WASHINGTON STATE DEPARTMENT OF
Natural Resources

Priority 3
Mass Wasting Assessment:
Landslide Hazard Inventory Project

South Prairie Creek Watershed, Pierce County, Washington

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1.0 Introduction and Summary of Methods

1.1 Use of This Report

The purpose of this mass wasting assessment is to identify non-federal non-tribal areas within the South Prairie Creek Watershed Administrative Unit (WAU) that have landforms[1] with moderate or high risk of landslides due to the effects of forest management (logging, roading, thinning, yarding, etc.). Maps of these watershed-specific landforms (Map A2 herein) will be used by the Department of Natural Resources, Region staff to identify those Forest Practice Applications (see Chapter 222-20 WAC) that will require a site investigation prior to assigning the class of forest practice relative to potential unstable slopes and landforms (Chapter 222-16-050).

Note! This is a reconnaissance study and its level of resolution must be kept in mind when using this document and Maps A1 and A2. For example, analysis of individual landslides or slopes is not an appropriate use of this report nor should it be used for zoning purposes. Moreover, the report was prepared according to the schedule necessary to produce a statewide screening tool as quickly as reasonably possible. For this reason, it is likely that some landslides or landforms have been accidentally omitted, some benign features are improperly mapped as landslides, and some data have been miscoded herein.

Lorraine Powell, Eric Bilderback, and Laura Vaugeois of the Department of Natural Resources reviewed this report and edited the text.

1.2 Previous Investigations

One landslide in the South Prairie Creek WAU has been mapped by Tabor and others (2000) and several letter reports on unstable areas have been prepared for Forest Practices Applications. However, no comprehensive study of slope stability in the South Prairie Creek watershed occurred prior to this investigation.

1.3 Summary of Methods

This assessment follows the Landslide Hazard Inventory Protocol dated August 17, 2004 (Department of Natural Resources, 2004), with minor modification.

Six sets of aerial photographs acquired between 1976 and 2001 were viewed with a mirrored stereoscope with 3x magnification (Table 1). Unfortunately, many key images were missing from DNR's collection in Olympia and could not be viewed. In addition, 1998 orthophoto coverage was used as a layer during GIS analysis and mapping. Note that many landslides identified from the orthophotos and indicated as having a 1998 identification date Appendix A are actually relict landslides and are probably considerably older than the 1998 acquisition date of these data.

Only two additional landslides were located during a reconnaissance field investigation of part of the area on September 1 and 2, 2004; however, 25% of landslides mapped from aerial photography and all landforms were confirmed or rejected in the field.

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[1] Landforms as defined herein can be more inclusive than the small-scale unstable landforms commonly defined in rule (WAC 222-16-050). These rule-identified landforms include inner gorges, convergent headwalls, the outsides of meander bends, bedrock hollows, and the toes of deep-seated landslides. These will be referred to as "rule-identified landforms" herein.

Table 1. Photographic surveys used in this study. (Note the large number of missing images.)

Year	Scale	Image	Flight Number	Reference/Ownership	Comment
1976	1:12,000	color	NWC76_24B to 31B	DNR	5 missing photos
1985	1:8,000	black & white	SPS85 15 to 41	DNR	9 missing rolls
1981	1:8,000	black & white	SP81_64 to 77	DNR	12 missing photos
1995	1:8,000	black & white	NW95_51 to 69	DNR	23 missing photos
1995	1:8,000	black & white	NW95_51 to 69	DNR	23 missing photos
1998	1:8,000	orthophotos	NWH_98	DNR	complete coverage
2001	1:8,000	color	NWC01_10-16, 45-65	DNR	20 missing rolls

Mapping was generally accomplished by heads-up digitizing the landslides directly on Department of Natural Resources (DNR) digital orthophotos, but additional control has been established by rectifying some landslides with DNR ("drg75") topographic contours as an ArcGIS shapefile. The maximum resolution of these techniques is about 10 meters. A slope/convergence map (SLPSTAB; Vaugeois, 2000) and a ArcGIS slope-percent map derived from a USGS 10-meter digital elevation model (DEM) covering the study area aided in predicting areas of potential shallow-rapid slope failure and in delineating the watershed specific landforms.

The resulting landslide coverage is displayed as Map A-1 and is available as PDF files, shapefiles, or ArcInfo coverages from the DNR, Forest Practices Division. Pertinent attributes of the landslides are recorded on data sheets (Appendices A, B). Slope gradients were determined by exploring DEM-derived slope percent pixels within the upper parts of each landslide polygon on the Map A1 shapefile. Note that the steepest slope increment only corresponds to the "slope at failure" in medium to large translational landslides. (See *Angle of Slide* in Jackson, 1997). The slope angle cannot be determined precisely for small or narrow landslides where accuracy is limited by the 10-meter resolution of the DEM. (Due to averaging, slope angles derived from DEMs are generally lower than those measured in the field, but are less subjective than slope angles casually derived from aerial photography.) Conversely, the steepest slopes on rotational failures are on the failure plane and therefore steeper than the slope of the ground just before landslide initiation. As a result, the slope gradients presented are approximations.

Once the locations of mass wasting features were mapped and evaluated, watershed specific landforms[2] with similar mass-wasting potential were delineated. These landforms are shown on Map A-2, which is also available in other formats from the DNR, Forest Practices Division.

2.0 Physical Setting Pertinent to Mass-Wasting Interpretations

2.1 Introduction

The South Prairie Creek Watershed covers 70-mi^2 in the west-central part of the North Cascades physiographic province near the hamlet of Burnett in Pierce County, south of Buckley (Map A1). The study area includes the drainage area of South Prairie Creek, exclusive of U.S. Forest Service ownership. However, 28 landslides on Forest Service land in the southeast part of the greater South Prairie Creek watershed have been inventoried to improve the hazard interpretations on adjacent fee State lands.

