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The Multiple Contributions of Dams and Reservoirs after the 2011 Great East Japan Earthquake

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ABSTRACT:
Japan suffered unprecedented damage on March 11, 2011 when the disastrous Great East Japan Earthquake struck the eastern part of Japan. Despite the massive disaster, dams in the afflicted areas continued to function properly and made various contributions in the Tohoku and Kanto regions, including increased power generation by flexible dam operations to ease the power shortages caused by the loss of power in East Japan, emergency provision of substitute water to the afflicted areas, and flexible dam operations to meet the demand according to the state of damage in the downstream areas. It has been reported that many dams served as basic infrastructure for the restoration and rehabilitation of the afflicted areas, with some of them serving purposes other than those originally intended for the dams. This paper examines the roles of the dams after the earthquake and shows that the dams served as particularly useful infrastructure. The paper also addresses key considerations in appropriately responding to crisis situations in dam management in future. (This paper is a summary of the paper submitted to the 24th Congress with some updating.)

Keywords: Great East Japan Earthquake and Tsunami, Dam management, Flood control operation, Hydro- power generation, Contribution to local community

1. INTRODUCTION

The magnitude (Mw) 9.0 Great East Japan Earthquake that occurred off the Sanriku coast at 14:46 on March 11, 2011, wreaked havoc over a wide area of eastern Japan, mainly the Tohoku and Kanto regions(Cabinet Office, 2011). Major damages are shown in Table 1 (The Government of Japan, 2011; MLIT, 2011). As of July 26, 2011, the dead and missing exceeded 20,000, with more than 240,000 partially and totally damaged buildings.

While there have been no reports of damage that seriously threatened the safety of dams managed or controlled by MLIT standard, dam operators were requested to maximize hydropower generation to compensate for the power shortage caused by the tsunami damage to nuclear power plants. The dams were also requested to provide substitute water to other river system dams because of damage to their water supply systems. In addition, since the flow capacity of rivers was expected to be greatly reduced due to extensive damage along rivers, particularly in the midstream and downstream reaches, by the earthquake and ensuing tsunami[3)], dam operators needed to be able to respond quickly and appropriately, including flood control, in the coming flood season with a full and accurate understanding of the state of damage downriver.

This paper introduces case examples of dams that made various contributions by their flexible responses, shows the usefulness of dams as infrastructure and examines necessary issues for dam management in future to cope with crisis situations.

2. INCREASE IN POWER GENERATION BY CREATIVE DAM OPERATION

Operators of dams located in the jurisdictional area of Tohoku Electric Power Co. and Tokyo Electric Power Co. operated their dams creatively to increase the hydropower generation efficiency as they had been asked to maximize power generation capacity because of the power shortage resulting from the damage to power plants caused by the earthquake and subsequent tsunami.

Table 1. Major damage (as of 17:00, March 19, 2012)

Human damage	
Fatalities	15,854 persons
Missing	3,145
Injured	6,025
Damage to buildings	
Destroyed	129,280 buildings
Partly destroyed	254,512
Damaged	692,371
Infrastructures	
River (MLIT-managed sections)	2,115 locations
Coast	Approx. 190 km destroyed/partly destroyed
Sewerage (treatment plant)	12 lcoations
Sewerage (sewer)	642 km
Port and harbor (no. of damage reports)	1,705
Port and harbor (reported cost of damage)	¥412.6 billion

Source: Reference materials of the HQ for Emergency Disaster Control and MLIT

Dams managed by the Tohoku Regional Development Bureau of MLIT, which are generally operated so as to reduce the power generation and increase the reservoir level to provide irrigation water to paddy fields in March and April in an ordinary year, shifted to prioritizing power generation based on detailed forecasts of the snowmelt in mountains and minimizing the ineffective flow. Although the operators of the Naruko Dam usually store the water from the snowmelt and allow the reservoir level to rise in mid March, the Naruko Power Plant of Tohoku Electric Power Co. maximized its power generation output in response to the power shortage (Fig. 1) (Naruko dam office, 2011). The Shijushida Dam, located on the Kitakami River system, generated 349 MWh, or about 2.1 times the output before the earthquake, in the 24 hours from March 17 to 18, and the Gosho Dam of the same river system increased the power output about 1.7 times from that before the earthquake to 216 MWh. In total, 16 dams directly managed by the Tohoku Regional Development Bureau operated dams with priority on power generation to help overcome the power shortage in the afflicted areas downstream.

