

THE HIGH COST OF LANDSLIDES

Landslides cause about \$2 billion in damage and more than 25 deaths each year in the U.S. Direct costs include repair of roads and property. Indirect costs, such as loss of property value and tax revenue, and environmental effects, such as degradation of water quality, can exceed direct costs. The Washington Dept. of Transportation routinely budgets \$15 million a year for cleanup of landslides on highways.

FREQUENTLY ASKED QUESTIONS

What is a landslide?

A landslide is the downward movement of soil or rock under the influence of gravity.

Where do landslides occur?

Landslides occur on unstable slopes or relatively flat areas prone to liquefaction during earthquakes.

What causes landslides?

Landslides occur when the strength of earth materials on a slope becomes less than the force of gravity or when an additional load is placed on the slope. Common triggers include:

- **Rainfall** – Prolonged or intense rainfall or rain-on-snow events (Pineapple Express) can all trigger landslides.
- **Earthquakes** – Intense shaking during earthquakes can cause ground to fail.
- **Water-level change** – Rapid lowering of water levels can trigger landslides, especially along dams, coastlines, reservoirs, and rivers.
- **Human activities** – Vegetation removal, surface and underground mining, loading on a slope, excavation of the base of a slope, and leakage from pipes can all trigger landslides.
- **Geology** – Easily weathered rock types and sand and clay soils are especially susceptible to landslides.



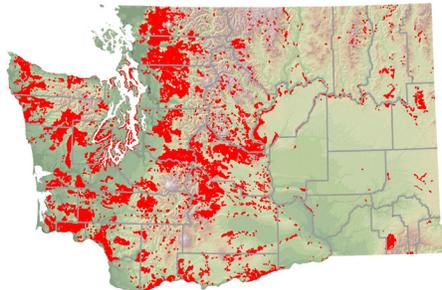
WASHINGTON STATE DEPARTMENT OF
Natural Resources

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www.dnr.wa.gov/geology

Landslide Hazards in Washington State



Red dots show mapped landslides (from the landslide layer of the Washington Interactive Geologic Map, <http://www.dnr.wa.gov/geologyportal>).

LANDSLIDE WARNING SYSTEM

In cooperation with the National Weather Service and NOAA, we have developed a model based on recent storm and landslide data that will forecast landslide initiation thresholds to help reduce losses from landslides (<https://fortress.wa.gov/dnr/landslidewarning>).

The Division of Geology's mission is to collect, develop, use, distribute, and preserve geologic information to promote the safety, health, and welfare of the citizens, protect the environment, and support the economy of Washington. To this end, we conduct and maintain an assessment of landslide hazards in Washington. This assessment includes identification and mapping of landslides and an estimation of potential consequences and the likelihood of recurrence. We also provide technical assistance to state and local government agencies on the interpretation and application of this assessment. Every year, we respond to and (or) record hundreds to thousands of landslides.

Warning signs of an impending landslide

Landslides can be categorized as shallow or deep-seated. Shallow landslides are common in Washington, often forming as slumps along roadways or fast-moving debris flows down valleys or concave topography. They are commonly called "mudslides" by the news media. Deep-seated landslides are often slow moving, but can cover large areas and devastate infrastructure and housing developments. Shallow landslides typically occur in winter in Western Washington and summer in Eastern Washington, but are possible at any time.

Signs of a Shallow Landslide (generally fast-moving):

- Sudden decrease in creek water levels, especially during storms
- Sudden increase in creek water levels, often with increased sediment in the water
- Sounds of cracking wood, knocking boulders, or groaning of the surrounding ground, or unusual sounds, like the sound of an oncoming freight train, especially if the sound increases
- A hillside that has increasing springs, seeps, or saturated ground, especially if it has been dry
- Formation of cracks or tilting of trees, especially evergreens, on a hillside

Signs of a Deep-Seated Landslide (generally slow-moving):

- Newly developing cracks, mounds, or bulging on streets, sidewalks, or the ground in general
- Sagging or taut utility lines; leaning telephone poles, fences, or trees
- Sticking windows or doors; new and/or growing cracks in walls, ceilings, or foundations
- Broken or leaking underground or surface utilities, such as water, septic, or sewer lines
- Separation of foundation from sill plates; movement of soil away from foundation
- Changes in water well levels or cessation of well functioning
- Increase or changes in spring or seep activity; ground becoming soggy or wet

If you notice signs of a shallow landslide, leave the area immediately if it is safe to do so. A landslide can easily destroy or bury a car or house. Report the problem immediately to your local Emergency Management Agency. Signs of a deep-seated landslide should be reported to your local Health or Planning Department, as this type of landslide, though slower, can affect water, sewer, streets, and whole neighborhoods. (See Resources on back page.)

REPORT A LANDSLIDE

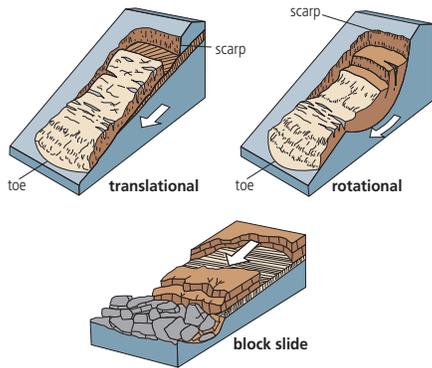
Report landslides to your local emergency management department. Find it at www.emd.wa.gov/myn/myn_contact_info.shtml.

