Washington State University

Shore Stewards

Washington State University Extension

SPOTLIGHT ON... BLUFF STABILITY

Glacial Origins

Much of Puget Sound's uplands are comprised of and underlain by glacial and interglacial deposits of sand, gravel, silt, and clay. Repeated glaciations have sculpted, compacted, transported, and deposited these materials. The most recent of these, together with stream and shoreline processes, formed the landscape we see today. This landscape is generally characterized by steep, eroding bluffs of glacial and interglacial sediments, and narrow beaches. In places such as the northern end of Whidbey Island, and the islands of Skagit, Whatcom, and San Juan Counties, bedrock is exposed and the beaches are commonly discontinuous.

Factors Affecting Bluff Stability

Several geologic, topographic, and watershed-related characteristics can determine general slope stability and the type, rate, and severity of erosion common to shorelands comprised of glacial and interglacial materials. (Rocky shores and sites of exposed bedrock are not discussed specifically but much of the information on the role and management of vegetation will apply.) The Coastal Zone Atlas for your county is a valuable source of information. County planning and engineering offices usually have a copy available for the public. Property owners should become familiar with the characteristics of their land before beginning clearing or grading.

Topography

The presence of swales, gullies, or drainage channels on or adjacent to a shore site can affect surface water movement. These features can direct surface water flow towards or away from the bluff face and slope. They also affect the accumulation of sub-surface water and groundwater. The sometimes steep sides of such features can concentrate and accelerate runoff, increasing surface erosion. These features often indicate the site of past erosion or landslides. Modifications of existing topography should not be undertaken lightly.

Soil Type, Bluff Materials and Stratigraphy

Soil types vary greatly depending on the kind of materials they are formed from, the plants that have grown and died within them, their composition, and many other factors. A detailed discussion of soil types can be found in the Soil Survey for your county. Contact your Soil Conservation Service Office. For the purposes of this guide, we will be discussing the basic properties of soils that dictate how much water they can hold, how well they grow plants, whether they can support and anchor trees and how susceptible they are to erosion. Simply put, soil is the upper layer of "dirt" we are all familiar with. It has characteristics of texture, color, depth, moisture, and fertility. Soil is what our hypothetical landowner scraped away with the brush during land clearing.

Bluff materials refer to the sand, gravel, clay, silt, and glacial till that comprise many Puget Sound bluffs. Their characteristics and properties can influence the extent to which a site may be prone to erosion and slope instability.

Stratigraphy, the sequence of bluff materials in a particular shore profile, can influence whether your property is well-drained or boggy, if your trees are prone to blowing down, or whether you should move your house site back another fifty feet.

The **properties** of bluff materials vary depending on whether they are generally coarse or fine textured. Soil types derived from bluff materials will have many properties in common, but will differ in factors such as depth, organic material (humus), and mixing of coarse and fine textured materials. For example, soils with high percentages of clay materials will be more prone to compaction than sandy soils, and soils with high humus content hold water better than purely mineral soils. The properties and characteristics that property owners need to know are outlined below.

Coarse-textured materials (sand, gravel)

- Readily permeable to water infiltration
- Highly susceptible to wave action
- Soils prone to surface erosion
- Soils readily penetrated by plant roots
- Soil less subject to compaction

Fine-textured materials (clays, silts)

- Resist water infiltration
- Become slick when wetted
- Somewhat resistant to surface erosion
- Resistant to penetration of plant roots
- Susceptible to wave action
- Clay soils highly susceptible to compaction

Glacial till (wide range of textures)

- Resistant to water infiltration
- Resistant to surface erosion
- Moderately resistant to wave action
- Soil resistant to further compaction

Glacial till (or hardpan) is usually comprised of combinations of the above and is characterized by being very hard and compact. The materials that make up Puget Sound bluffs can be extremely diverse in composition. There will often be mixtures of the coarse and fine-textured soils within one layer and the thickness of individual layers can vary considerably. The stratigraphy of these soils can also be complex.

