The following material is provided to help prepare you for this lab. The second piece of reading material is USGS Fact Sheet 2004-3072. This lab has five purposes:

1. To teach you about the causes and affects of landslides, with emphasis on those in your neighborhood.
2. To show you how we can use geology to analyze slope stability to predict and, in some instances, mitigate landslides.
3. To give you more experience of making observations and to help you interpret them.
4. To introduce the social aspects of geologic hazards, risk, and the roles of advice and zoning in an urban area.
5. To get you outside into the fresh air.

Mass Wasting

The down-slope movement of rock and soil under the force of gravity is called mass wasting. A Landslide is a mass movement of rock or sediment (including soil) by mass wasting. Other examples of mass wasting are rock falls, debris slides, and soil creep. Soil creep is the most important example because it moves the largest amount of material, but it is the least spectacular because it is so slow.

There have been several attempts to classify mass wasting, based mainly on the speed of the movement, and whether the material involved has high internal strength (rock), or little internal strength (unconsolidated material, or regolith, including soil and deeply weathered rock). Slope movements may be as slow as 1 mm/year to as rapid as >100 km/hr.

Motion on a slope starts when the slope material crosses a threshold from stability to instability. Factors that help rock and sediment cross this threshold include:

a) water: commonly the most important factor. Water fills pores and increases the weight of the material and it causes certain clays to swell and lose strength. Water also reduces internal friction (strength) in sediments by lubricating the grains and by actually propping them apart if pore-water pressure is high.

b) changing the slope (or part of it): for example, natural undercutting of a cliff by the ocean, or artificial steepening by a bulldozer for construction of buildings or roads. Increasing the steepness of a slope promotes mass wasting. Decreasing the steepness of a slope helps prevent mass wasting.

c) weight: placing a greater load on the land promotes downhill movement (e.g. by construction).

d) physical disturbance: examples are vibrations from machinery, shock from earthquakes, or walking of animals.

e) internal strength of material: solid rock is more resistant to mass wasting than regolith, soil, loose sand, etc. Features such as rooted vegetation can increase the cohesiveness of material.

f) structure of material: presence of planes of weakness in the rock such as bedding, foliation, joints, and faults.

g) climate: Relates back to features such as erosion, vegetation, and water influx (rainfall and storm distribution).

Natural Hazards

Mass wasting is a natural geologic process on hill slopes that may threaten life or property. Flooding, tsunami, volcanism, earthquakes, and coastal erosion are other examples geologic hazards.

The average annual number of deaths from landslides is about 10 in the United States and it is 25 in Japan, where population is denser, average slopes are steeper, and earthquakes are more frequent. The largest number of deaths resulting from landslides was in 1920 in China, when about...
200,000 were buried and killed from slope failures in unconsolidated earthy silt that was severely shaken by earthquakes. In 1970, 40,000 people were killed by a large earthquake-triggered landslide in Peru. A terrible landslide disaster on the Philippine island of Leyte has been in the news lately.

Whereas hazard just refers to the frequency of a particular process, risk describes the chance that something harmful will happen with respect to human life or property within some period of time.

\[ \text{Risk} = \text{Frequency} + \text{Impact} \]

For example, steep slopes, high rainfall, frequent earthquakes, weak slope materials and susceptible subsurface structures lead to a high landslide hazard in Japan. Adding in the high population density means that there is a high landslide risk in Japan as well. Consider these factors for where you live.

Human activity generally increases the risk of mass wasting. The recent mass wasting on Round Top drive near UH is a good example. Commonly, the decision to attempt to decrease the risk, and the method employed, is the result of a cost-to-benefit analysis. The monetary cost to design, construct, and maintain a structure or a buffer zone is compared to the value of the property saved (or expected to be saved). However, the cost of lives saved, people displaced, or scenic views destroyed, are less easily calculated. In some instances a legal limitation of how land can be used, i.e. zoning, may be applied to areas prone to natural hazards. Higher insurance rates or taxation may be applied to these areas. Hawai’i depends mainly on advice from consultants about natural hazards. All too frequently consultants are hired after some problem has occurred. Prudent planning can help avoid costly mistakes.

**Mass Wasting in Hawai’i**

Soil avalanches are common in the tropics where there is no freezing and thawing to help to dislodge individual pieces of rock and soil, and where slopes are steep and chemical weathering rots the bedrock deeply. Roots of vegetation normally binds the soil mantle, or regolith, to the underlying bedrock. Eventually the thickness of the soil becomes an unstable mass on the steep slope. Heavy rains may trigger a slide. Averaged over time, slides have lowered O’ahu’s surface about 6 cm per century. Slumps and debris slides are common in Hawai’i where the original hill slope has been changed by excavation or grading for a highway or housing.

