The History of Sediment Disasters and Sabo Projects in the Yomase River Basin, Nagano Prefecture, Japan

Makoto KITAHARA[1*], Masashi TASHITA[1], Masaru NISHIZAWA[1], Masaaki KINOSHITA[2], Takao YAMAZAKI[2], Kunihiro HASEGAWA[2], Junichi KANBARA[3], Kimio INOUE[4], Kouji OYA[4] and Kazuhiko NAKANE[4]

[1] Sabo Section, Nagano Prefectural Government, Japan (692-2 Habashita, Minaminagano, Nagano, Nagano 3808570, Japan)
[2] Hokushin Construction Office, Nagano P.G. , Japan (955 Hekida, Nakano, Nagano 3838515, Japan)
[3] Sabo Department, Ministry of Land, Infrastructure, Transport and Tourism, Japan (2-1-3 Kasumigaseki, Chiyoda-ku, Tokyo 1008918, Japan)
[4] Sabo Frontier Foundation, Japan (2-7-4 Hirakawacho, Chiyoda-ku, Tokyo 1020093, Japan)
*Corresponding author. E-mail: kitahara-makoto@pref.nagano.lg.jp

The Yomase River originates from the Shiga Highlands, which is an ancient volcano, and runs for a total length of 26 km with a catchment area of 117 km^2. A vast alluvial fan of 6 km in length and 25 km^2 in area is formed at the downstream area of the river. There are hot springs located along the Yomase River, including the Yudanaka/Shibu Hot Spring in the midstream reach of the river, and they have often suffered devastating sediment and flood disasters. The prefectural government of Nagano started sediment control projects in 1906, but the sabo facilities constructed by the prefecture were destroyed by heavy rainfall between 1909 and 1910, and the hot spring resorts also suffered serious damage. The authors studied the topography and geology of the Yomase River, the history of sediment disasters, and the relationship between the disasters and the sabo projects, and learned that the location maps of the sabo facilities constructed from 1906 to 1910 are stored at the Nagano Prefectural Museum of History. Then, we performed a detailed review of those documents. Analysis of the relationship between the catchment area and the bed slope provided knowledge useful in our review of the limit conditions related to the past construction of dry masonry dams and to the future preservation of those old dams.

Key words: Historical sediment disaster, Sabo projects history, Historical sabo facilities, Dry masonry dams

1. INTRODUCTION

The Yomase River is a torrential wild river that discharges a large amount of sediment from the Shiga Highlands, an area that used to be a volcano, and joins the Chikuma River at Yanagisawa, Nakano City. It has a total length of 26 km and a catchment area of 117 km^2. The Yokoyu River and Kakuma River, both of which originate from the Shiga Highlands with an elevation of about 2,000 m, join near the Yudanaka/Shibu Hot Spring in Yamanouchi Town. Hot spring towns, such as Yudanaka and Shibu, develop over dried riverbeds or fluvial terraces of the Yokoyu, Kakuma, and Yomase Rivers, and have often suffered devastating damage by sediment and flood disasters. The downstream reach of the Yomase River also forms a vast alluvial fan of 6 km in length and 25 km^2 in area, indicating very active discharge of sediments.

The prefectural government of Nagano started sediment control projects in 1906, but the majority of the sabo facilities constructed by the prefecture were seriously destroyed by heavy rainfall between 1909 to 1910, and the hot spring resorts located along the midstream channels also suffered serious damage. Therefore, the authors studied the topography and geology of the Yomase River, the history of the sediment disasters, and the relationship between the disasters and the sabo projects (sediment control projects). The results are reported in this paper.

Fig. 1 Location map

2. METHOD

We gathered and organized relevant materials and documents from the Sabo Section of the Construction Department, the Nagano prefectural government, Hokushin Construction Office, Nagano Prefectural Museum of History, Nakano Municipal Library, Wagokai, and Sabo Library. In particular, the Nagano Prefectural Museum of History maintains large survey maps prepared by actual measurement carried out from 1909 to 1910 and documents related to the Yokoyu River sabo works (sediment control works). We perused these historical documents and photographed them with the permission of the Museum.

