1. OUTBURSTS OF LANDSLIDE DAMS AND THEIR PREVENTION

Takahisa Mizuyama[1] , Shigekiyo Tabata[2], Toshio Mori[2], Fumito Watanabe[3] and Kimio Inoue[4]

ABSTRACT

Landslides and debris flows due to heavy rains or earthquakes threaten to dam up rivers and create dam lakes. This phenomenon is called landslide dam. Landslide dams inundate upstream areas. When they break, large surges or debris flows are occasionally generated causing disasters. Outbursts of landslide dams that have occurred to-date were recently studied. Landslide dams break down mostly due to the overflowing of the dams after the landslide dam lakes have become filled with water. The dam's breaking is due to a gentle and gradual erosion by overflow rather than by abrupt overflow. The erosion mechanism by overflow was investigated through flume experiments and computer simulation. An empirical method was proposed to predict peak flood discharge when an outburst of a landslide dam occurs without any associate landslide. The procedures for the first survey prepared after a landslide dam are shown and emergency measures for the landslide dam are illustrated. The Tonbi-kuzure, a large scale landslide was triggered by an earthquake 140 years ago. The landslide dam and subsequent debris flow were reproduced by a computer simulation. Inundation by the debris flow in the Toyama alluvial fan was successfully simulated.

---

1 Professor, Division of Forest Science, Graduate School of Agriculture, Kyoto University Kyoto 606-8502, Japan (Tel.: +81-75-753-6087; Fax: +81-75-753-6088; email: Mizuyama@kais.kyoto-u.ac.jp)

2 Sabo Frontier Foundation, Sabo-kaikan, Hirakawa-cho 2-7-4, Chiyoda-ku, Tokyo 102-0093, Japan

3 Tateyama Sabo Office, Ministry of Land, Infrastructure and Transport, Japan (at present, stays in Indonesia as a JICA expert.)

4 Nippon Koei Corp. Ltd. Koji-machi 5-4, Chiyoda, Tokyo 102-8539, Japan

Key words: Landslide dam, peak discharge, countermeasures

INTRODUCTION

Large landslides or debris flows due to heavy rainfall, earthquake etc. block mountain rivers to form landslide dams. Dammed water inundate the upstream area and the downstream area is flooded by surges when the landslide dam breaks. These phenomena have not happened often, we can, however, find much supporting topographic evidences both inside and outside of Japan. Figure 1 shows one example. It resulted from a heavy rainfall in August 5, 1895, 4 years after Noubi earthquake of October 28, 1891. The magnitude of the earthquake was estimated M8.0. Many landslides occurred at the time of the earthquake and some landslides formed landslide dams. Although it is difficult to stop landslides and the formation of landslide dams, we do know about the formation of landslide dams and can predict their outbursts and flooding if the necessary information is available. This study first reviews past landslide dams and their related disasters. The characteristics of landslide dams are summarized. The peak flood discharge is predicted through flume experiments and related computer simulations. A flood is simulated assuming there is an outburst of the landslide dam. Finally, the procedures and methods for the simulation are shown to obtain information for mitigate a disaster.

