1. **Explain how the impact of landslides depends on the affected area's population density, economic infrastructure, and population preparedness.**

Population Density- increases vulnerability, fatalities  
  
Economic Infrastructure- technique used to mitigate land movement dependent on economic factors such as the funding that is available for landslide mitigation  
  
Population Preparedness- prevent/reduce fatalities and infrastructure damage

1. **Distinguish between the different modes of failure (falls, flows, slides, topples, and spreads) and how they are influenced by geology.**
2. Falls
   1. sudden, vertical movement of material
   2. occur on steep slopes with loose rock that may periodically detach from a surface on which little or no shear/sliding takes place
   3. mechanical weathering, which is the physical break-up of material by freeze-thaw cycles, salt crystal growth, root wedging and penetration, and absorption of water without chemical changes
3. Topples
   1. require the forward rotation of material (rocks) about a pivot point below the center of gravity of the unit or in the slope
   2. require fractured material oriented perpendicular and parallel to the slope face, which allows the material to be broken up into coherent pieces that roll forward down a slope
4. Slides
   1. involve large volumes of rock or soil material moving as an initially coherent mass on a sliding surface
   2. **Rotational slides**
      1. where blocks of soil or weak rock move along a curved rupture surface that forms due to the shear forces in the slope exceeding the shear strength of the soils/rocks. During failure, blocks of material rotate and tilt.
   3. **Translational slides**
      1. where blocks of strong rock move upon a weak plane or pairs of intersecting weak planes in the rock (joints, faults, bedding, etc.)
5. Spreads
   1. **Lateral Spreads**
      1. occur where there is a slow to rapid extensional movement of rock or soil - usually related to the sudden liquefaction of a weak soil layer (such as quick clays) and often triggered by earthquakes or explosions
      2. In areas where loose soils are saturated with water, seismic shaking (i.e. from an earthquake) can cause water pressures to dramatically increase. This results in **liquefaction**, the sudden loss of strength in the soil transforming its behaviour into that of a liquid
   2. **Sensitive Clays and Spreads**
      1. are young marine clays that are deposited with a **House of Cards**-like structure. During an earthquake, this cardhouse structure may collapse and liquefy
6. Flows
   1. occur when there is a relatively large volume of water present in a mixture of soil and debris
   2. Rather than moving downslope as a coherent mass, the material flows downhill as a chaotic, viscous mixture
   3. **Rock or soil creep**
      1. soil and upper bedrock zones moves downslope extremely slow
      2. measured in millimeters or centimeters per year
      3. creates the most long-term economic problems compared to any other landslide type because it usually goes undetected until the damage is already done
   4. **Debris flow**
      1. rapid flow of fully saturated debris (organic matter, sand, gravel, boulders) in a steep channel
      2. form a distinctive debris fan at the mouth of the channel or gulley as the material spreads outs because it is no longer confined
   5. **Debris avalanche**
      1. rapid and shallow flow of partially to fully saturated debris on a steep slope that is not confined to an established channel
7. **Compare and contrast landslide causes and how they differ from landslide triggers. List and describe some external and some internal causes of landslides.**

A cause is a factor that makes slopes susceptible to movement without actually initiating a landslide. On the other hand, a trigger is the event that actually initiates movement by driving the Fs < 1.0

External causes: erosion, seasonal precipitation, volcanic activity, earthquakes, anthropometric activity  
Internal causes: vegetation, water content

1. **Assess the balance between the strength of the slope and the destabilizing forces due to erosion, vegetation, precipitation, and anthropogenic activity that are acting on it (Factor of Safety).**

Erosion: Increase of Erosion, Increase of Shear Stress and thus, Decrease of Strength of Slope

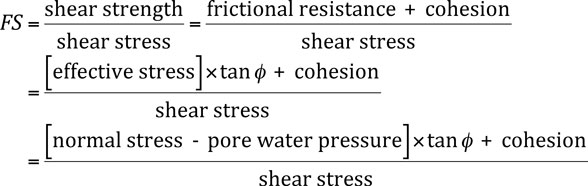
Vegetation: Increase of Vegetation, Increase of Soil Cohesion and Absorption of Water, thus, Increase Shear Strength and Strength of Slope

Precipitation: Increased precipitation, Decrease in Shear Strength and Increase in Mass/Shear Stress, thus, Decrease of Strength of Slope

Anthropogenic Activity: Increased Activity, Decrease in Shear Strength and thus, Decrease of Strength of Slope

1. **How do key triggers and causes affect the Factor of Safety?**

a trigger is the event that actually initiates movement by driving the Fs < 1.0



1. **Describe how groundwater affects shear stress and shear strength, and how it contributes towards the increased likelihood of a landslide.**

-An elevated groundwater table tends to trigger more deep-seated and slower moving landslides such as slumps versus shallower, more fluid, and faster moving (and more dangerous) flows.  
- increases shear stress above shear strength

