JAPAN'S "FOLLOW-UP SYSTEM FOR MANAGEMENT OF DAMS" AND ITS ACHIEVEMENTS

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ABSTRACT

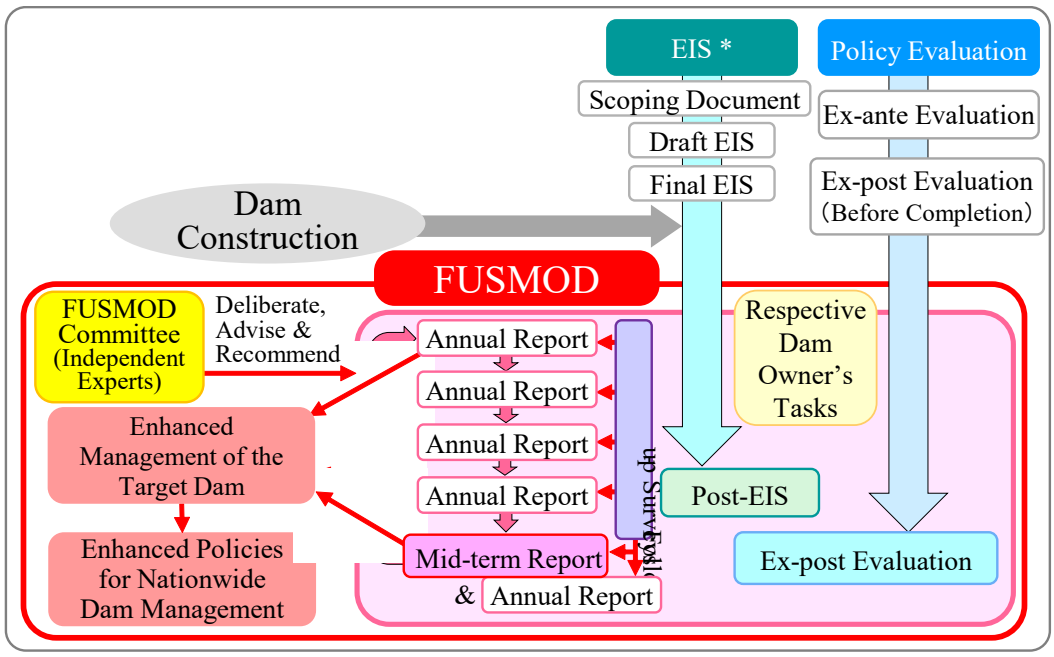
The Ministry of Land, Infrastructure, Transport and Tourism (MLIT) of Japan started test operation of the Follow-up System for Management of Dams (FUSMOD) in 1996 and its regular operation in 2002. FUSMOD aims to facilitate statutory post-assessments of dam construction projects, and to improve management of 141 dams and reservoirs operating under the jurisdiction of MLIT. To comply with FUSMOD, each dam owner is required to perform surveys for post-environmental assessment as well as for the post-assessment of the project in charge. These post-assessments are not once-and-for-all type but a series of periodical reviews of dam projects. Using the results of surveys, each dam owner periodically reviews the hydrological records to examine the performance of flood control and water supply, changes on sedimentation, water quality, flora and fauna, demography and regional economic effects. FUSMOD, by analysing data generated through various surveys and daily management, provides an opportunity for dam owners to realize how they need to rectify their management of dams. We demonstrate the benefits of FUSMOD by describing examples of operations that have been successfully rectified under FUSMOD. These include improved operation of water quality control facilities such as selective intake facilities and aeration facilities based on continuous water quality survey results. Another example is review of survey plan for water quality. The changes contributed to more efficient dam management through acquisition of pivotal data for dam management. Under FUSMOD, measures for controlling invasive alien species introduced in connection with dam construction projects, and evaluation of the impact of dams on local industries through water supply and their recreational function, for example, are also studied. The results lead to rectify related policies and procedures. FUSMOD enables dam owners to conduct meta-analysis through analyses and assessment results for various dams. The achievements thanks to meta-analyses include revisions of reservoir water quality survey guidelines and reservoir sediment management guidelines. Moreover, FUSMOD, through continuously released summaries of analyses and assessments to the general public by MLIT, ensures dam management is accountable.

