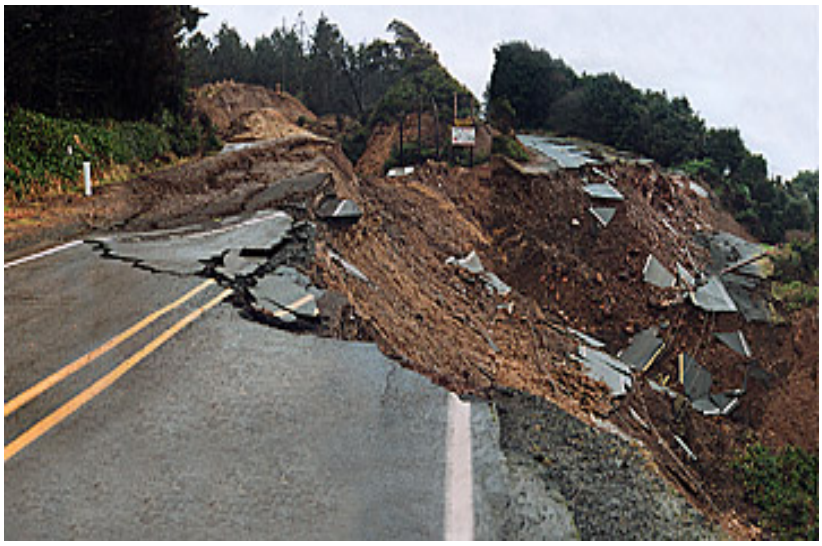
LAND MOVEMENT

DEFINITIONS:

Landslide – ground movement that may include rock falls, deep failure of slopes, and shallow debris flows.

Debris Flow / Mudflow – fast-moving landslides composed of a slurry mixture of water, mud, and rock that may accumulate trees, cars, and even houses as they travel downhill and are particularly dangerous to life and property because they move quickly and often strike without warning. Very large debris flows or mudflows are associated with volcanic eruptions.

BACKGROUND INFORMATION:



Landslides occur in every state and U.S. territory. The Appalachian Mountains, the Rocky Mountains and the Pacific Coastal Ranges and some parts of Alaska and Hawaii have severe landslide problems. Any area composed of very weak or fractured materials resting on a steep slope can and will likely experience landslides.

Although the physical cause of many landslides cannot be removed, geologic investigations, good engineering practices, and effective enforcement of land-use management regulations can reduce landslide hazards.

USGS scientists continue to produce landslide susceptibility maps for many areas in the United States. In every state, USGS scientists monitor stream flow, noting changes in sediment load carried by rivers and streams that may result from landslides. Hydrologists with expertise in debris flows and mudflows are studying these hazards in volcanic regions.

The force of gravity acting on a steep slope is the primary reason for a landslide. However, there are other contributing factors that may include but are not limited to:

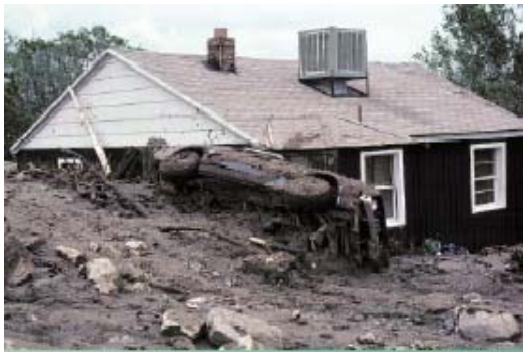
- Erosion by rivers, glaciers, or ocean waves that undercut steep slopes.
- Weakening of rock and soil slopes through saturation by heavy rains or snowmelt.
- Ground movement due to earthquakes.
- Ground failure due to excessive weight from the accumulation of rain or snow; stockpiling of rock, ore, or waste piles; or large man-made structures.

Deep-seated landslides are found along the slopes of the shoreline, often referred to as ancient landslides, which may become active in particularly wet conditions. These large landslides range in size from less than an acre to several acres and may extend over a mile of shoreline.

Shallow landslides with debris avalanches are the most common type, typically occurring during prolonged periods of heavy rainfall and involve a relatively thin layer of extremely dangerous wet soil and vegetation that can travel quickly with destructive force.

Mid-slope benches can be hazardous slide areas. These relatively level benches on an otherwise steep slope may indicate past slope movement.

Shoreline or steep inland areas are periodically struck with very large, rapid landslides. These large slumps or slides can cut 50 or more feet into the upland and involve tens of thousands of tons of earth.