The Kanto Regional Development Bureau also started flexible operations to help maintain a stable supply of power by providing water to the Tsukui Power Plant located on the Sagami River, which has a higher power generation efficiency than the Aikawa No. 2 Power Plant (Ishigoya Dam) located on the Nakatsu River in the Sagami River system, to increase power generation output, on March 17. Specifically, part of the flow, which is generally fed from the Ishigoya Dam to the Nakatsu River, was preferentially sent to the Tsukui Diversion Channel to generate about 230,000 kWh (equivalent to the power for about 510 households) for the 45 days from March 17 to April 30 (Fig. 2).

Dams in the upstream reaches of the Tone River were also operated so as to prioritize power generation although they usually generate power by using the water in the reservoir which is kept primarily for supplying water to the downstream areas or to maintain the river environment. Specifically, the Fujiwara Dam and Minakami Power Plant in the Tone River system were operated to prioritize power generation; their operators estimated the reservoir replenishment by snowmelt and the weather forecast and carefully adjusted operations. As a result, power generation was increased to 27,500 kW, sufficient to power about 9,100 households.

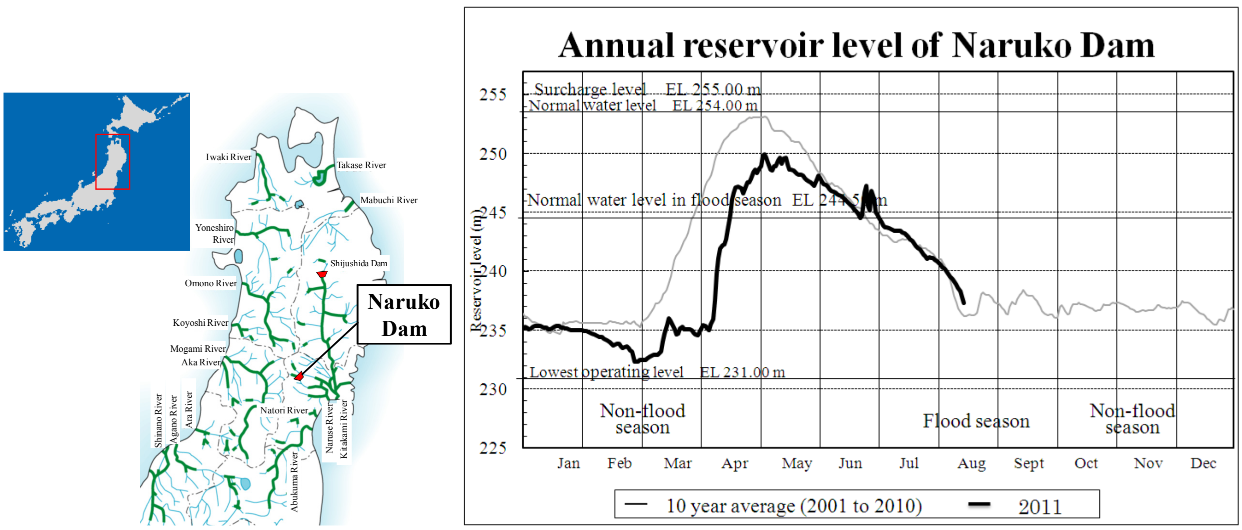

Figure 1. Performance of Naruko Dam in recent year’s and this year’s annual reservoir level curve

