River Environment Improvement Method by Sediment Transport Experiment in the Downstream Reach of a Dam

Hiroshi Ogawa
Director, Shimokubo Dam Operation and Maintenance Office, Japan Water Agency, Japan

Akihiro Kanayama
Senior Engineer, Shimokubo Dam Operation and Maintenance Office, Japan Water Agency, Japan

1. Introduction

The Shimokubo Dam is a multipurpose dam managed by the Japan Water Agency. The objectives of the dam are flood control, river discharge maintenance, water supply (domestic and industrial use), and hydropower generation. 36 years have past since the beginning of dam operation. Thus, there are various themes for the dam, such as reservoir function maintenance measures against sediment flowing into the reservoir and measures against riverbed degradation in the downstream reach of the dam because of interrupted sediment transport by the dam.

An approximately 1.5km section of the downstream reach of the dam has a particularly beautiful landscape designated as a scenic spot and natural monument called as Sanba Seki Kyo (gorge). Landscape deterioration has been conspicuous due to the riverbed degradation, diminished sandbars, and weakened cleansing effects of sediment transport impinging on the rock (sediment transport polished rock surface by impinging action when the material flows with water).

This paper introduces the sediment transport experiment being conducted since 2003 as a measure to improve the landscape of the river downstream of the dam and as measures for river environment preservation and reservoir function maintenance.

2. Effects of Shimokubo Dam Operation to the Sediment Transport System of the Kanna River

The Shimokubo Dam is built on the Kanna River that is one of the right-side tributaries of the Tone River system. The dam's catchment area is 323 km^2 that occupies 79% of the Kanna River's entire catchment area 407 km^2. The area of the mountainous region that produces riverbed material within the entire catchment area of the river is 374 km^2. This area's 86% is included in the catchment area of the Shimokubo Dam.

The continuity of the sediment transport system in the downstream reach of the Shimokubo Dam was cut off by the sediment deposit in the reservoir created by the Shimokubo Dam. As a result, severe riverbed degradation has occurred in the river section from the dam to the tip of the alluvial fan created by the river system. Judging from those photographs that were taken before dam construction, there are some river sections whose riverbeds have been degraded almost 5m deep. The riverbed material in the river immediately downstream of the dam has become coarser. In the section of "Sanba Seki Kyo (gorge)," riverbed gravel has disappeared thereby causing the deterioration of landscape. (Fig. 1)

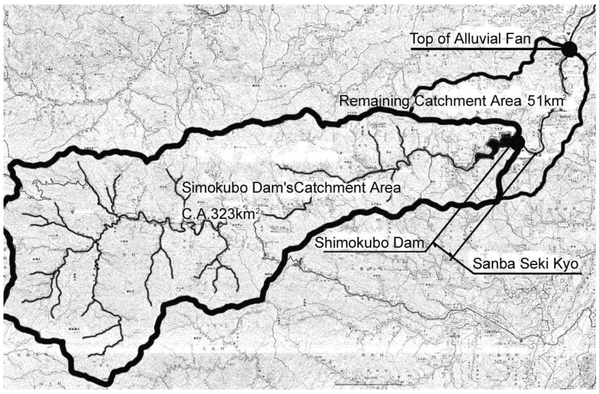

Fig. 1 Kanna River and the Catchment Area of Shimokubo Dam

3. Condition of Sediment in the Reservoir Created by Shimokubo Dam

The Shimokubo Dam has been operated 36 years after completing construction. There is a tendency that the amount of sediment in the reservoir extremely increases after a relatively large flood. The amount of sediment accumulated by the end of 2004 was 8,057x10^3 m^3 that was 81% of the reservoir's design sediment capacity 10,000x10^3 m^3. The actual sedimentation is progressing with a speed 2.2 times faster than that of initially predicted. (Fig. 2)

4. Present Condition of Sanba Seki Kyo and the Purpose of Sediment Transport Experiment

Deterioration of the Landscape of Sanba Seki Kyo has progressed due to the reason that the sediment transport system of the river is cut off by the Shimokubo Dam as follows:

① Riverbed degradation, coarsened riverbed material, and diminished sediment material on the riverbed.