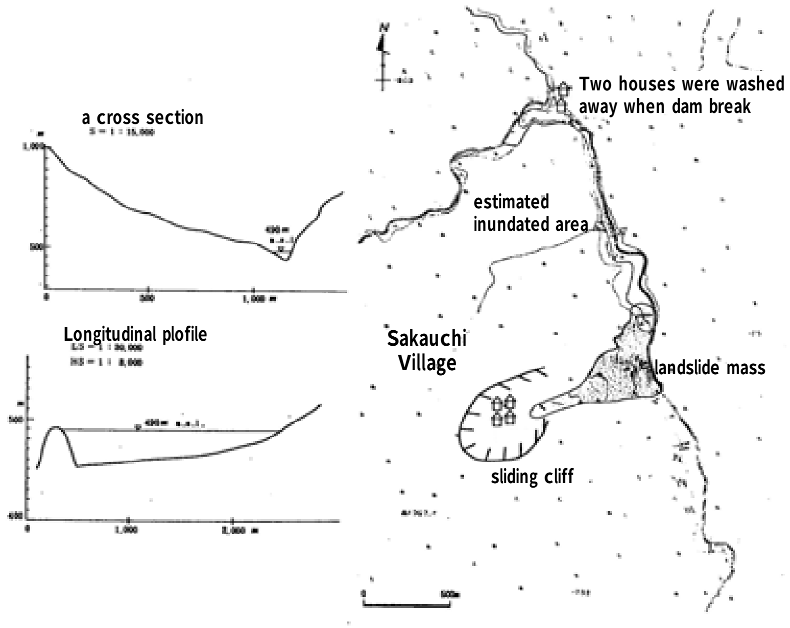

Fig1: Landslide and landslide dam at Nan-no Tani (valley) by Noubi earthquake of October 28, 1891.

CHRACTERISTICS OF LANDSLIDE DAMS

Schuster and Costa (1986) analyzed the cause of landslide dam breaks and found that most of the landslide dams were destroyed by overtopping. The survival times of landslides dams relate to the ratio of the dam capacity and the inflow discharge (Figure-2). It is the most important to judge when a high surge will occur when dam breaks. Figure-3 shows the percentage of the occurrences of high surges. The parameter, the Index for landslide dam break (Idb) explains the occurrences of high surges to some extent.

$$I_{db} = A \Big/ (HB)$$

where, A; drainage area (km^2), H; height of landslide dam (m) and B; length of landslide dam (m).

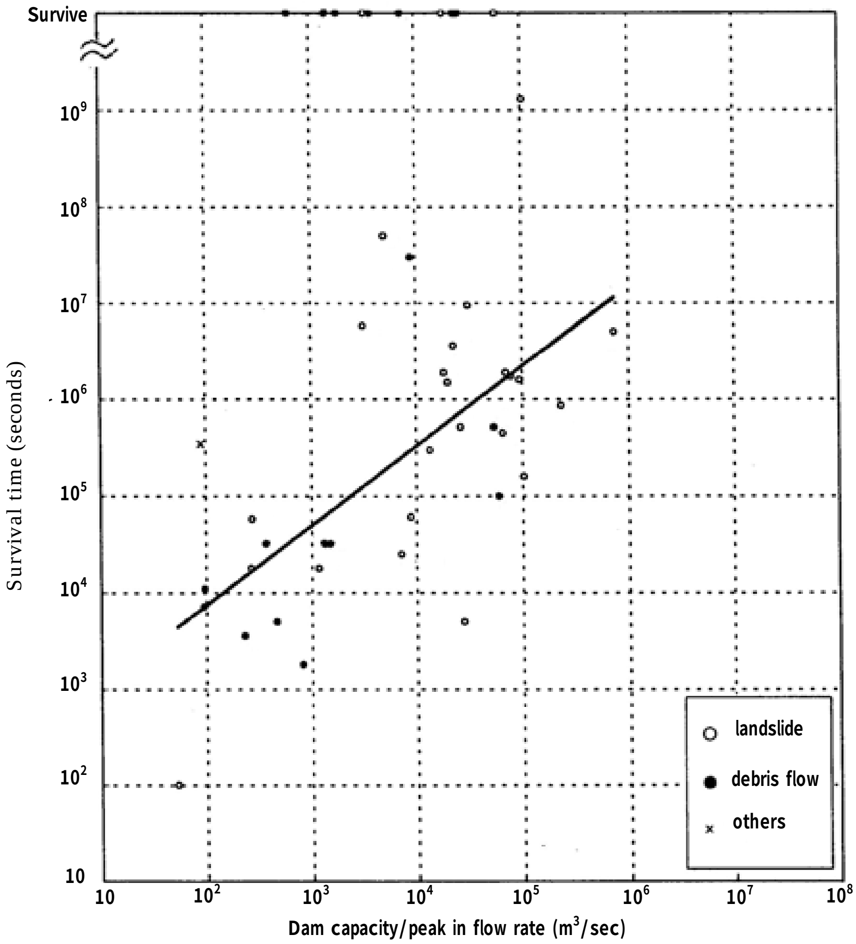

Fig2: Relationship between the ratio of landslide dam capacity to peak inflow rate of the 100-year flood and the survival time.