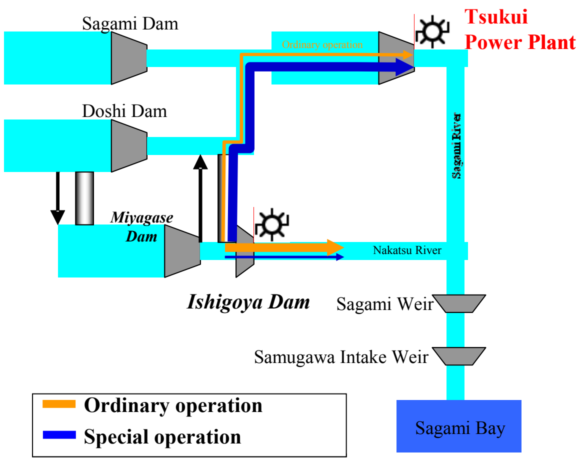

Figure 2. Reservoir operation for Ishigoya dam

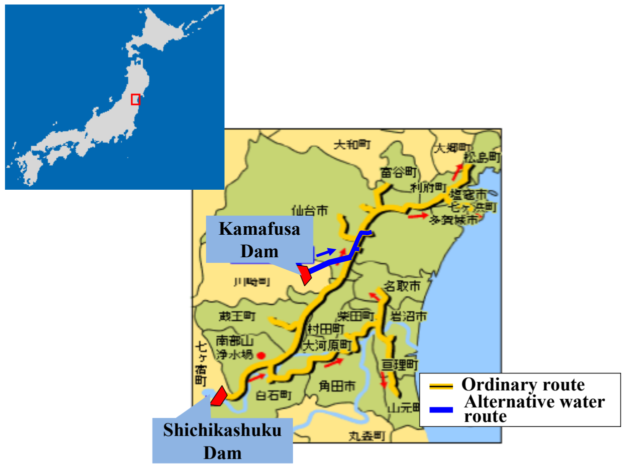

Figure 3. Water conveyance route from shichikashuku dam and Kamafusa dam

3. ALTERNATIVE WATER SOURCES IN THE AFFLICTED AREAS

A central core rock fill dam with a total reservoir capacity of 109 million m^3, the Shichikashuku Dam, located upstream of the Shiraishi River in the Abukuma River system, can supply up to 595,000 m^3 of water daily to seven cities and ten towns including Sendai city (Fig. 3). As the supply of drinking water to Sendai city was cut off by the earthquake due to damage to a water pipe of the Sennan-Senen Wide-area Water Supply System of Miyagi prefecture (Fig. 4), water intake from the Kamafusa Dam, located upstream of the Goishi River of the Natori River system, was rapidly increased to 530 m^3/hr as a temporary measure, together with flexible and careful dam operation, to maintain the essential supply of water to the afflicted area. This emergency operation was carefully coordinated with the Sennan-Senen Wide-area Water Supply System, Sendai municipal water supply, Natori Land Improvement District and other members of the Kamafusa Dam Water User Coordination Committee.

Figure 4. Damaged water pipe of the Sennan-Senen Wide-area Water Supply System of Miyagi prefecture

4. FLOOD CONTROL OF DAMS CONSIDERING DAMAGES IN DOWNSTREAM RIVER AREAS

The Great East Japan Earthquake and subsequent tsunami caused serious damages including
large-scale subsidence, slip failure, and cracking to river management facilities, at 2,115 locations as of July 26, 2011, centering on rivers flowing in the Tohoku region including the Abukuma, Natori, Kitakami and Naruse Rivers. Crustal changes resulting from the earthquake also caused wide-area ground settlement centering on the coastal areas of Miyagi and Iwate prefectures[5]. In response to the damage, the Tohoku Regional Development Bureau rapidly took measures to restore the damaged locations (structural measures) and, based on the restoration condition, revised the standards for announcing flood forecasts and warnings (non-structural measures).

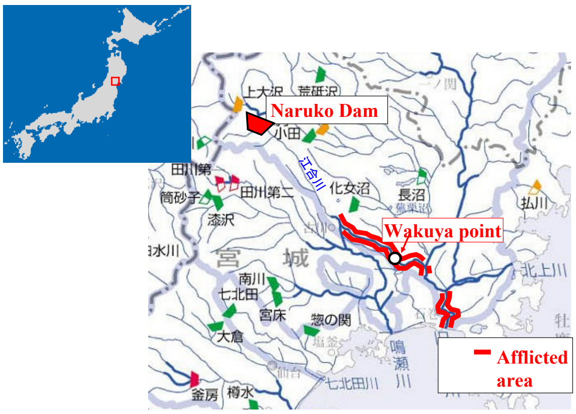

Figure 5. Location map of Naruko dam and afflicted area

Levee damage and ground settlement reduced the flow capacity of rivers and the strength of levees, and so river flooding was a logical concern with the approaching flood season. Operators of dams upstream of the damaged rivers studied measures to reduce or mitigate flooding in downstream rivers and decided to operate dams flexibly to maintain the flood discharge below the flooding risk water level*by maximizing the flood control capacity.

