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A CLEAR WATER BYPASS PIPELINE SYSTEM MITIGATES TURBID WATER DISCHARGE FROM A DAM

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INTRODUCTION

There are some dams which degrade downstream water quality. The discharge of turbid water sometimes causes serious problems both environmentally and socially, especially if downstream turbidity in the river is increased by the dams' operation. This was the experience with the Urayama Dam, which was constructed on a small river in Japan. The Japanese Government and the Japan Water Agency successfully mitigated the problem by installing a water bypass pipeline system, which sends clear water directly from the river upstream to an intake tower of the dam and enables to avoid discharging turbid water.

In Japan, there are few prior examples of clear water bypasses, and the Urayama Dam is attracting interest not only from concerned professionals but also from residents downstream for its successful reduction of the negative environmental impact of dam operation.

Table –1 Outline of the Urayama Dam

Purpose	Tap Water, Flood Control, Maintenance of River Function and Power Generation
Effective Capacity	56 million m^3
Dam Dimensions	Height 156 m, Length 372 m
Construction Cost	$17.3 billion, including compensation for private property
Operator	The Japan Water Agency

Fig.1 The Urayama Dam

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OUTLINE OF THE DAM

The Urayama Dam is located in Saitama Pref., Japan. It was constructed and is operated by the Japan Water Agency for providing tap water, flood control, maintenance of river function and power generation. The capacity of its reservoir is relatively large compared to its inflow, and the yearly replacement rate is 1.1 to 1.4. The soil of the catchment area contains very fine mineral particles.

PROBLEM CAUSED BY DAM OPERATION

The dam was completed in 1999 and soon experienced high turbidity of inflow due to intense rainfall from typhoons. Most of the entire catchment area was steep forested slopes, some poorly maintained, and heavy rain resulted in severe soil erosion.

Before the dam construction, the inflow of turbid water was thought to be manageable with a floating turbidity curtain and an intake tower with depth-selective withdrawal. However, the recession of forestry resulted in poor forest maintenance and unexpected inflow levels of highly turbid water. In addition, an increase in wildlife population damaged the forest and the ground surface.

To make things worse, in most areas of Japan, the air temperature falls sharply enough to cause thermal overturn and thorough mixing of reservoir water in autumn. This redistributes settling mineral particles, and the turbidity of the reservoir water remains elevated for a long period.

In both 1999 and 2001, the Urayama Dam had to discharge turbid water of more than 20 NTU (Nephelometric Turbidity Unit) for more than 5 months.

These operations damaged the environment of the river downstream. In addition, purification plants for tap water and industrial water located in the downstream could not run smoothly, which resulted in economic damage to the users of the river water.

Fig.2 Turbid Inflow

Fig.3 Floating Turbidity Curtain

SOLUTION

In 2003, the Ministry of Land, Infrastructure and Transportation of Japan initiated a new project, the Clear Water Bypass Pipeline at the Urayama Dam, as a project of improving river environment.

The detailed design and construction work were entrusted to the Japan Water Agency, the owner and operator of the Urayama Dam. The construction work was carried out without halting dam operation. The bypass system was completed in 2007 with a total expenditure of 28 million US dollars from the government's budget.

DESIGN CONCEPT AND OUTLINE

The bypass system was adopted for environmental protection, so it was designed observing the principles of low emission of green house gas and low negative impact on the surrounding environment both for its construction and operation.

The system is mainly composed of three parts, an intake weir, a pipeline, and an outlet. The pipeline was constructed in a bridge style or placed on the ground surface in order to avoid disturbance to the environment, because the route is so steep that sizeable excavations would have been unavoidable if the pipes had been buried.

The pipeline's hydro-profile was designed so as to enable water to flow by gravity alone, avoiding the CO_2 emissions involved in pumping. Also, a suspended pipe system used to cross a valley saved both the natural environment and the project budget, as compared with the alternative of constructing a new bridge.

