

# **PLANNING OF WARNING AND EVACUATION SYSTEM**

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## CHAPTER 1 IDENTIFICATION OF SEDIMENT DISASTER HAZARD AREAS

### 1.1 Debris Flow Hazard Areas

The survey for the identification of debris flow hazard areas shall be limited to the range that needs to be considered at this moment for establishing a warning and evacuation system for the people, without including the range that needs to be considered for the future. The survey shall be conducted in accordance with the flowchart in Fig. 1.1. The details of each survey step, including the contents and the methods, are shown below.

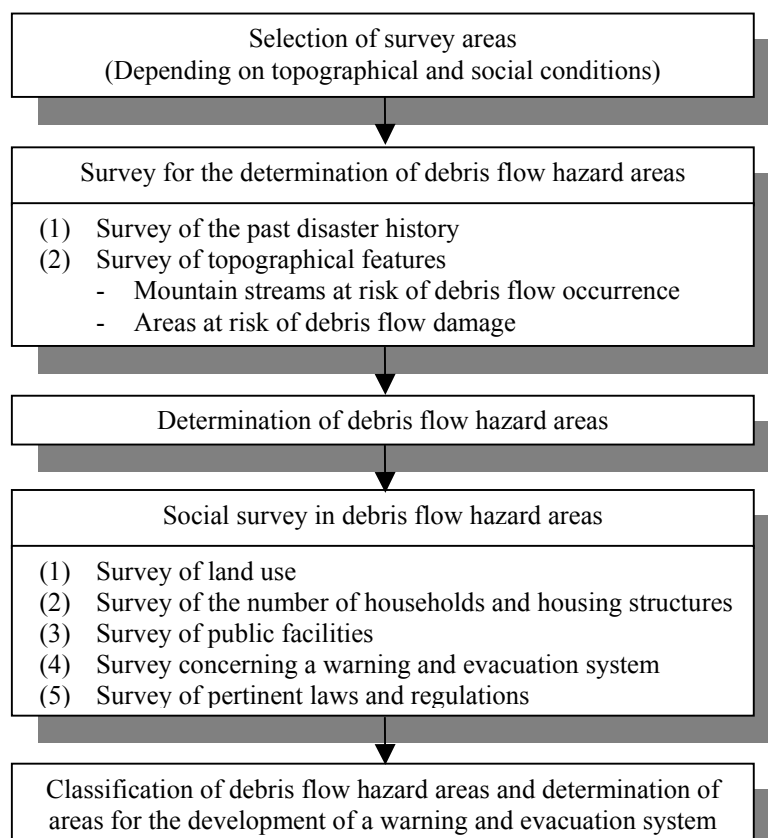


Fig. 1.1 Survey steps for the identification of debris flow hazard areas <sup>16)</sup>

#### 1.1.1. Selection of survey areas

The survey areas are the areas that may sustain damage due to a debris flow and the mountain streams at which a debris flow may occur. Utilizing topographical maps on a scale of 1/25,000 in principle, areas that satisfy both the topographical and social conditions shown below shall be taken out as the survey areas. If large-scale topographical maps above 1/25,000 are available, those maps shall be used. If the only maps available are small-scale maps below 1/25,000, insufficient information shall be confirmed during a field survey.

##### <Topographical conditions>

##### - Areas at risk of debris flow damage:

These areas are located between the point at which a debris flow enters into a fan at the foot of a mountain (it is usually a point where a debris flow begins to flood, which is called a debris flow flooding point) and the lowermost point a debris flow will reach (this is usually the point where the ground gradient is 2°).

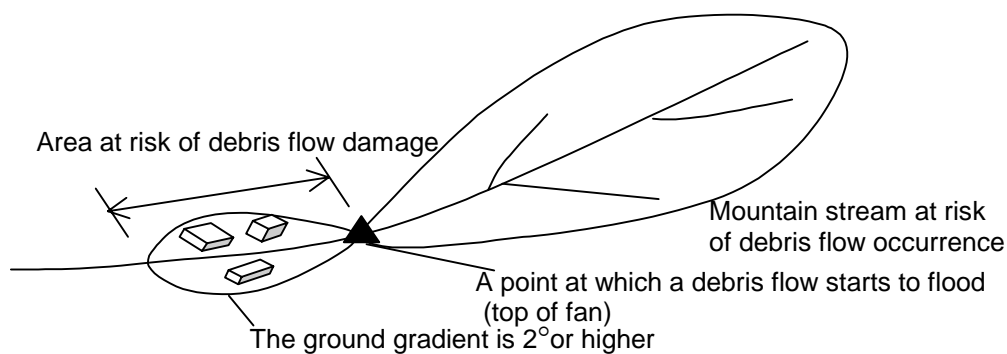
- **Mountain streams at risk of debris flow occurrence:**

These mountain streams are located in the upper area than the point at which a debris flow begins to flood. To be specific, they have the following features.

- (1) Mountain streams having a valley-like configuration on a map of 1/25,000
- (2) Mountain streams at which a debris flow or a sediment flow occurred in the past. This includes mountain streams having a fan-like configuration.
- (3) Mountain streams assessed as at risk of debris flow occurrence from their topographical and geological conditions. An example is a mountain stream located in a river basin having a large devastated area or a large bare area.

<Social conditions>

Survey should be made to find if houses, public facilities, roads, and railways often used by people are located in a hazardous area or a hazardous mountain stream.



**Fig. 1.2 A representation of the area for survey** <sup>16)</sup>

**1.1.2 Survey for the determination of debris flow hazard areas**

To collect data needed for the determination of debris flow hazard areas, the selected survey areas shall be investigated in detail by such methods as the reading of existing topographical maps, a field survey, and a collection of reference materials. If it is a survey to find the necessary preventive measures against debris flows, the detailed survey should consist of 1) survey of past disaster history, 2) topographical survey, 3) geological survey, and 4) survey of conditions of existing preventive works. But, in the case of survey for the development of a warning and evacuation system against debris flows, 1) and 2) are needed as the minimum requirement. They are explained below.

**(1) Survey of past disaster history**

Survey should be made on debris flows that occurred in and around the selected survey areas in the past, and their scales and the damages shall be gasped. Survey should be performed mainly on the following items.

- Date, time, location, and causes of a debris flow
- The scale of a debris flow (total volume of sediment discharge, flooding area)
- Damage to humans (the number of persons killed or injured), damage to houses, structure of damaged houses (wooden/non-wooden), and level of damage to houses (total collapse, half collapse, partial collapse)
- Rainfall (cumulative rainfall, daily rainfall, hourly rainfall, 10-minute rainfall)

- Others (thickness of sedimentation due to flooding)

## (2) Topographical survey

The topographical survey, as shown in Table 1.1, shall be conducted at mountain streams at risk of debris flow occurrence and in areas at risk of debris flow damage separately. It is best to use topographical maps on a scale of 1/2,500 or over. But, if the only maps available are small-scale topographical maps below 1/2,500, insufficient information shall be confirmed during a field survey.

**Table 1.1 Survey for the determination of debris flow hazard areas**

Mountain streams at risk of debris flow occurrence	Areas at risk of debris flow damage
<p>&lt;Gradient of streambed&gt;  <u>Reading of topographical maps</u>                      Using large-scale topographical maps of 1/2,500 or over, the ground gradient and the streambed gradient shall be grasped.</p> <p><u>Field survey</u>                      When large-scale topographical maps of 1/2,500 or over are not available, the streambed gradient that is closely related to the occurrence, flow, and sedimentation of a debris flow shall be measured at the site. During a field survey, detailed measurements shall also be performed on such matters as the changing position of streambed gradient, the streambed gradient above and below the structures, and the streambed gradient at a point where a valley becomes wider, utilizing a pocket compass (a hand level) and other devices. The ground gradient shall be measured in a similar manner.</p>	<p>&lt;Gradient of ground and gradient of streambed&gt;</p>
<p>&lt;Area of a debris flow occurrence basin&gt;                      The area of a basin above the debris flow flooding point shall be measured (this is called the area of a debris flow occurrence basin). If it is a volcanic area, the area of a basin having a gradient of 10° or higher shall be measured as the area of a debris flow occurrence basin. If it is an ordinary area, the area of a basin having a gradient of 15° or higher shall be measured as the area of a debris flow occurrence basin.</p>	<p>&lt;Transverse configuration&gt;                      To obtain basic data for the estimation of the flowing scale (flow rate), the flooding point, and the flooding range of a debris flow, a field survey shall be conducted on 1) transverse configuration, 2) gradient of a stream bank, 3) width of a stream, 4) relative height of a terrace, and 5) relative height of the subject of conservation and the streambed. Using these results, a transverse profile shall be prepared. The precision level of this survey shall be the level of a simple survey, as necessity calls.</p>
	<p>&lt;Plane configuration&gt;                      To obtain basic data for the estimation of the flooding scale and flooding range of a debris flow, the plane configuration shall be grasped utilizing the results of a ground gradient survey, reading of aerial photographs, and a transverse configuration survey. Before going out for a field survey, crook and narrow sections of a stream course, plains at the bottom of a valley, flat areas (residential areas, arable land), artificial structures (roads, railways, bridges) shall be identified using maps, and they shall be confirmed during a field survey.</p>

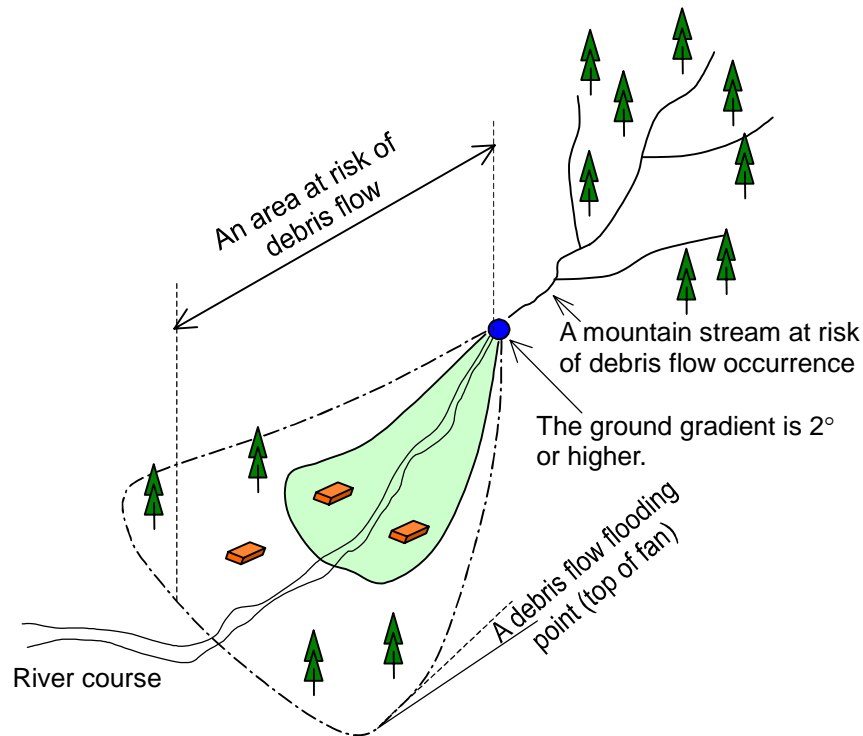
### 1.1.3 Determination of debris flow hazard areas

The debris flow hazard area is defined as follows.

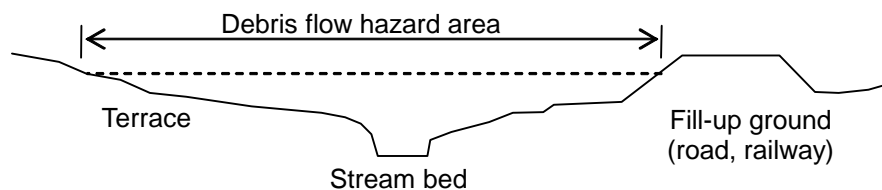
An area located below the debris flow flooding point (top of fan) and having a ground gradient of 2° or higher. However, an area clearly admitted beyond the reach of a debris flow from its topographical conditions is excluded (See Fig. 1.3).

The debris flow hazard area shall be determined in accordance with the procedures shown below, based on the survey results mentioned in Section 1.1.2 above.

- 1) The debris flow flooding point shall be determined using topographical maps and the results of a field survey, with a focus on the following items.
  - Outlet of a valley: a point at which the valley width becomes large
  - Top of fan: a point at which the valley width becomes large and the streambed gradient becomes gentle
  - Point of gradient change: a point at which the gradient of a streambed abruptly changes from steep to gentle
  - Crook: a point at which the river course is bent sharply (flooding will occur on the exterior side because a debris flow flows straight).
  - Outlet of a narrow section: a point at which the valley width abruptly changes from narrow to wide
  - Debris flow flooding point: a point at which a debris flow began to flood in the past disasters
- 2) A point at which the ground gradient becomes 2° shall be identified in the area below the debris flow flooding point.
- 3) The debris flow hazard area shall be determined by focusing on the area located between the debris flow flooding point and the lowermost point where a ground gradient is within 2° or higher, and by taking other factors into account, including topographical features around the stream and the location/scale of artificial structures. Besides these, other factors shall also be taken into account. They include topography in the area, distribution of sediment carried by past debris flows, past disaster history, and other debris flows that occurred at nearby streams or at streams having a similar topography and geology. To determine the range of reach, attention shall be paid to the topographical features and sedimentation in the area, including 1) fan type topography 2) presence of a group of boulders, 3) presence of unlayered sediment containing both sand and gravel. The transverse profile of a debris flow hazard area (See Fig. 1.4) shall be determined based on the field confirmation of the relative height of a streambed and surrounding terrains, a river terrace, artificial structures, etc.



**Fig. 1.3 A representation of the debris flow hazard area**<sup>16)</sup>



**Fig. 1.4 A representation of the transverse profile of a debris flow hazard area**<sup>16)</sup>

#### 1.1.4 Social survey in debris flow hazard areas

##### (1) Survey of land use

The state of land use (roads, watercourses, ponds and marshes, residential areas, farmlands, forests, etc.) shall be surveyed in debris flow hazard areas.

##### (2) Survey of the number of households and housing structures

The number of households and the structure of houses shall be surveyed in debris flow hazard areas.

##### (3) Survey of public facilities

The conditions of public facilities and business establishments located within debris flow hazard areas shall be surveyed to grasp the region-wide potential effect of a debris flow. Survey shall also be made on the structures of those facilities and business establishments to find their safety level against a debris flow. The subjects to be surveyed are as shown below. With regard to (i), the type, length, and number of facilities located within the survey area shall be surveyed. As to (ii), the type of facilities and their structure shall be surveyed.

**(i) Public facilities, like a road and a railway:**

National roads, prefectural roads, municipal roads, rivers, roads, railways

**(ii) Public buildings, like a post office and a social welfare facilities:**

- Public buildings, such as a police station, a post office, other public offices, business establishments, hotels and inns, stations, schools
- Social welfare facilities and medical facilities used by elderly people, handicapped people, infants, and others who need special consideration in disaster prevention (these are referred to as the facilities for vulnerable people)

**(4) Survey concerning a warning and evacuation system**

To grasp various conditions related to the development of a warning and evacuation system in debris flow hazard areas, survey shall be made on the following items.

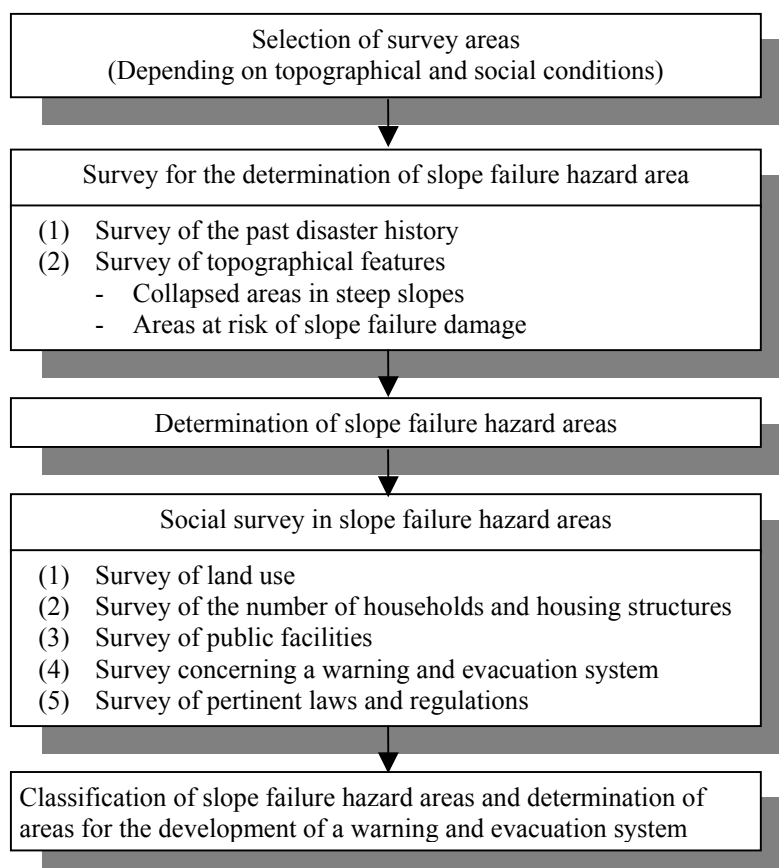
- (i) Designation/non-designation of the debris flow hazard area
- (ii) Presence/absence of voluntary disaster prevention groups
- (iii) Installation of measurement devices such as a water gauge and a flow meter
- (iv) Location of a rain gauge and its operator
- (v) Setting of standard rainfalls
- (vi) Development of a transmission system for conveying rainfall information, forecast of disaster occurrence (advisory and warning), and disaster information
- (vii) Designation of evacuation routes, location of refuge facilities (located within the disaster hazard area or not), structure of refuge facilities (wooden/non-wooden),
- (viii) Dissemination of disaster-related knowledge and information to the people, including distribution of disaster prevention maps
- (ix) Disaster prevention training

**(5) Survey of pertinent laws and regulations**

Survey shall be made on laws and regulations that have been enforced concerning the areas at risk of debris flow damage.

## 1.2 Slope Failure Hazard Areas

The survey for the identification of slope failure hazard areas shall be limited to the range that needs to be considered at this moment for establishing a warning and evacuation system for the people, without including the range that needs to be considered for the future. The survey shall be conducted in accordance with the flowchart in Fig. 1.5. The details of each survey step, including the contents and the methods, are shown below.



**Fig. 1.5 Survey steps for the identification of slope failure hazard areas** <sup>16)</sup>

### 1.2.1. Selection of survey areas

The survey areas are the areas that may sustain sediment damage due to a slope failure. Utilizing topographical maps on a scale of 1/25,000 in principle, areas that satisfy both the topographical and social conditions shown below shall be taken out as the survey areas. Each survey area shall be taken out as the area having some kind of unity so that a warning and evacuation system can be established efficiently and other administrative measures implemented smoothly. If large-scale topographical maps above 1/25,000 are available, those maps shall be used. If the only topographical maps available are small-scale maps below 1/25,000, insufficient information shall be confirmed during a field survey.

#### <Topographical conditions>

A slope failure hazard area is an area having a gradient of 30° or higher and a height of 5 m (See Fig. 1.6). Unlike a landslide case, it is difficult to locate the very site of slope failure in advance because a slope failure is an initial stage movement of a slope. Hence, the above definition is used to specify a hazardous slope at risk of collapse. As the average



friction angle of loose sandy soil is around  $30 \sim 35^\circ$ , the slope gradient  $30^\circ$  is a gradient at which a fall can occur even though excessive pore water pressure is not generated. In that sense, although it is an approximated value, the slope gradient  $30^\circ$  presented in the definition is a meaningful value. Because slopes having a gradient of  $30^\circ$  or higher are numerous, survey shall be limited to the slopes having a height of 5 m or higher in view of their vulnerability.

#### <Social Conditions>

A survey of social conditions shall be conducted at: 1) steep slopes, 2) slopes having houses, public facilities, and farmland around the slope, and 3) slopes around which houses, public facilities, and farmland may be built in the near future in view of current land use and land development plans.

### 1.2.2 Survey for the determination of slope failure hazard areas

To collect data needed for the determination of slope failure hazard areas, the selected survey areas shall be investigated in detail by such methods as the reading of topographical maps, a field survey, and a collection of reference materials. If it is a survey to find the necessary preventive measures against slope failures, the detailed survey should consist of 1) survey of past disaster history, 2) topographical survey, 3) geological survey, and 4) survey of conditions of existing preventive works. But, in the case of survey for the development of a warning and evacuation system against slope failures, 1) and 2) are needed as the minimum requirement. They are explained below.

#### (1) Survey of past disaster history

Survey should be made on slope failures that occurred in and around the selected survey areas in the past, and their scales and the damages shall be grasped. Survey should be performed mainly on the following items.

- Date, time, location, and causes of a slope failure
- The scale of a slope failure (height of a steep slope area, gradient of a steep slope area, height of collapse, depth of collapse, width of collapse, width of spread of soil and rock, length of collapse, range of reach of soil and rock, volume of collapsed soil and rock)
- Damage to humans (the number of persons killed or injured), damage to houses, structure of damaged houses (wooden/non-wooden), level of housing damage (total collapse, half collapse, partial collapse)
- Rainfall (cumulative rainfall, daily rainfall, hourly rainfall, 10-minute rainfall)
- Others (constants of soil, etc.)

#### (2) Topographical survey

The topographical survey shown in Table 1.2 shall be conducted at steep slopes at risk of collapse and in areas at risk of damage due to a slope failure individually. It is best to use topographical maps on a scale of 1/2,500 or over. But, if the only maps available are small-scale maps below 1/2,500, the insufficiency of information shall be confirmed during a field survey.

