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WARNING AND EVACUATION STANDARDS INFORMATIVE TO THE PUBLIC FOR THE PREVENTION OF SEDIMENT-RELATED DISASTERS

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ABSTRACT

An attempt to establish standard rainfalls as the criteria for judging disaster occurrence began in Japan in 1984, with an extensive effort to collect and analyze sediment disaster-related rainfall data across the country. Improved methods of standard rainfalls have been proposed in recent years. Those improvements include the revised concept of the working rainfall and the incorporation of a short-term rainfall forecast. To enable an effective function of warning system, it is important to communicate sediment-related disaster information, including the standard rainfalls, to the local people in a way practical to them. For that purpose, the authors proposed a method to prepare handy maps for disaster prevention in cooperation with local people, describing the locations and occurrence times of various phenomena and etc.. In this paper, an overview of the standard rainfall setting method is introduced, and the method of warning and evacuation-related information serviceable to the public which was proposed by the authors is presented. However, there are many problems to establish an efficient warning system against sediment-related disasters.

Keywords: sediment-related disasters, warning and evacuation measures, standard rainfalls for warning and evacuation

INTRODUCTION

The sediment-related disasters that occurred in Japan in recent years are shown in Fig. 1. As seen, a total of 1,629 sediment-related disasters occurred in 46 prefectures in Japan in 1998. It consists of 317 debris flows, 152 landslides, and 1,160 slope failures. The average number of sediment-related disasters in the past five years is 1,077 per year.

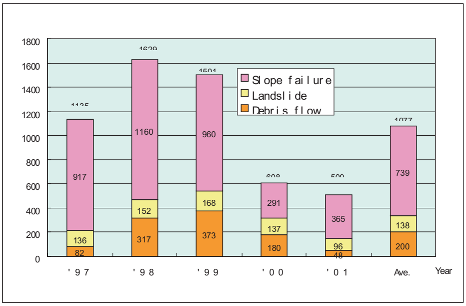

Fig.1 Recent occurrence of sediment-related disasters

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Responding to this seriousness, the Ministry of Land, Infrastructure and Transport and prefectural governments have been implementing various structural measures, such as installation of sabo works, to protect human lives from debris flows, landslides, and slope failures. However, because existing sediment-related disaster hazard areas are virtually countless and the number is further increasing with the changes in land use conditions, the installation ratio of structural works is still as low as approximately 20%. As a result, establishment of an effective warning and evacuation system has become a prime concern as the non-structural measures not relaying on structural works.
In the present paper, the outline of the standard rainfall setting method being studied as an effective measure for warning and evacuation against sediment-related disasters is introduced. Then, the method proposed by the authors as the means to publicize disaster-related information in a form serviceable to the public is explained. After that, examples of recent information systems being implemented by administrative organizations are presented, together with problems associating with disaster prevention.

1. OVERVIEW OF STANDARD RAINFALLS FOR WARNING AND EVACUATION

A number of studies have been carried out to derive the prediction method of sediment-related disasters using the rainfall as the index. In 1984, the Ministry of Construction (presently, the Ministry of Land, Infrastructure and Transport) presented the Guidelines for the Setting of Standard Rainfalls for Warning and Evacuation against Debris Flows (tentative). Today, using these guidelines as the basis and incorporating various modifications, prefectural governments and other organizations are trying to establish standard rainfalls for warning and evacuation. The setting method of standard rainfalls for warning and evacuation based on these guidelines is introduced below.

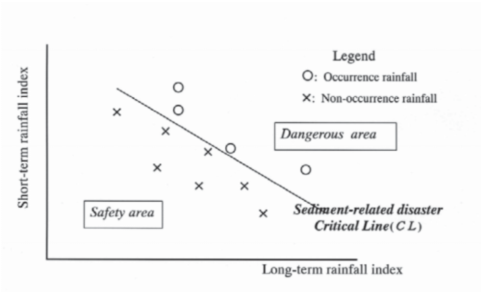


Fig.2 Concept of Sediment-related Critical Line

1.1 Outline of the setting method of standard rainfalls

As the basic units for the setting of standard rainfalls, areas are grouped by the similarities of field conditions susceptible to sediment-related disasters, such as topography, geology, and others. Then, standard rainfalls are set for each of those areas. The basic procedure is that the short-term rainfall index is placed in the ordinate and the long-term rainfall index in the abscissa in the X-Y graph. Various rainfalls in the past when sediment-related disasters occurred and did not occur are plotted in the graph and then a line that separates the occurrence rainfalls and the non-occurrence rainfalls is drawn, as shown in Fig. 2. This line is called the Critical Line (CL). When a rainfall that may reach the upper right side of the graph which is the dangerous area is forecasted, it is judged that there is a possibility of disaster occurrence. And, it is used as one of criteria for judging the need of warning and evacuation.