Table-2 Outline of the Urayama Dam Clear Water Bypass Pipeline System

Purpose	To improve the environment of the river downstream
Capacity	0.7 m^3/s (equal to compulsory discharge from the Dam)
Dimensions	Pipe diameter: 1 m, Pipeline length: 6 kilometers
Type	Pressure, Gravity flow
Cost	$28 million including compensation for private property

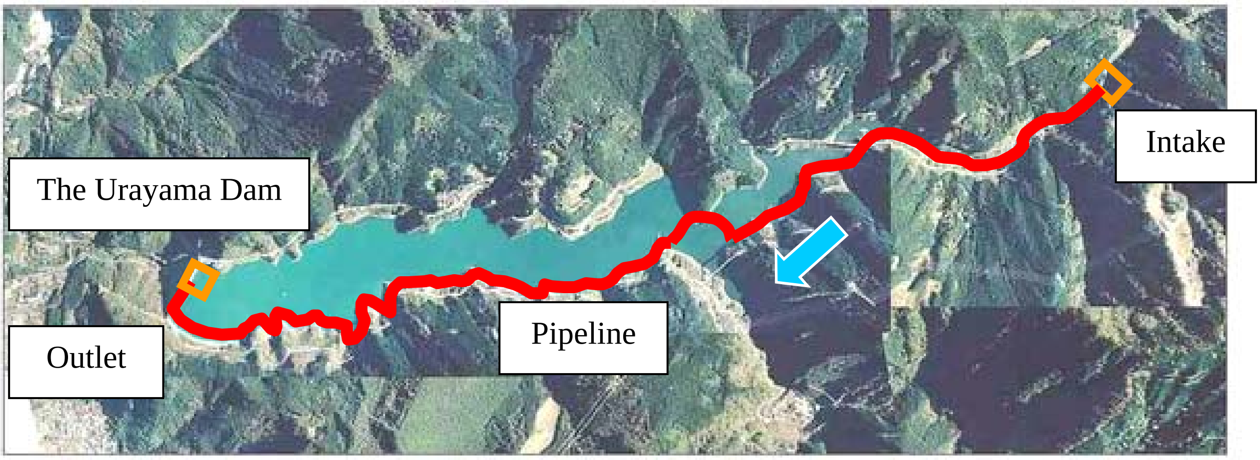

Fig.4 Layout of the Urayama Dam Clear Water Bypass Pipeline System

DETAILED DESIGN

Intake

The intake facility was constructed on a small and steep river just at the upstream end of the reservoir. In order to avoid screen blockage by debris and sand, a downstream-faced intake was adopted. The intake screen is flushed continuously and remains functional. The intake facility is equipped with a sand basin to avoid sedimentation in the pipeline. Also, a fish ladder is provided.

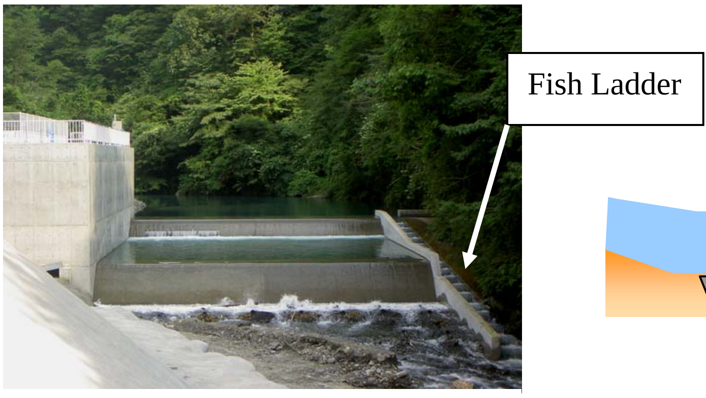

Fig.5 Intake

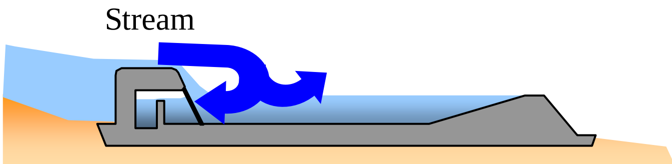

Fig.6 Cross-section of Intake

Pipeline

The most suitable type of pipe for each section was selected from steel pipe, fiber-reinforced plastic mortar pipe (FRPM) and polyethylene pipe. This was the first project in Japan to use polyethylene pipe in suspension as a permanent structure. The suspended section is fixed to the ground only at the ends. The material is flexible enough to follow changes in water level, and the middle of the suspended section stays 2 meters beneath the water surface to allow boats and flotsam to pass it over. Also, rotation joints adjacent to the fixed end points allow the pipe to swing up and down, avoiding internal stress in the pipe. We are sure that the suspended pipeline is a breakthrough as a way for a pipeline to cross water area at low cost.

