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EFFECT OF A CURRENT CONTROL SYSTEM ON WATER QUALITY MANAGEMENT OF MIHARU DAM RESERVOIR

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INTRODUCTION

The Japanese archipelago is located in the Asia Monsoon area, where rain falls intensively in special seasons of a year, such as in the rainy and typhoon seasons. Steep mountains extend lengthwise in the middle of the islands, and a huge amount of floods flow down to the lower reaches, where population and property concentrate. To ensure the water supply needed for social and economic activities of people, many multi-purpose dams as well as other kinds of dams have been constructed in various parts of Japan.

Miharu Dam is a multi-purpose dam constructed in mountain village area to control flood, maintain normal function of the river flow, and supply irrigation and municipal water. The reservoir has faced diverse problems on water quality, such as turbid water, cold water, and eutrophication. As a mean for the conservation of the water quality in the reservoir, a current control system was introduced to control eutrophication.

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The current control system discharges nutrients and other contaminants, which flow into the reservoir during floods, to the lower reaches; and combined with surface aeration, the system has effectively controlled the growth of water bloom (Hirose et al, 1994).

OUTLINE OF MIHARU DAM AND ITS BASIN

Miharu Dam is a multi-purpose dam constructed on the Ohtakine River of the Abukuma River system. First impounding started in October 1996, and the dam was completed in March 1998. The Ohtakine River flows into the Abukuma River in Koriyama City, where is the central city in this region. The dam is located at 10 km upstream of the confluence of the two rivers. The Miharu Dam has a catchment area of 226.4 km^2 and a reservoir area of 2.9 km^2. About 30,000 people live in the basin, but sewerage treatment services are not yet provided to the entire population. Stock raising and upland farming are also widely conducted, including about 7,000 cattle and over 4,200 ha of mulberry and tobacco fields, although the area is recently decreasing. Under these circumstances, deterioration of water quality of Miharu Dam reservoir was predicted from the start of planning the project. Various types of facilities for the water quality conservation were installed in the reservoir during the construction of the dam and have been operated since the first impounding, and their effects have been carefully monitored since operation of the dam has started.