The study area, occupying 20,900 acres of the 44,665-acre South Prairie Creek watershed, ranges in elevation from about 295 ft above mean sea level at the confluence of South Prairie Creek and the Carbon

[2] Referred to simply as "landforms" hereafter.

River upstream to the 5,796 ft. on the summit of Old Baldy Peak (U.S. Geological Survey, 1956a-d; 1986a, b).

Precipitation within the watershed is high, averaging about 50 inches per year in the lower elevation western and central parts of the watershed to about 75 inches per year in the higher elevation hills and subalpine landforms (DNR, 2003). Most of the annual rainfall occurs between September and June. During the winter months, elevations between 1,800 feet and 3,200 feet are susceptible to rain-on-snow events, which, when they occur, often trigger widespread mass wasting along the Cascade foothills. Groundwater hydrology in the much of the watershed consists primarily of transmission through forest duff and soil because the substrates are dominantly poorly permeable till, volcanic mudflow deposits, older cemented outwash, and bedrock. Highly permeable continental glacial gravels are the only important exception.

2.1 Geology

2.1.1 Bedrock Units

Bedrock in subalpine and other bedrock-dominated hills is composed of younger (Miocene to Quaternary) volcanic and intrusive igneous rocks (finely crystalline "granites"[3]), which are generally resistant to erosion, form steep cliffs, and talus slopes (parts of Landforms 6 and 13 through15). Small exposures of bedrock also crop out in the incised inner gorge system of South Prairie Creek (Landforms 7 through 10). These are mostly volcanic conglomerate[4] and older sandstone, siltstone, claystone, and coal[5]. Of particular note are Oligocene volcanic conglomerates of the Ohanepecosh Formation. Between the hamlet of Burnett and Beaver Creek, outcrops of this unit (Landform 10) are particularly unstable with numerous deep-seated landslides and superimposed shallow rapid failures.

2.1.2 Poorly-Consolidated Surficial Units

Surficial units in the study area consist of sediments[6] deposited from the continental and local alpine glaciers, volcanic mudflow deposits, and alluvium deposited from streams. About 200,000 years ago, a large ice cap covered the area of Mt. Rainer and shed gravels onto a northwest tilted apron, part of which is preserved in the central study area between Wilkeson and New Pond Creeks (part of Landform 5). This unit is compact, cemented, and therefore, relatively stable. About 15,000 years ago, the continental ice sheet covered the northern and western part of the study area, depositing till and shedding outwash gravels over the low hills in the central part of the study area (the northern and western parts of Landform 5). These sediments are stable because the outwash gravels are well drained and the till is cohesive. About 5,500 years ago, the north side of Mt. Rainier collapsed forming the giant Osceola mudflow (Crandell, 1963). This mudflow inundated the northern parts of the study area (Landform 4) and rerouted the White River. (See below.)

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[3] The term "granite" is used casually herein to assist lay readers. Real granite is an uncommon rock type. Most of the intrusive rock within the study area, that is, rock that cooled from magma in a deep underground chamber, is actually intrusive andesite or granodiorite (Walsh and others, 1987).

[4] Conglomerate is a rock made up of rounded pebble-sized fragments of other rock, in this case, volcanic fragments.

[5] Coal was mined from three underground mines in the watershed (Daniels, 1914).

[6] The term 'sediment' is used in the strict sense, e.g., unconsolidated material such as free-flowing sand, gravel, boulders, etc., and semi-cohesive, clay rich deposits such as till.

2.1.3 Geomorphology

The study area can be divided into seven main physiographic elements and subdivided into 15 Landforms. From the southeast, the physiographic elements are:

1) Subalpine and other bedrock-dominated hills (Landforms 6, 13, 14,15).
2) Low-relief, northwest-tilted terrace covered by glacial gravels derived from an ancient ice cap that covered Mt. Rainer about 200,000 years ago (Landform 5, south),
3) Low-relief hills covered by glacial gravels deposited at the edge of the most recent continental ice sheet about 15,000 years ago (Landform 5, north). Water rushing from the margin of the continental ice sheet flowed southwest cutting two prominent valleys in these hills. One of these forms the channel of South Prairie Creek and it northeastern continuation east of Spiketon Road and the other forms the swampy valley trending east from Wilkeson.
4) Lowlands covered by 5,500-year old deposits of an Osceola volcanic mudflow from Mt. Rainier (Landform 4).
5) The deeply incised gorge system of middle and upper South Prairie Creek (Landforms 7, 8, 9, 10). This broad, terrace-lined channel cross-cuts part or all of the other physiographic elements and formed in response to rapid uplift, possibly along the Mt. Rainier fault zone.
6) The Lower South Prairie Creek valley, which has had a complex geologic history. Prior to 5,500 years before present, the White River flowed through the Buckley area and down the lower South Prairie drainage where it cut meander scarps and terraces (Landform 1). After damming by the Osceola mudflow, the White River was forced northward into its present day channel (Crandell, 1963). The pre-mudflow meander scarps have been eroded by the slow moving present-creek (Landform 2) while the floodplain appears to be aggrading (Landform 3).
7) Large deep-seated landslides spread across the landscape and are delineated as Landform 11 and 12.

3.0 Summary of Results

During this review, a representative sample of 120 landslides ranging from 'questionable' to 'definite' field-confirmed failures was inventoried using data obtained between 1976 and 2004 (Form A-1, Appendices A, B) within and directly adjacent to the study area. It is important to note that 28 of these landslides were inventoried in a large clear-cut on federal lands outside (east of) the southern part of the study area. This procedure, which is not consistent with other watersheds inventoried during the Landslide Hazard Zonation Project, was applied in order to more accurately characterize the overall hazard of landforms in this part of the watershed.