1. FOLLOW-UP SYSTEM FOR MANAGEMENT OF DAMS

1.1 Purpose and position of the FUSMOD in Japan's legal framework

Figure 1 shows the role of the Follow-up System for Management of Dams (FUSMOD) in relation with relevant legal procedures. FUSMOD aims to conduct post-assessments of dam construction projects, pursuant to the Environmental Impact Assessment Act, for 141 dams and reservoirs (see Figure 2) operating under the jurisdiction of the Ministry of Land, Infrastructure, Transport and Tourism of Japan (MLIT), and to improve management of dams operating under MLIT jurisdiction. FUSMOD also plays the role of conducting post-assessments pursuant to the Government Policy Evaluations Act. MLIT started test operation of FUSMOD in 1996 and its regular operation in 2002. FUSMOD surveys and analyses the natural environment around dams, and the effectiveness of dam projects in terms of flood control, water supply, and recreational resources. It is a post-assessment tool used in the public works assessment system in Japan.

FUSMOD is also regarded as a procedure that fulfils the monitoring role in environmental assessments pursuant to the Environmental Impact Assessment Act.



*EIS: Environmental Impact Statement

Figure 1 : Role of FUSMOD in relation with relevant legal procedures.

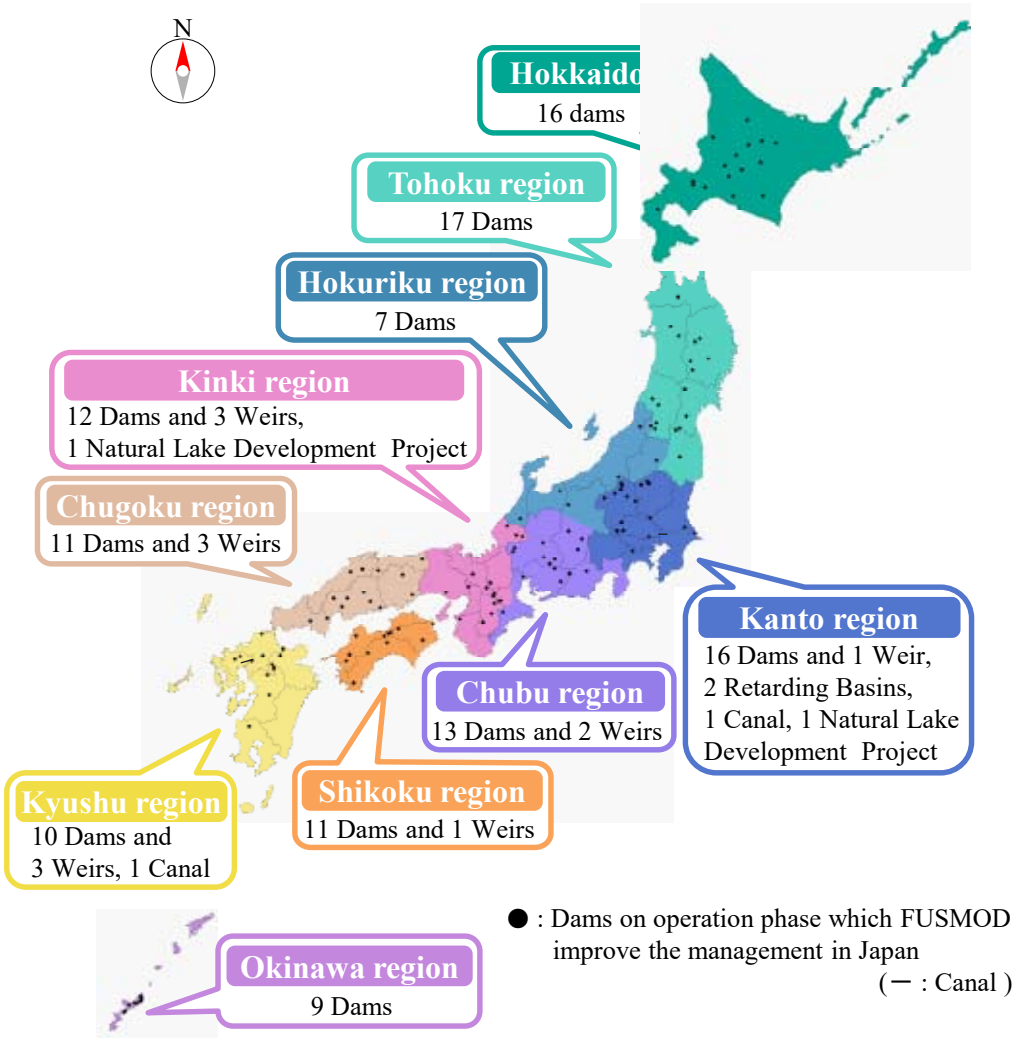


Figure 2 : Map of dams where FUSMOD is regularly conducted.

1.2 Components under FUSMOD

Surveys under FUSMOD are transitional phase surveys that are conducted during the transition period from the last stage of construction phase to the early stage of operation phase, with the initial impoundment between them, and the follow-up surveys that are conducted at the operation phase after the transition. Figure 3 shows the process flow of FUSMOD.