**Table 1.2 Survey for the determination of slope failure hazard areas**

Steep slopes at risk of collapse	Areas at risk of damage due to a slope failure
The following surveys are important for the determination of a range at risk of collapse. Therefore, confirmation at the site is desirable.	Survey of hazardous areas shall be performed at the bottom of a steep slope and at the flat area. The following items shall be grasped.
<Gradient> An angle made by the horizontal line and the line linking the bottom of a steep slope and the natural inflection point of gradient shall be surveyed.	<Micro-topography> Micro-topography of the area showing a small ruggedness, such as a small hill, artificial fill, river, and irrigation channel
<Height of a steep slope> The difference of elevation between the lower end and the upper end of a steep slope shall be surveyed (this is referred to as the height). If uneven places that are not really steep exist at the midway of a steep slope, the lower end and the upper end of a steep slope can be determined in view of an entire slope (in principle, a point 5 m ahead must be viewed without serious obstruction).	<Artificial structures> Artificial structures built on excavated areas or fill-up areas, such as a railway and a road

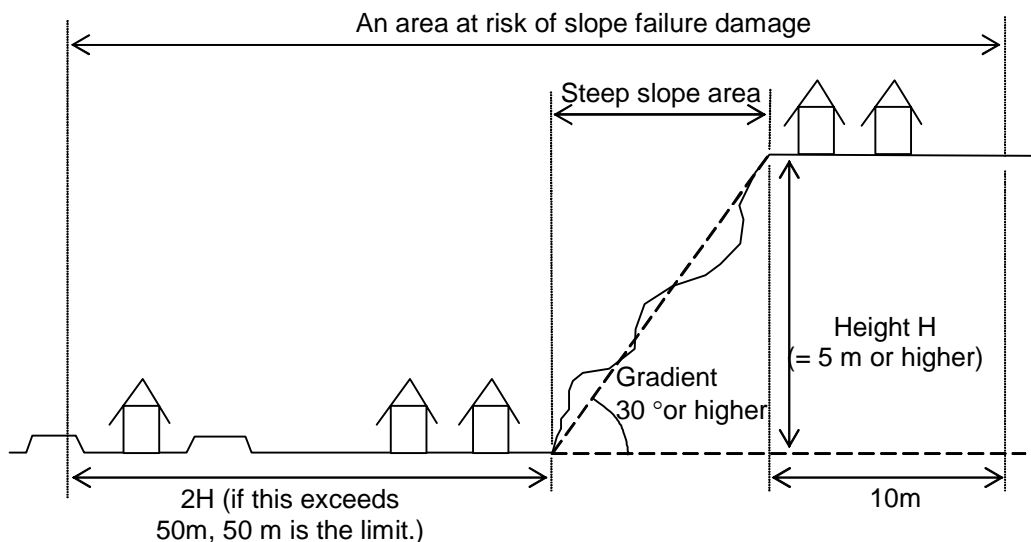
### 1.2.3 Determination of slope failure hazard areas

The slope failure hazard area is defined as follows (See Fig. 1.6).

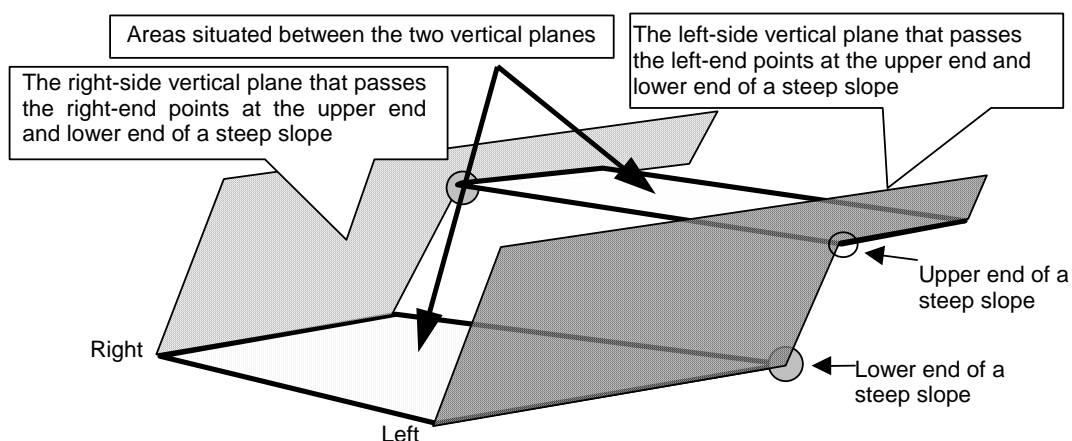
- 1) An area having a gradient of 30° or higher and a height of 5 m or over.
- 2) An area located within a horizontal length of 10 m from the upper end of a steep slope
- 3) An area located within twice the height of a steep slope (if this exceeds 50m, the limit is 50 m) from the bottom of a steep slope (However, part of the area which is clearly admitted not within the reach of soil and rock from its topographical features is excluded).

Using data obtained from topographical survey of a steep slope, the cross sectional configuration as well as the plane configuration of the steep slope shall be grasped. Then, incorporating the results of a field survey and a disaster history survey, the slope failure hazard area shall be determined by taking the steps shown below.

- 1) The lower end and the upper end of a steep slope are determined.
- 2) The height and gradient of a steep slope are determined.
- 3) Three areas are determined as the slope failure hazard area: (i) a steep slope area itself; (ii) an area located above the steep slope and within 10 m from the top of the slope; (iii) an area located below the steep slope and within the twice the height of the steep slope from the bottom of the steep slope (if this exceeds 50m, the limit is 50 m). The area in these cases means the area situated between the right-side vertical plane that passes the right-end points at the upper end and lower end of a steep slope and the left-side vertical plane that passes the left-end points at the upper end and lower end of a steep slope (See Fig. 1.7).



**Fig. 1.6 A representation of the slope failure hazard area** <sup>16)</sup>



**Fig. 1.7 Determination of right-end and left-end points of a steep slope area** <sup>16)</sup>

### 1.2.4 Social survey in slope failure hazard areas

The Social survey in slope failure hazard areas shall be conducted in accordance with Section 1.1.4, which outlined the social survey in debris flow hazard areas. For the survey of hazardous slopes, aerial photographs are extremely useful. Aerial photographs are also very effective for the determination of hazard areas and the identification of houses. To distinguish houses by wooden or non-wooden, a picturing scale of 1/10,000 or 1/12,500 is appropriate (the picturing scale of ordinary aerial photographs is also acceptable).

### 1.3 Selection of Areas for the Development of Warning and Evacuation System

Although it is desirable to develop a warning and evacuation system in all the sediment disaster hazard areas, this is not always possible because of financial constraints and other reasons. Accordingly, sediment disaster hazard areas for the development of a warning and evacuation system shall be selected based on priority in consideration of various factors, including the hazard level, social and economic importance of the area, and the possibility of human damage. The classification of sediment disaster hazard areas is explained below.

### 1.3.1 Debris flow hazard areas

In Japan, the debris flow hazard mountain streams are classified into three groups based on the social conditions of the debris flow hazard areas (type and number of subjects for conservation).

- 1) **Debris flow hazard mountain stream I:** Mountain stream flowing in an area having 5 or more houses for conservation, or mountain stream flowing in an area having an important public facilities, like a public office, school, hospital, station, power plant, even though the number of houses for conservation is less than 5
- 2) **Debris flow hazard mountain stream II:** Mountain stream flowing in an area in which the number of houses for conservation is 1 or more but less than 5
- 3) **Mountain stream equivalent to debris flow hazard mountain stream III:** Mountain stream flowing in an area which has no houses for conservation at present but may be developed for housing construction later

This kind of classification shall be decided based on the social conditions of each country or each region. As a reference, the following classification is also available.

- 1) **Debris flow hazard mountain stream I:** Mountain stream flowing in an area having houses for conservation and a public facilities for people
- 2) **Debris flow hazard mountain stream II:** Mountain stream flowing in an area having houses for conservation but no public facilities for people
- 3) **Debris flow hazard mountain stream III:** Mountain stream flowing in an area having no houses for conservation and no public facilities for people

### 1.3.2 Slope failure hazard areas

The slope failure hazard areas are classified into three groups based on social conditions (type and number of subjects for conservation).

- 1) **Slope failure hazard area I:** Steep slope area (including an artificial steep slope) having a slope gradient of 30° or higher and a slope height of 5 m or higher on which 5 or more houses are located (this includes a steep slope area having a public office, school, hospital, station, inn, or a facilities used by disaster vulnerable people such as a social welfare facilities, even though the number of houses located is less than 5.)
- 2) **Slope failure hazard area II:** The same area as above, but the number of houses located is 1 to 4.
- 3) **Slope area equivalent to a slope failure hazard area III:** The same area as above, which has no houses at present, but may be developed for housing construction later.

This kind of classification shall be decided based on the social conditions of each country or each region. As a reference, the following classification is also available.

- 1) **Slope failure hazard area I:** Steep slope area (including an artificial steep slope) having a slope gradient of 30° or higher and a slope height of 5 m or higher on which houses for conservation and a public facilities for people are located
- 2) **Slope failure hazard area II:** The same area as above, having houses for conservation but no public facilities for people.
- 3) **Slope failure hazard area III:** The same area as above, but no houses for conservation and no public facilities for people

## CHAPTER 2 MONITORING AND FORECAST OF SEDIMENT DISASTERS

### 2.1 Monitoring of a Debris Flow

As the direct monitoring methods for detecting the precursors and the occurrence of a debris flow, two methods are available: one is the use of a wire sensor, a vibration sensor, and a monitoring camera; the other is a visual observation by local people. Visual observation of debris flow movements by local people is simple but effective, and is able to be carried out even if without rainfall data. It is regarded as an important method among the debris flow monitoring systems.

#### 2.1.1 Establishment of the debris flow visual observation system

The flow modes of a debris flow are diverse due to such factors as the gradient at the debris flow occurrence point, width of a stream or a river, materials on the streambed, thickness of accumulated sediment, and rainfall intensity. In general, however, the following modes of debris flows are observed in the upstream, midstream and downstream of a river. It is known that there are precursors of sediment disasters described in Table 2.1.

<Mode of debris flow>

- In the upstream, a debris flow occurs intermittently and it is a large-viscous flow containing a relatively small amount of water.
- In the midstream, a debris flow moves like a hydraulic bore with a small wave height. Containing relatively large amount water, the flow becomes like a liquefied flow and tends to flow in the lower direction.
- In the downstream, a debris flow becomes like a concrete mortar-like flow containing a large amount of water. Compared with an ordinary water flow, it is a viscous flow.

**Table 2.1 Precursors of sediment disasters**

Slope failure	Debris flow	Landslide
- Water from a precipice or a slope becomes muddy.	- A rumbling sound of the mountain is heard.	- Cracks appear on the ground.
- Cracks appear on a precipice or a slope.	- The water level in the river lowers, though rain is continuing.	- Water in a well or a valley becomes muddy.
- Small stones fall.	- The river water becomes muddy or includes driftwood.	- Water gushes out from a precipice or a slope.
- A sound is heard from a precipice or a slope.		

In the debris flow visual observation system, these precursors of sediment disasters and the occurrence of a debris flow are visually observed. The detected information is reported to the debris flow monitoring center and can be used for recommendation and cancellation of evacuation.

When the visual observation method is taken, an observer is required to grasp those debris flow modes in different areas of a river and it is important that a visual observer has an ample knowledge about the precursors of a potential disaster which can be detected by human eyes in order to judge the occurrence of a debris flow with no time to lose. Flood in river and stream is one of the important precursors of debris flow and other sediment

disasters. Thus, it is necessary to monitor the water level of rivers and unusual water level of rivers must be reported immediately. If the precursors are observed, the information must be transmitted to relevant organizations. Then a warning and evacuation action should be taken immediately and an evacuation of people should be initiated. In case a large-scale debris flow is occurring, the speed of a warning transmission should be faster than the speed of the debris flow itself. If the downstream area is an important area, a visual observation point should be placed at two or three locations at least in the upstream and the midstream of a river.

### **2.1.2 Establishment of a debris flow detection/monitoring system**

The debris flow detection/monitoring system is designed to detect the occurrence of a debris flow with a detection sensor and report it automatically. The debris flow detection equipment consists of the following devices.

- 1) Wire sensor: The debris flow occurrence is detected by the cut of a wire due to debris flow forces. Another type is to detect it from the contact of an electricity-charged wire to the swell of a debris flow.
- 2) Vibration sensor: The debris flow occurrence is detected by capturing vibration caused by debris flow movements.
- 3) Monitoring camera: The occurrence, the flowing state, and the scale of a debris flow are detected through a monitoring TV installed in a monitoring station or a control center.

## **2.2 Collection and Arrangement of Rainfall Data**

### **2.2.1 Determination of representative rainfall gauging stations**

To determine some representative gauging stations for related data collection, existing rainfall gauging stations located in and around each sediment disaster hazard area discussed in Chapter I shall be taken out, and their features as shown below shall be grasped.

- An organization in charge of management or administration
- Location of a rainfall gauging station and its altitude
- Types of rain gauges installed (gauging system: daily rain gauge/hourly rain gauge; recording system: automatic rain gauge/ordinary rain gauge)
- Availability of past rainfall data (daily rainfall, hourly rainfall, gauging period, years of data accumulation)

Based on these results, a representative rainfall gauging station that collects rainfall data of each sediment disaster hazard area shall be determined. The representative rainfall gauging station should be located in an area having similar rainfall characteristics with those of a target area, can gauge the hourly rainfall, and should have a longest possible gauging history.

### **2.2.2 Collection and Arrangement of Rainfall Data**

The rainfall data as shown below shall be collected at a representative rainfall gauging station and then recorded in the designated data forms.

- 1) Daily rainfall: Daily rainfall data during a longest possible period shall be collected. Then, a chronological table of daily rainfall shall be prepared.

- 2) Hourly rainfall:
  - Rainfall data at the time of disaster occurrence (causing rainfall): hourly rainfall during a series of rains (a continuous rain having a period of no rainfall for 24 hours or over before and after) including the time when a sediment disaster occurred.
  - Rainfall data other than above (non-causing rainfall): hourly rainfall during a series of rain which include a rain having a continuous rainfall of 40 mm or over or hourly rainfall intensity of 10 mm or over.
- 3) Past maximum rainfall: Daily rainfall and hourly rainfall intensity that are ranked as the upper ten including the past maximum.
- 4) Results of rainfall analysis: Probability daily rainfall and probability hourly rainfall

### **2.3 Policy for the Setting of Standard Rainfalls for Warning and Evacuation against Sediment Disasters**

It is possible to forecast the occurrence of a debris flow or a slope failure from the rainfall data, but its accuracy level differs largely depending on the level of data obtained. Although it is known that real-time gauging of hourly or 10-minute rainfall is the most appropriate for a highly accurate forecast of disaster occurrence, the available gauging level in developing countries is usually the daily rainfall. Further, gauging itself is not sometimes conducted in remote regions away from large cities. These adverse situations, or the insufficiency of rainfall data, should be duly considered when determining the setting method of standard rainfalls for the development of a warning and evacuation system in those countries.

#### **2.3.1 Case when hourly rainfall data are accumulated**

##### **(1) When causing and non-causing rainfall data are accumulated**

To make a practical prediction of the occurrence of sediment disasters, gauging of hourly rainfall is a prerequisite. Hence, the present Guidelines demand that a rain gauge that can gauge an hourly rainfall should be installed in areas where the only available data at present is the daily rainfall and in areas where the rainfall itself is not being gauged. On the other hand, in areas having both the hourly rainfall data and the past sediment disaster records, prediction of the occurrence of sediment disasters is possible if those data are analyzed. There are many methods to set standard rainfalls for the development of a warning and evacuation system. In the current Guidelines, the following three standard methods, which are mostly applied and become the practical standard, are explained.

- 1) Method A (Guideline Method)
- 2) Method B (Guideline Method)
- 3) Committee Method

The Method A and Method B are the methods presented in the “Guidelines for the Setting of Rainfall for Warning Issuance and Evacuation Instruction against Debris Flow Disasters (Tentative)” (1984). Of the two methods, priority is placed on Method A. Method B is used only when Method A is not adaptable well. These methods (especially Method A) are easy to use because predictions are possible with the use of only one rainfall index. Because of this advantage, they have been widely used in Japan. But, they do have disadvantages. For example, standard rainfalls established by those methods can be easily exceeded at the time of a long rain or an intermittent rain, and they do not have a standard for the

cancellation of a warning.

To remedy such disadvantages of Method A and Method B, Yano Method was proposed and then came the Committee Method. The Committee Method was proposed in the Guidelines entitled “Setting Method of Standard Rainfall for Warning and Evacuation against Collectively-Occurring Steep Slope Failures (Tentative)” (1993) which was prepared by the Committee for Studying Comprehensive Sediment Disaster Control Measures set up by the Ministry of Land, Infrastructure and Transport. Though the Committee Method has corrected the disadvantages of Method A and Method B, it is in a sense difficult to understand compared with those two methods because the standard for the occurrence of sediment disasters is expressed in a line form as “ $Y = aX + b$ ”.

The standard rainfalls for warning and evacuation against sediment disasters that are presently established in prefectures in Japan are shown in Appendix-2. They are mostly established based on Method A and Committee Method. As of February 2004, about 50% of debris flow prediction systems employ the Committee Method, 38% Method A, and the remaining 12% either Method B or Yano Method. With regard to the prediction of steep slope failures, although the setting ratio of standard rainfall is still about 50% at present, 90% of them use the Committee Method, 9% Method A, and 1% other method.

As seen, the Committee Method is becoming the mainstream setting method in Japan, but Method A is still widely used owing to its ease of use. In the present Guidelines, three methods - Method A, Method B, and Committee Method - were explained. Before determining which to use, features of each method, adaptability to a given region, and usage of standard rainfall shall be carefully studied and then the best possible setting method of standard rainfall for warning and evacuation against sediment disasters shall be chosen.

**(2) When sediment disasters have not occurred  
(or data of causing rainfall are not accumulated)**

In some regions, rainfall data related to the occurrence of sediment disasters may not be accumulated because of non-occurrence of such disasters, even though the hourly rainfall has been gauged. In this case, it is still possible to establish the standard rainfall for warning and evacuation if those non-causing rainfalls are analyzed. Also, the standard rainfall can be tentatively set up by referring to the analysis results of rainfalls in Japan or in other regions. What is important above all is to start operating a sediment disaster prediction system as early as possible. The data can be accumulated after that, and when enough data are accumulated, they can be reanalyzed using one of the setting methods shown above. Through such process, the existing system can be improved to an advanced sediment disaster prediction system with high accuracy.

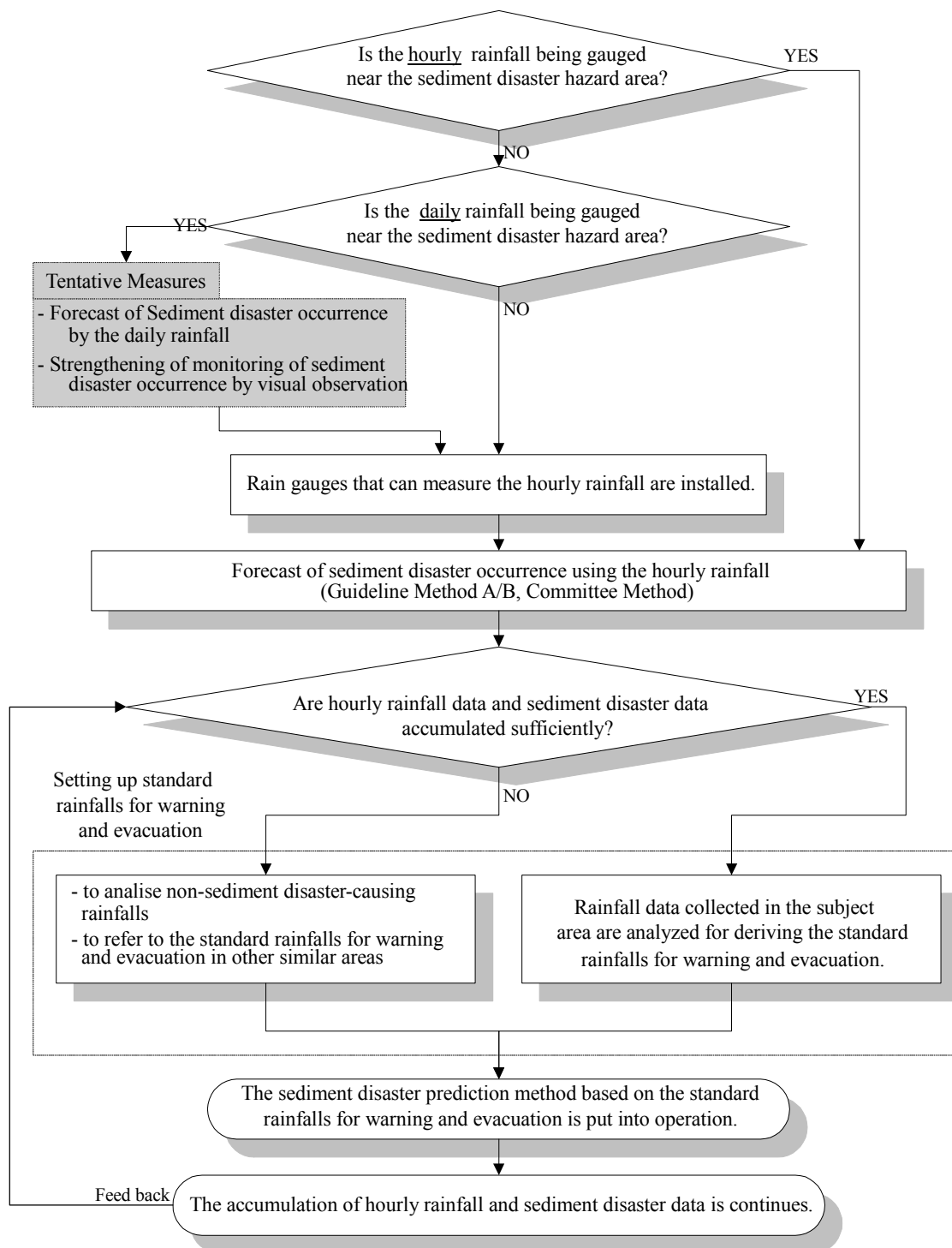
**2.3.2 Non-case when hourly rainfall data are accumulated**

On the other hand, in an area where the only rainfall being gauged is the daily rainfall, an hourly rainfall gauge should be installed in or around the sediment disaster hazard area. If the installation of an hourly rainfall gauge takes a long time, standard rainfalls may be determined using the daily rainfall data as the tentative measures before the hourly rainfall data become sufficient. In an area where rainfall data are not available at all, the visual observation system should be strengthened as the measures against sediment disasters. As mentioned earlier, in sediment disaster hazard areas where the hourly rainfall data are not currently available, it is important to start its gauging as soon as possible and set the



standard rainfalls for warning and evacuation using either the Guideline Method or Committee Method so that an efficient warning and evacuation system can be established without delay.