Figures 1 through 5 characterize failures in the study area together with the aforementioned failures on U.S. Forest Service lands. Compared to other watersheds of similar size in Washington, the landslide frequency, even including the 24 failures from outside the study area, is moderate to low. (See Section 5.0 below.)

Of the landslides identified during this mass wasting assessment, 47% were mapped as shallow rapid - undifferentiated failures, 34% were debris flows, 2% were debris avalanches, 9% were deep-seated - undifferentiated, 3% were small sporadic deep-seated, 1% were earthflows, and 2% were rock topples (Figure 2).

A large percentage of mapped failures are small relative to most Priority 1 and 2, Landslide Hazard Inventory Project watersheds. Of all shallow rapid failures, 64% are smaller than 0.2 acres and 94% are

smaller than 1 acre (Figure 3). The small size of these failures results from three main factors: 1) the most unstable Landforms, Numbers 8, 9,and 10 are mostly failing on short, steep, slope panels along the incised portions of South Prairie Creek, and therefore, large debris flows to not have enough room to attain large size, 2) unstable slopes in the highest elevation and steepest parts of the watershed (Landforms 9, 13, 14) are so steep that thick soils do not accumulate, and 3) much of the watershed is covered by stable landforms in well-drained or cohesive soils.

Throughout the watershed, most failures are associated with rule-identified features including inner gorges, bedrock hollows, and convergent headwalls. Undercutting of rule-identified meander scarps (Landform 2) by South Prairie Creek has not resulted in mapped landslides. Most of the stream-influenced failures mapped during this study are located in the incised inner gorge system of South Prairie Creek in Landform 10.

Landforms 10 and 12 are very unstable.

Slopes within the South Prairie Creek watershed are most susceptible to failure following road construction; road-related failures account for 44% of all mapped landslides (Figures 3). On managed lands, landslides associated with clear-cuts (0 to 5 years) represent only 19% of all recorded failures. Young (5 to 15 years) and submature stands (15 to 50 years) each represent 9% of the mapped failures. Landslides in mature stands represent a combined total of 15% of observed slope failures.

Table 3. Mean DEM-derived slopes and standard deviations in percent for various landslide components and physiographic elements in the South Prairie Creek study area. Note that DEM-derived slopes are commonly 10 to 20% lower than slopes measured in the field because of the 10-meter averaging effect of the DEM and because slopes may be too short to be recorded on the DEM.

Failure Component	Bedrock-Related Mean Slope Percent
Deep Seated Initiation	111%, s.d.= 35%
Deep Seated Toe	77%, s.d.= 35%
Shallow Rapid Initiation	89%, s.d.= 29%

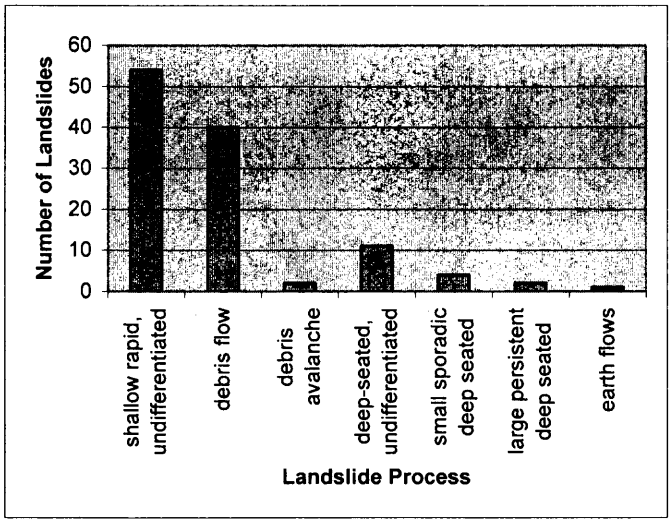

Figure 1. Number of landslides observed within the South Prairie Creek study area by mass wasting process.

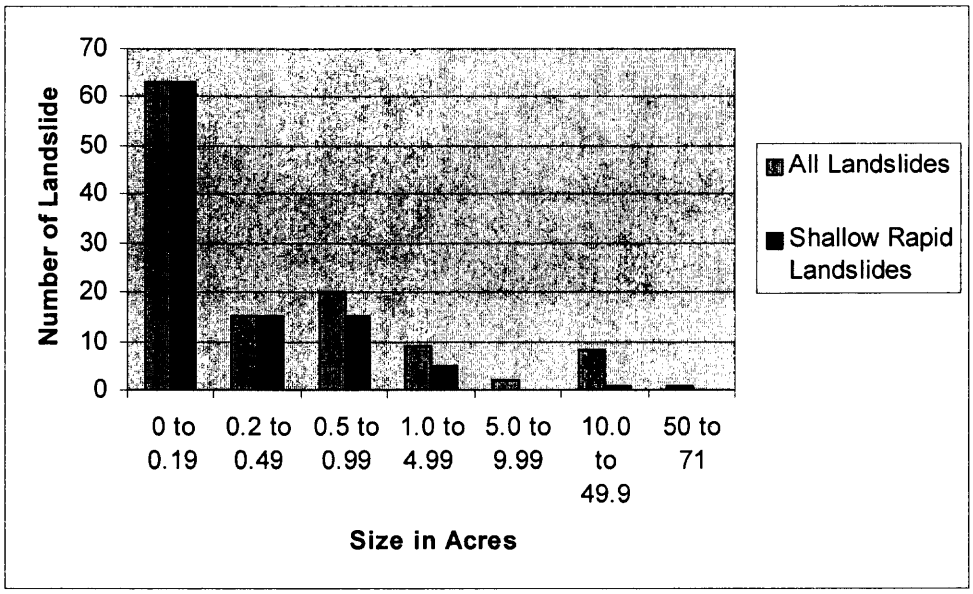

Figure 2. Size distribution of landslides within the South Prairie Creek study area.

