Management against Sediment Disasters in the Imogawa-River Basin Caused by the Mid Niigata Prefecture Earthquake in 2004, Japan

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Abstract

This report describes various management operations by the central government against sediment disasters caused by the Mid Niigata Prefecture Earthquake on October 23, 2004. The operations include installation of emergency and permanent measures for stabilization of the landslide dam at Higashi-Takezawa district and also policy making of sabo (erosion and sediment control) master plan for the Imogawa-River basin. The earthquake caused many collapses and landslides in the Imogawa-River basin. The landslide that occurred at Higashi-Takezawa district formed the landslide dam whose height reached as high as 30m. The water level could become high enough for overtopping and successive collapse of its blockage. Therefore, sabo works by the central government were operated in order to plan emergency countermeasures and to implement them. Yuzawa Sabo Office, Ministry of Land, Infrastructure and Transport was directly responsible for these emergency actions. The emergency actions included pumping out water from the reservoir to reduce the water level so that the landslide dam could be kept undestroyed and constructing temporary drainage channel preparing for the coming snow melting and rainy season. These emergency measures could ensure the safety of the downward area.The local headquarter established in the Yuzawa Sabo Office kept monitoring the changing conditions in the area and further planned and performed preventive and recovery actions with consulting the expert meeting. In addition, an advisory committee on landslide dams in the Imogawa-River basin and ad hoc meeting for mitigation of successive disasters were established in order to discuss about emergency and permanent measures for stabilization of landslide dams and also sabo master plan for the Imogawa-River basin. Most of past large earthquakes caused serious sediment disasters. A large number of cracks, gaps and/or loosening of grounds were caused by the large earthquakes. Therefore, during the period of snow melting and rainy season in 2004/2005, aerial (by helicopter) and terrestrial patrolling were performed. As a result of patrolling, no significant new collapses that could possibly affect the downstream area were found.

However, considering that the area was subjected to the heaviest rainfall corresponding to the maximum daily rainfall record of the area in the rainy season in 2005 and heavy snowfall as well, the monitoring activities should be continued. It is necessary to evaluate sediment production and discharge in and from the Imogawa-River basin at the earliest opportunity for the soonest recovery of the target area.

Keywords: earthquake, collapse, landslide, landslide dam, emergency action, permanent measure, sabo master plan, Imogawa

1. Introduction

At 17:56 on October 23, 2004, an earthquake with a magnitude of 6.8 occurred in the Mid Niigata Prefecture on the northeastern part of Japan. In Kawaguchi Town close to the hypocenter, a seismic intensity of 7 (by JMA scale: Japan Meteorological Agency) was recorded for the first time since the beginning of its recording using a seismometer. Strong aftershocks followed one after another, for example, a seismic intensity of 6 was recorded four times. Due to this earthquake, a large number of collapses and landslides were caused around the Mid Niigata Prefecture. In particular, in the Imogawa-River basin, which is located close to the hypocenter, a large volume of sediment produced by those collapses and landslides accumulated in the river courses and blocked them seriously. As a result tremendous damage was caused in the entire basin area, such

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Table 1. Seismic intensity recorded due to the Mid Niigata Prefecture Earthquake (press release by JMA, as of 2004.12.28)

Date	Time	Maximum Seismic Intensity
Oct.23	17:56	7
	17:59	5 upper
	18:03	5 upper
	18:07	5 upper
	18:11	6 upper
	18:34	6 upper
	18:36	5 lower
	18:57	5 upper
	19:36	5 lower
	19:45	6 lower
	19:48	5 lower
Oct.24	14:21	5 upper
Oct.25	0:28	5 lower
	6:04	5 upper
	10:40	6 lower
	8:57	5 upper
	11:15	5 upper
	3:43	5 lower
	18:30	5 lower

