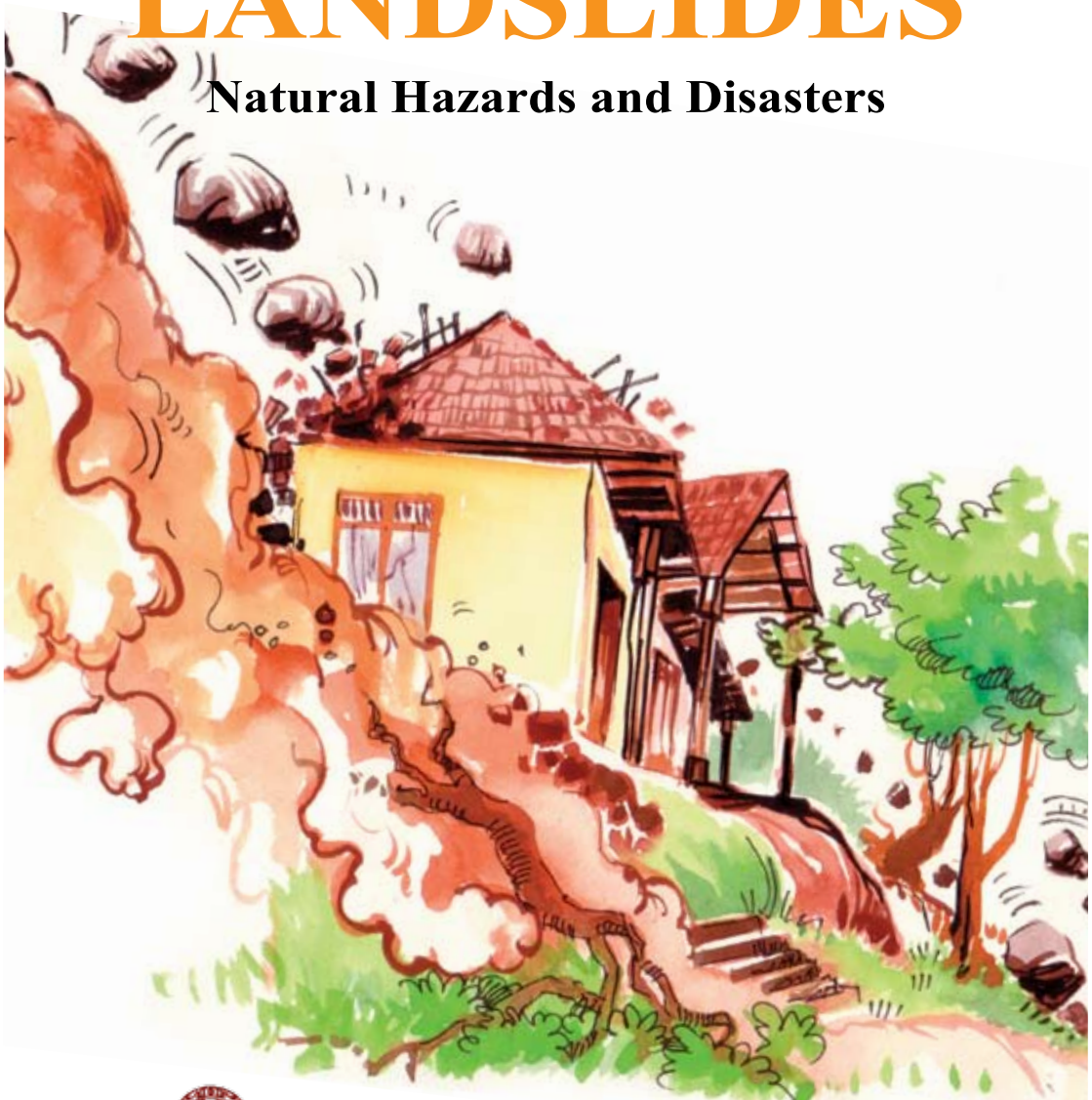


Learning to live with

LANDSLIDES

Natural Hazards and Disasters



**Department of Institutional Development
National Institute of Education**

2008



Ministry of Education

**Ministry of Education National Institute of Education
Education for Social Cohesion, Disaster Risk Management and
Psycho-social Care Programme**



National Institute of
Education

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LANDSLIDES
Natural Hazards and Disasters

2008

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Adapted for Sri Lanka

by

Kumari M. Weerasinghe
Scientist, Landslide Studies and Services Division
National Building Research Organisation
(Texts)

Anuradha Malalasekara
Lecturer, Department of Linguistic,
University of Kelaniya, Daligama, Kelaniya
(Texts)

Kapila Dahanayake
Senior Profesor, Department of Geology,
University of Peradeniya
(Editing)

Susil Jayashantha Perera
(Illustrations)

FOREWORD

Disaster resilient schools and the well being of school children are significant goals under the overarching commitment towards quality education for all. Adequate disaster preparedness and prevention start with knowledge and skills – thus education is one way to create a safe and disaster resilient society. In the classroom, knowledge, innovation and skills to reduce disaster risks can be created.

The dramatic impacts of the Tsunami 2004 and the floods and landslides 2003/ 2006 on the education situation of children, have shed light on the urgent need for disaster safety education. The Disaster Management Act no 13 of 2005 was enacted providing strong legislative and institutional arrangements for disaster risk reduction. In this context, education and public awareness to meet these challenges are also strongly recommended.

The objective of this educational booklet on landslides– to be seen as part of a series of booklets on natural hazards - is to prepare school children, teachers, parents and the community for future natural disasters. The booklet shall enable teachers and school children to learn about landslides: In an illustrative way it explains the different types of landslides, the indicators of a landslide phenomenon and what negative effects and losses landslides can cause on human beings and the environment.

Furthermore, the booklet provides landslide preparedness tips: It advises on how we shall act to be prepared for landslides and how to act correctly to reduce the likelihood of landslides. It advises how to act correctly before, during and after a landslide, taking into consideration the various types of landslides that can occur in different living areas of human beings. Finally, psycho-social aspects for well being in the aftermath of a landslide are considered. The booklet explains ways that can help children and their families to get back to normal life after the disaster.