(1) Setting method presented in the Guidelines (tentative) issued by the Ministry of Construction (Guideline Method)
This is the standard rainfall setting method presented originally for debris flows by the Ministry

of Construction in 1984. In the latter half of the 1980s, the basic form of standard rainfalls began to be studied in most prefectures in the nation. In the Guidelines, two methods – method A and Method B – are described, and it is mentioned that when appropriate rainfall values are not obtainable with the use of Method A, Method B can be used as an alternative. The rainfall indexes used in Method A are as follows.

Long-term rainfall index: working rainfall
Short-term rainfall index: one-hour rainfall intensity
The definition of the working rainfall is as follows.

$$R_W = R_C + R_{WA}$$

where R_W: working rainfall, R_C: continuous rainfall (total rainfall of a series of rain having a non-precipitation period before and after of this rain), R_{WA}: antecedent working rainfall

$$R_{WA} = \sum_{t=1}^{14} \alpha_t \times Rdt$$

α_t : decrease coefficient, $\alpha_t = 0.5^{t/T}$

T : number of days of half-life (1 ~ 3 days)

t : number of days before the start of rain, Rdt : daily rainfall of t days before

The problem with this working rainfall definition is that a rainfall tends to exceed the established standard rainfalls in case of a long rain, because the working rainfall just continues to increase if a non-precipitation period of more than 24 hours does not exist.

(2) Setting method proposed by Yano (Yano Method)

To overcome the above mentioned problem of the Guideline Method, Yano proposed a method to set the standard rainfalls by altering the definition of the working rainfall. In his definition, the working rainfall is reduced to half by the unit of hours. In his method, the working rainfall is defined as follows.

The working rainfall: $\sum \alpha_t r_t$

where α_t : decrease coefficient, $\alpha_t = (0.5)^{t/T}$, t : hour,

T : half-life (usually 12 ~ 72 hours), r_t: hourly rainfall of t hour(s) ago

This method can be used even under a long rain because, unlike the Guideline method, the working rainfall does not just increase but decrease during the period of non-precipitation (or small-precipitation). It is also usable as a yardstick when considering the cancellation of warning and evacuation.

(3) Setting method proposed by the Committee for Comprehensive Sediment Control Measures (Proposal Method)

This is a method discussed at the Committee for Comprehensive Sediment Control Measures (chairman: Aritsune Takei, professor emeritus of Kyoto University) which was organized by the Ministry of Construction. It was formally proposed in 1993 as the “Setting Method of Standard Rainfalls for Warning and Evacuation against Collectively-occurring Steep Slope Failures (Tentative)”. This is called the Proposal Method.

As the rainfall indexes, the working rainfall with a half life of 1.5 hours is placed in the ordinate and the working rainfall with a half life of 72 hours is placed in the abscissa. The definition of the working rainfall is the same with that of Yano Method. In the Committee Method, the “collectively-occurring steep slope failures” is defined as the collapses that occur in a limited planar area at or around the peak of a series of rain after the working rainfall has reached a certain level qualitatively. This method is recognized as effective for debris flows as well, and now being established as the representative setting method of standard rainfalls for warning and evacuation.

1.2 Setting of warning and evacuation lines and their operations

The critical line (CL) is a line beyond which the occurrence of sediment-related disasters becomes highly probable. Hence, if a rainfall is likely to cross this line, warning and evacuation actions must be initiated immediately. This allowance time should include the time necessary to transmit an evacuation recommendation to the people and the time necessary to move to an evacuation area. In the standard rainfall setting method, it is specified that an evacuation preparation should be started two hours before reaching the CL, and an evacuation itself one hour before reaching the CL.

Therefore, the rainfall obtained by deducting one-hour rainfall from the rainfall at the CL is called the Evacuation Rainfall and the line at that time is called the Evacuation Line (EL). And, the rainfall obtained by deducting two-hour rainfall from the rainfall at the CL is called the Warning Rainfall and the line at that time is called the Warning Line (WL).