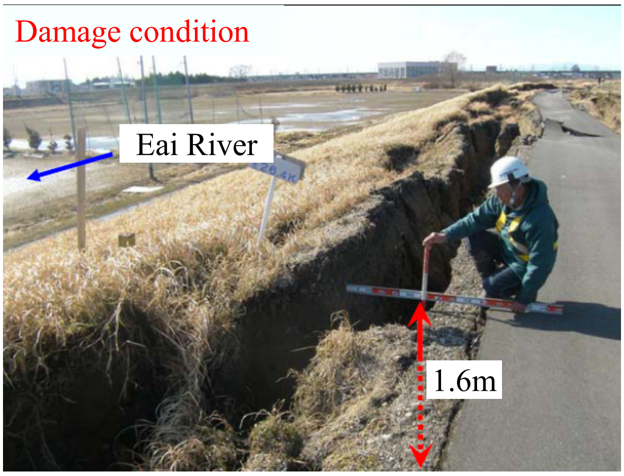

Figure 6. Damage of Eai River
(Left bank: 25.9km + 20m to 26.9km)

The Naruko Dam is a multi-purpose dam constructed upstream of the Eai River of the Kitakami River system in Miyagi prefecture (Fig. 5). Its conventional flood control rule is to maintain a constant-volume discharge of 250 m^3/s (Fig. 7) for a flood control initiation flow. The levee was collapsed at 249 locations on the Eai River and the former Kitakami River (Fig. 6), downstream of the Naruko Dam. In response, the flooding risk water level* at the Wakuya reference point (about 50 km downstream of the dam) was tentatively reduced from 5.30 m to 4.60 m before the flood season. After the warning level of water was reduced, the Naruko Dam revised the following two steps dam operation rule. The first step was that the dam operators would consider preparations for flood storage and carry them out with the approval of water users prior to flooding when the inflow 24 hours in the future is forecast to be equal to the flood control initiation flow or when the river water level at the downstream Wakuya point exceeded the flooding risk water level (4.60 m). The second step was that the dam operators would consider a constant-volume discharge operation of 170 m^3/s when the inflow 3 hours in the future is forecast to be 170 m^3/s and carry it out when the inflow is confirmed to remain below 60% of the flood control capacity by forecasting.

The Kamafusa Dam is a multi-purpose dam constructed upstream of the Goishi River of the Natori River system in Miyagi prefecture (Fig. 8). Its conventional flood control rule is a constant-rate and constant-volume discharge operation after the flood control initiation flow of 300 m^3/s (maximum flow of 850 m^3/s) (Fig. 9). As the levee was collapsed at 35 locations along the Natori River downstream of the Kamafusa Dam, the flooding risk water level at the Natoribashi reference point (about 20 km downstream of the dam) was reduced from 9.10 m to 7.40 m. In response to the reduced water level reference, the Kamafusa Dam revised the following two steps dam operation rule. The first step is that the dam operators would prepare for flood storage and reduce the reservoir level to 1.0 meter below the normal water level in the flood season when the inflow 24 hours in the future is forecast to be the flood control initiation flow (300 m^3/s) and the cumulative rainfall in the river basin is forecast to exceed 80 mm. The resultant capacity is equal to the irrigation capacity which is reduced by the damage to downstream paddy fields. The second step is that the dam operators would consider its operation by considering the flooding risk water level at the Yokata standard point three hours prior to the arrival of the flow from the dam at 600 m^3/s and carry out that operation when the forecast confirms that the discharge operation of a constant-rate and constant-volume maximum discharge of 600 m^3/s would not cause the water level to exceed the water level for initiation of the flood discharge control operation. In other words, dam operators should shift the currently regulated maximum discharge of 850 m^3/s to a constant-rate and constant-volume discharge operation of 600 m^3/s depending on the forecasts of inflow of water to the dam reservoir.

