IMPROVEMENT OF DAMS

TO DISCHARGE RIVER MAINTENANCE FLOW

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1. Introduction

A dam-and-conduit type hydropower plant takes river water on the upstream river, conveys it to a powerhouse through a headrace, and returns it to the river at an outlet. This type of hydropower plant does not supply water downstream from a dam. Thus, the hydropower plant will cause a river to be dried up if tributaries between the dam and the outlet supply little water to the main stream particularly in the dry season, which will give adverse impact on the original environment and the river. In the 1980s, as Japanese people's sense of value changed and the quality of life took priority over economical satisfaction. Local communities located near hydropower plants which blocked river flow strongly demand the restoration of beautiful rivers filled with abundant clear water. A lot of instances proved that it was difficult to meet these demands under the present conditions. Thus it had been difficult or almost impossible for river water users, such as electric power utilities, to make full use of river water only for hydropower generation.

The Ministry of Land, Infrastructure, Transport and Tourism, MLIT, responsible for river management, consulted with the Ministry of Economy, Trade and Industries, METI, that has jurisdiction over hydropower production about these problems. The MLIT announced notification ensuring the flow rate at which river water should be discharged downstream from the dam during a dry season to solve the dried-up river problems, named a river maintenance flow rate, in 1988.

This notification stipulates that hydropower plants shall discharge river maintenance flow to the downstream river from the dams when each hydropower plant renews its water rights for electric power generation for corresponding to the following conditions as shown in Table-1. In Japan, river water is regarded as public property and its user shall take permission to use the river water from a river manager.

Table-1 Hydropower plants corresponding to notification

1	A dam or intake weir takes water from a river system and discharges it to another river system or directly to the sea; or	
2	Length of a dried-up section is more than 10 km and corresponds to the following conditions;	
	a	A catchment area of the dam or intake weir is more than 200 km^2;
	b	All or a part of the dried-up section is designated as the area for the Nature Park Act; or
	c	An area along the dried-up section is developed as a tourist site or a community.

The notification sets up a standard of the river maintenance flow rate as 0.1 to 0.3 m^3/s per 100 km^2 of catchment area. As a result, by the end of March 2002, in line with the notification, clean flowing water had been restored in dried-up sections at 287 electric power plants, and as shown in Figure-1, the total section length was 3,500 km, indicating that about 37% of a total of 9,600 km of dried-up section had been restored.

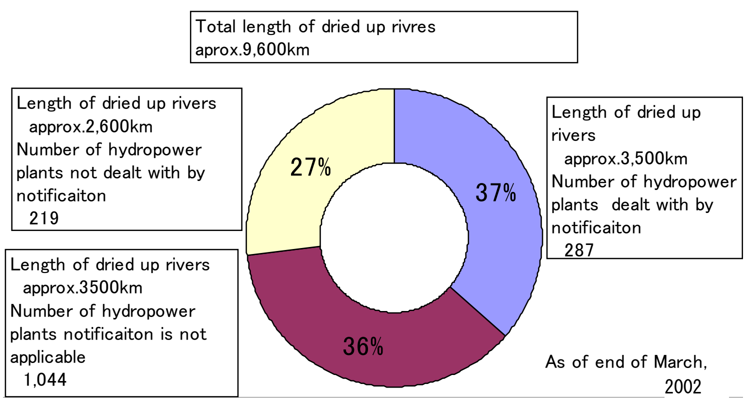


Figure-1 Length of river courses restored from dried up condition under Notification (Class A River Systems)[1)]

To cope with the notification, electric power utilities have improved their facilities so that river maintenance flow is discharged from dams and other intake facilities which have blocked river flow. J-POWER has also improved dams and intake weirs to discharge river maintenance flow, and some cases of improvement and those effects are introduced in this report.

2. Case Study

To discharge river maintenance flow, J-POWER has carried out following improvement works considering circumstances of each dam and intake weir.

1) Drilling a dam body to install an outlet conduit;
2) Installing an outlet valve on a spillway gate;
3) Installing a small turbine and generator and discharging water just downstream from a dam; and
4) Installing a fishway and discharging river maintenance flow through it

Those improvement works resulted in increase in number of fish going upstream of the river and in improvement of river water quality.