It is hoped that the present publication contributes to help saving children's and teachers' lives and to enable them to spread the key messages of disaster preparedness and risk reduction further to the community. Their active participation is desired for moving the world towards a safer living place and a sustainable developed society.

Prof. Lal Perera

Director General

National Institute of Education

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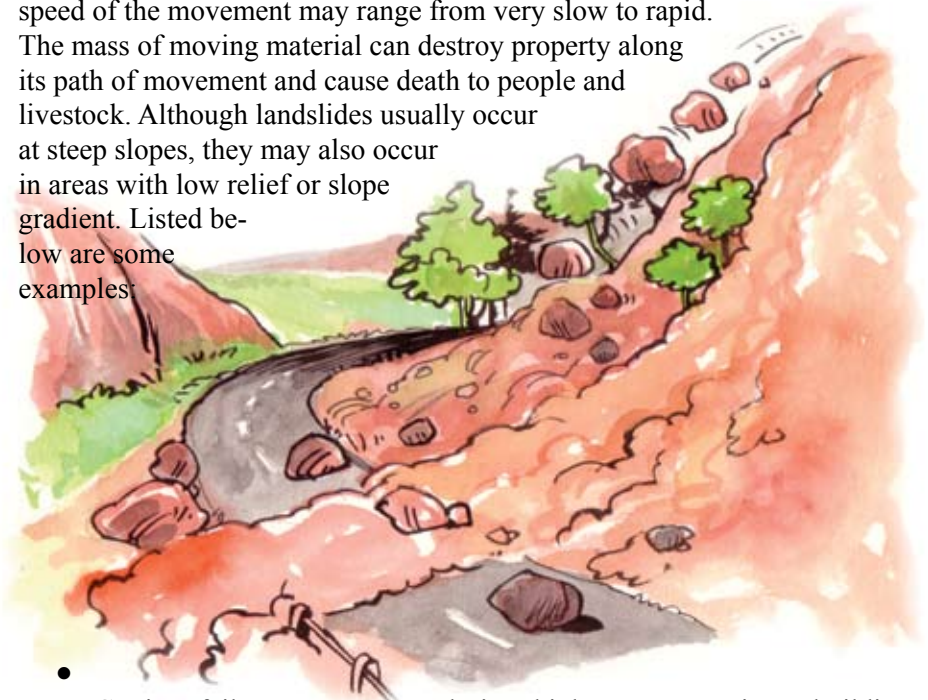
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1. INTRODUCTION

Landslides

A landslide occurs when part of a natural slope is unable to support its own weight. For example, soil material on a slope with slippery surface underneath, can become heavy with rainwater and slide down due to its increased weight. A landslide is a downward or outward movement of soil, rock or vegetation, under the influence of gravity. This movement can occur in many ways. It can be a fall, topple, slide, spread or flow. The speed of the movement may range from very slow to rapid.

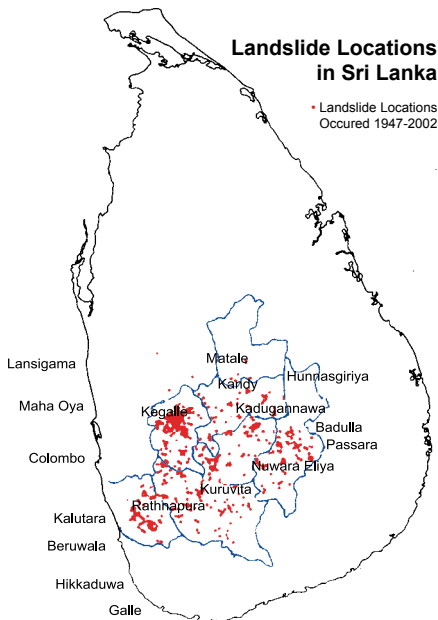
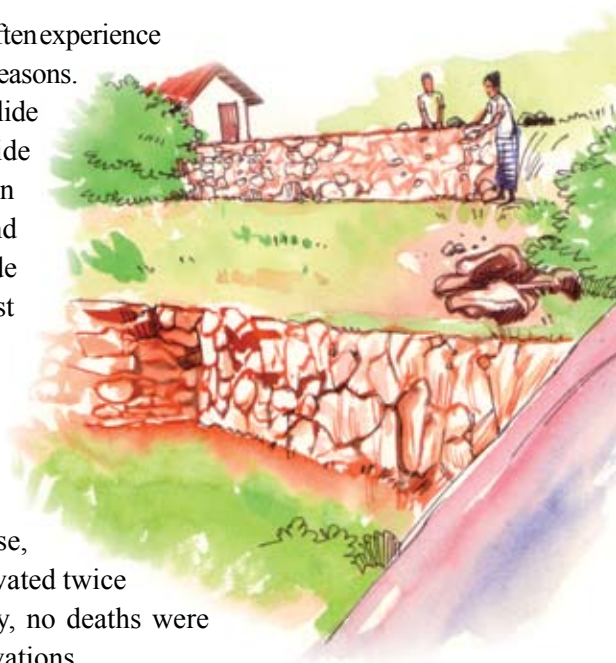
The mass of moving material can destroy property along its path of movement and cause death to people and livestock. Although landslides usually occur at steep slopes, they may also occur in areas with low relief or slope gradient. Listed below are some examples:



-
- Cutting failures can occur during highway excavations, building construction, etc.
- River bank failures
- Lateral spreading of soil material
- Collapse of mines, waste piles and garbage fills
- Slope failures associated with quarries and open-pit mines
- Underwater landslides at the bottom of lakes or reservoirs and offshore marine settings.

2. LANDSLIDES IN SRI LANKA

The central highlands of Sri Lanka often experience landslides during the rainy seasons. Landslide at Watawala landslide in 1992, Hela Uda landslide in 1993, Naketiya landslide in 1997, Mulhalkele in 1986 and Elapatha, Abepura landslide in 2003 can be named as most devastating landslides that occurred in the recent history claiming many lives, damaging the property and having a significant impact on the country's economy. Out of those, the Hela Uda landslide got reactivated twice in 2003 and 2006, but fortunately, no deaths were recorded during those two reactivations.