One of the largest and best-documented soil avalanches occurred in late October 1981 in Ka‘u. Although no one saw the actual sliding take place, it was measured and described soon afterwards. A mass of several million tons of soil fell down a cliff at the headwaters of Olokele Stream (debris fall), and continued 5 km down Olokele Canyon (debris avalanche). The scar was 800 m high and 300 m wide.

The biggest disaster from mass wasting in historic times in Hawai’i resulted from the largest in a series of earthquakes in the spring of 1868. The earthquakes, in Kaʻū, Hawai’i, were felt throughout the Hawaiian Islands, and almost certainly originated from slippage along the onshore and offshore faults south of Kīlauea Volcano. The largest quake displaced the land about 4 m, destroyed every European-style building in Kaʻū, and probably was in the range of magnitude 7.5 to 8.0. There had been heavy rains, and the great shock of 2 April 1868 triggered a mudflow in Wood Valley, about 30 km SW of Kīlauea. The mudslide or mudflow buried 31 people and about 500 head of livestock. The 2 April 1868 quaking was so intense that a great mass of rock fell from a sea cliff of Kohala Mountain near Waipiʻo Valley, instantly forming a peninsula about 1 km² at the base of the cliff.
**Talus and Slope Creep in Hawai‘i**

Rainwash and mass wasting (rockslides, rock falls, soil avalanches) add rock fragments and soil to the foot of steep slopes and cliffs. Pieces of rocks that accumulate downslope are called talus. A *talus apron* (or talus slope) forms when the fragments of rocks pile up relatively uniformly at the base of slopes. A *talus cone* is a cone-shaped heap of talus, formed where the debris might be concentrated at the mouth of a steep gully.

In time the debris weathers to soil, which may creep down the talus as *colluvium*: sediment and soil moved down slope by creep or rain-wash. *Alluvium* is sediment deposited by streams. In wet areas, creep is aided by soil, especially when it is wet, and by deep chemical weathering that forms clay minerals with virtually no strength. In dryer areas, the clay in soil particles repeatedly expands and contracts, with a net down-slope motion, as rainy and dry periods follow one-another. Downslope creep in Hawai‘i appears to be about 1 cm per year or less.

**Honolulu Landslides**

Slow-moving landslides have been a problem in Honolulu for many decades. GG101L students will observe the Hulu-Woolsey slide in the field. Two houses on Woolsey Place were damaged in the 1940s, and the City recognized that site as landslide-prone but construction was allowed to continue. Between 1972 and the “New Year’s” storm of 1987, water mains were broken 74 times in the Woolsey and Alani areas, indicating slow ground movement. The Alani-Paty slide moved sharply (centimeters per day) after the 1987 storm. The City spent over $50 million in attempts to stabilize the slides, but the lower parts still continue to move ~1 cm per year.

Luckily, Honolulu has had few severe rains since 1987.

Slides have also affected residents on the talus slopes of Pālolo, ‘Āina Haina, and Kuli‘ou‘ou valleys. In the 1950s a quarry was excavated above the Wai‘ōma‘o branch of Pālolo Stream. This changed the slope of the hillside enough that sliding started slowly in March 1954. Unfortunately, a subdivision had been completed on that slope in 1952. Heavy rains (>20 cm in 2 days) in November 1954 accelerated the motion of an area about 150 m wide and 180 m from head to toe. Attempts from 1955 to 1970 by the City and County of Honolulu to move utilities above ground and to stabilize the slide by draining it failed. The City (meaning we) purchased the most damaged properties, and in 1976 converted the area into a park. It still slides slowly down towards Wai‘ōma‘o Stream.

Landslide terminology is almost hopelessly complicated. Depending on the classification scheme you use, the Mānoa and other Honolulu landslides are *debris slides* or *translational landslides* or *block slides* or *creeps*. Their slip surfaces are 5 to 10 m deep and are underlain by gooey, plastic-like clay, which is impermeable to water and has little strength. Interestingly, almost all of the Honolulu landslides occur on the Eastern sides of valleys.

This lab will involve riding the UH campus shuttle bus to Faculty housing and walking around the Mānoa neighborhood where there is an active slide. Please be considerate to the people that live there.

**What to bring to lab for the landslide lab:**
Good walking shoes, hat, water, something to write on, plastic bag to keep your papers dry, sunscreen, raincoat or umbrella, and good humor.