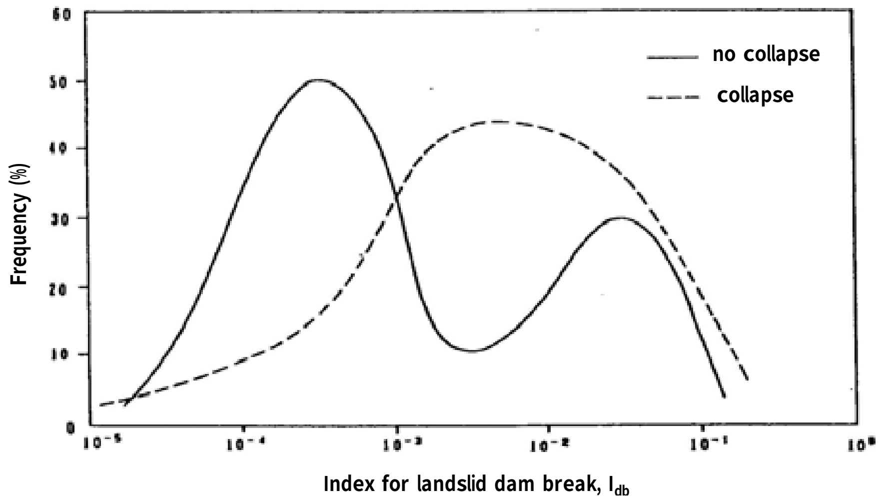

Fig3: Frequency of the occurrence of landslide dam collapse and not with the Index for landslide dam break (Idb).

DAM BREAK AND PEAK DISCHARGE

The processes of a dam breaking by overtopping erosion is illustrated in Figure 4. The flow on the downstream slope is debris flow. Erosion processes for non-cohesive material can be calculated. Dam material, however, is usually cohesive. Landslides could occur during the erosion process. At present these landslides are not being considered. Costa (1988) drew Figure 5 showing peak discharge rate of artificial dams, landslide dams and glacier dams, respectively. The calculated results for non-cohesive material and different torrent gradients are shown in Figure 6. An empirical equation used for predicting the peak discharge rate of the outburst of a landslide dam is as follows (Tabata et al., 2001),

$$y = 0.542\ x^{0.565}$$

$$x = \left(\sqrt{gh^3} \Big/ \tan\theta \Big/ q_{in} \right) \times 10^3 、\qquad y = q \Big/ q_{in}$$

where, q; peak discharge rate per unit width, q_{in}; inflow charge rate to the dam lake, g; gravitational acceleration, h; dam height, θ; torrent bed gradient.

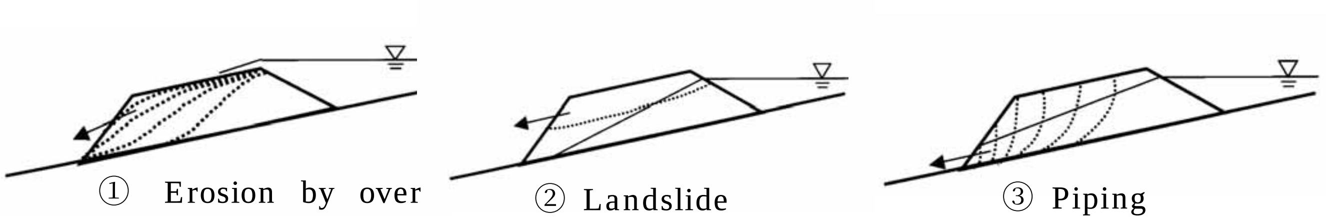

Fig4: Processes of a landslide dam breaking by overtopping erosion.