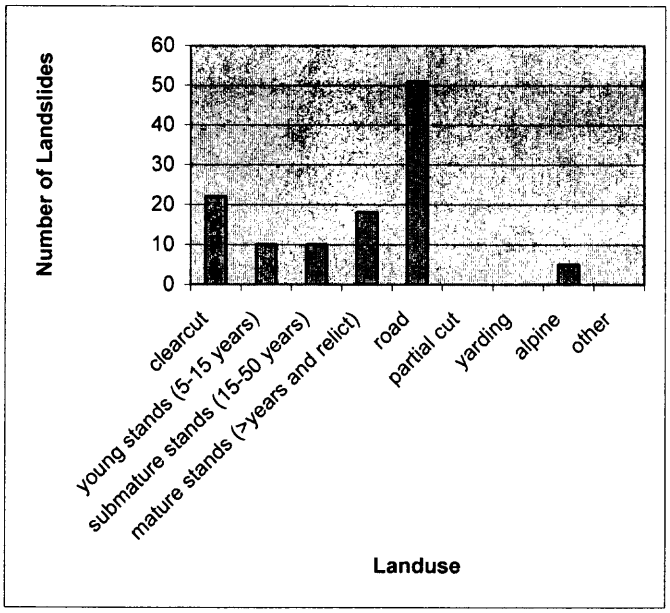

Figure 3. Number of landslides observed within the South Prairie Creek study area by land use association.

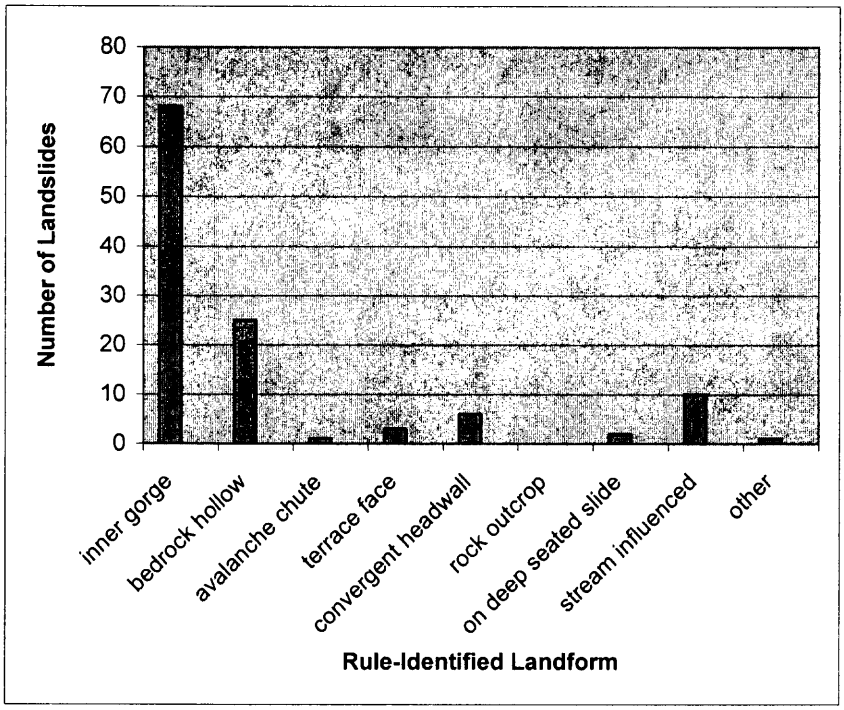

Figure 4. Number of landslides observed within the South Prairie Creek study area by rule identified or similar small-scale landform association.

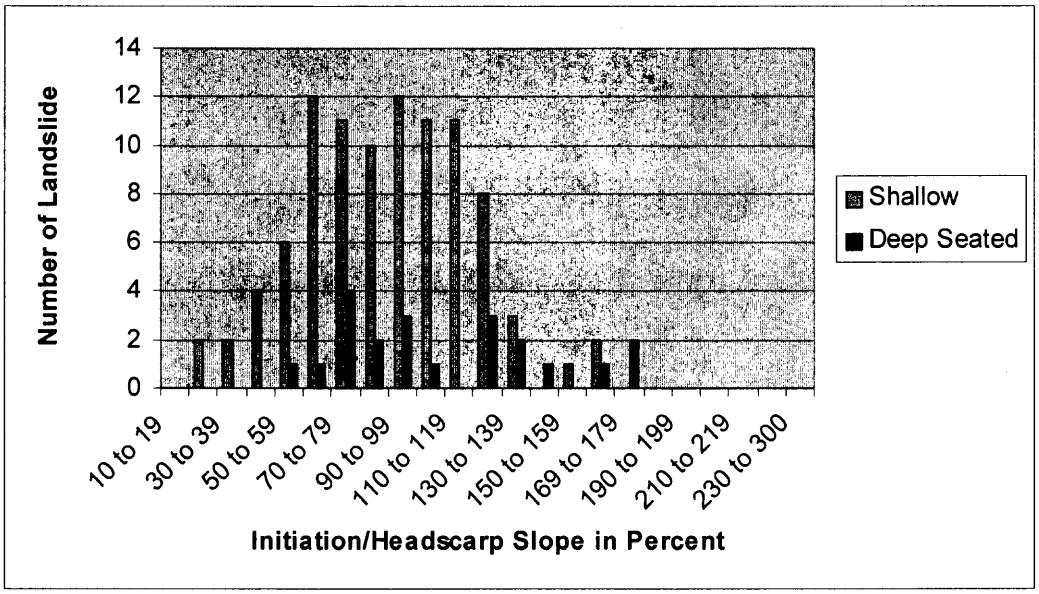

Figure 6. Distribution of all landslides by initiation/headscarp slope for the South Prairie Creek study area.