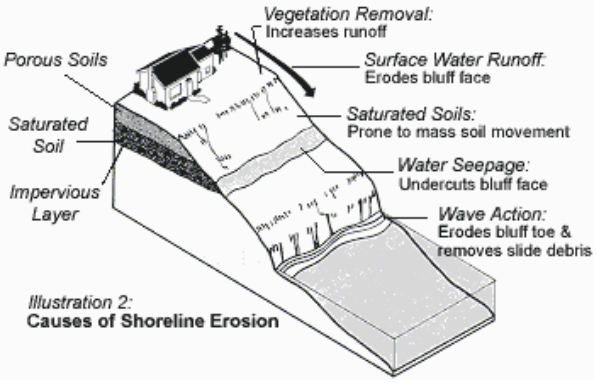
Steepness of Slope

The tendency of bluff materials to fall, slide, or flow downslope depends on the force of gravity, other factors being constant. For example, sand and gravel banks are stable at around 30 to 40 degrees. If the slope is modified by wave attack or other means, that material will seek a new equilibrium causing a mass soil movement. Many vegetated slopes in Puget Sound are at or beyond this equilibrium point. The removal of vegetation can tip the balance of forces.

Steep, almost vertical bluffs composed of glacial till are common in the area and can sometimes stand for years if undisturbed. When subjected to wave attack and erosion, however, they may collapse.

The importance of slope gradient in determining stability must be assessed in conjunction with factors such as soil characteristics, stratigraphy, topography, and watershed characteristics. These factors are greatly influenced by the shore processes discussed below.

Natural Processes



The erosive agents of water and weather act on bluffs in several ways (Illustration 2). As mentioned, these processes occur constantly, altering and modifying shorelands over time.

Beach processes, in particular the transport of beach materials along the shore by the combined action of waves, currents, and wind, can create a protective area between the waters of the Sound and the toe of a bluff. This area is called a backshore and is generally stable and dry from year to year. These are the beaches we walk on at high tide in the middle of winter when most others are inaccessible. Often they support the growth of vegetation and are above the drift line where logs accumulate. The result of net accumulations of sand and gravel, they are termed "accretional beaches" and they are relatively rare in an area where most beaches are erosional (that is, the result of net removals of sand and gravel). They are significant in terms of bluff stability because they offer a natural buffer from the erosive forces of wave activity. The shore shown in Illustration 2 has no protective backshore and thus is subject to wave attack.

Water is widely regarded as the most important force at work on shore sites. It can be misleading to discuss water-related processes separately; they often act in combination. Property owners should be cautious when attempting to control one problem because they may create other hazardous situations.

Wave action on shorelines with narrow beaches can attack the base of bluffs, eroding the toe, steepening the slope, and decreasing bluff support. This process is most active during winter months when storm-generated waves increase in size, and storms in frequency.

While wave attack is often an important cause of mass soil failures, it is not always a precipitating factor. Other factors, such as surface erosion or groundwater may actually be the cause of a bluff failure. The construction of traditional erosion control structures such as bulkheads, seawalls, and other devices designed to protect the toe of shore slopes from erosion can be expensive and ineffective. Current research has indicated that, in some cases, they will actually aggravate unstable situations by directing or deflecting wave energy that can result in outflanking or undermining the structure.

Remember that bluffs undergoing active erosion from wave attack cannot be protected by the presence of vegetation. If you determine that your bluff is actively eroding, it is wise to site upland structures far enough back from the slope so they are not in jeopardy. In many Puget Sound counties there are bluff setback requirements in the zoning ordinance to guide homeowners. Prudent setbacks allow natural beach processes to occur without the need for disruptive and expensive engineering solutions.

Groundwater influences bluff properties in a variety of ways. The extent to which a particular site is subject to groundwater problems is a function of bank materials, stratigraphy, and our wet winter weather (though rainfall varies greatly within Puget Sound). During the winter, rainstorms are frequent and of long

duration while evaporation from the ground is reduced due to increased humidity. Like wave action, groundwater impacts increase during the winter.

Much of the rain falling on the land soaks into the ground. If the upper layers are coarse-textured and permeable, the water percolates down until it reaches a layer of lower permeability such as the denser clays. This interruption of groundwater movement is often referred to as perched water; its subsequent lateral movement and discharge on exposed bluffs is commonly observed as seeps or springs.

The two influences of increased groundwater on slopes are shown in Illustration 2. When the soils above the impermeable layer become saturated, they are subject to landslides in the form of slumps, earthflows, and debris avalanches. This movement on a previously stable site is the result of a drastic reduction of the soil's ability, when wet, to resist the force of gravity (Illustration 6). This is the most common way groundwater affects slope stability.

