ASSOCIATED PROGRAMME
ON FLOOD MANAGEMENT

INTEGRATED FLOOD MANAGEMENT TOOLS SERIES

MANAGEMENT OF SEDIMENT-RELATED RISKS

ISSUE 12
FEBRUARY 2011

Global Water Partnership

World Meteorological Organization
Weather • Climate • Water

The **Associated Programme on Flood Management** (APFM) is a joint initiative of the World Meteorological Organization (WMO) and the Global Water Partnership (GWP).

It promotes the concept of Integrated Flood Management (IFM) as a new approach to flood management. The programme is financially supported by the governments of Japan, Switzerland and Germany.

www.floodmanagement.info

The **World Meteorological Organization** is a Specialized Agency of the United Nations and represents the UN-System's authoritative voice on weather, climate and water.

It co-ordinates the meteorological and hydrological services of 189 countries and territories.

www.wmo.int

The **Global Water Partnership** is an international network open to all organizations involved in water resources management. It was created in 1996 to foster Integrated Water Resources Management (IWRM).

www.gwp.org

Integrated Flood Management Tools Series No.12

Cover photo: Namib desert, © and courtesy of European Space Agency

Layout, design and iconography : www.lamenagerie.net

To the reader

This publication is part of the *"Flood Management Tools Series"* being compiled by the Associated Programme on Flood Management. The *"Management of Sediment-related Risks"* Tool is based on available literature, and draws findings from relevant works wherever possible.

This Tool addresses the needs of practitioners and allows them to easily access relevant guidance materials. The Tool is considered as a resource guide/material for practitioners and not an academic paper. References used are mostly available on the Internet and hyperlinks are provided in the *References* section.

This Tool is a *"living document"* and will be updated based on sharing of experiences with its readers. The Associated Programme on Flood Management encourages disaster managers and related experts engaged in management of sediment-related disasters around the globe to participate in the enrichment of the Tool. For this purpose, **comments and other inputs are cordially invited**. Authorship and contributions would be appropriately acknowledged. Please kindly submit your inputs to the following email address: apfm@wmo.int under Subject: *"Management of Sediment-related Risks"*.

Acknowledgements

This Tool was developed with the collaboration of the Sabo Department, Ministry of Land, Infrastructure, Transport and Tourism **(MLIT)**, Japan. It is based on their Guidelines for Construction Technology Transfer, Development of Warning and Evacuation System against Sediment Disasters in Developing Countries (MLIT, 2004). The tool also received beneficial contributions and comments from the Swiss Federal Institute for Forest, Snow and Landscape Research **(WSL)**, Switzerland.

CONTENTS

FIGURES, TABLES & BOXES

1 INTRODUCTION

1 Water-related disasters most perceived by the public are those caused by large-scale riverine floods. There is evidence, however, that the most deadly events, which are driven by extreme precipitation, are those that are difficult to predict, such as debris flows and landslides, which have a spatially limited character and can occur far away from major rivers; they occur mostly in mountainous areas.

2 Sediment-related disasters are defined as phenomena that cause direct or indirect damage to the lives and properties of individuals, inconvenience their lives, and/or deteriorate the environment through large-scale movement of soil and rock.

3 Debris flows and landslides have the potential to cause serious damage to human activity and property, and cause the highest amount of deaths when they occur near areas that are populated. Sediment-transfer processes are part of the natural landscape change, but large events often occur infrequently (decades to centuries, perhaps even longer). They cannot be stopped completely. Because debris flows and landslides occur unexpectedly and as an instantaneous event in an entire small basin, it is difficult to predict and set up adequate facilities to safeguard against them. Debris flows and landslides have become more of a potential risk for humans living around hilly regions and mountains, as the demand for urbanization and agricultural areas has increased.

Table 1 — Sediment- and water-related disasters

	Sediment-related disasters: Slope failure Debris flows Landslides 	Water-related disasters: River flood Inland flood 
Features on phenomenon	– affects smaller areas – occurs suddenly because of heavy rainfall – easily results in loss of human lives and property – seldom reoccurs at the same site except in volcanic regions	– affects larger areas – occurs gradually because of rise in river water level – destroys property in cases of dyke breaks, whereas inland flood only inundates them without any serious structural damage – reoccurs in the same region
Features on evacuation actions	– difficult to judge hazard level and predict because not only rainfall but also topographic and geologic conditions decide its occurrence – difficult to recognize hazard level because it is difficult to see it visually and recognize it	– easier to judge hazard level and predict through watching actual water level rise – easier to recognize hazard level through seeing water level visually
Public awareness	– difficult to evacuate because of less obvious increase in hazard level	– easier to evacuate because of obvious increase in hazard level

4 Debris flows and landslides, however, have been essential sources of sediment. They supply sedimentation to downstream morphology and ecology of rivers, and provide the potential for land development, such as floodplains, once the land environment becomes stable. Thus, the impact of debris flows and landslides is two-fold: it can benefit sediment supply downstream; and it can cause property loss and casualties.

5 Integrated Flood Management **(IFM)** recognizes the river basin as a dynamic system in which there are many interactions and fluxes between land and water bodies, and seeks to maximize the efficient use of floodplains and minimize the loss to life. In terms of IFM, risk management should outline the river basinís development state and potential. The outline for a sustainable

livelihood perspective seeks ways of working towards identifying opportunities to enhance the performance of the basin as a whole. In this context, the following elements are required:

- Adopting a basin-wide approach, such as land-use control, which includes the frameworks for institutional cooperation and stakeholder participation;
- Increasing preparedness and response capacity of local authorities and populations located in debris flows and landslide-prone areas;
- Fostering closer cooperation and coordination for forecasting and warning services of institutions to reduce the vulnerability of affected populations;
- Providing public participation, which is necessary for more effective and efficient ways to manage bottom-up situations, such as community-basis rather than top-down venues;
- Recognizing upstream changes in structural measures for debris flows and landslides, which can change the characteristics of a flood and associated water quality and sediment transport.

6 The primary objective of this document, therefore, is to provide a tool to introduce approaches in identifying debris flows and landslide areas as well as to show how they can be managed successfully to minimize the loss of life through the process of:

- Understanding characteristics of debris flows and landslides;
- Identifying the benefits and losses through sediment phenomena in river basins;
- Introducing historical experiences and options to tackle sediment-related disaster management;
- Providing detailed guidelines for debris flows and landslides hazards, risk assessment and management.

7 The tool is written primarily for flood managers at the municipal and higher administrative levels to facilitate the necessary dialogue with land-use planners at the local, and catchment levels; urban and agricultural planners; developers of individual land parcels; and the like.

8 Sediment-related disasters are roughly categorized into two types:

- Type 1: direct sediment-related disasters that cause direct damage as a result of sediment movement; and
- Type 2: indirect sediment-related disasters that cause a flood or an inundation through the aggregation of a riverbed or blocking of a river course.

Disasters of Type 2 are not the subject of this tool, except for the description provided in **Section 3.2.3** with regard to the formation of landslide dams.

9 This tool is based on the *Guidelines for Construction Technology Transfer, Development of Warning and Evacuation System against Sediment Disasters in Developing Countries*, which was developed by MLIT (MLIT, 2004).

2 CAUSES AND IMPACTS OF SEDIMENT-RELATED RISKS

10 To fully understand sediment-related risks, familiarity with the different components that construct risks is crucial. Often, risk is understood only superficially by equating it with the occurrence of an extreme event or hazard (flood, drought, earthquake, storm, landslide and so forth) caused by natural forces or by a combination of natural forces and human influences. Although the occurrence of such a hazard is the primary precondition, it is only one component in the creation of risk. The second component is that someone or something has to be at risk, that is, vulnerable to a hazard. This widespread definition makes the basic structure of risks very clear.

11 With reference to the term vulnerability, however, a further distinction is necessary to enhance the understanding of the creation of sediment-related risks. The notion of vulnerability in this definition does not distinguish between the mere physical exposure to hazards, on the one hand, and the susceptibility of individuals or things to hazards, on the other hand. At first glance, this might be considered a distinction without difference, but when analysis of sediment-related risk is involved and the question of which measures are most effective in reducing such risk, this distinction does make a difference. Hence, the following chapters are based on this extended definition of risk: *"Risk is the probability of a loss, and this depends on three elements: hazard, exposure and vulnerability. If any of these three elements in risk increases or decreases, then risk increases or decreases respectively"* (APFM, 2008, p. 3).

Risk = function (Hazard x Exposure x Vulnerability)

12 While exposure in the context of sediment-related hazards refers only to the question of whether individuals or assets are physically in the path of debris flows or not, vulnerability may be defined as: *"The conditions determined by physical, social, economic and environmental factors or processes that increase the susceptibility of a community to the impact of hazards."*

13 For risk reduction to be achieved in an integrated way, it is imperative that the construct of flood risks be understood, which consists of:

- Magnitude of the hazard expressed in terms of frequency and severity (depths of inundation and related velocities);
- Exposure of human activity to the hazard;
- Vulnerability of the elements at risk.

This is exemplified in the diagram below with regard to flood risks:

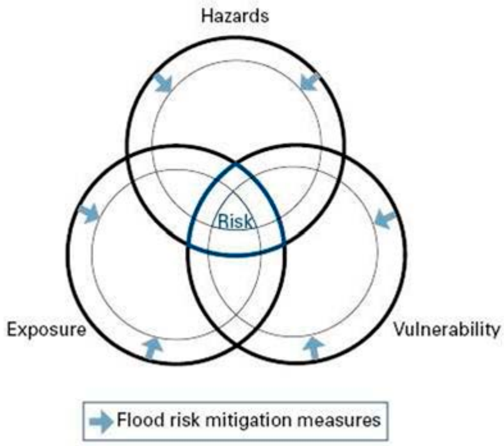


Figure 1 — Drawing of flood risk and its reduction (WMO, 2006b, p. 9)

2.1 Understanding sediment-related hazards

2.1.1 Phenomena that cause sediment-related disasters

14 Sediment-related hazards are defined as phenomena that cause direct or indirect damage to the lives and properties of individuals, inconveniences to their lives, and/or the deterioration of the environment, through the large-scale movement of soil and rock. Damage due to these hazards occurs in several forms: 1) the ground on which buildings and farmland are situated is lost due to a landslide or erosion; 2) properties, livelihoods and infrastructure are ruined by the destructive force of soil and rock during their movement; 3) farmland are buried by large-scale accumulation of discharged sediment; and 4) aggradation of a riverbed and filling of a reservoir are caused by sediment discharge along a river system, which may invoke flooding, disorder of water-use functions and deterioration of the environment.

15 Phenomena that cause direct sediment-related hazards include debris flows, slope failures and landslides. They are explained in **Table 2** and **Figure 2**[1].

16

[1] There are many classification schemes in the technical literature (Varnes, Hungr, and so on), which would produce different technical definitions and descriptions of these phenomena.

Table 2 — Phenomena that cause direct sediment-related hazards: debris flows, slope failures and landslides (Tsukamoto and others, 1991)

Debris flow	This is a phenomenon in which soil and rock on the hillside or in the riverbed are carried downward quickly under the influence of continuous rain or torrential rain. Although the flow velocity differs by the scale of debris flow, it sometimes reaches exceeds 40 km/hr, thereby destroying homes and farmland in an instant.
Slope failure	This is a phenomenon in which a slope abruptly collapses when the cohesiveness of the soil that has already been weakened by high soil water content reaches a critical slope failure value that is triggered by rainfall or an earthquake. Because of the instantaneous nature of this event, individuals fail to escape if it occurs near a residential area, thus leading to a higher rate of fatalities.
Landslide	This is a phenomenon in which part or all of the soil on a slope moves downward under the influence of groundwater and gravity. Because a large amount of soil mass is usually moved, serious damage can occur. If a slide has started as a slow-motion event, it is extremely difficult to contain it.