4.0 Landforms

4.1 Introduction

The 15 Landforms defined herein have been delineated to show areas having similar mass wasting potential and potential to deliver to public resources. Mass wasting potential is based mainly on landslide process, geology, failure density, lithology, hydrology, geomorphology, and topography. The following sections briefly describe the characteristics of each Landform. Additional information is given in Appendices A and B.

4.2 Form A-2: Landform Descriptions

In the following descriptions, "Confidence" statements refer to the confidence in the specific landform. Generally confidence in landslide identification and the precision of mapping is generally moderate as the study is designed to provide representative samples rather than exhaustive analysis. In the following sections, low hazard landforms are described with an abbreviated description (Form A2), whereas moderate and high hazard landforms that will trigger a field investigation by Department of Natural Resources Region personnel are described with a complete Form A2. The landforms are crudely organized geographically with high numbers found progressively further to the southeast within the watershed.

LANDFORM NUMBER: **1**
LANDFORM NAME: **Relict Meander Scarps and Terraces**
OVERALL HAZARD: **Low**

Description:

Landform 1 comprises arcuate scarps and flat-topped terraces in the lower Prairie Creek drainage. South Prairie Creek did not cut most of these scarps and terraces. Instead, these were carved by the paleo-White River, which originally flowed through this area. About 5,500 years ago, the paleo-White River was dammed by the Osceola mudflow (lahar) and diverted northward into its present drainage. Since that time, meander scarps along South Prairie Creek have remained mostly stable, although risk from roading and harvest may exist owing the to steepness of these scarp slopes. No landslides were mapped in this 523-acre landform and the Landslide Area Rate for Delivery (See below) is zero. Moderate confidence.

LANDFORM NUMBER: **2**
LANDFORM NAME: **Active Meander Scarps**
OVERALL HAZARD: **High (Rule Identified)**

Description:

Landform 2 comprises the arcuate scarps in the lower Prairie Creek drainage basin where South Prairie Creek is actively eroding the paleo-meanders described in Landform 1. Continued erosion at the toe of these slopes will generate landslides. Landform 2 is rated as high-hazard because it is rule-identified.

Number- and Cumulative Area of All Landslides: 0 0 acres.

Observed Slope on Failure (from DEM): No failures observed.

Slope Shape: Convergent planar.

Materials:

Continental glacial sediments deposited from the Vashon ice sheet and minor deposits from the Osceola mudflow.

Elevation: Min: 297' Max: 615 Typical: 400'

Total Area: 56 acres

Mass Wasting Processes: Shallow-rapid and deep-seated rotational slides possible.

Non-Road-Related Landslide Density: No failures observed.

Forest Practice Sensitivity: High (rule-identified).

Mass Wasting Potential: High. Natural undercutting undoubtedly will result in future landslides.

Number of Delivering Landslides: 0

Area of Delivering Landslides: 0 acres

Landslide Area Rate For Delivery: 0

Delivery Potential and Delivery Criteria Used:

South Prairie Creek lies at the toe of these slopes.

Trigger Mechanisms:

Undercutting by erosion along the outside of meander bends.

Confidence: High.

Comments:

South Prairie Creek appears to be markedly underfit (too little water and current to move its overall bedload or to continue to erode large parts of its channel. For this reason, it is likely that the creek will remain in the same general location and continue eroding the localized areas of Landform 2 for some time to come.

LANDFORM NUMBER: 3
LANDFORM NAME: **Alluvial Plains**
OVERALL HAZARD: **Low**

Description:

Landform 3 includes sand, gravel, and boulders deposited recently on floodplains by creeks and rivers (Geologic Unit Qa). No landslides were mapped in this 1,021-acre landform and the Landslide Area Rate for Delivery (See below) is zero. High confidence.

LANDFORM NUMBER: 4
LANDFORM NAME: **Volcanic Mudflow Plains**
OVERALL HAZARD: **Low**

Description:

Landform 4 includes low hills, rivers valleys, and abandoned fluvial terraces covered with deposits of the Osceola mudflow (Geologic Unit Qvl(o)), a chaotic deposit of angular ash, pumice, mud, sand, silt, gravel, and boulders. This mudflow, also known as a lahar, was sufficiently watery that it could not inundate higher elevations or create steep topography. After the mudflow dried out, it became a cohesive deposit that is generally stable. No landslides were mapped in this 3,377-acre landform and the Landslide Area Rate for Delivery (See below) is zero. Confidence is high.

LANDFORM NUMBER: 5
LANDFORM NAME: **Glacial Sediment-Mantled Hills**
OVERALL HAZARD: **Low**

Description:

Low-relief hills, valley margins, and terraces covered with continental glacial deposits. During the late ice age about 15,000 years ago, the most recent continental ice sheet flowed down from the Fraser River valley and eventually impinged on and stopped at the low hills of the northern South Prairie Creek watershed depositing a blanket of sediment. Much of this is undifferentiated glacial material known as "drift" (geologic Unit Qgd of Walsh, and others, 1987). Elsewhere, these deposits have been differentiated as till (Geologic Unit Qvt), an olive gray mix of rounded sand, gravel, clay, and boulders, which was deposited beneath the ice or differentiated as outwash sand and gravel (Geologic Unit Qgo), which was deposited beyond the edge of the ice. The outwash is well drained and the till, though poorly permeable, is cohesive. Therefore, both units are typically stable.

Much earlier in the ice age, perhaps 200,000 years ago, an ice cap formed along the Cascade Crest, around Mt. Rainier shedding a blanket of outwash gravels[7] northwestward into the South Prairie Creek watershed. These are preserved on a northwest-tilted terrace, which is truncated on the northwest by a subtle, northeast-trending erosional escarpment. The outwash is mapped as Geologic Unit Qap. Gaps between the pebbles are now filled with clay and mineral cements forming a hard surface that is generally stable.

