

INTRODUCTION

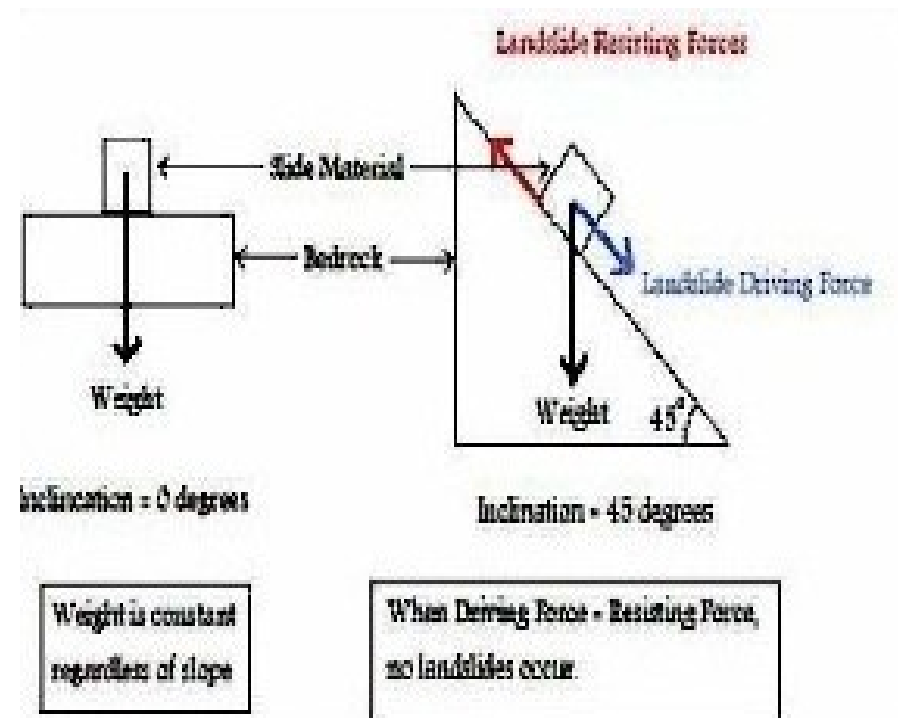
- A landslide is a downward or outward movement of soil, ~~or~~ **vegetation**, under the influence of **gravity**.

- Factor of Safety(F):

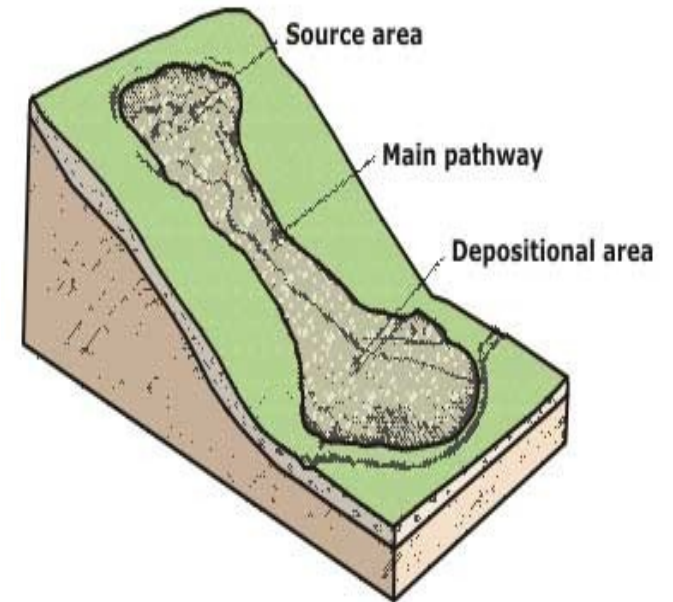
$$F = \frac{\text{Resisting Force(R)}}{\text{Driving Force(D)}}$$

