1 **Introduction to Environmental Geology, 5e**

Chapter 10

Slope Processes, Landslides, and Subsidence

2 **Mass wasting: summary in haiku form**

Mass wasting: downhill
quickly like an avalanche,
or slowly like creep.

3 **Case History: La Conchita Landslide**

- Landslide occurred in La Conchita on January 10, 2005, destroyed 36 homes and killed 10 people
- Triggered by heavy rainfall, reactivation along an older landslide surface (35,000 years ago, 6,000 years ago and 1995)
- Debris flow up to 45 km/h (30 mph)
- La Conchita should not be built on the landslide deposits and under the foot of the slope
- Total risk exposure over the next 50 years is about $190 million
- Potential solution: Relocate people and better land use regulation

4 **Case History: La Conchita Landslide**

Figure 10.1

5 **Introduction**

- Landslide and other ground failures posting substantial damage and loss of life
- In the United States, average 25 to 50 deaths and up to about 100 to 150 if collapses of trenches and other excavations are included; damage more than $3.5 billion
- Mass wasting: Comprehensive term for any type of downslope movement
- For convenience, definitions of landslide here includes all forms of mass-wasting movements
- Landslide and subsidence: Naturally occurred and affected by human activities

6 **Slope Processes**

- Slopes: The most common landforms, dynamic and evolving system
-
- Consists of cliff face (free-face) and talus slope or upper convex slope, a straight slope and a lower concave slope
-
- Dynamic evolving feature, depending upon topography, rock types, climate, vegetation, water, and geologic time
-
- Materials constantly moving down the slope at varied rates

7 **Slope Processes**

Figure 10.4

8 **Types of Landslides (1)**

- Slow or rapid failure of slope: Slope gradient, type of slope materials, amount of water present, rate of movement
-
- Rate of movement: Imperceptible creep to thundering avalanches
-
- Types: Creep, sliding, slumping, falling, flowage or flow, and complex movement (sliding and flowage)

9 **Types of Landslides (2)**

Figure 10.5

10 **Slope Stability**

- Factor of Safety
  - FS = Resisting Forces/Driving Forces
  - If FS > 1.25, then conditionally safe or stable slope
  - If FS < 1.25, then unsafe or unstable slope
  -
- Driving and resisting forces determined by the interrelationships of the following variables:
  - Existing of slip surface
  - Type of Earth materials
  - Slope angle and topography
  - Climate, vegetation and water
  - Time

11 **Slope Stability**

Figure 10.A

12 **Human Land Use and Landslide**

- Urbanization, irrigation
-
- Timber harvesting in weak, relatively unstable areas
-
- Artificial fillings of loose materials
-
- Artificial modification of landscape
-
- Dam construction

13 **Vaiont Dam (1)**

- On October 9, 1963, in Italy and lasted in less than 7 minutes, killed about 2,600 people
-
- Caused by a huge landslide in which more than 238 million cubic meters (0.06 mi^3) of rock debris moved at speeds of about 95 km per hour (59 mi per hour)
-
- Generating waves of water up to 300 ft high
-
- Multiple factors
  - Weak carbonate rocks and clayey layer
  - Geologic fractures, sinkholes
  - Steep slope surface and creep due to the increased water pressure of the reservoir

14 **Vaiont Dam (2)**

Figure 10.D

15 **Human Activities and Landslides**

- Human use on the magnitude and frequency of landslides varies from nearly insignificant to very significant
- Timber Harvesting: Possible cause-and-effect relationship between timber harvesting and erosion
- Urbanization: Human activities are most likely to cause landslides in urban areas, examples from Rio de Janeiro, Brazil, and Los Angeles, California.
- Housing development into steep slopes, inadequate control of stormwater runoff, modification of
  sensitive slopes, irrigation

16 **Minimizing the Landslide Hazard (1)**

- Identifying potential landslides

  - Photographic analysis
  - Topographic map and detailed field check
  - Historic data
  -
- Landslide hazard inventory map
  - Grading code from the least stable to the most stable
-
- Application of geologic and engineering knowledge before any hillside development

