SUB-SECTION 4G.3

PUYALLUP TRIBE ALL HAZARD MITIGATION PLAN
LANDSLIDE HAZARD[1]

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Identification Description

Definition[2]

A landslide is the gravity-driven down-slope movement of a sliding mass composed of rock, soil, and vegetation. It can pick up and include anything else that might be in its path whether part of the natural or the developed environment. A landslide occurs when the down-slope weight of the slide mass exceeds the strength of the soil along the slip surface. That is, when the driving force (down-slope weight) exceeds the resisting force (soil strength). Factors influencing the stability of a slope include:

- Steepness of slope,
- Composition of soil and rock,
- Groundwater conditions,
- Recent precipitation patterns,
- Slope aspect,
- Earthquake,
- Vegetation on slope, and
- Anthropogenic activities (land clearing, grading, etc.).

Types[3]

There are four broad categories of landslides that commonly occur in Pierce County and they are outlined below.

Shallow bluff

Figure 4.3-1 Northeast Tacoma – Landslide 01/2007

Shallow bluff failures occur on the steep Puget Sound marine bluffs. These landslides are limited in area (usually less than 1-2 acres). The removal of vegetation from the marine bluff, usually done to improve views, can lead to serious slope erosion and instability.

Deep Seated Landslides

Deep seated, large landslides can be as large as tens to hundreds of acres, and can occur on slopes with an average slope gradient as low as 15%. These landslides are usually reactivations of older, pre-historic failures and they are typically slow moving.

Debris flows

Debris flows are the most hazardous to life. They are fast moving, water-saturated masses of soil, rock, and debris (tree trunks, limbs, etc.) that move down steep slopes and channels. Debris flows are typically triggered by intense rainfall, and can run long distances when confined to a channel. This type of failure is most common to the mountainous portions of Pierce County. For a more detailed description of this type of landslide and vulnerabilities to it, see the Volcanic Hazard Chapter.

Submarine Landslides

Submarine landslides (landslides that occur primarily underwater) have also occurred in Pierce County on the delta of the Puyallup River. Triggering factors for submarine landslides include:

- Rapid sedimentation resulting in an over-steepened and unstable slope,
- Loss of soil strength due to static liquefaction caused by rapid drop in water level at high to low tide transition,
- Loss of slope support because of bottom current erosion of material at the base of the delta slope,
- Additional loading at top of the delta slope (e.g., artificial fill) increases the down-slope weight of the soil (driving force), and
- Earthquake shaking causing loss of soil strength (liquefaction) and increase in down-slope force on soil mass.

Large submarine landslides in the Pacific Northwest typically occur on the deltas of major rivers or streams, which can lead to tsunamis, see Tsunami Sub-Section 4.4.

Profile

Location and Extent

Landslides directly and indirectly affect a small portion of the developed areas in the County. Map 4.3-1 shows the landslide hazard areas for Pierce County. The landslide hazard areas within the County include the walls of the major river valleys, the more mountainous regions, the coastal areas, and parts of the peninsula. Map 4.3-2 illustrates the slope stability of the coastal zones within the County. The most unstable coastal slopes are located on a small portion of the Kitsap peninsula, on the southwestern side of Fox Island, at Salmon Beach, and at various areas near DuPont.

Planning Area

Map 4.3-3 shows the landslide hazard areas for the Planning Area. Landslides impact less than 16% of the Planning Area. The hazard areas are concentrated on the various slopes along the Puyallup River Valley and on the shoreline on the northwest corner of the Planning Area.