When, $F < 1 =$ landslide occur

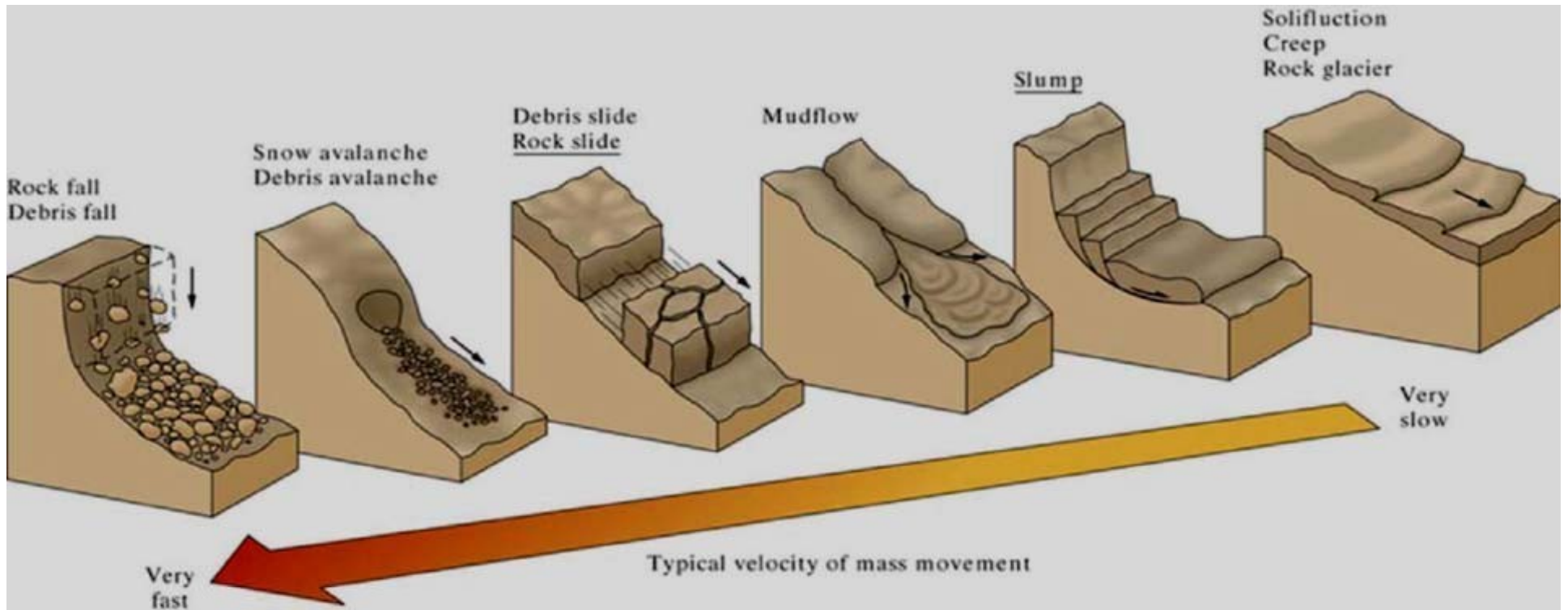
- Resisting forces(R) preventing the mass from sliding down the slope are **inversely proportional** to the same **hill slope angle** and **directly proportional** to the **friction angle** of the material.



- In addition, the resisting forces can be significantly reduced in case of rain or earthquake vibrations.
- Three distinct physical events occur during a landslide: the initial slope failure, the subsequent transport, and the final deposition of the slide materials.
- **Types of landslide:**