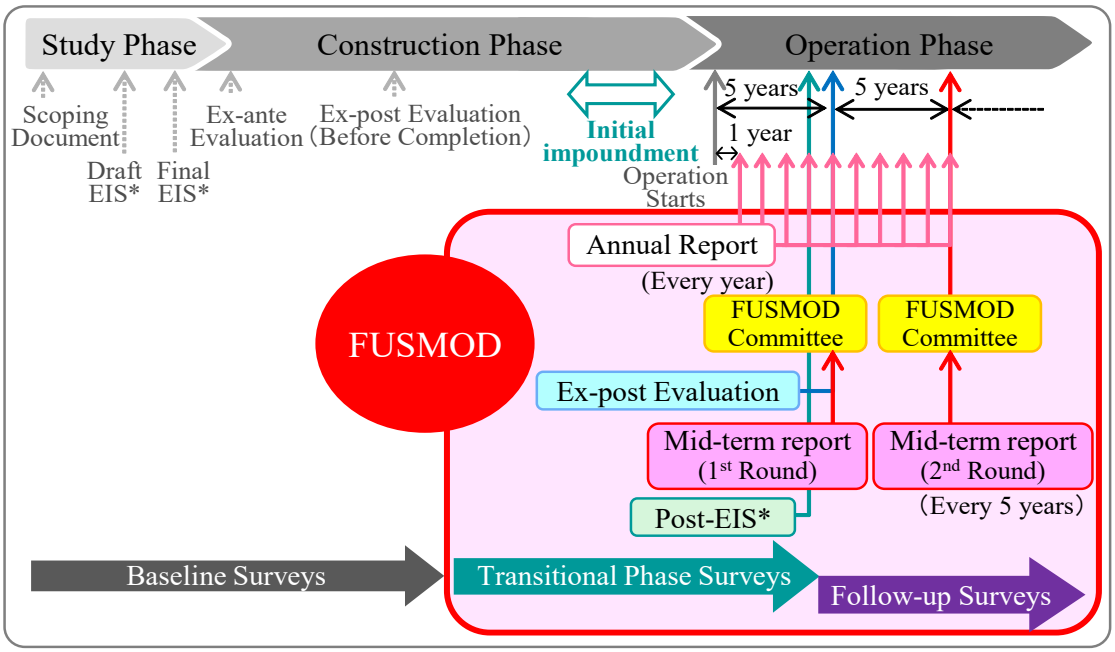


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Figure 3 : Process flow of FUSMOD.

Transitional phase surveys are conducted to analyse and assess environmental changes in detail, before and after the end of dam construction.

Follow-up surveys (see Table 1) are conducted on dams in the operation phase. Surveys at each dam cover categories of surveys relating to water quality, vegetation and wildlife, sedimentation and effects on regional and local economies. When the process moves from the transitional phase surveys to follow-up surveys, vegetation and wildlife surveys shift to those by the National Census on River Environment, which is a system of periodical environmental surveys in a uniform manner applied to all the MLIT's rivers and dams under operation. However, more intense surveys remain applied to species with special care. They include species to which special protection measures are applied.

Table 1 : Categories of surveys covered by Follow-up Surveys.

Categories	Sub-Categories	
Water quality	Indicators based on Japan's Basic Environment Law,	
	Eutrophication,	Cold/Warm water discharge
Vegetation and wildlife (National Census on River Environments)	Fish and shellfish, Zooplankton/phytoplankton, Amphibians/ reptiles/mammals Birds,	Benthos, Plant surveys, Land insects,
Sedimentation	Sedimentation volume,	River morphology
Effects on regional and local economies	Number of visitors and their activities, Demography around dam reservoirs, Flood control records, Water supply records,	Downstream water levels Stream flow regime

Each dam owner annually prepares an Annual Report that summarises the results of follow-up surveys as well as results of analyses based on those results (MLIT 2003). Then, based on all these results, every five years the dam owner analyses the results of the last five years to strive for appropriate dam management. The content of the analyses is deliberated by relevant FUSMOD Committee. A FUSMOD committee is a group of independent experts in engineering, economics, ecology, et.al. with local familiarity. One committee is organized in each region and there are ten committees in Japan. FUSMOD committees scrutinize results of the dam owner's analyses and make assessment. The results are compiled into a Mid-term Report (MLIT 2014).