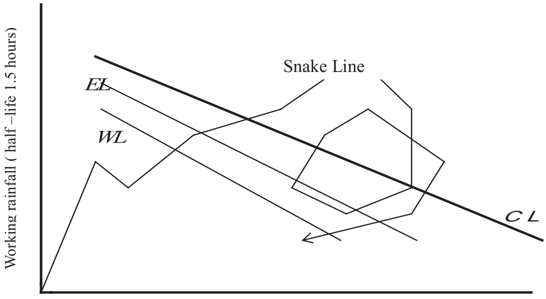


Fig.3 Evacuation Line, Warning Line and Snake Line

Working rainfalls are plotted in the figure by real time as shown in Fig. 3 (the line linking working rainfalls depicted at every hour is called the snake line). A warning is in principle issued when the rainfall exceeded the WL, and an evacuation decision is in principle made when the rainfall exceeded the EL taking into accounts other aspects as well, such as the expected rainfalls in later hours and the various conditions in the area. In general, the EL and WL are set at the positions obtained by deducting the past maximum to probability one-hour and two-hour rainfalls from the rainfall at the CL, respectively.

1.3 Recent trend towards the improvement of standard rainfall accuracy

(1) Consideration of topographical factors

The methods shown above are the methods trying to establish the CL from past rainfalls by assuming that the sediment-related disaster conditions in a given area are always the same. As a result, the standard rainfalls are the same in any place in the same area, ignoring various differences. This is a farfetched treatment to cover the paucity of disaster occurrence data. In these years, however, an attempt has been made to propose a method that can establish the

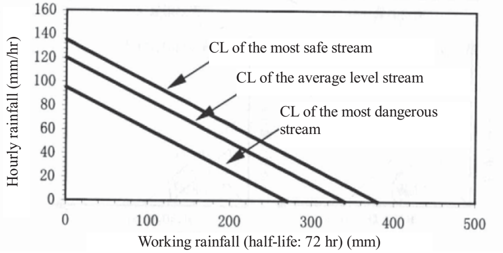


Fig. 4 Concept of the setting of CL with consideration of topographical factors

critical rainfall and the CL much more accurately with the incorporation of various factors, such as topography and geology, besides rainfall indexes. In this method, factors such as rainfall, topography, and geology that are deeply related to sediment-related disasters like collapses and debris flows are focused, their level of effect on the occurrence/non-occurrence of disasters is evaluated statistically, and then they are incorporated in the derivation process of the critical rainfall and the CL according to their level of effect.

(2) Utilization of the short-term rainfall forecast

The EL and the WL are the indicators telling the timing of warning and evacuation activities, but not the prediction of disaster occurrence itself. Hence, even though a warning or an evacuation is issued, the rainfall may not reach the CL if raining stops after the issuance. Also, if the rainfall is larger than expected, the time before reaching the CL may be shortened. To address this difficulty, administrative organizations are increasingly incorporating the short-term rainfall forecast into the decisions related to warning and evacuation.

Currently, the Meteorological Agency is forecasting a one-hour rainfall up to three hours ahead using, as the initial value, the radar AMeDAS analysis rainfall which is obtained from the radar data and the AMeDAS rainfall data, and distributing them to weather stations and other organizations. This forecast is considerably minute because the entire nation is zoned by a mesh size of 5 km, and hence highly effective for the warning and evacuation-related judgments. This rainfall forecast is also offered to the public through the online service of the Japan Weather Association and other entities. Since April, 2001, the forecast time has been extended up to six hours ahead.

The forecast rainfalls of one to two hours ahead are highly useful for warning and evacuation-related decisions. Hence, the general trend these days is to incorporate these short-term rainfall forecasts into the standard rainfalls and to use them for decisions related to warning and evacuation. Figure 5 shows an example of figures for standard rainfall-related judgments in which a short-term rainfall forecast is incorporated.