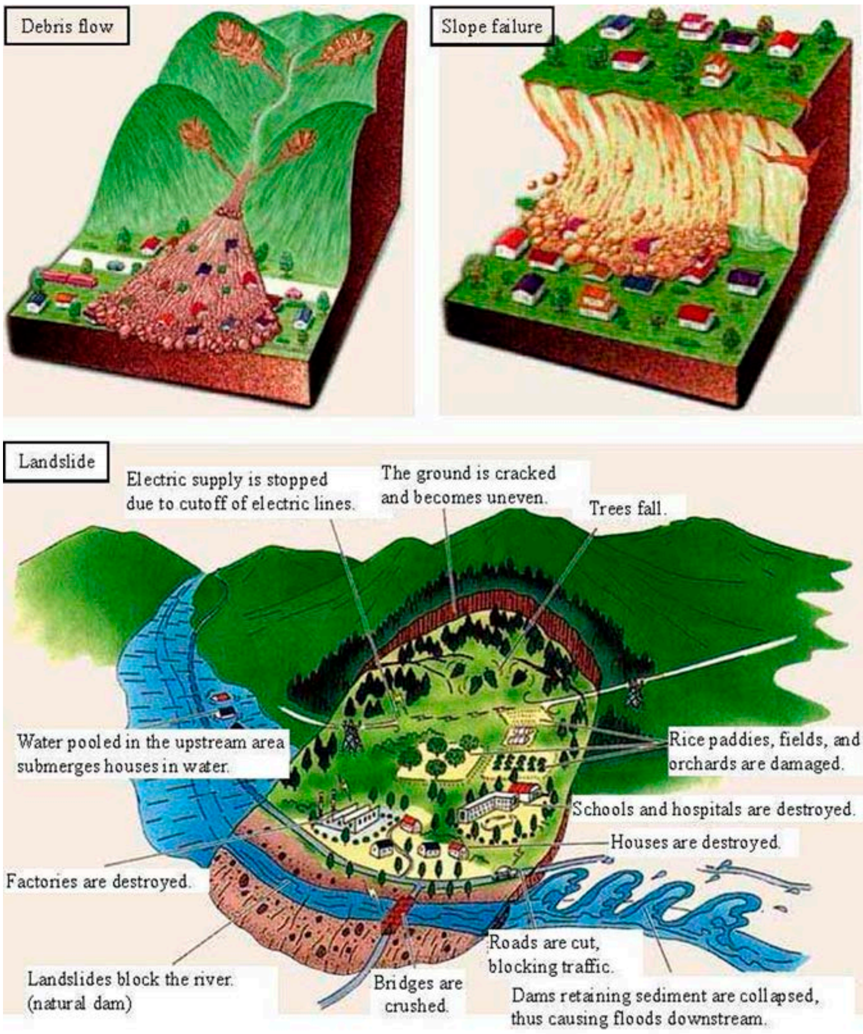


Figure 2 — Phenomena that cause direct sediment-related hazards: debris flows, slope failures and landslides (MLIT, 2010)

2.1.2 Types of debris flows

Debris flows occur in a variety of forms depending on the conditions of the site and the factors contributing to their occurrence. When classified by the contributing factors, debris flows are roughly divided into five types, as shown in **Table 3**. Except for the landslide dam collapse type, all types of debris flows are primarily related to short-term (less than one hour) rainfall intensity.

Table 3 — Types of debris flows classified by contributing factors (Tsukamoto and others, 1991)

Type	*Features*
Riverbed sediment movement (sediment gradient)	Sediment transport in a riverbed occurs when sediment accumulated in the riverbed exceeds the gradient made by the bed-load transport of sediment and by direct transport as a function of flow velocity in the channel.
Slope failure	A slope failure directly changes into a debris flow.
Landslide dam collapse	A debris flow is caused by the collapse of a landslide dam, which is formed by landslide or slope failure.
Landslide	A debris flow occurs as the last-stage phenomenon of a landslide. It occurs because the soil is almost liquefied
Volcanic activity	In a narrow sense, this refers to debris flows caused by a volcanic eruption or an earthquake. But, in a broad sense, it refers to debris flows that occur in areas of an active volcano. A volcanic mudflow is also included in this type. Debris flows of this type are rich in fine grains, flow rapidly and readily occur even under small rainfall.

17 The flow mode and flow characteristics of debris flows differ largely depending on the type, size and concentration of stoney grains that they contain. If a large amount of coarse gravel and a relatively small amount of fine grain finer than silt are contained, it is called a gravel-type debris flow. In contrast, if a small amount of coarse gravel and a large amount of fine grain are contained, it is called a mudflow-type debris flow. If the amount of clay and silt is especially large, it is called a viscose-type debris flow.

Gravel-type debris flow: a debris flow occurred at Kamikamihori Valley in Mt. Yakedake, Japan

Mudflow-type debris flow (viscous-type debris flow): a debris flow occurred at Jiangja Creek, Yunnan Province, China

Figure 3 — Examples of gravel-type debris flow and mudflow-type debris flow (MLIT, 2010)

2.1.3 Slope failures and landslides

18 The Working Committee on World Landslide Inventory, which was set up in cooperation with the United Nations Educational, Scientific and Cultural Organization **(UNESCO)** and international

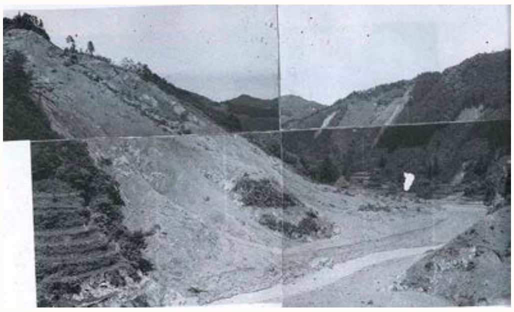
academic societies related to foundation engineering, has defined a landslide as the "movement of a mass of rock, debris or earth down a slope". It classified landslide movements into not only a slide but also a fall, topple, spread and flow in terms of kinematics.

19 It is possible, however, to categorize landslides into the following two groups, depending on which precautionary measures are taken against them. One is a phenomenon in which a slope moves almost instantaneously due to weakened self-retainability of the earth from rainfall, a rise of underground water level or other similar events. Many individuals living in residential areas would fail to escape from this event, thus resulting in a higher rate of fatalities. The other is a phenomenon in which a relatively large soil mass on a slope moves slowly downward along the slip surface of the slope due to groundwater and other causes. Since this kind of landslide occurs over an extensive area and a large amount of soil mass is moved in general, it can cause serious damages.

20 The differences between landslides and slope failures are outlined in **Table 4**. As shown, landslides are different from debris flows and slope failures in that landslides are slow in moving speed and are not caused directly by rainfall. In other words, slowly moving landslides do not seem to be a meteorological but rather a geological phenomenon. Therefore, this type of landslide is not included in the subject of this manual. Because the term "landslide", however, is much more popular and general than the composite term "slope failure", hereinafter, the term "landslide" is used not to mean "landslide" as mentioned above, but to mean "slope failure".

Box 1 — Landslide burst outburst flood

In general, a slope failure or a landslide affects only areas adjacent to the slope compared to a flood or debris flow. If, however, the landslide occurs near a river channel and is large enough, it could sometimes cause a landslide dam. It could outburst after ponding and run further down as a debris flow or flash flood. It often results in serious damages to the downstream flow because it does not necessarily occur with rainfall but can be totally unexpected.



The photographs show a large landslide and a landslide dam that were formed in the Arita River, Japan, in 1953. Extraordinary rainstorms caused the large flood and consequently serious damages to the downstream area. The rainstorm also caused gigantic landslides along the river. The landslides blocked the river course and after several weeks, a landslide dam outburst flood attacked the downstream area again and resulted in a secondary shock to the population, which had recovered from the first damage.

Table 4 — Features of slope failure and landslide (Takahashi, 1991)

Geology	Occurs in specific geology and geological structure	Almost no relation to geology
Topography	Occurs at a gentle slope in a so-called landslide topography	Occurs at a steep slope
Depth of movement	Several meters to over 10 meters	Within 1 to 2 meters
Scale of movement	Large	Small
Speed of movement	Usually slow, sometimes abrupt	Abrupt
Triggering factors	Groundwater, earthquake	Torrential rainfall, earthquake
Signs of movement	Tilted trees, cracks on the ground surface	Almost none
Land use	Used as arable land	Not used
Possibility of recurrence	Possible	Not possible for several years to over a decade

2.1.4 Potential factors and triggering factors of sediment-related hazards

21 Both potential factors and triggering factors should be considered as contributors in the occurrence of sediment-related hazards. Potential factors are the conditions of the site where a sediment-related hazard occurs; and triggering factors are the forces applied to the occurrence site as external forces. Potential factors and triggering factors of debris flows and landslides are summarized in **Table 5**.

Table 5 — Potential factors and triggering factors of sediment-related hazards (Takahashi, 1991)

	Debris flow	*Slope failure*
Potential factors	**Topography of river basin:** Existence of an unstable hillside in a steep slope, ease of convergence of surface water, presence of groundwater and spring water. **Topography of river:** Longitudinal gradient of riverbed, plane and longitudinal configurations of river course. **Unstable sediment:** Thickness of weathered soil layer in a hillside slope, thickness and amount of riverbed sediment, volumetric concentration and grain size distribution of accumulated sediment, accumulated sediment due to slope failure.	**Geology:** In addition to the strength of rocks, dominant factors are the level of weathering, alteration, fissure and fracture, direction of layers, conditions of permeable layers and distribution of loose layers, such as surface layer. **Topography:** Failures tend to occur at slopes of 40°-50°, and at slopes or locations that easily collect rainwater, such as a concave-type slope, the bottom of a long slope and the bottom of a gentle slope. **Vegetation:** Forests have a collapse prevention effect with regard to surface failures caused by infiltration of torrential rainfall.
Triggering factors	**Rainfall, snowmelt:** Overland flow during high-intensity rainstorms. Other triggering mechanisms include spontaneous liquefaction, damming of water behinddebris dams with subsequent breaching , and outflow of snowmelt (such as due to a volcanic eruption)	**Rainfall, snowmelt:** The risk of occurrence of slope failures increases if a rainfall of strong intensity occurs when the ground is already moist. Earthquake, volcanic activity: The ground becomes unstable when stress conditions in the slope are altered due to an earthquake or a volcanic eruption. **Groundwater:** An increase in pore water pressure caused by subsurface flow due to rainfall leads to slope failure. **Artificial activities:** Deforestation, artificial changes of a natural slope by cut and fills.

Box 2 — Sediment-related hazards

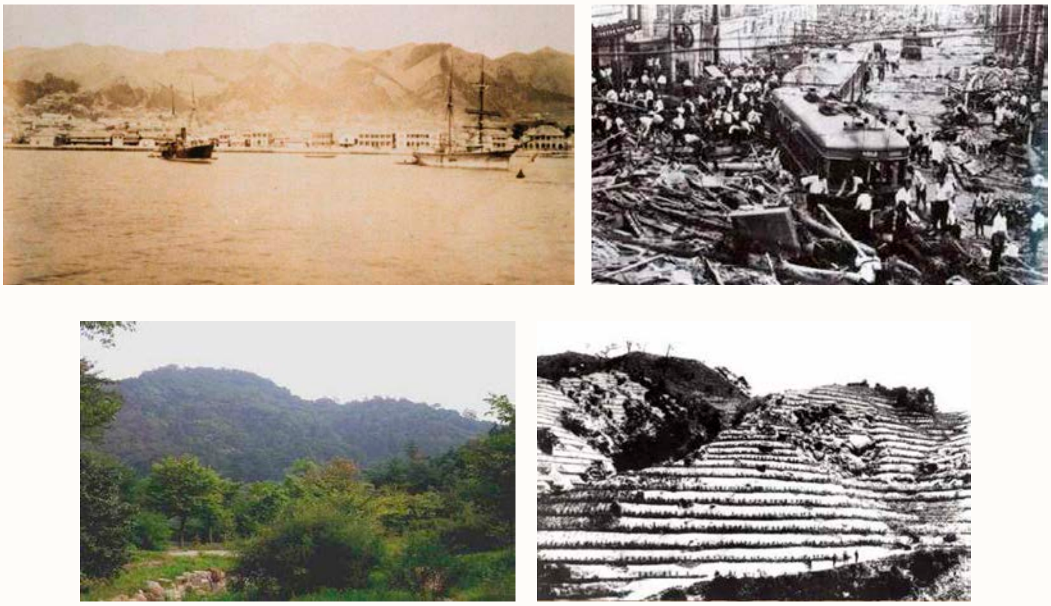
Frequency and magnitude

In general, it is very difficult to know the magnitude-frequency relationship of sediment-related disasters because debris flows occur once every half-century, or less frequently, whereas for an ordinary river flood, various magnitudes of floods can be observed within several decades. For debris flows, in many cases, few smaller debris flows may occur before one less frequent large one. The concept can be described as follows: floods can be seen as "water movement" in or out the riverbed (if out, then an inundation occurs); therefore, one can make statistic analysis on the river flow even in periods when the "flood" is regularly contained in the riverbed. In the case of debris flow, one cannot do the same, as there is no direct relation between quantity of rainfall and quantity of debris flow: below a certain threshold of rainfall, which will trigger the debris flow, there will be no debris flow at all. If there is very strong rainfall that is stronger than an established threshold value debris flow can occur instantaneously.