2. ACHIEVEMENTS OF FUSMOD

2.1 Improved operating and survey methods

2.1.1 *Improved operation of water quality control facilities*

Under FUSMOD, as shown in Figure 4, water quality in reservoir and downstream, eutrophication status and current mitigation measures for the eutrophication are analysed and needs for improvement are examined by relevant dam owner first. Results of the assessment is also drafted the dam owner. Then relevant FUSMOD committee deliberates the analyses and assessment and make advices and recommendations, if necessary. The assessment may include revision of operating rules of water quality control facilities, modification of existing facilities and installation of additional facilities. Following the assessment and recommendations, the dam owner draw up an improvement plan and runs water quality simulations and designs for the modification/instalment works, if needed. The followings are two examples of FUSMOD applications.

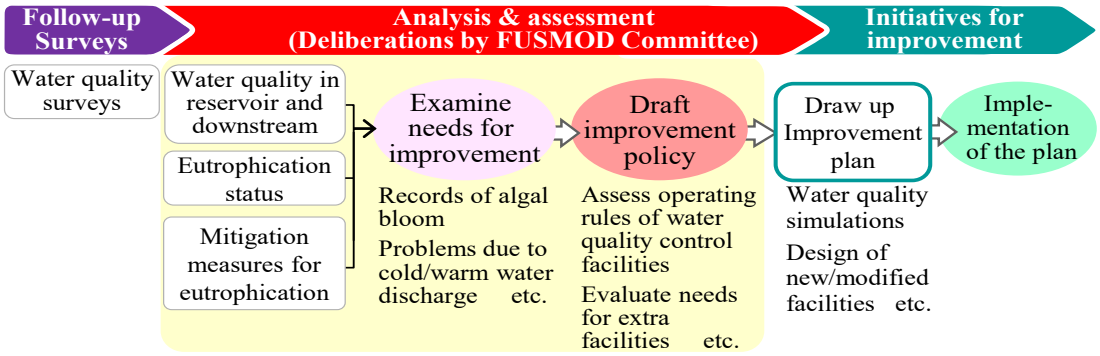

Figure 4 : Sample process flow for improvement of water quality control facilities.

One example is a selective intake facility at Dam A in Hokkaido, the northernmost region of Japan. It previously took in water from a layer near the surface because the dam owner operated it with a priority on water temperature. However, the long-term trend showed muddier water than anticipated, so the rules of operation were changed to prioritize more on turbidity. Water intake elevation was lowered by two meters to mitigate the discharge of muddy water.

Another example is Dam B in Okinawa, the southernmost region of Japan. The initial target of the aeration facilities of the dam was anaerobic conditions at the bottom of the reservoir and hypolimnetic aeration was adopted. However, oxygen consumption was greater than expected because of inflow load and dissolved oxygen at the middle layer became low. With an advice from the FUSMOD committee, the dam owner adopted destratification; namely different operation of aeration facilities to break the metalimnion and cause overturn in the reservoir.

2.1.2 *Revision of survey plans to cope with contingencies and to gain efficiency*

A survey plan under FUSMOD may need revision when unprecedented event or unknown phenomenon happen. The needs for the revision may also be recognized even without any new events or phenomena if more effective ways of the surveys are identified. The points of the revisions can include location of survey stations, frequency, seasons, methods, scope, depth of analyses, for example. All the revisions above can be products of FUSMOD. A dam owner may succeed in coping with some contingency by advice from a FUSMOD committee. A dam owner may be able to acquire more robust data with less cost or succeed obtaining pivotal data with which some challenges may be solved. The example below shows how FUSMOD controlled detailed surveys to tackle the problem of possible “black water” downstream (see Figure 5).

The owner of Dam C in Hokuriku region began a survey after receiving a report from locals who tell that rocks on riverbeds downstream were turning black possibly due to the water quality of the discharged water from the dam. Although no evidence of the problem of the water quality was confirmed, receiving advice from the members of the FUSMOD committee, the dam owner analysed the water quality of the reservoir and found a decline of dissolved oxygen in the bottom layer was causing deoxidation of the sediment and elution of iron and manganese could cause the black water phenomenon. In light of this, they revised their plan to add surveys of total iron and dissolved iron as well as total manganese and dissolved manganese in summer. These additional surveys would better prepare them for any future black water phenomena.

The dam owner subsequently continued the detailed surveys for five years and found no significant elution of iron and manganese. The FUSMOD committee endorsed the assessment and allowed termination of the detailed surveys. In 2018, a decade after the termination, the dam owner made a detailed endline survey to confirm their progress over time and reconfirmed FONSI (finding of no significant impacts).