Occurrences[4]

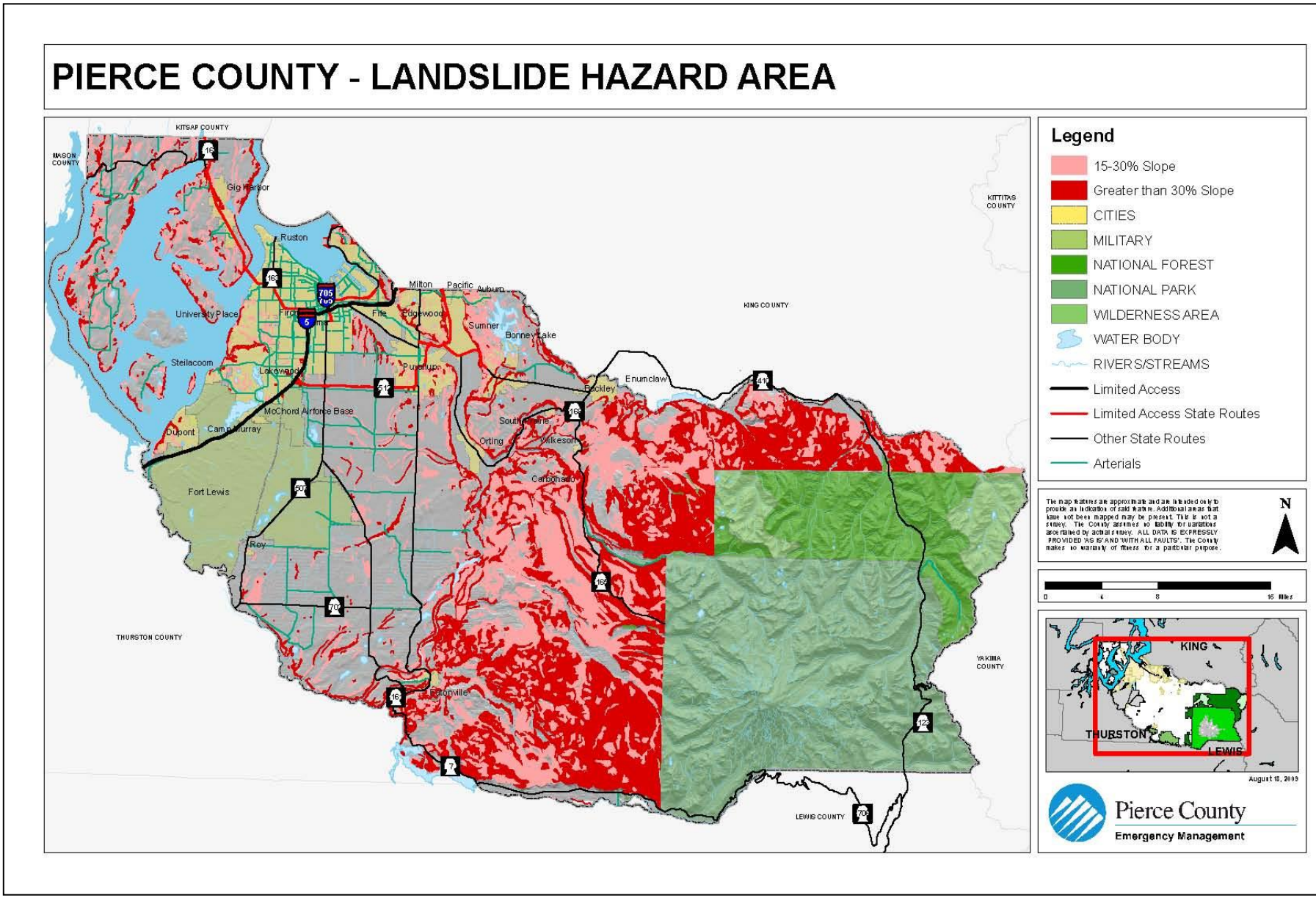
Topographic and geologic factors cause certain areas of Pierce County to be highly susceptible to land sliding. Ground saturation and variability in rainfall patterns are also important factors affecting slope stability in areas susceptible to landslides. Strong earthquake shaking can cause landslides on slopes that are otherwise stable.

There is a history of landslides throughout Pierce County. In 1996, severe storms and flooding led to landslides occurring just west of Tacoma, and along Pioneer Avenue East, causing damage to homes and infrastructure. Examples of large, deep seated landslides can be found in Pierce County on Fox Island, between Brown and Dash Points, along the Tacoma Narrows, and in the Dupont area. Table 4.3-1 lists some of notable and destructive landslides within Pierce County.