Slope material that becomes super-saturated with water may develop into a debris flow or mud flow as it moves downhill. These flows generally occur during periods of intense rainfall or rapid snowmelt. Debris flows usually start on steep hillsides as shallow landslides that liquefy and accelerate to speeds that are typically about 10 miles per hour but can exceed 35 miles per hour. The consistency of debris flows ranges from watery mud to thick, rocky mud that can carry large items such as boulders, trees, and cars. These flows continue flowing down hills and through channels, growing in volume with the addition of water, sand, mud, boulders, trees, and other materials. When these flows reach canyon mouths or flatter ground, the debris spreads over a broad area, sometimes accumulating in thick deposits that can damage developed areas.

Among the most destructive types of debris flows are those that accompany volcanic eruptions. The picture at left is of a house located along the North Fork of the Toutle River that was damaged from an extremely large debris flow (called a lahar) resulting from the 1980 eruption of Mount Saint Helens. This debris flow traveled about 14 miles down the valley destroying roads, bridges, and approximately 200 homes. The depth of the debris flow can be noted by the light gray coloration on the trees.

HISTORY:

Skagit County's somewhat steep terrain, high precipitation, and its abundance of unconsolidated glacial sediments, and the possibility of earthquakes all combine to make the county susceptible to land movement.

While small slides and debris flows occur on a somewhat regular basis, there have been several slides and/or debris flows that have resulted in loss of life and/or property damage.

Recent Land Movement Events in Skagit County
(Information obtained from Skagit County Department of Emergency Management files)

Date	Location	Description of Event
May 18, 1965	Lower Baker Dam Powerhouse – near Town of Concrete	A large landslide that occurred just east of the Town of Concrete that partially buried the Lower Baker Powerhouse owned and operated by Puget Sound Energy. This slide was so large that the powerhouse was abandoned and a new powerhouse was constructed approximately 200 feet east of the original powerhouse.
January 24, 1982	Various locations throughout Skagit County	Excessive rainfall caused six (6) mudslides in various areas of Skagit County including: Del Mar Drive on Fidalgo Island; along the South Skagit Highway; Burpee Hill near Concrete; Cascade River Road; Concrete-Sauk Valley Road; State Route 530 south of Rockport.
January 10, 1983	Near Cruse Road north of Sedro-Woolley	A very large debris flow occurred killing one person and 300 veal calves; a large barn and a mobile home were completely destroyed.
November 2, 1985	Cascade River Park	A large debris flow occurred on the North side of the Cascade River within the Cascade River Park development killing two persons and destroying two mobile homes.
November, 1990	Biz Point area – Fidalgo Island	Heavy rains caused excessive runoff from storm water drainage systems and bank erosion in the Biz Point area
November 10, 1990	Grandy Creek	Heavy rains caused severe flooding throughout Skagit County and numerous mudslides occurred in the Grandy Creek area causing the Grandy Creek Campground to be evacuated.
November 25, 1990	Burpee Hill – north of Concrete	Numerous mudslides occurred in various areas on Burpee Hill causing property damage and damage to two homes; damage to a portion of Burpee Hill Road; and damage to Puget Sound Energy's facility.
January 18, 1990	Burpee Hill – north of Concrete	Additional mudslides occurred in various areas on Burpee Hill.
February 10, 1990	Mill Addition – Town of Concrete	A mudslide occurred on a steep slope above the Mill Addition Plat within the Town of Concrete that potentially threatened seven families.
December 28, 1990	Salmon Beach – Gibralter Road	A slump of a mid-slope bench area near the shoreline of Similk Bay cause damage to several homes and resulted in the temporary evacuation of a total of 28 homes; two homes were severely damaged and officially posted as uninhabitable by the Skagit County Building Official.

(this table is continued on the following page)