Fig. 2.1 shows the level-up steps of the sediment disaster forecast method with consideration for the differences in rainfall gauging levels.



**Fig. 2.1 Level-up steps of the sediment disaster forecast method in consideration of differences in rainfall gauging levels**

## **2.4 Setting of Standard Rainfalls for Warning and Evacuation by the Guideline Method**

The Guideline Method (Method A and Method B) was presented in the "Guidelines (tentative) for Setting of Rainfalls for Warning Issuance and Evacuation Instruction against Debris flow Disasters" which was prepared by the former Ministry of Construction in 1984. This method is intended to forecast the occurrence of a debris flow using rainfall indexes that are obtained by combining rainfall intensity and a total rainfall. This type of index was derived because it is known from the actual state of debris flow disasters that a debris flow tends to occur even when the total rainfall is small if the rainfall intensity is large, and that it tends to occur even when the rainfall intensity is small if the total rainfall is large. This method was originally developed for debris flows, but it is also applicable to slope failures because the occurrence process of a debris flow is similar to that of a slope failure.

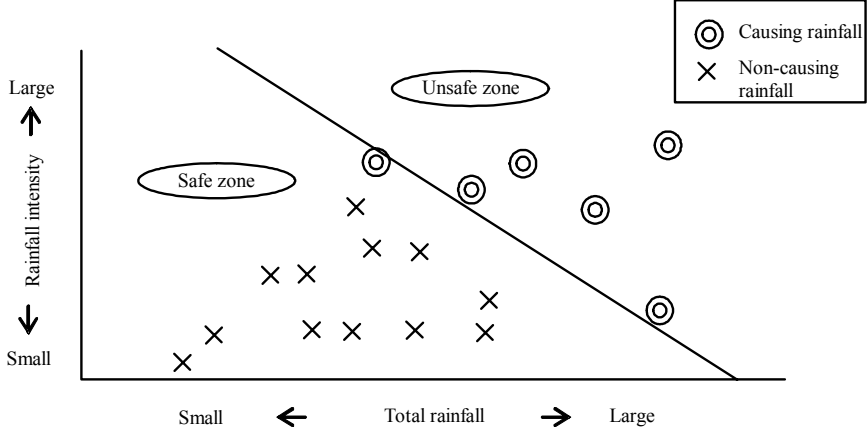
### **2.4.1 Outline of the Guideline Method**

The application area of the Guideline Method and the rainfall indexes used are summarized as shown in Table 2.2.

The setting procedure of standard rainfalls for warning and evacuation by the Guideline Method is as follows.

- 1) The representative rainfall gauging station for collecting the rainfall data of the target area shall be determined.
- 2) The rainfall data at the time when a sediment disaster, a debris flow or a slope failure, was caused (called the causing rainfall) and the rainfall data at the time when those disasters were not caused (called the non-causing rainfall) shall be collected and recorded in Form 1 and Form 2. See Table 2.3 and Table 2.4.
- 3) Even when setting the standard rainfalls for debris flows, slope failure-related data should also be collected because they are an effective set of data that indicates a behavior preceding a debris flow.
- 4) In the Guideline Method, two kinds of setting methods (Method A and Method B) are shown which are different in the use of rainfall indexes that are derived using the data in Form 1 and Form 2. In the Guideline Method, it is mentioned that if an appropriate value is not obtainable with the use of Method A, Method B may be used as the alternative. This means that use of Method A, which is easy to use, is recommended more than the use of Method B.
  - Method A: Hourly rainfall (ordinate) - Working rainfall (abscissa)
  - Method B: Effective rainfall intensity (ordinate) - Working rainfall (abscissa)

**Table 2.2 Application area and rainfall index of the Guideline Method <sup>10)</sup>**

Application area	It is specified in the Guidelines that, although stream-specific setting is more desirable, the same standard rainfalls can be used for more than one debris flow-prone mountain streams located in closer areas that have a similar topography, geology, and vegetation, if the rainfall data and the past disaster records are not sufficient for stream-specific setting. In the past setting cases, areas are usually grouped by the mechanical factors and characteristics and then standard rainfalls are set for each group which is usually a city or a town.
Rainfall index	<p>The rainfall index is expressed by a combination of the rainfall intensity and the total rainfall. As shown in the figure below, the rainfall intensity is shown in the ordinate and the total rainfall in the abscissa. Debris flow-causing rainfall and non-causing rainfall are plotted in the figure by the ⊙ and × symbols, respectively. Then, those two rainfall groups are separated with a liner line or a curved line descending to the right. The lower left side of this line is the safe zone where a debris flow may not be caused. The upper right side of this line is the unsafe zone where a debris flow may be caused.</p> 

## 2.4.2 Analysis of debris flow causing rainfall and non-causing rainfall

### (1) Collection and recording of data on debris flow-causing rainfall

Using past records and through an inquiry to the local people, the occurrence time of past debris flows and slope failures shall be identified. These data and the rainfall data obtained at a representative rainfall gauging station shall be recorded in Form-1 shown in Table 2.3. Because the total rainfall differs by the time of disaster occurrence, it is very important to obtain the highly accurate information about the exact occurrence time. In the case of old disasters, it is usually difficult to distinguish if it was a slope failure or a debris flow, in addition to the difficulty of getting the exact time of occurrence. Therefore, data should be collected from many organizations. For the collection of accurate data, it is desirable that a debris flow-prone mountain stream and a rainfall gauging station are located as closely as possible. If this is not satisfied, it is better to plan the installation of a new rain gauge to improve the future data.

### (2) Collection and recording of data on non-causing rainfall

From various data on a series of rain collected at a representative rainfall gauging station, the non-causing rainfall data shall be taken out. They are used to find a critical line that separates the occurrence and non-occurrence of sediment disasters. If a series of rain with

a small amount of rainfall that has little effect on the incidence of a sediment disaster is included in data analysis, analysis becomes complex. Therefore, data collection should be limited in principle to the rainfalls specified below. However, this can be changed in view of circumstances, such as the amount of causing rainfall and convenience of analysis. The obtained data shall be filled in Form 2 shown in Table 2.4.

- Debris flow: a continuous rainfall of 80 mm or over or hourly rainfall intensity of 20 mm or over
- Slope failure: a continuous rainfall of 40 mm or over or hourly rainfall intensity of 10 mm or over

### (3) Definitions of various rainfall indexes

When preparing Form 1 (Table 2.3) and Form 2 (Table 2.4), various rainfall indexes shall be operated. Here, the definitions of those indexes that appear in those forms are explained.

#### (i) A series of rain, continuous rainfall ( $R_C$ ), antecedent rain, antecedent rainfall ( $R_A$ )

One sequence of rain with more than 24 hours of non-rainfall duration before and after that rain is called "a series of rain". And, the total amount of rainfall during that period is called the "continuous rainfall ( $R_C$ )". This relationship is shown in Fig. 2.2. The rain during one- or two-week period before the start of a series of rain (this relates to the half-life of the working rainfall which is mentioned later) is called the antecedent rain and the rainfall during that period is called the antecedent rainfall ( $R_A$ ). Regarding the antecedent rain, the rain during 24 hours before the start of a series of rain is called the "rain of one day before," the rain between 48 hours before and 24 hours before the start of a series of rain is called the "rain of two days before". Using the same rule, the rain of n-days before can be specified. However, from the definition of a series of rain, the rainfall on one day before a series of rain is always zero.

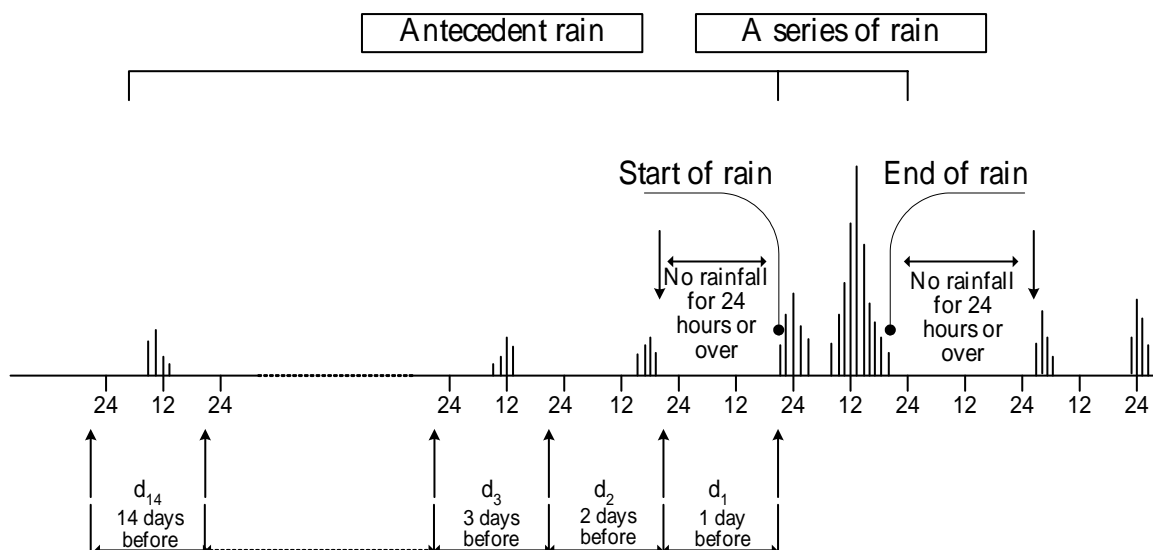


Fig. 2.2 Concept of a series of rain and the antecedent rain <sup>10)</sup>

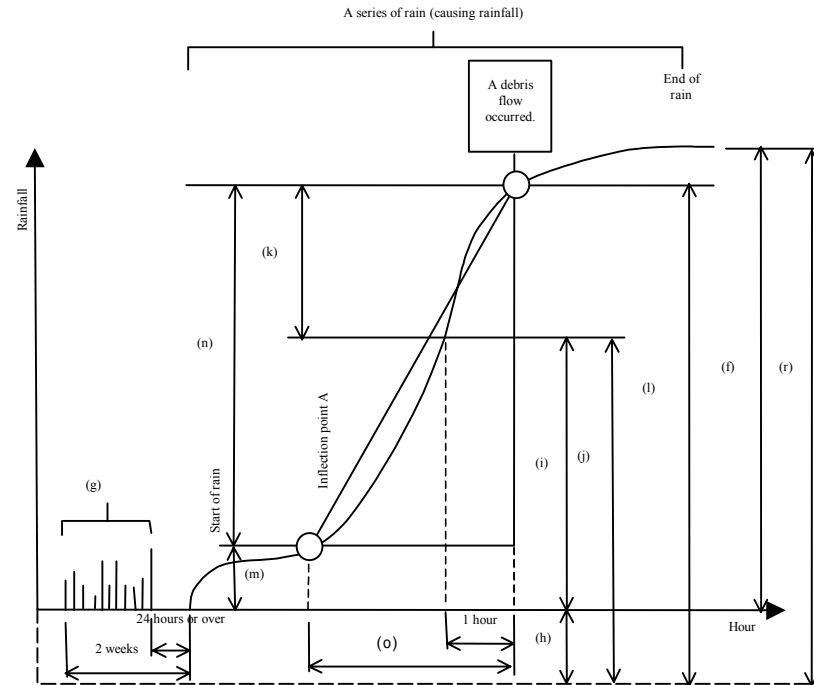
**Table 2.3 Form for recording the causing rainfall data (Form 1) <sup>10</sup>**

Municipality (Prefecture) (Representative rainfall gauging station)

(a) Reference No.	(b) Mountain stream	(c) Address	(d) No. of debris flow hazard stream	(e) Occurrence date/time	(f) Continuous rainfall (R <sub>C</sub> ) (date/time-date/time)	(g) Antecedent rainfall (RA)				(h) Antecedent working rainfall (R <sub>WA</sub> )	(i) Cumulative rainfall up to 1 hour before the occurrence of debris flow	(j) Working rainfall up to 1 hour before the occurrence of debris flow ((h) + (i))	(k) One-hour rainfall immediately before the occurrence of debris flow	(l) Working rainfall (R <sub>W</sub> ) up to the occurrence of debris flow ((i) + (k))	(m) Initial rainfall (R <sub>I</sub> ) (date/time)	(n) Effective rainfall (R <sub>E</sub> ) up to the occurrence of debris flow ((i) - (m))	(o) Effective time	(p) Effective rainfall intensity (I <sub>E</sub> ) ((n) + (o))	(q) Total working rainfall ((f) + (h))	(r) Distance between mountain stream and rainfall gauging station	(s) Remarks	
						2 days before	3 days before	4 days before	---													
a		b			c					d								eg			h	

Procedure for recording the causing rainfall data (Form 1).

- (a) Put a reference number in chronological order.
- (b) Fill in the name of a stream.
- (c) Fill in the address of a stream.
- (d) Fill in the stream No.
- (e) Fill in the date and time when a debris flow occurred. If the occurrence time is an inferred time, show it with ( ).
- (f) Fill in the continuous rainfall (R<sub>C</sub>) and the time when the rain started and ended.
- (g) Fill in the 24-hour rainfall of each day from 2 days before to 14 days before.
- (h) Fill in the antecedent working rainfall (R<sub>WA</sub>) for each specified half-life.
- (i) Fill in the cumulative rainfall from the start of a series of rain up to 1 hour before the occurrence of debris flow.
- (j) Fill in the working rainfall up to 1 hour before the occurrence of debris flow.
- (k) Fill in the one-hour rainfall immediately before the occurrence of debris flow.
- (l) Fill in the working rainfall up to the occurrence of debris flow.
- (m) Fill in the initial rainfall (R<sub>I</sub>) and the time of Inflection Point A.
- (n) Fill in the effective rainfall (R<sub>E</sub>) up to the occurrence of debris flow.
- (o) Fill in the effective time up to the occurrence of debris flow.
- (p) Fill in the effective rainfall intensity (I<sub>E</sub>) up to the occurrence of debris flow.
- (q) Fill in the total working rainfall of causing rain.
- (r) Fill in the distance from stream to representative gauging station.

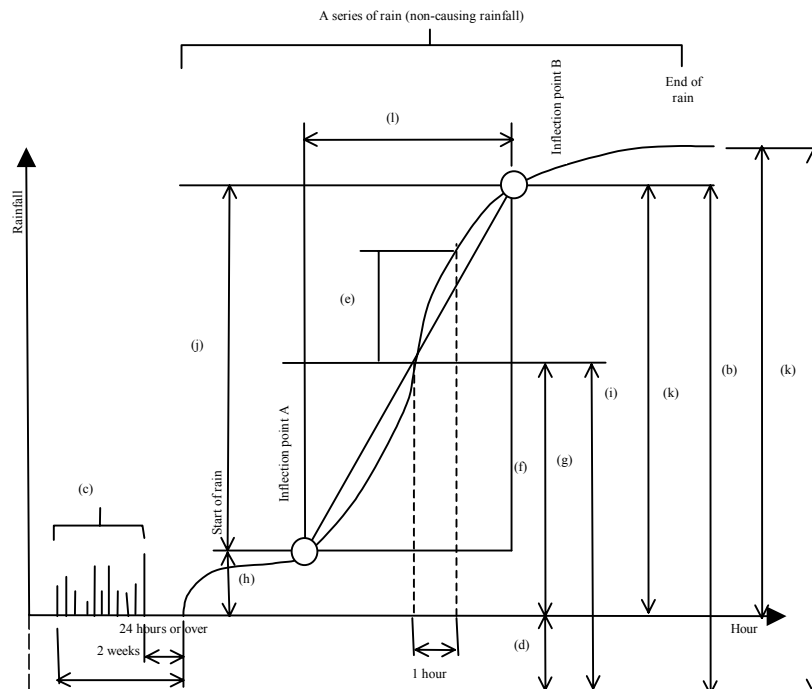


**Table 2.4 Form for recording the non-causing rainfall data (Form 2) <sup>10</sup>**

		Municipality		Prefecture		Representative rainfall gauging station										
(a) Reference No.	(b) Continuous rainfall ( $R_C$ ) (date/time-date/time)	(c) Antecedent rainfall (RA)			(h) Antecedent working rainfall ( $R_{WA}$ )	(e) Maximum hourly rainfall of non-causing rain (date/time-date/time)	(f) Cumulative rainfall up to before the start of a maximum hourly rainfall	(g) Working rainfall up to before the start of a maximum hourly rainfall ((d) + (f))	(h) Initial rainfall ( $R_I$ ) (date/time)	(i) Cumulative rainfall up to Inflection Point B (date/time)	(j) Effective rainfall ( $R_E$ ) up to Inflection Point B ((i) - (h))	(k) Working rainfall up to Inflection Point B ((d) + (i))	(l) Effective time	(m) Effective rainfall intensity ((i) + (l))	(n) Total working rainfall ((b) + (d))	Remarks
a	b	2 days before	3 days before	4 days before	14 days before	Half-life				d			c		f	

Procedure for recording the non-causing rainfall data (Form 2).

- (a) Put a reference number in chronological order of rainfall data.
- (b) Fill in the continuous rainfall ( $R_C$ ) and the time when a rain started and ended.
- (c) Fill in as done in (g) in Form 1.
- (d) Fill in as done in (h) in Form 1.
- (e) Fill in the maximum hourly rainfall in a series of rain and its starting time.
- (f) Fill in the cumulative rainfall from the start of a series of rain up to before the start of a maximum hourly rainfall.
- (g) Fill in the working rainfall up to before the start of a maximum hourly rainfall.
- (h) Fill in the initial rainfall ( $R_I$ ) and the time of Inflection Point A.
- (i) Fill in the cumulative rainfall from the start of a series of rain up to Inflection Point B and the time of Inflection Point B.
- (j) Fill in the effective rainfall up to Inflection Point B.
- (k) Fill in the working rainfall up to Inflection Point B.
- (l) Fill in the effective time up to Inflection Point B.
- (m) Fill in the effective rainfall intensity ( $I_E$ ) up to Inflection Point B.
- (n) Fill in the total working rainfall of non-causing rain.



(ii) **Working rainfall ( $R_W$ ), antecedent working rainfall ( $R_{WA}$ ), deduction coefficient**

The working rainfall is a cumulative rainfall that takes into account the effect of an antecedent rainfall. In general, debris flows occur under the influence of not only debris flow-causing rainfall but also antecedent rainfall. The degree of influence of an antecedent rainfall normally reduces as time becomes distant from a debris flow-causing rain. To derive the effect of an antecedent rainfall, the 24-hour rainfall of one day before the debris flow-causing rain is multiplied by the coefficient of " $\alpha_1$  time" and a 24-hour rainfall of two days before the debris flow-causing rain is multiplied by the coefficient of " $\alpha_2$  time". In this way, the 24-hour rainfall up to " $t$ " days before, or " $dt$ ", is multiplied by the coefficient of " $\alpha_t$  ( $\alpha_t < 1$ )". And, the total of them is called the antecedent working rainfall ( $R_{WA}$ ).

$$R_{WA} = \alpha_1 \cdot d_1 + \alpha_2 \cdot d_2 + \dots + \alpha_{14} \cdot d_{14} = \sum_{t=1}^{14} \alpha_t \cdot d_t$$

Where, the coefficient " $\alpha_t$ " is called the deduction coefficient of " $t$ " days before. There are many ways to determine " $\alpha_t$ ". When the half-life is assumed to be one day, which means the value of  $\alpha$  becomes 1/2 of " $\alpha_{t-1}$ " when one day has passed, the antecedent working rainfall ( $R_{WA}$ ) is calculated as follows.

$$R_{WA} = 0.5 \cdot d_1 + 0.25 \cdot d_2 + 0.125 \cdot d_3 \dots$$

When judging if a debris flow will occur or not, the appropriateness of judgment shall be evaluated by changing the half-life to 2 days and 3 days. The relationship between the deduction coefficient and the half-life is given by the following equation.

$$\alpha_t = 0.5^{t/T}$$

Where,  $T$  : day(s) of half-life;  $t$  : day(s) before the start of rainfall

The results of operation regarding the deduction coefficient when the half-life is 1, 2, and 3 days are shown in Table 2.5. As to the period when the deduction coefficient is less than 0.004, operation can be omitted because an effect on operation values is usually very small. But, when the antecedent rainfall is large and the values derived by multiplying a deduction coefficient are not negligible, the omission rule can be ignored.