No landslides were mapped in this 13,507-acre landform. Therefore, Landform 5 is generally stable.

LANDFORM NUMBER: 6
LANDFORM NAME: **Low Relief Bedrock Hills**
OVERALL HAZARD: **Low**

Description:

In the northern part of the WAU, Landform 6 consists of thin colluvial soils and sedimentary or minor igneous rock that form gentle to moderate slopes and rounded hills. The materials include sandstone, siltstone, and claystone with minor coal and volcanic rock of the Puget Group and its subdivision, the

[7] These gravels are mapped as Hayden Creek outwash by Crandel (1963).

Spiketon Formation[8] (Geologic Units $Ec_2(s)$ and $Ec_2(s)$). These rocks are poorly permeable, but very strong, and can form moderate to steep cliffs without frequent slope failure. In the southern part of the WAU, Landform 6 is dominated volcanic rock and soils, but also has intrusive igneous rock. The materials are andesite, fragmental volcanic rocks, and lesser granitic rocks of the Fifes Peak (Geologic Units Mva(fp), Mvt(pc) and Ohanepecosh Formations (Geologic Unit Ovc(oh)). Further south, fine-grained 'granitic' rocks [Geologic Units Mian, Migd(cr)] are also present. All of these rocks are covered with thin colluvial soils and local veneers of glacial drift or alluvium. Six small landslides were mapped in Landform 6, but only 1.5 acres of delivered materials were recorded and no predictive patterns could be discerned within the 17,101-acre area. The Landslide Area Rate for Delivery (See below) is only 3, indicating that sediment delivery to public resources is small.

[8] The Spiketon Formation was named for a type locality within the study area.

LANDFORM NUMBER: 7
LANDFORM NAME: **Deeply Incised Gorge Systems**
OVERALL HAZARD: **High (Rule Identified in part)**

Description:

Landform 7 comprises areas with moderate slopes forming the incised inner gorge system of South Prairie Creek. This inner gorge system results from rapid uplift of the region south from Enumclaw to the Puyallup River[9]. All of the intervening rivers as well as South Prairie Creek have cut deeply into the underlying strata forming spectacular gorges, such as the valley under the bridge directly north of the hamlet of Burnett (Map A1). In Landform 7, this gorge system locally meets the rule-identified definition of inner gorges and is characterized by moderate slopes. These are generally on the order of 250- to 600-feet tall and average about 340 feet. Although landslides are not common on planar slopes within Landform 7, subsidiary Landforms 8, 9, and 10 are superimposed on this inner gorge system and are unstable. Landform 7 is rated high hazard because some parts consist of a rule identified inner gorge.

Total Number and Cumulative Area of All Landslides: 6 0.9 acres.

Observed Slope on Failure (from DEM): Min: 64% Max: 112% Mean: 82%, s.d.= 20%

Slope Shape: A wide variety of slopes shapes are included, all of which lie with the master inner gorge system.

Materials:

Volcanic rocks of the Fifes Peak and Northcraft Formations (Geologic Units Mva(fp), Mvt(pc), Mvc, and Evc(n)), and sedimentary rocks of the Spiketon Formation (Geologic Unit Ec2s). These relatively hard bedrock units are sufficiently resistant to form stable cliffs, but when soil build-up eventually occurs, failure is possible owing to local steep slopes.

Elevation: Min: 229' Max: 5,796 Typical: 700'

Total Area: 1,146 acres

Mass Wasting Processes: Mostly shallow-rapid slides with minor debris flows and small sporadic deep-seated slides.

Non-Road-Related Landslide Density: 384

Forest Practice Sensitivity: Moderate.

Mass Wasting Potential:

Moderate. Although only six landslides have been identified in a relatively small area, some parts of the Landform probably meet the rule-identified definition of inner gorge; hence the high rating that will assure the Department makes a field inspection of forest management applications.

Number and Area of Delivering Landslides: 5 0.8 acres

Landslide Area Rate For Delivery: 26

Delivery Potential and Delivery Criteria Used: Some landslides could terminate in South Prairie or Beaver Creeks.

Trigger Mechanisms:

Natural slides will occur as soil build up occurs over a period of centuries. Road construction could trigger failure.

Confidence: Moderate. Several key photographs are missing from DNR collections.

Comments: A lack of failures in historic clear-cuts down to creek level indicate that much of the inner gorge system is relatively stable.

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[9] In the author's opinion, this incised gorge system almost certainly results from rapid uplift of the land, some of which occurred before the 5,500-year-old Osceola mudflow, and some after. Terraces covered by mudflow deposits in the western watershed are uplifted and the Fraser Glaciation outwash channel at Wilkeson is left high and dry by post 13,000-year-old incision.

LANDFORM NUMBER: **8**
LANDFORM NAME: **Gorge, Hollow, or Headwall in Inner Gorge System**
OVERALL HAZARD: **High**

Description:

Landform 8 comprises rule identified subsidiary landforms superimposed on the deeply incised gorge system of South Prairie Creek. Several shallow rapid landslides characterize these highly convergent landforms, but the total is fewer than would be anticipated considering the very steep slopes and strongly convergent topography.

Total Number and Cumulative Area of All Landslides: 8 2.4 acres

Observed Slope on Failure (from DEM): Min: 55% Max: 121% Mean: 93%, s.d.= 26%

Slope Shape: Convergent

Materials:

Volcanic rocks of the Fifes Peak and Northcraft Formations (Geologic Units Mva(fp), Mvt(pc), Mvc, and $Evc_{(n)}$), and sedimentary rocks of the Spiketon Formation (Geologic Unit Ec_{2s}). These relatively hard bedrock units form steep slopes.