1. An excessive amount of water within a slope increases its mass, increasing **shear stress** within parts of the slope.
2. Another aspect of water that affects slope stability is fluid pressure. In some cases fluid pressure can build in such a way that water can support the weight of the overlying rock mass. This is the case when the slope is composed of sediment where grains are not cemented together and excess water sets the grains apart. When this occurs, friction is reduced, and thus the **shear strength** holding the material on the slope is also reduced, resulting in slope failure.
3. Water increases the weathering of rocks when it flows into even the narrowest of rock fractures. When water goes through its freeze/thaw cycles, it can expand in volume by 9%. This volume change is a very powerful force that can wedge apart rocks, often causing them to fall from steep slopes in mountains and canyons.
4. In sediment (loose rocks, sand, silt, and clay), water helps or hinders cohesion.
5. **Outline the different factors, both natural and human, that contributed to the Vaiont landslide disaster.**

Human: Dam Construction, Introduction of Water Content (Increased weathering of rocks through rock fractures)

1. **Differentiate the mechanism by which liquefaction landslides develop in loose sands and sensitive clays.**

Water Saturated Sand: water between all particles keeps them apart and allows them to flow

Sensitive Clays: deposited with House of Cards Structure. During an earthquake, this cardhouse structure may collapse and liquefy

1. **Explain why British Columbia has the highest frequency of landslides in Canada and what the future holds as the population expands into mountainous regions.**

Western Canada's **mountainous terrain** leads to higher shear stress which drives down the Fs. Furthermore, **complex geology**, the **abundance of unconsolidated glacial sediments** sitting on top of bedrock, and **high precipitation** are factors in lowering shear strength. **Frequent earthquakes** increase the trigger frequency.

Recall, that by definition, natural disasters must include a human component. A 60 million-ton landslide that occurs in the middle of the Coast Mountains and does not affect humans is not considered a natural disaster. However, if the same-sized landslide were to occur along the North Shore it would be. Therefore, humans need to be also taken into account inadvertently when looking at landslides in a natural disasters context.

People heighten landslide natural disasters by:

1. Developing on steeper slopes
2. **List the different human activities that contribute to increased landslide hazards.**
3. Developing on steeper slopes

This is usually a response to overpopulation, overcrowding, and a lack of space. Sometimes the most scenic and sought-after real estate are cliff-side lots with views of the ocean. These are more susceptible to landslides as a result of coastal erosion and the undercutting of sea-side cliffs.

1. Removing vegetation
2. Excavation and slope loading
3. Altering water drainage
4. Altering climate

Warmer global temperatures affect weather patterns and precipitation. Increased precipitation in high-risk areas with unstable slopes will result in elevated landslide frequencies.

1. **Relate the type of landslide damage expected as a function of its velocity.**

The greater the velocity and density of the flow, the greater the corresponding amount of destruction.

1. **Identify tell-tale signs of an unstable slope.**

- Crescent-shaped cracks or terraces on hillslide

- Tongue-shaped area of bare soil or rock on hillside

- Large boulders or piles of talus at base of cliff

- Exposed bedrock w/ layering that is parallel to slope

1. **Compare and contrast avoidance, prevention, and protection strategies for dealing with landslide hazards.**

1. **Avoidance (Avoid the problem).** An often used method of avoiding the problem is relocating a facility, structure, or route of a planned new road or rail line, to avoid areas along which landslide hazards may be a problem.

2. **Landslide prevention**. This approach works towards preventing a landslide from occurring. This is usually done by reducing the driving forces (e.g. active mass, pore pressure, etc.) or by increasing the resisting forces (e.g. anchors, buttresses, etc.)

3. **Landslide protection**. Landslide protection works towards minimizing the hazard presented, for example by rockfalls. As it would be difficult to prevent the numerous individual rock blocks that might endanger a road or structure from falling, the alternative is to allow them to fall while protecting structures by catching the rock blocks before they do any damage (e.g. using rock fall nets, etc.). Hazards can be minimized by controlling the distance and direction of travel of the falls.

1. **List the mitigation techniques commonly used for avoidance, prevention and protection strategies.**

Some useful ways of engineering an unstable slope or reducing the harmful affects of a landslide include:

* pumping or draining water from the interior of the mass
* installing surface drainage devices
* planting vegetation
* building retaining walls
* reinforcing the slide mass by using netting, bolts, soil nails, or shotcrete (as asbestos-based concrete that is sprayed and hardens)
* injecting cement, silicate, or an acrylamide-based slurry into drilled holes to increase stability and lower porosity of unstable rock and/or compressible soils

Damage and loss of life from landslides can be dramatically reduced by:

* identifying high risk areas
* putting in place effective warning and response procedures
* proper land-use management
* and employing effective mitigation techniques