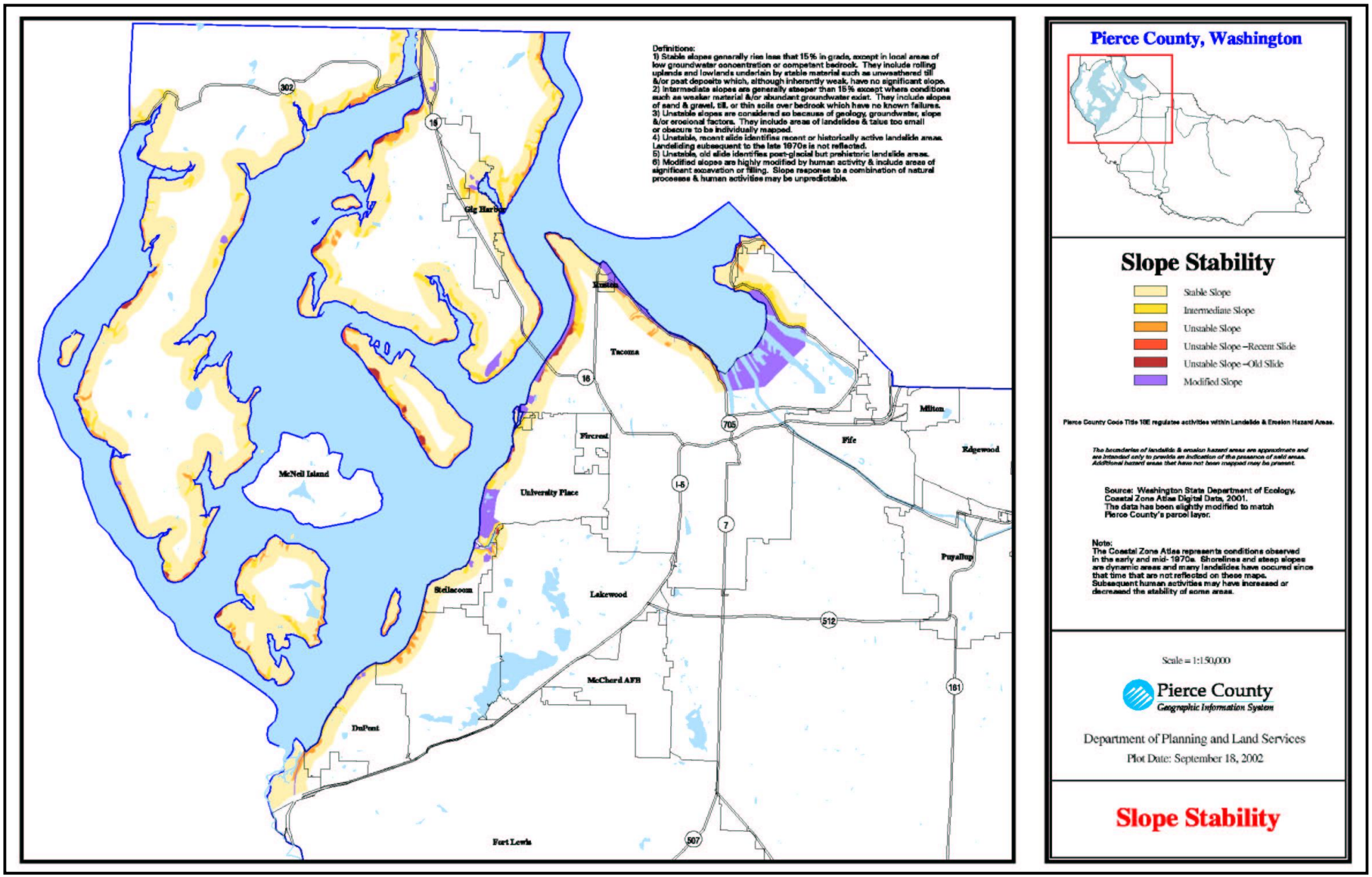
Table 4.3-1 Notable Landslides in Pierce County