What to do if you think you are at risk

- Contact a licensed geologist or engineering geologist for a site-specific inspection.
- Listen for warnings on NOAA weather radio (recommended), TV, or local radio.
- Evacuate prior to a storm event, which can cause sudden flooding and landslides, blocking escape.
- Keep away from landslide-prone areas until you are sure it is safe to return.

Types of Landslides

SLIDES—downslope movements of soil or rock on a surface of rupture. They commonly occur along an existing plane of weakness. The main modes are translational (along a flat plane) and rotational (along a concave surface). Slides may be deep-seated or shallow.



Slides are often slow-moving, but can move rapidly. Many of the larger landslide areas in Washington, such as the Bonneville and Aldercrest-Banyon landslides, are a complex of deep-seated, rotational slides.

Earthflows have a characteristic “hourglass” shape. The slope material liquefies and runs out, forming a bowl or depression at the head. The flow is elongate and usually occurs in fine-grained materials on moderate slopes under saturated conditions.

Mudflows are earthflows that are wet enough to flow rapidly and contain at least 50% clay, silt, and sand. Both mudflows and earthflows may be slow to rapid.

Debris Flows usually occur in steep gullies and contain more coarse material than a mudflow. They move very rapidly and can travel for many miles. Fires that denude slopes of vegetation intensify the susceptibility of slopes to debris flows.

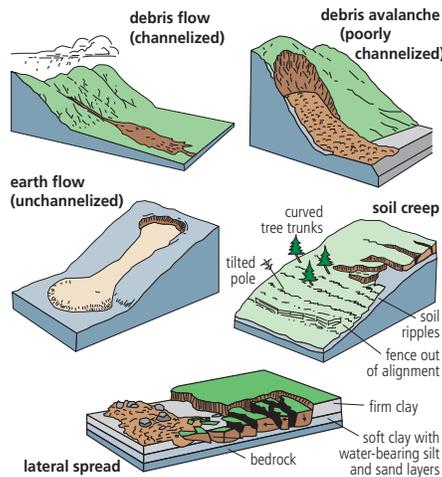
Debris Avalanches are poorly channelized debris flows that move very rapidly to extremely rapidly. They are often large and can move like a snow avalanche at times.

Lahars are debris flows that originate on volcanoes. An eruption can melt snow and ice very rapidly, causing a deluge of rock, soil, ash, and water that accelerates down the slopes of a volcano, devastating anything in its path. Lahars can also happen spontaneously. They can travel great distances and damage structures in flat areas surrounding a volcano. The communities near rivers draining Mount Rainier and Glacier Peak are at greatest risk.

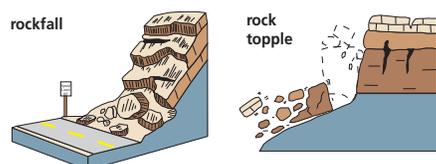
Lateral Spreads occur on very low angle slopes toward a free face. Movement is accompanied by cracking of the ground. Failure is caused by liquefaction (when soils are transformed from a solid to a liquid state), usually as a result of earthquake shaking.

Soil Creep is the slow, steady, downward movement of slope-forming soil or rock. Creep is indicated by curved tree trunks, bent fences or retaining walls, tilted poles or fences, and small soil ripples or ridges.

FLOWs—mixtures of water, soil rock and (or) debris that have become a slurry and commonly move rapidly downslope. The main modes of flows are channelized and unchannelized. Lahars are volcanic mudflows.



ROCKFALLS AND TOPPLES—usually rapid, downward movement of large pieces of bedrock. Sometimes a single boulder comes down, sometimes enough rocks to cover a road. Rockfalls and topples are common in Washington’s mountain passes.



RESOURCES

The frequency of landslides and their effects can be reduced by appropriate land-use planning and more stringent engineering requirements for construction on hillsides. Information about slide-prone areas is now readily available, so every homeowner should obtain this information and take necessary precautions. Links to free information are given below.

Washington Division of Geology and Earth Resources

- Webpage—www.dnr.wa.gov/geology
- Interactive Geologic Map—www.dnr.wa.gov/geologyportal

City/County Emergency, Health, and Planning Departments

Emergency management by county—www.emd.wa.gov/myn/myn_contact_info.shtml

Counties—www.mrsc.org/byndmrsc/counties.aspx

Cities—www.mrsc.org/byndmrsc/cities.aspx

Washington State Department of Ecology

Puget Sound Landslides; landslide mitigation—www.ecy.wa.gov/programs/sea/landslides/index.html

Washington State Department of Transportation

Road closures due to landslides; landslide mitigation—www.wsdot.wa.gov/

U.S. Geological Survey (USGS)

Landslide Hazards Program—<http://landslides.usgs.gov/>

Federal Emergency Management Agency (FEMA)

Landslides—www.ready.gov/landslides-debris-flow

Landslide Insurance

<http://insurance.wa.gov/your-insurance/home-insurance/landslides/>

Landslide figures modified from U.S. Geological Survey Fact Sheet 2004-3072 and Cruden, D. M.; Varnes, D. J., 1996, Landslide types and processes. In Turner, A. K.; Schuster, R. L., editors, Landslides—Investigation and mitigation: National Academy Press; National Research Council Transportation Research Board Special Report 247, p. 36-75.