**Table 2.5 Half-life and deduction coefficient ( $\alpha_t$ )<sup>10)</sup>**

Days before the start of rainfall	Half-life			Days before the start of rainfall	Half-life		
	1 day	2 days	3 days		1 day	2 days	3 days
1	<b>0.50000</b>	0.70711	0.79370	13	0.00012	0.01105	0.04961
2	0.25000	<b>0.50000</b>	0.62996	14	0.00006	0.00781	0.03937
3	0.12500	0.35355	<b>0.50000</b>	15	0.00003	0.00552	0.03125
4	0.03250	0.25000	0.39685	16	0.00002	0.00391	0.02480
5	0.03125	0.17678	0.31498	17	0.00001	0.00276	0.01969
6	0.01563	0.12500	0.25000	18	0.00000	0.00195	0.01563
7	0.00781	0.08839	0.19843	19	0.00000	0.00138	0.01240
8	0.00391	0.06250	0.15749	20	0.00000	0.00098	0.00984
9	0.00195	0.04419	0.12500	21	0.00000	0.00069	0.00781
10	0.00098	0.03125	0.09921	22	0.00000	0.00049	0.00620
11	0.00049	0.02210	0.07875	23	0.00000	0.00035	0.00492
12	0.00024	0.01563	0.06250	24	0.00000	0.00024	0.00391

Note 1: The shaded area in the table shows the period when an influence on the working rainfall would not be serious.

Note 2: For example, if the 24-hour rainfall is 200 mm when the deduction coefficient is 0.004, the value added to the working rainfall becomes  $0.004 \times 200 \text{ mm} = 0.8 \text{ mm}$ .

**(iii) Inflection point A, Inflection Point B**

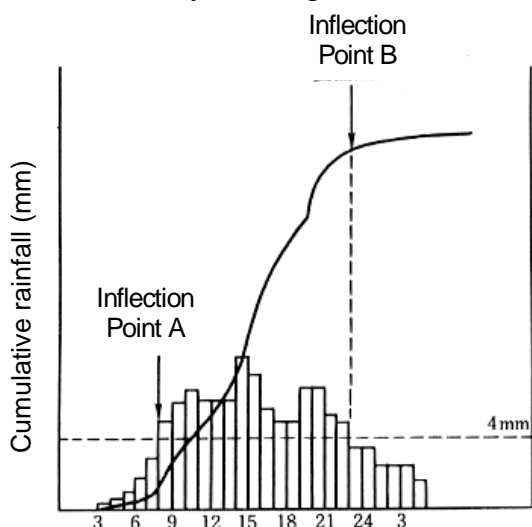
Inflection Point A is a point when the value in the cumulative rainfall curve of a series of rain begins to increase sharply. It is usually a point when an hourly rainfall of 4 mm or over begins to rain for the first time. Inflection Point B is a point when the value in the cumulative rainfall curve of a series of rain begins to stop a sharp increase. It is usually a point when an hourly rainfall of less than 4 mm begins to rain for 3 hours or more (See Fig. 2.3).

**(iv) Initial rainfall (RI)**

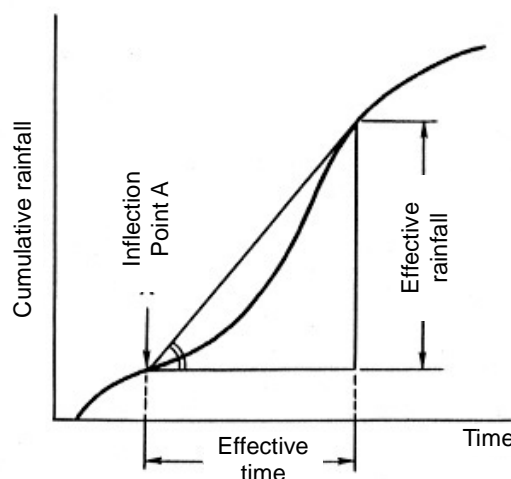
The initial rainfall is a cumulative rainfall from the start of a series of rain up to Inflection Point A.

**(v) Effective rainfall (RE) , effective time, and effective rainfall intensity (IE)**

The effective rainfall is a rainfall derived by deducting a cumulative rainfall up to Inflection Point A from the cumulative rainfall of a series of rain up to a given point. Namely, it is a cumulative rainfall after Inflection Point A. The effective time is the raining hours from Inflection Point A up to an effective rainfall. The effective rainfall intensity is a value derived by dividing the effective rainfall by the effective time (See Fig. 2.4).



**Fig. 2.3 Definitions of Inflection Point A and Inflection Point B**



**Fig. 2.4 Effective rainfall, effective time, and effective rainfall intensity<sup>10)</sup>**

**2.4.3 Setting of standard rainfalls by Method A (Guideline Method)<sup>10)</sup>**

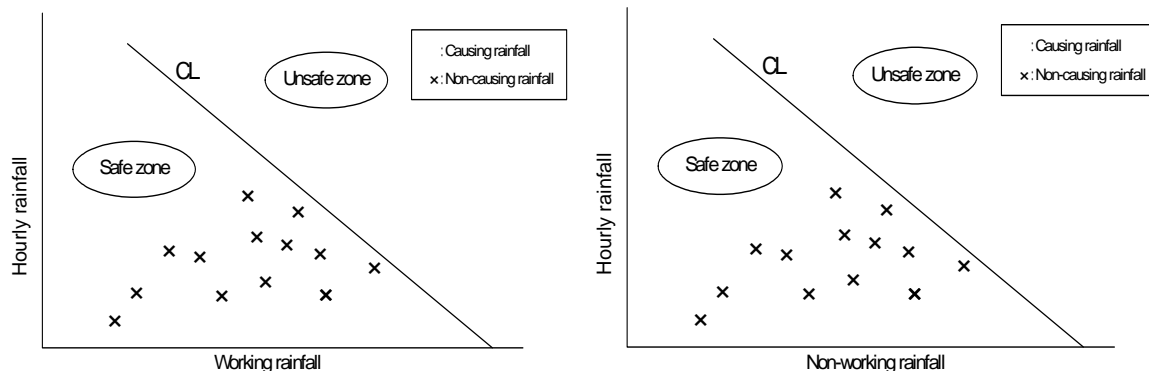
**(1) Setting of the critical line (CL)**

An X-Y graph is prepared by placing (j) and (k) in Form 1 (Table 2.3) and (g) and (e) in Form 2 (Table 2.4) in the abscissa and the ordinate as shown in Fig. 2.5. The rainfall indexes depicted in the X-Y graph are defined as shown in Table 2.6. Attention should be paid to the fact that one-hour time lag is intentionally introduced between the two axes. It is a kind of idea to express a standard rainfall for warning and a standard rainfall for evacuation (these are explained later) using only one rainfall index. In that respect, this X-Y graph is essentially different from an ordinary X-Y graph used in mathematics.



**Table 2.6 Definitions of rainfall indexes depicted in a graph <sup>10)</sup>**

	The X axis (abscissa)	The Y axis (ordinate)
Causing rainfall	(j): The working rainfall up to 1 hour before the occurrence of debris flow	(k): One-hour rainfall immediately before the occurrence of debris flow
Non-causing rainfall	(g): The working rainfall up to before the start of a maximum hourly rainfall	(e): The maximum hourly rainfall in a series of rain

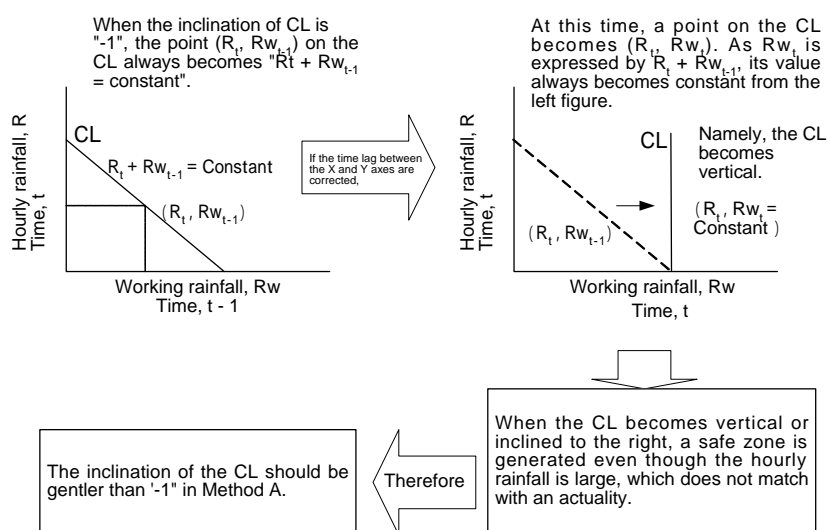


**(a) If causing rainfalls are available**

**(b) If causing rainfalls are not available**

**Fig. 2.5 The X-Y graph by Method A <sup>10)</sup>**

In Fig. 2.5, a boundary line is drawn between the debris flow causing rainfalls and the non-causing rainfalls. The upper right side of the boundary line is the unsafe zone where a debris flow may occur and the lower left side of the line is the safe zone where a debris flow may not occur. This boundary line is called the Critical Line (CL) which distinguishes the occurrence and non-occurrence of a debris flow. When the inclination of the CL is shown by "a", the inclination "a" should be gentler than "-1" and within the range of "-1 < a < 0", as shown in Fig. 2.6.



**Fig. 2.6 The limit of the critical line (CL) by Method A <sup>10)</sup>**

**(2) Setting of the warning line (WL) and the evacuation line (EL)**

Methods for setting the standard rainfall for issuing a warning (hereafter referred to as the standard rainfall for warning) and the standard rainfall for instructing an evacuation (hereafter referred to as the standard rainfall for evacuation) are explained below. In the following sections, the standard line indicating the standard rainfall for warning is called the "Warning Line (WL)" and the standard line indicating the standard rainfall for evacuation is called the "Evacuation Line (EL)".

Before setting the WL and EL, it is needed to determine the timing to give a warning issuance or an evacuation instruction. It means that how many hours before the forecasted occurrence time a warning issuance or an evacuation instruction should be given so that people as well as organizations can take necessary actions for safety. After that, the WL and EL are set in consideration of an estimated rainfall during the spare hours (forecasted rainfall) and the Critical Line (CL). In the Guideline Method, a setting method using conditions in Table 2.7 is shown. But, the timing of warning issuance and evacuation instruction can be determined based on the conditions of each area. As to the estimated rainfall during the spare hours, the probable rainfall or the short-term rainfall may be used depending on conditions, such as the non-hit rate of a warning. The setting method of the WL and EL based on conditions shown in Table 2.7 is given below.

**Table 2.7 The timing of a warning issuance and an evacuation instruction, and the forecasted rainfall during spare hours employed in the Guideline Method <sup>10)</sup>**

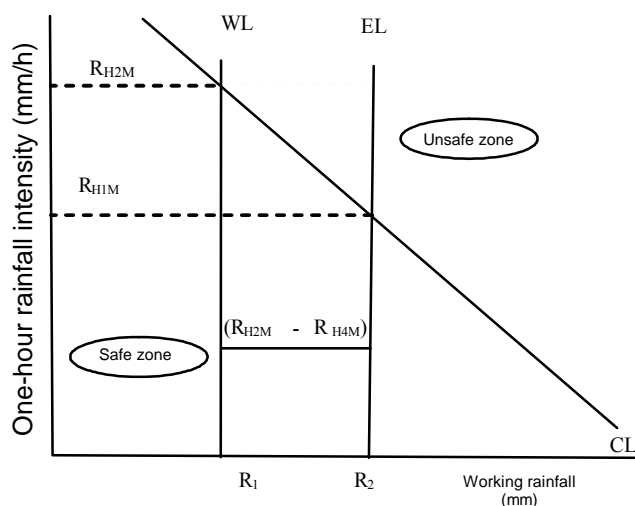
Type	Timing of issuance/ instruction	Forecasted rainfall during the spare hours
Issuance of a warning	2 hours before reaching the CL	Past maximum 2-hour rainfall ( $R_{H2M}$ )
Instruction of an evacuation	1 hour before reaching the CL	Past maximum 1-hour rainfall ( $R_{H1M}$ )

**<Setting of the evacuation line (EL)>**

The past maximum 1-hour rainfall is shown by  $R_{H1M}$ . An interpretation of Fig.2.7 is that if the working rainfall of a given rain has reached  $R_2$  and if the forecasted rainfall for 1 hour from now is more than  $R_{H1M}$ , then it will enter the area in the upper right side of the CL, or the unsafe zone. When  $R_2$  is derived by assuming that the forecast rainfall for 1 hour from now, or  $R_{H1M}$ , will be the past maximum 1 hour rainfall, it will be the standard rainfall for evacuation instruction. In an actual setting of the EL, the forecasted rainfall for 1 hour from now, or  $R_{H1M}$ , is placed in the ordinate and a straight line passing that point is drawn in parallel to the abscissa. And then, a perpendicular line is drawn from the intersection point of the straight line and the CL toward the abscissa. That line is the EL.

**<Setting of the warning line (WL)>**

The past maximum 2-hour rainfall is shown by  $R_{H2M}$ . If one hour before reaching the EL is assumed as the WL, a straight line that is obtained by parallel displacement of the EL toward the left side by " $R_{H2M} - R_{H1M}$ " becomes the WL (Fig. 2.7).



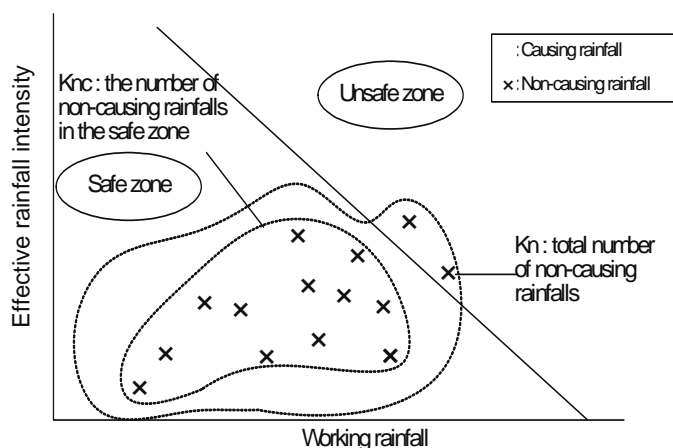
**Fig. 2.7 Setting of the warning line (WL) and the evacuation line (EL) (Method A)** <sup>10)</sup>

**(3) Investigation of the adequacy of the CL, EL, and WL**

An adequacy of the established CL, EL, and WL is investigated in terms of separability, frequency of issuance, and the non-hit rate.

**<Separability>**

If all debris flow causing rainfalls come in the unsafe zone in the upper right side and all non-causing rainfalls come in the safe zone in the lower left side taking the CL as the boundary line, it can be said that both rainfalls show a good separability. Actually, however, some of non-causing rainfalls come in the unsafe zone as seen in Fig. 2.8. Hence, the separability of the CL is investigated using the number of non-causing rainfalls. The total number of non-causing rainfalls is assumed as "Kn" and the number of non-causing rainfalls that come in the safe zone is assumed as "Knc". Then, calculation is made using an equation,  $S_c = K_{nc} / K_n$ . It is judged that the greater the value of  $S_c$ , the better the separability is.



**Fig. 2.8 Investigation of separability** <sup>10)</sup>

**<Frequency of warning issuance and evacuation instruction>**

With regard to the established WL and EL, the frequency of warning issuance and evacuation instruction per year is investigated. The number of data in which the total working rainfall of a causing rainfall (Form 1, (q)) exceeds "R<sub>1</sub>" and "R<sub>2</sub>" in Fig. 2.7 is

assumed as " $K_{yw}$ " and " $K_{ye}$ ", respectively. And, the number of data in which the total working rainfall of a non-causing rainfall (Form 2, (n)) exceeds " $R_1$ " and " $R_2$ " is assumed as " $K_{nw}$ " and " $K_{ne}$ ", respectively. Then, the frequency of warning issuance and the frequency of evacuation instruction are derived using the following equations, respectively.

$$\text{Frequency of warning issuance: } F_w = \frac{k_{yw} + k_{nw}}{n} \quad (\text{time/year})$$

$$\text{Frequency of evacuation instruction: } F_e = \frac{k_{ye} + k_{ne}}{n} \quad (\text{time/year})$$

Where, "n" is the number of years in which the data are collected.

#### <Non-hit rate of warning issuance and evacuation instruction>

Even though a warning is issued and an evacuation is instructed, a sediment disaster does not necessarily occur. This kind of non-hit rate is calculated using the following equations. The non-hit rate here is not intended for assessing the accuracy of the CL, but for assessing the adequacy of a forecasted rainfall used for the setting of the EL and WL.

$$\text{Non-hit rate of warning issuance: } M_w = \frac{k_{nw}}{n} \quad (\text{time/year})$$

$$\text{Non-hit rate of evacuation instruction: } M_e = \frac{k_{ne}}{n} \quad (\text{time/year})$$

#### (4) Setting of the standard rainfalls for warning and evacuation

After comparing various procedures and confirming the adequacy of the CL, EL, and WL, the standard rainfall for warning and the standard rainfall for evacuation are established as follows.

Standard rainfall for warning:  $R_1$  (mm)

Standard rainfall for evacuation:  $R_2$  (mm)

#### 2.4.4 Setting of standard rainfall by Method B (Guideline Method)

##### (1) Setting of the critical line (CL)

To set the CL, the relationship between the effective rainfall intensity (ordinate) and the working rainfall (abscissa) is plotted in the X-Y graph using the data of debris flow-causing rainfalls and non-causing rainfalls that were filled in Form 1 and Form 2. Namely, plotted in the figure are "(l) working rainfall up to the occurrence of debris flow" and "(p) the effective rainfall intensity up to the occurrence of debris flow" which were filled in Form 1 for causing rainfalls, and "(k) working rainfall up to Inflection Point B" and "(m) effective rainfall intensity up to Inflection Point B" which were filled in Form 2 for non-causing rainfalls.

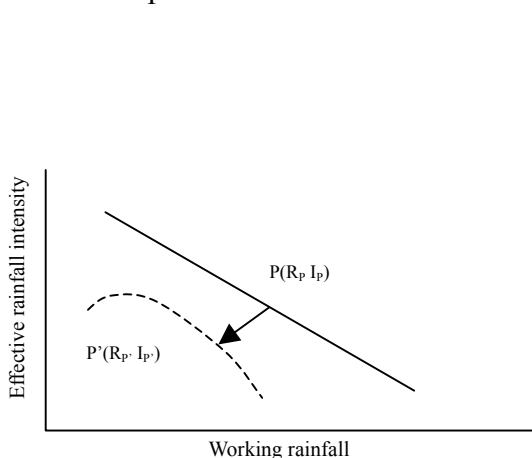
A restriction on the inclination of the CL, namely,  $CL > -1$ , which is imposed in Method A does not apply to Method B, because a time lag of one hour between the abscissa and the ordinate is not assumed in Method B.

**(2) Setting of the warning line (WL) and the evacuation line (EL)**

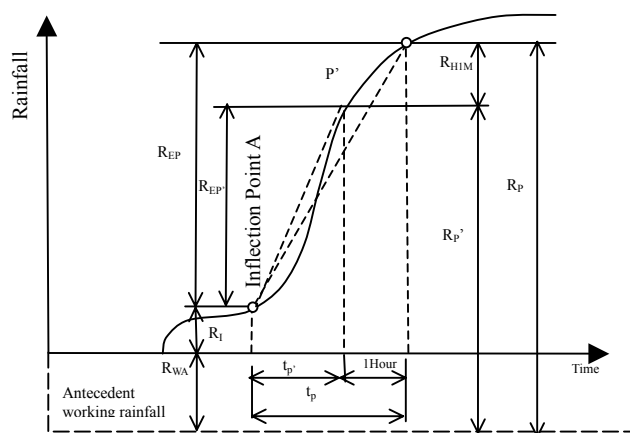
An approach to the forecasted rainfall and the timing of warning issuance and evacuation instruction of Method B is the same as that of Method A. The setting procedure of the WL and the EL by Method B using the same conditions in Table 2.7 is shown below.

**<Setting of the evacuation line (EL)>**

A given point on the critical line (CL) in Fig. 2.9 is assumed as Point P ( $R_p, I_p$ ) and a position one hour before reaching Point P is assumed as Point P' ( $R_{p'}, I_{p'}$ ). When the forecast rainfall for the evacuation instruction is the past maximum one-hour rainfall ( $R_{H1M}$ ), then Point P' is a point on the evacuation line (EL). As the equation of the CL is already obtained, the unknown point P' can be obtained from the known point P. Figure 2.10 shows the relationship between the time and the accumulative rainfall of a series of rain which passed Point P' and then reached Point P.



**Fig. 2.9 Setting of the evacuation line (EL)<sup>10)</sup>**



**Fig. 2.10 Relationship between the time and the accumulative rainfall<sup>10)</sup>**

From Fig. 2.10,  $R_{p'}$  is expressed,

$$R_{p'} = R_p - R_{H1M} \dots\dots\dots (1)$$

The rainfall intensity,  $I_{p'}$ , can be can be obtained by the following equation.

$$I_{p'} = \frac{R_{EP'}}{t_{p'}} = \frac{R_{EP} - R_{H1M}}{t_p - 1} \dots\dots\dots (2)$$

Also,  $T_p$  becomes,

$$t_p = \frac{R_{EP}}{I_p} = \frac{R_p - (R_{WA} + R_I)}{I_p} \dots\dots\dots (3)$$

If Equation (3) is substituted for Equation (2),

$$I_{p'} = \frac{R_p - (R_{WA} + R_I) - R_{H1M}}{\frac{R_p - (R_{WA} + R_I)}{I_p} - 1} \dots\dots\dots (4)$$

Usually, values of  $R_{WA}$  and  $R_I$  are unknown and their values are considerably smaller than the value of  $R_p$ . Then, if  $R_{WA} + R_I = 0$  is assumed, Equation (4) is expressed as follows by

approximation.

$$I_{P'} = \frac{R_P - R_{H1M}}{\frac{R_P}{I_P} - 1} = \frac{(R_P - R_{H1M})I_P}{R_P - I_P} \dots\dots\dots (5)$$

Namely, relative to Point P ( $R_P, I_P$ ) on the CL, Point P' ( $R_{P'}, I_{P'}$ ) which is the point one hour before can be obtained using Equation (1) and Equation (5).