as disruption of roads and inundation of houses due to dammed up water courses. A total of 1,419 collapses and 75 landslides were caused in the Imogawa-River basin because of this earthquake. Responding to the occurrence of so many collapses and landslides, the Yuzawa Sabo Office of the Hokuriku Regional Development Bureau, the Ministry of Land, Infrastructure and Transport (MLIT) immediately arranged preparation for the emergency operations. Aerial (by helicopter) and terrestrial patrolling were carried out and provided firsthand information to the Niigata Prefecture Government and other organizations. On October 24, the day after the major earthquake, a helicopter patrolling confirmed that numerous large-scale landslide dams were formed in the Imogawa-River basin. Among others, a landslide dam formed at the Higashi-Takesawa district was particularly serious, with the blockage height as high as 30m. The water level in the upstream area rose significantly and threat of overflowing and successive collapse of the landslide dam was imminent. Therefore, emergency actions were needed. It was decided that the Central Government should undertake emergency actions, and the Yuzawa Sabo Office was assigned its front-line responsibility. This report describes emergency actions to the landslide dam that formed at the Higashi-Takesawa district due to a landslide triggered by the earthquake. It also describes the plan of permanent measures for the stabilization of the landslide dams as well as a basic policy on the sabo master plan of the entire Imogawa-River basin which was discussed by the "Advisory committee on landslide dams in the Imogawa-River basin". The committee was comprised of academics and practical experts. In addition, the results of surveys conducted during snow melting and rainy seasons in 2004/2005 are reported.

2. Overview of the Imogawa-River basin

The Imogawa-River basin is located in the Mid Niigata Prefecture. It is a river with a drainage area of 38.4km^2, a channel length of 17.2km, and an average bed slope of 1/70. It is a right tributary of the Uonogawa-River of the Shinanogawa-River drainage system. It originates around Mt. Sarukuradake (679m asl) and joins with the Uonogawa-River after flowing down from north to south. In the Imogawa-River basin, formations of the Pliocene Epoch of the Tertiary Period to the Pleistocene Epoch of the Quaternary Period are distributed. Those formations are mainly composed of sedimentary rocks, such as mudstone, alternation of sandstone and mudstone, and sandstone. Those formations are distributed in the north-northeast to south-southwest direction, and are associated with several fold axes. The fold axes are named; Mt. Konpira syncline, Toge anticline, Kajigane syncline, and Matsukura anticline, in order from west to east. The interval between those fold axes is about 1 km.[1),2)]

Cracks tend to be caused in the formations around the fold axes because of tectonic movements. The geology along the Imogawa-River basin consists of relatively new and fragile sedimentary rocks of the Neogene