We also prepared slope gradation maps using 1mDEM, prepared by the Forestry Affairs Department of Nagano Prefecture, to clarify the topographic conditions of the area.**Fig. 2** is a colored slope gradation map of the upstream area of the Yomase River. The detailed microscopic topography of the area upstream of the confluence of the Yokoyu River and Kakuma River is described. When conducting the field survey, we had with us aerial photos as well as enlarged slope gradation maps so that we could understand the topographic and geologic conditions, the status of existing sabo dams, and the condition of sedimentation. The map shows the lava flow topography flowing down from Mt. Shiga, the former lake area judged to be dammed by this lava flow (shown by a dotted line), the Ochiai Landslide that stretched from west to east at the center of the former lake, a narrow part of the Yokoyu River near Yaen-Koen Park, and the dried riverbed and fluvial terrace at the confluence of the Yokoyu River and Kakuma River.

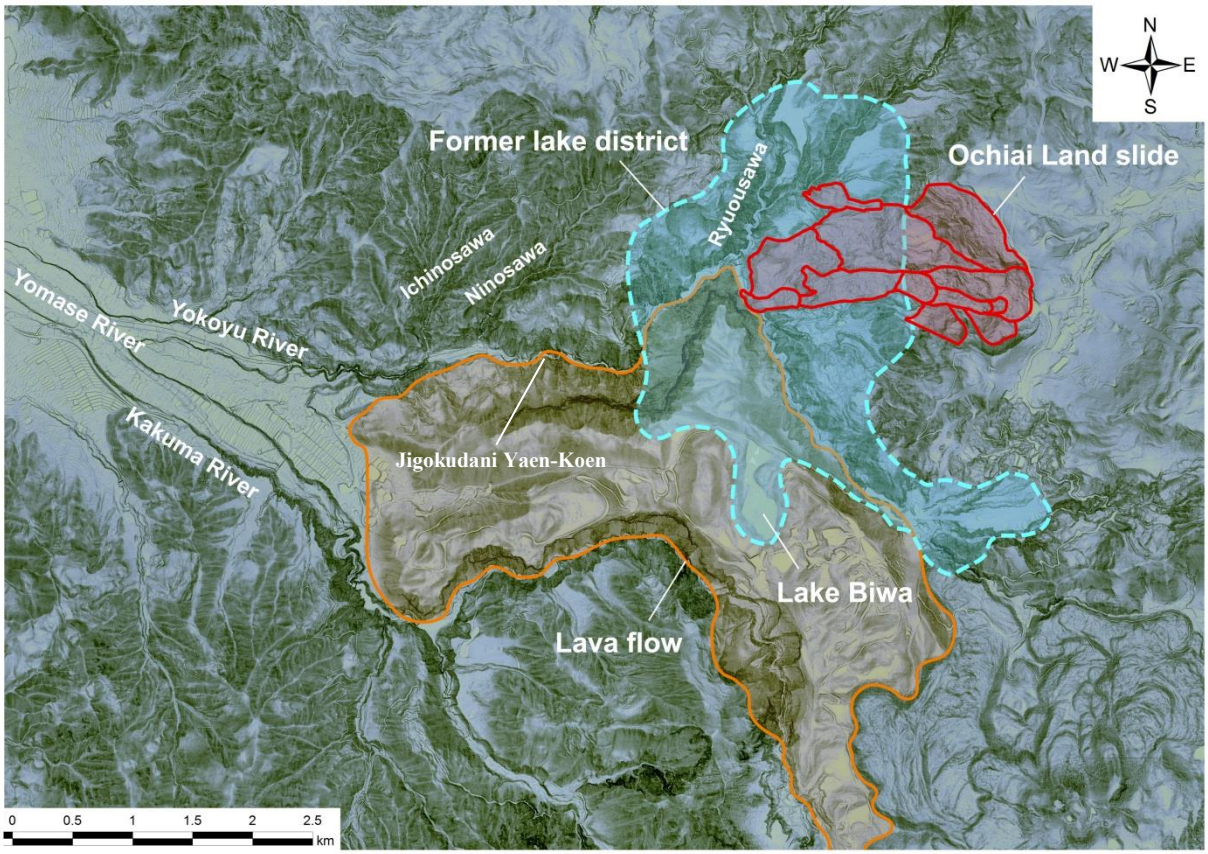

Fig. 2 Colored slope gradation map of the upstream reach of the Yomase River

3. TOPOGRAPHY AND GEOLOGY OF THE CATCHMENT AREA OF THE YOMASE RIVER

Fig. 3 shows the geology of the catchment area of the Yomase River and a distribution map of the landslide topography. The current landslide sites and landslide configurations are concentrated on the right bank of the Yokoyu River and the left bank of the Kakuma River. The geology is characterized by the wide distribution of intrusive rocks such as diorite porphyry and quartz diorite porphyry that constitute the bedrock and the andesitic lava and andesitic pyroclastic rocks erupted from Shiga volcanic mountains. Diorite porphyry and quartz diorite porphyry are exposed on the right bank of the Yokoyu River and the left bank of the Kakuma River, and lacustrine deposits and debris flow deposits are distributed at the Ochiai area.