Cause and effect

The consequences of deforestation and especially uncontrolled logging on risk of debris flows or slope failures can be significant, in particular concerning the erosion processes related to debris flows and slope failures. Consequently, reforestation [deforestation is usually at random]policy and planning should be subject to risk assessment. The technical aspects of forestry and agricultural practices may also be subject to regulation, but more difficult to enforce. Also, land use may be determined to some extent by economic mechanisms, which may not be conducive to good flood management.

In the nineteenth century, the devastation of forests reached its peak in many parts of the world, especially in industrialized countries. It caused serious sediment-related hazards, such as debris flows, slope failures and floods triggered by riverbed rise. These disasters prompted governments to implement erosion control policies or soil and water conservation mechanisms as well as development of legal systems to restrict deforestation. Although these activities were extremely laborious and required much time and expense, after lengthy efforts, they have been remarkably successful in reducing sediment-related hazards.



The first two upper photographs show the devastated Rokko Mountains in Japan during the nineteenth century, and serious damage caused by debris flows in 1910. The lower two photographs show the revegetation that occurred between 1903 and 2005.

2.2 Exposure

22 The term exposure refers exclusively to whether or not individuals or valuables are in the range of risk. When there is an increase in population and assets that are physically exposed to debris flows and landslides, this means an increase in damages. Land-use planning, therefore, must be properly coordinated (WMO, 2006, p. 11). Quick and unplanned growth of habitat areas results in a greater number of individuals that live in areas that are potentially vulnerable to debris flows and landslides. This is true especially for urban areas in many developing countries that are growing rapidly. Unprecedented migration from rural areas to cities has also led to an uncontrolled urban sprawl with increased human settlements, industrial growth and infrastructure development in hazard areas. In addition, urban development has occurred near mountainous areas, where there is high risk for debris flows and landslides.

Figure 4 — Urbanization pressures on risk area

23 During the urbanization process, land-use planning to reduce the risk of debris flows and landslides from floods must be considered. This risk consideration in land-use planning also depends mostly on the disaster frequency. Because many years or decades will pass without debris flows and landslides, it is more difficult to maintain risk awareness of both the population and authorities. Unfortunately, many urbanization processes take place either without any planning or with plans that ignore or underestimate the risks. Often, construction and land-use regulations, underlying legal frameworks, as well as concrete plans do exist but are not enforced. In addition, the technological difficulty in evaluating risks of debris flows and landslides and insufficient knowledge about these mechanisms have made it harder to control land use in advance.

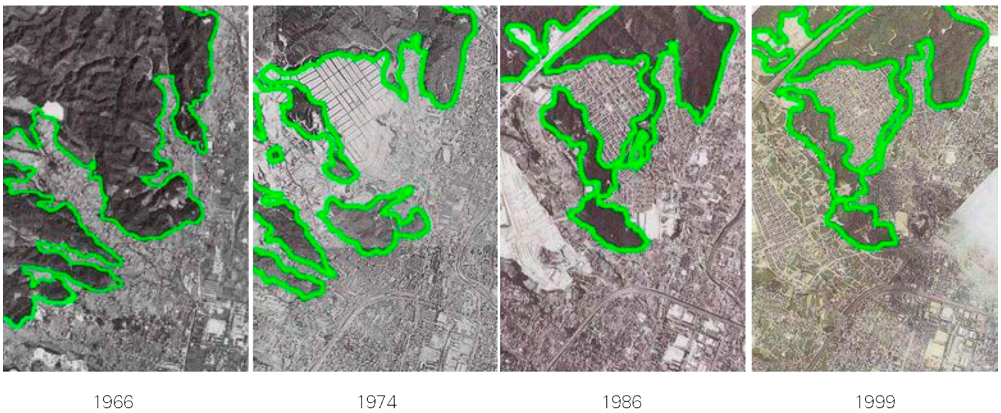


Figure 5 — Example of the increase in exposure of inhabitants in Hiroshima City: increase in disaster-prone sites in urbanized area from 1966 to 1999

2.3 Vulnerability

24 The term "vulnerability" is represented by the inability or incapacity of society or a group of individuals to anticipate, cope with, resist and/or recover from the impact of debris flows and landslides and the likelihood of these phenomena to have adverse impacts. It is the condition that determines the transformation of a hazard into a disaster. It not only impedes appropriate response but accentuates the severity of the impact, which may be further exacerbated long after a disaster has struck. Vulnerability to debris flows and landslides is a combination of complex, dynamic and interrelated mutually reinforcing conditions that can be divided into three major groups, as follows:

- Physical or material;
- Constitutional or organizational;
- Motivational or attitudinal.

Conditions of vulnerability are outlined in **Box 3** below (WMO, 2006b, p. 11).

Box 3 — Vulnerability conditions

Physical/material conditions

- Initial well-being, strength and resilience (high mortality rates, malnutrition, disease)
- Weak infrastructure, such as buildings, sanitation, electricity supply, roads and transportation
- Occupation in a risky area (insecure/risk-prone sources of livelihood)
- Degradation of the environment and inability to protect it

Constitutional/organizational conditions

- Lack of leadership, initiative or organizational structure
- Lack of or limited access to political power and representation
- Lack of or poorly resourced national and local institutions
- Unequal participation in community affairs
- Inadequate skills and educational background
- Weak or non-existent social support networks
- Limited access to outside world

Motivational/attitudinal conditions

- Lack of awareness of development issues, rights and obligations
- Certain beliefs and customs and fatalistic attitudes
- Heavy dependence on external support

2.3.1 Physical vulnerability of individuals and infrasctructure

25 Many cases of sediment-related disasters have been reported where individuals were not affected because they were able to detect sings of an impending event in time, which allowed them to evacuate in time. This example indicates that when the local population has knowledge of potential disasters in their area, it could make the difference between life and death. In the past, fewer individuals lived in areas susceptible to sediment-related disasters; even if they

lived in such areas, they were prepared for such disasters owing to prior knowledge from former generations. With the rapid increase of population that has taken place, however, and the enlargement of arable land, populations living in hazardous areas have increased enormously (as shown in **Figure 5**). Individuals living in newly developed areas often do not have knowledge about sediment-related disasters. This change in the social environment is one contributing factor for causing greater damage during disasters. While a detailed discussion of these vulnerabilities is given in other sections, they are presented here in the context of debris flows and landslides to discuss how to prevent hazardous events from turning into disasters both at the societal and individual levels.

26 We can find many examples of population growth and migration of large populations in developing countries towards unplanned urban settlements in marginal areas, where there is a high risk of debris flows and landslides. This increases drastically the vulnerability of the poorest sectors of society to sediment-related hazards.

27 The poorest sectors not only refer to economically disadvantaged groups but also to socially vulnerable groups, such as minorities and ethnic groups. Basic infrastructure that is underdeveloped also contributes to their vulnerability. Two more factors aggravate this spatial marginalization: the limited livelihoods of inhabitants living in marginal areas who rely exclusively and excessively on natural resources, such as forests, and thus cause deforestation or degradation of the environment, increasing the risk for debris flows and landslides; and the lack of familiarity with respective hazards of the poor who migrate from rural areas, and thus tend to underestimate the risk of living in such exposed areas.

2.3.2 Unfavourable organizational and economic conditions

28 Because of its geographical nature, development in marginal areas occurs in an unorganized and dispersed manner. Such conditions disturb community participation or social support networks. Government authorities also find it difficult to support such areas because they represent less political power and inefficiency in public expenditures. These marginal areas, on the other hand, sometimes face the problem of emigrating populations, especially populations that may play an important role in organizing community activities.

2.3.3 Attitudes and motivations

29 Reluctance towards flood preparedness and mitigation measures also may be the result of lack of hazard knowledge or of fatalistic attitudes. For example, populations that have the prior experience of sediment-related disasters are better prepared for the next disaster, while populations that have no prior experience are not able to escape in most cases (**Figure 6**).

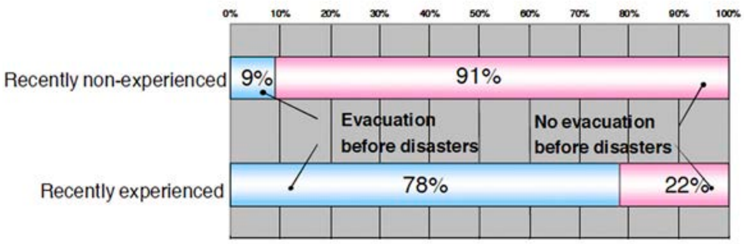


Figure 6 — Result of questionnaires to residents who experienced sediment-related disasters caused by heavy rainfall in July 2006 (MLIT Survey, 2006)

30 In addition, dependence on external support can reduce individual responsibility to deal with problems pro-actively.

31 Vulnerability should not be considered as merely being exposed to an unsafe condition, but as the result of different processes that make individuals and their properties more or less susceptible to the impact of hazards. Among the root causes of these processes, socio-economic factors are the driving forces, including access to or exclusion from education, medical facilities, economic opportunities, political participation and the use of natural resources. Those entitlements usually depend on the socio-cultural background of the population in terms of class, ethnic origin, gender and religion. Such capacities are also referred to as resilience, the opposite of vulnerability (APFM, 2008).

3 APPROACHES FOR MANAGEMENT OF SEDIMENT-RELATED RISKS

In the case of sediment disasters, it is difficult to install preventive infrastructure at every needed location because this is not feasible on an economic basis. This implies that integrated approaches to sediment disasters focus on the management rather than the prevention of debris flows and landslides. To mitigate damage, it is important to establish an effective warning and evacuation system, which includes knowledge of hazard areas, prediction of dangerous phenomena leading to a disaster and designation of sediment-related hazard areas.

Absolute protection from sediment-related disasters is technically not feasible and economically and environmentally unviable. No design standard of protection can account for the inherent inaccuracies in the estimates of the magnitude of potential disasters. In addition, it takes a long time to implement the preparation for mitigation of disasters (APFM, 2009a, p. 11). It is reasonable to consider appropriate risk management to decide on the priorities for their planning and construction. Integrated and holistic risk management assumes that the systematic action in a cycle of prevention, response and recovery is undertaken. There is no absolute guarantee for security or safety because a residual risk always remains. Risk management, hence, calls for the identification, analysis, control, avoidance, minimization, or elimination of unacceptable risks through risk-sharing mechanisms (APFM, 2009b).

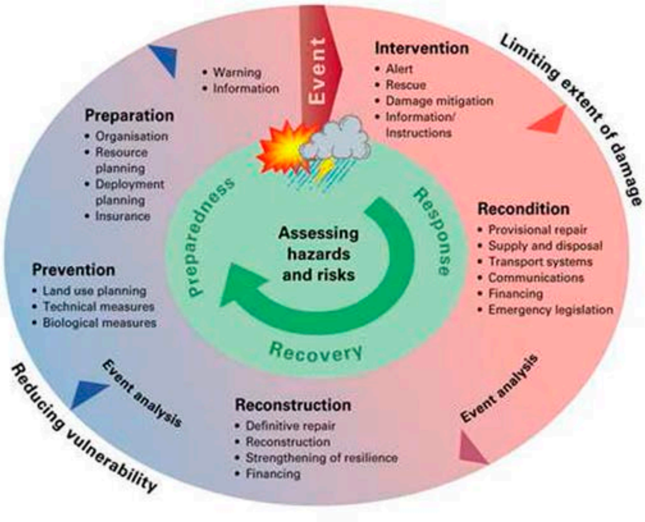


Figure 7 — Risk management stages (FOEN, 2010)

This section provides information on structural and non-structural measures for debris flows and landslides management.

3.1 Assesment of sediment-related risks

3.1.1 Identification of hazard area

Before looking at measures, the identification of dangerous areas is the first step in management planning. In this tool, the focus is on debris flows and landslides. No measures will be effective without knowing where debris flows or landslides occur and how far debris flows or landslides spread[2].