Elevation: Min: 229' Max: 5,796 Typical: 700'

Total Area: 525 acres

Mass Wasting Processes: Mostly debris flows and other shallow-rapid landslides with a few small sporadic deep-seated slides.

Non-Road-Related Landslide Density: 3,276

Forest Practice Sensitivity: High.

Mass Wasting Potential: High. Although few landslides have been mapped, Landform 8 contains mostly rule-identified features.

Number and Area of Delivering Landslides: 7 total 2.3 acres

Landslide Area Rate For Delivery: 158

Delivery Potential and Delivery Criteria Used:

High. Because of steep slopes and proximity to water, virtually any landslide that occurs will terminate in South Prairie or Beaver Creeks.

Trigger Mechanisms:

Slides occur from harvest, roading, and natural causes. Caution! Landslides in Landform 8 can initiate slightly uphill from the slope-break as a result of roading.

Confidence:

Moderate. Several key photographs are missing from the DNR collection.

Comments:

Although these features are commonly in excess of 80% and doubly convergent, the Landslide Area Rate for Delivery is barely high enough to qualify as 'high' hazard.

LANDFORM NUMBER: 9
LANDFORM NAME: **Cliffs in Incised Gorge Systems**
OVERALL HAZARD: **High (Rule Identified)**

Description:

Landform 9 comprises very steep to vertical or overhung cliffs within the inner gorge system of South Prairie Creek. It is rated as high hazard because it is part of a rule identified inner gorge [system].

Total Number and Cumulative Area of All Landslides: No failures observed.

Observed Slope on Failure (from DEM): No failures observed.

Slope Shape: Generally planar.

Materials:

Volcanic rocks of the Fifes Peak and Northcraft Formations (Geologic Units Mva(fp), Mvt(pc), Mvc, and $Evc_{(n)}$), and sedimentary rocks of the Spiketon Formation (Geologic Unit Ec_{2s}). These relatively hard bedrock units form abrupt cliffs.

Elevation: Min: 229' Max: 5,796 Typical: 700'

Total Area: 46 acres

Mass Wasting Processes: No landslides have been observed in this landform.

Non-Road-Related Landslide Density: 0

Forest Practice Sensitivity: High.

Mass Wasting Potential: Low. Few landslides have been identified and little soil buildup has occurred, thus limiting the potential for slope failure.

Number and Area of Delivering Landslides: No failures observed.

Landslide Area Rate For Delivery: No failures observed.

Delivery Potential and Delivery Criteria Used:

Because of steep slopes and proximity, virtually any landslide that occurs will terminate in South Prairie Creek.

Trigger Mechanisms:

Harvest is unlikely owing to slopes in excess of 140%, but yarding could trigger small failures from small pockets of soil.

Confidence:

Moderate. Several key photographs are missing from DNR collections.

Comments:

These slopes form the 70%-plus side slopes of the deeply incised gorge system, and as such, these are rule-identified.

LANDFORM NUMBER: **10**
LANDFORM NAME: **Highly Dissected Inner Gorge System (in Volcanic Conglomerate)**
OVERALL HAZARD: **High**

Description:

Landform 10 includes some of the least stable ground in the watershed. Although a landform, namely a highly dissected inner gorge system is recognizable, the underlying reason for the instability and the boundaries of the landform both devolve from the underlying geologic unit. This unit is composed of volcanic conglomerates of the Ohanepecosh Formation. Many deep-seated landslides (probably more than have been mapped) and shallow rapid failures characterize Landform 10.

Total Area: 1,094 acres

Observed Slope on Failure (from DEM): Min: 34% Max: 174% Mean: 113%, s.d.= 35%

Slope Shape: Convergent overall, but a wide variety of slope shapes is present.

Materials: Conglomerates of the Ohanepecosh Formation (Geologic Unit Ovc(oh). Conglomerate is a rock composed of rounded fragments of other rocks, in this case volcanic rocks derived from the Cascade Range.

Elevation: Min: 229' Max: 5,796 Typical: 700'

Total Number and Cumulative Area of All Landslides: 29 116.5 acres.

Mass Wasting Processes:

A wide variety of deep-seated and shallow rapid processes have been identified.

Non-Road-Related Landslide Density: 4,113

Forest Practice Sensitivity: High.

Mass Wasting Potential: High. 29 landslides have been identified.

Number and Area of Delivering Landslides: 16 total 5.0 acres

Landslide Area Rate For Delivery: 163

Delivery Potential and Delivery Criteria Used:

High. Most landslides that occur in this landform will terminate in South Prairie Creek. Some small sporadic deep-seated landslides may deliver.

Trigger Mechanisms:

Although natural deep-seated failures dominate, landslides also occur from harvest, roading, and poorly designed drainage systems. All of the slopes in this unit may be subject to failure, regardless of slope shape.

Confidence:

Moderate. Several key photographs are missing from DNR collections. Furthermore, field examination will likely reveal many landslides in addition to those inventoried herein.

Comments:

Several additional unstable landforms including 'inner gorges in the gorge system' and 'inner gorges on relict landslides' lie are superimposed on Landform 10 but are not delineated as additional high-hazard Landforms for simplicity. Note that the highly dissected nature and frequent landslides in Landform 10 derive from instability of the underlying geologic unit, the Ohanepecosh Formation conglomerates, and not from the landform per se. The geologic unit is among the least stable part of the watershed and essentially identical slopes in other geologic units are far more stable. (See Landforms 7, 8, and 9.)