DATE	DESCRIPTION
2006 (Federal Disaster #1671)	Estimated ten plus inches of rain in the lowlands (4-5 day period) and 18 plus inches up on Mt. Rainier (36 hr period). The Carbon River experienced numerous slides in the vicinity- East of Orting and North of 177th. Major landslides also occurred in Mt. Rainier National Park closing the Park.
2006	After receiving rain for 31 of 33 days in January and February landslides occurred in various areas throughout the County.
2001 (Federal Disaster #1361)	During the February 28th earthquake, a portion of the hillside above Salmon Beach slid down the hill, damaging a number of homes and destroying electric service and physical access to the community.
1996 (Federal Disaster #1159)	Combined with heavy rain and flooding, about 20-30 landslides occurred in the region. The slides damaged or destroyed eight homes and damaged utility lines; a landslide south of DuPont pushed two locomotives and two rail cars into Puget Sound, spilling 3,000 gallons of fuel; damaged State Route 165 and undermined a bridge abutment at the Carbon River near Carbonado.
1991	A slide occurred along the lower portion of the Nisqually River near Fort Lewis, blocking the River with debris. The River backed up, temporarily changed course, and flowed through a forested section that abutted up against the opposing wall of the slide. The river-flow gradually eroded the remains of the slide. This gradual erosion prevented a sudden release of water, possibly preventing flooding down-river.
1984	Ground gave way below railroad tracks in the area south of DuPont resulting in a derailment of several cars of an Amtrak carrying passengers. The train engineer suffered a non-fatal heart attack soon after the event. Several people sustained minor injuries requiring transportation and treatment.
1949	This occurred three days after the 1949 Olympia earthquake. Water saturated ground broke immediately to the north of Salmon Beach below Fort Nisqually and slid into the Tacoma Narrows. The slide generated a tsunami in the Tacoma Narrows. The slide missed waterfront homes, but the tsunami damaged them.
1894	A submarine landslide in the Puyallup River delta caused a damaging tsunami that killed two people.

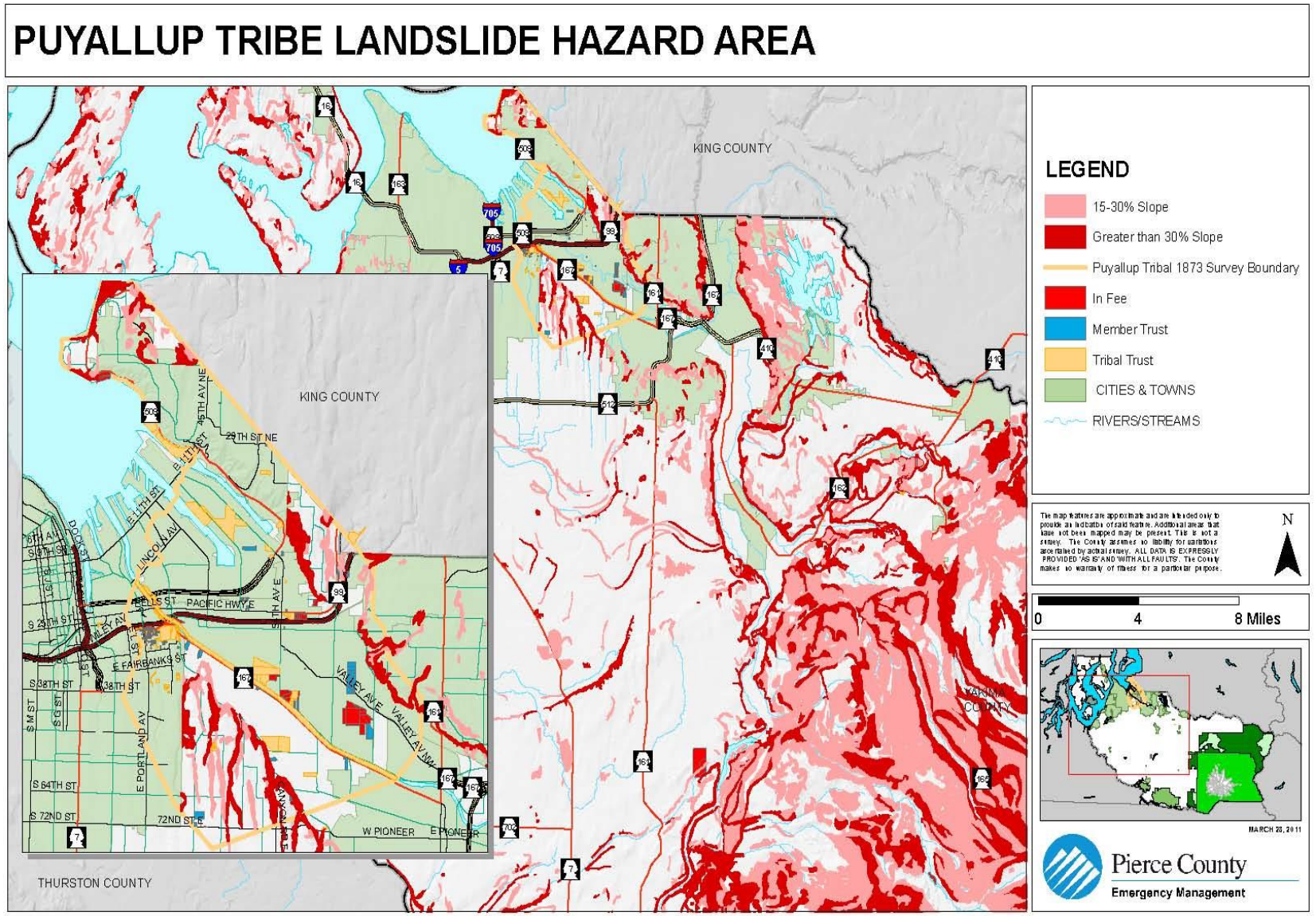
Map 4.3-1 Pierce County Landslide and Soil Erosion Hazard