Fig.7 Steel Pipe Section (1)

Fig.8 Steel Pipe Section (2)

Fig.9 FRPM Pipe Section (1)
(Under Construction)

Fig.10 FRPM Pipe Section (2)
(Completed with Concrete Cover)

Fig.11 Suspended Pipe Section (1)
(Before Submerging)

Fig.12 Suspended Pipe Section (2)
(Construction Work)

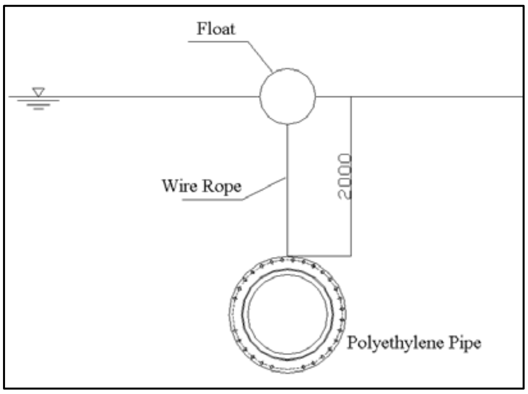

Fig.13 Suspended Pipe Section (3)
(Cross-section)

Fig.14 Suspended Pipe Section (4)
(Rotation Joint)

Outlet

As power generation is one of the purposes of the Urayama Dam, it is necessary that the operation of the bypass pipeline does not reduce power generation. Therefore the outlet had to be installed upstream of the power station to avoid any head loss.

The outlet was located in a selective intake tower in the reservoir. The tower had been originally equipped with gates that allowed the separation of the water inside from reservoir water. Water from the bypass pipeline is poured directly into the inside of the tower, without mixing with turbid reservoir water.

Fig.15 Outlet (1)
(Intake Tower)

Fig.16 Outlet (2)
(Inside the Intake Tower)

Control System

The outlet is equipped with a regulating valve. To ensure safe operation and to save human resources, the flow is remotely controlled from the operation room of the project office. Fundamental live data such as turbidity at the intake is periodically collected through a data telemetry system. Furthermore, the accumulated data can be checked on the Internet.

Fig.17 Remote Control System
(Operation Room)

Fig.18 Construction Work
(A Crane on the Pontoon)

CONSTRUCTION WORK

We carried out the construction of the bypass system in harmony with the operation of the dam, getting consensus approval from all the organizations concerned. More than half of the pipeline route was inaccessible from existing roads. We transported materials such as pipes with a tug boat and pontoons and placed or assembled them with cranes fixed on the pontoons, controlling the reservoir water level so as to make the work possible.

As a result, we did not have to construct any temporary roads at all. Thus construction work conducted in parallel with dam operation brought us great benefits both in terms of cost reduction and environmental conservation.

PROJECT EFFECT

The bypass system was completed in March 2007 and the opportunity for practical operation soon arrived. In September 2007, the dam was hit by a huge typhoon that brought 583 mm of rain in only 64 hours. Inflow turbidity measured over 1000 NTU at the maximum. As a result, the turbidity of the reservoir rose to 538 NTU at the surface (-2 m depth) and discharge turbidity exceeded acceptable levels downstream.

The bypass system began to operate on October 8th, after the turbidity of the inflow fell sufficiently and sediment in the intake basin was removed. Then we turned operation on and off because another rainfall raised the turbidity of the inflow.

It took about a week to completely replace the turbid water in the intake tower and discharge pipe with a clean flow from the bypass system. After that, the discharge water showed low turbidity. The operation demonstrated the functionality of the clear water bypass pipeline system and the appropriateness of its design.

A month after the start of bypass operation, the autumn overturn of the reservoir began as the air temperature declined. This lifted suspended particles, which had gradually been settling in accordance with Stokes' Law, making the turbidity almost uniform from the bottom to the surface. Even after the overturn, the turbidity of discharged water was less than 20 NTU, while that of reservoir water was as much as 110 NTU.