The National Building Research Organization is mapping the districts of Matale, Kandy, Nuwara Eliya, Badulla, Kegalle, Ratnapura, Kalutara, Galle, Matara and Hambantota in terms of their landslide potential. These maps can be utilized to identify the degree of hazard associated with a specific area and as a result, the maps are an invaluable tool for relocating highly vulnerable communities and infrastructure, identifying economical mitigatory measures and also for planning future developments.

3. CAUSES OF LANDSLIDES

The basic causes of slope instability can be:

- Weakness in the composition, material or geological structure of rock or soil formation
- External factors, which impact the ground water regimes. Examples are
 - Heavy rain
 - Snowmelt
 - Changes in ground water level etc.
- Earthquakes or volcanic activities
- Creation of new site conditions such as changes to natural slope due to construction activities.

Natural and manmade changes to such unstable slopes can trigger landslides.



3.1 Man-made causes

These are human activities on slopes such as:

- Construction done without proper engineering and geological inputs
- Improper farming practices
- Indiscriminate removal of vegetation cover and deforestation, etc.

These activities may cause increase in slope gradient or significant change in surface and ground water regimes adding to the instability of slopes.

Excavation or cuts increase the slope angle if carried out without specialist advise. Mining, blasting rock or reclamation of land can also destabilize slopes. Farming activities on slopes involve removal of vegetation cover usually followed by terracing. Sometimes, farmers burn down vegetation as a convenient method



of clearing land for cultivation. Commercial logging results in deforestation. These activities increase surface run-off of rainwater and expose the soil to erosion. Changes in water regime results in raising or lowering of ground water table. Alteration of surface drainage can also be a contributory factor. Irrigation alters natural surface drainage. Surface run-off of irrigated water on slopes exposes soil under cultivation to erosion. Part of this water is absorbed by soil increasing its weight, which can put an additional load on the slope. Seepage and accumulation of irrigated water on slopes can raise the ground water table. This can also be a result of wastewater discharge, water pipe leakage from permanent and temporary storage facilities such as ponds and subsurface irrigation facilities.

Human activity can also lead to the lowering of the water table. Pumping from underlined water supply wells, rapid lowering of water level in rivers, lakes or reservoirs can bring about lowering of the water table under soil.

3.2 Natural factors

There are several natural factors that can cause slope failures. These are outlined below.

- Intense rainfall or deposition of snow will raise the ground water table; decrease the soil strength and increase weight of associated materials.
- Rapid snowmelt in mountains- rapid melting of snow adds water to soil/ rock mass on slopes (not common in Sri Lanka).
- Fluctuation of water levels due to the tidal action.
- Lowering of the water levels in rivers, reservoirs, etc.
- Erosion caused by continuous runoff over a slope. The removal of toe and lateral support of a soil mass by flow of water in streams, rivers, wave action etc., can bring about instability of the soil/rock mass.
- Deposition of loose sediments in delta areas.
- Decomposition of rocks
- Ground vibrations created during earthquakes (not common in Sri Lanka).
- Volcanic activity – In areas where there is an existing volcano, volcanic ash deposits (sometimes called as lahars deposits) are prone to erosion and subjected to mud flows due to intense rainfall (not reported in Sri Lanka).

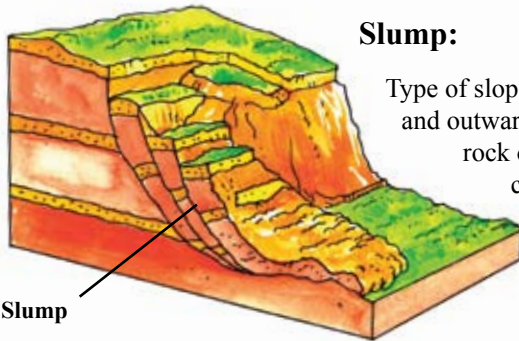


3.3 Combination of factors

There is the possibility that several natural factors occur simultaneously. In some cases, one hazard triggers another. For example, an earthquake may trigger a landslide, which in turn may dam a valley causing upstream flooding and subsequent dam burst. This will lead to flooding in lower catchment areas.

Another example can be where heavy rainfall is accompanied by cyclonic wind. This can cause wind debris flow and flooding in the same area. Interactive events that occur in sequence may produce cumulative effects that are significantly different from those expected from any single event.

4. TYPES OF LANDSLIDES AND SLOPE FAILURES:

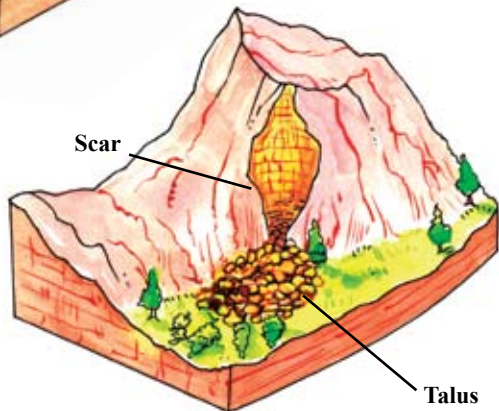


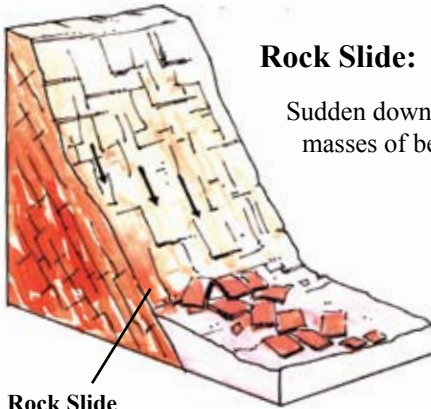
Slump:

Type of slope failure in which a downward and outward rotational movement of rock or soil occurs along a curved concave up surface.