Other facilities in which discharge of river maintenance flow is required will be improved as electric power utilities including J-POWER renew their water rights in the future.

Drilling Dam Body

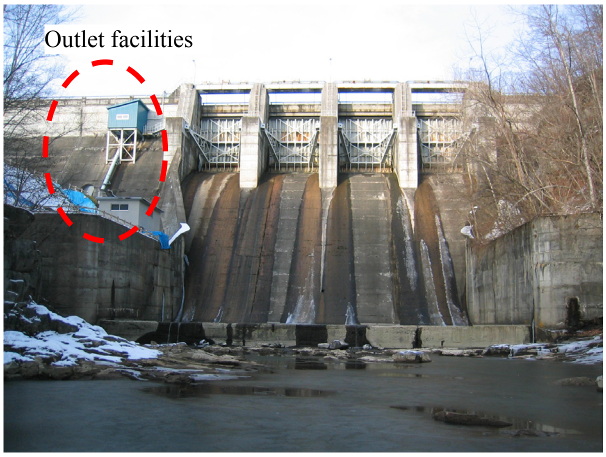


Figure-2 Kakkomi Dam and outlet facilities

At first, improvement works of the Kakkomi Dam is introduced as an example of drilling a dam body to install a river maintenance flow discharge outlet[2)].

The dam, located on the Tokachi River in eastern Hokkaido, is a concrete gravity dam completed in 1955 with a dam height of 34 m, a crest length of 185 m and a volume of 43,700 m^3. Figure-3 illustrates its outlet in plan and section.

The dam has a dried-up section of about 23km and comes under the above-mentioned notification, so it was determined in March 1989 to discharge water from the dam at the rate of 1.0 m^3/s starting from April 21 until November 30 in consideration of several factors such as the river water use and ecosystem through the consultation with the river manager.

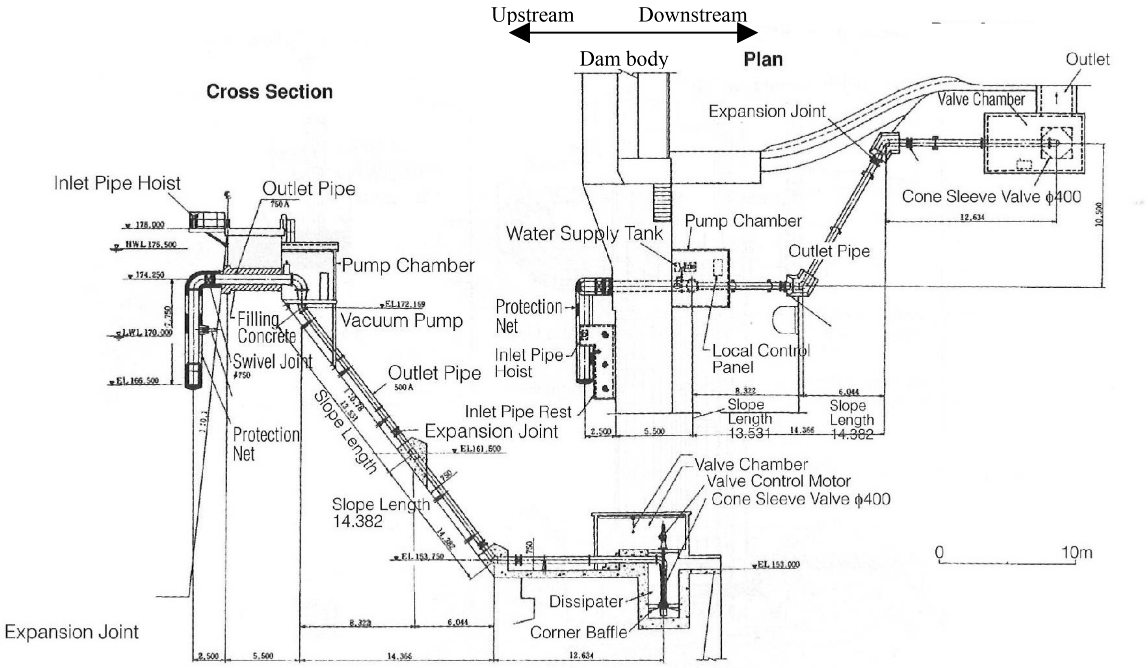


Figure-3 Plan and cross section of outlet at Kakkomi Dam

Since existing facilities were not able to be used to discharge river maintenance flow from the existing dam, a new outlet had to be built. In determining a discharge method, the following fundamental factors were taken into account:

1) Facilities function properly and safely;
2) Maintenance and management are easy;
3) Installation and operation costs are reasonable; and
4) Fewer restrictions are imposed on the reservoir water level during construction.