② Deteriorated cleansing effects

Photographs taken before and after dam construc-

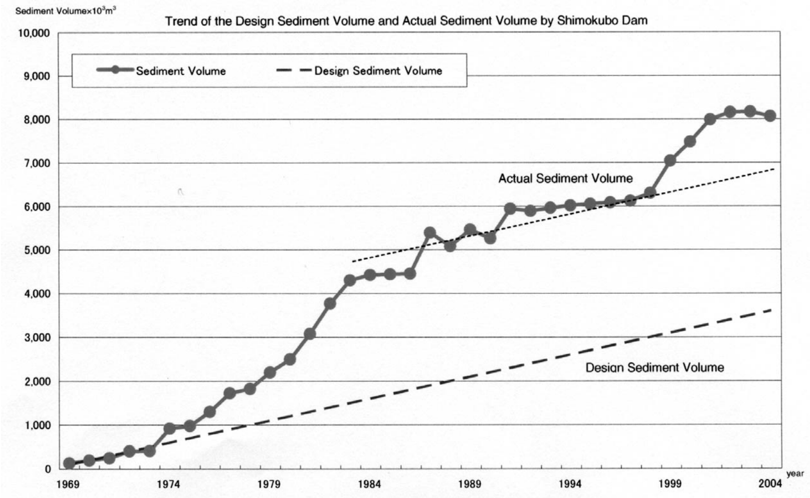

Fig. 2 Change in Sediment Volume

tion were compared with each other in order to learn the conditions of the diminished sediment material on the riverbed and the amount of riverbed degradation then set up landscape improvement target.

There were gravel areas on the riverbed in Sanba Keki Kyo before dam construction as seen in Photo 1 (a). However, after dam construction, the sediment material on the riverbed was washed away by floods and no sediment material has been supplied and, as a result, the riverbed has been degrading and the gravel areas recently disappeared as seen in Photo 1 (b). When comparing Photo 2 (a), showing the river condition immediately before dam construction, with Photo 2 (b) of recent river condition, it can be estimated from the size of the large piece of rock in these photos and site survey result that the riverbed has degraded approximately 2 m. For this reason, a landscape improvement target is set up to restore the diminished gravel areas to the original state and the degraded riverbed up to an approximately 2 m height from the present elevation (called the riverbed restoration target).

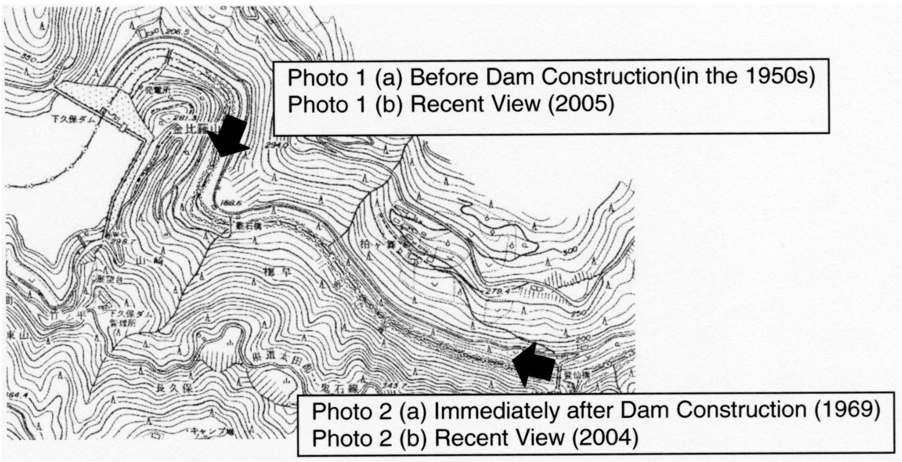

Photo 1 (a) Before Dam Construction(in the 1950s)

Photo 1 (b) Recent View (2005)