Rock Fall:

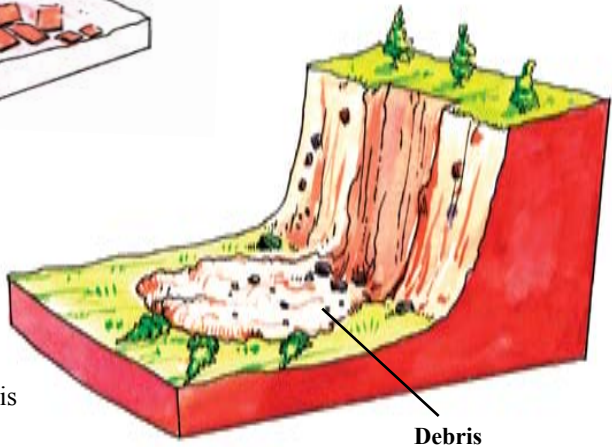
Free falling of detached bodies of bedrock (boulders) from a cliff or steep slope





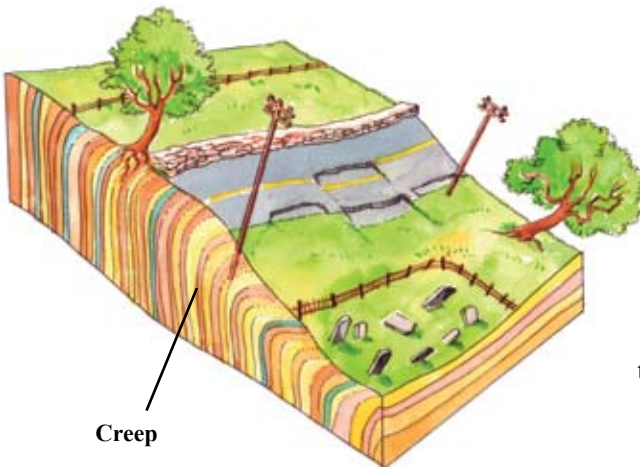
Rock Slide:

Sudden downslope movement of detached masses of bedrock is called a rockslide.



Debris Fall:

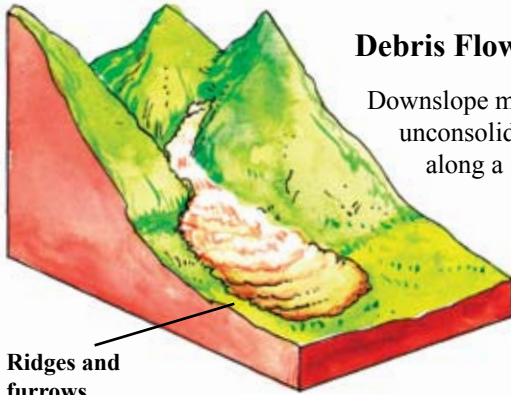
Free falling is not only rock but also overlying sediments and vegetation is known as debris fall.



Creep:

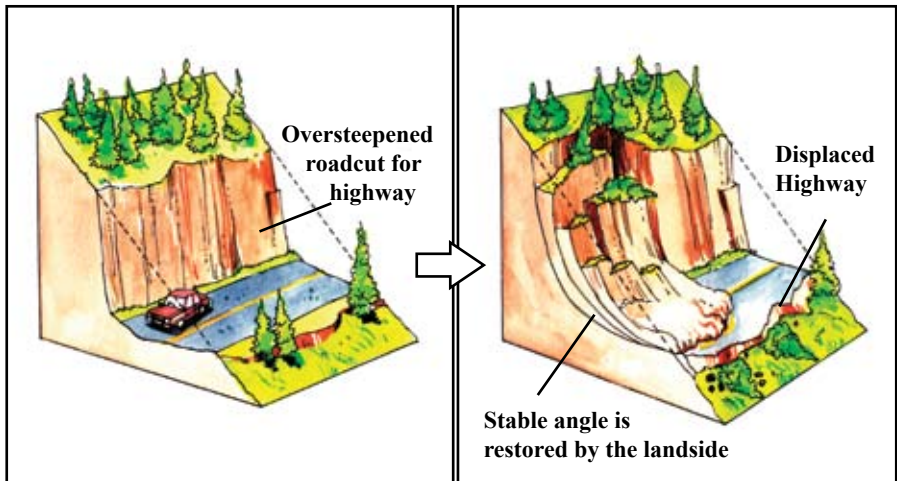
Imperceptibly slow downslope movement of earth cover or regolith. Utility poles, fence posts and gravestones etc. appear tilted or deformed on the surfaces where affected by creep.

Debris Flow



Debris Flow:

Downslope movement of collapsed, unconsolidated material typically along a stream channel.

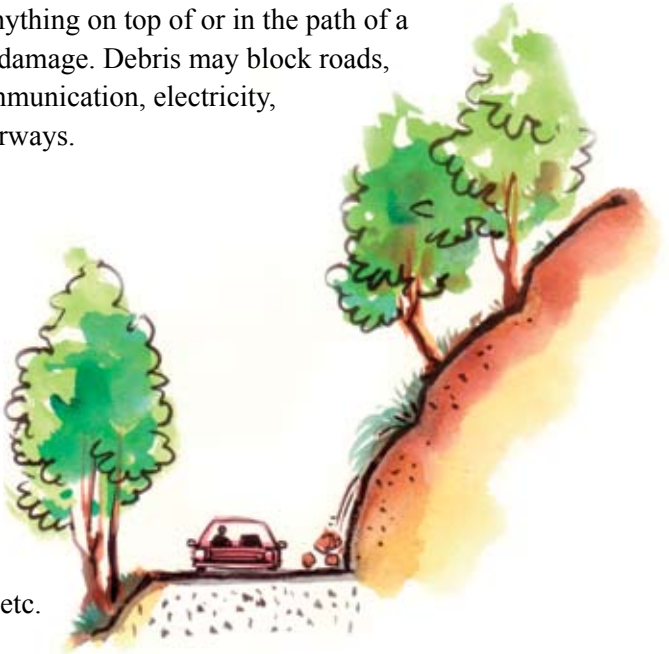


Slope Failure due to Slope Modification

When natural Slopes are modified by human activities, slides often occur.