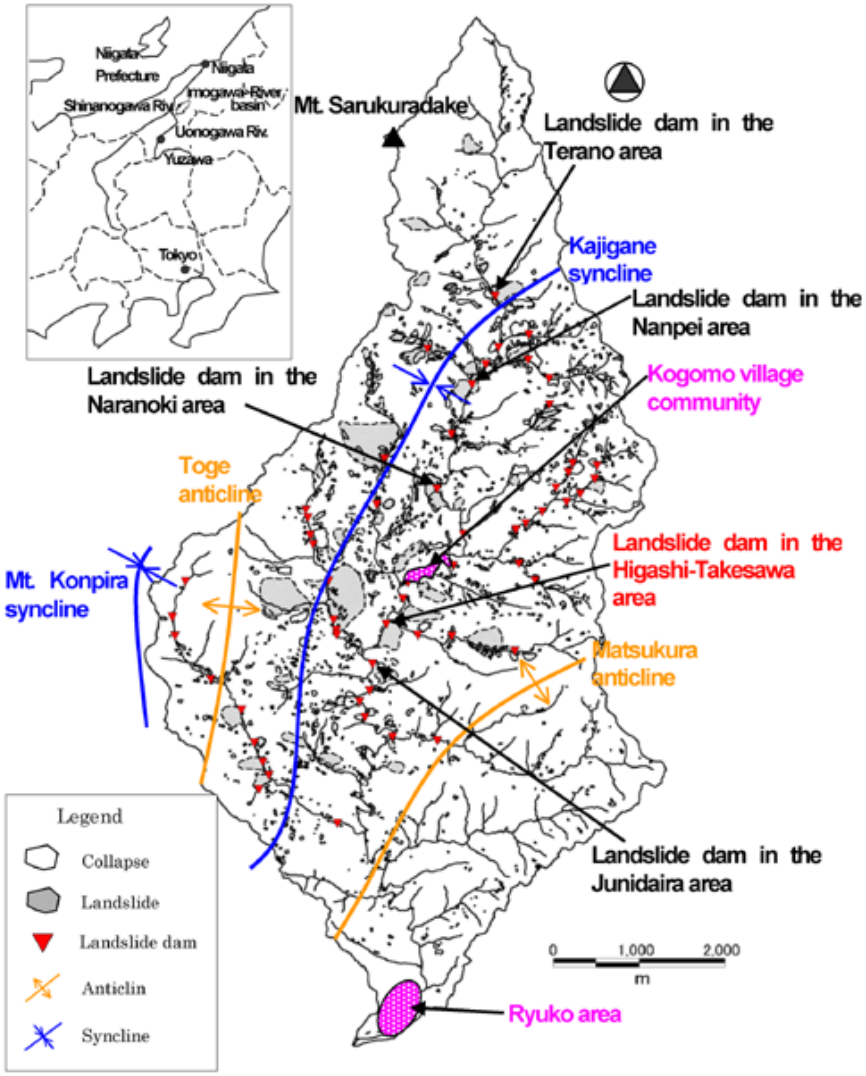

Fig. 1. Collapses, Landslides, and Landslide dams in the Imogawa-River basin caused by the Mid Niigata Prefecture Earthquake

Period or later. These sedimentary rocks are weak because of weathering and easily become clayey under the influence of groundwater and other factors. Therefore, combined with the cracks in the formations, this area is known as the one of the major landslide prone areas in Japan. Most of collapses and landslides triggered by this earthquake occurred in the areas located between the Kajigane syncline which runs north to south in the center of the basin and the Toge and Matsukura anticlines which lie on the east and west of the Kajigane syncline. An enormous amount of sediment produced by those collapses and landslides accumulated in the river course and formed landslide dams at 55 places in the Imogawa-River basin. Five of them formed along the main stream of the Imogawa-River basin (in areas of Terano, Nanpei, Naranoki, Higashi-Takesawa, and Junidaira) possess particularly large volumes.

3. Emergency actions for the landslide dam at Higashi — Takesawa district

Landslide dam at the Higashi-Takesawa district was formed by the sediment of a landslide. Water level raised and increased soon after the blockage of the river course. Inundation damage was caused to the Kogomo village community in the former Yamakoshi Village. Because water level in the upstream area has risen significantly, there was a danger of overflowing as well as the collapse of the landslide dam. In the event of an overflowing, the Ryuko district in the downstream area might be in danger of serious damage by flood or debris flows.

The Niigata Prefecture Government started emergency actions. However, the prefecture did not have

appropriate data for coping with such a large-scale landslide dam. Therefore, by the request of the prefecture governor, emergency actions began to be undertaken by the central government from November 5. The Yuzawa Sabo Office was assigned to supervise this work. At that date time, the water level in the upstream area has risen up to 6 m below the level of danger of overflowing（161m asl）.

3.1. Conditions and objectives of emergency actions

In implementing emergency actions for the landslide dam at the Higashi-Takesawa district, there were problems and requirements. Emergency actions had to be completed before snow season because the snow layer amounted to about 3m in depth.
[Conditions]

1. Roads to the working site were severely disrupted by the earthquake and it was difficult to transport construction equipment and materials for emergency actions.
2. The water level on the upstream side of the landslide dam rose day after day and it was necessary to lower the water level as soon as possible.
3. It was necessary to secure a safe discharge of snowmelt water in the snow-melting season.