Lava flows erupted from the Shiga volcanoes from the Middle Pleistocene to the Late Pleistocene stopped river flows to create a lake area in the landslide area of Ochiai, and highly fragile lacustrine sediments were developed in

the lake area. The Yokoyu River and Kakuma River currently run along the boundary between the lava flow from the Shiga Volcano and the bedrock.

4. PAST SEDIMENT DISASTERS IN THE YOMASE RIVER BASIN

The midstream reach of the Yomase River has been used as a hot spring resort since the Kamakura Period. It is believed that even back then, the hot spring resort was popular with many bathers. Records including the Nakano City History of Chikuma River Flood Control (1994) also indicate that the midstream reach had suffered many sediment disasters. Table 1 compiles the past sediment disasters that occurred in the basin of the Yomase River.

The Entoku Tanbo (Entoku Paddy Field), which covers the area between Nakano City and Obuse Town, used to be a lake called Lake Endo. It is recorded that the shogun Minamoto Yoritomo enjoyed viewing cherry blossoms from a boat on Lake Endo in 1197. It is believed that the Yomase River wildly ran in the alluvial fan and drained into Lake Endo until around the 15th century. The river flooded repeatedly during the Edo Period, causing damage to hot spring towns and surrounding villages (**Fig. 4**). In one of the recent flood events, the Kakuma River flooded in 1950, destroying the dike, and damaging the Honami Hot Spring.

Table 1 Past sediment disasters in the Yomase River basin

No.	Year	Description
1	1406	A major flood changed the course of the Yomase River, which originally ran toward Entoku Paddy Field, to what it is today.
2	1614	Major landslides occurred in Mt. Kosha due to heavy rainfall. Two landslides ran down toward the Yomase River and crushed villages on the way. Flooding occurred in the river, and the damage to Entoku Paddy Field was particularly serious.
3	1742	An enormous flood (called Inu-no-Mansui) occurred in the Chikuma River and inundated the paddy and upland fields in the alluvial fan of the Yomase River.
4	1757	Heavy rainfall caused a flood, making the Yokoyu River overflow and washing away the Kawara-yu hot spring building. A major landslide occurred on the mountain behind Shibu Oyu hot spring.
5	1847	A major earthquake, the Zenkoji Earthquake, occurred, and there were major landslides from Mt. Iwakura, which dammed the Sai River. The vast landslide dam was breached and resulted in a big flood in Entoku Paddy Field.
6	1910	A major flood occurred in the Yomase River basin, washing away the sabo facilities that had been constructed previously.
7	1950	Heavy rainfall caused a major flood in the Yomase River. The overflowing water of the Kakuma River breached the levees and almost totally destroyed Honami Hot Spring.