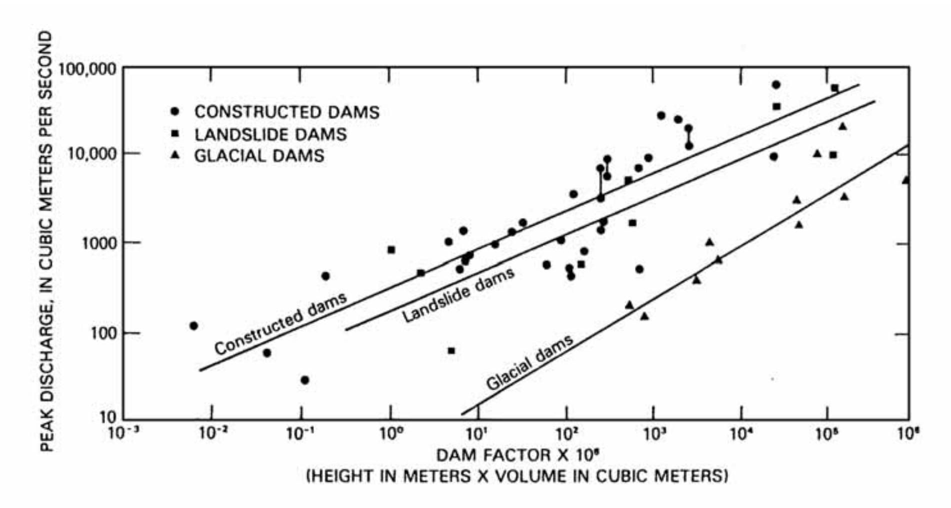

Fig5: Flood peak discharge versus dam factor (height x volume x 10^6) for constructed, landslide, and glacial dams (from Costa, 1985)

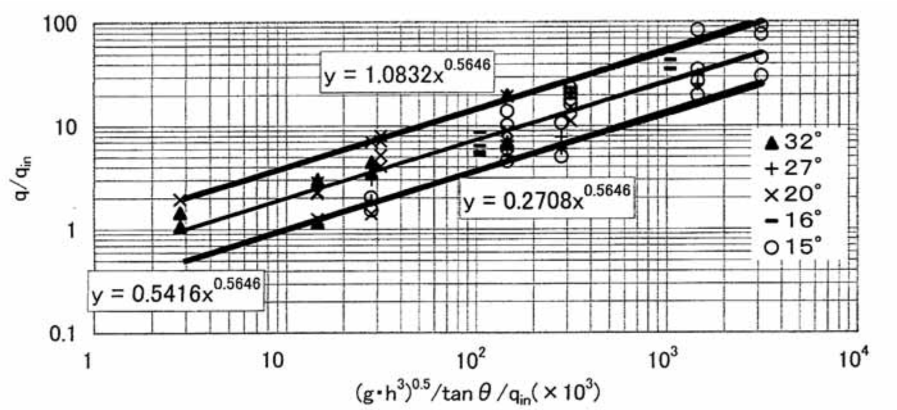

Fig6: A graph for empirical prediction of peak flow rate per unit width when landslide dams outburst.

REPRODUCTION OF THE OUTBURST OF LANDSLIDE DAM FLOOD AT MOUNT TATE-YAMA

The crater of Mount Tate-yama was collapsed by the Hietsu earthquake of (M7.0-7.1) in 1858. The collapsed mountain body blocked the Joganji River and formed landslide dams. These dams broke twice during heavy rainfalls in April and in June. The outbursts caused floods downstream in the Toyama plain as shown in Figure 7 (Ouchi et al., 1989). The floods in the Toyama plain are reproduced in Figure 8. Figure 9 is predicted flooding area when same dam outburst happens under the present series of sabo dams in place (Tabata et al., 2000).