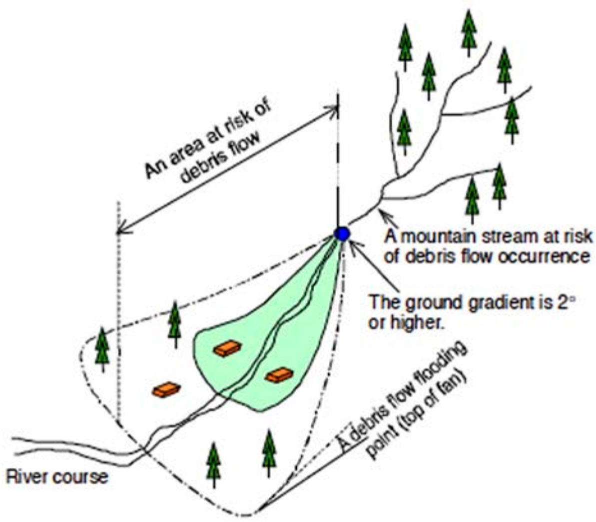


Figure 8 — Image of debris flow hazard area (MOC, 1999)

2 For detail procedures on how to identify debris flow and landslide hazard areas, refer to (MLIT, 2004, pp. 1-11).

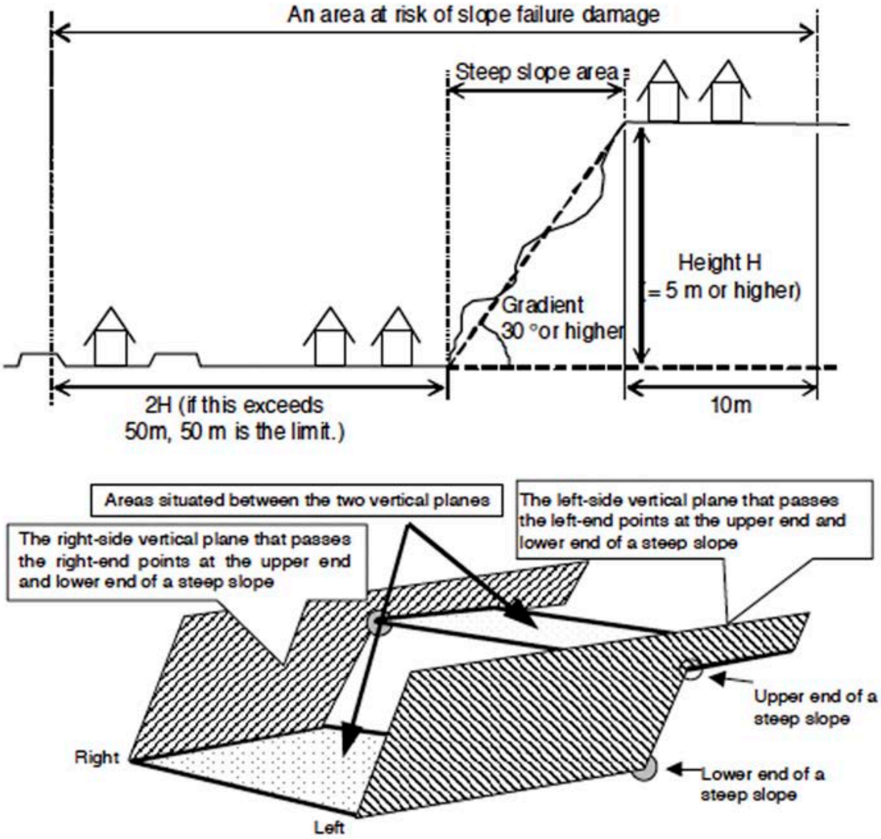


Figure 9 — Images of landslide hazard area (MOC, 1999)

3.1.2 Strategy to minimize sediment-related risks

32 As mentioned in **Chapter 2**, "Risk" can be shown as:

Risk = function (Hazard X Exposure X Vulnerability)

Structural measures reduce the value of "Hazard", in the equation. Likewise, warning and evacuation of non-structural measures reduce the value of "Vulnerability", and preparedness and regulation reduce the value of "Exposure". Therefore, the relationship between Risk and measures can be shown as:

Risk = function {(Hazard - H0) X (Exposure - E0) X (Vulnerability - V0)}

where:

- H0 = Effectiveness of structural measures
- E0 = Effectiveness of preparedness and regulation
- V0 = Effectiveness of warning and evacuation

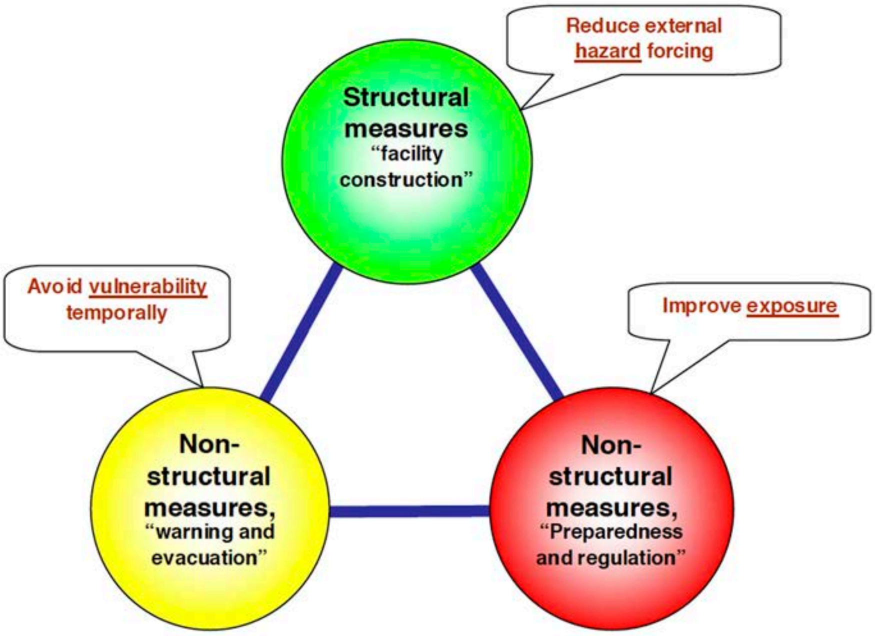


Figure 10 — Concept of measures against sediment-related risk

3.2 Structural measures

3.2.1 Structural measures against debris flow

33 To control debris flows, three types of strategies are considered:

- prevent the start of debris flow movement;
- prevent the growth of debris flow movement while flowing down;
- reduce the energy of debris flow movement and bring it under control.

34 Preventive measures against debris flows should be determined by considering topographical conditions, types of conservation, and the cause and flow mode of a debris flow in each of the following: the occurrence area, the flowing area and the sedimentation area. Primary preventive measures to be taken in each area are described as follows:

- **Occurrence area:** soil retaining works, groundsill works, and so forth;
- **Flowing area:** sabo dam, sabo dam with slits, and so on;
- **Sedimentation area:** revetment works, training dike works, channel works, dam works, sand pockets, and so on.

35 Sabo dams are physical structures that control large amount of sediment outflow like a debris flow without causing damages along the downstream. Sabo dams are the first measures to be considered against debris flows. They can provide a variety of functions, ranging from a storage function, such as the arrest and accumulation of debris flows; a control function of sediment load; an erosion control function; a conversion function of transportation mode; and a grading function of grains. Sabo dams can provide a certain level of effectiveness even after they are filled with sand and gravel. They can prevent lateral (along with channel) debris flow and thereby

reduce the supply of sediment to a stream, possibly reducing the size and hazard potential of debris flows.

36 In Europe, the United States and Japan, there has been some design and engineering work recently to install flexible ring-net barriers as either a replacement for a check dam or as a direct permeable mitigation structure, especially for small channels.

Sabo dam No. 1 on the Name River in the Nagano prefecture, Japan

Sabo dam in the Aratani River, Japan: A debris flow and driftwood restrained

Figure 11 — Sabo dams constructed in the flowing area of debris flow (MLIT, 2010)

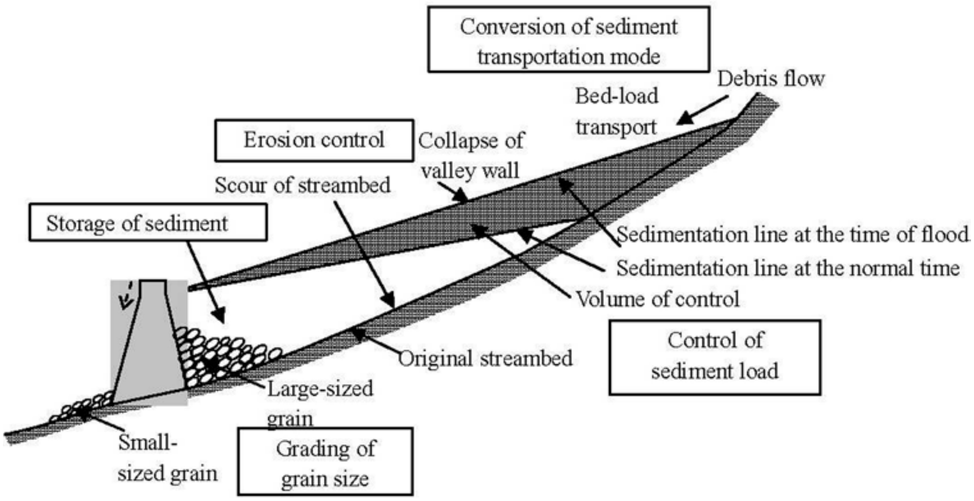


Figure 12 — Various functions of a sabo dam (Tsukamoto and others, 1991)

Series of Gabion sabo dams; Dahachowk, Nepal

Gabion sabo dam under construction; Girubari, Nepal

Figure 13 — Gabion sabo dam

3.2.2 Structural measures against slope failures

37 Structural measures against slope failures are classified into two types of works: control works and restraint works. Control works are employed to mitigate or remove the factors that may lead to slope failures, whereas restraint works are intended to prevent failures by the installation of structures. They are summarized as shown in **Table 6** and **Figure 14**.

Table 6 — Structural measures against slope failures

Type	Primary purpose	Type of works
Control works	To mitigate the effect of rainfall	Drainage works, vegetation works, slope protection works
	To remove a soil mass highly likely to collapse	Cutting of an unstable soil mass
Restraint works	To reinforce the surface soil layer in a slope	Cutting of slope to improve the form, retaining wall works, anchor works (for example, woven wire-mesh barriers), fencing works, loading embankment works

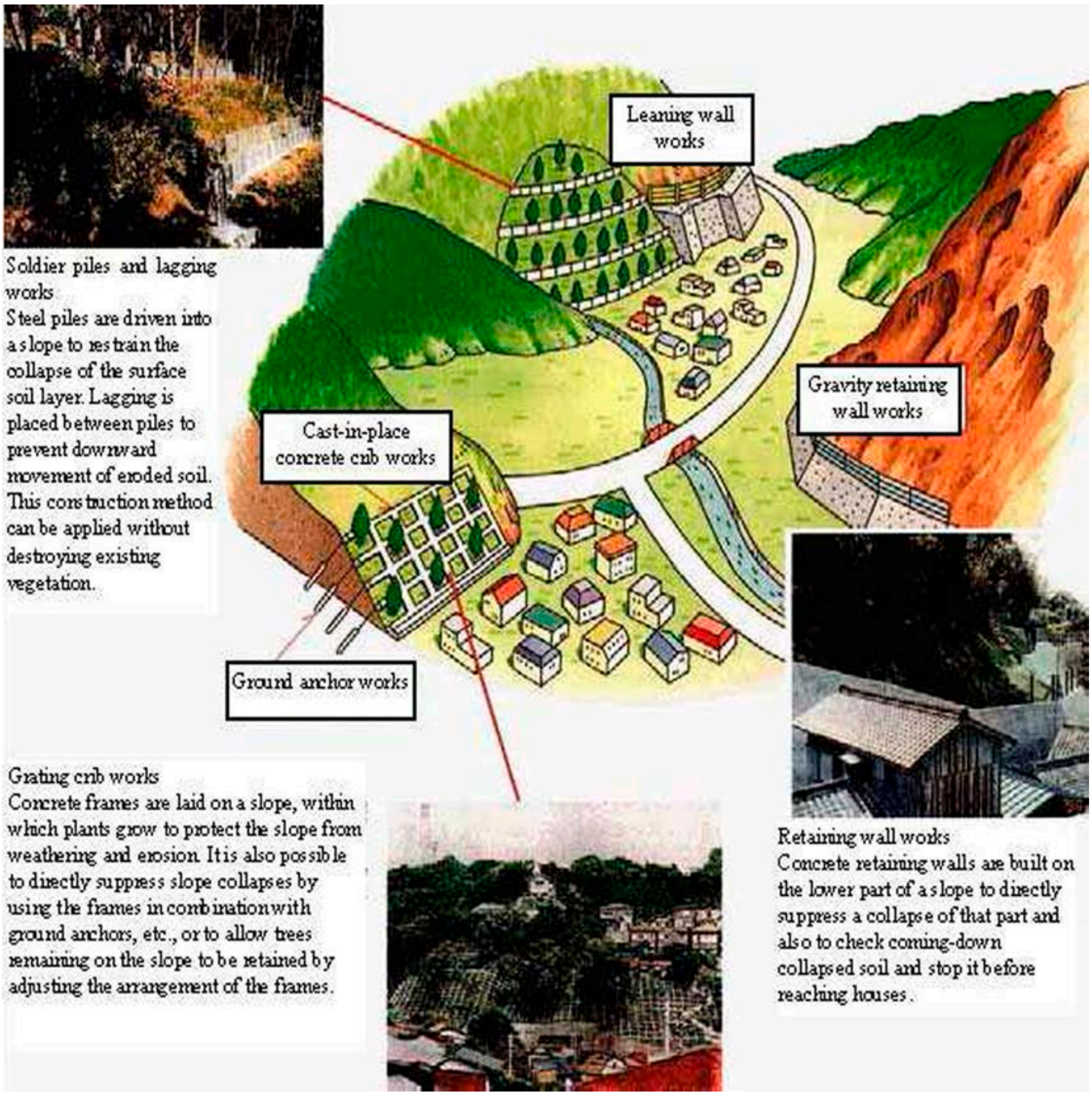


Figure 14 — Preventive measures against slope failures (MLIT, 2010)