As a result of a comparison study, a siphon facility was adopted. As a discharge facility, an outlet conduit in a steel siphon type was planned to be installed on the right bank side of the dam body. Passing through the dam body, the conduit descends along the downstream slope of the dam body. To discharge river maintenance flow at the rate of 1.0 m^3/s, its opening is controlled with the cone sleeve valve situated at the end in accordance with the reservoir water level.

The construction works of the discharge facility were conducted in the following order:

1) Drilling in the dam body;
2) Installations of equipment including an outlet conduit;
3) Construction of a valve chamber and a pump pit; and
4) Placement of filling concrete around the embedded outlet conduit.

Because a 1.8 m wide and 2.0 m high hole with the shape of semi-circular top and rectangular bottom was to be drilled into the existing dam body to install an conduit of 750 mm in diameter, the soundness of the dam block as well as the stability against stress concentration around the opening were studied. As a result, they were proved to satisfy the criteria.

In considering the drilling volume of 12 m^3, an abrasive water jet method was adpoted for edge cutting and the works were executed by applying a static expansive demolition agent and a breaker. In the abrasive water jet method, water pressurized up to 150-300 MPa is jetted out from an orifice at high speed, and by using its energy, abrasive is emitted at accelerated speed from an abrasive nozzle installed at the jet generator to cut a material like concrete. Two methods are commonly used to feed abrasive into an abrasive nozzle: using air flow or water flow. In this project, a water flow feeding method was adopted. The construction works were carried out from mid October to late December, 1991.

Figure-4 shows arrangement of machinery, and Figure-5 and 6 show the construction works.

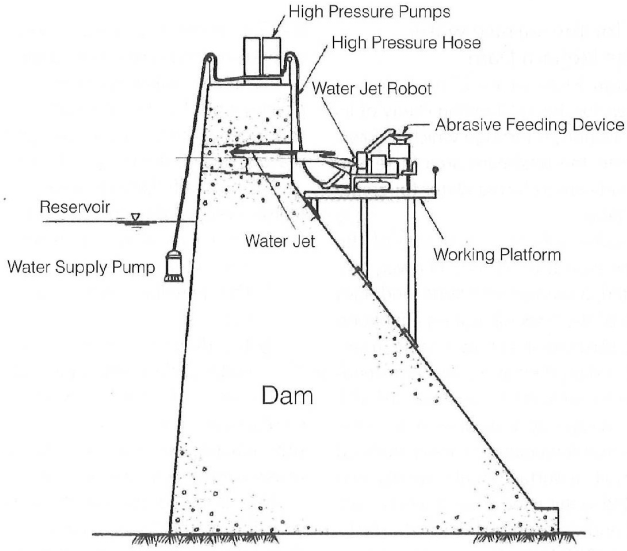


Figure-4 Arrangement of machinery

Figure-5 Dam body after drilling

Figure-6 Installation works of outlet

Highly reliable works were required for the placement of filling concrete around the embedded outlet conduit. In this project, because thorough compaction by vibrators was expected to be difficult to achieve due to limited working space, flyash enriched concrete was placed.

Taking it into account that the concrete placement was to start at the beginning of winter, the unit cement content was set at 290 kg/m^3 so that concrete strength would reach the target value earlier.

Even though the minimum air temperature declined to minus 5℃ after concrete placement, the curing was sufficiently executed so that specific compressive strength could be obtained.

The Nanairo Dam and the Kuki Dam are other examples of drilling a dam body to install discharge outlets.