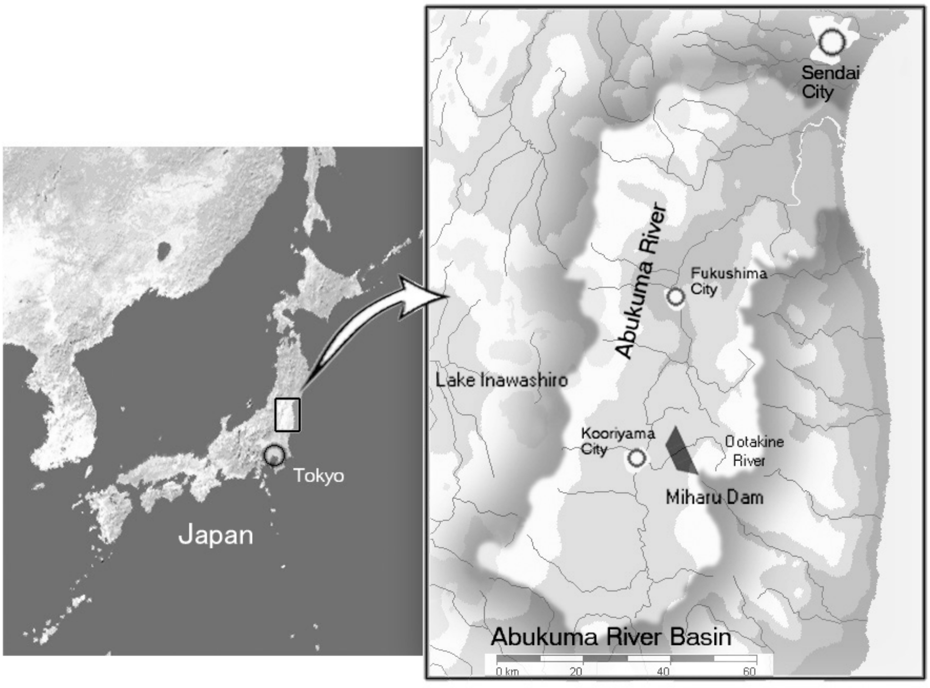

Figure .1 Location of the Abukuma River and Miharu Dam

WATER QUALITY CONSERVATION FACILITIES OF MIHARU DAM

Water quality of the Miharu Dam reservoir

The water quality has been periodically monitored in Miharu Dam reservoir. The monitoring items are listed in Table 1. The reservoir is installed with two automatic water quality monitoring systems, which automatically monitor the vertical distributions of water temperature, pH, DO and turbidity.

The monitored results show that the quality of water flowing into the reservoir has been about 1.9 mg/l of T-N (total nitrogen) and 0.06 mg/l of T-P (total phosphorus) on annual average. The water in the reservoir contains 1.6 mg/l of T-N and 0.04 mg/l of T-P. Although the values are smaller than those in the inflow, they are still larger than the standards of eutrophication 0.6 to 1.5 mg/l of T-N and 0.01 to 0.035 mg/l of T-P, showing that the reservoir is in an eutrophic state. The ratio of N:P is over 30, which is larger than the ratio of (N:P = 16), showing a restriction by phosphorus.

Since the start of the operation, water bloom has been observed every year in the reservoir. For example, growth of water bloom was observed in August and September although the scale was small in 2005.

Table. 1 Monitoring items of Miharu Dam

Periodic water quality monitoring items	once / a month	pH, BOD, COD, SS, DO, number of coliform group, turbidity, T-N, T-P, D-T-N, D-T-P, cholorophyll a, NH_4-N, 2MIB,

Water quality conservation facilities in Miharu Dam

As described above, various types of facilities have been installed in Miharu Dam since the time of its construction to control eutrophication and the resultant deterioration in water quality, such as fore ponds, a bypass pipe, surface aeration systems, a selective withdrawal facility, a deep aeration system, an aeration in a cove, as listed in Table 2. The locations of the facilities and points of monitoring water quality are shown in Figure 2.

Table. 2 Water quality conservation facilities of Miharu Dam

Name		Facility	Effect
Fore-pond		4 ponds in tributaries Capacity: 114,000-225,100 m^3	Remove SS-type nutrient load by sedimentation
Bypass pipe		Diameter: 1.5 m Length: 2.4 km	Prevent nutrient-rich water from flowing into the reservoir
Current control system	Surface aeration	4 facilities (compressor: 22 kW, diffusive aeration: 3.7 m^3/min)	Curb algal proliferation by forming a water circulation layer
	Outlet	Selective withdrawal (max. 25 m^3/sec) and conduit (max. 100 m^3/sec)	Smoothly discharge nutrient-rich water lump in small floods
Deep aeration		2 facilities (compressor: 22 kW, diffusive aeration: 3.0 m^3/min)	Prevent the bottom zone from being in an anaerobic condition
Aeration in a cove		1 facility (22 kW, 3.7 m^3/min)	Improve stagnant water in coves