Map 4.3-2 Pierce County Shoreline Slope Stability Areas[5]



Map 4.3-3 Planning Area Landslide and Soil Erosion Hazard



Because there have been no documented landslide occurrences in the Planning Area, the Planning Team determined the probability of recurrence for the landslide hazard to be "an unknown but anticipated occurrence." This is based on information from past landslide occurrences and information from local hazard experts.

Recurrence Rate

Small landslides happen in Pierce County every year. Since very few of them have any effect on the citizens they are irrelevant for determining the recurrence rate. Landslides with minor impact are defined as landslides impacting five or less developed properties or causing $1,000,000 or less damage. Significant landslides are those that begin to have a major impact on the fabric of a local community. For the purposes of this plan they are defined as being six or more developed properties or damages greater than $1,000,000. The probability of recurrence for minor landslides in Pierce County could be ten years or less with the potential for significant slides being 100 years or less. This is based on information from past landslide occurrences and information from local hazard experts.

Vulnerability

As the demand for a "home with a view" and industrialization continues to grow, the potential for damage, destruction, and life-loss grows.

Landslide vulnerability is largely dependent on slope, material, and water saturation. Water saturation is most prevalent during the rainy season of the winter and spring months. An unequivocal predictor of landslide vulnerability is the occurrence of previous landslides in the same area.[6]

Typical effects include, but are not limited to, damage to or destruction of portions of roads and railroads, sewer and water lines, and homes and public buildings. Many of the losses due to landslides may go unrecorded because claims are not made with insurance companies, there is a lack of coverage by the press, or because landslides affecting transportation may be recorded as "maintenance". Even small landslides are expensive. Clean-up costs may include debris clearance from streets, drains, streams, and reservoirs as well as new or renewed support for road and rail embankments and slopes. Damages may include minor vehicle and building damage; personal injury or death, and; livestock, timber, crop, and fencing losses and damaged utilities systems.[7]

The occurrence of rapidly increasing development near or on steep slopes throughout the region makes these areas vulnerable to landslides. With increasing development and the creation of a new bridge, this vulnerability should continue to rise. Further, the continued development along the bluffs above the river valleys means that the landslide vulnerability in these areas will continue to rise as well.