Next, a general equation of the evacuation line (EL) is shown. When the equation of the critical line (CL) is expressed as  $Y = aX + b$ , Point P ( $R_P, I_P$ ) is a point on this straight line and it has a following relationship.

$$I_P = a \cdot R_P + b \dots\dots\dots (6)$$

If  $R_P$  and  $I_P$  are eliminated from Equations (1),(5), and (6), it becomes,

$$I_{P'} = \frac{a(R_{P'})^2 + (b + aR_{H1M})R_{P'}}{(1-a)R_{P'} + (1-a)R_{H1M} - b} \dots\dots\dots (7)$$

Namely, relative to the equation of the critical line (CL) which is  $Y = aX + b$ , a general equation of the evacuation line (EL) is expressed as shown below when the Y: effective rainfall intensity and X: working rainfall.

$$Y = \frac{aX^2 + (b + aR_{H1M})X}{(1-a)X + (1-a)R_{H1M} - b} \dots\dots\dots (11)$$

**<Setting of the warning line (WL)>**

As with the setting of the evacuation line, a given point on the CL in Fig. 2.9 is assumed as P ( $R_P, I_P$ ) and the forecasted rainfall is assumed as the past maximum 2-hour rainfall ( $R_{H2M}$ ). If the position two hours before reaching the point P is P'' ( $R_{P''}, I_{P''}$ ), then  $I_{P''}$  is expressed as follows.

$$I_{P''} = \frac{a(R_{P''})^2 + (b + aR_{H2M})R_{P''}}{(1-2a)R_{P''} + (1-2a)R_{H2M} - 2b}$$

A general equation showing the WL becomes as follows (See Fig. 2.11).

$$Y = \frac{aX^2 + (b + aR_{H1M})X}{(1-a)X + (1-a)R_{H1M} - b}$$

**<Curves of the evacuation line (EL) and the warning line (WL)>**

The EL and WL are the curved lines that pass the origin of the coordinate axes (0, 0) and are convex shaped toward the upside.  $R_u$  is a working rainfall value below which is usually uninfluential to the occurrence of a debris flow. That value is approximately 40 mm. But, if an appropriate value other than this is found from the collected data, that value should be used.

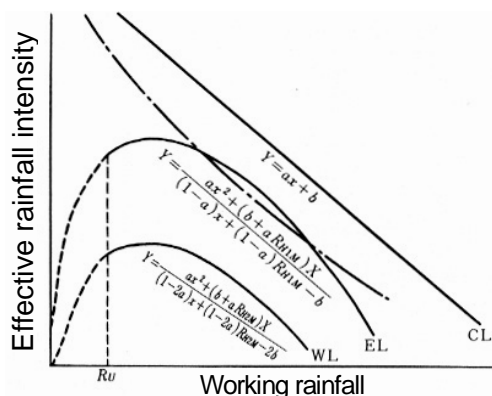


Fig. 2.11 General equations expressing the EL and the WL <sup>10)</sup>

(3) Investigation of the adequacy of the CL, EL, and WL

An approach to this investigation is basically the same with that taken in Method A. Focusing on the differences from Method A, adequacy of the three lines is investigated as shown below.

<Separability>

Using the same method with that in Method A, the separability of the critical line (CL) is investigated.

<Frequency of warning issuance and evacuation instruction>

With regard to the established WL and EL, the frequency of warning issuance and evacuation instruction per year is investigated. The number of data in which the total working rainfall of a causing rainfall exceeds the WL and the EL in Fig. 2.12 is assumed as "K' <sub>yw</sub>" and "K' <sub>ye</sub>", respectively. And, the number of data in which the total working rainfall of a non-causing rainfall exceeds the WL and the EL in Fig. 2.12 is assumed as "K' <sub>nw</sub>" and "K' <sub>ne</sub>", respectively. Then, the frequency of warning issuance and the frequency of evacuation instruction are derived using the following equations, respectively.

$$\text{Frequency of warning issuance: } F'_w = \frac{k'_{yw} + k'_{nw}}{n} \quad (\text{time/year})$$

$$\text{Frequency of evacuation instruction: } F'_e = \frac{k'_{ye} + k'_{ne}}{n} \quad (\text{time/year})$$

Where, n is the number of years in which the data are collected.

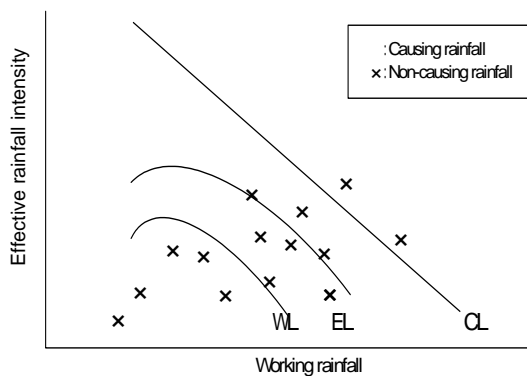


Fig. 2.12 Investigation of the frequency of warning issuance and evacuation instruction <sup>10)</sup>

### <Non-hit rate of warning issuance and evacuation instruction>

Even though a warning is issued and an evacuation is instructed, a debris flow does not necessarily occur. This kind of non-hit rate is calculated using the following equations.

$$\text{Non-hit rate of warning issuance: } M'_w = \frac{k'_{nw}}{n} \quad (\text{time/year})$$

$$\text{Non-hit rate of evacuation instruction: } M'_e = \frac{k'_{ne}}{n} \quad (\text{time/year})$$

#### (4) Setting of the standard rainfalls for warning and evacuation

After comparing various procedures and confirming the adequacy of the CL, EL, and WL, the standard rainfall for warning and the standard rainfall for evacuation are established as follows.

$$\text{Standard rainfall for warning: } Y = \frac{aX^2 + (b + aR_{H1M})X}{(1-2a)X + (1-2a)R_{H1M} - 2b} \quad (X \geq R_u)$$

$$\text{Standard rainfall for evacuation: } Y = \frac{aX^2 + (b + aR_{H1M})X}{(1-a)X + (1-a)R_{H1M} - b} \quad (X \geq R_u)$$

Where a, b: constants

### 2.4.5 Features of Guideline Method and care for use

#### (1) Judgment by the snake line and care for use

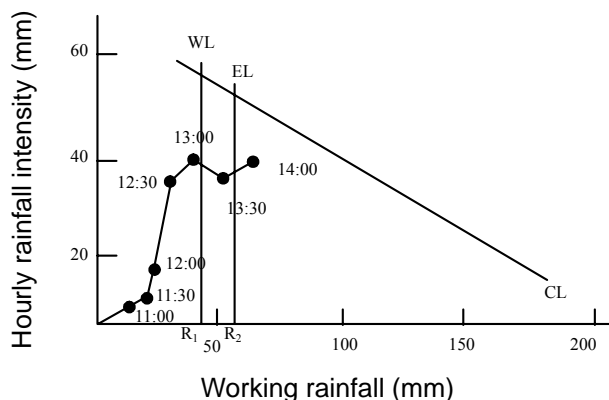
The snake line is a line that shows the changes of two rainfall indexes with time, as seen in Fig. 2.13. In this figure, the snake line is depicted at an interval of 30 minutes. If the interval is made shorter, judgment will become more accurate.

Figure 2.13 contains several points that may easily be misunderstood. Hence, care is needed concerning the points explained hereafter. Figure 2.13 is intended to visually show how the rainfall indexes are approaching to the EL and the WL which are predetermined by Method A. This figure also contains the CL. It seems at first glance that the figure is also intended to show how the rainfall indexes are approaching to the CL. But, this is not the case. As mentioned earlier in the section of standard rainfall setting, one-hour time lag is assumed between the abscissa and the ordinate in the case of Method A. It means that when the working rainfall shown in the abscissa in the figure has reached the  $R_1$  or  $R_2$ , the snake line will reach the CL if the past maximum 1-hour rainfall or the past maximum 2-hour rainfall which were chosen as the forecast rainfalls will rain from that time on. In other words, the ordinate should show the forecast rainfall, and should not show the rainfall intensity gauged at the same time with the gauging of the working rainfall in the abscissa. Hence, to avoid a misunderstanding, care is needed not to simply compare the snake line and the CL shown in the figure.

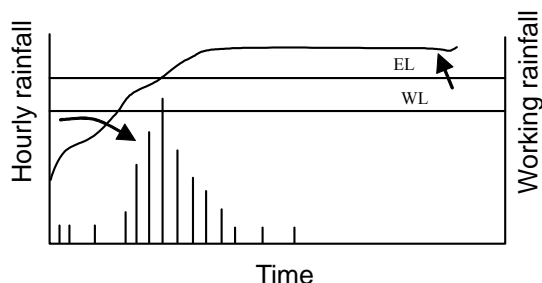
The EL and the WL in Method A are the standards defined by only the working rainfall in the abscissa. So, the changes of an index in the ordinate are basically needless. If it is desired to place an index in the ordinate by all means, a figure like Fig. 2.14 is good enough. The time axis in this figure is easy to understand and will not cause a misunderstanding. What is mentioned above is a problem innate to Method A only, and has



nothing to do with Method B which assumes no time lag between the abscissa and the ordinate.



**Fig. 2.13 Judgment by the snake line employed in Guideline Method <sup>10)</sup>**



**Fig. 2.14 Improvement of the judging method <sup>10)</sup>**

**(2) Characteristics of snake line movement**

In Method A and Method B, the working rainfall is derived by the addition of the antecedent working rainfall to the continuous rainfall. Hence, the snake line in the figure always goes upward relative to the abscissa during the period of a series of rain. As a result, if a small amount of rainfall continues for a long time or an intermittent rain continues, the snake line will easily exceed the WL and the EL or the exceeding period will drag on. This causes a problem especially when attempting to cancel a warning or an evacuation instruction.

**2.5 Method Proposed by the Committee for Studying Comprehensive Sediment Control Measures (Committee Method)**

The Committee Method is the method proposed by the Committee for Studying Comprehensive Sediment Control Measures which was organized by the Ministry of Land, Infrastructure and Transport. It was originally proposed as the "Setting Method of Standard Rainfall for Warning and Evacuation against Collective Precipice Failures (Tentative)". But, it is rated as effective for debris flows because the tank model used for this derivation is found to be effective for the forecast of debris flow occurrence.

**2.5.1 Outline of the Committee Method**

Table 2.8 summarizes the applications area and the rainfall index with regard to the setting method of standard rainfalls for warning and evacuation by Committee Method.

The setting procedure of standard rainfalls for warning and evacuation is as follows.

- 1) A representative rainfall gauging station for collecting the rainfall data of the target area shall be determined.
- 2) The rainfall data at the time sediment disasters (debris flows and slope failures) were caused (called the causing rainfall) and the rainfall data at the time those disasters were not caused (called the non-causing rainfall) shall be collected and recorded in forms.

- 3) The data on the precipice collapse that occurs collectively and the data on other disasters shall be separated and filled into respective forms. The X-Y graph shall be prepared for the causing rainfalls and the non-causing rainfalls by placing the working rainfall with a half-life of 72 hours in the abscissa and the working rainfall with a half-life of 1.5 hours in the ordinate. Using this graph, various standard lines are determined.

**Table 2.8 Application area and rainfall index of the Committee Method <sup>10)</sup>**

Application area	This is applicable to the areas at risk of slope failures, such as steep slope hazard areas. In view of the fact that the rainfall data and slope failure cases are not sufficient, the same standard rainfalls may be employed in closely-located areas having a similar topography, geology, and vegetation.
Rainfall index	It is known from past researches that the timing of slope failure occurrence can be explained from the changes in the water storage height of the tank model. It is verified that there is a good agreement between the changes of the water storage height of the 1st layer tank which indicates the changes in the surface water and the changes in the working rainfall with a half-life of 1.5 hours, as well as between the changes in the water storage height of the 2nd and 3rd layer tanks which indicate the changes of groundwater and the changes in the working rainfall with a half-life of 72 hours.  Hence, it is determined that the working rainfall, which is easy to use, shall be used as the rainfall index to evaluate the critical rainfall between the occurrence and non-occurrence of slope failures.

The operation method of the working rainfall in the Committee Method is different from that in the Guideline Method which calculated the working rainfall by the unit of day. Namely, all the rainfalls up to one hour before the occurrence of a sediment disaster (debris flow or slope failure) are assumed as the antecedent rainfall. Those rainfalls are multiplied by the deduction coefficient and then integrated using the equations shown below. In the case of non-causing rainfalls, the working rainfall is operated at the time of a maximum hourly rainfall during a series of rain, in the same way as done in the Guideline Method.

$$R_w = \sum \alpha_{i_i} \times R_{i_i} \quad \alpha_{i_i} = 0.5^{i/T}$$

where  $R_w$  : working rainfall

$R_{i_i}$  : one-hour rainfall at the time  $i$  -hours ago

$\alpha_{i_i}$  : deduction coefficient at the time  $i$  - hour ago

$T$  : half-life (hour)

In the Committee Method, two types of rainfall indexes are operated. Namely, the working rainfalls at the time sediment disasters occurred and did not occur are operated employing the half-life of 1.5 hours and 72 hours. When calculating the working rainfall, the problem is that the rainfalls of how many hours before should be included in the calculation. In general, the desirable retroactive calculation period is the period when the deduction coefficient remains 0.004 or over considering from the effect on the working rainfall, as mentioned in the working rainfall calculation of the Guideline Method. The time when the half-life becomes less than 0.004 is approximately 12 hours before when the half-life is 1.5 hours and about 574 hours (24 days) before when the half-life is 72 hours.

## 2.5.2 Collection and recording of the data on causing/non-causing rainfalls of sediment disasters

### (1) Collection and recording of the data on causing rainfall

Utilizing past records and through an inquiry to the local people, the occurrence time of past sediment disasters and other related data shall be grasped. These data and the rainfall data obtained at representative rainfall gauging stations shall be recorded in a form shown in Table 2.9.

Because the total rainfall differs by the occurrence time of a disaster, it is very important to gather highly accurate information about the occurrence time. In the case of old disasters, it is usually difficult to distinguish if it was a slope failure or a debris flow, in addition to the difficulty of getting the exact occurrence time. Therefore, data should be collected from as many organizations as possible. For the collection of accurate data, it is desirable that debris flow-prone mountain streams and rainfall gauging stations are located as closely as possible. If this is not satisfied, it is better to consider the installation of a new rain gauge to improve the accuracy of future data.

**Table 2.9 Form for recording the data on causing rainfall <sup>10)</sup>**

Item	Application
(a) Reference No.	
(b) Type of failure	Precipice failure (collective occurrence), precipice failure (individual occurrence), debris flow, etc.
(c) Hazard area/mountain stream	
(d) Address/lot	
(e) No. of hazard area /hazard stream	
(f) Amount of sediment moved	
(g) Damage	
(h) Date/time of occurrence	
(i) Representative gauging station	
(j) Distance to the representative gauging station	
(k) Working rainfall one hour before a disaster occurred (half-life: 72 hours)	Depicted in the X-Y graph.
(l) Ditto, above (half-life: 1.5 hours)	
(m) Working rainfall at the time a disaster occurred (half-life: 72 hours)	
(n) Ditto, above (half-life: 1.5 hours)	
(o) Remarks	

### (2) Collection and recording of the data on non-causing rainfall

Rainfalls that did not cause sediment disasters shall be selected from among a series of rains having a 24-hour non-precipitation period before and after. The data collected are filled in the form as shown in Table 2.10. Basically, the data collection should be limited to the rainfalls shown below, because analysis becomes complex if rainfalls with a small amount of precipitation are included. However, this can be changed depending on the amount of causing rainfalls or for convenience of analysis.

- Debris flows : a continuous rainfall of 80 mm or over, or an hourly rainfall

- intensity of 20 mm or over
- Slope failures : a continuous rainfall of 40 mm or over, or an hourly rainfall intensity of 10 mm or over

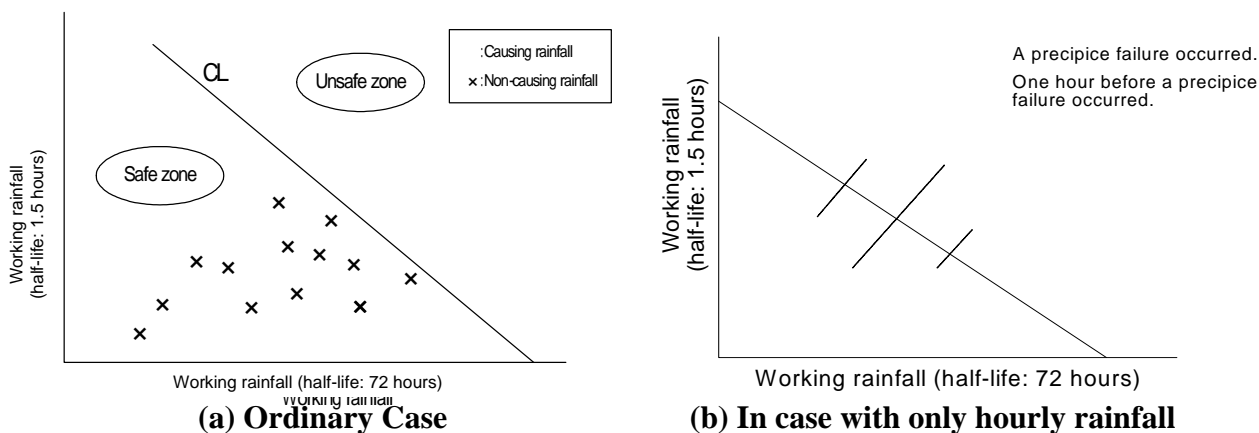
**Table 2.10 Form for recording the data on non-causing rainfall <sup>10)</sup>**

Item	Application
(a) Reference No.	
(b) Representative gauging station	
(c) Continuous rainfall (date/time-date/time, total rainfall)	The same as the Guideline Method
(d) Maximum hourly rainfall during a continuous rainfall (date/time, rainfall value)	
(e) Working rainfall at the time of a maximum hourly rainfall (half-life: 72 hours)	
(f) Ditto, above (half-life: 1.5 hours)	
(g) Time at which a maximum working rainfall occurred	The time when $\sqrt{x^2 + y^2}$ is at its maximum during a series of rain. (Time when the distance from the origin becomes the largest.)
(h) Working rainfall at the time of a maximum working rainfall (half-life: 72 hours)	Depicted in the X-Y graph.
(i) Ditto, above (half-life: 1.5 hours)	
(j) Remarks	

### 2.5.3. Setting of standard rainfalls

#### (1) Setting of the critical line (CL)

Using the data of slope failures or debris flows that occurred collectively in the target area, the rainfalls up to the time those disasters occurred and the rainfalls up to the time those disasters did not occur shall be evaluated by the working rainfall (half-life: 72 hours and 1.5 hours). Then, the critical line (CL) is drawn at the boundary of those two rainfalls. See Fig. 2.15(a). If the only available data is the hourly rainfall data, the CL can be drawn between the working rainfalls one hour before the occurrence of disasters and the working rainfalls at the time those disasters occurred. See Fig. 2.15(b).



**Fig. 2.15 Setting of critical line (CL) <sup>10)</sup>**

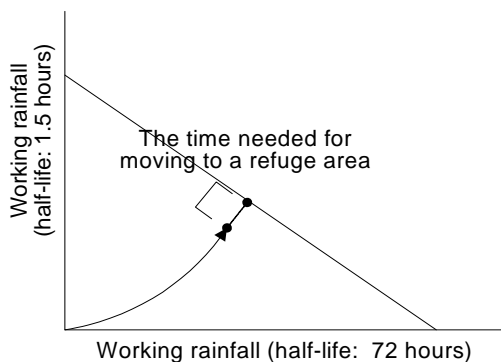
## (2) Setting of the evacuation line (EL)

If, in view of the amount of forecast rainfall, the snake line obtained by the working rainfall is expected to reach the CL after some hours needed for evacuation has passed, an evacuation action should be started immediately. And, this boundary line is called the evacuation line (EL). See Fig. 2.16(a).

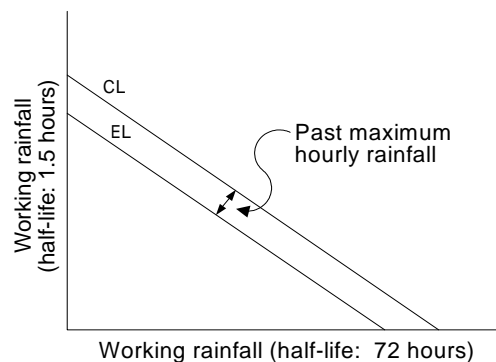
The forecast rainfall shall be estimated from the short-term rainfall forecast obtained from a radar rain gauge. It should be used after its adequacy to the target area is confirmed. When the short-term rainfall forecast is not available, the forecast rainfall during the time needed for evacuation should be determined from the past rainfall records of the area, and using it the EL shall be established.

The time needed for evacuation shall be determined in consideration of the actual conditions of each area. The following is a setting example of the EL when the time needed for evacuation is assumed as one hour.