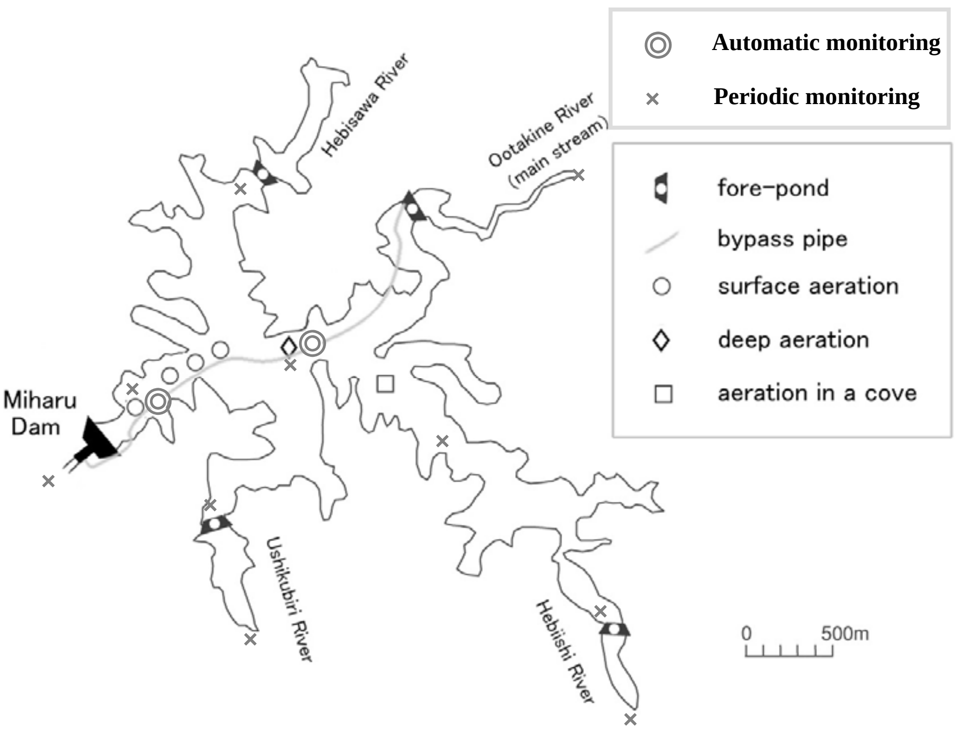

Figure. 2 Water quality conservation facilities of Miharu Dam

CURRENT CONTROL SYSTEM

Mechanism of current control

The key aspect of the "Current Control System" is a combined operation of a surface aeration destratification system and outlet facilities (a selective withdrawal facility and a conduit gate). The current control system circulates the water and keeps the water temperature uniform up to a depth of 15 to 20 m even in the times of small- to medium-scale floods. The circulation makes blue-green algae to descend from the surface to the middle layer and controls the amount of solar radiation that reaches the algae. The system also keeps the inflow that is highly turbid and nutrient-rich in the thermocline using the differences in density of water and discharges the most contaminated water quickly from the selective withdrawal facility and the conduit gate, which are installed at the level of thermocline.

The surface aeration system supplies air continuously at EL301 m forming a circulated water layer of 17 m from the surface, as normal water level during the flood season is EL318 m. The resultant warm surface layer becomes difficult to mix with the underlying cold water due to temperature and density differences. Since most inflowing turbid water is heavier than the surface water and lighter than the deeper cold water, the turbid water spreads on the thermocline and is discharged to the lower reaches through the conduit gate.