Planning Area

The Planning Team determined that the Planning Area currently has a low vulnerability to the landslide hazard because less than 5.7% of structures are on a sloped terrain with slight landslide/erosion risk (see Map 4.3-3). The Planning Area is not in an avalanche runout zone. As noted above, increased development along hillsides increases the vulnerability to landslides. This is less the case within the reservation boundary as it is further east and on the peninsula. The valley walls in the reservation have not undergone the same clear cutting and subdivision development as these other areas and will not as the neighborhoods have slowly developed over the past several years.

In the entire Planning Area, approximately 2,338 acres (15%) are vulnerable to the landslide hazard. The total damage to the Planning Area could equal approximately $455,276,700 (the assessed value of approximately 1,516 parcels in the Planning Area).

Of the 485 Tribal Trust parcels in the Planning Area, 30 parcels (6.2%) are located in landslide hazard areas. The total estimated losses to these parcels would equal $10,154,200.

Impacts

Health and Safety of Persons in the Affected Area at the Time of the Incident

The impacts include the injury and possibly death to persons in the affected area. Death may result from suffocation from being buried by the landslide or traumatic injury from the impact of sliding material, or the collapse of structures by the landslide. In some areas there is the possibility that a structure could be actually pushed into a water feature like a lake, river or Puget Sound. In these cases it is possible that a person could be trapped inside the structure and actually drown as a result of the slide.

Figure 4.3-2 Ski Park Road – Landslide

The other impact relating to landslides has to do with underwater landslides. In this case the possibility exists that an underwater landslide could initiate a tsunami that could affect the surrounding areas, in particular Commencement Bay. This issue is covered in the Tsunami Hazard Sub-Section of the Plan.

Health and Safety of Personnel Responding to the Incident

Personnel responding to the scene of a landslide must be aware of the potential for more land to collapse while they are attempting to respond to or rescue persons from the slide impact area.

Other possible hazards include ruptured gas lines and charged electrical wires. Also, hazardous chemicals associated with the damaged facility could have spilled and be in the environment.

Continuity of Operations and Delivery of Services

Due to the very limited terrain covered by any individual landside in the Planning Area, unless the landslide has a major affect on some portion of the infrastructure, its impacts to the continuity of operations for any jurisdiction should be limited.

The interruption in the delivery of services should be very localized, if at all, and in most circumstances, of short duration. Individual departments or organizations, especially ones with infrastructure tied to the landscape like sewer utilities, water purveyors, and others could have their delivery of services compromised on a very local level but seldom on a large scale. Even a major landslide knocking out the City of Tacoma's water pipeline from King County would have a work around from the City's well system that could cover the lack of water until the pipeline was repaired. There is the potential for a limited number of areas to be temporarily cut off from the rest of the County by landslides. The majority of these are located in the more rural areas of Pierce County. For example, a landslide located under the north end of the Home Bridge on the Key Peninsula can cut off the entire lower end of the Longbranch Peninsula. The same can be said for Ski Park Road on the east side of Ohop Lake. In the latter case they are cut off from much of the rest of the County every few years by landslides. The overall effects would be limited and the roads should be opened within a short period of time. Generally, during normal years, most landslides are taken care of quickly, however in the advent of an earthquake generating a number of landslides throughout the County, as well as other damage affecting the infrastructure; it could be weeks before some areas are accessible for emergency vehicles and crews.

Property, Facilities, and Infrastructure

Due to their probable location in the less settled portions of the Planning Area, many of the landslides will have no affect on the developed property. However in the developed areas there is a danger of roads, railroad tracks, gas, water and sewer lines either being buried, broken, or in some cases swept away when undercut by a slide as in Figure 4.3-3[8]. Private property has the same problem. While many of the landslides will not be large enough to affect large numbers of homes or businesses many could affect individual parcels of private property. It is also possible that damage to water and gas lines will increase danger from fire.