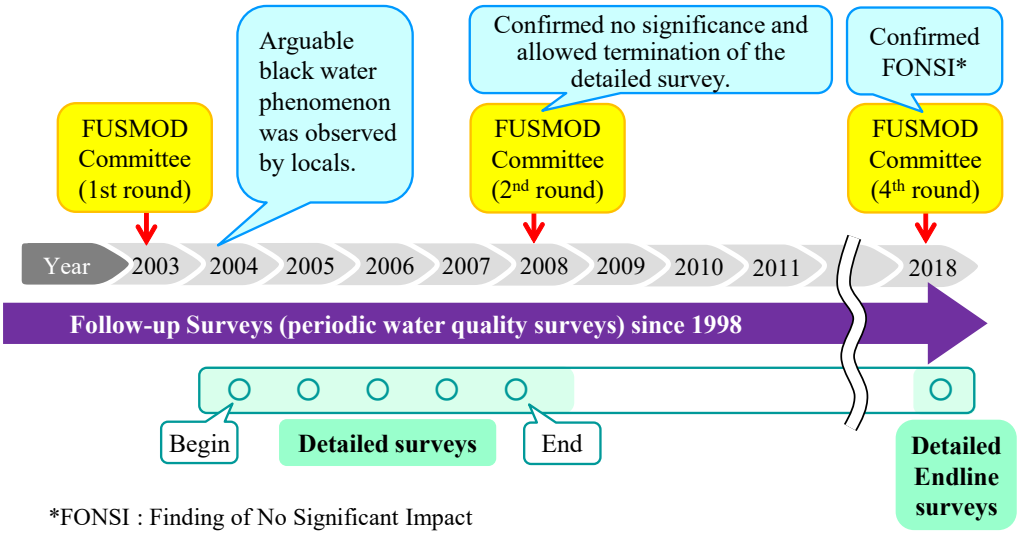

Figure 5 : Example of an appropriate and rational water quality survey plan revision.

2.2 Countermeasures to invasive alien species

Transitional phase surveys and follow-up surveys on vegetation has shown that invasion of alien species happens especially easily in places where the land has been denuded by construction works or by changes of water level at reservoirs.

For example, at Dam D in the Hokuriku region, FUSMOD helped determine that in the drawdown zone, the area covered by *Camellia rusticana* (snow camellia) communities and by lakeside annual herbs communities was declining, while the area covered by the invasive alien species *Amorpha fruticosa* (false indigo) had increased. Analysing the causes revealed ecological characteristics of *A. fruticosa*, i.e., it flowers in May and June when the water level drops and bears fruit and disperses its seeds by September when the water level rises again, thus suggested that the species distribution expanded as a result of this lifecycle suited to water level fluctuations of the dam and due to its physiological characteristics that allow it to withstand submergence in the water. Based on the above results, the FUSMOD Committee of Dam D drew up a draft plan to prevent the spread of and exterminate *A. fruticosa* as shown in Figure 6. Drawdown operation in May was delayed and higher water level was maintained during the time of the former drawdown operation. This revision makes *A. fruticosa* communities remain submerged longer time during the time of pollination.

In October, reservoir water level is raised because risk of large flood decreases. Seed dispersal of *A. fruticosa* also occurs in October. With the information obtained by the surveys, the dam operation was revised to delay the raising operation. The revision contributed to preventing germination of the pollens on the zone suitable for *A. fruticosa* communities.

These revisions of the reservoir operation might not be viable if FUSMOD were not supported all over Japan. Knowledges derived from FUSMOD is shared and can be used in other dams. Using the accumulated knowledges, dam owners can make revisions with more confidence.

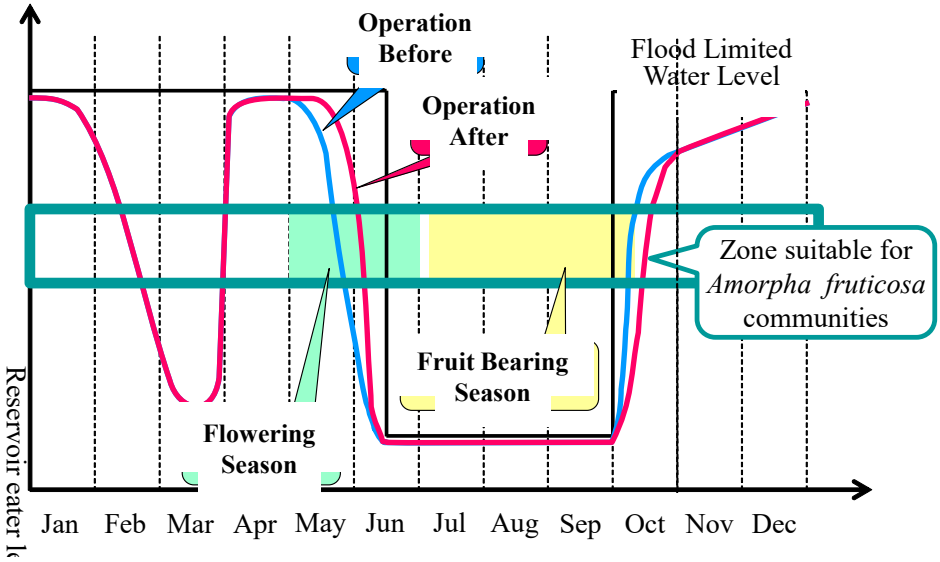

Figure 6 : Sample plan to prevent the spread of and exterminate an invasive alien species.