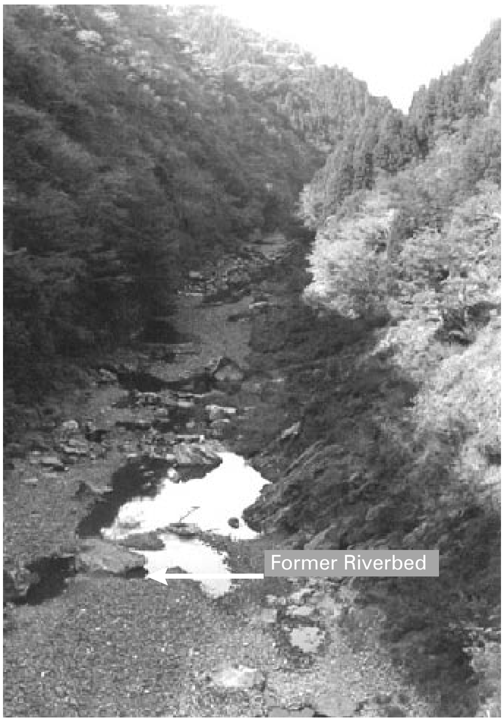

Photo 2 (a) Immediately after Dam Construction (1969)

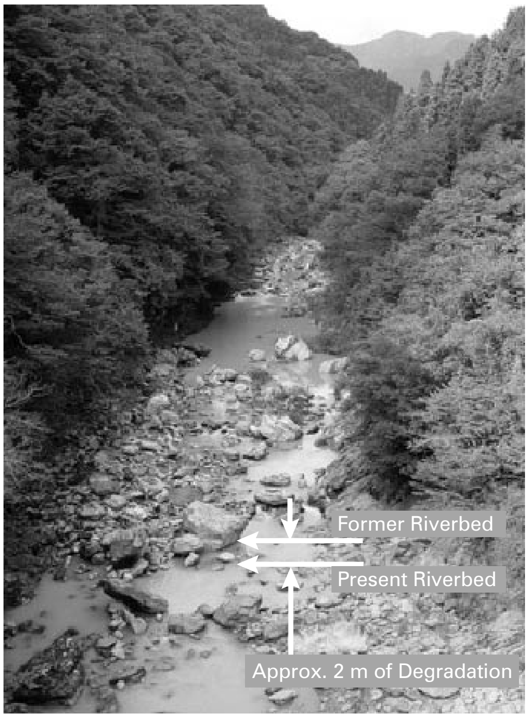

Photo 2 (b) Recent View (2004)

The cleansing effects of the sediment transport in the river should be learned by comparing photographs to be taken before and after conducting the sediment transport experiment.

5. Method of the Sediment Transport Experiment

The sediment transport experiment has been conducted since 2003. In the experiment, sediment material deposited in the sediment trap dam within the reservoir is taken, transported to and dumped into the downstream of the dam by dump trucks. The dumped sediment material is washed away by discharge from the reservoir. The sediment trap dam is located 8.5 km upstream of the Shimokubo Dam. When the reservoir level rises higher than the limited water level of E.L. 283.8 m during the flood season (July through September), sediment material can be mined. (Photo 3-6, Fig. 3)

6. Sediment Transport Experiment Conducted

The first sediment material dumping was conducted on July 16, 2003. An approximately 1,000 m^3 of the dumped sediment material was washed away by the 5-hour period reservoir discharge having about 100 m^3/s of the maximum that was released from the midnight of July 26 in order to handle the flood caused by the front in the July period.

The second sediment material dumping was conducted on October 22, 2003. An approximately 200 m^3 of the dumped sediment material was washed away by the reservoir discharge having a maximum of approximately 40 m^3/s for a 9-hour period that was released during a period of October 10 through 15 to handle the flood caused by Typhoon No. 22 in 2004. Approximately 800 m^3 of the remaining sediment material was washed away by the reservoir discharge having a maximum figure of about 300 m^3/s for a 2-hour period released during a period from October 19 to 26 to handle the flood caused by Typhoon No. 23 in 2004.

The third dumping of an approximately 2,000 m^3 sediment material was carried out on March 25, 2005. In this experiment the sediment material was pushed till the middle of the river so that the material could be washed away even by a relatively small amount of reservoir discharge. For the purpose of crest gate inspection, an approximately 5 m^3/s one-hour period reservoir discharge was conducted on May 8, 2005. A small amount of the sediment material was washed away by this discharge. (Table 4, Photo 8, 9)

7. Restoration of Riverbed Material

Restoration of riverbed material can be seen in the river section downstream of the sediment material dumping place due to the effects of the dumped sediment material. However, it is feared that the riverbed material restored only by the above-mentioned dumping method and the amount dumped might be washed away when the river section receives a magnitude of reservoir discharge that handles a certain size of floods or a design maximum discharge (discharge in the range of 500 m^3/s to 800 m^3/s).