3.2.3 Structural measures against landslide-generated dams

38 Landslide dam is formed by hillside landslides, rain, earth fall caused by earthquakes, landslides, debris flows and other circumstances. At times, it is also formed by a massive outwash from a main river to a tributary river. When a landslide dam is formed, it yields an extreme amount of sediment, potentially causing extensive damage. Generally speaking, the cause of a failure of a landslide dam is thought to be an overflow or piping. Emergency measures include founding a diversion tunnel, draining by pump, installing a cutoff, installing groundsill (a block, etc.) and other bed wall(s) to prevent downstream scouring, levee heightening in lower reach, and clearing debris from the sabo dam in the lower reaches.

39 Observation of the water level of the dam is essential and real-time information needs to be provided to the local government for warning and evacuation. After the emergency phase, government authorities should make efforts to avoid secondary disasters and to support the communityís resilience from the disaster.

Tanjiashang landslide dam; 2008, China (Photo: Xinhua News Agency)

Chuetsu Earthquake; 2004, Niigata Pref., Japan
(*Left*: Just after occurrence, *Right*: Countermeasures completed)

The Iwate-Miyagi Inland Earthquake; 2008, Iwate and Miyagi Pref., Japan
(Construction of an emergent drainage channel to lower water level; Just after earthquake; Countermeasures completed)

Figure 15 — Landslide dam and countermeasures

3.3 Non-structural measures

40 Non-structural measures consist of:

- Monitoring, forecasting and warning of sediment risks;
- Disaster preparedness and response; and
- Regulatory mechanisms.

41 The fundamental step for non-structural measures is mapping of sediment hazards. Depending on the population density, land-use planning or spatial planning should also be fundamental. For Switzerland, for example, with a lower population density in mountains and severe weather and geographical conditions, spatial planning and natural hazards are highly recommended (Federal Office, Switzerland, 2006).

42 **Sediment Hazard Maps**: To mitigate damage resulting from sediment disasters, the local population should know about the various dangers existing in their areas. One way to prepare populations is to provide them with maps containing accurate and easy-to-understand disaster prevention information. Through distribution of such disaster prevention information, potential damage can be prevented or kept to a minimum. Disaster prevention maps should be prepared with the goal of improving both disaster prevention awareness and evacuation. Disaster prevention maps should include the following information:

- Sediment disaster hazard areas in each zone;
- Locations of safe and adequate refuge facilities; and
- Evacuation routes and directions.

43 To prepare disaster prevention maps, the following surveys should be carried out.

- Survey of sediment disaster hazard areas in each zone: This survey is conducted to indicate the disaster hazard areas clearly and to find potential obstructions during evacuation;
- Survey of refuge facilities: This survey is conducted to find the safe refuge facilities located in the vicinity. Refuge facilities shall be examined in terms of refuge period, gathering place for evacuation, temporary refuge and long-term refuge;
- Survey of evacuation routes: Adequate and safe evacuation routes shall be determined in each area by considering road conditions and range of hazard areas shown on hazard maps;
- Survey of vehicles usable for evacuation: This survey is conducted to find the availability of vehicles to transport disaster-vulnerable individuals during evacuation and the conditions of those vehicles.

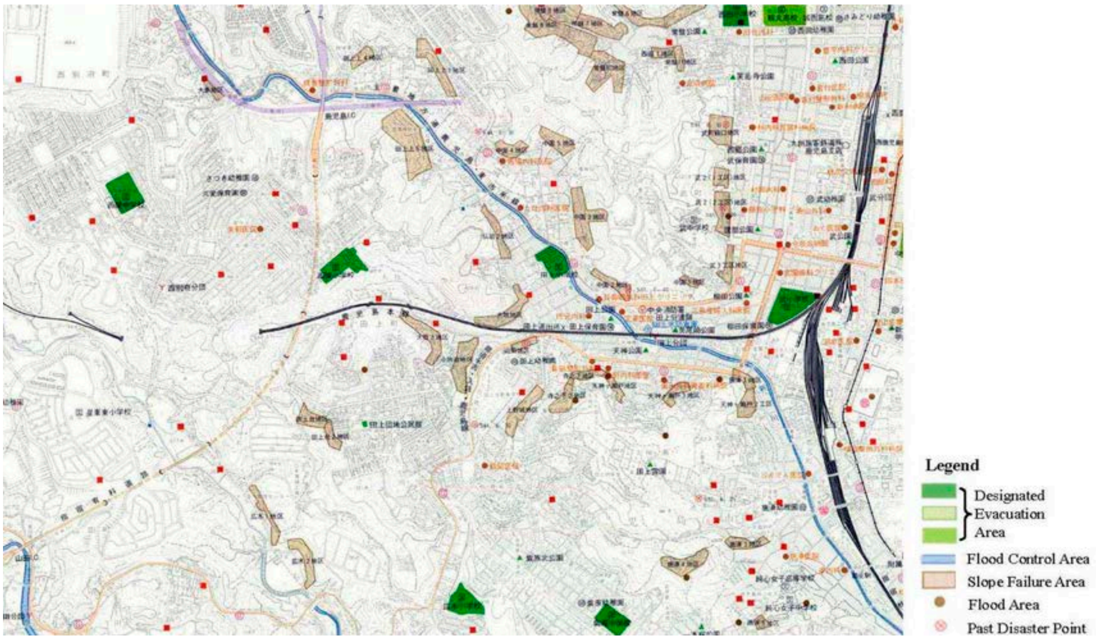


Figure 16 — An example of a disaster prevention map for sediment disasters, prepared for Kagoshima City, Japan (CAO, 2010).

3.3.1 Monitoring, forecasting and warning

44 Evacuation activities are recognized as important measures in disaster prevention because they are not only effective but also the last resort for escaping from disasters. This means that, even if sediment disasters are adequately forecasted and warning information and an evacuation instruction are provided to the population, disaster prevention would not be effective if the population could not be evacuated to safe places.

3.3.1.45 Monitoring and observation of sediment hazards

46 A warning and evacuation system against sediment disasters is based on monitoring and observation of impending sediment disasters based on forecasts that exceed established threshold rainfall values. The structure diagram of a sediment hazard monitoring and observation system in relation to the disaster warning system is shown in **Figure 17**. The system consists of the following elements:

- i **Sediment disaster monitoring system:** A system to detect the precursors and the occurrence of sediment disasters
- ii **Rainfall gauging system:** A system to gauge and record rainfalls for the forecast of sediment disasters
- iii **Sediment disaster forecast system:** A system to forecast the occurrence of sediment disasters from rainfall data
- iv **Information transmission network:** Two types of networks are available: i) transmission network of gauging information; and ii) transmission network of disaster information
- v **Organizations responsible for the delivery of warning information on sediment disasters:** Organizations in charge of the delivery of warning information on sediment disasters

vi **Organizations responsible for the emergency measures against sediment disasters:** Organizations in charge of emergency measures against sediment disasters to be provided to the local population

vii **Organizations concerned with sediment disasters:** Organizations related to the lifeline systems that may be damaged due to sediment disasters and organizations related to disaster prevention and emergency retrofit. The lifeline systems include four types of systems: i) utility systems supplying water, electricity and gas; ii) treatment systems handling sewage and wastes; iii) traffic-related systems, such as roads and bridges; and iv) communication systems for telephone lines and data transmission

viii **Local disaster prevention organizations:** Organizations that transmit disaster-related information to the local population directly and provide guidance 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 voluntary disaster prevention groups set up by the local population

ix **Local population:** Residents who suffer direct or indirect damage due to sediment disasters

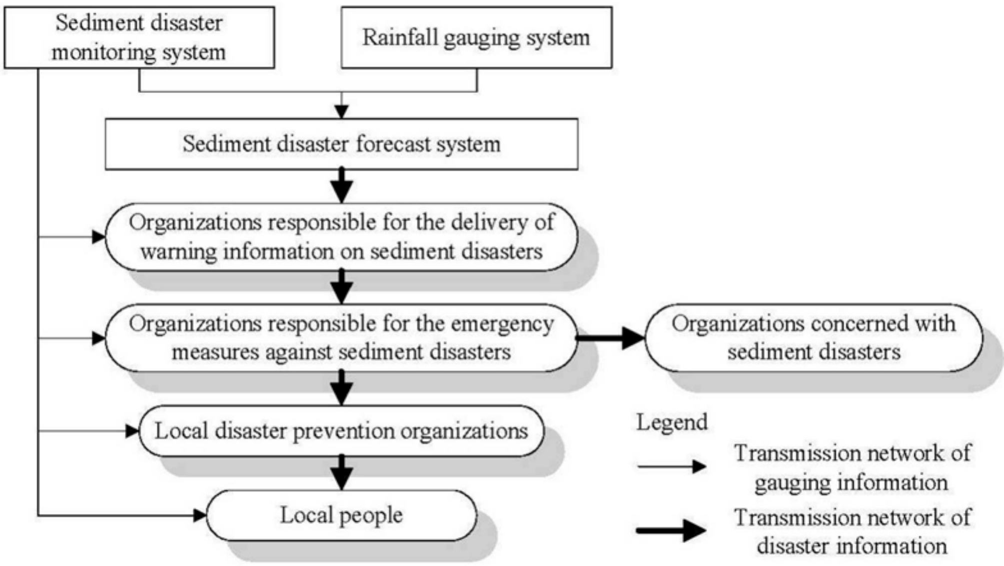


Figure 17 — Structure of sediment disaster warning system (DPRI, 2001)

3.3.1.47 Warning and evacuation system

48 A system should be in place for predicting sediment disasters. Warning information obtained by this system must be available to all individuals, and must be used for individuals' evacuation preparation and action. In developing countries, however, such a telemetric system is usually not established. Therefore, an observer must collect information from rain gauge(s) installed near affected areas, and conduct observations of early indicators of possible sediment disasters. Then, the observer must contact the disaster monitoring centre (or another mandated local authority) to report the detected information. A warning and evacuation system may be operated as follows (**Figure 18**):

i Observers of rainfall and sediment disasters must contact the disaster monitoring centre with a radio or a cellular phone when the risk of sediment disasters is detected;

ii In response, the centre predicts sediment disasters and judges the necessity of recommending evacuation;

iii When an alarm or evacuation recommendation is given, residents carry out the evacuation preparation or the evacuation itself.

49 In operating a warning and evacuation system, the necessary staff needs to be in place and organized to distribute sediment disaster information and carry out the suitable operation.