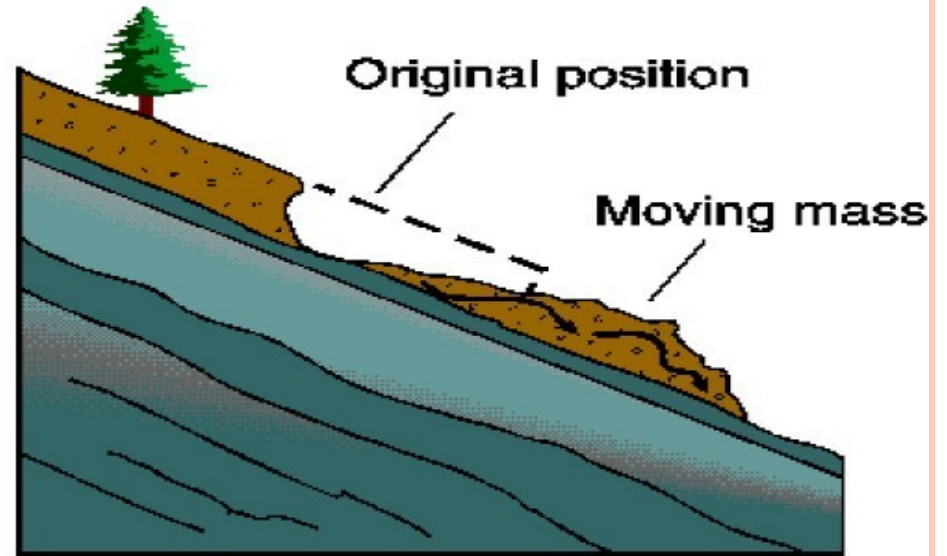
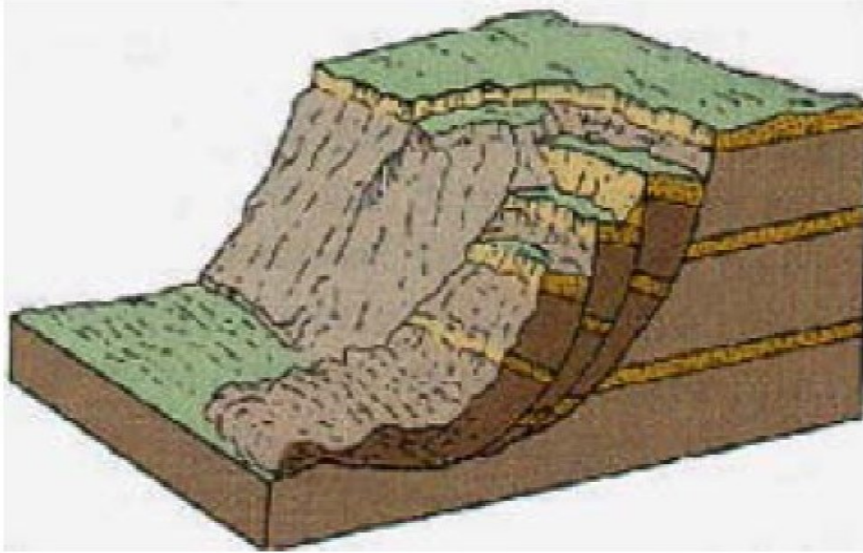
TYPES OF MOVEMENT	TYPES OF MATERIAL		
	Bedrock	Soils	
		Coarse Grained Soil	Fine Grained Soil
Falls	Rock fall	Debris fall	Earth fall
Topples	Rock topple	Debris topple	Earth topple
Slides	Rotational	Debris slide	Earth slide
	Translational		
Lateral spreads	Rock spread	Debris spread	Earth spread
Flows	Rock flow	Debris flow	Earth flow
Complex: Combination of two or more types of movement			



- The speed of the movement may range from very slow to rapid.
- The speed of the landslide will make an event even more difficult to avoid and therefore, more or less risky.
- It is important to distinguish the different types of landslides to be able to understand how to deal with each of them.

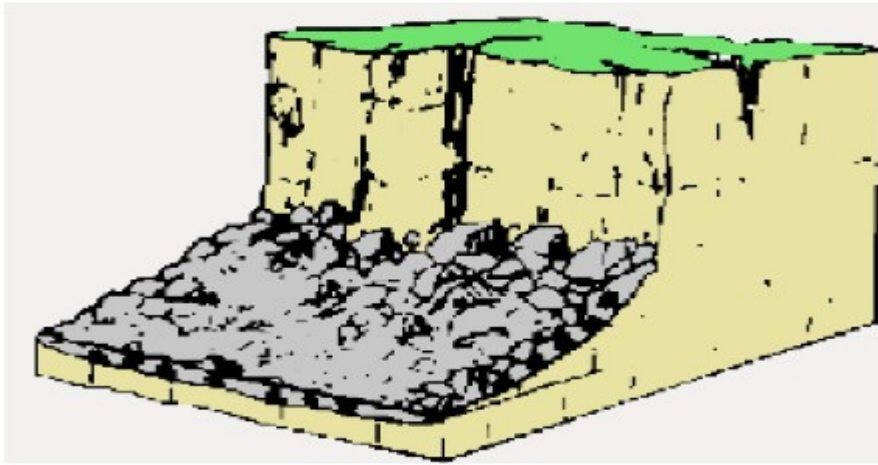
COMMON TYPES OF

LANDSLIDES



a) **Rotational slides** move along a surface of rupture that is curved and concave.

b) **Translational slides** occurs when the failure surface is approximately flat or slightly undulated