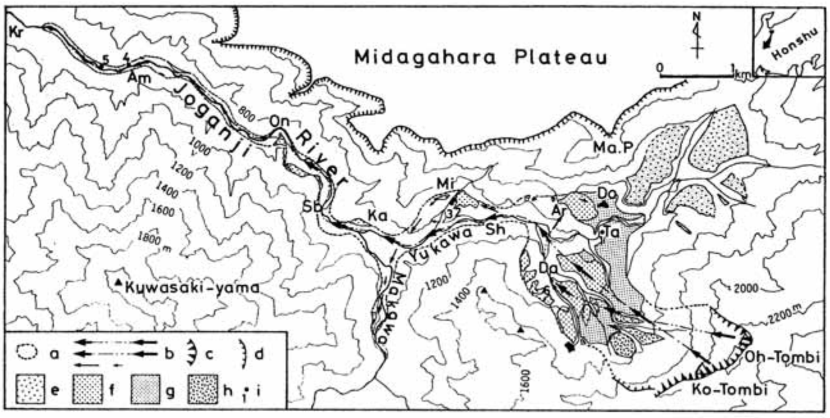

Fig7: Map showing the distribution of geomorphic surfaces and Tombi landslide debris in the study area.

a: Estimated extent of the Tombi debris avalanche. b: Estimated paths of the Tombi debris avalanche. Arrows indicate the movement of debris. Large arrows with dash-dotted lines indicate the estimated major courses of the debris avalanche, which are approximated by the combination of straight lines and circular arcs. The dash-one-dotted line indicates the estimated major path of debris from Ko(small)-Tombi to Karatani along the Yukawa-Joganji valley, and this is assumed to be the path of the Tombi landslide debris. The dash-two-dotted line shows th debris movement from Oh(large)-Tombi. c: Tombi landslide scarp. d: Other cliffs. e: Matsuo-daira and equivalent surfaces. f: Geomorphic surfaces formed by the Tombi landslide debris, including older depositional land surfaces which it covered. g: Geomorphic surfaces formed by Tombi landslide debris with apparent modification by later debris flows or flood flows. h: Bedrock hills or humps with relatively thin layers of landslide debris. i: Sampling points for C^{14} dating.

Da: Dashihara, Ta: Tateyama Hot Springs, Do: Dojou pond, Mi: Mizutani, Ka: Kamba-daira, Sb: Sabutani, On:Onigajou narrow, Am: Amadori, Kr: Karatani, Ma.P: Matsuo Pass, Ar: Arimine Nino-tani.

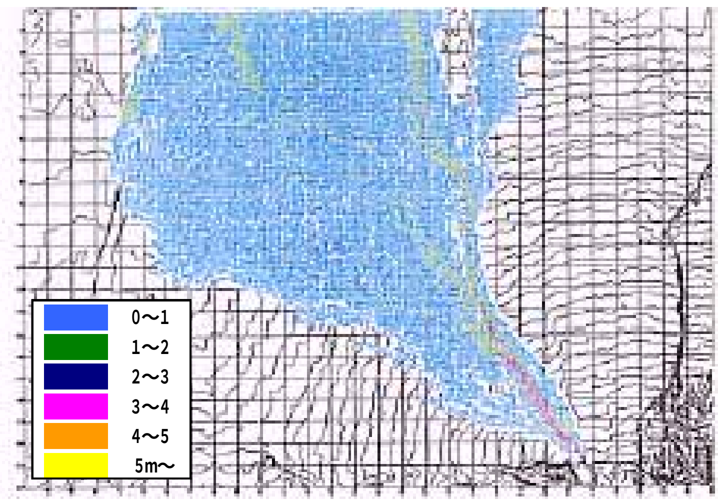

Fig8: Reproduction of the 1858 flood area on Toyama alluvial fan assuming no sabo facilitieas.