Recent Land Movement Events in Skagit County - continued (Information obtained from Skagit County Department of Emergency Management files)		
Date	**Location**	**Description of Event**
July 10, 1991	Big Lake	A debris flow caused by a beaver dam break damaged a portion of West Big Lake Boulevard and a Washington State Fishing Access and boat launch and blocking access to two homes.
May 5, 1994	Highway 20 east of Anacortes	A large rock slide occurred just east of the City of Anacortes blocking traffic for several days.
May 3, 1995	Big Lake	A debris flow caused by a beaver dam break damaged a portion of West Big Lake Boulevard and a Washington State Fishing Access and boat launch and blocking access to two homes.
February 8, 1996	Turner Ranch – 5502 East Sauk Prairie Road	A debris flow damaged a barn and adjacent feed shed and killed 1 bull, 20 cows, and 30 calves.
January 10, 1997	Lonestar Property - East Concrete	Area residents are concerned that the hill above their homes will slide – occupants of 15 homes in the immediate area were advised to leave. Several residents claim that a slide occurred at this same location in the late 1950's or early 1960's and destroyed three or four homes.
February 8, 1997	Lonestar Property - East Concrete (same as above)	A small side occurred knocking a garage from its foundation.
October 16, 1997	Jura Way – Similk Bay	A small slide occurred affecting one home.
December 13 -14, 2001	Frank's Place – Town of Concrete	A slide occurred affecting three homes.
February 22, 2002	Cascade River Park	A mud slide occurred along East Cascade Drive washing out a portion of road and requiring the evacuation of six cabins.
March 20, 2002	North Beach Area Samish Island	A slide occurred blocking access to three homes.
January 14, 2003	Hill Ditch and Johnson Road area	A debris flow caused by a beaver dam break damaged a portion of the Hill Ditch Levee and blocked access to three homes
February 22, 2003	Colony Creek	A large debris flow caused by a beaver dam break damaged a portion of Wood Road and also damaged the access an utilities serving two residences, and a footbridge. This same debris flow also damaged a private well, pond, and fish ladder along Deer Trails Lane further upstream on Colony Creek.

In addition to the above-referenced land movement events, one additional land movement event of significant size occurred in Skagit County during the past that we were unable to obtain specific information on. This event involved a large landslide that occurred east of Marblemount on the south side of the Cascade River in the isolated recreational community of Cascade River Park. This slide occurred in the late 1960's and destroyed several recreational cabins and covered a large number of vacant lots with debris; we were unable to determine if persons were injured or killed as a result of this slide. The slide was serious enough that a large portion of the development was permanently abandoned.

A few areas within Skagit County are known for occurrence of almost regular small-scale land movement events during the rainy winter months. One of these areas is located on the north slope of Day Creek Hill along the South Skagit Highway. In almost all cases, these slides are triggered by heavy rain events.

HAZARD IDENTIFICATION:

Some landslides move slowly and cause damage gradually, whereas others move so rapidly that they can destroy property and take lives suddenly and unexpectedly. Debris flows, sometimes referred to as mudslides, mudflows, lahars, or debris avalanches, are common types of fast-moving landslides. These flows generally occur during periods of intense rainfall or rapid snowmelt. They usually start on steep hillsides as shallow landslides that liquefy and accelerate to speeds that are typically about 10 mph, but can exceed 35 mph. The consistency of debris flows ranges from watery mud to thick, rocky mud that can carry large items such as boulders, trees, and cars. Debris flows from many different sources can combine in channels where their destructive power may be greatly increased. They continue flowing down hills and through channels, growing in volume with the addition of water, sand, mud, boulders, trees, and other materials. When the flows reach canyon mouths or flatter ground, the debris spreads over a broad area, sometimes accumulating in thick deposits that can wreak havoc in developed areas.

Areas that have experienced landslides in the past tend to be most susceptible to future landslides, especially during periods of wet weather. Because these areas consist of broken materials and frequently involve disruption of ground water flow, these dormant sites can be more vulnerable to slides caused by construction activities than adjacent, undisturbed soil.

As houses and roads are built on steeper slopes and mountainsides, landslide hazards become an increasingly serious threat to life and property. Increasing residential development along slopes such as Chuckanut Mountain and other similar hillsides throughout the county are at a greater risk to land movement than older developments located on hillsides with less slope. In addition, forest fires, clear-cutting of trees, and land clearing for housing developments may cause soils to become less stable thereby increasing the threat of slides and debris flows.

One or a combination of factors may precipitate a landslide. Undercutting of a slope by stream erosion or wave action, timber harvest or forest fire, or road building may cause landslides. Intense or prolonged rainfall, rapid snowmelt, freezing and thawing of soil, or sharp fluctuations in groundwater levels are all normal for Skagit County and may be the cause of a sudden landslide which may be combined with flooding. Shocks or vibrations caused by earthquakes, large explosion, or construction activity can also lead to landslides.