5. DIRECT EFFECTS

- * Physical Damage- anything on top of or in the path of a landslide will suffer damage. Debris may block roads, supply lines (telecommunication, electricity, water, etc.) and waterways.
- * Casualties- deaths and injuries to people and animals.
- * Indirect loss of productivity of agricultural and forests land, reduced property values, erosion, flooding in downstream area, etc.



6. INDIRECT EFFECTS

Influence of landslides in dam safety

- The safety of a dam can be severely compromised by land sliding in the upstream area of the dam or on the slopes bordering the reservoir. Possible impacts include:
- Flood surges caused by movements of large masses of soil into the reservoir. The wave formed by those failures can overtop the dam causing downstream flooding and possibly failures to the dam.
- Increased sedimentation in the reservoir, resulting in loss of water storage and increased likelihood that the dam will be overtopped during periods of excessive runoff.

Landslides and flooding

Landslides and flooding are closely associated because both are related to intense rainfall, runoff and ground saturation.

Debris flow can cause flooding by blocking valleys and stream channels, forcing large amounts of water to backup. This causes backwater flooding in the upstream area and if the blockage gives away, quick downstream flooding too.

In turn, flooding can cause landslides, due to rapidly moving floodwaters, which often undercut slopes or abutments. Once support is removed from the base of saturated slopes, land sliding often takes place.

Landslides and seismic activity

The occurrence of earthquake in steep landslide-prone areas greatly increases the likelihood of devastating mudflows and reactivation of mass movements on slopes.

Large fills can become unstable due to moderate seismic activity if proper lateral support is not provided.

Damage to electrical wires may also start fires.

7. LOSSES DUE TO LANDSLIDES

Landslides result in both direct and indirect losses in several ways.

7.1 Direct losses

- *Loss of life*

Landslides can result in death and injury of people and animals. The moving mass can bury people and animals under debris.

- *Loss of property and assets*

The force and speed of debris, mud or earth mass generated due to mass movement may destroy houses, buildings and other properties on its path.

- *Loss of infrastructure and lifeline facilities*

Earth mass can block or damage infrastructures such as roads, railway, bridges, telecommunication, electrical supply lines, etc.

- *Loss of Resources*

Earth mass can effect water resources in the area by blocking rivers, diverting waterways, blocking irrigation channels, reducing storage capacity of tanks, reservoirs, ponds, etc. it can cause production losses to open cast mines, rock quarries, etc.

- *Loss of farmland*

Productive land area may be covered with debris or blocked from access.

- *Loss of places of cultural importance*



7.2 Indirect losses

- *Loss in productivity of agricultural or forest lands*

Due to being buried by debris, lack of access or being under flood.

- *Reduced property values*

Due to unwillingness of people to purchase disaster prone land.

- *Loss of revenue*

Due to loss of productivity, transport breakdown, etc.

- *Increased cost*

Due to investments in preventing or mitigating future landslide damage.

- *Adverse effect on water quality*

Occur in water storage facilities such as streams, reservoirs, storage tanks etc.

- *Secondary physical effects*

Such as flooding which in turn generates both direct and indirect costs.

- *Loss of human productivity*

Due to death and injury.

- *Reduction in quality of life*

Due to the deaths of family members and the destruction of personal belongings, which may also have great sentimental value.

- *Impact on emotional wellbeing*

Any disaster can have a profound impact on people's emotional wellbeing affecting their feelings, thoughts, actions and relationships. The sudden overwhelming disruption and danger to life and property can put tremendous psychological



pressure on a person, often even affecting the ability to function at the time of the crisis. The impact a disaster can have on a person also depends on his/her past experiences of crises, how well he/she has been prepared for such events both physically and mentally and his/her attitude or level of resilience.



8. INDICATORS OF LANDSLIDE PHENOMENON

1. Areas prone to landslides and or rock fall hazards

- Areas with a history of landslides
- Base on mountainous slopes with small streams or drainage paths. Areas adjacent to a base or top of a cut or fill slope.
- Developed hill slopes (settlement) where leaching field septic systems are located. Area adjacent to the base of rock mass showing joints.
- Area at the base of a steep slope with a lot of detached but buried boulders.

2. Areas that are considered to be safe from landslides but have a potential risk

- Escapement or faces of hard bedrock that have not moved in the past but have a few joints or narrow cracks developed within the mass.
- At the top or along the nose of ridges adjacent to steep high slopes.
- Steep slope areas with thick soil masses free from vegetation.
- Areas where slope angle changes abruptly and variations occur in the thickness of soil overburden as a result of construction activities.
- Relatively flat areas with thick soil mass and frequent seepage.

Features that might be noticed prior to major landslides or rock falls in mountainous areas.

- Sudden appearance and rapid expansion of cracks on road pavements or ground surface.
- Sudden appearance of springs, seepage traces or patches with ground saturation in areas that have not typically been wet before.
- Sudden movement of soil masses away from building foundations.
- Movement of pavements, decks, sidewalls of structures, or bulging of retaining walls relative to the main structure.
- Tilting or leaning of trees, lampposts, telecommunication poles, fences, retaining walls, etc.

- Sudden breakage of water supply lines and other underground installations.
- Subsidence of roads, pavements, ground, etc.
- Rapid increase in water levels in pool creeks, streams, etc. in mountainous areas.
- Increased turbidity in stream water flow.
- Sudden appearance and disappearance of cracks.
- Sudden appearance and rapid enlargement of cracks on walls of houses.
- Sticking doors and windows, visible open spaces between windows and their frames.