17 **Minimizing the Landslide Hazard (2)**

- Preventing landslides
  - Drainage control: Reducing infiltration and surface runoff
  - Slope grading: Reducing the overall slope
  - Slope supports: Retaining walls or deep supporting piles
  -
- Warning of Impending Landslides
  - Landslide warning for critical evacuations
  - Correcting landslides: Draining

18 **Warning of Impending Landslides**

- Monitoring changes
  - Both human and electrical monitoring systems: Tilt meters, geophones, shallow wells, rainfall
-
- Landslide warning system
  - Information for public awareness and education
  - Enough time for public evacuation
  - Stop or reroute traffic flow
  - Emergency services

19 **Warning of Impending Landslides**

Figure 10.24

20 **Snow Avalanche**

- Mountainous region
-
- Rapid downslope movement of snow and ice
-
- Thousands of avalanches yearly in the western United States
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- More deadly if large-slab avalanches
-
- Preventive measures:
  - Well-designed explosives
  - Engineering structures to retain, divert, or retard avalanches

21 **Subsidence**

- Form of subsurface ground failure
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- Occurred naturally or induced by human activities
-
- Slow settling or rapid collapse
-
- Causes: Withdrawal of fluids (water, oil and gas, steam) or removal of solid materials (dissolution, mining)

22 **Process of Subsidence**

Figure 10.5e

23 **Removal of Solid Materials (1)**

- Sinkholes: a circular area of subsidence caused by the collapse of a near-surface subterranean void or room in a cavern
  - Dissolution of carbonate rocks, limestone, and dolomite
  - Affecting most of the conterminous states
  - Natural or artificial fluctuations in water table increasing the problem
  - Triggering other problems: Sinkholes as waste dumping sites

24 **Removal of Solid Materials (2)**

- Salt Deposits
  - Salt dissolution and pumping
  - On November 21, 1980, subsidence associated with a salt mine occurred in southern Louisiana. Lake Peigneur
  - An oil-drilling operation punched a hole into an abandoned mine shaft of the Jefferson Island Salt Dome, a still-active multimillion-dollar salt mine located about 430 m (1,410 ft) below the surface
  - 10 barges, a tugboat, and an oil-drilling barge disappeared in a whirlpool of water into the mine
  - Nine of the barges popped to the surface 2 days later

25 **Removal of Solid Materials (2)**

Figure 10.30

26 **Removal of Solid Materials (3)**

- Coal mining
  - Most common where underground mining is close to the surface of the land or where the rocks left as pillars after mining are weak or intensely fractured
  - Usually, only 50 percent of the coal is removed. the remainder as pillars that support the roof weakens over time in active coal mines and abandoned coal mines
  - Ground failure due to depleted subsurface pressure
  - In the United States, more than 8000 km^2 (3,090 mi^2) of land subsidence due to underground coal mining

27 **Perception of the Landslide Hazard**

- Landslide hazard maps not preventing development
- Common perception: “It could happen on other hillsides, but never on this one.”
- Infrequency and unpredictability of large slides reducing awareness of the hazards
- Often people taking the chances and unknown risks

28 **What Can You Do? (1)**

- Professional geologic evaluation for a property on a slope
- Avoid building at the mouth of a canyon, regardless of its size
- Consult local agencies for historic records
- Watch signs of little slides—often precursor for larger ones

29 **What Can You Do? (2)**

- Look for signs of structure cracks or damages prior to purchase
- Be wary of pool leaking, tilt of trees and utility poles
- Look for linear cracks, subsurface water movement

- Put observations into perspective, one aspect may not tell the whole story

Critical Thinking Topics

- Discuss the reasons why our society could not prevent slope development.
-
- Assume you have been hired by a community to make the citizens more aware of the landslide hazard in very steep topographic area. Outline a plan of action and defend it.
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- Compare and contrast landslide hazards and impact risks in the east coast versus west coast, tropical versus polar regions.

Chapter 10 Images Follow:

End of Chapter