The Nanairo Dam, concrete arch gravity type and 61 m high, was completed in 1965 to form a lower pond of the Ikehara Pumped Storage Power Plant with maximum output of 350 MW. Fluctuations in water use in the Ikehara Power Plant are re-regulated by the Nanairo Power Plant with the maximum output of 82 MW located just downstream of the dam and the reservoir water is discharged at an outlet through a tailrace of about 2 km long, which formed a dried-up section between the dam and a tributary. After a comparison study, a hole was drilled through a dam body to install a conduit and a discharge valve with capacity of 2.5 m^3/s was attached at its end. The improvement works started in August 1998 and were completed in April 2000. Figure-7 shows the situation of discharging water to the stilling basin of the dam.

Figure-7 Discharging from outlet valve at Nanairo Dam

After discharging the river maintenance flow, the original river flow was restored and the fresh water fish such as ayus, sweetfish, swam upstream to the dam. Water quality of the dried-up section satisfied environmental standards and, what is better, discharging the river maintenance flow improved biological environment downstream the dam.

Figure-8 shows the river circumstances before and after installation of the discharge outlet.

Before discharging river maintenance flow

After discharging river maintenance flow

Figure-8 River circumstances at Nanairo Dam

The Kuki Dam, concrete gravity type and 28 m high, was completed in 1963 as a main intake dam of the Futamata Power Plant with maximum output of 72.1 MW. To solve the problem of a dried-up section, a hole was drilled through a dam body to install a conduit and a jet flow gate with capacity of 0.4 m^3/s was attached at its end. The improvement works started in September 1994 and were completed in March 1995.

Installing Outlet Valve

In this section, examples of installing an outlet valve on a spillway gate or a sand flushing gate for discharging river maintenance flow are introduced. The Futatsuno Dam, arch type and 76 m high, stores water of the Shingu River and conveys it to the Totsukawa No.2 Power Plant with maximum output of 58 MW. Since its completion in 1962, the dam has dried up the river and in renewing water rights for the hydropower river maintenance flow was to be discharged from the dam. The dam has seven spillway gates with a type of a roller gate of 12.50 m wide and 12.00 m high. After a comparison study for installation of an outlet, a plan to install outlet valves on a spillway gate was adopted. Three jet flow gates were installed on a spillway gate located at the right bank side to discharge river maintenance flow of 3.0 m^3/s at the maximum. Figure-9 shows the situation of water discharged from a spillway gate.

Figure-9 Discharging river maintenance flow from spillway gate of Futatsuno Dam

Figure-10 shows the river circumstances before and after installation of the outlet valves.

Before discharging river maintenance flow

After discharging river maintenance flow

Figure-10 River circumstances at Futatsuno Dam

The improvement works started in November, 1990 and were completed in May 1991.

As other examples, the Hiranabe Dam and the Kurobuchi Intake Weir are introduced.

The Hiranabe Dam, gravity type and 38 m high, takes water from the main stream of the Nahari River and conveys water to the Nagayama Power Plant with maximum output of 37 MW through a headrace of about 8.2 km long.

To solve the problem of a dried-up section, a discharge valve was installed on a sand flush gate of the dam. According to the notification, river maintenance flow of 0.65 m^3/s from April 1 to September 30 shall be discharged and 0.43 m^3/s from October 1 to March 31. The improvement works started in September, 1989 and were completed in February, 1999.

Figure-10 shows the river circumstances downstream of the dam before and after installation of the outlet valves.

Before discharging river maintenance flow

After discharging river maintenance flow

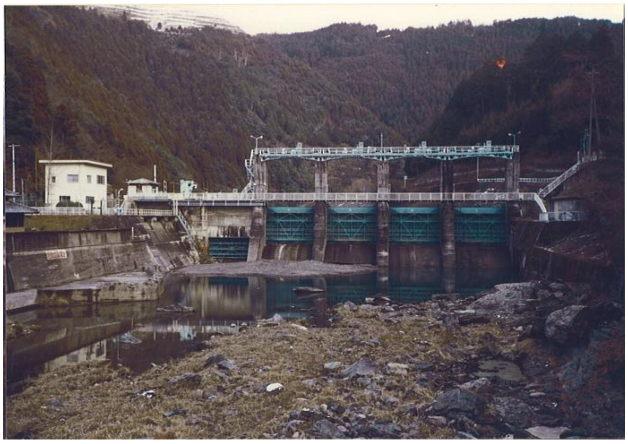
Figure-10 River circumstances at Hiranabe Dam

The Kurobuchi Intake Weir, gravity type and 13.5 m high, takes water from the Nyu River and conveys water to the Nishi-Yoshino No.2 Power Plant with maximum output of 13.1 MW through headrace of about 5 km long.