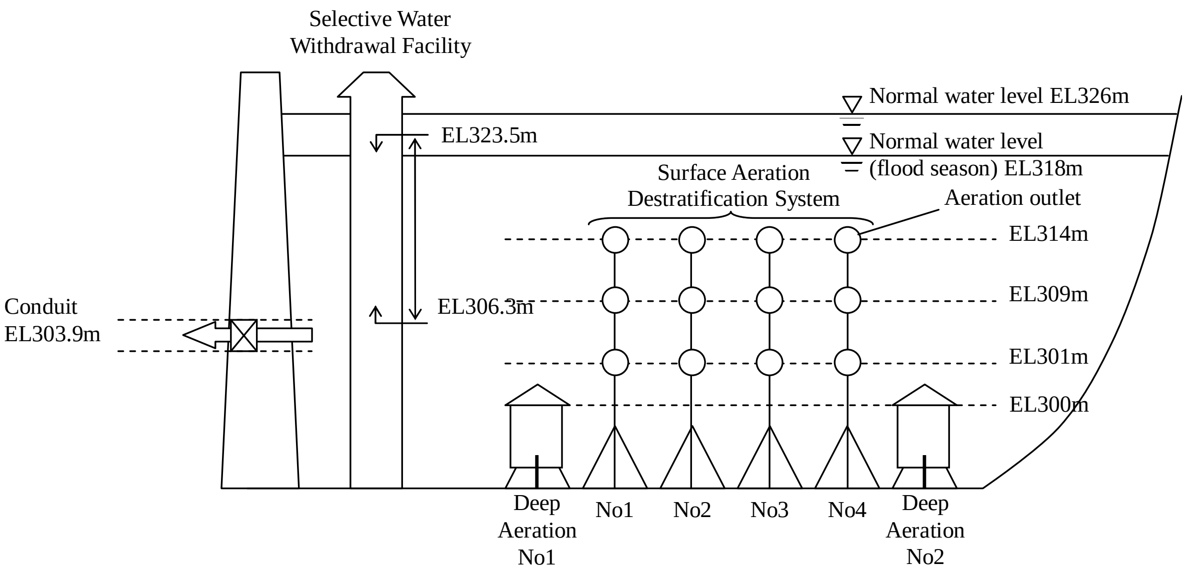

Figure. 3 Water quality conservation facilities of Miharu Dam (schematic view)

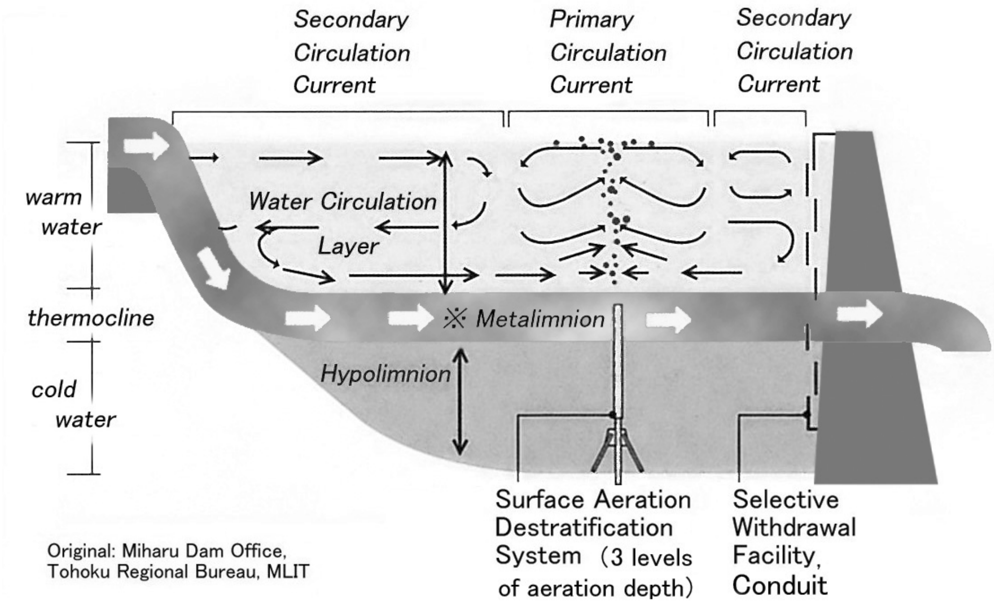

Figure .4 Basic mechanism of the Current Control System

Combining the surface aeration system and the conduit gate

In Miharu Dam, the surface aeration system is combined with the conduit gate so as to quickly discharge turbid water that inflows during small- to medium-scale floods. The surface aeration system forms and maintains the thermocline and guides the inflowing turbid water to spread on a fixed level, and the conduit gate discharges the turbid water.

The surface aeration system is operated from the beginning of the stratification period (Nagayoshi et al, 2006), when the surface water temperature starts to exceed 12 degree-centigrade, and supplies air at EL301 m. According to the monitored data in the past 10 years, the period of starting the operation is usually early April.

Monitored values and operating rules

The maximum outflow discharge during floods of Miharu Dam is 100 m^3 / s. The current control system discharges water from the selective withdrawal facility when the hourly discharge is smaller than 25 m^3 / s and from the conduit gate when the discharge is more than 25 m^3/s in principle.

The supply of air at EL 301m is to be stopped and air supplies at EL 309 m when the automatic water quality monitoring systems detect turbid water of over 50 degrees in water shallower than EL301 m during a flood of over 25 m^3 / s. This is to prevent the aeration system from spreading the turbid water, which flows into the shallow water layer during a flood.