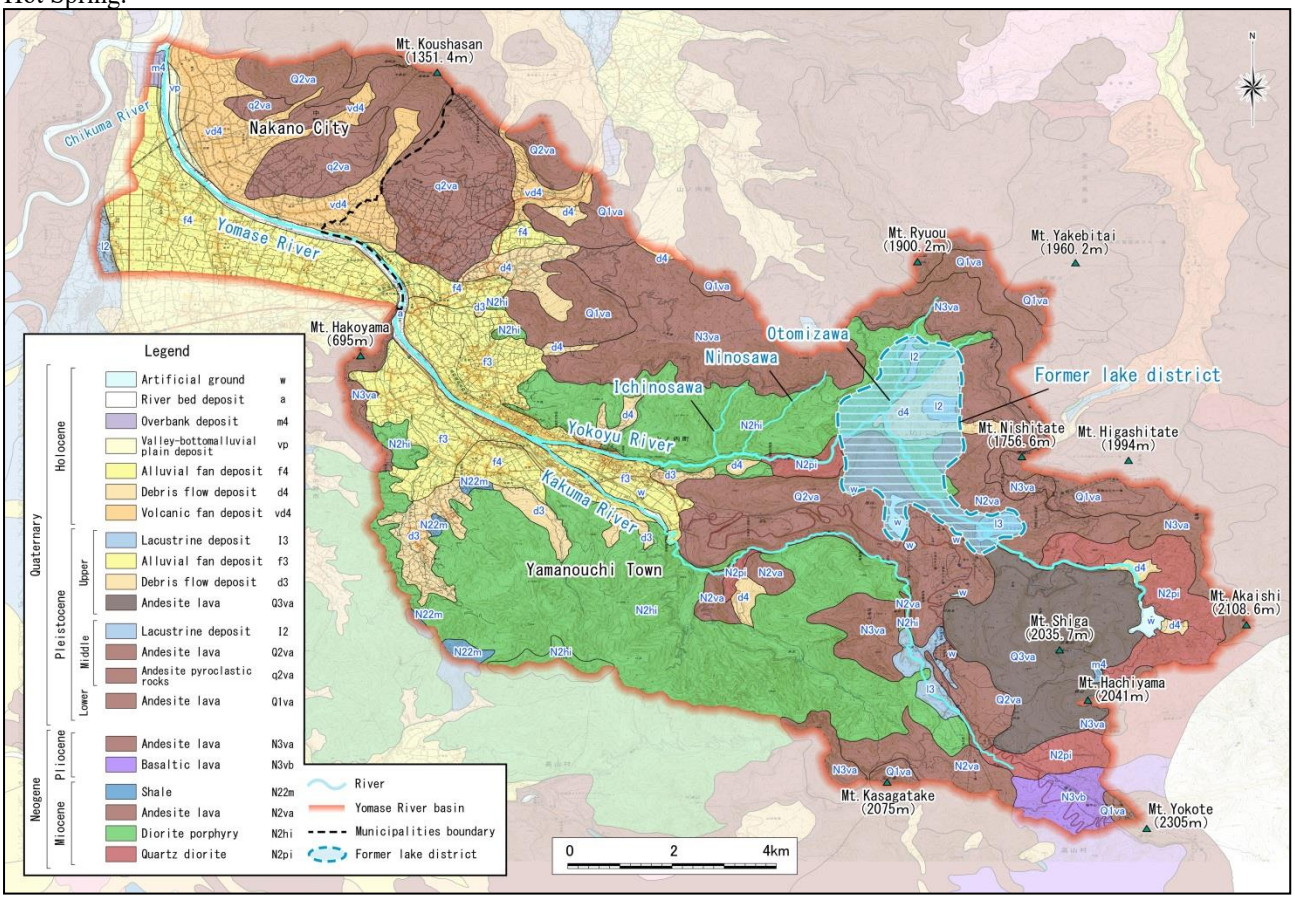

Fig. 3 The geology of the catchment area of the Yomase River

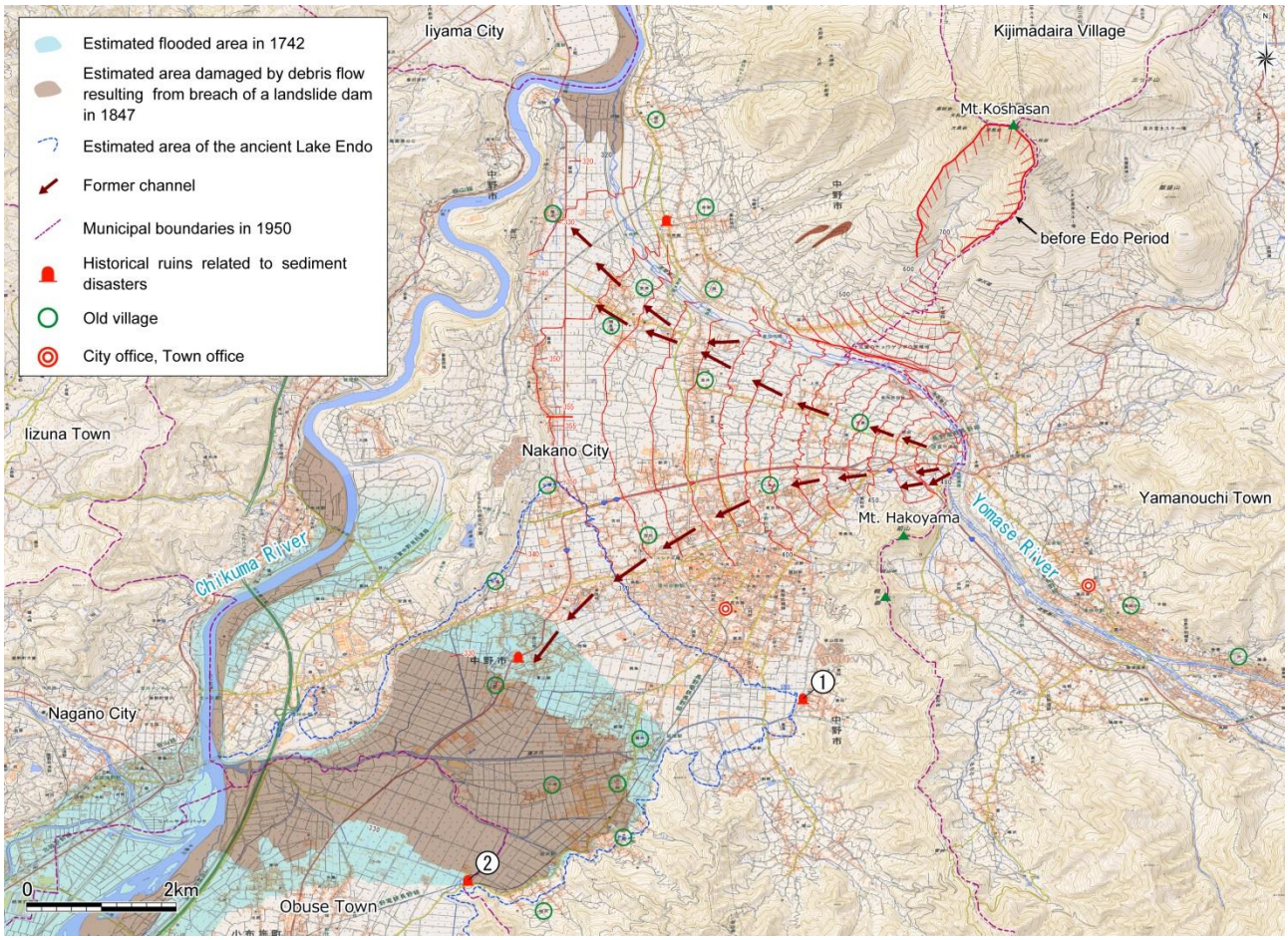

Fig. 4 Damage map of the alluvial fan of the Yomase River

Fig. 5 Boat-mooring stones in the compound of Takaifunatsuki Shrine (Fig. 4, Historical ruins related to sediment disasters ①)

Fig. 6 Remnants of a boat-mooring stone of Sakurasawa (Fig. 4, Historical ruins related to sediment disasters ②)

Fig. 7 Part of the Shinshu Earthquake Illustration (illustration of the Zenkoji Earthquake in 1847) (stored at the Sanada Treasures Museum)

5. HISTORY OF SEDIMENT DISASTERS AND THE SABO PROJECTS

The Nagano prefectural government started sabo work for the Asa River, Ushibuse River, and Hoshina River when the Sabo Act was promulgated in 1897, and started a sabo project in the upstream reach of the Yokoyu River, a right tributary of the Yomase River, in 1906. **Fig. 8** is a 1908 map of the sabo facility construction locations in the Yokoyu River stored in the Nagano Prefectural Museum of History. It was found that many sabo works were planned and constructed near the bottom of the Ochiai Landslide area (the Birikuso area) near the confluence of Ryuozawa on the right bank of the Yokoyu River. In those days, major works included dry masonry dams, diversion canal works, and sodding works. However, a serious sediment disaster occurred in August 1910, and the majority of the sabo facilities constructed were destroyed and washed away. Almost none survived until today. While some facilities under planning can be seen in **Fig. 8**, this diagram is very valuable as a layout map of sabo facilities constructed from 1906 to 1910.

In the 5th Book of the History of Nagano Prefecture (1915), it is recorded that sabo facilities constructed between 1906 and 1910 were seriously destroyed by a flood disaster in 1910, and since the damage was so serious that it was judged impossible to reconstruct them, it was decided that those facilities be put to disuse. Hence, the sabo project was aborted in October 1910.

However, partially due to the strong petition from affected local residents, the Home Ministry started a sabo project, as a national project, in the upstream reach of the Shinano River in 1918, and the Yokoyu River was included in the project area. The facilities were constructed directly by the Hirao Sabo Factory of the Niigata Civil Engineering Branch Office until 1933, and 65 sabo facilities were constructed for the Yokoyu River. Many of them still remain extant. The field survey discovered some of those facilities including wet masonry dams.

In 1932, a public works project for rural promotion was planned. The authority of this project was transferred from the Home Ministry to Nagano Prefecture, and the sabo works project was then started as prefectural public works.