9. PREPAREDNESS

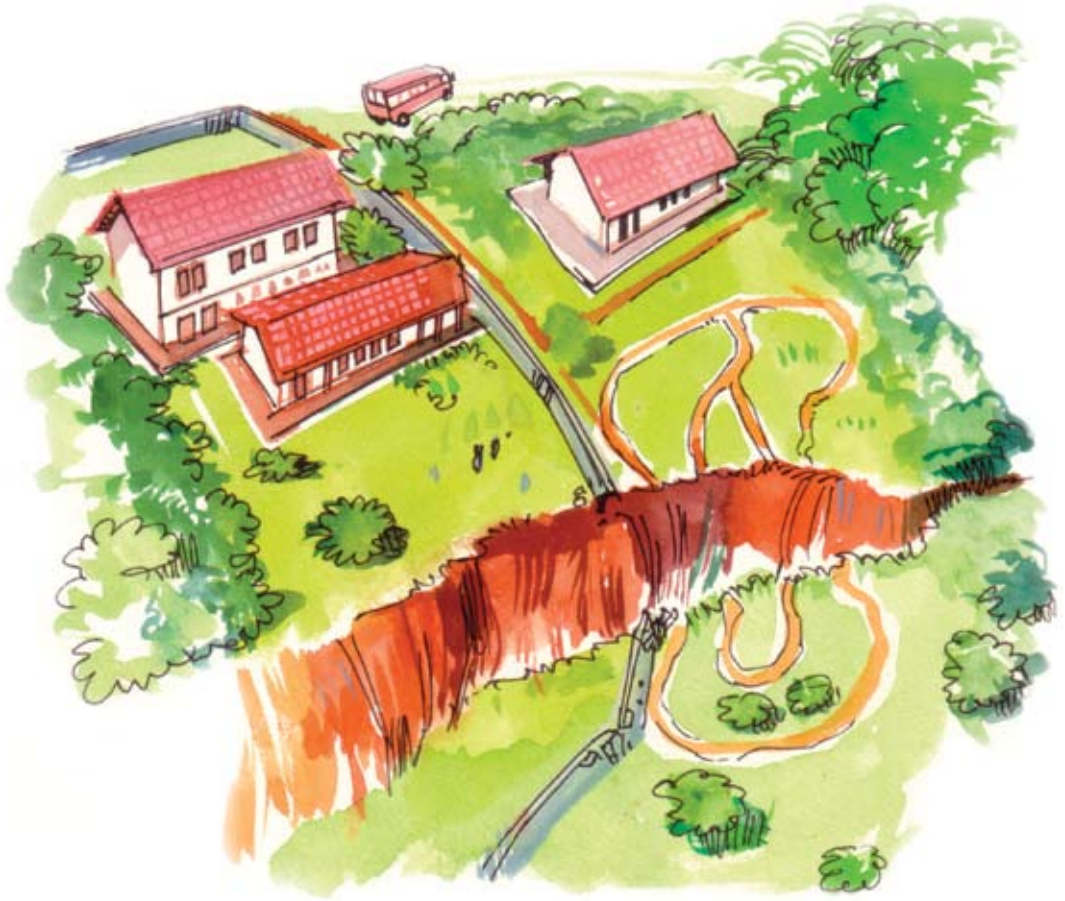
9.1 Landslide preparedness measures

- Meet the divisional secretary/Grama Niladhari and discuss the problem of landslides of your community given that it experiences them regularly.
- Community members can prepare hazard maps and define the limits of danger zones so as to regulate the activities within those zones.
- Organize Watch Groups and Rescue Teams within the community.



9.2 Measures to reduce the likelihood of landslides

- Try to protect the slopes. Prevent people from excavating, removing materials from the soil or cutting trees without proper advice from specialized institutions such as National Building Research Organization (NBRO).



- Replant trees where they have been removed on slopes and slope base to prevent erosion. Plants with wide spreading root systems such as ‘Wetamara’ and Savandara’ are suitable for this purpose. Keep records of erosion, landslide masses and falling rocks. Never construct buildings on their debris without proper guidance. Loosened masses can subside when load is added to them.
- Avoid building houses at the base of slopes that are prone to landslides. Before purchasing a piece of land or building on your own land, try to get as much information as possible on its history of landslides. Elders of the area can give you information on past incidents. Landslide hazard zonation maps, if available, can be used to identify the degree of landslide hazard potential of the area. Landslide hazard zonation maps and construction guidelines can be obtained from the NBRO, DMC, or the Divisional Secretary’s office of the area.
- When constructing on a slope, use a design that suits the natural slope. This will also save on the cost of construction. Prepare the ground, so that, it cascades parallel to the natural contours of the slope. Do not remove vegetation and large trees while constructing.
- Observe the features on the upslope area before you start any construction. Fill areas constructed above lacking appropriate slope retaining structures and having rock debris or boulders that can move into your land. If you are in doubt, obtain advice from a specialist on the subject.
- Do not obstruct natural streams or drainage paths during construction. Direct the surface water from your land towards the natural gully enabling water to quickly drain away from the slope.
- Avoid dropping rock pieces, boulders, loose earth etc. down the slope during construction. Introduce a retaining structure to prevent movement of cut or filled slopes, if you need to cut or fill your land located on a slope.

10. GENERAL ADVICE

Preparedness measures for those living in landslide prone areas that should be observed during periods of heavy rain.

These are general guidelines for those living in a landslide prone area.

- Listen to weather forecast on the radio, TV etc. about heavy rains. Continuous heavy rainfall during a 24-hour period or a high-density rainfall within a period of few hours has the potential to trigger landslides. This threshold limit may vary depending on the strength of the material and slope gradient.
- Be alert if you are living in an area in which landslides occur regularly. Organize groups to inspect the slopes.
- Remain awake during nights of heavy continuous rain and be ready to move to a safer location.
- Observe the signs mentioned above such as appearance of cracks and their rapid expansion over the slope. They may indicate the possibility of a landslide. Inform the divisional secretary/Grama Niladhari when such signs are recognized.
- Listen for abnormal sounds of soil and rock movement or breaking of trees. They may be associated with landslide movements.
- Never go closer to observe cracks on the slope. If you spot cracks, inform the divisional secretary/Grama Niladhari and move out from the area.
- In case you have to evacuate, do so immediately. Do not try to collect belongings. Landslides can occur suddenly.
- While evacuating, do not cross possible landslide paths.
- When you see falling rocks, seek cover behind trees and other solid objects.
- Psychosocial Preparedness: is to be ready in one's thoughts, feelings and behavior to respond to the disaster appropriately: Speak clearly to your family about facing difficult situations and how to respond in a time of crisis. Be free to talk about issues such as:

- Being prepared in your mind to face any eventuality, being courageous.
- Staying calm, and not to allow yourself to panic or get into a heightened state of fear.
- Thinking clearly, and acting thoughtfully.
- Doing imaginary games or exercise that help you and your children to prepare for events by imagining and discussing options that can be very helpful, eg: “what will I do if...” or “where shall I go if ...”
- Staying together as far as it is useful and supporting to each other.
- Looking out for those who are especially vulnerable, eg: very small children, very old people, sick or disabled people.
- Keeping in mind that this is a temporary crisis and that it will pass.