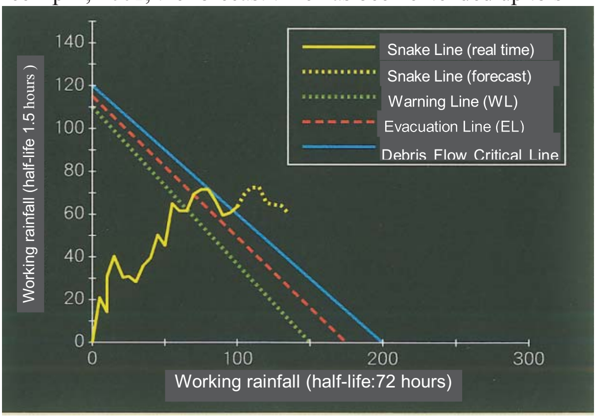


Fig.5 Conceptual diagram for assessing amount of rainfall utilizing rainfall forecast

2. PROPOSAL OF STANDARD RAINFALLS FOR WARNING AND EVACUATION INFORMATIVE TO THE PUBLIC

In recent years, many prefectural governments began to offer standard rainfalls for warning and evacuation to the general public through the Internet and other means, but cases are not a few that such information is stopped at the municipality level. It is indispensable to provide disaster-related various information, including standard rainfalls, to the local people to make them judge the need of evacuation when a disaster occurs. However, for the local people with little knowledge about sediment-related disasters, it is not easy to know when and how they should make a decision to evacuate, even though they vaguely know where is the dangerous area. It is also not easy for them to find where refuge areas are and to arrive at those places under a torrential rain. To alleviate this situation, it is effective to present various information in a coordinated way by combining a variety of activities, such as publicizing, enlightenment and disaster prevention education. As one of ways to meet this need, the authors proposed a method to prepare the Country Watching Map (CWM), and a typical CWM was completed in a model area in Niigata Prefecture.

2.1 Proposal of Country Watching Map (CWM)

The Country Watching Map (CWM) prepared in the Higashi-Tatsushima area in Sado Island, Niigata Prefecture, is explained here. In Sado Island on which this model area is located, a severe sediment-related disaster occurred August 4, 1998 due to a torrential rain that started in the early morning, and 24 debris flows, 10 slope failures, and 12 landslides were caused. Although no human life was lost, the damage was severe, including 3 total collapsed houses, 20 partially collapsed houses, 20 inundations above floor level, and 46 inundation below floor level.

Before starting the actual preparation, a meeting was held with the local people where the troubles they encountered during the 1998 disaster and their expectations for disaster prevention were discussed. Through these talks, actual conditions at the time of the disaster as well as varied problems connected to disaster prevention were identified. Further, when the preliminary map was prepared, the former area head who diligently led an evacuation activity during that disaster was invited several times to review the contents and reflect his opinions in the map.

(1) Contents of Country Watching Map (CWM)

The following contents are included in the Country Watching Map (CWM).

1) Information necessary to judge the level of danger

As the information useful to the judgment of danger, the actual disaster state and the actual experience that have never been dealt in this kind of map are included in this map. For this purpose, a survey was held in the area and information was collected on various phenomena during the disaster, including a gush of water from slopes, flooding of gutters along the roads, inundations above and below floor level, steep slope failures, blocking of rivers by bridges, flooding of rivers, debris flows, and landslides. These phenomena caused by a torrential rain and the rainfalls at the time were compared focusing on the temporal and spatial changes, and the results were compiled in the map to be utilized for warning and evacuation-related judgments (Fig. 6).

Date	No.	Time	Cumulative rainfall (mm)	Phenomena occurred
August 2	①	Around 12:00	69	Water began to gush out from a mountain slope near the back of Hatano's house (1).
August 4	②	Around 3:00	172	Severe gush of water was observed at a mountain slope near the back of Hatano's house (1).
	③	Around 5:00	178	Roadside gutters overflowed. A sound of flowing stones was heard from the Higashi-Tatsushima River. Hatano, head of the area then, felt a danger of flooding and reported it to the city government.
	④	Around 6:00 ~	184	A flood fighting activity began with the removal of covers of gutters.
	⑤	Around 7:00	236	The Higashi-Tatsushima River was filled up and an inundation seemed unavoidable.
	⑥	Around 7:30	258	A slope failure occurred at the back of Kenichi Suzuki's house (3) and two houses collapsed totally. The Higashi-Tatsushima River overflowed.
	⑦	Around 7:30 ~	258	After reporting the danger to the city government, Hatano, head of the area, led a voluntary evacuation.
	⑧	Around 9:00	306	An inundation above floor level occurred at the house of Genichi Miura (7).
	⑨	Around 10:30	344	Another inundation above floor level occurred at the house of Shoichi Kikuchi (9).