In 1964, the Jigokudani Yaen-Koen Monkey Park opened. International fame followed, and many tourists came to visit the valley of the Yokoyu River.

After a disaster in 1990, the Ochiai area was designated as a landslide prevention area, and full-scale landslide control works started.

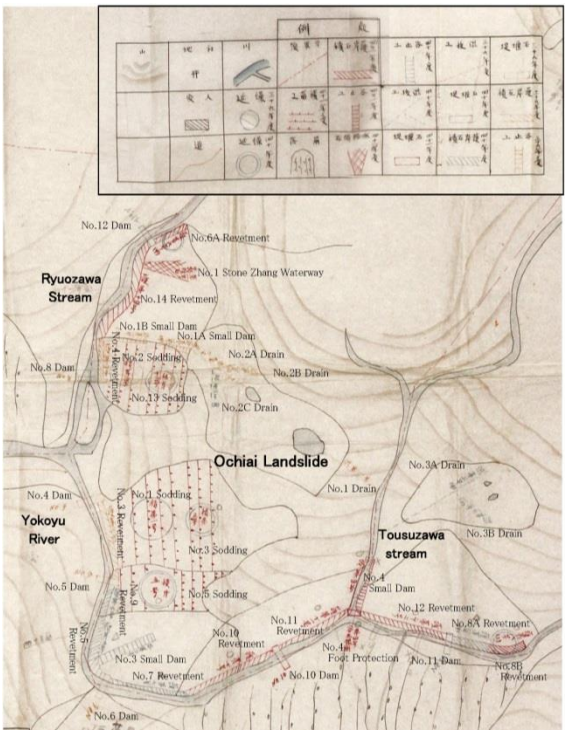

Fig. 8 A sketch of the sabo facility locations in the Yokoyu River in 1908
(stored in the Nagano Prefectural Museum of History)

6. DEVELOPMENT OF THE HONAMI HOT SPRING TOWN AND THE DISASTER IN 1950

According to the Publication Society of Yamanouchi Town History (1973), the Honami area located on the opposite side of Yudanaka Hot Spring was devastated and denuded by a flood in 1898 and had remained barren land for a long time. In 1925, a hot spring was found by drilling at Honami, and channel works were developed for the Yomase River, which led to Honami's establishment and prosperity as a hot spring community.

A torrential rainfall in August 1950 caused a flash flood and burst the dike on the left bank of the Kakuma River. Debris entered into the Honami Hot Spring, killing six people and destroying many buildings and cultivated land (**Fig. 9** to **13**).

In response to this damage, many channel works were constructed centering on the area near the confluence of the Yokoyu River and Kakuma River, and Honami Hot Spring Town was restored.