Figure 8. Location of Kamafusa Dam and afflicted areas

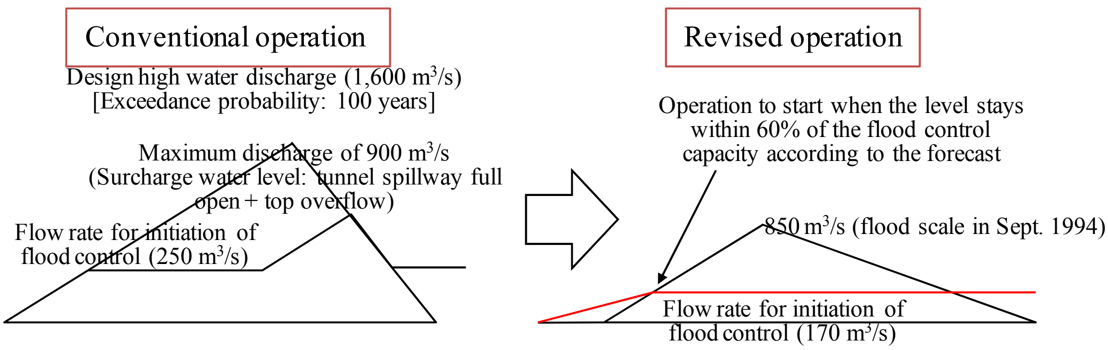

Figure 7. Conventional flood control and revised flood control for Naruko Dam

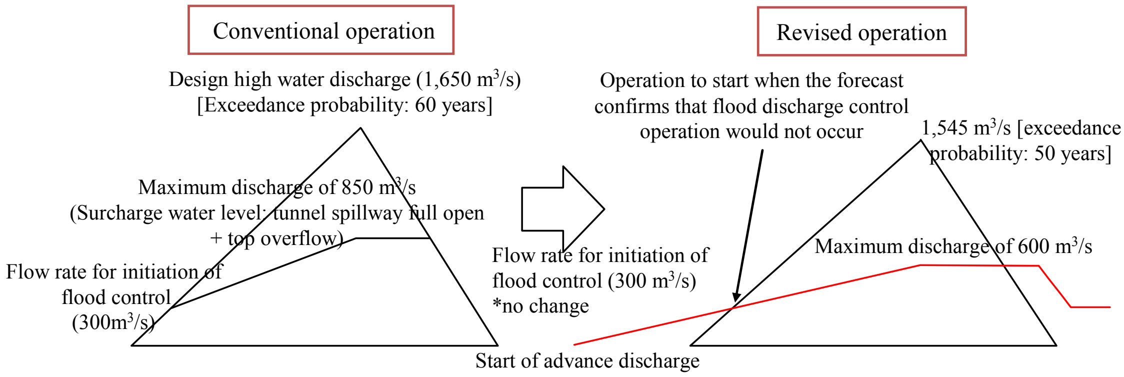

Figure 9. Conventional flood control and revised flood control for Kamafusa Dam

*Flooding risk water level: Water level at which water may cause flooding that will cause serious damage such as inundation of hoses in present river condition.

5. OTHERS (USE OF THE LAND AROUND THE DAM RESERVOIR FOR TEMPORARY HOUSING FOR EVACUATED RESIDENTS)

Following the damage to Fukushima No. 1 Nuclear Power Plant, the village office of Katsurao-mura, Futaba-gun, Fukushima prefecture, planned to evacuate villagers to Miharu town, and the mayor of Miharu town approved the plan on April 5, 2011. The next day, the mayor asked MLIT about using the developed area around the Miharu Dam, located upstream of the Ootakine River of the Abukuma River system, for housing the villagers to be evacuated. The area had already been used by Miharu town for various purposes for both townspeople and non-townspeople without disrupting dam management. Since the relocation of evacuees and use of the land were not expected to affect dam management and that safety of the area would be ensured amid the continuing aftershocks, the dam management decided to allow the land to be used for temporary housing of Katsurao villagers (Fig. 10).

Progress: Building interior work under way as of May 24

Figure 10. Land for temporary housing near Miharu Dam

6. SUMMARY

This paper introduced examples of dams which made various contributions and were operated flexibly in response to the damage caused by the Great East Japan Earthquake, thus demonstrating the usefulness of dams as important infrastructure in emergency situations.

These experiences highlighted the following important points about future dam management in crisis situations:

(1) Structural safety of the dam and alternative functions in the event of a crisis
The top priority is to ensure emergency power. This requires the availability of stand-by power generators and fuel to run them. It is important to note that some dams could not generate commercial power for up to 90 hours and it remained difficult to acquire fuel after the earthquake. In addition, since local power outages made it impossible to operate hydropower equipment at some dams, it is essential to prepare for the loss of power. In addition to power supplies, it is necessary to always be prepared for emergency situations.

(2) Allowance for flexible operation
When a dam is constructed, the dam must be built to perform its intended functions and designed to minimize waste. But the experience of this disaster showed the value of flexibility that allowed dams to cope with varying demands. Dam operators should consider whether they can provide an alternative water source, operate dams flexibly to assist afflicted downriver areas and, if necessary, provide land for evacuation. Such actions, if feasible, should be considered during daily operations.

(3) Daily preparedness and cooperation with the local community
Dams often serve more purposes than originally intended as public facilities. They can play key roles in disaster prevention in major disaster situations and should be used as such. This notion is now widely recognized; it is essential to be prepared for various emergency situations and to maintain close communication with the local community on a daily basis.

Japan experienced unprecedented multiple diasters of a gigantic earthquake, tsunami and damage to nuclear power stations. We must summarize and analyze the lessons learned from this disaster and improve our preparedness for future disasters, particularly the Tokai, Tonankai and Nankai Earthquakes which are expected to occur in the near future and cause major damage.

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