It would be necessary to examine the shape of piled up material and the amount of material to be dumped to suit the amount of reservoir discharge and the discharge duration. (Photo 9, 10)

Photo 3 Mining of Sediment Material

Photo 4 Dumping of Sediment Material

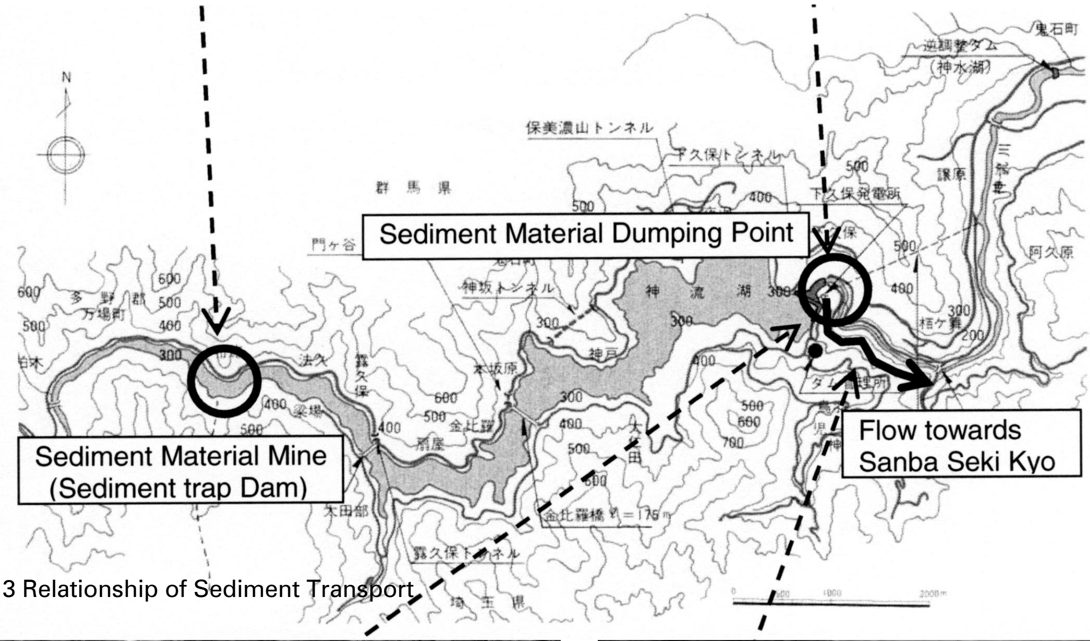

Fig. 3 Relationship of Sediment Transport

Photo 5 Sediment Transport by Reservoir Discharge

Photo 6 Sediment Material Deposited on Riverbed

Table 4 Result of Sediment Transport Experiment

Dumped/ Washed Away	Date	Amount Dumped Material	Reason for Reservoir Discharge	Maximum Discharge and Period	Amount Washed Away
Dumped	16 Jul 2003	1,000 m^3			
Washed Away	26 Jul 2003		Front	Approx 100 m^3/s for 5 hours	Approx 1,000m^3
Dumped	22 Oct 2003	1,000 m^3			
Washed Away	10 through 15 Oct 2004		Typhoon No. 22	Approx 40 m^3/s for 9 hours	Approx 200m^3
Washed Away	19 through 26 Oct 2004		Typhoon No. 23	Approx 300 m^3/s for 2 hours	Approx 800m^3
Dumped	25 Mar 2005	2,000 m^3			
Washed Away	8 May 2005		Gate Inspection	Approx 5 m^3/s for one hour	Small amount

Photo 7 Flow Condition on 11 Oct 2004 ($Q = 40\ m^3/s$)

Photo 8 Flow Condition on 22 Oct 2004 ($Q = 100\ m^3/s$)

Photo 9 Riverbed before Sediment Transport Experiment (July 2003)

Photo 10 Present Riverbed Condition (May 2005)
Note: Restoration of riverbed material can be seen.

8. Cleansing Effect

It is considered that the cleansing effects of the river flow increased because of the reason that the river water contained dumped sediment material. Photos 11 and 12 show the riverbed conditions before and after conducting the sediment transport experiment. It can be seen that the previous dark surface of Sanba Seki became a shiny surface by the cleansing effect.