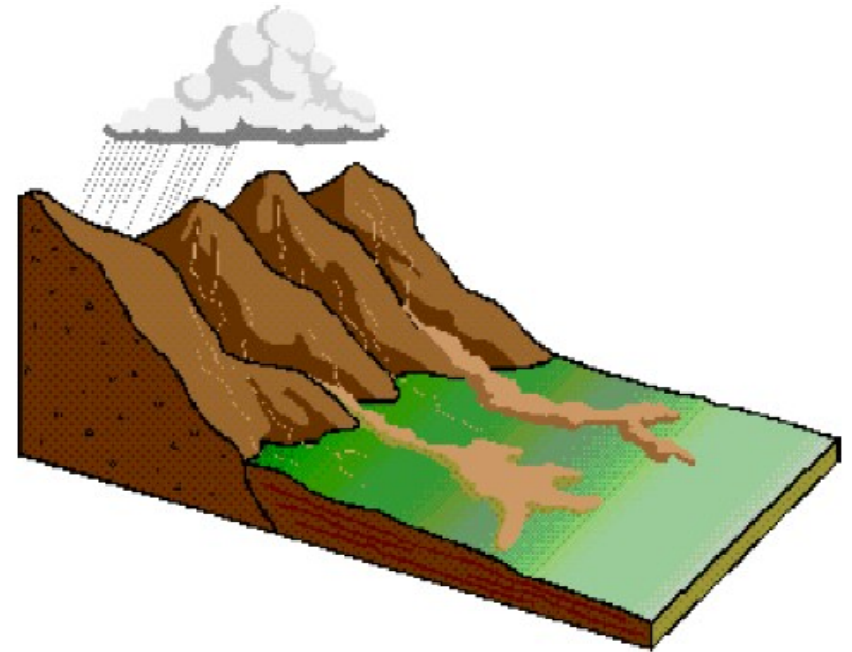
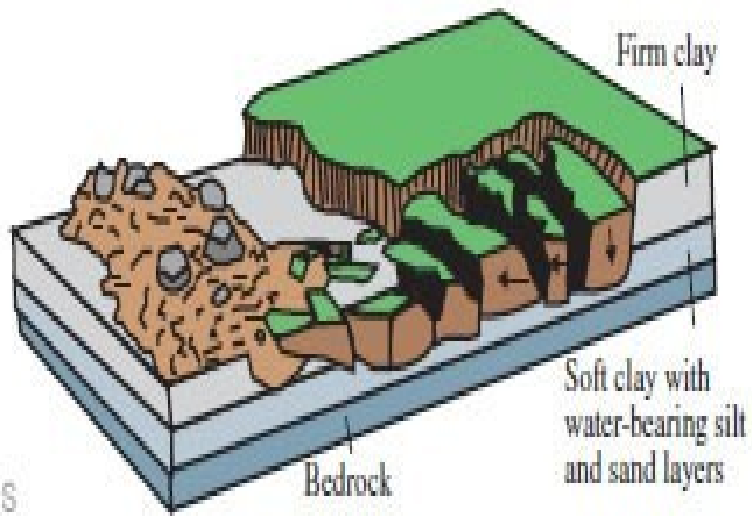
c) Rock Fall:

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



d) **Rock toppling** occurs when one or more rock units rotate about their base and Collapse.

USGS



e) **Lateral spreading** occurs when the soil mass spreads laterally and this spreading comes with tensional cracks in the soil mass.

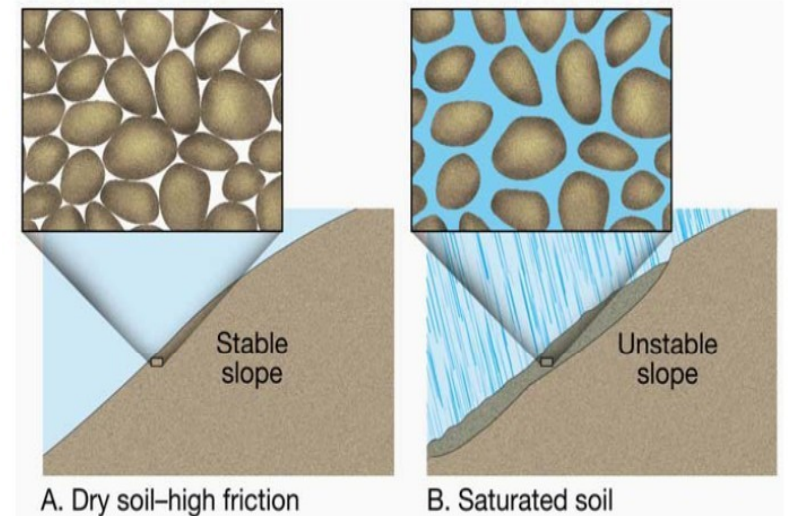
f) **Debris Flow:** Down slope movement of collapsed, unconsolidated material typically along a stream channel.