To fulfill these requirements, the objectives of emergency actions were set as follows.
[Concrete objectives]

1. To transport equipment and materials for emergency actions by helicopter, and to construct a road for carry heavy machinery by land.
2. To reduce water level by constructing an emergency pumping drainage.
3. To secure a flow cross-section for the safe discharge of snowmelt water by constructing a temporary drainage channel.

3.2. Implementation system of emergency actions

To implement emergency actions responding to the continuously changing situations on the site, the Local Headquarters for Emergency actions for landslide dams at the Imogawa-River basin (Head: Director of Land Conservation Division, Sabo Department of MLIT) was established at the Yuzawa Sabo Office. The local headquarters was operated until December 28 when the construction of the temporary diversion channel at the Higashi-Takesawa district for discharging snowmelt water was completed. During that period, countermeasures were planned and implemented with the participation of over 400 officials (man-days), including those from the Sabo Department of the River Bureau of MLIT, the River Department of the Hokuriku Regional Development Bureau, and its local offices, as well as with the support from academic and practical experts of the Niigata University and the National Institute for Land and Infrastructure Development, etc.

3.3. Emergency actions for the landslide dam at the Higashi-Takesawa district

3.3.1. Conditions of the landslide dam

The landslide dam at the Higashi-Takesawa district was formed as a result of landslide (350 m long, 295 m wide, and 30 m deep (estimated value)) that occurred on the left bank slope of the Imogawa-River basin. The amount of the original landslide movement at the upper part of the slope was about 70 m. The end of the landslide mass blocked the Imogawa-River and reached to the National Road 291 running parallel to the river. The sediment volume that blocked the river course was 655,940 m^3 and the maximum dammed up water volume was 2,560,500 m^3 , at the highest water level.

Based on the results of site reconnaissance, it was judged that the sliding soil mass itself was stable, and that the possibility of its collapse due to water pressure was slight, because the length of the blockage was large enough compared with the water depth. However, as the water level continued to rise day after day, drainage of dammed up water was urgently needed to prevent the collapse of the blockage due to overflowing.

3.3.2. Emergency actions for the landslide dam

At the Higashi-Takesawa district, the emergency actions were undertaken while continuous monitoring of the landslide on the left bank side was carried out. In implementing emergency actions, helicopters were utilized to transport the necessary construction materials to the working site, and an access road was constructed

Photo. 1. Landslide dam in the Higashi-Takesawa area

to bring in heavy machinery by land. A crossing-road and a floating walkway were also installed over the water dammed up area .

1. Construction of emergency pumping drainage

   To prevent overflowing, an emergency pumping drainage (L=102m) was excavated at the landslide dam location. Then, a total of 12 pumps with a maximum drainage capacity of 0.5 m^3/s were installed on the upstream side and operated for 24 hours a day. Also, large-sized sandbags (1t / a bag) were piled up at the lower part of landslide soil mass to form an earth embankment. However, the water level continued to rise and the ground around the outlet of the pumping drainage eroded rapidly. Hence, it was decided to change the pumping drainage course to an erosion-resistant area outside the accumulated sediment, and it was moved to the area of the former Higashi-Takesawa Elementary School.

2. Installation of temporary drainage conduit

   To reduce the water level on the upstream side before starting excavation of the temporary drainage channel, a temporary drainage conduit was installed (high density polyethylene pipe: D=1.0m×5 lines, L=250m) by placing an inlet at the point with 155m asl. By this installation, the water above the inlet level at 155m asl high became possible to flow down up to the full-pipe flow capacity (10 m^3/s) even without pumps, which resulted in a considerable reduction of the water level.

3. Construction of temporary drainage channel

   To safely discharge snowmelt water, a temporary drainage channel was constructed (L = 280 m). Considering the stability of the landslide during and after the construction as well as the construction feasibility before the snow season begins, it was determined to place the starting point of a temporary drainage channel at 149.5m asl.