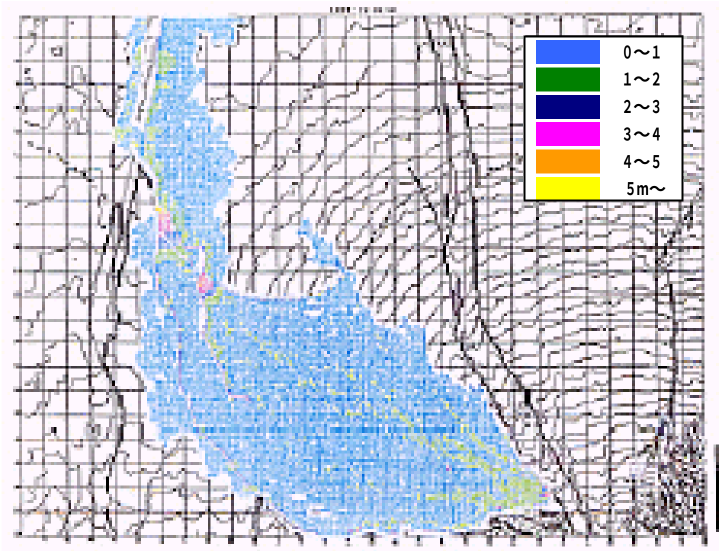

Fig9: Reproduction of the 1858 flood area on Toyama alluvial fan assuming present sabo facilitieas.

MEASURES FOR THE OCCURRENCE OF LANDSLIDE DAMS

After a heavy rainfall or strong earthquakes, the mountain areas should be immediately patrolled using a helicopter to see whether landslide dams were formed. If landslide dams are found, an urgent warning should be announced to those living downstream to evacuate to safety zones. Urgent and permanent measures for occurrences of landslide dams must be taken. The contents and procedures for the measures including survey are shown as a flow chart in Figure 10.