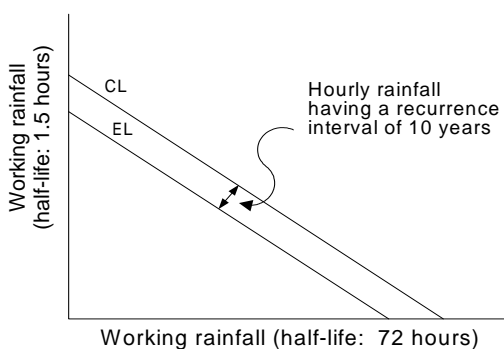
- 1) As with Method A and Method B in the Guideline Method, the past maximum hourly rainfall of the area shall be used as the forecast rainfall (See Fig. 2.16(b)).
- 2) If the frequency of issuance and the non-hit rate become excessive when the forecast rainfall is set according to 1), the hourly rainfall having a recurrence interval of 10 years, which is often used for the setting of standard rainfalls for warning and evacuation against debris flows, shall be used (See Fig. 2.16(c)).
- (3) If the frequency of issuance and the non-hit rate become excessive even when the forecast rainfall is set according to 2), the hourly rainfall having a recurrence interval of 2 years shall be used as the minimum (See Fig. 2.16(d)).



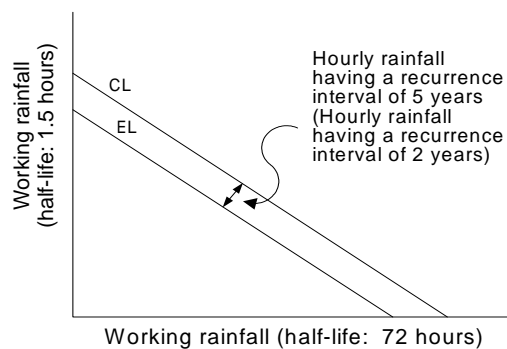
(a) The point at which an evacuation action should be started in the forecast by the short-term rainfall



(b) Setting of the EL (Process (1) above)



(c) Setting of the EL (Process (2) above)



(d) Setting of the EL (Process (3) above)

**Fig. 2.16 Setting of the evacuation line (EL) <sup>10)</sup>**

## (3) Setting of the warning line (WL)

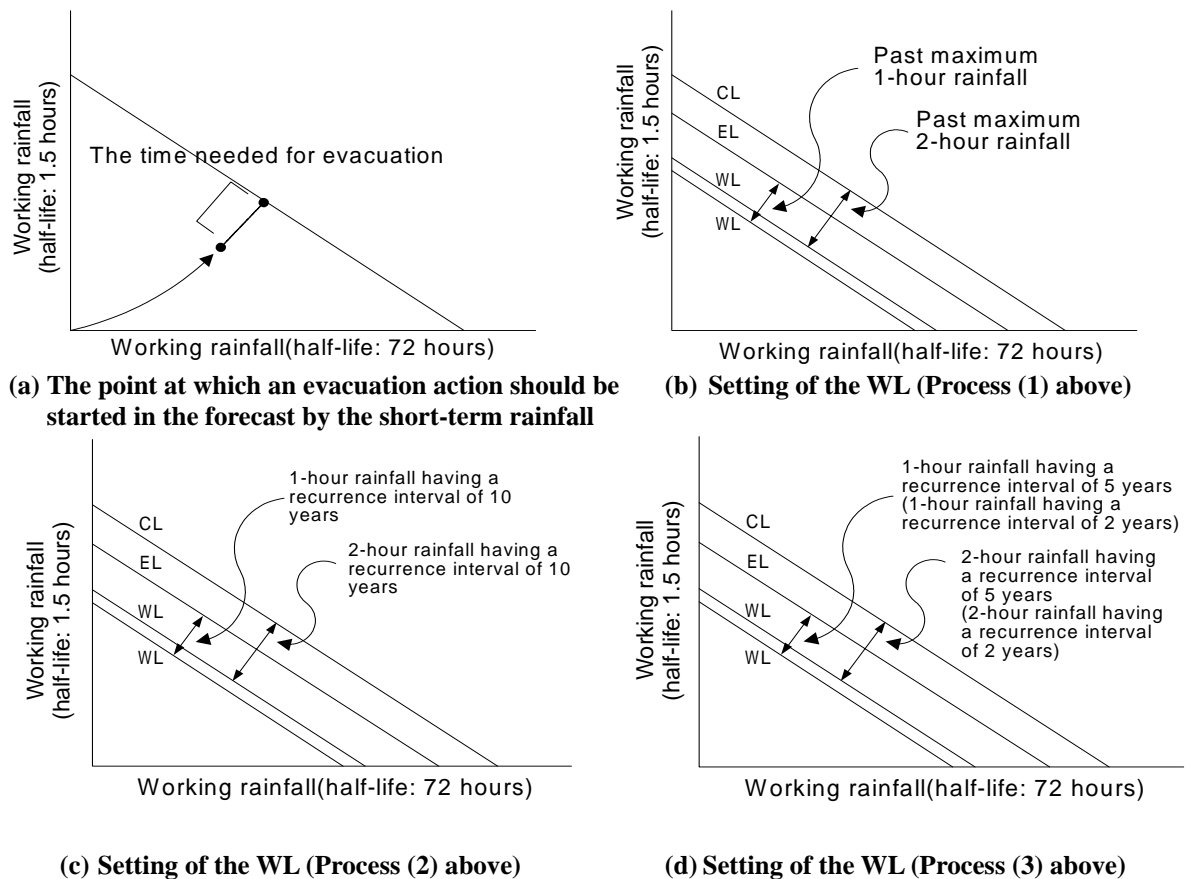
As with the setting of the EL, if the snake line obtained by the working rainfall satisfies the following conditions in view of the amount of forecast rainfall, a warning action should be started immediately. And, this boundary line is called the warning line (WL). See Fig. 2.17(a).

When the snake line obtained by the working rainfall is expected to reach the CL after some hours needed for evacuation has passed.

When the snake line obtained by the working rainfall is expected to reach the EL after some hours needed for the preparation of evacuation has passed.

Note) [Time needed for evacuation] = [time for evacuation preparation] + [time for moving to a refuge area]

The forecast rainfall shall be estimated from the short-term rainfall forecast obtained from a radar rain gauge. It should be used after its adequacy to the target area is confirmed. When the short-term rainfall forecast is not available, the forecast rainfall during the time needed for evacuation should be determined from the past rainfall records of the area, and using it the WL shall be established.



**Fig. 2.17 Setting of the warning line (WL)<sup>10)</sup>**

The time needed for evacuation shall be determined in consideration of the actual conditions of the area. The following is a setting example of the WL when the time needed for evacuation is two hours - one hour for preparation to evacuate and one hour for moving to a refuge area.

- 1) As with Method A and Method B in the Guideline Method, the past maximum 1-hour rainfall or the past maximum 2-hour rainfall of the area shall be used as the forecast rainfall (See Fig. 2.17(b)).

- 2) If the frequency of issuance and the non-hit rate become excessive when the forecast rainfall is set according to (1), the 1-hour rainfall having a recurrence interval of 10 years or the 2-hour rainfall having a recurrence interval of 10 years shall be used (See Fig. 2.17(c)).
- 3) If the frequency of issuance and the non-hit rate become excessive even when the forecast rainfall is set according to (2), the 1-hour rainfall having a recurrence interval of 2 years or the 2-hour rainfall having a recurrence interval of 2 years shall be used as the minimum (See Fig. 2.17(d)).

#### **(4) Investigation of the adequacy of the CL, WL, and EL**

Adequacy of these lines shall be evaluated in the same way as done in Method A and Method B. The most appropriate time to evaluate the frequency in which non-causing rainfalls exceed each line is at the time when the maximum working rainfall is obtained (this is shown in (g) and (h) in Table 2.10), although it may be changed depending on the gradient of lines.

#### **(5) Setting of the standard rainfalls for warning and evacuation**

After comparing various procedures and confirming the adequacy of the CL, EL, and WL, the standard rainfalls for warning issuance and evacuation instruction shall be established.

### **2.5.4. Features of Committee Method and care for use**

#### **(1) Determination of the half-life**

The half-life is considered as an index to describe the water storage/discharge characteristics of the area. A half-life of 1.5 hours that indicates the ground surface characteristics is probably not so much different in any areas. But, a half-life of 72 hours that indicates the underground characteristics may be different in areas. Therefore, in the case of a half-life of 72 hours, some adjustment can be made in accordance with regional characteristics. Adjustment may be done on a trial and error basis using the results of tank model-based discharge analysis or using the empirically obtained half-life value that can separate causing rainfalls and non-causing rainfalls readily.

#### **(2) Characteristics of snake line movement**

The standard rainfalls set by the Committee Method are effective for situations like a long rain and an intermittent rain or for judgment of cancellation of evacuation. Although the snake line derived by this method is a valuable criterion for deciding the cancellation of evacuation, actual cancellation must be determined based on an overall judgment of meteorological information, forecast rainfall, ground surface conditions in and around the area, and the conditions of hazardous mountain streams. Especially, when attempting to cancel an instruction or a recommendation of evacuation, not only rainfalls but also the conditions around the hazardous mountain streams shall be fully checked before deciding an actual cancellation.

## 2.6 Setting of Standard Rainfalls in Case When Hourly Rainfall Data are not Accumulated

### 2.6.1 Setting of standard rainfalls using the total rainfall

#### (1) Recording of rainfall data using rainfall indexes

The Guideline Method (Method A and Method B) and the Committee Method are the methods to establish the standard rainfalls for warning and evacuation based on the working rainfall and the rainfall intensity. However, if the only rainfall being gauged is the daily rainfall, the rainfall intensity cannot be obtained. In that case, the standard rainfalls must be set using only the total rainfall which is obtainable from daily rainfall data. The following are available as the rainfall indexes usable for the setting of standard rainfalls for warning and evacuation based on the total rainfall.

- 1) 1-day rainfall: Rainfall on the day a sediment disaster occurred.
- 2) 2-day rainfall: The total of the rainfall on the day a sediment disaster occurred and the rainfall on the previous day
- 3) 3-day rainfall: The total of the rainfall on the day a sediment disaster occurred and the rainfalls on the previous two days
- 4) Cumulative rainfall: Cumulative rainfall of a series of rain including the day a sediment disaster occurred
- 5) Working rainfall: The total of the cumulative rainfall and the antecedent rainfall (the basic idea is the same with that in Guideline Method)

A rainfall gauging station located in or around the target area is selected as the representative rainfall gauging station and the data of causing rainfalls shall be taken out. Then, the values of the five rainfall indexes shall be calculated and filled into the form as shown below. If the number of disaster occurrence is few, rainfalls that had large 1-day, 2-day, and 3-day rainfalls shall be taken out from among non-causing rainfall data. Assuming that a sediment disaster occurred on the day of the largest 1-day rainfall, the values of the five rainfall indexes shall be calculated and filled into the form in the same way as done with the causing rainfalls.

**Table 2.11 Form for recording the rainfall indexes  
used for the total rainfall-based setting method**

No. of a series of rain	1-day rainfall	2-day rainfall	3-day rainfall	Cumulative rainfall	Working rainfall
Causing rainfalls					
1					
2					
:					
Non-causing rainfalls					
1					
2					
:					



## (2) Setting of standard rainfall indicating the critical state

Regarding each rainfall index shown in Table 2.11, the lowest value of causing rainfalls and the highest value of non-causing rainfalls shall be compared. And, the rainfall index exhibiting the highest separability between the two rainfalls shall be used to establish the standard rainfall showing the critical state preceding the occurrence of sediment disasters. In general, however, the separability between the causing rainfalls and non-causing rainfalls is not so good in the case of setting method using the total rainfall. Hence, the standard rainfall showing the critical state shall be established based on the overall consideration of the non-hit rate, the frequency of warning issuance and evacuation instruction, etc.

## (3) Setting of standard rainfalls for warning and evacuation

When the standard rainfalls for warning and evacuation are set based on the total rainfall, the underlying rainfall data is basically the daily rainfall. Hence, a forecast for warning issuance and evacuation instruction must be done using the rainfall index value up to the previous day. But, if a warning is issued based on the forecast maximum one-day rainfall and if the spare time before disaster occurrence is one day, a warning will be issued very often, almost every time when it rains, because the forecast one-day rainfall becomes very large. This is not practical.

The past rainfall data obtained from a daily rainfall gauge is naturally the daily rainfall only. But, if some ideas are taken, it is possible to gauge the rainfall intensity when a sediment disaster is feared due to heavy rain. They are, for example, to gauge the water stored in a daily rainfall gauge every hour or read the scale of the stored water every hour. See Fig. 2.18.

Hence, presupposing that the rainfall can be gauged every hour during the warning period using some means as shown above, the standard rainfalls based on the total rainfall can be set in the same way as done in Guideline Method and Committee Method. The setting conditions are shown in Table 2.12. However, in areas where the only available data is the daily rainfall, the past maximum 1-hour/2-hour rainfall and the probable 1-hour/2-hour rainfall as shown in the table may not be obtainable from their data. In that case, they can be specified from the hourly rainfall data obtained in other areas which have similar the daily rainfall characteristics.

**Table 2.12 Timing of warning issuance and evacuation instruction and the forecast rainfall during the spare hours in the setting method based on the total rainfall**

Type	Timing of warning/evacuation	Forecast rainfall during the hours shown left
Issuance of a warning	2 hours before reaching the critical rainfall	Past maximum 2-hour rainfall / probable 2-hour rainfall
Instruction of an evacuation	1 hour before reaching the critical rainfall	Past maximum 1-hour rainfall / probable 1-hour rainfall

### 2.6.2 Setting of standard rainfalls when rainfall data are not available at all

In areas where appropriate rainfall data are not available at all but regarded as at risk of sediment disasters, an hourly rain gauge must be installed as soon as possible and data accumulation must be started so that they can be used for judgments related to warning

issuance and evacuation instruction. Until an hourly rainfall gauge is installed, efforts should be made to catch the precursors and forecast the occurrence of sediment disasters as quickly as possible so as to enable safe evacuation of the local people and to keep the resulting damage to a minimum.

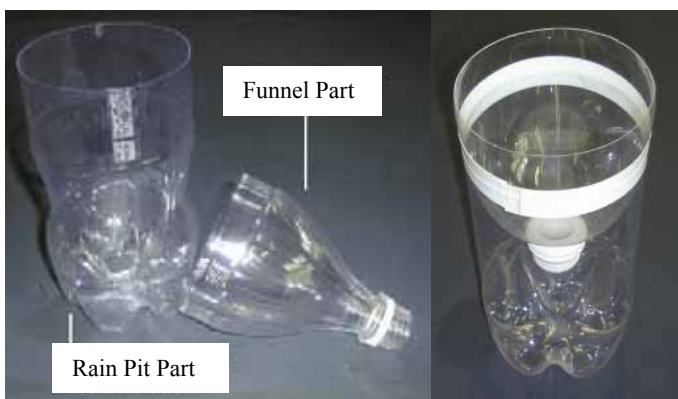
**(1) Location of rainfall gauging station and accumulation of data**

A rainfall gauging station shall be installed in or around the area at risk of sediment disasters. It can be installed near the office of a disaster prevention organization if the disaster hazard area is relatively small and the rainfall characteristics of the area is roughly identical to that around the office. A rain gauge installed should be able to measure the hourly rainfall by real time. Even though this type of rain gauge is not installed for some reason, it is still important to try to obtain the daily rainfall and the rainfall intensity by using a simple daily rain gauge or a hand-made rain gauge such as a cup. Figure 2.18 shows the example of simple rain gauges.



A cup rain gauge

The easiest method of rainfall measurement is to use a container with the bottom with cylinder forms, such as a tea canister, and to collect rain water. Rainfall can be calculated by the depth of collected rain by ruler.



A plastic bottle rain gauge

The center of a bottle is cut and the top portion is attached inside out. Rainfall (cm) can be calculated by the amount of rainfall (cm<sup>3</sup>) divided by the cross-section area of a bottle (cm<sup>2</sup>).



A storage type rain gauge

The rain water which collected into the storage bottle is moved to a graduated cylinder, and rainfall is calculated. Hourly rainfall can also be measured by measuring for every hour.

**Figure 2.18 Examples of simple daily rain gauges**

## **(2) Setting of standard rainfalls for warning and evacuation**

If a rainfall gauging station is installed near the sediment disaster hazard area and the hourly rainfall becomes gaugeable, a disaster forecast can be started using the standard rainfalls currently employed in other areas (including Japan) having a similar topography, geology, and weather conditions as the tentative measures. As the disaster forecast method, either Guideline Method or Committee Method shall be used. As the standard rainfalls for warning and evacuation, the most appropriate rainfalls for the target area shall be selected from various standard rainfalls currently employed in other areas having a similar topography, geology, and hydrology. The example of standard rainfalls for warning and evacuation against sediment disasters in Japan is shown in Appendix-2. According to this, there is no clear tendency between topography, geology and rainfall condition in the standard rainfalls for warning and evacuation. However, it is important to set up the standard rainfalls for warning and evacuation by using standard and safety values and to establish the tentative standard rainfalls.

In this way, by establishing tentative standard rainfalls for warning and evacuation and concurrently starting the gauging of hourly rainfall, the disaster forecast system as well as the warning and evacuation system can be launched. As time advances, the rainfall data will increase, a warning or an evacuation instruction may be issued, and a sediment disaster may occur. Accumulation of these sediment disaster-related data is extremely important. Based on these data, the standard rainfalls established by either Guideline Method or Committee Method are reviewed, revised, and upgraded to a highly sophisticated sediment disaster forecast system.

### **2.6.3 Tentative measures before a rainfall gauging station is installed**

Before slope failures, debris flows, or landslides that cause serious sediment disasters occur, particular precursors are sometimes observed. In the case of debris flows, a rumbling sound is heard from the mountain or the water level in the river lowers even though the rain is continuing. In the case of slope failures, a sound is heard from the precipice or the slope, or small stones fall.

Until the day when a new rainfall gauging station is installed and the sediment disaster forecast system is put into operation, local people or voluntary disaster prevention groups should acquire knowledge about these precursors and keep a watch on the state of sediment disaster hazard areas. It is also needed to prepare a plan about the measures to be taken in case some precursors are detected, such as strengthening of a patrol or initiation of an evacuation action. See Fig. 3.3.

## **2.7 Preparation and Utilization of Country Watching Map (CWM)**

### **2.7.1 Outline of country watching map (CWM)**

The setting method of standard rainfalls for warning and evacuation against sediment disasters with the use of rainfall data was explained in Chapter 2 above. However, it may take a long time before a warning and evacuation system based on those standard rainfalls becomes fully established. In some case, the establishment of a warning and evacuation system itself may not be easy if the rainfall data is insufficient or the data itself is not at all available.

To prevent the occurrence of sediment disasters in situations like this, it is needed to set up a disaster prevention system that can respond to the local nature of disasters on the basis of disaster prevention units formed by community or similar scale. The system should be such that the local people participate in the development process and assume their roles in disaster prevention based on a common vision with administrative organs. This kind of disaster prevention system based on the area-wide cooperation is called the Everyone Watching System (EWS). As shown in Fig. 2.19, the EWS is a system that administrative organs as well as the local people share the roles of disaster prevention, cooperate for enhanced preparedness against disasters from ordinary times, and join forces to conserve people in case a disaster is feared under a torrential rain or others.

One of the measures supporting the EWS is the Country Watching Map (CWM). The CWM is a basic material that helps establish the EWS through the consistent devotion to disaster prevention from normal times to disaster times.

### **2.7.2 Preparation of Country Watching Map (CWM)**

#### **(1) Roles of administrative organs**

Prefectural governments and municipal governments are required to set up disaster prevention units and, on the basis of those units and in cooperation with local people, they collect data on past sediment disasters, prepare an easy-to-use CWM, and distribute them to local areas. When a torrential rain hits their area, they gather disaster-related information from the local people and, if necessary, instruct them to evacuate to safe areas in close cooperation with them.

#### **(2) Roles of the local people**

Based on the CWM prepared in cooperation with administrative organs, the local people are required to set up a disaster prevention structure and should be prepared for potential disasters through activities, such as the gauging of hydrological conditions, disaster prevention education, grasp of hazardous locations, and disaster prevention training even from normal times. When a torrential rain hits their area, they should judge the area's hazard level by comparing with past sediment disaster records or relevant documents and, if necessary, begin to evacuate or take some actions in close cooperation with administrative organs.

#### **(3) Preparation of Country Watching Map (CWM)**

Two kinds of information should be included in the Country Watching Map (CWM): 1) information necessary to judge the danger level in case of a torrential rain; 2) information

necessary for evacuation

1) Information necessary to judge the danger level in case of a torrential rain

The information for the practical judgment of the degree of danger which has never been dealt in this kind of maps shall be included in the CWM utilizing past disaster records and empirical knowledge accumulated in each area. Namely, hearings shall be conducted and the data collected on a variety of subjects related to disasters, ranging from precursors of torrential rains, flood damages, and sediment disasters. To be specific, phenomena caused by torrential rains (gush of water from slopes, overflow of water from roadside gutters, inundation below and above floor level, blocking of rivers by bridges, flooding of rivers, debris flows, precipice failures, slope failures, and landslides) and the rainfalls at those times shall be summarized clearly, together with their temporal and spatial changes. These data are called the Disaster Integrated Watching Rainfall (DIWR) and shall be used as the criteria for judgments related to warning and evacuation.

2) Information necessary for evacuation

As the information needed for evacuation, the refuge facilities and evacuation routes which are determined in each unit, dangerous locations during evacuation (overflows, precipice failures, slope failures, debris flows), and resident-related information (disaster vulnerable people: infants, elderly persons, handicapped persons; housing conditions: temporary vacant houses, etc.) shall be surveyed and included in the CWM. See Fig. 2.20.