10.2 Advise for those who live adjacent to filled ground or reclaimed land where slope protection measures are not adequate to retain the filled mass.

- Observe any land subsidence. If your house is located on hill or at the edge of such an area, inform the authorities e.g. divisional secretary/ Grama Niladhari when you notice changes.



10.3. Advise for those who live adjacent to river banks.

- Listen to weather forecasts especially for heavy rains in the upstream areas, which may cause floods in the lower areas.
- Observe any cracks that may appear parallel to the riverbank.
- Observe any cracks on the ground where your house is located.
- Observe any cracks on the walls or foundation of your house.
- If you notice any expansion of those cracks, inform the authorities and immediately move to a safer area.
- Such observations have to be made both during the rise and the decline of the water levels. Rapid draw down of water may cause more dangerous slips on riverbanks than while water is rising.
- Do not send children to make such observations. The riverbank may collapse without warning. Keep children away from the slopes on the riverbanks.

10.4. Advise for people living at the foothills closer to stream beds with large upstream catchments area.

- People living in these areas can be surprised by flash floods.
- Weather forecasting institutions cannot predict flash floods. Listen to weather forecasts about heavy rainfalls. Observe cloud movements towards mountain peaks. Heavy rainfalls, which have a potential to trigger landslides, may be caused by cloudbursts. Resulting flash floods can contain a considerable quantity of mud and can be very dangerous.
- Be alert if you live in an area where flash floods occur regularly. Organize groups to inspect river flow conditions.
- Living or camping out in the rainy seasons on flood plains where there is a history of flash floods is very dangerous. Be extremely careful.
- Observe any unusual movement of wild animals into the village during heavy rain. It may be an indication of the development of floods in the upstream area.



10.5. Advise for those who live on a slope or at the base or in an area closer to a spring or small stream.

- Be specially alert. If you observe a sudden drop or increase in water flow with water changing from clear to muddy, alert your neighbors and keep away from that area.



10.6. Advise for those who live at the base of mountains in areas which high volcanic activity. This would not be common in a country like Sri Lanka.

- Observe the slopes with deposits of ash and rock debris. Organize groups to inspect the slopes during the period of continued rain. Remain awake in the night and be ready to move to safer locations with short notice.
- If landslide occurs on a slope where deposits of ash are observed, it can create a considerable volume of mud. Therefore, do not move in the direction of the valley if you are requested to evacuate. Move to the identified safer areas.

Additional advice for specific locations:

For those who live at the base of mountains in areas with high seismic activity:

- There is a strong possibility that an earthquake, even a minor one, may trigger landslide movements especially in areas where landslides occur regularly. Therefore, be alert when an earthquake occurs. Try to recognize groups to monitor the situation.
- Organize groups to inspect slopes during and after heavy rains. Remain awake and be ready.
- An earthquake can be a warning for a landslide. If a noticeable change is observed in upslope area such as appearance of cracks, fall of boulders, collapse or smaller mudflows, do not stay at the base of the slope. Move away.
- Ground shaking associated with earthquakes will continue for sometime. There can be a series of earthquakes that follows each other. If you were requested to evacuate, do not return until the authorities announce that the area is safe.
- Landslides, as a result of ground shaking, can create a large volume of mudflow along the slope into the valley. Therefore, do not move in the direction of the valley if you are requested to evacuate, move to elevated areas.