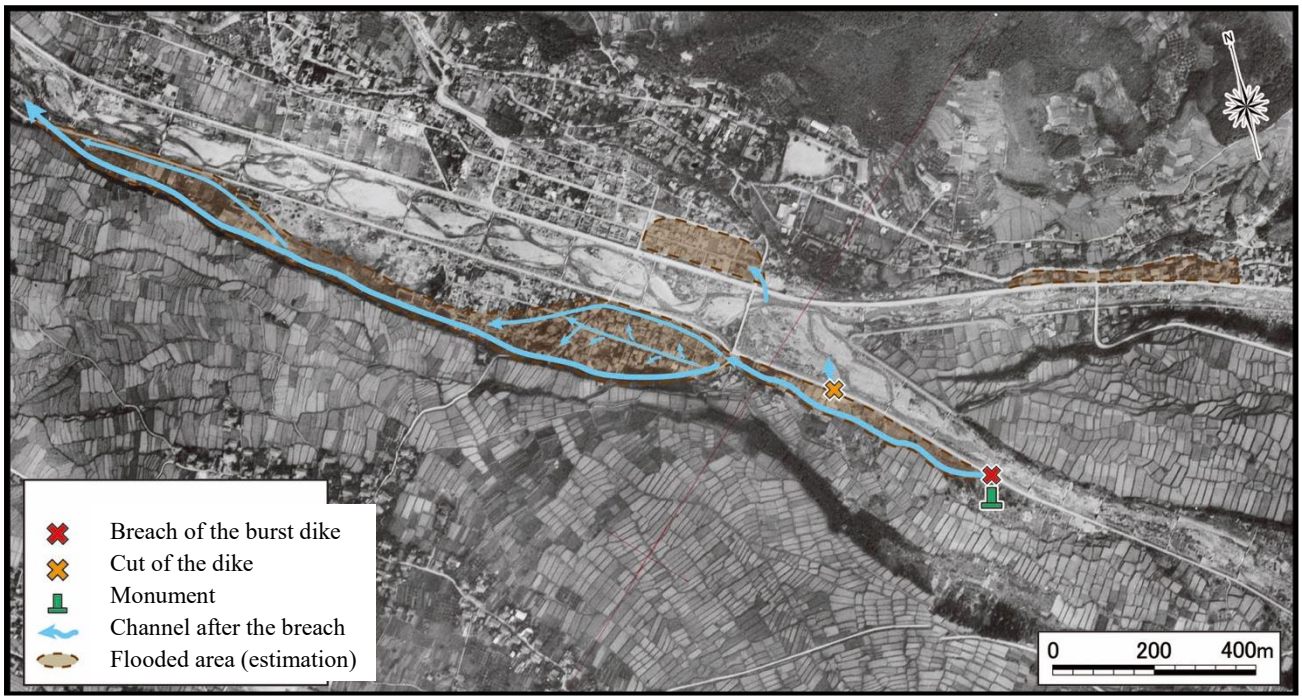

Fig. 9 Status of damage in 1950 (aerial photo taken by the US Forces in 1947)

Fig. 10 Status of disaster

Fig. 11 Status of disaster

Fig. 12 Dike breach

Fig. 13 Monument at the former site of the Honami Hot Spring flood damage

7. DISCUSSION

It is understood that the first use of concrete in the construction of sabo dams was the Ashiyasu Sabo Dam in the Midai River in Yamanashi Prefecture. This dam was started construction in 1916. It is reasonable to believe that when concrete came to be used as a construction material, it had a major effect on the sediment control works for the Yomase River, where sabo facilities had been often washed away by floods. One of major causes of sabo dam destruction is the scouring of the foundation. Considering the fact that scouring is more likely to be caused by flooding in a river with wide catchment area and a greater bed slope, the locations of well-known historical sabo facilities (excluding stepped dams), including those of the Yomase River, are analyzed with the catchment area and bed slope as indicators (**Fig. 14**).

The No. 34 and No. 28 Sabo Dams, constructed as a direct project of the national government, were constructed as wet masonry dams at locations where dry masonry sabo dams had been constructed in the Meiji Period. These two dams still remain today (**Fig. 15** and **16**).

The analysis revealed that more dry masonry sabo dams are located in zones where the river catchment area is smaller and the bed slope is softer compared with wet masonry sabo dams. Sabo dams, which were originally built as dry masonry dams but replaced by wet masonry dams, are located between dry masonry zones and wet masonry zones.

This research includes reorganization of data from these viewpoints, for example, and it is expected to provide information useful in our review of the limit conditions related to the construction conditions of dry masonry dams used from when they were constructed and our discussion on future preservation planning.