   Because concrete-mixing trucks could not arrive at the working site due to road disruptions, the temporary drainage channel was constructed by the shotcrete spraying work ($t = 20cm$) to the graded river course section. To prevent erosion, protective blocks were placed at the outlet of the channel by carrying them to the site by helicopter. As the largest possible channel size was excavated in the range not damaging the stability of the landslide, a flow cross-section that could drain 240 m3/s of water resulting from rainfall with a recurrence interval of 100 years was successfully secured.

   Before starting construction of a temporary drainage channel, earth removal work was carried out at the head of the landslide to prevent reduction of its stability, because a considerable amount of soil was to be excavated at the low are of the landslide soil mass.

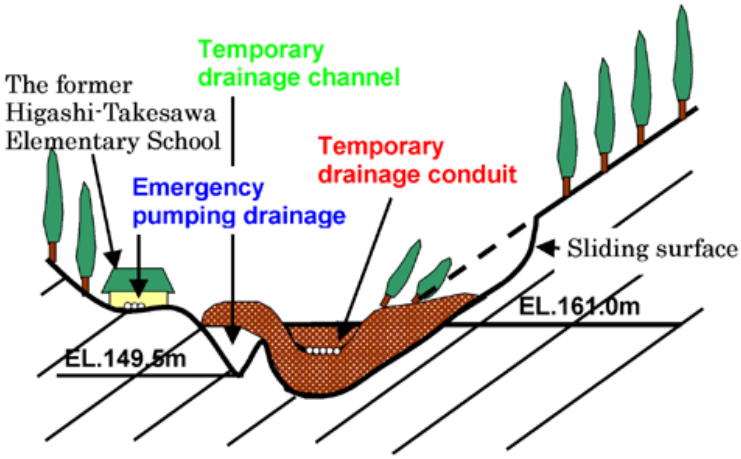

Fig. 2. Cross-section of the landslide dam in the Higashi-Takesawa area

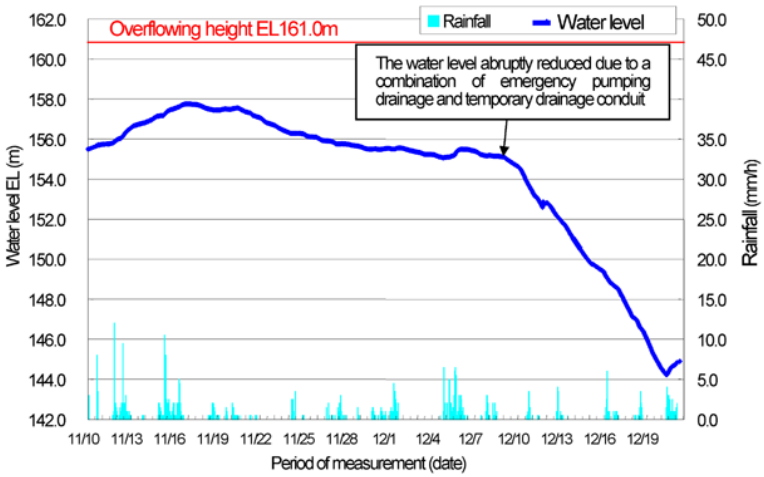

Fig. 3. Water level fluctuations at the landslide dam in the Higashi-Takesawa area. Both the water level and rainfall were measured at this location. Before the earthquake, the riverbed at this location was about 130 m asl.