CAUSES OF LANDSLIDES

A) Natural Factors:

- **Gravity:** Gravity works more effectively on steeper slopes.

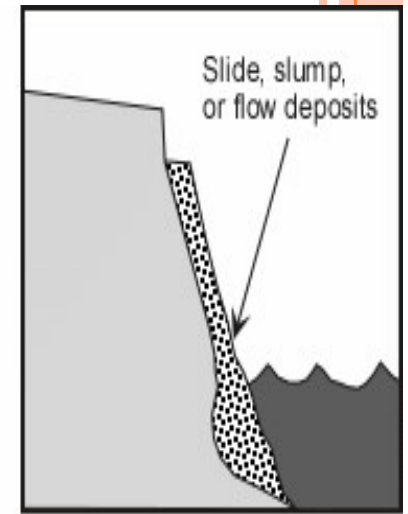
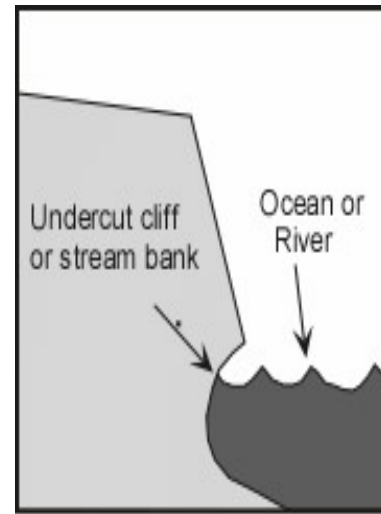
- **Geological factors:** Geology setting that places **permeable** sands and gravels above **impermeable layers** of silt and clay or bedrock.



- **Heavy and prolonged rainfall:** slides occur often with intense rain by **creating zone of weakness**, also water tables rise with heavy rain makes some slopes unstable.

- **Earthquakes:** Ground vibrations created during Earthquakes.

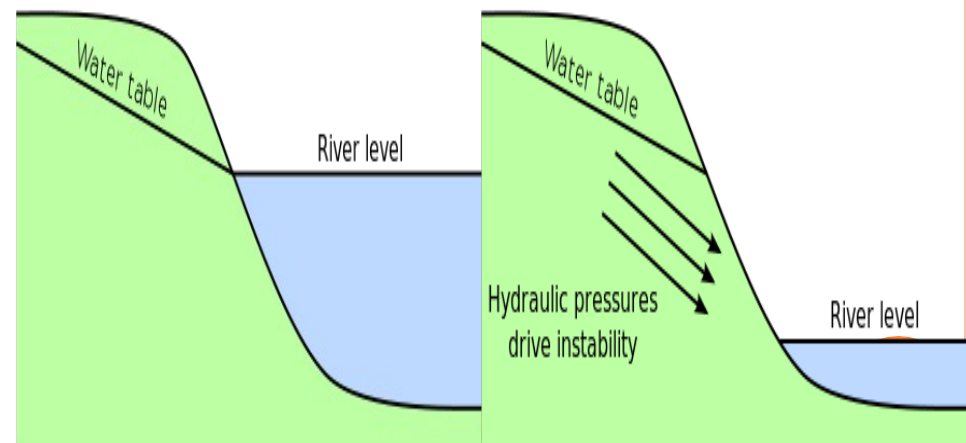
- **Waves:** Wave action can erode the beach or the toe of a bluff, cutting into the slope, and setting the stage for future slides.



- **Volcanoes:** volcanic ash deposits (sometimes called lahars deposits) are prone to erosion and subjected to mud flows due to intense rainfall.