**(4) Survey items for the preparation of CWM**

The following items shall be surveyed before preparing the CWM.

- Survey of natural features (topography, geology, and vegetation)
- Survey of social features (disaster vulnerable people, housing conditions, etc.)
- Survey of disaster history
- Survey on the present state of the disaster prevention system
- Survey of dangerous locations
- Survey of points that need inspection (spring water and water paths on hillside)
- Survey of indexes for the judgment of danger level and relevant standards
- Survey of refuge facilities and evacuation routes

**2.7.3 Effect of Country Watching Map (CWM)**

The Disaster Integrated Watching Rainfall (DIWR) compiled in the CWM is a familiar topic and easy to understand for the local people because it is prepared from past rainfalls in their own area and they themselves are involved in the formulation of the map. The joint efforts between the residents and the administrative organs during the preparation process of the map also work to enhance communication between the two parties and strengthen their cooperative relationship, besides a deeper understanding of the contents of the map itself. These effects serve to arouse stronger disaster prevention awareness in the area which will result in a more active development of disaster prevention efforts.

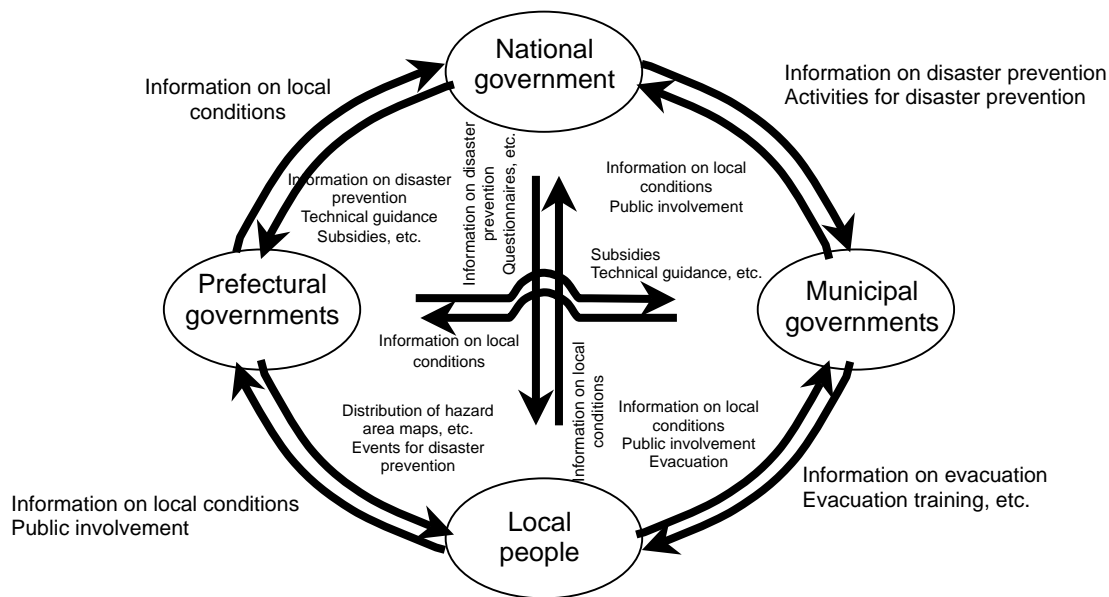


Fig. 2.19 Basic structure of the Everyone Watching System (EWS) <sup>20)</sup>

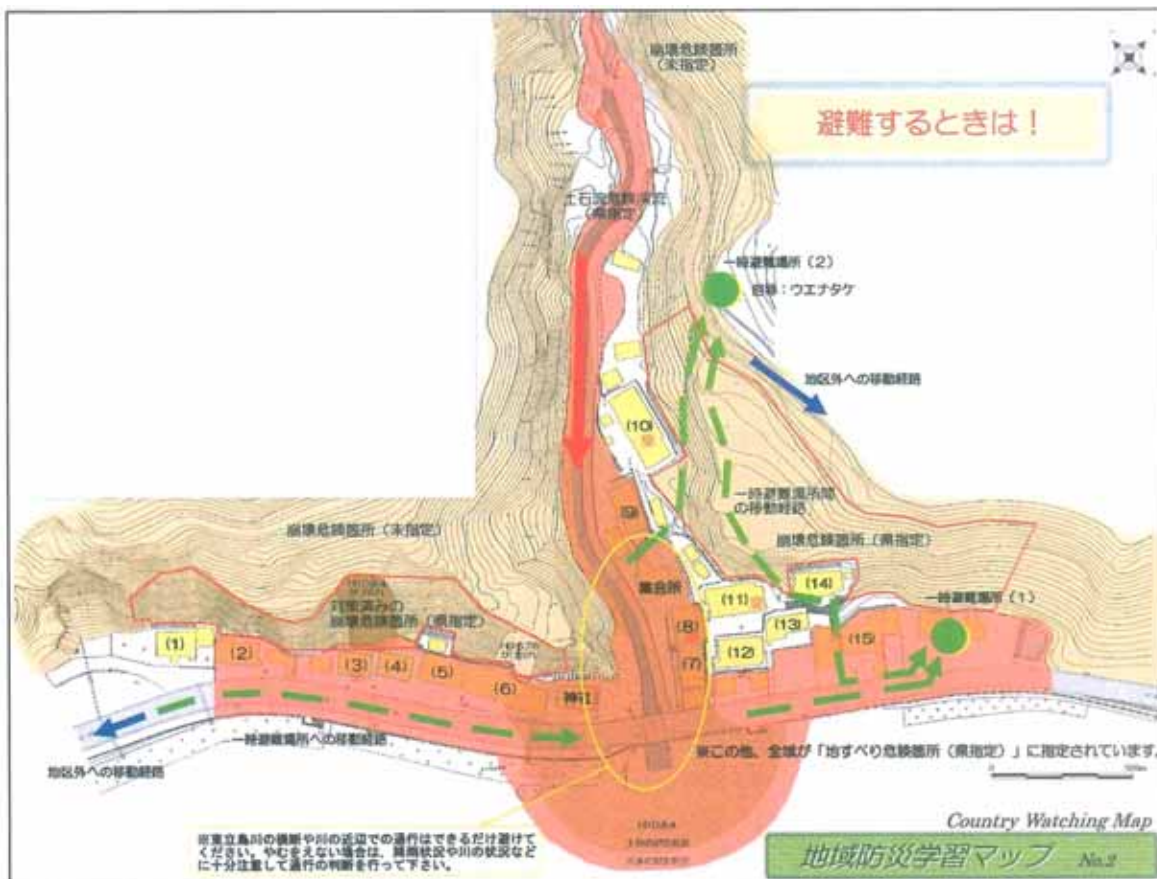


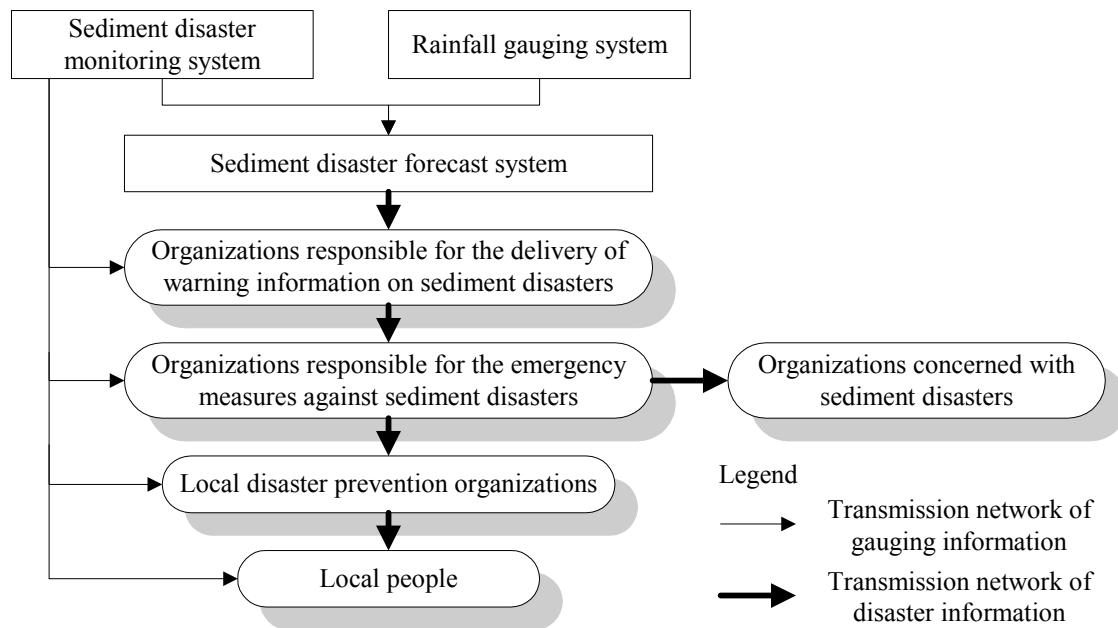
Fig. 2.20 Country Watching Map (CWM) showing information necessary for evacuation

## CHAPTER 3 DELIVERY AND TRANSMISSION OF SEDIMENT DISASTER INFORMATION

### 3.1 Structure of the Sediment Disaster Warning System

The structure of the sediment disaster warning system is shown in Fig. 3.1. The system consists of the following elements.

- 1) **Sediment disaster monitoring system:** A system to detect the precursors and the occurrence of sediment disasters
- 2) **Rainfall gauging system:** A system to gauge and record the rainfalls for the forecast of sediment disasters
- 3) **Sediment disaster forecast system:** A system to forecast the occurrence of sediment disasters from rainfall data
- 4) **Information transmission network:** Two types of networks are available: 1) transmission network of gauging information; 2) transmission network of disaster information
- 5) **Organizations responsible for the delivery of warning information on sediment disasters:** Organizations in charge of the delivery of warning information on sediment disasters
- 6) **Organizations responsible for the emergency measures against sediment disasters:** Organizations in charge of emergency measures against sediment disasters to be provided to the local people
- 7) **Organizations concerned with sediment disasters:** Organizations related to the lifeline systems which may be damaged due to sediment disasters and organizations related to disaster prevention and emergency retrofit. The lifeline systems include four types of systems: the utility systems supplying water, electricity, gas; treatment systems handling sewage and wastes; traffic-related systems such as roads and bridges; and communications systems for telephone lines and data transmission.
- 8) **Local disaster prevention organizations:** Organizations that transmit disaster-related information to the local people directly and engage in the guidance of people during evacuation. These organizations include the local offices of the prefectural governments and the organizations responsible for the delivery of warning information on sediment disasters, as well as the voluntary disaster prevention groups set up by the local people.
- 9) **Local people:** Residents who suffer direct or indirect damage due to sediment disasters



**Fig. 3.1 The structure of the sediment disaster warning system <sup>3)</sup>**

## 3.2 Roles of Organizations Responsible for Sediment Disasters

### 3.2.1 Organizational structure on disaster prevention

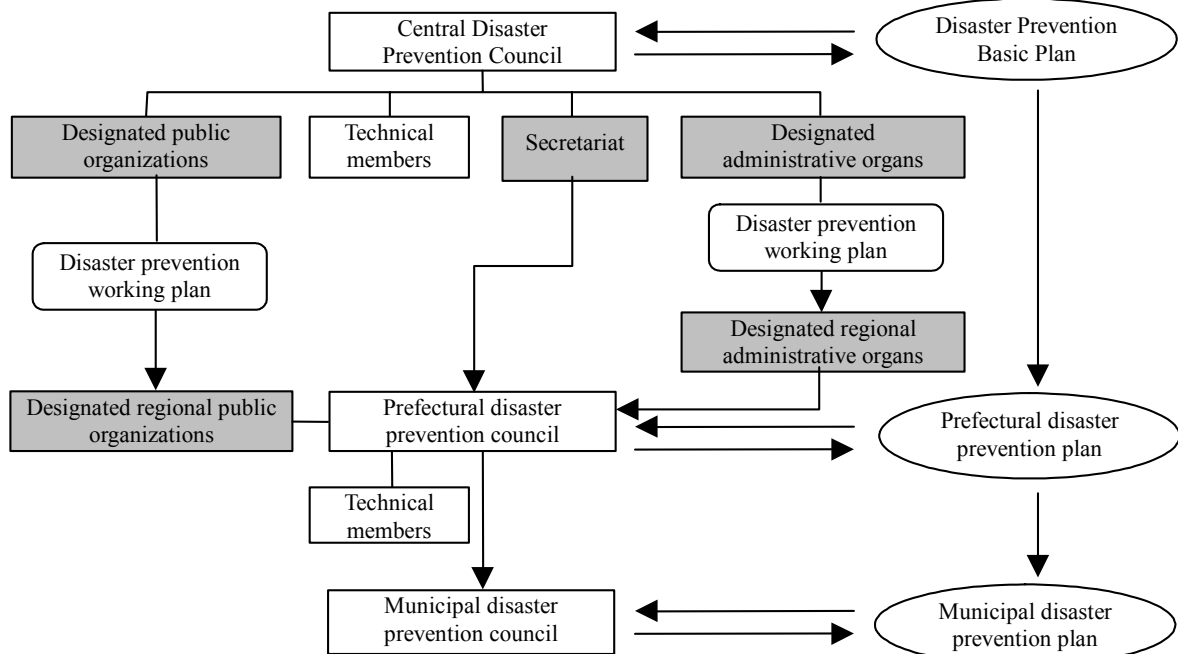
Sediment disasters are just one of many disasters. Therefore, organizations responsible for sediment disasters should be regarded as just one of functions of the overall structure having a mission for disaster prevention. The following is the outline of the organizational structure on disaster prevention currently in effect in Japan. It is usable as a reference when countries in the world attempt to establish a disaster prevention structure or to strengthen their existing structures.

The Disaster Prevention Basic Measures Law which is regarded as the constitution of disaster prevention in Japan was enacted in 1961. The principal objectives of this law are: 1) to define the administrative responsibility for disaster prevention; 2) to promote comprehensive administrative disaster prevention; 3) to promote systematic administrative disaster prevention; 4) financial assistance to major disasters; and 5) measures for disaster-related emergency situations. As the disaster prevention system in Japan, the Disaster Prevention Basic Measures Law stipulates that prefectural and municipal governments should formulate their own prefectural/municipal disaster prevention plans, together with detailed accounts on the structure and the contents of those plans. The prefectural/municipal disaster prevention plans are the plans that define the prevention of disaster occurrence (disaster prevention measures), emergency responses in case of disaster occurrence (emergency response measures against disasters), and an approach to post-disaster recovery (retrofit and restoration measures), with a goal to conserve the land, life and properties of the Japanese people from natural disasters, large-scale fires, and other calamities.

The disaster prevention structure and the disaster prevention plans defined by the Disaster Prevention Basic Measures Law are shown in Fig. 3.1. In this law, the national government, prefectural governments, municipal governments, and designated public organizations are specified as the core disaster prevention organs that bear the prime responsibilities of conserving the land, life and properties of the Japanese public from disasters. Among those



organs, the national government bears the largest responsibility and its aggressive leadership in disaster prevention is emphasized. On the other hand, as the most basic administrative unit directly connected to the local people, municipal governments are expected to perform a very important role and responsibility in such fields as 1) transmission of warnings; 2) preparatory measures and evacuation; 3) emergency response measures.



**Fig. 3.2 Disaster prevention structure and disaster prevention plan in Japan stipulated in the Disaster Prevention Basic Measures Law**

### 3.2.2 Roles of organizations responsible for the delivery of warning information on sediment disasters

Organizations responsible for the delivery of warning information on sediment disasters shall: 1) formulate plans for the sediment disaster monitoring system, the rainfall gauging system, and the sediment disaster forecast system; 2) operate and maintain those systems; and 3) deliver warning information on sediment disaster to the organizations responsible for emergency measures, based on the monitoring results and disaster forecast results. In Japan, the sabo section of the civil works department of each prefectural government usually serves as the responsible organization for the delivery of warning information on sediment disasters, and regional weather stations of the Meteorological Agency supplement insufficient information from the rainfall gauging system.

### 3.2.3 Roles of organizations responsible for emergency measures

It is important to clearly specify the responsible organizations that undertake emergency measures when a sediment disaster is forecasted. In Japan, it is specified that prefectural governments and municipal governments take on an important role to execute emergency measures against disasters. As to warning and evacuation against disasters, it is stipulated in Article 60 of the Disaster Prevention Basic Measures Law that the mayor of each municipal government bears the authority and responsibility for evacuation instruction and other relevant actions. It is advised that each country in the world should make clear what organization is responsible for emergency measures in case sediment disasters occur in

their country, in consideration of their own laws and social situations. Those countries are also required to secure some form of communication systems that can convey disaster-related information such as warnings and evacuation recommendations. The principal roles of responsible organizations for emergency measures against sediment disasters are as follows:

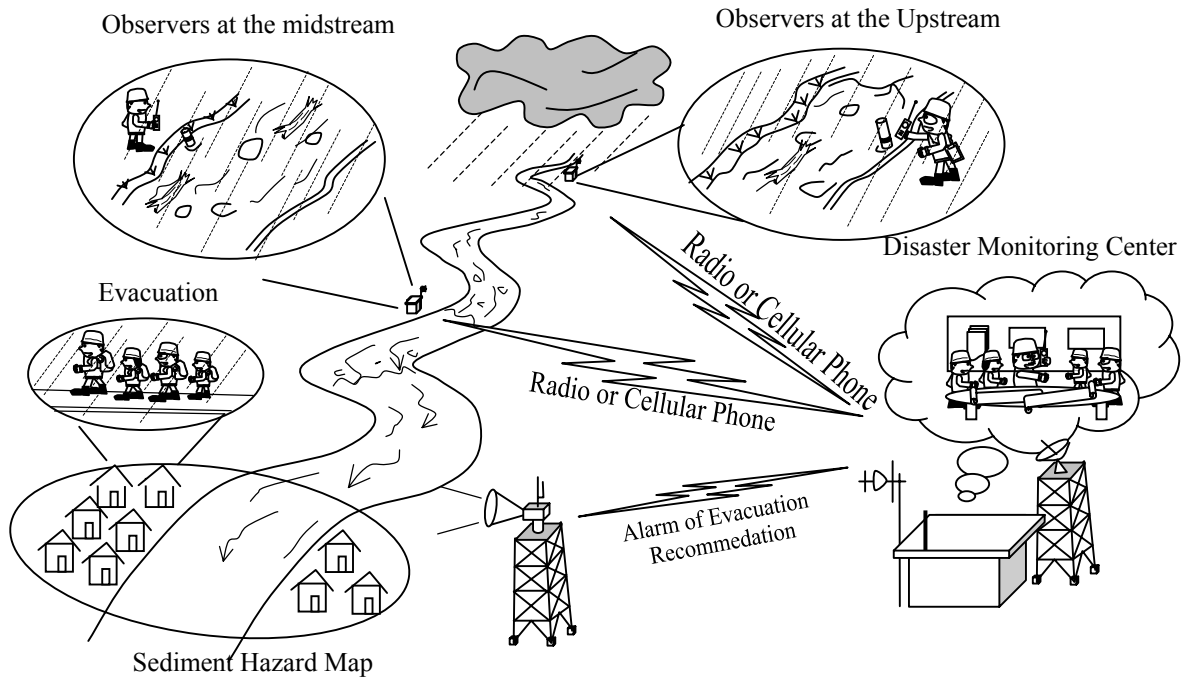
- 1) Collection and transmission of disaster-related information
- 2) Transmission of warnings on sediment disasters
- 3) Establishment of sediment disaster hazard areas
- 4) Order to take emergency response against sediment disasters
- 5) Evacuation instruction for emergency response against sediment disasters
- 6) Emergency measures for emergency response against sediment disasters

### **3.3 Operation of Warning and Evacuation System against Sediment Disasters**

A warning and evacuation system against sediment disasters must be based on monitoring and observation of sediment disasters or forecast by standard rainfalls for warning and evacuation, which is explained in Chapter 2. Then the system shall be used for the prediction of sediment disasters. Warning information by the system must be informed to residents, and it must be used for residents' evacuation preparation and its action. In developing countries, a telemeter system is not usually established. Therefore, an observer must collect the information on rain gauge installed near the area, and visual observation of sediment disasters. Then an observer must contact to the disaster monitoring center and must report the detected information to the center. A warning and evacuation system can be operated as follows: See Fig. 3.3.

- 1) Observers of rainfall and sediment disasters must contact to the disaster monitoring center with a radio or a cellular phone when the risk of sediment disasters is detected.
- 2) In response, a center predicts sediment disasters and judges the necessity of evacuation recommendation.
- 3) When an alarm or evacuation recommendation is given, residents carry out the evacuation preparation or the evacuation.

In operation of warning and evacuation system, it is necessary to build staff arrangement and organization required for sediment disasters information, and carry out the suitable operation.



**Fig. 3.3** Examples of operation of warning and evacuation system against sediment disasters

### 3.4 Warning Information on Sediment Disasters

#### 3.4.1 Objective of warning information on sediment disasters

The objective of warning information on sediment disasters is to support organizations responsible for emergency measures so that they can make adequate judgments at any time concerning emergency measures, such as an evacuation instruction given to the local people, when sediment disasters are forecasted. The contents of the warning information should be such that the local people can also utilize it for their own judgments.

#### 3.4.2 Contents of warning information on sediment disasters

##### (1) Contents of warning information

The warning information on sediment disasters shall include the following six items as the minimum requirement to condense all the information necessary for quick judgment, because information from a sending organization to emergency response organizations is sometimes transmitted via fax or orally.