Where seeps appear on bluff faces, the discharged water erodes the soil below, causing the upper unsupported layers to fall or slide. This can be a problem where bank materials below the seep discharge are erodible sand or gravel.

Vegetation can play an important role in maintaining stability in these situations. The removal of groundcovers and trees from uplands and bluff faces is a major contributing factor in triggering these events. (This will be discussed at length in Chapter 2.) However, vegetation alone cannot prevent occurrences of this nature if they are precipitated by other factors. Unusually heavy rains can often increase local groundwater influences (such as saturated soils) and initiate serious mass soil movements. Clearing of adjacent property can exacerbate these problems on your land.

Surface water runoff and the sediments it carries as it flows have been perceived as relatively unimportant as an erosional hazard in the Puget Sound area. However, while its effects are not as dramatic as landslides or bluff collapse caused by wave action, surface erosion can become a serious problem that is difficult to repair. Aside from the impacts to water quality, marine life, and soil productivity, soil erosion by surface water can have serious implications for bluff property owners. The two most serious initiators of surface erosion on shore properties are clearing of ground and tree cover and the compaction or disturbance of shallow soils by construction-related activities such as grading.

Illustration 3 shows the process of surface erosion and the damage it can cause. The process is initiated by the force of **raindrops** striking bare ground and dislodging soil particles. Once dislodged they are transported and become agents of further erosion. **Sheet erosion** occurs when the ground can no longer absorb water or the rate of flow exceeds the percolation rate (like filling a coffee filter too fast). More soil is dislodged and joins the flow. Topographic features concentrate the flow and are deepened, developing into **rills** and **gullies**.

Governing the severity and rate of surface erosion are slope, topography, and the properties of the affected soils. Obviously the steeper the slope, the faster the water flows and the greater its erosive capacity. Topographic features such as ditches and swales direct the flow. Soils such as sand and gravel are more prone to surface erosion than denser fine-textured soils.

Weathering of shore landforms by wind, rain, and freeze/thaw cycles is constantly occurring. Wind can be a cause of substantial erosion on sandy bluffs exposed to heavy gales if there is no vegetative cover. Rainwater falling on undisturbed sites causes some weathering but is not an important consideration when vegetative cover is present. The freeze/thaw cycle levers and breaks up the surface of exposed bluff faces and contributes to weathering, even on rocky slopes, but is rarely of concern in the Puget Sound area.

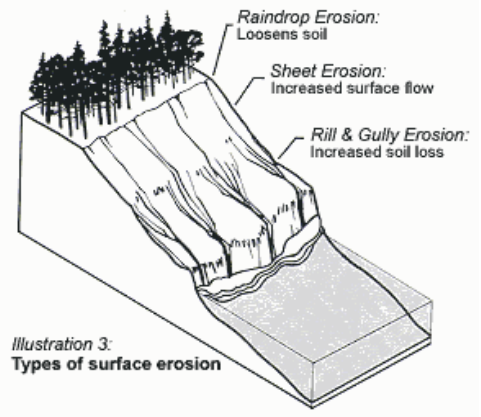


Illustration 3:
Types of surface erosion

Human Impacts

Human impacts that modify the factors and causes discussed above can potentially initiate or accelerate erosion and mass soil movements. Many of the problems encountered by our hypothetical owner in the Introduction could have been avoided or minimized. Below is a list of alterations and modifications common during site development. Their impacts should be considered carefully.

- hydrologic changes, both surface water and groundwater flow
- topographic changes due to excavation or filling
- vegetation removal
- construction or road building in marginally stable areas
- soil compaction by heavy equipment

Bibliography and Links

1. Vegetation Management: A Guide for Puget Sound Bluff Property Owners, Washington State Department of Ecology. Publication. May, 1993 Publication 93-31. (Prepared by Elliott Menashe, Greenbelt Consulting. PO Box 601, Clinton, WA 98236. (360) 341-3443.)
https://fortress.wa.gov/ecy/publications/publications/9331.pdf

2. Managing Vegetation on Shoreline Slopes, Washington State Department of Ecology. Website.
http://www.ecy.wa.gov/programs/sea/pubs/93-31/intro.html

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