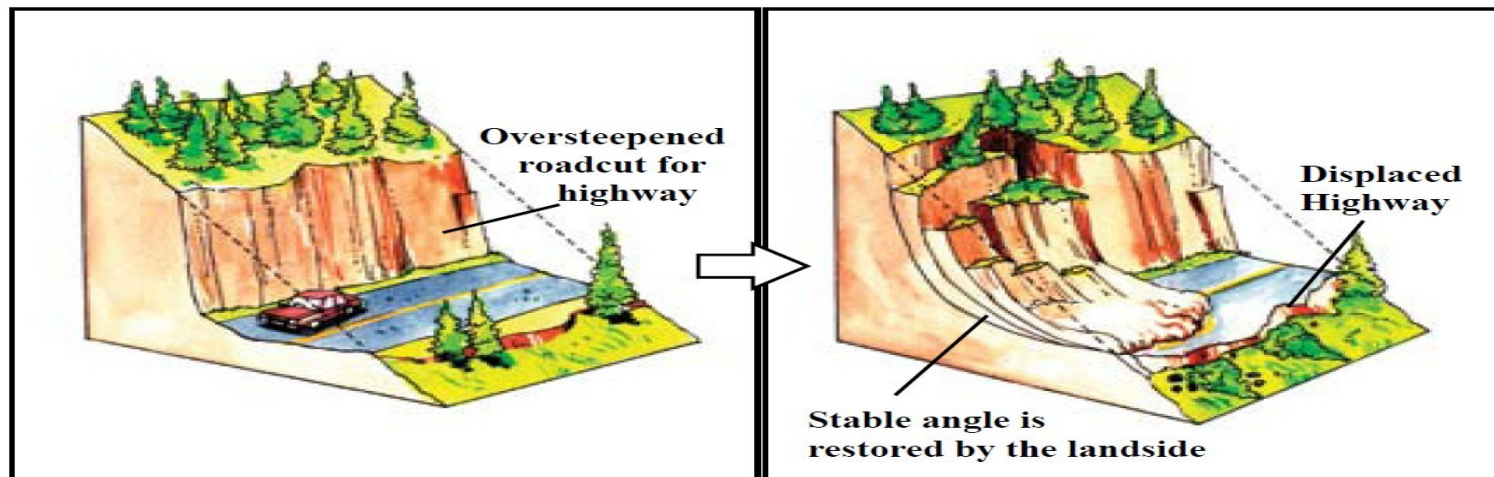
- **Fluctuation of water levels** due to the tidal action.

- **Deposition of loose sediments** in delta areas.



B) Anthropogenic Factors:

- **Inappropriate drainage system:** Surface runoff 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.**
- **Cutting & deep excavations on slopes for buildings, roads, canals & mining:**
causes modification of natural slopes, blocking of surface drainage, loading of critical slopes and withdrawal to toe support promoting vulnerability of critical slopes.





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- **Change in slope/land use pattern, deforestation, agricultural practices on steep slopes:** contributed to creep and withdrawal of toe support in many cases.

C) **Combination of factors:**

- 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 catchments areas.

EFFECTS AND LOSSES DUE TO LANDSLIDES

A) Direct Effects:

- **Physical Damage**-Debris may block roads, supply lines (telecommunication, electricity, water, etc.) and waterways.
- **Causalities**- deaths and injuries to people and animals.

B) Indirect Effects:

- **Influence of landslides in dam safety**- failure of the slopes bordering the reservoir, Flooding caused by movements of large masses of soil into the reservoir.

- **Landslides and flooding-** Debris flow can cause flooding by blocking valleys and stream channels, forcing large amounts of water to backup causing **backup/ flash flood.**

C) **Direct losses:**

- Loss of life, property, infrastructure and lifeline facilities, Resources, farmland and places of cultural importance.

D) **Indirect losses:**

- Loss in productivity of agricultural or forest lands, Reduced property values, Loss of revenue, Increased cost, Adverse effect on water quality and Loss of human productivity,