2.3 Assessing contribution to regional and local economy

2.3.1 *Water supply*

The benefits of water supply of dams may not be easily understood by policy makers as well as by public if the benefits are not presented in an easily understandable way. FUSMOD, therefore, expresses the benefits in such a way. In addition, if problems such as excessive accumulation of sediment or looming effects of climate change are found, water resources development policy may need to be rectified. Not only the benefit but also changes of circumstances should be presented.

Figure 7 shows the dam construction progress, annual precipitation, and number of days with water supply restrictions over time in Okinawa region that consists of small islands at the southern end of Japan. Figure 8, moreover, shows relationship between annual precipitation and the number of days with water supply restrictions. Three lines represent the relationships and show how the risk of drought has diminished as more dams operated. Through 1982, water was in short supply and restrictions were put into effect, even in years with annual precipitation of 2,500 mm or more. The data show, however, that there have been no water restrictions in recent years, even when annual precipitation was far lower than 2,000 mm.

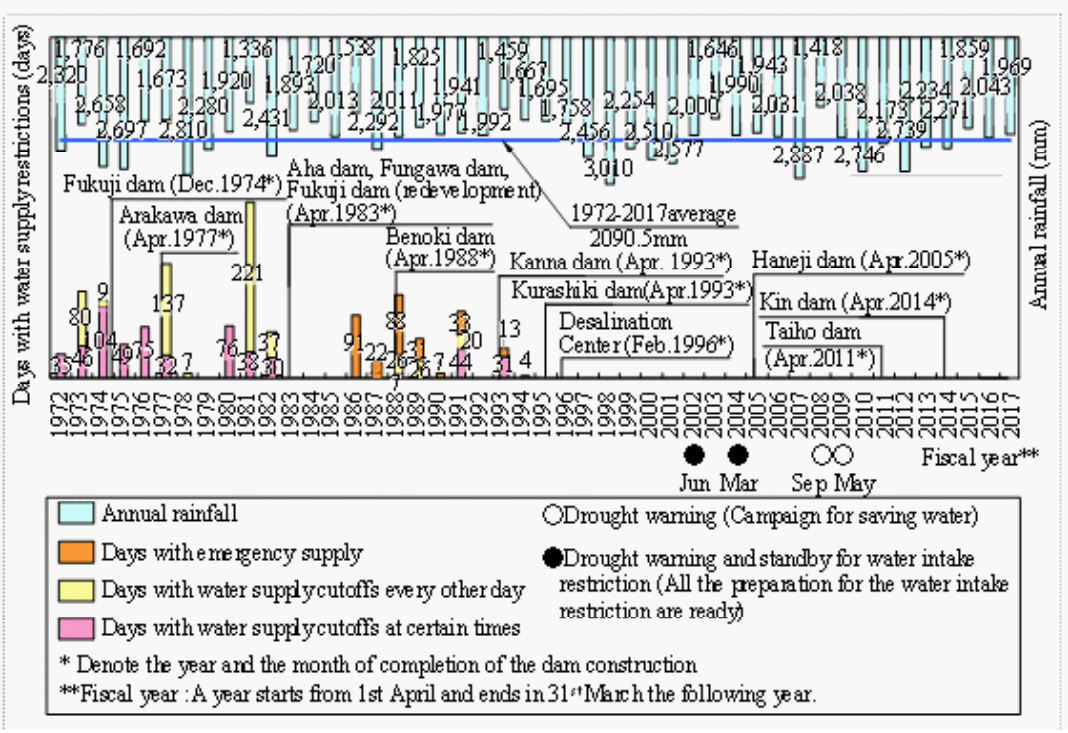

Figure 7 : Dam construction and trends in water supply restrictions.