The Environment

The impacts are generally local and would not include large scale damage to the environment. Generally the slides will affect individual hillsides, possibly blocking rivers or streams. This can cause a backup of water that once it breaks through could cause a flashflood downstream. The possibilities exist that a major slide in a river could damage spawning beds or create an obstacle to fish migration. Any landslide that breaks pipelines, sewer lines, etc. or impacts the transportation or storage of hazardous chemicals could cause considerable environmental damage that could take decades to correct.

Economic and Financial Condition

Due to the very limited terrain covered by any individual landside in the Planning Area, the impacts to the economy for any jurisdiction affected should be limited. The biggest potential problem economically could come from a major slide taking out a section of railroad track along the coast. This could impact the transportation of goods into and out of the Port of Tacoma for a short time until either the tracks are repaired or a work around is established.

Financially, while a landslide within the boundaries of the Planning Area could cause some strain, the limited area covered should restrict the actual financial hardship to the local jurisdiction. There are areas that slide on a regular basis in both the unincorporated areas of the County and within the City of Tacoma. These are handled yearly with the local budgets and to date have not stressed those budgets. If any area of the Planning Area were to experience a landslide of the proportions of the Aldercrest-Banyon landslide in Kelso and the subsequent Haussler Road Landslides on the opposite side of the ridge in 1999, it could cause financial difficulties due to the streets and other utilities affected or destroyed; see Figure 4.3-4 below.

Figure 4.3-3 SR-165 Bridge along Carbon River – Landslide 2/1996

Public Confidence in the Jurisdiction's Governance

The majority of landslides that occur each year in Pierce County do not affect homes, businesses or infrastructure to the extent that there is any lasting impact noticed by the public. That could take a turn in another direction if the Planning Area has a landslide that destroys a number of homes or a major arterial that could take months to reopen. If a number of homes are destroyed and, in particular, if people are killed or injured, there will be questions asked as to why people were allowed to build on unstable slopes.

Figure 4.3-4 Aldercrest Drive – Landslide 1/1999

Resource Directory

Regional

- **Pierce County Department of Emergency Management**
  http://www.co.pierce.wa.us/PC/Abtus/ourorg/dem/abtusdem.htm

- **WA State Department of Ecology Coastal Zone Atlas**
  http://www.ecy.wa.gov/programs/sea/femaweb/pierce.htm
-
- **WA State Department of Ecology: Puget Sound Landslide**
  http://www.ecy.wa.gov/programs/sea/landslides/

- **WA State Department of Natural Resources**
  http://www.wa.gov/redirDNR/splash.html

National

- **American Planning Association--Landslide Hazards and Planning**
  http://www.planning.org/Landslides

- **How to do landslide hazard analysis**
  http://www.itc.nl/ilwis/

- **Landslide and Mudflow Fact Sheet**
  http://www.fema.gov/library/landslif.htm

- **Landslide hazard maps (San Francisco Bay Area)**
  http://wrgis.wr.usgs.gov/open-file/of97-745

- **Landslide overview map of US**
  http://landslide.usgs.gov/html_files/landslides/nationalmap/national.html
  http://landslides.usgs.gov/html_files/nlic/maporder.html

- **USGS**
  http://www.landslides.usgs.gov

Endnotes

[1] Background and specific information for the Landslide Section provided through consultation with landslide hazard expert, Tim Walsh, Washington State Department of Natural Resources.
[2] Modified from Pierce County HIVA (DRAFT), Landslide Section, September 5, 2002, p. 1. http://www.co.pierce.wa.us/xml/abtus/ourorg/dem/HIVAWEB.pdf
[3] *Ibid*, p. 1, 2.
[4] *Op cit*, Pierce County HIVA C p. 2,-3.
[5] Information on this map comes from Pierce County Planning and Land Services Department's interpretation of data on the Coastal Zone Atlas of Washington, Volume 7, (Pierce County). Washington State Department of Ecology, 1979.
[6] *Ibid*, p. 3.
[7] *Ibid*, p. 3.
[8] Landslides and Landslide Hazards in Washington State Due to February 5-9, 1996 Storm--U.S. Geological Survey Administrative Report-- Debris flow undermining abutment of bridge across the Carbon River on Washington SH-165 south of Carbonado, Washington.

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