When the turbid water spreads into the shallow water despite of the modification, the surface aeration systems are stopped to settle the contaminants. The current control system of Miharu Dam is efficiently operated by monitoring the quantity and quality of inflowing water.

However, the combinations have been ineffective during some floods in 2003 to 2005, and the operation has also been affected by meteorological and hydrological phenomena.

Monitoring of water quality (effects of the current control system)

To examine the effects of current control system, the turbidity and the concentration of D-T-P (dissolved total phosphorus), which contributes to the growth of phytoplankton, are monitored four points in total. (Two points in the reservoir, one point in the upper reach and one point in the lower reach)

The flood in July 2005 occurred when precipitation of 2 to 5 mm/hr continued. The peak of inflow was only 20 m^3 / s, and slightly turbid water flowed in over a long time, resulting in the turbid water spreading over the entire reservoir. The current control system could not efficiently discharge contaminants in form of highly turbid water (Figure 5).

On the other hand, the flood in August involved an inflow of 100 m^3 / s, and highly turbid water flowed into the thermocline (EL303 m) and was efficiently discharged to the lower reaches through the conduit gate. During the flood, the turbidity of the water above EL301 m exceeded 50 degrees, and the surface aeration systems were stopped. The aeration system was restarted on the next day when the turbidity of the water above EL309 m dropped below 50 degrees (Figure 6).

The discharge of D-T-P load by the current control system was investigated by comparing the D-T-P load in the inflow with the D-T-P load in the water discharged from the dam. The resultant discharge ratio (amount inflowed / amount discharged) is shown in Table 3.