To solve the problem of a dried-up section, a discharge valve was installed on a sand flush gate of the weir. According to the notification, river maintenance flow of 0.3 m^3/s shall be discharged throughout the year.

After discharging river maintenance flow, stagnant water which were scattered on the dried-up section was removed and natural environment of the river was restored.

Figure-11 shows the river environment before and after installation of the outlet valves.



Before discharging river maintenance flow

After discharging river maintenance flow

Figure-11 River environment at Kurobuchi Intake Weir

Installing Small Turbine and Generator

In this section, an example of installing a small turbine and generator to discharge river maintenance flow constantly is introduced.

With the aim of making an effective use of abundant fluvial energy in the middle reach of the Tenryu River, J-Power planned the Akiha No. 3 hydropower project with the output of 46.9MW following the existing Akiha No. 1 Power Plant (output: 45.3MW, maximum discharge: 110m^3/s, operation commenced in January 1958) and the Akiha No. 2 Power Plant (output: 34.9MW, maximum discharge: 110m^3/s, operation commenced in June 1958), both of which take water from the Akiha Dam. Starting from May 1988, the construction works had been executed until August 1991. Figure-12 shows a downstream view of the Akiha Dam and Akiha No.3 Power Plant.

Figure-12 Downstream view of Akiha Dam and Akiha No.3 Power Plant

The Akiha No. 3 hydropower project was proposed to effectively use a substantial amount of water spilled from the Akiha Dam, the intake dam for the both Akiha No. 1 and No. 2 Power Plants. The case study of this project comes under two items; installation of a small turbine and generator and drilling a dam body. The examples are to be introduced in the same order.

While studying the Akiha No.3 Project, how to discharge river maintenance flow was examined. The project was planned as a dam-and-conduit type hydropower plant, being similar to the Akiha No.1 and No.2 Power Plant, which formed a dried-up section between the dam and the outlet and did not satisfy requirements of the notification. To solve the problem, a plan to install a small turbine and generator by using river maintenance flow was adopted to collect potential energy from water discharged just downstream of the dam. The capacity of the small turbine was decided to be 6.0 m^3/s according to the rate of river maintenance flow. As a result, the river environment was restored to its original state.

Secondly, drilling of the dam body is explained[3)]. One of the technical problems of the Akiha No.3 project was how to connect the intake to the penstock. As a result of thorough review, an idea to drill the dam body to short-cut a distance between its apron and the power plant was suggested. After investigating the stress imposed on a drilled dam, its construction cost and the possible shutdown duration of the Akiha No. 1 and No. 2 Power Plants, the drilling of the dam was determined as an optimum. Then a detailed design was carried out and an execution procedure was examined.

Figure-13 illustrates the plan and cross section of the project.