Land stability cannot be predicted with current technology. Due to population density and desire of people to have a home with a view, an increasing number of structures are built on top of or below slopes subject to land sliding. Landslides in these areas can take lives, destroy homes and businesses, undermine bridges, derail railroad cars, cover fish habitat and oyster beds, interrupt transportation infrastructure, and damage utilities.

The following list is a compilation of comments and suggestions made by various stakeholders and the public regarding possible problems that could result from a land movement event.

In addition to damaging homes, businesses, property, and the environment, a land movement event in Skagit County could potentially result in the following:

- Disrupted and/or damaged transportation routes and systems.
- Damage to underground as well as above-ground utilities.
- Secondary damage may occur due erosion caused by broken water transmission lines.
- Streams may be partially or completely blocked and/or diverted from their normal channels. A very large land movement event could possibly block river channels resulting in the formation of a lake upstream of the blockage and the threat of a sudden release of this trapped water upon failure of the material.

VULNERABILITY ASSESSMENT:

Homes, businesses, schools, hospitals, roads, bridges, and other infrastructure located on or near previous slide areas, steep slopes, or alluvial fans are most vulnerable to the impacts of landslides, debris flows, or mudflows. Property and lives may be lost and transportation routes as well as utility infrastructure may be damaged. A large landslide that affects creeks, rivers, or lakes may cause flooding.

Canyon bottoms, stream channels, and areas near the outlets of canyons or channels are particularly hazardous. Multiple debris flows that start high in canyons commonly funnel into channels; there, they merge, gain volume, and can travel long distances from their sources.

Debris flows commonly begin in swales on steep slopes making areas down-slope from swales particularly hazardous.

Road cuts and other altered or excavated areas of slopes are particularly susceptible to debris flows. Debris flows and other landslides onto roadways are common during heavy rain events and can occur during milder rain events than those needed for debris flows on natural slopes.

Areas where surface runoff is channeled (such as along roadways and below culverts) are common sites of debris flows and landslides to occur.

Due to its location at the base of steep slopes, certain portions of the Town of Concrete are especially vulnerable to landslides as is a portion of State Route 20, located just east of the town limits.

PROBABILITY and RISK:

Based on historical evidence, there is a **moderate probability** of a large, destructive landslide occurring in Skagit County. Because of the infrequency of landslide events occurring in

populated areas of Skagit County, there is a **low to moderate risk** associated with this hazard during the majority of the year **with the risk increasing to moderate during the rainy fall and winter months**.

CONCLUSION:

Washington is one of seven states listed by the Federal Emergency Management Agency as being especially vulnerable to severe land stability problems. Earthquakes combined with heavy precipitation may increase risk for those previously thought to be on stable ground.

With an increasing population desiring "view" property and tree removal to be able to "see the view" there is increasing risk of landslides in residential areas. Those buildings on or near steep slopes and bluffs could be at risk in seasons of heavy rains or a prolonged wet spell. The property located below these steep slopes and bluffs is particularly vulnerable.

The Shannon and Wilson study in Seattle found that 88% of the slides that occurred within the City of Seattle occurred within a potential slide area or along steep slopes. Furthermore, this study also found that only about 1% of the land area of the region is actually vulnerable to slides, 84% of the slides recorded had human-related causes; thus indicating the willingness of people to ignore signs of potential danger in order to possess the most desirable view property.

Landslide, mudflow and debris flow problems are often complicated by land mismanagement. By studying the effects of landslides in slide-prone regions, plans for the future can be made and the public may be educated to prevent development in vulnerable areas. Applying established ordinances where geological hazards have been identified will prevent some landslide losses. Careful maintenance of vegetation on slopes, prevention of erosion, and engineered drainage of slopes and mitigation using qualified expertise is necessary to protect these areas.

As with all other hazards, people need to become familiar with their surroundings. Slopes where debris flows have occurred in the past are likely to experience them in the future.

Buildings should be built away from steep slopes, streams, rivers, intermittent stream channels, and the mouths of mountain channels. Those persons who live in slide-prone areas need to be aware of storm-water drainage patterns on slopes near their homes and note places where runoff water converges. Residents of slide-prone areas should be aware of hillsides and watch for any signs of land movement such as very small landslides or debris flows or progressively tilting trees.

It is well known that many of the land movement problems that occur are related to storm water runoff and the effects this runoff has on adjacent and/or adjoining areas. Local government needs to better assess the possible water runoff and associated land movement problems associated with the creation of new residential and business developments. At some point, proper regulations will need to be put into place that will assure that storm water runoff created by new developments does not adversely impact areas downhill and/or downstream.