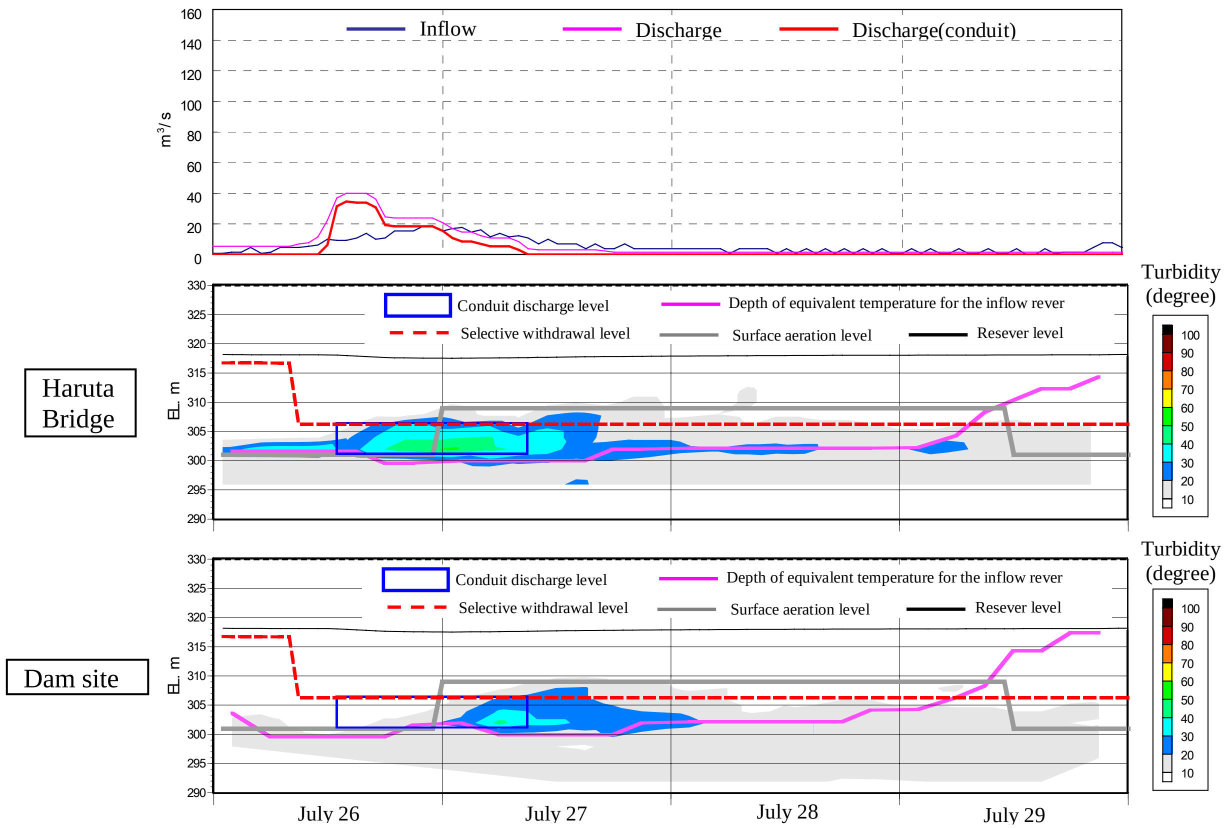

Figure. 5 Change in turbidity in Miharu Dam Reservoir (July 2005)

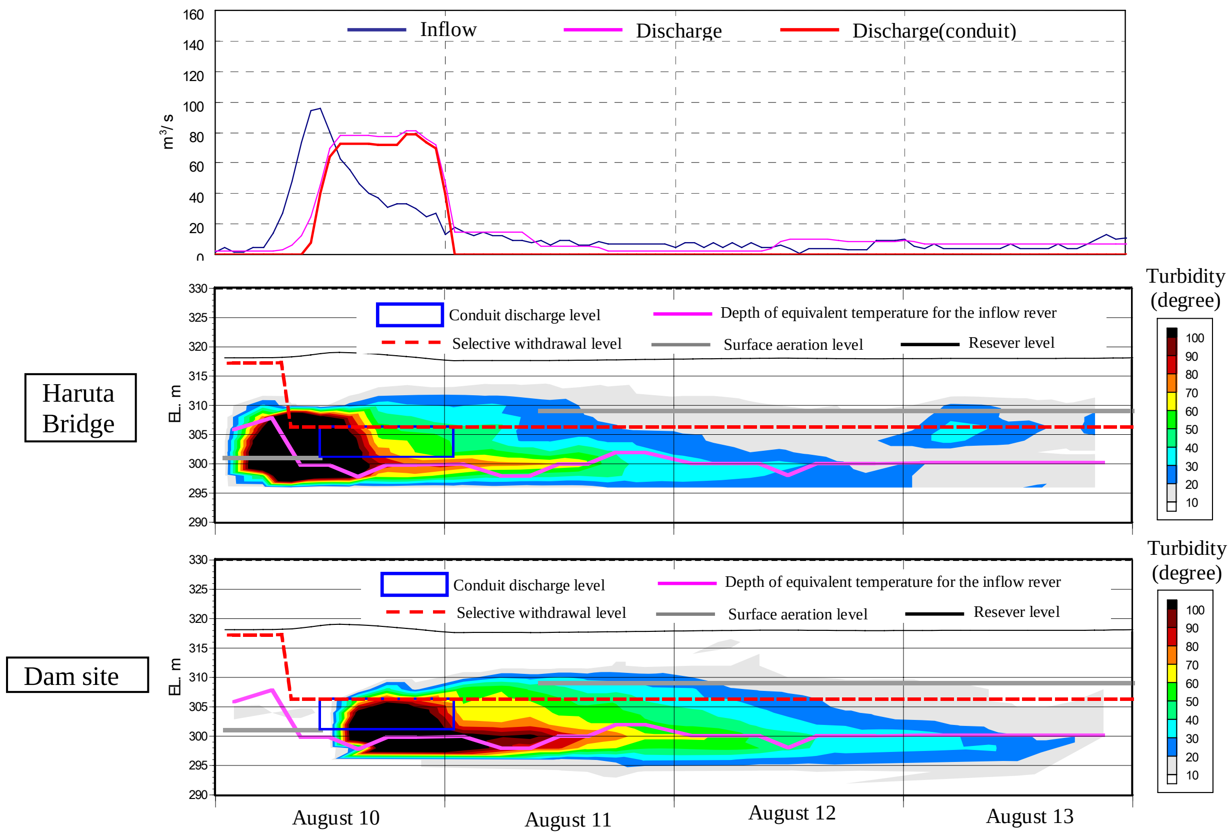

Figure. 6 Change in turbidity in Miharu Dam Reservoir (August 2005)