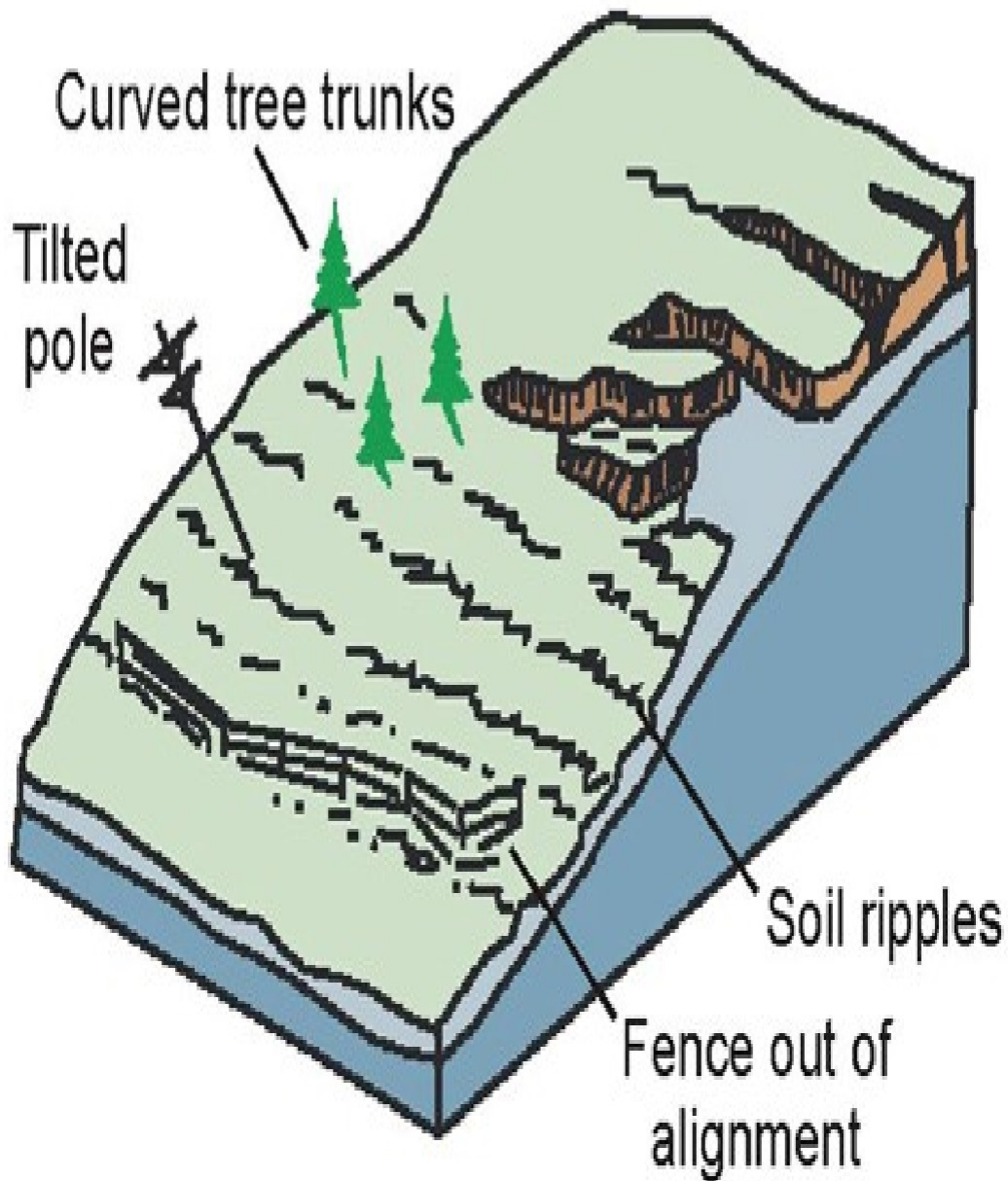
INDICATORS OF LANDSLIDES PHENOMENON

A) Terrain/Morphologic Features Indicating Risk of a Landslide-

- **Steep slopes:** slope with **angles over 30 degrees** should be avoided if possible.
- **Old landslides sites:** the old landslide can be **reactivated**, for example, by **heavy rainfall or an earthquake**.
- **New cracks** or unusual bulges in the ground or street pavements.

B) Landslide Risk Indicators:

- **Tilting or cracking** of concrete floors and foundations.
- **Soil moving away** from foundations.
- **Broken** water lines and other underground utilities.
- **Leaning** telephone poles, trees, retaining walls, or fences.
- Rapid **increase in ground water levels**, possibly accompanied by **increased turbidity** (soil content).
- **Sticking doors and windows**, and visible open spaces indicating jambs.
- **Sudden decrease** in ground water levels though rain is still falling or just recently stopped.



- In most cases in the field there will be a combination of morphological and landslide risk indicators to be considered.

HAZARDS

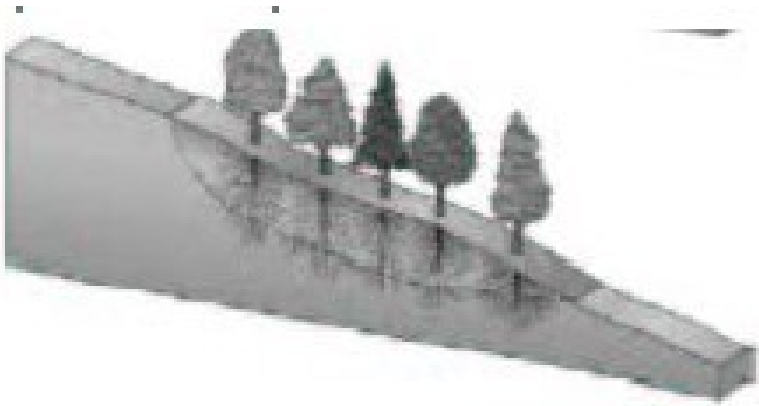
A) Passive Intervention

- Choose a **safe location** to build your home, away from steep slopes and places where landslides have occurred in the past.
- Prevent **deforestation** and **vegetation removal**.
- Avoid weakening the slope.