The cleansing effect is larger at the downstream side of rock than the upstream side that is hit by the river flow. Because river flow mixes sediment material in behind the rock with the turbulent water. Photos 13 and 14 show the upstream-side surface and downstream-side surface of rock. It can be seen the great difference in the cleansing effect. Photo 15 is the side view of the rock.

Photo 11 Sanba Seki Kyo in 1997

Photo 12 Sanba Seki Kyo in 2004

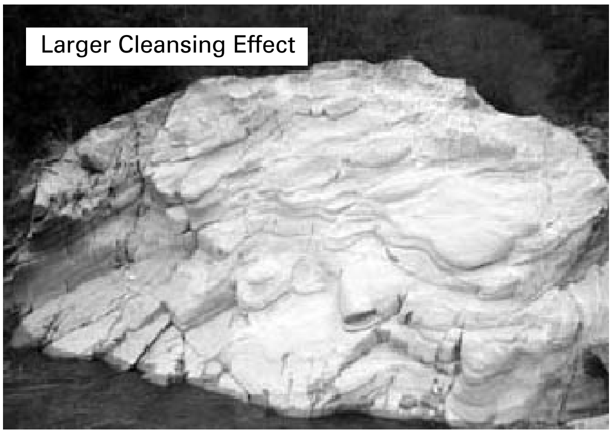

Photo 13 Downstream-side Surface

Photo 14 Upstream-side Surface

Photo 15 Side View of Rock

9. Result of Sediment Transport Experiment

Through the sediment transport experiment that has been carried out since 2003, the restoration of the riverbed and the improvement of the landscape by the cleansing effect of sediment transport are confirmed in some section of Sanba Seki Kyo (gorge). However, it is feared that restored riverbed might be washed away again depending upon the amount of reservoir discharge and the discharge duration. Thus, the continuous examination of the measure against riverbed degradation would be necessary in the future. It is considered that the cleansing effect of sediment transport will last long as long as the sediment transport is maintained.

The experiment result is periodically reported to area residents and they highly evaluate the landscape improvement effect.

10. Measures for Reservoir Function Maintenance and Sediment Transport Experiment

The Japan Water Agency plans to start a sediment transport experiment by taking into account continuous and concrete reservoir function maintenance measures from fiscal year 2005.

We are going to clarify the necessity and themes of sediment transport in view of both reservoir function maintenance and the preservation of the river environment downstream of the dam.

And these themes are planed to be discussed with river management agencies, water users and area residents in Kanna River Sediment Transport Committee.

Monitoring survey of river environment will be carried out by taking into the advices and opinions of scholars and specialists in order to learn the quantitative effects of sediment transport and submit the obtained data to the above-mentioned Kanna River Sediment Transport Committee.

11. Monitoring Survey Plan

It is planned to conduct the monitoring surveys of the river's plan and cross sections, riverbed conditions, river bank vegetation, fish species and benthos in order to evaluate the effects of the sediment transport experiment. The river's plan will be monitored by taking aerial photographs from a helicopter. The river flow, riverbed conditions, river bank vegetation (physiognomic vegetation), etc. will be clarified on the aerial photograph maps and basic environmental information maps (photographs) will be prepared in order to visually learn their secular changes and make the maps a comprehensive data book.

In view of safety against floods, cross section surveys will be conducted in those river sections that may need to be monitored for possible flooding. The changes of these sections will be carefully investigated.

As an impact and response biotic indicator that may be influenced by the sediment transport experiment, fish species and benthos surveys will be carried out. As for fish species, by asking scholars and specialists and fishery related people, it was decided upon to study Ayu fish (Japanese sweet fish), Ugui (dace), Kajika (Japanese freshwater bullhead), and bottom fish. As for benthos, it is planned to classify the aquatic insects by the living patterns and feed and, as a result, riverbed environment will be evaluated based on the changes in the living conditions of those insects.

12. Conclusion

Measures against the sedimentation in a reservoir to maintain reservoir functions are big issues for many dams. We consider that, in addition to the ordinary method to use sediment material for concrete aggregate, the method to move deposited sediment material into rivers downstream of dams to improve river environment would be extremely effective means as a measure against sediment problems.