4. Permanent measures for landslide dams and sabo master plan for the entire Imogawa-River basin

In the Imogawa-River basin, while taking emergency actions for the large-scale landslide dam at the Higashi-Takesawa district and other area, it was also necessary to implement permanent measures for other landslide dams. There was a danger that discharge of a large amount of unstable sediment over a long period might affect not only the Imogawa-River basin but also the Uonogawa River. Therefore, formulation of a sabo master plan that can adequately address these problems was urgently needed. Because these measures against landslide dam and a sabo master plan had to deal with rapid and serious devastation which was unprecedented in recent years, advanced technologies that could meet severe topographical, meteorological, and construction conditions were required. Therefore, to gain advice and suggestion from academics and experts, the Advisory committee on landslide dams at the Imogawa-River basin (Chairman: Prof. Hideaki Marui of Niigata University) was established. The meetings were held four times from November.17, 2004 to March.1, 2005. The committee deliberated on the direction of the permanent measures for the landslide dam at the Higashi-Takesawa district and other districts, as well as on the basic policy related to the sabo master plan of the entire Imogawa-River basin.

4.1. Permanent measures for landslide dams

4.1.1. Requirements of permanent measures

Permanent measures for landslide dams such as at the Higashi-Takesawa district were determined to be carried out as the measures concerning the unstable soil mass which blocked the river course and as the measures for the stabilization of the landslide on the left bank side which resulted in the blockage of river. To verify the safety of those measures, stability analysis was performed on the blockage of landslide dam (evaluation of stability in the river course direction) and the soil mass on slope (evaluation of stability in the direction perpendicular to the river course). Also, numerical analysis was performed on the possibility of piping at the landslide dam (possibility of erosion of the blockage) and its safety was verified. In implementing permanent measures for landslide dam such as at the Higashi-Takesawa district, the following two requirements had to be fulfilled.

1. To safely discharge water by the design rainfall specified in the sabo master plan (to prevent erosion of landslide dam due to overflowing).
2. To prevent the collapse of the landslide dam by the water pressure due to dammed up water in the upstream area, and to prevent flooding of water and sediment in the downstream area due to sediment discharge.

4.2. Permanent measures for landslide dam at the Higashi-Takesawa district

Concerning the landslide dam at the Higashi-Takesawa district, two measures were considered because the inundation damage reached the Kogomo village community in the upstream: one was to remove blockage to the depth of original riverbed; and the other was to consolidate the blockage keeping the present inlet height (EL: 149.5m) of the temporary drainage channel The original riverbed was 19.5m lower than the height of the temporary drainage channel. Therefore, if the blockage is consolidated at the present height, the construction cost is estimated to be 1.4 billion yen and 16 months construction period is needed. If the complete removal of blockage is operated, the construction cost is estimated to be 6.6 billion yen and 37 months construction period is needed, in addition to the need of removing 565,000 m3 of soils. Even though the landslide dam is completely removed and inundation in the Kogomo village is eliminated, it takes many years to ensure safety of the area. Therefore, in terms of promoting early return of evacuated villagers, a plan to consolidate the blockage at the present height and evacuated villagers would be transferred to safety area was recommended.

1. Prevention of erosion due to overflowing

Policy: To construct a channel to safely discharge water so that landslide dam will not be collapsed by the erosion due to overflowing.

Measures: Channel works（W = 2−14m, L = 230m, design discharge: 240m^3/s）

2. Prevention of collapse due to water pressure

Policy: To install sabo dams on the downstream of the blockage to prevent its movement due to water pressure and to retain it within the sedimentation area of those dams.

Measures: Construction of two sabo dams（H=14.5m, H=11.5m）.

4.3. Sabo master plan for the entire Imogawa-River basin

This advisory committee studied the possible sediment movements in the future based on the present conditions of the Imogawa-River basin, and recommended a sediment control policy for ensuring safety of local areas from sediment-related disasters caused by those phenomena.

4.3.1. Possible sediment movements and sediment disasters

Concerning possible sediment movements and sediment disasters in the Imogawa-River basin, this advisory committee predicted as follows:

1. Because a number of landslide dams caused by collapses and landslides exit in the river courses, flooding of water and sediment may occur as a result of sediment discharge due to erosion or collapse of those landslide dams.
2. Because a large amount of unstable sediment in the river basin may flow out constantly due to rainfall or snow melting, aggradations of the riverbed may be caused, resulting in flooding of water and sediment not only in the Imogawa-River basin but also in the lower reaches of Uonogawa-River.