B) Active Preventive Intervention

- **Reforestation:** Root systems bind materials together and plants do both prevent water percolation and take water up out of the slope.
- **Proper water** runoff must be ensured by providing a proper canalization network.
- **Drainage:** good ground drainage is essential to prevent saturation and consequent weakening. Drainage is also needed in civil work, like retaining walls.

- **Proper land use measures:** Adopt effective land use regulations and building codes based on scientific research.
- **Structural measures:** Nets, Retaining walls and major civil works to mitigate landslides. (Bioengineering).



C) Non- Structural measures:

- **Awareness generation:** Educate the public about signs that a landslide is imminent so that personal safety measures may be taken.
- **Financial Mechanisms:** Support the establishment of **landslide insurance**.
- **Legal and Policy:** legislation to direct a governmental or private program to reduce landslide losses should be strengthened.

D) Landslide Hazard Mapping and Use of GIS:

- Landslide Hazard Zonation of the Vulnerable Areas.
- Use of remote sensing and ground truth data for making **landslide hazard zone map**.
- Here, such maps are used to develop **mitigation plans** in consultation with experts.

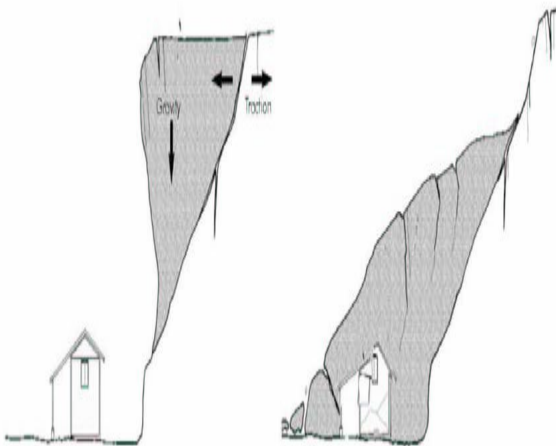
LANDSLIDE PREPAREDNESS AND SAFETY MEASURES

A) Before a landslide:

- Find out if landslides have happened in your area in the past.
- Look out for landslide warning signs like doors or windows jammed for the first time, new cracks appear in walls, bricks, foundations, retaining walls, tilt of utility poles or trees.
- Consider relocation in case your house is located in an area particularly vulnerable to landslides. While doing so, remember:
 - i) Do not build on or at the base of unstable slopes, on or at the base of minor drainage hollows, at the base or on top of an old fill slope, at the base or top of a steep cut slope.

- ii) Do not cut down trees or remove vegetation or avoid slope weakening.
- iii) If the house cannot be relocated, then **ensure proper drainage** and proper **retaining walls**.

- **Always stay alert and awake!!!** Listen to radio/television for warnings of intense rainfall, storm and damp weather. These usually trigger landslides/debris or mudflow.
- Make an **evacuation plan** in case of a landslide with all the emergency items.




B) During a landslide:

- Listen to any **unusual sounds** that might indicate moving debris, such as trees cracking or boulders knocking together. A trickle of flowing or falling mud or debris may precede larger flows.
- While you are outdoors during a landslide
- Try to get out of the path of the landslide or mudflow by running to the nearest **high ground** or **away from the path**.
- If you are near a river, be alert for any sudden increase or decrease in **water flow** or for a change from **clear to muddy water**. Such changes may indicate landslide upstream. So move quickly to safer areas.



- If the rocks and other debris are approaching, run to the nearest shelter such as group of trees or a building.
- While you are indoors during a landslide
- Stay inside and remain alert. Listen to radio/ television for any update. i.e. if landslide occurs outside.
- If your house falls apart due to landslide and if there is no escape, hold on to something strong and protect your head.

C) After a landslide:

- Stay away from the landslide area as there may be danger of additional slides. Do not drive through.
 - Watch for flooding which may occur after a landslide.
 - Check for injured or trapped persons near the slide, without entering the slide area. Direct rescuers to their locations.
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- **Help** neighbours who may require special assistance— infants, elderly people and disabled people.
- Listen to local radio/television stations for the latest **emergency information**.
- **Look for and report** broken utility lines to appropriate authorities.
- Check the **building foundation, walls** and surrounding land for damage. The safety of the areas needs to be assured before reoccupation.