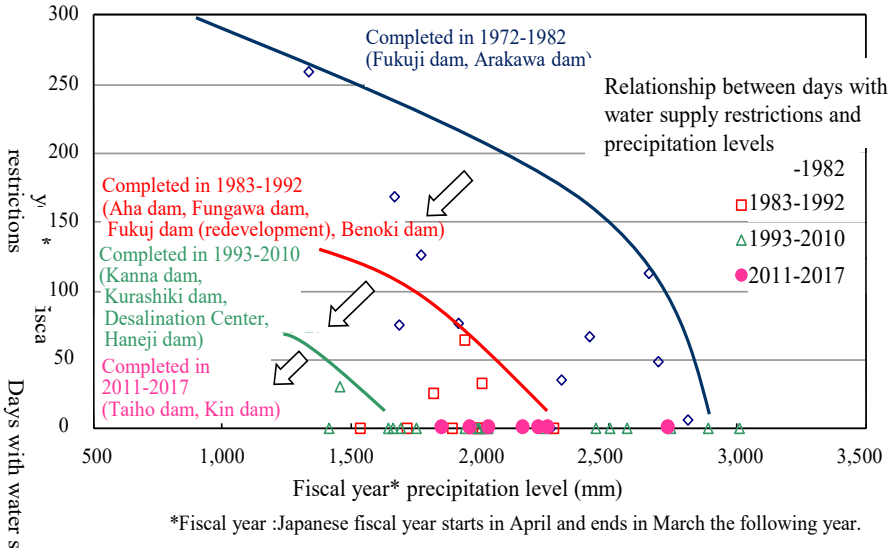

Figure 8 : Changes of risk of drought with respect to installation of dams.

2.3.2 *Effects on local economies*

Number of visitors and demographic changes around a dam reservoir are monitored under FUSMOD. They are used to evaluate economic effects of the dam to the locals. In addition to the measurement of the economic effects, FUSMOD pursue seeking ideas for further economic effects. In recent years, The Government of Japan is promoting tourism as part of the national growth strategy. "Infra-tourism" or sightseeing at large-scale infrastructure utilities such as dams and bridges is gaining popularity. Therefore, promotion of "dam tourism" become FUSMOD's concern now.

"Dams cards" that are given to visitors as a certificate of visiting dams were formalized in 2007. "Dam cards" has gained popularity and attracted enthusiastic collectors since then. One side of the card is a picture of a dam and the other side shows specifications and characteristics of the dam. FUSMOD recently uses the number of dam cards distributed as an indicator of infra-tourism. The number is steadily rising. FUSMOD Committees often recommend devising some other initiatives besides dam cards to attract more visitors, as they help stimulate local economies.

Dams have hosted many events in recent years. Water discharge, which was just a routine activity, turned to be a tourist attraction in many dams. Especially a test discharge event, conducted before the summer flood season, becomes a quite popular event recently. Some dams provide attractions in winter by illuminating dams at night for tourists. Reflecting these events led by dam owners, it also become popular to combine dam sites into the routes of area tours offered by travel companies. Moreover, private initiative to use dams and reservoir as recreational resources is increasing. Sightseeing tours with amphibious buses to see around dams and reservoirs is becoming popular, for example. Thus, dams are being increasingly used as tourism resources (see Figure 9).

FUSMOD analyses and assesses these initiatives too, and FUSMOD Committees deliberate their impact on the community and makes recommendation, if necessary. The recommendations include rollouts of success to other dams, instalment of a mechanism to involve local residents, promotion of interaction between people upstream and downstream and revision of signposts for tourists.

Figure 9 : Dam tourism initiatives.

2.4 Ensuring accountability

FUSMOD committees are composed of independent experts as already explained. Moreover, the Annual Reports, the Mid-term Reports and minutes are essentially publicized. Thus, the accountability of dam management is ensured.

2.5 Roll-out products of FUSMOD

Achievements of FUSMOD may be generalized and rolled out for other dams' operation as well as for new dam construction/redevelopment projects. Using accumulated data of FUSMOD all over Japan, meta-analyses have been made on the problems of water quality and sediment control. The results of the meta-analyses were used to compile the following handbook and manual, which are widely used in Japan.

(1) Dam Reservoir Water Quality Survey Handbook

This handbook was revised in March 2015 to help dam owners select appropriate survey methods, items, quantities, and procedures in light of dam reservoir conditions (MLIT 2015). The revision used results of water quality surveys that had been conducted continually under FUSMOD.

(2) Reservoir Sediment Management Manual (draft)

This manual describes availability of sediment control methods with respect to flow rate and sediment flux (MLIT 2018). FUSMOD's findings on sediment accumulation, effects of sediment control measures such as sediment control dams, sediment bypass tunnels, sediment transportation, were used to draft the manual.