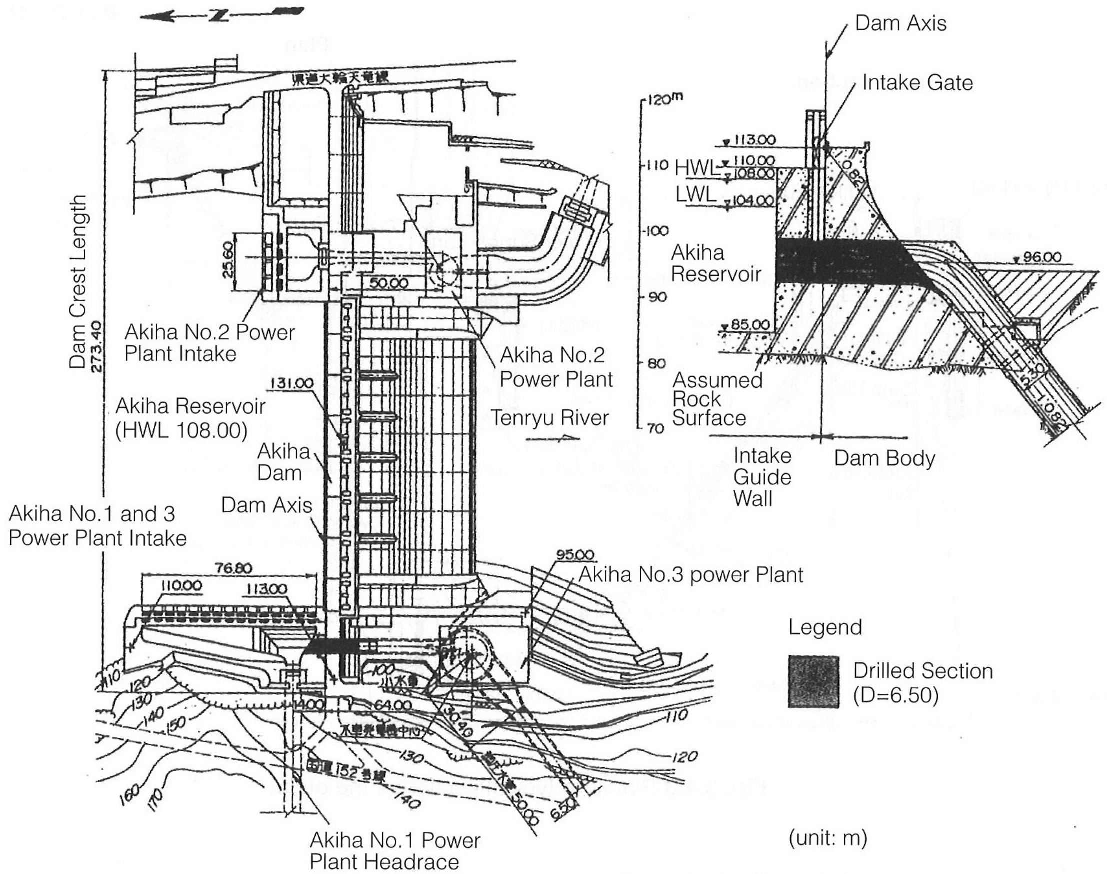


Figure-13 Plan and cross section of Akiha Dam

The followings are two major points which needed to be considered in drilling the dam body.

i) Stability of the dam body

The stability of the dam body before and after drilling was confirmed by using a calculation method common to ordinary concrete dams based on the following criteria:

- No perpendicular tensile stress should occur at the upstream toe of the dam;
- The safety factor against shear failure should be four and over; and
- The coefficient of subgrade reaction should be lower than its allowable value.

The dam stability under the normal as well as seismic conditions was examined under the condition that the reservoir water is at an empty, full and design flood levels. As a result, the criteria were satisfied in all cases.

ii) Stress around the opening

The stress around the opening was calculated basically by following a method to figure out the stress on the opening edge of a perforated board.

One factor to be taken care of most was the stress imposed on the circumference of the opening on the both crest and bottom sides.

The study revealed that the maximum tensile stress was sufficiently smaller than the estimated tensile strength of concrete, which ensured the safety of the opening.

In drilling the dam body, a method to satisfy the following conditions was selected:

1) Excavation can be carried out without damaging concrete around the opening;
2) Excavated surface should be so smoothed that excessive stress concentration may not occur;
3) The progress speed is high;
4) Machinery used is not too heavy or too large; and
5) Construction cost is reasonable.

Among various non-blasting tunneling

methods, a slot drilling method was adopted as an optimum approach.

In the slot drilling method, a tunnel is excavated in the following procedure:

1) Some stripes of slots are drilled around the circumference and inside of the excavated surface;
2) A hydraulic wedge is used to shatter; and
3) The muck is removed.

Figure -14 and 15 show the shape and size of the slot and process of the slot drilling method, respectively.