- 1) Time of announcement and division announced
- 2) Target area (municipal name, etc.)
- 3) The current danger level due to antecedent rainfall (warning issuance/ evacuation instruction)
- 4) Predicted time of disaster occurrence and the forecast rainfall up to that time
- 5) Recent events that may increase the potentiality of sediment disasters (earthquakes, volcanic eruptions, ash falls, forest fires, typhoons, heavy rains, or snowmelts)
- 6) Other information that an organization responsible for warning information considers important for disaster prevention

**(2) Care when announcing warning information**

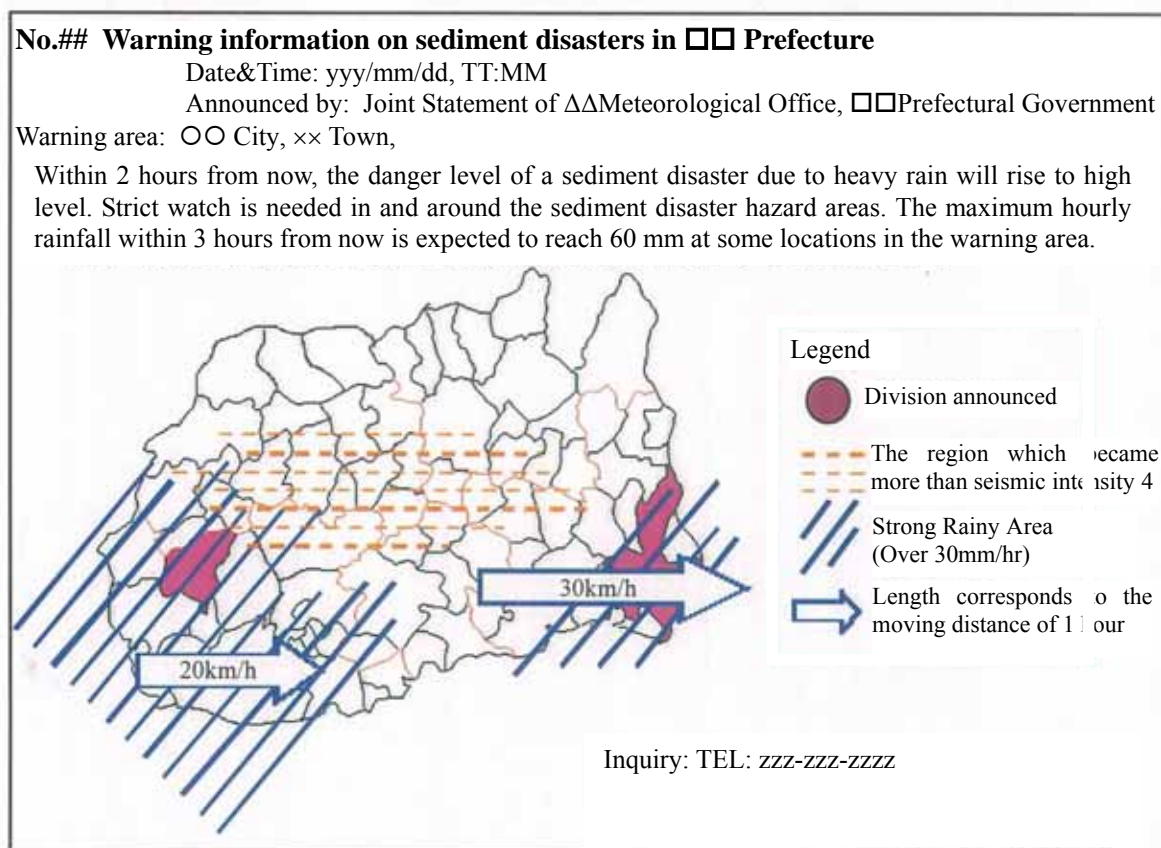
The principal objective of announcing warning information is to support disaster prevention efforts to save people from disasters by measures such as evacuation. Hence, the decision to announce warning information or not shall be made well in advance so that protective measures can be taken during that spared time. For that purpose, it is desirable that the announcement of warning information should be done approximately two hours before the expected disaster time by forecasting the rainfall of approximately two hours ahead, although it depends on the accuracy level of the rainfall forecast system.

**(3) Care when canceling warning information**

Special care is needed when canceling warning information because the danger of sediment disasters continues even after the rain has stopped. When canceling warning information, care should be taken not to cause a misunderstanding. An expression indicating that a caution against a sediment disaster is still necessary should be used to avoid a misunderstanding. It is something like "the heavy rain has weakened and the possibility of occurrence of multiple sediment disasters has decreased".

**3.4.3 Examples of warning information on sediment disasters**

Aim of warning information on sediment disasters is to be understood the contents of information at a glance, and the information sheet consists of the text and the figure. Fig. 3.4 shows an example in the case of receiving information in XX town.



**Figure 3.4 Examples of warning information on sediment disasters <sup>21)</sup>**

### 3.5 Communication Tools for Information Transmission

The following two information networks are available for the sediment disaster warning system.

- 1) Transmission network of gauging information: this is a transmission network to collect gauging information from the sediment disaster monitoring system and the rainfall gauging system.
- 2) Transmission network of disaster information: this is a transmission network to convey warning information on sediment disasters to responsible organizations, concerned organizations, local disaster prevention organizations, as well as to the local people.

Various tools are available to transmit this kind of information, as shown in Table 3.2. The most appropriate tools should be selected in consideration of the purpose of use, social situations, and economic conditions as well as their function and precision, so that the necessary information can be collected and transmitted swiftly and accurately even during a bad weather and a disaster.

**Table 3.2 Communication tools for information transmission <sup>22)</sup>**

Communication tools	Transmission network of gauging information	Transmission network of disaster information	
		Concerned organizations/local disaster prevention organizations	Local people
1) Radar rain gauge	○	-	-
2) Telemeter (radio system)	○	○	-
3) Special telephone line	○	○	-
4) Public telegram and telephone line	○	○	○
5) Information service vehicles	○	○	○
6) Warning signal (siren, etc.)	-	○	○
7) Verbal transmission	○	○	○
8) Mass media (radio, TV, etc.)	-	-	○

Note: the ○ symbol indicates that those tools are applicable.

## **CHAPTER 4 EVACUATION PLAN**

The evacuation activities are recognized as the important measures in disaster prevention, because they are not only very effective but also the last resort to escape from disasters. It means that even though sediment disasters are adequately forecasted and warning information and an evacuation instruction are duly given, disaster prevention is not fruitful if the local people cannot be evacuated to safe places. In this chapter, the following subjects are explained so that an adequate evacuation plan can be formulated against sediment disasters.

- 1) Tools for the evacuation of the local people
- 2) Development of evacuation facilities
- 3) Education and enlightenment on disaster prevention and evacuation
- 4) Disaster prevention and evacuation activities taken the local people

### **4.1 Tools for Evacuation of the Local People**

To involve the local people in the disaster prevention efforts and encourage them to make an adequate evacuation by themselves, it is essential that both the disaster prevention organizations and the local people clearly know their own roles and have a close cooperative relationship between them. To complete an evacuation successfully when a disaster has actually occurred, it is required to predetermine how the evacuation supervisor guides the people and how the people themselves are going to evacuate. For that purpose, disaster prevention maps, disaster prevention manuals, and disaster prevention posters shall be prepared in advance. See Fig. 2.20

#### **4.1.1 Disaster prevention maps**

To mitigate damage resulting from sediment disasters, it is important that the local people themselves know various dangers existing in their areas. One of the measures for this purpose is to prepare maps containing accurate and easy-to-understand disaster prevention information and present them to the local people. Through the distribution of such a handy disaster prevention information, the potential damage can be prevented or kept to a minimum.

The disaster prevention maps shall be prepared in such a way to improve the disaster prevention awareness of the local people and to be usable as a guide for evacuation. The disaster prevention maps should include the following information:

<Information to be included in the disaster prevention maps>

- 1) Sediment disaster hazard areas in each area
- 2) Locations of safe and adequate refuge facilities
- 3) Evacuation routes, evacuation directions

To prepare this kind of disaster prevention maps, the following surveys shall be carried out.

<Surveys needed for the preparation of disaster prevention maps>

- 1) Survey of sediment disaster hazard areas in each area: This survey is conducted to indicate the disaster hazard areas clearly and to find the potential obstructions during evacuation.

- 2) Survey of refuge facilities: This survey is made to find the safe refuge facilities located in the vicinity. The refuge facilities shall be examined in terms of the refuge period, a gathering place for evacuation, temporary refuge, and long-term refuge.
- 3) Survey of evacuation routes: Adequate and safe evacuation routes shall be determined in each area by considering the road conditions and the range of hazard areas showed on hazard maps.
- 4) Survey of vehicles usable for evacuation: Availability of vehicles to carry disaster vulnerable people during evacuation and the conditions of those vehicles are surveyed.

As an example of the disaster prevention map, the map prepared for sediment disasters by Kagoshima City, Japan is shown in Fig. 4.1.

#### **4.1.2 Disaster prevention manuals**

Two types of disaster prevention manuals are considered: one is for those responsible for disaster prevention and the other is for the local people. Main contents are as follows.

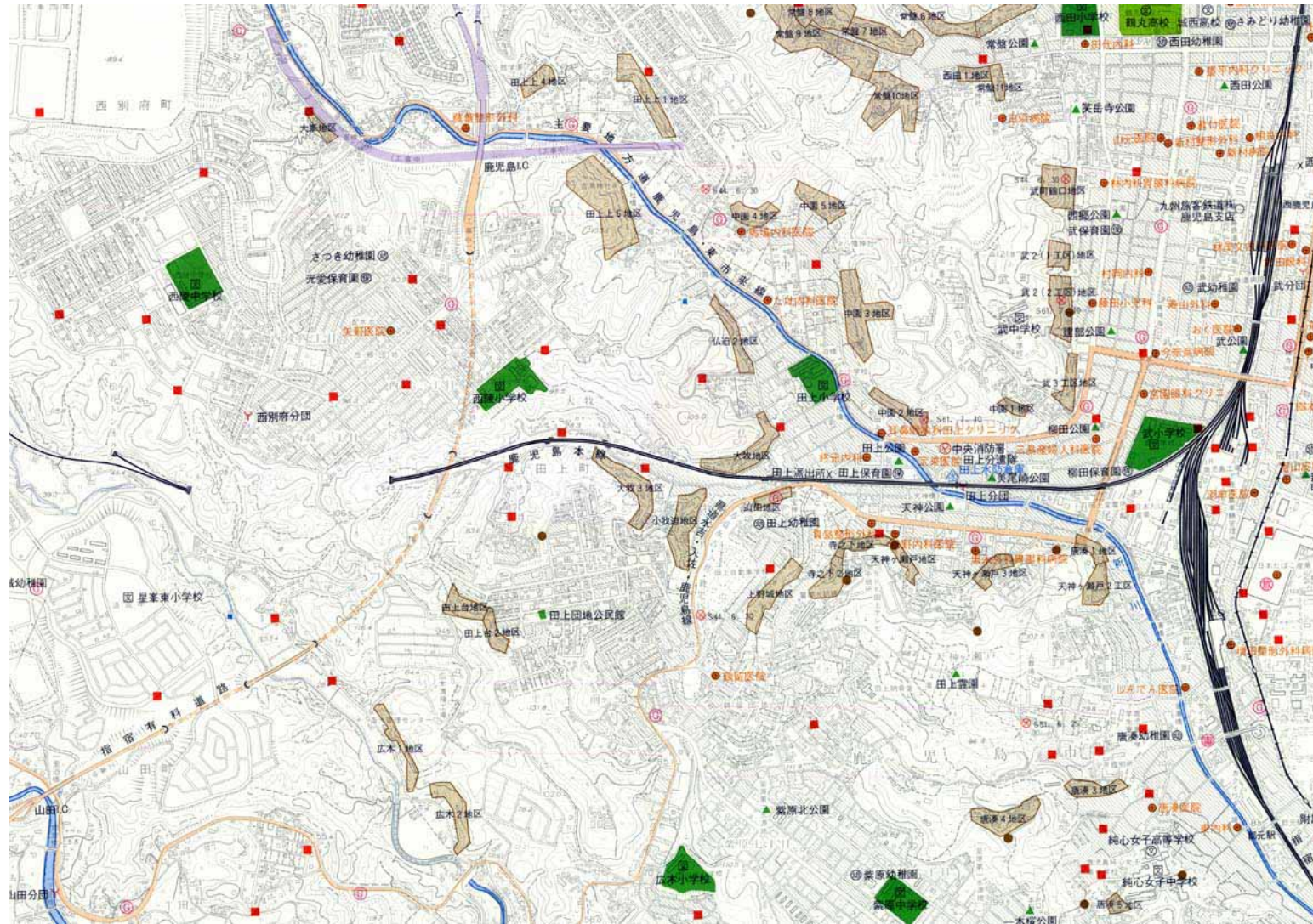
< Contents of disaster prevention manuals >

- 1) Conditions of sediment disasters in each area
- 2) Conditions of disaster prevention works and their effects
- 3) Sediment disasters in the past
- 4) Preparation of evacuation by warning levels
- 5) Detailed evacuation methods and instructions for evacuation
- 6) Disaster prevention maps (hazard areas, evacuation routes, refuge facilities)

To prepare this kind of disaster prevention manuals, the following surveys shall be performed.

<Surveys needed for the preparation of disaster prevention manuals >

- 1) Survey of natural conditions and disaster-related conditions: Survey shall be made on topography, geology, rainfalls, river conditions, sediment disaster hazard areas.
- 2) Survey of people's awareness on disasters: Survey shall be made on the disaster prevention awareness of the local people against sediment disasters and problems during evacuation.
- 3) Survey of social characteristics in areas: The number of residents and disaster vulnerable people (infants, elderly people, handicapped people, females) living in areas where evacuation may become necessary; social problems at the time of evacuation
- 4) Survey of past disaster history: Locations, disaster scale, and damage of past sediment disasters and behavior of people at the time of disasters
- 5) Survey of the current state of disaster prevention systems: Survey shall be made on the present conditions of voluntary disaster prevention groups, evacuation systems, warning systems, and information transmission systems.



**Legend**

- } Designated
- } Evacuation
- } Area
- Flood Control Area
- Slope Failure Area
- Flood Area
- Past Disaster Point

**Fig. 4.1** An example of the disaster prevention map prepared for sediment disasters (Kagoshima City, Japan)<sup>23)</sup>



## Evacuation

### 1. The Guard

The Guard was being lead by SATLAK, Operasi Unit and SATGAS.



### 2. Evacuation Priority

On the evacuation time, the first priority are the baby/children, old person, injured person, handicapped person, pregnancy women and women.



### 3. Evacuation Method

There are 3 methods to evacuate. But SATLAK will instruct the right method based on scale of eruption, when the right time the evacuation has to begin and the traffic condition of evacuation road.

**1 Individual Evacuation**  
Evacuate based on personal initiative to the temporary barrack by foot

**2 Rescue Evacuation**  
The injured persons will be evacuated from the dangerous area to the safe barrack or hospital by ambulances.

**3 Mass Evacuation**  
From those gathered place, people will be evacuated to the more safety place.

**Important !** For evacuation succesfully, the limit of goods to bring maximum 20 kg per person.

**Goods which is need to bring for emergency condition**

- Radio (with battery).
- Clothes (Under wear, T-shirt, Jacket Trousers, Sarong, etc)
- Important Goods (Money, Ornament, ID Card, Married certificate).
- For The Light (Candle, Matches, Flashlight with battery).

Use this at the evacuation time

**Evacuation Method Attention!!**

1. Lock your house.
2. Turn off the fire source in order to avoid burned.
3. Bring the goods property.
4. Wear easy clothes, protect your head with helmet or cloth and use the mask.
5. Follow the SATLAK guard instruction and do not take dry action based on rumors.

- Mask
- Helmet
- The Bag
- Trousers
- Don't bring along
- Livestock
- Furniture
- Food/Drink (Bread, rice, snack, instant noodles, drinking water).

**Additional 1**  
Especially for the baby

- Feeding bottle
- Diaper
- Milk

**Additional 2**  
Especially for the old person

- Medicine
- Spectacles
- Stick

**Additional 3**  
Useful goods

- Mask
- Plastic Bag
- Mat
- Cloth

Fig. 4.2 An example of the disaster prevention poster (Merapi Volcano, Indonesia) <sup>12)</sup>

### **4.1.3 Disaster prevention posters**

Disaster prevention posters for the people shall be prepared by extracting important points that should be kept in mind for disaster prevention or during evacuation. Those posters shall be put up at schools, churches, mosques, a village office, or other public facilities to enhance disaster prevention awareness of the local people and their knowledge for safe evacuation.

Various disaster prevention posters have been prepared in many countries in the world. Fig. 4.2 is an example prepared in Indonesia for sediment disasters (a pyroclastic flow, a debris flow) at volcanic Mt. Merapi.

## **4.2 Development of Evacuation Facilities**

The roads and signs used for evacuation should be adequately developed and maintained to enable quick and safe evacuation when a disaster is forecasted and people are instructed to evacuate. Also, refuge areas and refuge facilities should be adequately established so that people can conserve themselves from sediment disasters and lead a life for some in safety. This kind of evacuation facilities is explained below.

<Evacuation roads and evacuation signs>

The evacuation road at sediment disasters must be selected a safe road to disasters. In addition, the conditions of roads existing on the evacuation routes shall be surveyed and narrow or poor roads have to be widened or repaired so that vehicles for evacuation can go through smoothly. Together with the development of evacuation roads, evacuation signs to show adequate evacuation routes and evacuation directions to people shall also be improved.

<Refuge areas and refuge facilities>

The refuge areas shall be not only safe against sediment disasters but also safe against every kind of adversities. The refuge areas include temporary gathering places before evacuation, temporary refuge areas, short-term and long-term refuge areas. Depending on social conditions and forecasted disaster levels, appropriate refuge areas shall be selected and secured. In general, schools, community centers, park grounds, public facilities are used as the refuge areas.

Living in tents in the refuge area is one form of refuge life, but it is important to set up refuge facilities when the refuge life may drag on. It is good to use these refuge facilities as the public facilities at normal times.

<Provision and stockpiling of emergency goods>

To conserve the life and health of the people during disasters, the principal foods and the water must be stockpiled. As the emergency, food has to be kept in stock. As to the principal foods, the stocks in a wider area must be grasped and shall be supplied to a disaster-stricken area smoothly when a disaster has occurred. Also, presupposing that water works will fail if a disaster occurs, emergency water tanks shall be set up in safe places and emergency water supply vehicles shall be made available beforehand.

### **4.3 Education and Enlightenment on Disaster Prevention**

#### **4.3.1 Education and enlightenment for the local people**

To enhance the disaster prevention awareness of the local people and make them quickly evacuate when a disaster has occurred, it is very important to provide education and enlightenment on disaster prevention and evacuation to those people. The methods to be taken for such an education and enlightenment are explained below.

<Dissemination of disaster prevention knowledge>

To promote disaster prevention activities, the self-consciousness and cooperation of each resident is essential. For that purpose, the disaster prevention knowledge must be distributed and the disaster prevention awareness must be improved through school education and community activities.

<Events on disaster prevention>

To enhance the disaster prevention awareness of the local people and make them understand the danger of sediment disasters, a variety of events, such as a lecture and a fair for disaster prevention, shall be held utilizing disaster prevention manuals, disaster prevention maps, disaster prevention posters, and disaster prevention videos.

<Warning and evacuation training>

Simulating that a sediment disaster is occurring or has occurred, warning and evacuation training consisting of a warning transmission, an evacuation, and a disaster relief shall be carried out in cooperation of disaster prevention-related organizations, voluntary disaster prevention groups, and the local people. In particular, it is desirable to designate something like the Disaster Prevention Day or Disaster Prevention Week in areas and carry out a large-scale disaster prevention/evacuation training approximately once a year with the cooperation of the national government, prefectural and municipal governments, and disaster prevention-related organizations. The disaster prevention training shall be carried out according to the disaster prevention manuals and under the instructions of a supervisor charged with regional disaster prevention.

#### **4.3.2 Human resources development, organizational strengthening, and public consultation**

To enable smooth and adequate evacuation, quick and appropriate instructions to the local people, a cooperative relationship between the local people and the local officials in charge of disaster prevention, and the mental and financial support extended to the evacuees are all indispensable. For that purpose, human resources development, organizational strengthening, and public consultation as shown below are of prime importance.

- Training to improve an ability of the officials in charge of disaster prevention at prefectural/municipal governments
- Organizational strengthening of disaster prevention organizations (organizations responsible for the delivery of warning information, organizations responsible for the emergency response against sediment disasters, and local disaster prevention organizations) so that they can execute their disaster prevention measures effectively.
- Public consultation meetings relative to disaster prevention and evacuation

#### **4.4 Disaster Prevention and Evacuation Activities Taken by the Local People**

Disaster prevention and evacuation activities against sediment disasters shall be undertaken not only by disaster prevention organizations of the national and local governments but also by an active participation of the local people. Both of them should join forces to execute flood-fighting activities, evacuations, guidance as well as the relief of disaster-affected people. These activities are particularly important to prevent the enlargement of damage and to execute disaster prevention activities without impediments. For that purpose, establishment of voluntary disaster prevention groups by the local people themselves based on the solidarity in the area and their awareness to conserve one's own life and properties by oneself, shall be promoted actively.

To mitigate damage due to sediment disasters as the disaster prevention efforts by the local people, they should understand the types of sediment disasters, their precursors, and the measures that need to be taken. It is important to keep eyes on rainfalls, earthquakes, and other abnormal phenomena from ordinary times and prepare every possible countermeasure. As presented in Table 2.1 in Chapter 2, sediment disasters exhibit various precursors which can be detected by humans. When those precursors are captured before or after a long rain, a heavy rain, or an earthquake, the local people are encouraged to report it to an organization in charge of disaster prevention.