Moreover, vegetation and wildlife survey data under FUSMOD have been jointly analysed with the survey results of National Census on River and Dam Environment (NCRDE). The result of the analyses was used for revising the following manual.

(3) NCRDE Basic Survey Manual (Dam Reservoir Edition)

NCRDE consists of eight survey categories: fish, benthos, plankton, plants, birds, amphibians/reptiles/mammals, land insects, and 'base environment map'; vegetation map with information on river morphology and man-made structures such as dams, weirs, embankments and revetment works (MLIT 2019). Each category is surveyed every five or ten years. It has been conducted since 1990, 12 years before the beginning of FUSMOD. As FUSMOD gives opportunities to make the NCRDE surveys more effective, lessons learned are accumulated (MLIT 2016). NCRDE Basic Survey Manual was revised in 2016 and the lessons learned were reflected on the new version.

3. OUTLOOKS OF FUSMOD

3.1 More intensive reflection on dam management policies

There are three main challenges that are common to all dams in dam management in Japan. Firstly, Japan has an aging society with a diminishing number of children. In dam management, making correct operations with limited number of operators is a challenge.

Secondary, impacts of climate change on dam management are also a concern. Increasing frequency of heavy floods in Japan suggests needs for the revision of the discharge capacities of some dams as well as for sophisticated operation with full utilization of weather forecast. Declining amount of snowfall a rain can also impact water supply function of dams.

Finally, the number of aged dams is increasing in Japan and the progress of sedimentation can hamper flood control and water supply functions of dams.

Recent advices by FUSMOD committees often include needs of countermeasures against these challenges. In order to cope with the challenges, more intense reflection of the FUSMOD Committees' advices and recommendations on dam management policies will be important.

3.2 More robust diagnoses through continuation of PDCA cycle

Figure10 shows PDCA cycle for FUSMOD. Dams which support FUSMOD from its initiation has issued 4th Mid-term Report by now. As more data accumulates, more robust diagnoses can be made. Possible sources of deterioration such as sediment, slope stability, dam structures need to be monitored in order to prevent malfunctions. FUSMOD is similar to periodical complete medical check-ups. Continuation of the system works to utilize potential of a dam fully as well as to prevent its malfunctions. The PDCA cycle should be maintained and more rollouts from lessons learned from FUSMOD should be encouraged. For future problems of dam management, coping with the necessary measures in the appropriate timing and methods will lead to effective and ongoing use of dams over the long term by reinforcing the PDCA cycle.

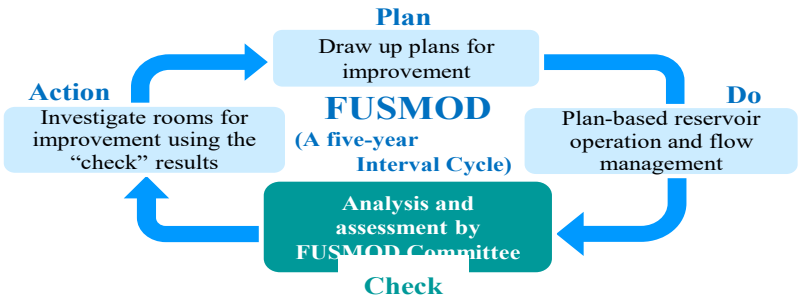

Figure 10 : PDCA cycle of the FUSMOD.

3.3 Construction of enhanced database for FUSMOD

Outcomes of FUSMOD-based surveys, analyses and assessments have been accumulating for two decades. Databases to make comparative assessments easier are one of the products to be realized.

4. CONCLUSIONS

FUSMOD supports post-EIS and ex-post policy evaluation for dam projects in Japan. It aims for continuous improvement of management for respective dams as well as of dam management policies as a whole in Japan.

Achievements of FUSMOD include, but not limited to, improved operation of water control facilities, revision of survey plans to cope with contingencies and to gain efficiency, countermeasures to invasive alien species and promotion of contribution of dams to regional and local economies with an emphasis on outreach. Rollouts of the outcomes of FUSMOD are sought and manuals that are used nationwide had sprung from them.

Ensuring accountability of dam projects is another important role of FUSMOD. FUSMOD activities are based on deliberation by independent group of independent experts called FUSMOD committees.

Dam management in Japan is facing challenges such as diminishing population, increasing flood frequency due to climate change and aging infrastructure including dams. More intensive reflection of advices and recommendations of FUSMOD committees on dam management policies is a strategy to deal with the challenges. Accumulation of the outcomes of FUSMOD is expected to make analyses and assessment made through FUSMOD more robust in the future as the PDCA cycle of FUSMOD are to be continuously maintained. Databases of FUSMOD outcomes should be updated for making comparative assessment easier.

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