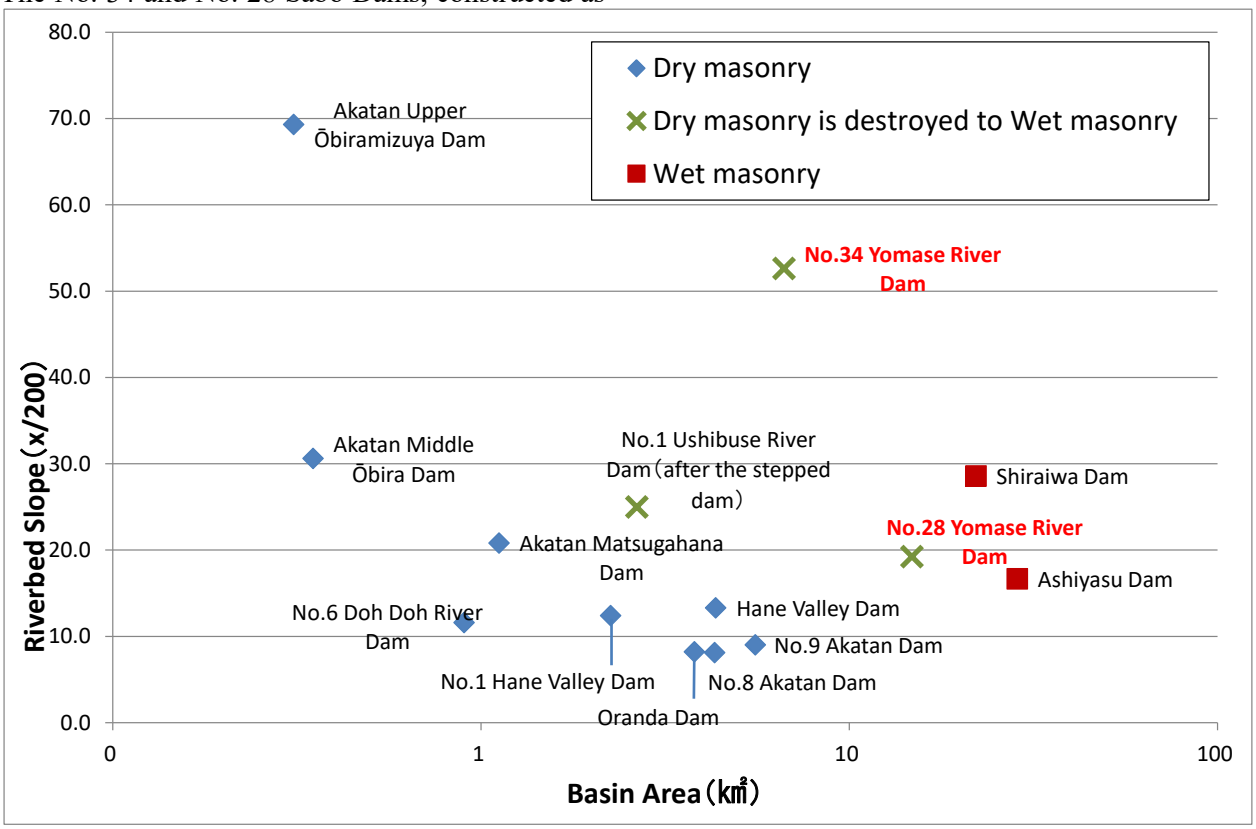

Fig. 14 The relationship among historical sabo dams, basin areas, and riverbed slopes

Fig. 15 No. 28 Sabo Dam of the Yomase River (constructed in 1924)

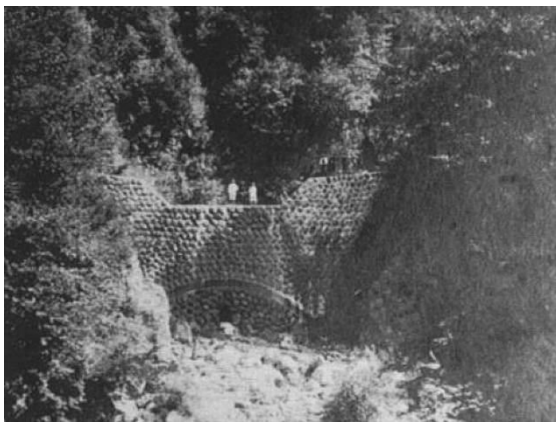

Fig. 16 No. 34 Sabo Dam of the Yomase River (constructed in 1923)

8. CONCLUSIONS

Our research provided valuable data that helps us to understand the development of sediment control and landslide control measures for the Yomase River. **Fig. 8** contains very valuable information on the layout of sabo facilities constructed at the end of the Meiji Period. It also provided us with the knowledge useful in reviewing the limit conditions about the then construction conditions of dry masonry dams and future preservation.

Many sabo dams were constructed in the Yokoyu River and Kakuma River basins even after the end of World War II. In addition, many channel works have also been constructed in the Yokoyu, Kakuma, and Yomase Rivers, which ensures greater safety for hot spring resorts.

Full-scale research and control work started in the Ochiai landslide prevention area in 1978. Many collection wells and drainage tunnels were constructed up until 2016, and it is understood that these facilities control landslide anomalies.

However, some measuring devices have indicated changes in the snow-melting period of 2017. In response, we intend to conduct a field survey again to check landslide anomaly points and reconsider the landslide occurrence mechanism in conjunction with the topographic and geologic conditions of the area.

The year 2018 will mark the 100th anniversary of the start of sediment control works for the sabo project for the Yomase River, as a direct project of the central government.

The authors intend to construct new sabo dams, improve existing sabo dams (including raising of the height of the dams), and repair existing sabo dams to prevent the degradation or deterioration of their functions or performance and further ensure the safety of the downstream reaches, including reinforcement of measures against woody debris. Since it is feared that awareness of disaster management has diminished because a few decades have passed without a major sediment disaster, the authors intend to put in order the records of past sediment disasters and sabo and landslide prevention projects conducted in the catchment area of the Yomase River and think up effective measures to encourage local residents to reacquaint themselves with the danger of sediment disasters and improve their sense of disaster preparedness.

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