Table. 3 Discharge ratio and discharge effectiveness (D-T-P)

Observed flood	Discharge Ratio (%) [A]	Discharge effectiveness of D-T-P load (%) [B]
26-27 July 2005	155	39
10-11 August 2005	121	46
25-27 August 2005	94	32
5-6 September 2005	175	78

[A] = [total discharge volume] / [total inflow volume]

[B] = [discharged load of D-T-P] / [total inflow load of D-T-P]

In 2005, the current control system was operated in Miharu Dam during four floods including the aforementioned floods. The operation showed that the current control system alone could not effectively discharge phosphorus when small floods successively occurred and that even in cases when phosphorus was efficiently discharged, only about 40% of phosphorus was discharged on average.

This shows that the use of the conduit gate with current control has enabled efficient discharge of phosphorus (discharge through the conduit accounted for three-fourths of the total discharge).

CONCLUSIONS

A current control system was introduced in the reservoir of Miharu Dam to minimize the supply of nutrients to the surface water layer of the reservoir. The system has been operated based on the data of the automatic water quality monitoring devices installed in the reservoirs, and has been effective in quickly discharging nutrients that flowed in.

Operation of the current control system and monitoring of the water quality will be continued in the reservoir of Miharu Dam to establish effective measures for controlling eutrophication.

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SUMMARY

The Japanese archipelago is located in the Asia Monsoon area, where rain falls intensively in special seasons of a year, such as in the rainy and typhoon seasons. Steep mountains extend lengthwise in the middle of the islands, and a huge amount of rain flows down to the lower reaches, where population and property concentrate. To ensure the water supply needed for social and economic activities of people, many multi-purpose dams as well as other kinds of dams have been constructed in all parts of Japan.

Miharu Dam is a multi-purpose dam constructed on the Ohtakine River of the Abukuma River system. Initial impoundment started in October 1996, and the dam was completed in March 1998. Since the dam is located in mountain village area and there are a number of pollution sources in the basin, from which loads are produced by human living and economic activities, deterioration of the reservoir water in Miharu Dam was expected from the start of planning the project.

Various types of facilities for the conservation of the water quality were installed in the reservoir during the construction of the dam and have been operated since the initial impoundment, and the water quality has been strictly controlled. However, water bloom has been reported every year. As a new mean for the conservation of the water quality, a current control system was introduced to prevent from eutrophication. The mechanisms of the system and results of its operation are described.

The current control system used in Miharu Dam circulates the water and keeps the water temperature uniform up to a depth of 15 to 20 m even in times of small to medium-scale floods using surface aeration systems. The circulation makes blue-green algae to descend from the surface to the middle layer and controls the amount of solar radiation that reaches the algae. The system also keeps the inflow, which is rich in nutrients (turbid water), in the thermocline using the differences of the density of water and discharges the most contaminated water quickly from the selective withdrawal facility and the conduit gate installed at the level. The system aims to control the growth of water bloom.

The current control system discharges water from the selective withdrawal facility when the hourly discharge is smaller than 25 m^3 / s and from the conduit gates above this value in

principle. The aeration system is also operated based on data from monitoring devices installed in the reservoir so as to prevent turbid water from spreading to the surface water layer. The current control system in Miharu Dam has been operated by improving its operating rules based on monitored quantity and quality of inflow to restore the water quality of the reservoir.

Miharu Dam was the first dam to which the current control system was introduced in full scale. The monitored data in 2005 showed that the system is effective in efficient discharge of turbid water and nutrient salts. Further attempts will be made for efficient operation of the system and to establish it as an effective mean for the conservation of water quality.