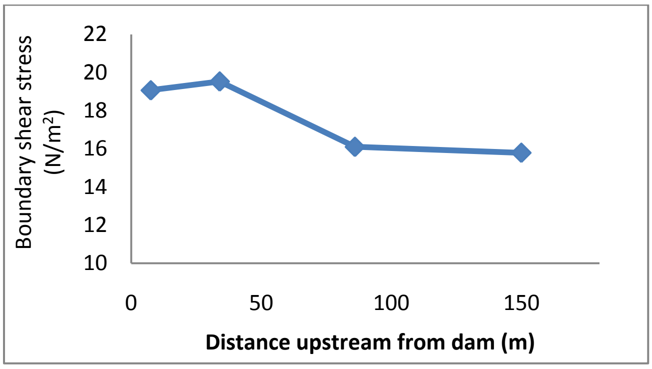

Figure 3. Boundary shear stress at four cross-sections of 7.5m, 34m, 86m and 150m distance from dam

4. CONCLUSIONS

Slit check dam restores river channel and diverse geomorphologic river unit by water flow and sediment transport. This research verified river response and river unit change through comparison with environmental conditions of pre-slit and post-slit. The results are as following.

- Degradation is proceeding at upstream reach of dam by fine sediment transport with high water flow.
- Geomorphologic river unit became diverse, and river units of high velocity such as step, rapid and riffle are reformed compare with previous river units of slow velocity such as pool.
- Boundary shear stress is highest as 19.53 N/m^2 at the cross-section, which is one part of step, on 34m distance from dam. Unconsolidated sediment still remains on the stream bottom and both banks, dynamic river response will be happened by high discharge of either snow melt, rainy season.

The river response and restoration will be affect life cycle of aquatic living. Therefore it is better to understand ecosystem restoration if aquatic animal such as invertebrates are considered.

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