Note: the number in ( ) in the table corresponds to the number of a house shown in Fig. 8.

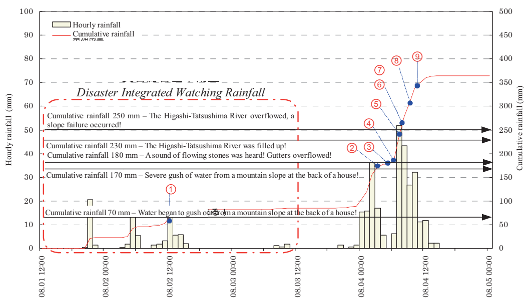


Fig.6 Rainfalls and phenomena at the time of a torrential rain on Aug. 4, 1998

2) Information necessary for evacuation

As the information necessary for evacuation, the following were included in the map: refuge areas and evacuation routes which are determined by each disaster prevention unit, dangerous areas to be careful during an evacuation (overflows, steep slope failures, debris flows), and information about the residents (infants, elderly persons, handicapped persons, sick persons, housing conditions such as temporary vacancy).

(2) Effect of Country Watching Map (CWM)

The information contained in the CWM is easy to understand to the local people because the contents are what they experienced in their own area, and their understanding deepens because they participated in the preparation of the map. Further, as they cooperated with administrative organizations during the preparation of the map, communications between the two parties go on smoothly and their collaborative relationship is strengthened greatly.

These mutual effects will help arouse disaster prevention awareness as a real desire, which will lead to a more active development of disaster prevention activities.

(3) Examples of Country Watching Map

Fig. 7 and 8 show the country watching maps thus prepared. Fig. 7 shows how the area will respond temporally and spatially against certain rainfalls by referring to actual damages observed during the disaster in 1998. For example, it tells that if raining is started, attention should be paid to the water gushing out from the slope in the west of the house (1) in Fig. 8. If the gush of water increases significantly, gutters which tend to overflow and the water level in the Higashi-Tatsushima River should be watched. If the gutters overflow or stones flow down the Higashi-Tatsushima River, it means that they are under a torrential rain. If the rainfall continues to increase, they should be alert for potential slope failures and may need to consider an evacuation.

However, it should be kept in mind that Fig. 7 shows only the development of various phenomena under one rainfall pattern, and that the process may not be identical if the rainfall pattern is different. If another disaster occurs in the future, the rainfalls and the development process of various phenomena should be collected and incorporated into the map so as to produce a more reliable, multi-purpose map. Fig. 8 shows the information highly useful during an evacuation, such as refuge areas, evacuation routes, and places to be cautious during evacuation. With regard to the resident information, the distribution of the so-called disaster vulnerable persons and their conditions, namely if they area at home or away from it, can be grasped. This enables swift and adequate evacuation through the mutual help of residents, particularly in cases such as an early evacuation of disaster vulnerable people and finding of persons not yet evacuated.

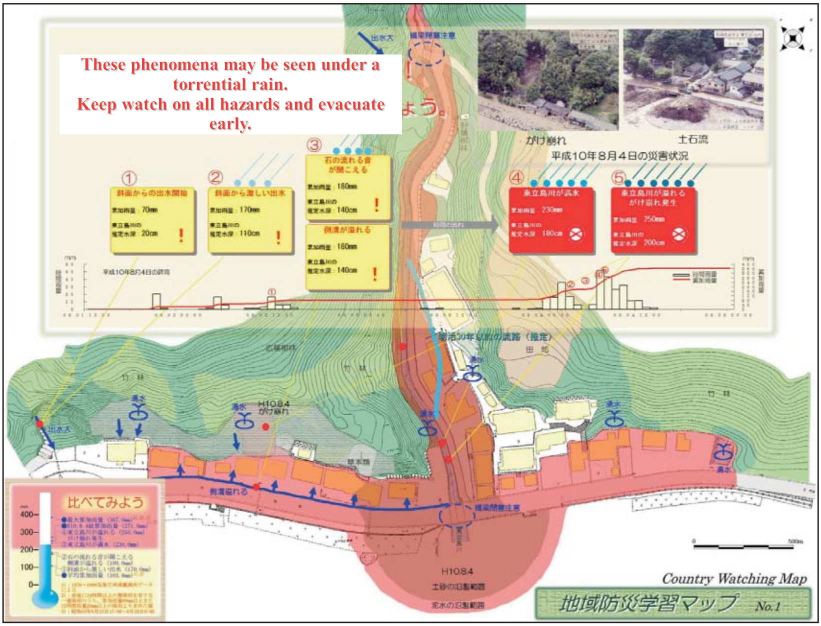


Fig.7 Country Watching Map (1)