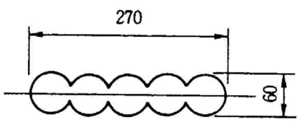
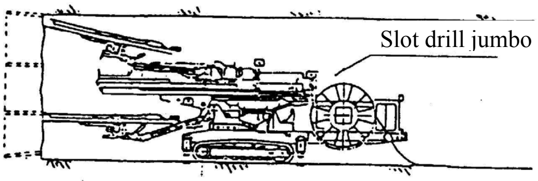
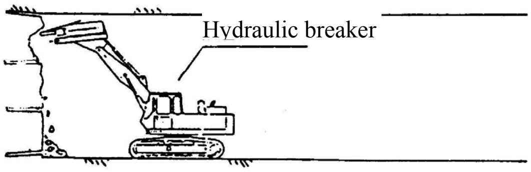


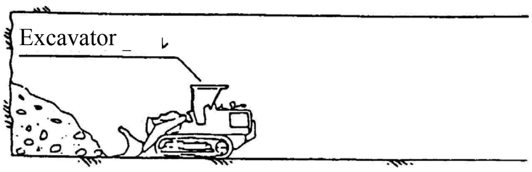
Figure-14 Shape and size of slot



1) Drill slots



2) Shatter dam concrete



3) Remove muck

Figure-15 Process of slot drilling

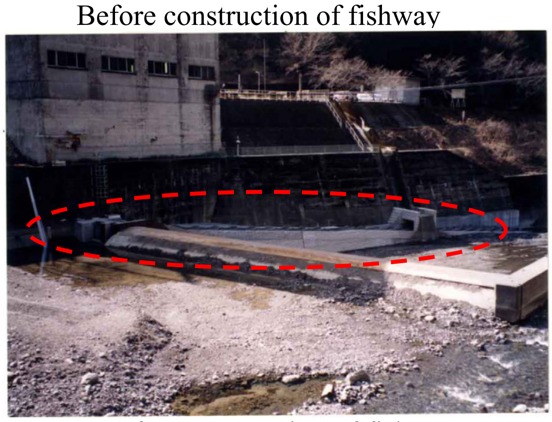
To evaluate the impact of drilling on the dam body, the oscillation, convergence and distortion around the opening were measured and the working face was observed closely. As a result, no impact was detected on the dam body.

Installing Fishway

In this section, an example of constructing a fishway to discharge river maintenance flow is introduced.

The Misakubo Power Plant is a dam-and-conduit type hydropower plant with maximum output of 50MW collecting river water from a main stream and some tributaries. Water used in the power plant flows into a tailrace tunnel going across the Misakubo River through a conduit installed in a concrete weir without returning directly to the river flowing just downstream of the power plant. The weir forms a dried-up section by taking river water, divides the river into two parts, and has prevented fish from swimming upstream and downstream. To solve the problem of the dried-up section, a fishway was constructed on the left bank side of the weir. The fishway is a concrete structure with 2.3 m wide and 59.2 m long. It helps several kinds of fish such as ayus, the Japanese name of sweetfish, trouts, etc., swim upstream and downstream, and works as an outlet discharging river maintenance flow. Figure-16 shows circumstances of the river before and after construction of the fishway.

Before construction of fishway



After construction of fishway

Figure-16 River circumstances at Misakubo Power Plant

3. Conclusion

This report introduces examples regarding improvement of dams and intake weirs to discharge river maintenance flow. Discharging river maintenance flow solved a problem of dried-up section in rivers and improved river environment, while reduced energy production.

The trade-off between environmental conservation and security of domestic energy was solved by thorough discussion of organizations concerned. And their contradictory interests were adjusted under the guidance of the river manager.

There are no standard improve methods to let a dam or intake weir discharge river maintenance flow. The optimum method shall be adopted after due consideration of the conditions of each site.

J-POWER still has many dams and intake weirs which form dried-up sections and those will be improved when their water rights for hydropower use are renewed.

References

1) River Bureau, MLIT: “Notification for River Maintenance Flow,” Attached data of the 6th Committee for Basic Policy of River Maintenance, July, 2003 (in Japanese)
2) Senzo Hakoshima et al.: “Installation Works of River Maintenance Flow Discharge Facilities at the Kakkomi Dam,” the Dam Digest No.570, April, 1992 (in Japanese)
3) Hajime Mineo: “The Outline of Construction Works for Akiha No.3 Power Plant,” Electric Power Civil Engineering No.215, July 1988 (in Japanese)