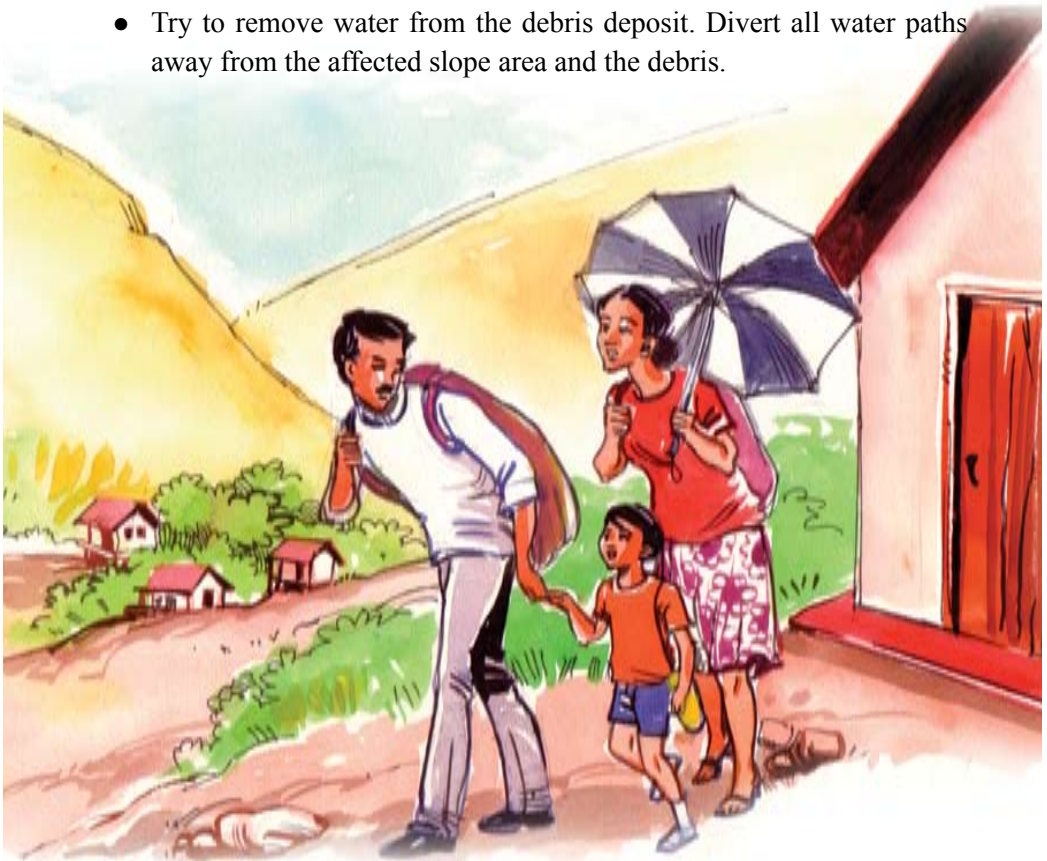
During any disaster

- Stay where there are people around you, give and receive assurance and comfort for each other.
- Children may need more care and comfort than normal: answer all their questions as best you can even if they ask the same question more than once. Give assurances that they are safe, and that life will return to normal if we respond well to the present situation.
- You will need all the strength and energy you have to face the crisis so conserve energy by not engaging in unnecessary and disorganized activity, but do only what is necessary.

- Do things together like cooking eating, chatting, religious observances which will help you successfully adjust to the crisis situation and live through it.

11. AFTER A LANDSLIDE

- Do not enter the area without permission from the authorities.
- Do not enter damaged buildings until the authorities declare them as safe.
- If you are engaged in the removal of debris or the digging up of bodies buried in the mass, do so in an organized way. Consult members of the affected community before using any heavy machinery or equipment. Lives can be saved if services of experienced rescue parties can be obtained.
- Try to remove water from the debris deposit. Divert all water paths away from the affected slope area and the debris.





- Do not allow children to go through the loose and new deposits of debris. The surface may appear to be dry but the wet conditions can prevail within the mass.
- Remember. One slide can follow another. The slide area can be further enlarged with subsequent movement of debris.
- Define the limits of the area as landslides affected area. It is better, if a signboard can be placed to warn others to not to disturb the area.
- Consult a specialized agency like National Building Research Organization, 99/1 Jawatte Road, Colombo 05, (Tel. 0112588946



Fax: 0112502611) before carrying out future development work in and around the affected area. A professional will be able to advise you on the best ways to prevent or reduce landslide risks, without creating further hazards. Advise community members accordingly.

- Replant damaged ground as soon as possible since erosion caused by loss of ground cover can lead to flash flooding.
- Make representations to your local authority to divert roads, pipelines and telecommunication lines from the affected area. Help them to find suitable safe areas to relocate them.

Be vigilant!

If a landslide occurs near your home, check the foundation and walls of your home for cracks. Search for any new cracks in the surrounding area. Lookout for any signs of landslide movement. Be vigilant during the periods of heavy rains. Be especially vigilant during and after intense rainfall.

Getting back to normal life after the natural disaster

Seeing one's home devastated and belongings spoiled can be very distressing. The disruption and threat to life and the things you may have lost will all add to your distress. It is important to understand that you and your family may react to this emotional distress in many ways. Feeling exhausted, sad and low in mood, hopeless about the future, easily angered, constant quarrelling, unable to sleep, constant body aches may be just some ways your body and mind will react to what has happened.

You need to look after your physical and emotional wellbeing and that of your family during the transition period.

These are ways that can help you and your family return to normal life:

- Get good rest and eat before commencing cleaning up. Having meals as far as possible at regular times and getting the right amount of sleep is very important to staying strong and overcome the crisis.
- Do unpleasant tasks (eg: burying dead animals) together rather than alone.
- Encourage and allow people to talk and share their feelings about what has happened if they want to. If some do not wish to talk about it do not force them to do so.
- Do little things that every one enjoys, eg. listening to the radio or music while cleaning up the house will help make an unpleasant task easier.
- Understand how the stressful event has made you and your family

feel and be patient with each other. Maintain good relationships. Good family support will make the return to normal life faster and better.

- It may take some time to get a house back into its original condition.
- When going back to your home go with family or friends who can help and support you.
- Some family members or children may not want to go back, may want to avoid the place or may develop strong fear reactions. Give them time, be patient with them and allow them to return and adjust when they are ready.
- Before entering the house, get advice from a skilled person about the supply of electricity, water, gas, etc. Get their advice on necessary repairs and do not enter the house if you can not get any advice.
- Make sure that there is no more threat of occurrence of landslides in the near future.
- Have the kitchen cleared and functioning as soon as possible so you can cook and serve food to your family and yourself. This will make you feel happier while it is also safer to cook your own food than wait to get it from an outside source.



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3. ***NBRO Landslide Studies and Research Division: Landslide history of Sri Lanka - Major events and disasters due to landslides in Sri Lanka.***
4. ***List of Publications/Research Papers prepared by the Landslide Studies and Services Division of NBRO***

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Contacts

National Building Research Organisation (NBRO)

of the Ministry of Housing and Construction Industry, Eastern
Province Education and Irrigation Development
99/1, Jawatta Road, Colombo 5, Sri Lanka
Phone: 0094-112-588946
Fax: 0094-112-502611
Email: nbro@sltnet.lk
Website: <http://www.nbro.gov.lk>

Disaster Management Center

Ministry of Disaster Management and Human Rights
2-222, B.M.I.C.H.
Buddhaloka Mawatha
Colombo 07, Sri Lanka
Hotline: +94 112 670002
Phone: +94 112 670071/77
Email: dgdmsl@gmail.com
Website: www.dmc.gov.lk

National Disaster Management Center

Ministry of Disaster Relief Services
Director: Mr.N.D Hettiarachchi
No. 189, Galle Road
Colombo 03, Sri Lanka
Phone: +94112431590
Fax: +94112431593
Email: dndmc@sltnet.lk
Website: <http://www.ndmc.gov.lk>