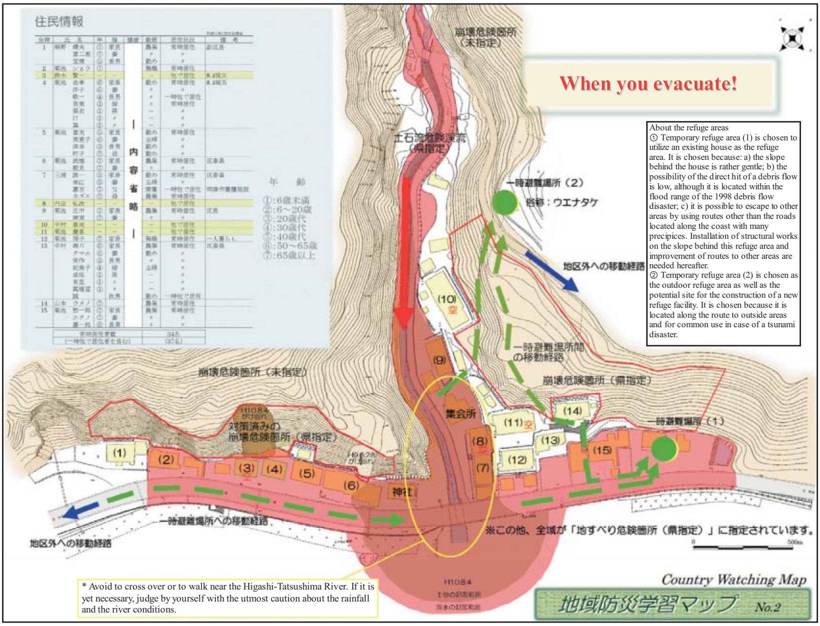
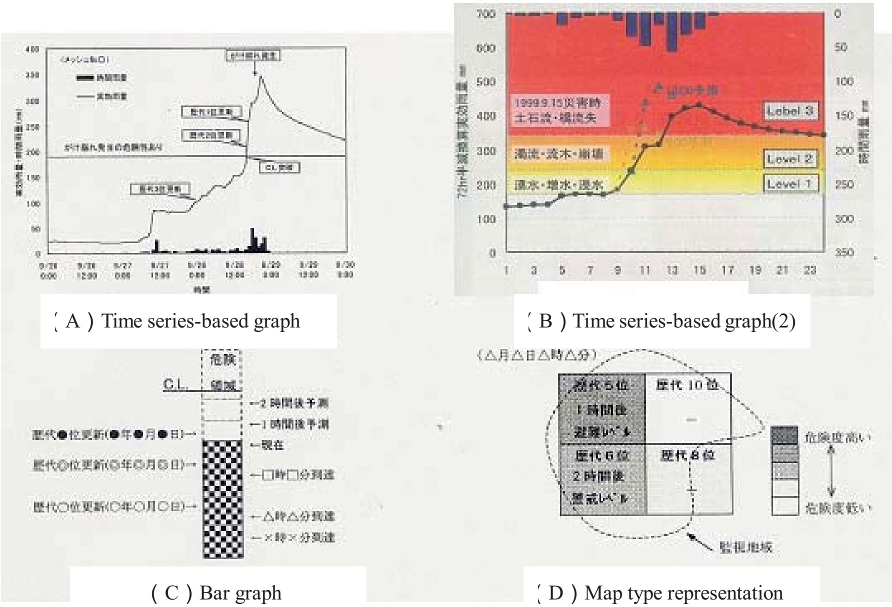


Fig.8 Country Watching Map (2)

2.2 Easy representation of standard rainfall-related information

The standard rainfalls are usually expressed using the snake line in the X-Y graph. However, it seems difficult to understand for ordinary people because the development of the working rainfall is expressed without using the time axis. To lessen the difficulties, the authors proposed simple expressions as shown in Fig. 9.