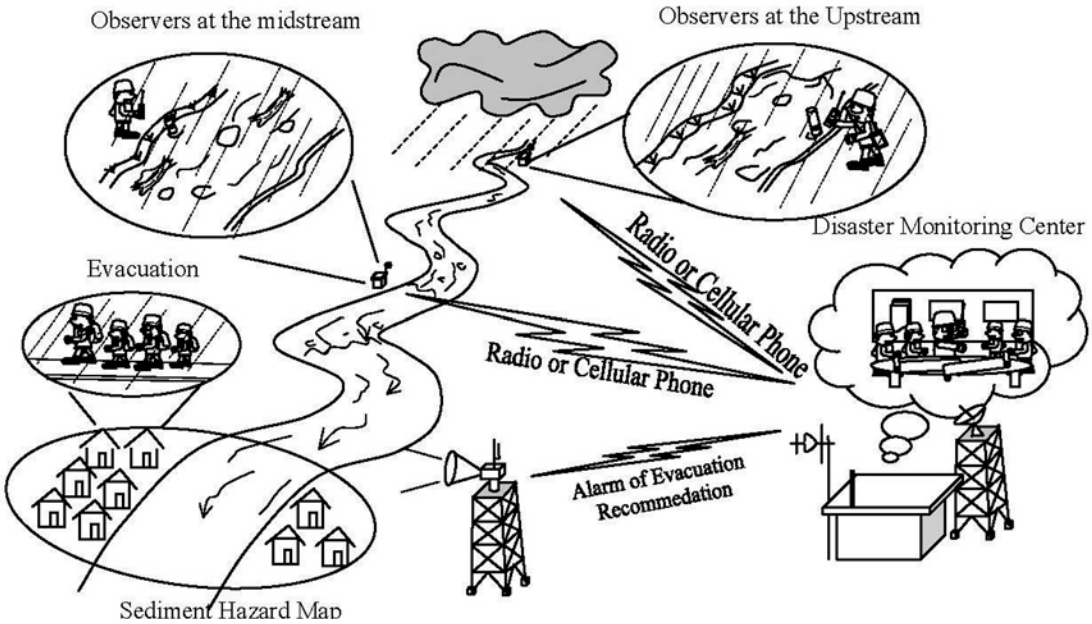


Figure 18 — Examples of operation of a warning and evacuation system against sediment disasters

3.3.1.50 Communication of warnings

51 Warning information on sediment disasters is necessary to support organizations responsible for emergency measures so that these organizations can make adequate judgements. These include evacuation instructions to the local population when sediment disasters are forecasted. The content of this information should be understandable so that the local population may use it accordingly.

52 Warning information on sediment disasters shall include the following six items at a minimum, as such information is often transmitted via fax or phone or short text message via mobile phone.

i Time of announcement authority issuing the announcement;

ii Target area (municipal name, and so forth);

iii Current danger level due to antecedent rainfall (warning issuance/evacuation instruction);

iv Predicted time of disaster occurrence and the forecast rainfall up to that time;

v Recent events that may increase the potentiality of sediment disasters (earthquakes, volcanic eruptions, ash falls, forest fires, typhoons, heavy rains, or snowmelts);

vi Other details that an organization responsible for warning information considers important for disaster prevention.

53 The principal objective of announcing warning information is to support disaster prevention efforts to save individuals from disasters by preventive measures, such as evacuation. Hence, the decision to announce warning information should be made well in advance so that protective measures can be taken during that time. Therefore, announcement of warning information should be made approximately two hours ahead of expected time of disaster (for example, forecasts of rainfall approximately two hours in advance), although timing may depend on the accuracy of the rainfall forecast system. During the final stage of providing warning information, caution is needed because the danger of sediment disasters continues even after the rain has stopped. When warning information is finalized, caution should also be taken to avoid misunderstandings. The message may be as follows: "The heavy rain has weakened and the possibility of occurrence of sediment disasters has decreased".

54 Warning information on sediment disasters should aim at depicting understandable and clear details at a glance. **Figure 19** provides an example of warning information on sediment disasters.

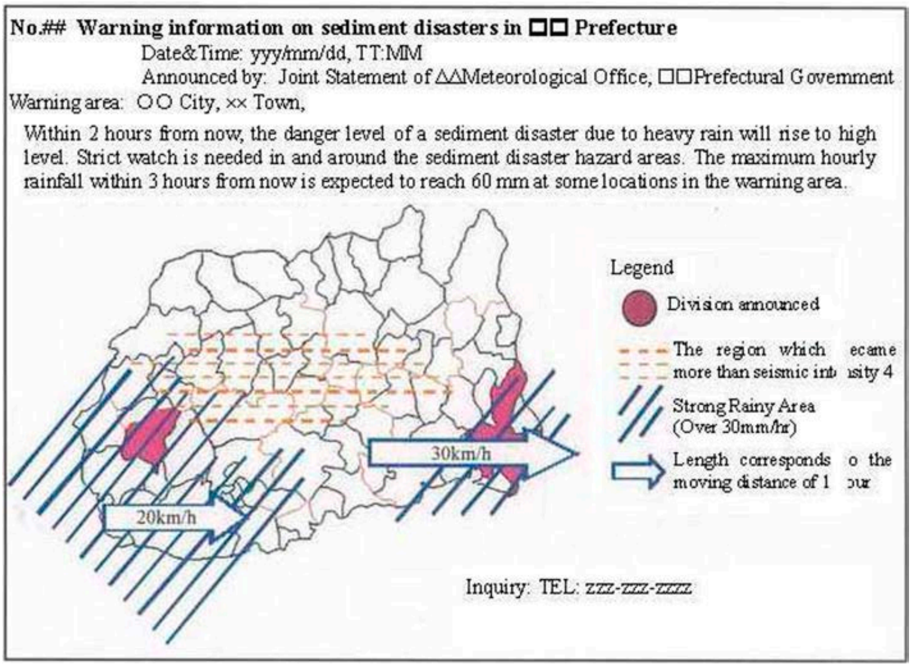


Figure 19 — Example of warning information on sediment disasters (MLIT/JMA, 2002)

3.3.1.55 Communication tools for transmission of warning

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

- 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;
- Transmission network of disaster information: this is a transmission network to convey warning information on sediment disasters to responsible organizations, concerned entities, local disaster prevention units, as well as to the local population.

57 Various tools are available to transmit this kind of information, as shown in **Table 7**. Appropriate tools should be selected taking into consideration the purpose of use, social situation and

economic conditions as well as function and precision, so that the necessary information can be collected and transmitted swiftly and accurately even during bad weather and/or disasters.

Table 7 — Communication tools for information transmission (MOC/IDI, 1997)

Communication tools	*Transmission network of gauging information*	*Transmission network of disaster information*	
		Concerned organizations/local disaster prevention organizations	Local population
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, and so forth)	-	-	○

Note: the symbol (○) indicates that those tools are applicable; the symbol (-) indicates that those tools are not applicable.

3.3.2 Disaster preparedness and planning

3.3.2.1 Disaster response manuals

2 Two types of disaster prevention manuals are considered: one is for those responsible for disaster prevention and the other is for the local population. The main contents are as follows.

Content for disaster prevention manuals

- i Conditions of sediment disasters in each area;
- ii Conditions of disaster prevention works and their effects;
- iii Sediment disasters in the past;
- iv Preparation of evacuation by warning levels;
- v Detailed evacuation methods and instructions for evacuation;
- vi Disaster prevention maps (hazard areas, evacuation routes, refuge facilities).

3 To prepare this kind of disaster prevention manual, the following surveys should be performed:

- i **Natural conditions and disaster-related conditions:** Surveys shall be made of topography, geology, rainfalls, river conditions, sediment disaster hazard areas;
- ii **Populationís awareness on disasters:** Surveys shall be made of the disaster prevention awareness of the local population against sediment disasters and problems during evacuation;
- iii **Social characteristics in areas:** Surveys shall be made of the number of residents and disaster-vulnerable individuals (infants, the elderly, the handicapped, females) living in areas where evacuation may become necessary; surveys shall also be made of social problems at the time of evacuation.

iv **Past disaster history:** Surveys shall be made of locations, disaster scale, and damage of past sediment disasters and behaviour of population at the time of disasters;

v **Current state of disaster prevention systems:** Surveys shall be made of the present conditions of voluntary disaster prevention groups, evacuation systems, warning systems and information transmission systems.

3.3.2.4 Participatory monitoring and watch

5 Establishment of a warning and evacuation system may not be easy if rainfall data are insufficient or unavailable. To prevent the occurrence of sediment disasters in situations like this, a disaster prevention system is needed that can respond to the local nature of disasters on the basis of disaster prevention units formed by the community or similar organizations.

6 The monitoring system should be set up so that the local population participates in the development process and assumes its role in disaster prevention based on a common vision with administrative units. This kind of monitoring system, based on area-wide cooperation, is called a Disaster Information Sharing System **(DISS)**. As shown in **Figure 20**, the Everyone Watching System **(EWS)** is one example of a system where administrative units as well as the local population share in the roles of disaster prevention, cooperate for enhanced preparedness against disasters from ordinary times and join forces to conserve individuals when a disaster is caused by torrential rain or other forces (Seeno and others, 2001).

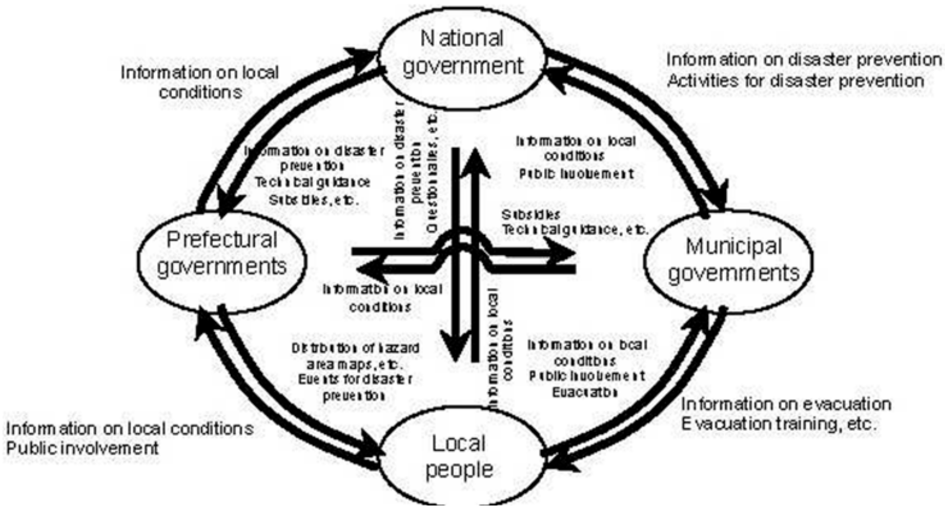


Figure 20 — Basic structure of the Everyone Watching System (EWS)

7 One of the measures supporting the EWS is the Country Watching Map **(CWM)**. The CWM is a mechanism that helps establish the EWS through consistently working towards disaster prevention from normal times to disaster times.

8 **Roles of administrative units:** Local governments are required to set up disaster prevention units and, on the basis of those units and in cooperation with the local population, collect data on past sediment disasters, prepare an easy-to-use CWM and distribute them to local areas. When torrential rain hits their area, for example, they gather disaster-related information from the local population and, if necessary, instruct them to evacuate to safe areas while closely cooperating with them.

9 **Roles of the local population:** Based on the CWM prepared in cooperation with administrative units, the local population is required to set up a disaster prevention structure and prepare for potential disasters through activities, such as the gauging of hydrological conditions, disaster prevention education, grasp of hazardous locations and disaster prevention training even during normal times. When torrential rains hit their area, individuals 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 action in close cooperation with administrative units.

10 **Preparation of Disaster Preparedness Map for Community (DPMC):** Two kinds of information should be included in disaster preparedness maps for communities:

- **Information necessary to judge the danger level in case of torrential rains:** Information for practical judgement of the degree of danger, which has never been dealt with in this kind of map, should be included in the DPMC by using past disaster records and empirical knowledge accumulated in each area. Namely, hearings should be conducted and data collected on a variety of subjects related to disasters, ranging from precursors of torrential rains to 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 rainfall during those times should be summarized clearly, together with their temporal and spatial changes. These data are called the Disaster Integrated Watching Rainfall **(DIWR)** and should be used as the criteria for judgements related to warning and evacuation.
- **Information necessary for evacuation: Information needed for evacuation should be surveyed and included in the DPMC:** These include 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 individuals, such as infants, the elderly, the handicapped; and housing conditions, such as temporary vacant houses, and so forth). See **Figure 21** for an example of the DPMC.