Acceptable turbidity for the tap water purification plant and the industrial water purification plant downstream of the dam is 20 NTU. From the viewpoint of avoiding interference with purification processes or water use, it can be said that the clear water bypass pipeline worked successfully.

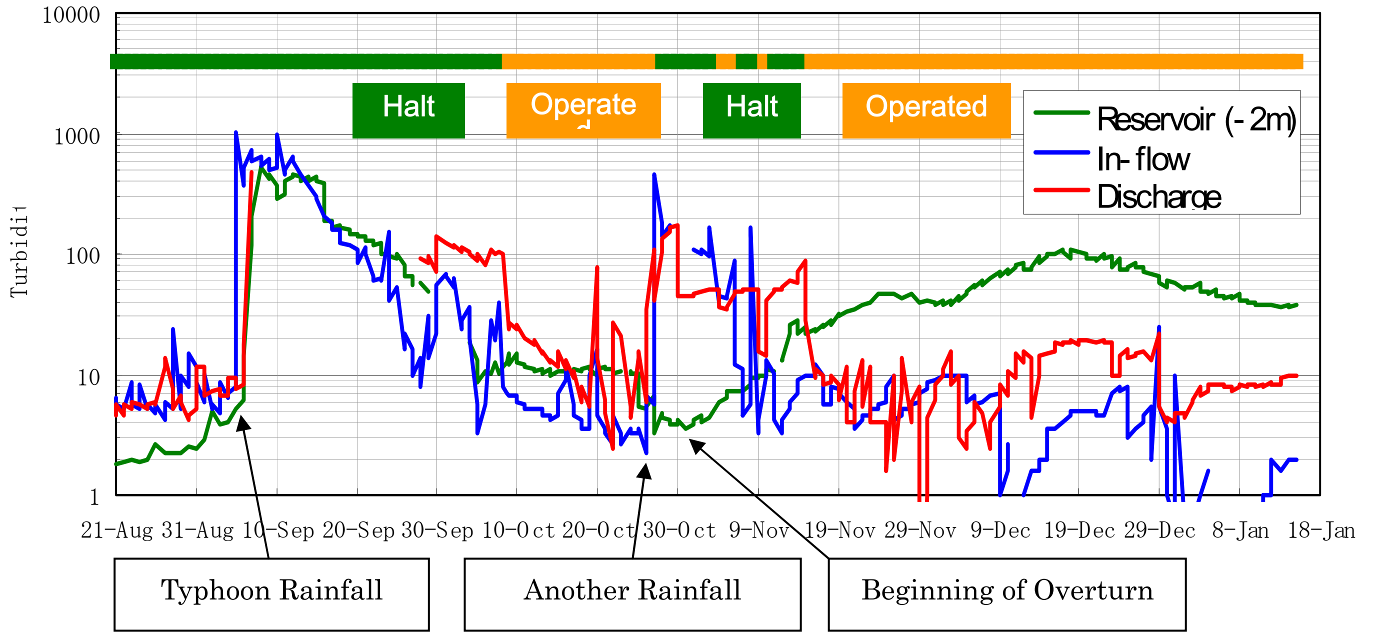

Fig.19 Inflow, Reservoir and Discharge Turbidity (NTU)

Fig.20 Before Operation (28 Sep. 07)
(Turbid Water Flows into the Main River)

Fig.21 During Operation (11 Oct. 07)
(Low Turbidity)

CONCLUSIONS

The turbidity of discharged water was dramatically reduced by operation of the clear water bypass pipeline system. It can be said that this system is effective when turbidity in the downstream river is increased by dam operation. In the case of the Urayama Dam, the construction cost of the bypass pipeline system was only 1.6 percent of that of the dam itself.

The clear water bypass system is very effective in reducing negative impacts on the environment. Furthermore, the system and its function are easy for the public to understand, which is important in obtaining public concurrence about dam construction and operation. For Japanese dam projects, it can be said that the clear water bypass system demonstrates our commitment to the environmental conservation and our respect for the area surrounding a dam.