(A) Time series-based graph
This is a method to express the temporal development of the working rainfall using the time series.
(B) Time series-based graph (2)
This is a method to set the CL shown in Graph (A) in several stages in accordance with the phenomena observed.
(C) Bar graph
This is a method to express the sum of the working rainfalls shown in Graph (A) in the form of a bar graph. The graph appears like a thermometer. It is intended to publicize the danger of sediment-related disasters in an easy-to-understand manner by indicating working rainfalls at the time of past disasters beside the scale mark.
(D) Map type representation
Shown in the three types of representations given above is the information at some specific locations. In contrast, the map type representation is intended to express information in a planar form.



(A) Time series-based graph
(B) Time series-based graph(2)
(C) Bar graph
(D) Map type representation

Fig.9 Presentation example of standard rainfall

3. EXAMPLES OF INFORMATION SYSTEMS OFFERED BY ADMINISTRATIVE ORGANIZATIONS

In these years, many prefectural governments and other organizations are offering information in a variety of forms. For example, there is a system that displays the danger level of rainfalls by each debris flow hazard mountain stream through the link with the GIS (Fig. 10). The Internet is also used to provide information to the people (Fig. 11). There is also a system that allows the people to know the evaluation results of standard rainfalls via cellular phones.

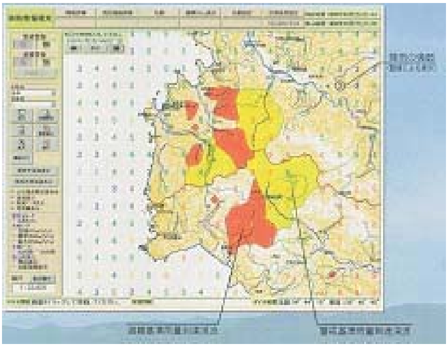


Fig.10 Display of warning and evacuation level (example)

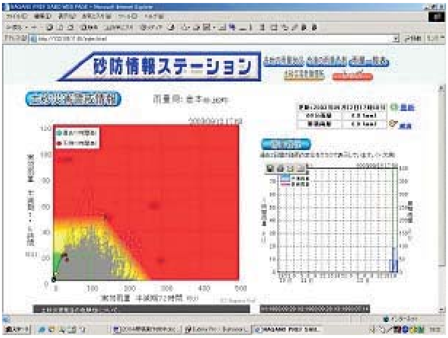


Fig.11 Example of Internet display (Information of standard rainfall)

CONCLUDING REMARKS

In the present paper, the recent trend in Japan concerning the setting method of standard rainfalls for warning and evacuation against sediment-related disasters was presented. And then, the method to deliver disaster prevention information and the method to represent standard rainfalls in a form easy to understand to the public, both proposed by the authors, were described. Examples of information delivery systems now being employed by administrative organizations were also introduced. Especially in these years, thanks to the development of information and communication technologies, rainfall-related information including the standard rainfalls for warning and evacuation has been made public through the Internet and it is accessible even from cellular phones.

Nevertheless, cases are still not many that a disaster was avoided because people responded to this kind of information well and evacuated in time. One of the reasons for this is the accuracy problem of the standard rainfalls. It is that, even though some rainfall exceeds the standard rainfalls, sediment-related disasters do not necessarily occur because they are such a complex phenomenon. Another reason is that the awareness against sediment-related disasters is still low among the local people as well as among the municipal governments.

Simply put, sediment-related disasters occur every year all across Japan, but if the counting level is lowered from the prefecture to the municipality and then to the area, the disaster occurrence frequency decreases greatly. As a result, disaster prevention awareness as well as the sense of risk against sediment-related disasters tend to be low in municipalities which have never experienced disasters by themselves. They are also unable to issue an evacuation recommendation before a disaster strikes because they do not have an experience. This kind of unpreparedness is observed in the questionnaire conducted on the residents who live along the

debris flow hazard mountain streams, in which approximately 50% answered that they do not know what the debris flow hazard mountain stream is.
To solve these problems, it is needed to enhance disaster prevention awareness of every one of residents, while advancing various non-structural measures steadily and systematically. It is particularly important to continue to provide a disaster prevention education, enlightenment activities, and publicity of various information to the local people as well as to the disaster prevention officials of municipal governments.

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