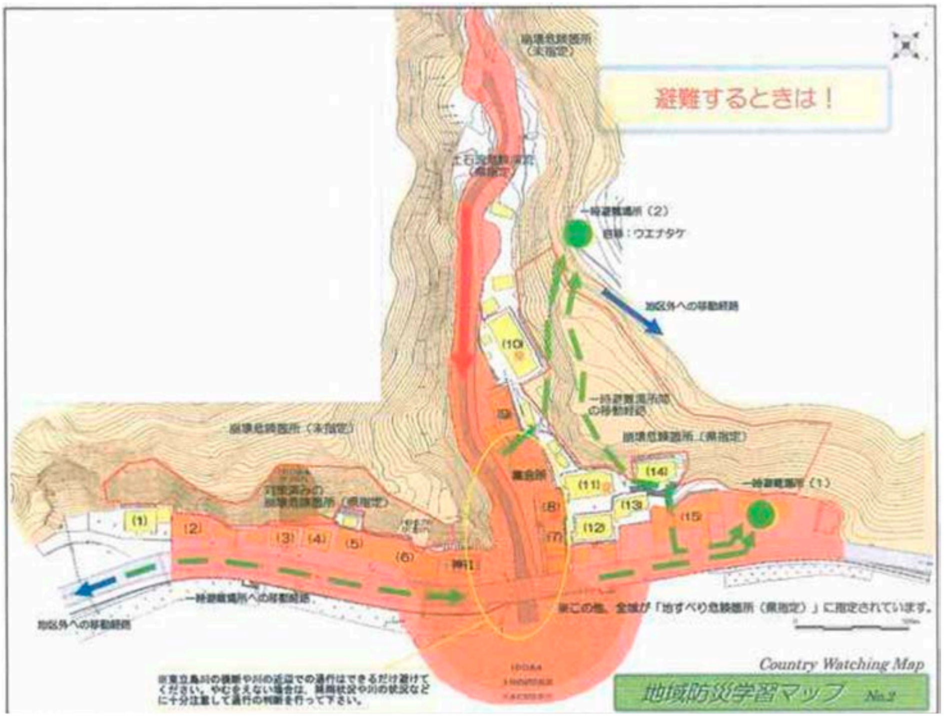


Figure 21 — Disaster Preparedness Map for Community (DPMC) showing information necessary for evacuation

11 **Survey items for preparing the DPMC -** The following items should be surveyed before preparing the DPMC:

i Survey of natural features (topography, geology and vegetation);

ii Survey of social features (disaster-vulnerable individuals, housing conditions, and so forth);

iii Survey of disaster history;

iv Survey of the present state of the disaster prevention system;

v Survey of dangerous locations;

vi Survey of points that need inspection (spring water and water paths on hillside);

vii Survey of indices for judging danger levels and relevant standards;

viii Survey of refuge facilities and evacuation routes.

3.3.2.12 Development of evacuation facilities

13 Roads and signs used for evacuation should be adequately developed and maintained to enable quick and safe evacuation when a disaster is forecasted and individuals are instructed to evacuate. Also, refuge areas and refuge facilities should be adequately established so that individuals can be protected from sediment disasters and live in safety. These evacuation facilities are explained below.

14 Evacuation roads at sediment disaster sites must be roads that are safe and not in the hazard zone of a potential sediment disaster. In addition, the condition of existing roads on evacuation routes should be surveyed; narrow or poor roads should be widened or repaired so that evacuation vehicles can go through easily. With the development of evacuation roads, evacuation signs that show adequate evacuation routes and evacuation directions should also be improved.

15 Refuge shelters should not only be safe against sediment disasters but serve a multi-hazard protection function. Shelters should include gathering places before evacuation, and places to be used in the short and long term. Depending on the locality as well as type and forecasted frequency, intensity and—where appropriate—its duration, appropriate shelters should be selected and secured. In general, schools, community centres, park grounds and public facilities should be used as refuge areas.

16 Living in tents in refuge areas is one form of refuge life, but it is important to set up more durable refuge facilities when refuge life is prolonged. This is especially important in areas where adverse weather conditions (cold spells, winter season, monsoon rains etc an be expected as a regular feature. During normal times, these refuge facilities should be used as public facilities.

17 **Public safety issues:** In refuge areas, public safety is an issue. This relates especially for the protection of women, children, senior citizens and the sick. As the population groups need to be protected from all sorts of harassment and exploitation, it is advisable to establish Community Watch groups when local government authorities are not available.

18 Provision and stockpiling of emergency goods: To conserve the life and health of the population during disasters, basic food and water must be stockpiled. As the emergency occurs, food should be kept in stock. When a disaster has occurred, stocks of basic food located in a wider area should be readily available for smooth distribution to the disaster-stricken area. Also, to prepare for failing public water supply including public wells when a disaster strikes, emergency water tanks should be set up in safe places and emergency water supply vehicles made available beforehand.

4 REQUIREMENT FOR MANAGEMENT OF SEDIMENT-RELATED RISKS

19 To reduce vulnerability of the population at risk towards sediment-related disasters, human and social factors need to be included in an integrated management framework for sediment ñ related disasters. Development and implementation of legal and institutional frameworks and community approaches is a prerequisite to maximize the effect of local disaster management efforts. Laws and by-laws (including ordinance acts for example) relating to IFM and sediment-related disaster management must address the mandates, rights and responsibilities of institutions and individuals at both the planning and implementation stages. A legal framework should ensure integration and coordination between various players; information generation and sharing; stakeholdersí participation; and clear definition of the rights, powers and obligations of all stakeholders involved. Regarding participation, communities play an essential role in every step in risk management, that is, preparedness for, response to and recovery from sediment-related disasters. This section provides requirements for achieving such frameworks and social approaches.

4.1 Legal and institutional framework

20 The establishment of legal and institutional frameworks for sediment-related disasters should be seen in the same context as those for Integrated Flood management **(IFM)** (APFM, 2006). As discussed in the previous chapter, sediment-related hazards occur suddenly in smaller areas depending on heavy rainfall in combination with topographic and geologic backgrounds; it is therefore not easy to predict them, or to judge or recognize their hazard level. To reduce vulnerability towards such sediment-related hazards, a legal and institutional framework should provide coordination and cooperation mechanisms between the various organizations, institutions, sectors and users at the local, regional and national levels. In Japan, under the Sabo (erosion control) Law of 1897, the prefectural governors are charged with construction and maintenance of sabo facilities (sabo dams, consolidation works, and so forth) and the control

of designated sabo areas, which the national government (the Ministry of Land, Infrastructure, Transport and Tourism) designates as areas where actions that could increase the risk of sediment-related hazards, such as cutting trees, are restricted. The law also stipulates that the national government can be charged with such a role if potential risks are extremely large and the benefits from sabo works could reach beyond one prefecture. Along with this legal framework, the epoch-making sediment disaster in the Hiroshima prefecture in 1999 gave the impetus for taking integrated disaster preventive measures and setting into force the law relating to Promotion of Measures for Sediment-related Disaster Prevention in a Restricted Area (Sediment-related Disaster Prevention Law) of 2000. The law was established to specifically include non-structural measures, such as establishment of warning and evacuation systems, restrictions on new residential developments and promotion of relocation of existing homes in disaster-prone areas. This law is recognized as the first legal system of direct building regulation with physical standards in the context of natural disaster prevention in Japan (APFM legal case study paper, p.45). On the other hand, because sediment-related disasters are just one type of disaster, organizations responsible for these disasters should be regarded as having one of many functions in the overall structure of disaster prevention (under the Basic Law for Disaster Countermeasures of 1961). **Figure 22** shows the outline of the organizational structure on disaster prevention in Japan.

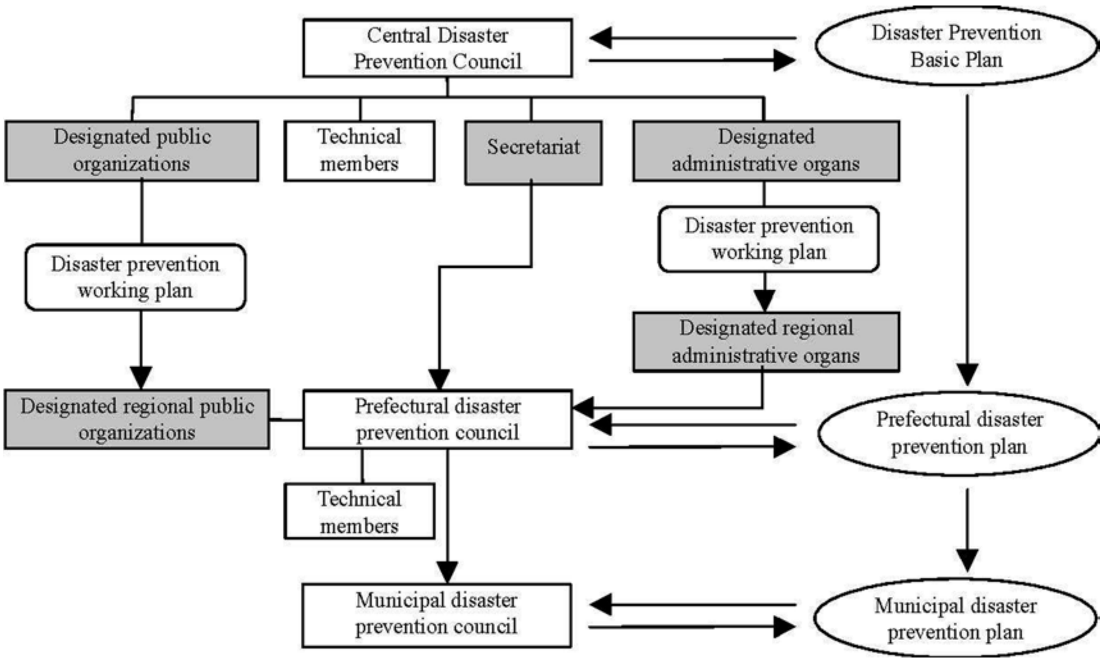


Figure 22 — Disaster prevention structure and disaster prevention plan in Japan stipulated in the Disaster Prevention Basic Measures Law (MLIT, 2004)

21 **Delivery of warning information on sediment disasters:** Organizations responsible for the delivery of warning information on sediment disasters should: 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.

22 Emergency measures: The responsible organizations in charge of emergency measures need to be clearly identified in case a sediment disaster is forecasted. In consideration of their own laws and social situations, all countries should clearly identify the organization(s) responsible for emergency measures in case these countries are at risk from sediment-related disasters. Countries are also required to secure some form of communication system that can convey disaster-related information, such as warnings and evacuation recommendations. In Japan, for instance, it is specified that prefectural governments and municipal governments take on an important role to carry out emergency measures against disasters under the Disaster Prevention Basic Measures Law. The principal roles of responsible organizations for emergency measures against sediment disasters are as follows:

- i Collection and transmission of disaster-related information;
- ii Transmission of warnings on sediment disasters;
- iii Establishment of sediment disaster hazard areas;
- iv Order to take emergency response against sediment disasters;
- v Evacuation instruction for emergency response against sediment disasters;
- vi Emergency measures for emergency response against sediment disasters.

4.2 Enabling participatory processes

23 Debris flows and landslides occur unexpectedly and possibly at several or many locations within a river basin. Thus, it is always more effective and efficient to allow for community-based management approaches that complement measures (including legal framewoks) enacted by national governments. Controlling the mechanical and incident factors through the installation of structural works and early warning systems is the most basic approach to disaster prevention. It needs to be fully recognized, however, that it is extremely difficult to identify the disaster site and occurrence time in advance, complete prevention of sediment disasters is virtually impossible,

24 Accordingly, together with continuous efforts to prevent the occurrence of sediment disasters, another important aspect to be considered is prevention of the spread of damage after a disaster has occurred. It is well known that evacuation is extremely effective in preventing and mitigating damage to populations caused by natural disasters.

25 To carry out an evacuation swiftly and adequately, disaster prevention organizations as well as the local population need to follow the activities outlined in **Table 8**. It is important to establish a warning and evacuation system in which the activities shown in the table are interlinked and coordinated systematically.

Table 8 — Activities needed for evacuating from disasters

	Normal time	*Warning time*
Disaster prevention organizations	– Preparation of disaster prevention plan – Dissemination of disaster prevention plan – Implementation of disaster prevention training – Establishment of information transmission system	– Collection and transmission of disaster information – Recommendation and instruction to evacuate – Guide for evacuees and rescue operation
Local population	– Voluntary disaster prevention organizations – Improvement of disaster	– Grasp of the state and judgement – Actual evacuation – Mutual cooperation in community
	prevention awareness – Disaster prevention training	

26 Disaster Evacuation Activities Taken by the Local Population: To involve the local population in disaster prevention efforts and encourage them to adequately evacuate by themselves, both disaster prevention organizations and the local population need to clearly know their roles and work closely together. To complete an evacuation successfully, it is necessary to predetermine how the evacuation supervisor guides individuals and how individuals are going to evacuate. For that purpose, disaster prevention maps, disaster prevention manuals and disaster prevention posters as well as other illustrative and educational materials should be prepared in advance.