3. It is highly likely that sediment disasters may be caused by the secondary erosion or secondary discharge of unstable sediment at collapses and the foot of landslides.
4. It is highly likely that debris flows will be triggered in case of tributaries having a steep riverbed.

4.4. Sediment control policy

To secure the safety of local areas against sediment movements and sediment-related disasters that may occur in the Imogawa-River basin in the future, the following sediment control policy was proposed.

1. To remove landslide dam or to control its discharge at landslide dam locations.
2. To control discharge of unstable sediment which is accumulated in the river course.
3. To control production of sediment at collapses and the foot of landslides (measures against the sediment production area).
4. To control occurrence of a debris flow and to entrap it's sediment in case of tributaries having a steep riverbed.

Based on this sabo master plan, the Yuzawa Sabo Office has been implementing necessary sabo works, according to the priority, at earthquake-damaged locations like a large-scale landslide dam, including the Higashi-Takesawa district where emergency countermeasures were undertaken, by maintaining coordination with a local reconstruction plan. Those sabo works are expected to complete until March, 2007 (Photo. 3).

5. Monitoring system and the results of survey in the snow melting and rainy season in 2004/2005

An enormous amount of unstable sediment and landslide dams still remain in the Imogawa-River basin. Also, geological defects such as cracks, lags, and looseness probably exist in the ground as a result of strong shaking of the earthquake. Because of these conditions, t is feared that, if some severe rainfall attacks, unstable sediment existing in the river course may flow out and new sediment may flow down from hillside slopes. To secure safety for the construction of sabo works in such dangerous conditions and to monitor sediment discharge to the downstream areas, aerial (helicopter) and terrestrial patrolling were performed in the snow melting and rainy season in 2004/2005. In particular, at the Higashi-Takesawa district, the landslide soil mass was monitored using a groundwater gauge, borehole inclinometer, and surface inclinometer installed on them, and the rainfall and water level in the reservoir areas were also gauged, in addition to the overall monitoring with the installation of monitor cameras. From this monitoring, no new collapses that might have a significant effect on the downstream areas were found. However, because of the potential of sediment production and sediment discharge is still high, monitoring has been continued to date. When a rain or an earthquake exceeding the standard occurs, the degree of sediment discharge and the conditions of sabo facilities are always checked. We are also considering to improve the monitoring system so that an immediate response could be undertaken in emergency situations.

5.1. Concluding remarks

This report described an overview of the sediment disasters, such as a large-scale landslide dam formed in the Imogawa-River basin by the Mid Niigata Prefecture Earthquake in 2004, together with the risk management response taken by the Central Government. A large amount of unstable sediment produced by collapses and landslides as well as landslide dams formed by displaced soil mass still remains in the river basin. This sediment may flow out over a long period due to snow melting or rainfall, causing effects on the main stream of the Uonogawa-River. What is needed hereafter is to carry out permanent measures for landslide dams in the Higashi-Takesawa area and other areas based on the suggestion by the Advisory committee and the results of survey. It is also needed to formulate a sabo master plan by reflecting the actual state of sediment movement after the earthquake, based on the basic policy proposed by the Advisory committee, and maintaining coordination with a local restoration plan. In addition, sabo works should be promoted in the entire Imogawa-River basin, together with the implementation of landslide prevention measures. The Yuzawa Sabo Office carried out aerial (helicopter) and terrestrial patrolling from the snow melting to rainy season in 2004/2005. We will continue to grasp the actual state of sediment production and sediment discharge through patrolling and monitoring of the Imogawa-River basin. Providing information to local people and implementing activities for early restorations of damaged areas by the earthquake are also important tasks.

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