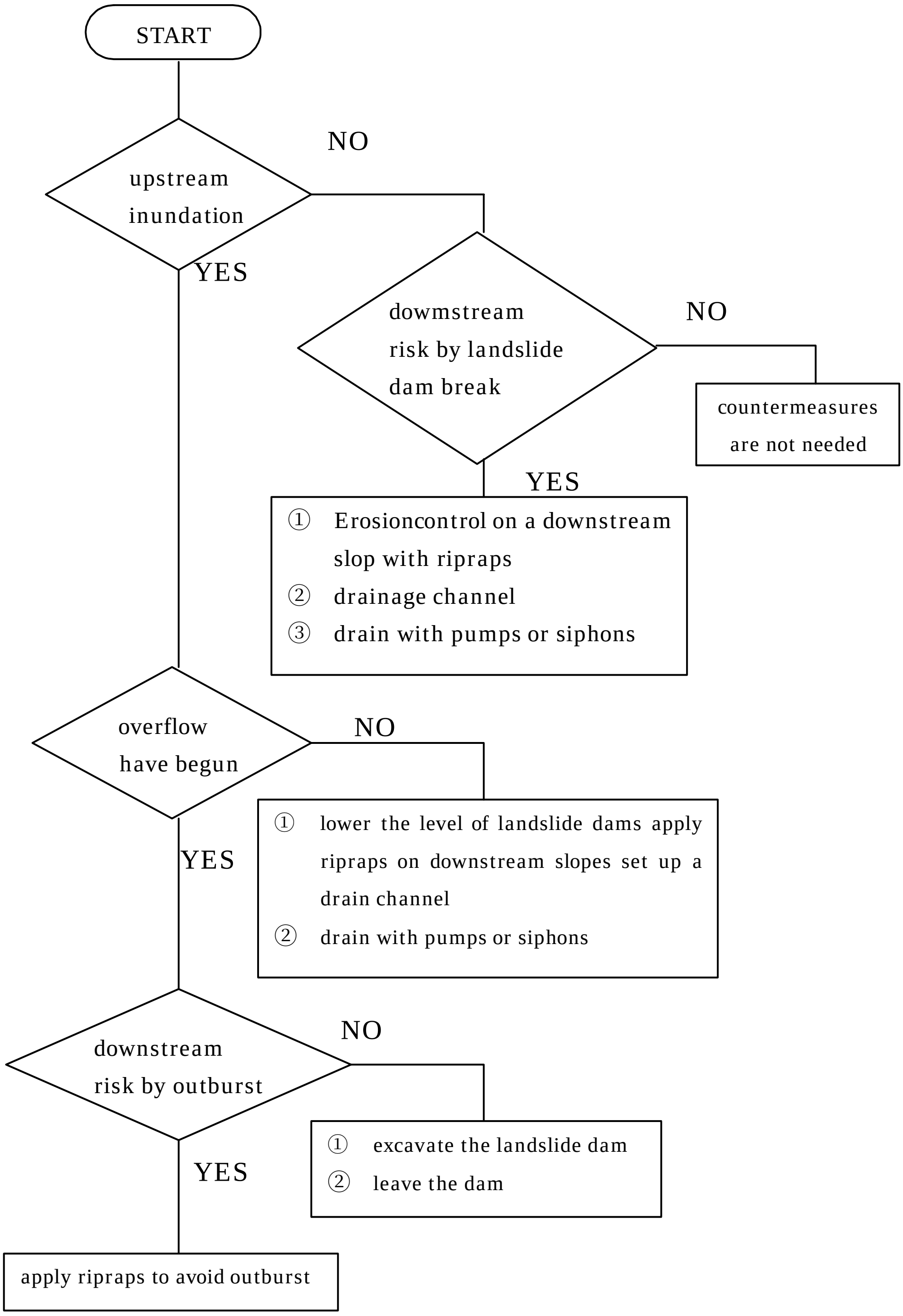

Fig10: Urgent countermeasures for landslide dams (MLIT, 1992)

AFTERWORDS

Although landslide dams do not form frequently, earthquakes or heavy rainfalls occur someday and cause landslides which may form landslide dams. Once landslide dams are formed, the dams outbursts can cause heavy damage. Therefore, appropriate counter measures must be taken quickly. Preparation for and drilling of countermeasures and evacuations should be conducted repeatedly. Methods for acquiring and transmitting related information will be improved further. Countermeasures themselves will also be improved. These developments should be adopted as countermeasure systems for landslide dams.

REFERENCES

Schuster, L. and Costa, E. (1986) A perspective on landslide dams, Landslide Dams, *Geotechnical Special Publication No.3, ASCE*, New York, 1-20

Costa, J. (1988) Flood from dam failures, *Flood Geomorphology*, 436-439

Ishikawa, Y., M. Irasawa and S.F.Kuang (1992) Study on prediction and countermeasures of flood disasters caused by landslide dam failure, *Jour. of Japan Society of Erosion Control engineering (JSECE)* 45-1, 14-23 (in Japanese)

Tabata, S., T. Ikeshima, K. Inoue and T. Mizuyama (2001) study on prediction of peak discharge in floods caused by landslide dam failure, *Jour. of JSECE* 54-4, 73-76 (in Japanese)

Tabata, S., T. Mizuyama, K. Inoue and M. Sugiyama (2000) Sediment movement caused from the Tombi landslide by the 1858 Hietsu earthquake (M7.0-7.1) in Central Japan, *Jour. of JSECE* 53-1, 59-70 (in Japanese)

Ouchi, S. and T. Mizuyama (1989) Volume and movement of Tombi Landslide in 1858, Japan, *Transactions Japan Geomorphological Union* 10-1, 27-51