27 Disaster prevention and evacuation activities against sediment disasters should be undertaken not only by disaster prevention organizations of national and local governments, but also by the local population. Both should join forces to carry out multi-hazard activities including flood management activities, evacuations, guidance as well as relief of disaster-affected individuals. These activities are particularly important to minimize damage, prevent collateral damages and to execute disaster prevention activities without delays. For that purpose, establishment of voluntary disaster prevention groups by the local population based in the area and their awareness to conserve lives and properties should be promoted.

28 To mitigate damages due to sediment-related disasters, the local population should understand types of sediment disasters, their precursors, early indicators and measures to minimize impacts. Focus should be on extreme precipitation, early indicators for slope failures, mass movements, earthquakes and other phenomena to prepare for possible countermeasures. As presented in **Table 9**, sediment disasters exhibit various precursors that can be detected by humans. When those precursors are captured before or after a long rain, a heavy rain, or an earthquake, the local population is encouraged to report it to an organization in charge of disaster prevention. Such precursor events do not necessarily mean that a sediment disaster will follow, or that a sediment disaster may not be preceded by a precursor event. In this sense, **Table 9** shows possible precursors and their usefulness in being shared by individuals that experienced previous disasters in the region.

Table 9 — Precursors of sediment disasters

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

4.3 Education and awareness

4.3.1 Education and awareness on disaster prevention

29 To enhance disaster prevention awareness of the local population and encourage individuals to evacuate quickly when a disaster has occurred, it is important to provide education and awareness on disaster prevention and evacuation to the population. Methods to be adopted for education and awareness are explained below.

30 **Dissemination of disaster prevention knowledge:** To promote disaster prevention activities, self-consciousness and cooperation of each resident is needed. Therefore, disaster prevention knowledge must be distributed and disaster prevention awareness must be improved through school education and community activities.

Disaster prevention posters for the population shall be prepared by extracting important points that should be kept in mind for disaster prevention or during evacuation. Posters should be placed at schools, churches, mosques, local offices or other public facilities to enhance disaster prevention awareness of the local population and their knowledge for safe evacuation.

31 **Events on disaster prevention:** To enhance disaster prevention awareness of the local population and promote understanding of the danger of sediment disasters, a variety of events, such as lectures and fairs for disaster prevention, should be held using disaster prevention manuals, maps, posters and videos. Posters are especially useful for building awareness of disaster prevention. **Figure 23** is an example of a poster prepared in Indonesia for sediment disasters (a pyroclastic flow and a debris flow) at Mt. Merapi as an example of a highly dangerous volcano in Indonesia.

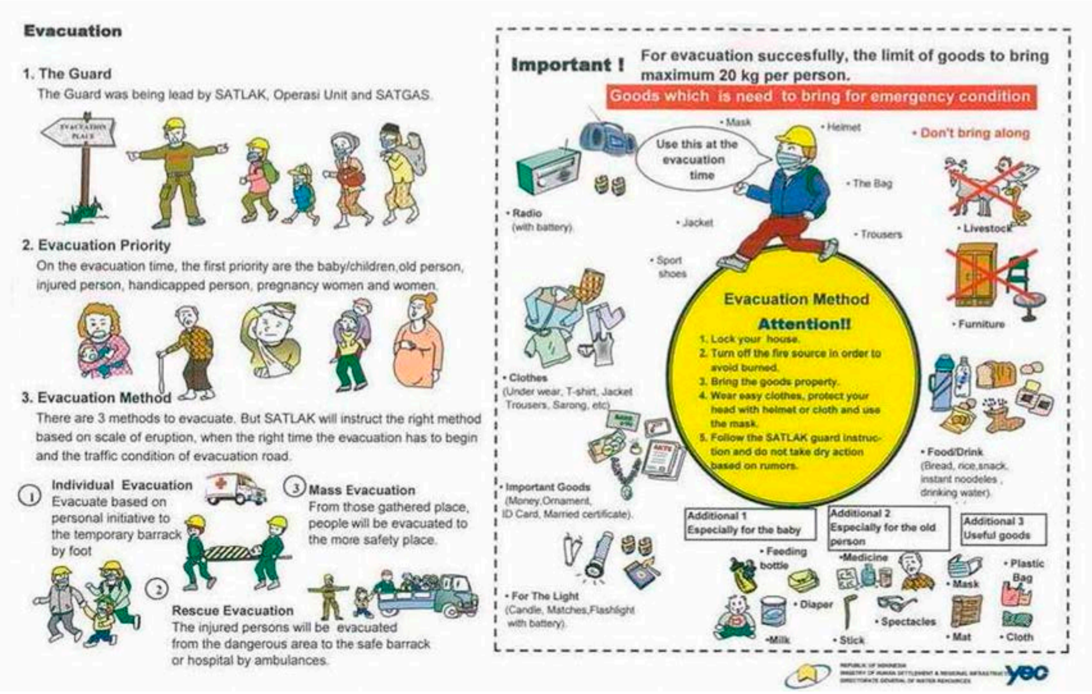


Figure 23 — An example of the disaster prevention poster, Merapi Volcano, Indonesia (Kimpraswil and Yachiyo, 2001)

32 **Warning and evacuation training:** In cooperation with disaster prevention organizations, voluntary disaster prevention groups and the local population, simulations should be carried out of sediment disasters occurring or having occurred as well as warning and evacuation training, consisting of warning transmission, evacuation and disaster relief. In particular, events such as Disaster Prevention Day or Disaster Prevention Week should be carried out in areas, as well as large-scale disaster prevention/evacuation training. These events should be held once a year with the cooperation of national, prefecture, district and municipal governments as well as disaster prevention organizations. Disaster prevention training should be carried out according to disaster prevention manuals and under the instruction of a supervisor in charge of regional disaster prevention.

4.3.2 Human resources development and organizational strengthening

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

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

5 CONCLUSIONS AND RECOMMENDATIONS

34 Debris flows and landslides are primary sources of sediment, and supply sedimentation to downstream morphology and ecology of rivers, but have serious and high damage potential to human activity and property when they occur near populated areas. They are characterized as largely unexpected and sudden onset events, affecting entire sub-basins. Population pressure and demand for agricultural areas encourage encroachment of human activities in high risk areas especially in hilly and mountainous regions prone to sedimentñrelated disasters. In managing these risks, the following issues should be considered:

- Sediment-related disasters are categorized into three: debris flow, slope failure and landslide, based on potential (topography, geology, and so forth) and triggering (rainfall, snowmelt, groundwater) factors;
- The fast and unplanned growth of habitat areas results in a larger number of individuals living in areas potentially vulnerable to debris flows and landslides. The management of these areas needs an appropriate approach for planning of land use and development;
- With the rapid increase of populations and enlargement of arable land owing to social demands, more individuals without disaster experience now live in hazardous areas. Such a social environmental change should be closely monitored with regard to the vulnerability for debris flows and landslides;
- Sabo dams are structural measures against debris flows, whereas control and restraint works, such as drainage and slope cuts, are preventive measures against slope failures. It is difficult, however, to install these preventive works in every risk area; thus, integrated approaches with non-structural measures are imperative for their management;
- A sediment-related disaster warning system should be supported with a comprehensive legal and institutional framework. Under this framework, monitoring and forecast organizations as well as the local population should play a role for delivery of warning and emergency measures;

– Warning information on sediment-related disasters requires:
  - suitable operation on observation of rainfall and sediment disasters carried out by capable staff;
  - adequate judgements on whether or not to announce warnings well in advance so that protective measures can be taken during that time; and
  - effective and appropriate tools available to transmit disaster information swiftly and accurately even during bad weather and/or disasters.
– Complete prevention of sediment-related disasters is virtually impossible because it is extremely difficulty to identify the disaster site and occurrence time in advance; therefore, disaster prevention organizations and the local population need to take action both during normal and warning times. The Disaster Information Sharing System (DISS) is a good example of administrative units coming together with the local population to share in the roles of disaster prevention, cooperate for enhanced preparedness and join forces to save individuals in cases of emergency;
– Tools for evacuation, such as disaster prevention maps, manuals and posters, can facilitate evacuation activities. Disaster prevention maps contain hazard areas, locations of safe and adequate refuge facilities and evacuation routes. Manuals provide conditions of disasters and their prevention, past events, preparation and evacuation action along with maps. Evacuation facilities, such as road signs, should support them;
– Through appropriate dissemination, individualsí capacity to help themselves should be enhanced. Precursor information can help save lives before, during and after disaster events.

REFERENCES

All references were accessed 17 February 2011

A

Associate Programme on Flood Management (APFM), 2009a: *Integrated Flood Management - Concept Paper*
www.floodmanagement.info/pdf/concept_paper_e.pdf

APFM, 2009b: *Risk Sharing in Flood Management.* A Tool for Integrated Flood Management
www.floodmanagement.info/pdf/ifm_tools/Tools_Risk_Sharing_in_FM.pdf

APFM, 2008: *Urban Flood Risk Management.* Tools for Integrated Flood Management
www.floodmanagement.info/pdf/ifm_tools/Tools_Urban_Flood_Risk_Management.pdf

APFM, 2006a: *Legal and Institutional Aspects of Integrated Flood Management*
www.floodmanagement.info/pdf/ifm_legal_aspects.pdf

APFM, 2006b: *Social Aspects and Stakeholders Involvement in Integrated Flood Management*
www.floodmanagement.info/pdf/ifm_social_aspects.pdf

C

Cabinet Office Japan (CAO), 2010: *Disaster Prevention Map of Kagoshima City, Japan in 1999*
www.bousai.go.jp/map/kagosima

D

Disaster Prevention Research Institute (DPRI), 2001: *Disaster Prevention Handbook (in Japanese), Asakura Shoten Publisher, Tokyo, Japan, p.* 724.

F

Federal Office for Spatial Development, Federal Office for Water and Geology, and Swiss Agency for the Environment, Forests and Landscape, 2006: *Spatial Planning and Natural Hazards, Recommendation*
www.bafu.admin.ch/publikationen/publikation/00806/index.html?lang=en

Federal Office for the Environment, Switzerland (FOEN), 2010: *Natural Hazards in Switzerland*
www.planat.ch/index.php?userhash=47851918&l=e&navID=5

J

Japan Meteorological Agency (JMA), 2002: *Report on Warning Information on Sediment Disasters and Necessary Countermeasures (in Japanese)*
www.jma.go.jp/jma/kishou/chousa/030529houkoku.pdf

K

Kimpraswil and Yachiyo Engineering Co. Ltd, 2001: *Consulting Services for Mt. Merapi and Mt. Semeru Volcanic Disaster Countermeasures Project (Phase II).* Mt. Merapi Project, Main Report for Review Master Plan Study.

M

Ministry of Construction (MOC), 1999: *Research guideline for sediment disaster risk area (in Japanese).*

Ministry of Construction/Infrastructure Development Institute (MOC/IDI), 1997: *Research for technical transfer on civil engineering, sediment-related disaster, water resources management, emergency system.*

Ministry of Land, Infrastructure and Transport, Japan (MLIT), 2004: *Guidelines for Construction Technology Transfer, Development of Warning and Evacuation System against Sediment Disasters in Developing Countries.*

MLIT, 2010
www.mlit.go.jp/river/sabo/index.html (in Japanese)

S

Senoo, K., K. Haraguchi, T. Kikui and Y. Saito, 2001: *The disaster prevention system easy to understand for the local people - The establishment of disaster prevention system by the Country Watching Map.* Journal of the Japan Society of Erosion Control Engineering, Vol. 53, No. 5, Ser. No. 232, pp. 31-37.

T

Takahashi, S., 1991: *Sabogaku-Gairon [Introduction of erosion and sediment control] (in Japanese), Kajimasyuppan, p.* 254.

Tsukamoto, Y. and S. Kobashi, 1991: *Shin-Sabo-Kougaku [New Erosion and Sediment Control Engineering] (in Japanese), Asakurashoten, Tokyo, Japan, p.* 193.

For more information, please contact:

Associated Programme on Flood Management
c/o Climate and Water Department
World Meteorological Organization

tel +41 (0) 22 730 83 58
fax +41 (0) 22 730 80 43
email apfm@wmo.int
www.floodmanagement.info

World Meteorological Organization
Communications and Public Affairs Office
7 bis, Avenue de la Paix – P.O. Box 2300
CH-1211 Geneva 2 – Switzerland

tel +41 (0) 22 730 83 14/15
fax 41 (0) 22 730 80 27
email cpa@wmo.int
www.wmo.int

GWP Global Secretariat
Linnégatan 87D - PO Box 24177
SE-104 51 Stockholm – Sweden

tél +46 8 1213 86 00
fax +46 8 1213 86 04
email gwp@gwp.org
www.gwp.org