LANDFORM NUMBER: **11**
LANDFORM NAME: **Relict Deep-Seated Landslides**
OVERALL HAZARD: **Low**

Description:

Landform 11 comprises the scarps, bodies, and toes of relict deep-seated landslides where these lie outside of Landform 10. Landform 11 also includes parts of areas directly upslope and beside these deep-seated landslides in order to offer a modicum of protection beyond the slope break. These relict landslides are recognized as somewhat unstable because the process of slipping disrupted drainage and permeability within the landform and weakens the rocks and sediments. However, few landslides have been mapped on these features, except with Landform 10, where a deep-seated landslide-based landform is not differentiated. Landslides 1014 and 10 15 have failed on terraces above western South Prairie Creek where paleo-oxbow swamps trap water and saturate the underlying sediments.

Total Number and Cumulative Area of All Landslides:		9	303.3 acres.
Observed Slope on Failure (from DEM):	Min: 61%	Max: 110%	Mean: 80%, s.d.= 15%
Slope Shape:	Convergent planar.		

Materials: Angular fragments of sediment that form the landslide bodies together with varied rocks and sediments.

Elevation:	Min: 229'	Max: 5,796	Typical: 700'
Total Area:	457 acres		
Mass Wasting Processes:	Mostly shallow-rapid slides with minor debris flows.		
Non-Road-Related Landslide Density:	0		
Forest Practice Sensitivity:	Low		
Mass Wasting Potential:	Low. Only three dormant distinct or recent landslides have been identified in this relatively small area.		
Number and Area of Delivering Landslides:	3 total	0.36 acres	
Landslide Area Rate For Delivery:	28		

Delivery Potential and Delivery Criteria Used:

Low based on Landslide Area Rate for Delivery. However, the toes of some failures are rule identified and therefore are likely to deliver, and others have very steep (>100%) scarps and bodies such that any slide that initiates on the relict feature is likely to carry down-slope to the drainage network.

Trigger Mechanisms:

Roading is of most concern but harvest on rule-identified portions is also likely to trigger failures.

Confidence:

Moderate. Because of the steep, north-facing slopes are hidden on some aerial photography; some landslides may not have been inventoried. Therefore, Landform 11 as mapped is considered representative rather than exhaustive.

Comments:

More relict landslides are present in Landform 10, but not differentiated as a separate landform.

LANDFORM NUMBER: **12**
LANDFORM NAME: **Inner Gorges and Hollows on Deep-Seated Landslides**
OVERALL HAZARD: **Very High**

Description:

Landform 12 comprises the standard rule identified features where they are superimposed on relict deep-seated landslides.

Total Number and Cumulative Area of All Landslides: 1 0.57 acres.

Observed Slope on Failure (from DEM): One landslide observed with a 65% initiation slope.

Slope Shape: Convergent.

Materials: Angular fragments of materials that form the landslide bodies together with varied rocks and sediments.

Elevation: Min: 229' Max: 5,796 Typical: 700'

Total Area: 8 acres

Mass Wasting Processes: Mostly minor debris flows and other shallow-rapid slides.

Forest Practice Sensitivity: High for roading, High for harvest.

Non-Road-Related Landslide Density: 71,250

Mass Wasting Potential: Moderate. One landslide has been identified in this relatively small area.

Number and Area of Delivering Landslides: 1 total 0.57 acres

Landslide Area Rate For Delivery: 2,445

Delivery Potential and Delivery Criteria Used:

Very High. These are rule identified convergent features that generally tail out in drainages.

Trigger Mechanisms:

Harvest, roading, or yarding.

Confidence:

Moderate. Some aerial photographs are missing from DNR's collection and the Landslide Area Rate for Delivery is not statistically valid owing to the paucity of landslides.

Comments:

Only one landslide has been mapped and, as a result, the Landslide Area Rate For Delivery does not have statistical validity. However, the high rate of delivery relative to the small size of the landform should be considered as a red flag. Elsewhere in Washington, the author has observed that drainages developed on relict landslides are consistently unstable to very unstable.

LANDFORM NUMBER: **13**
LANDFORM NAME: **Subalpine Inner Gorges, Hollows, and Headwalls**
OVERALL HAZARD: **High**

Description:

Landform 13 comprises rule identified and lower angle convergent landforms on shallow bedrock at higher elevations within the southern part of the watershed. Bedrock units in this area are resistant to erosion, so cliffs, talus, and other steep slopes are common.

Total Number and Cumulative Area of All Landslides: 14 4.9 acres.

Observed Slope on Failure (from DEM): Min: 54% Max: 131% Mean: 102%, s.d.= 25%

Slope Shape: Convergent

Materials:

Most of the area is underlain by volcanics rocks (Geologic Unit Mva(fp), Mvt(pc), and Mvc), which are primarily stable andesitic lava flows and less stable fragmental or ash-rich rocks, but fine grained granitic rocks (Geologic Units Mian, Migd(cr)) are also present.

Elevation: Min: 229' Max: 5,796 Typical: 700'

Total Area: 422 acres

Mass Wasting Processes:

Shallow-rapid slides and lesser debris flows. Deep-seated landslides are not common, probably because the slopes are too steep for thick soil buildups.

Non-Road-Related Landslide Density: 6,184

Forest Practice Sensitivity: High.

Mass Wasting Potential: High. 14 landslides have been identified in a relatively small area.

Number and Area of Delivering Landslides: 9 total 2.2 acres

Landslide Area Rate For Delivery: 189

Delivery Potential and Delivery Criteria Used:

High. Landslides observed delivering to type 3 to 5 drainages.

Trigger Mechanisms:

Because some slopes on each hillside in the southern end of the watershed are extremely steep (>100%), roading building necessarily cross these slop resulted in cutback and fill failures. These continue to deliver over a period of decades.

Confidence:

Moderate. Some aerial photographs are missing from DNR's collection.

Comments:

Analysis of 29 landslides in a large clearcut on adjacent U.S. Forest Service lands in identical geologic and physiographic characteristics indicates that the high overall hazard rating herein should be considered as the 'most-stable' scenario.

LANDFORM NUMBER: **14**
LANDFORM NAME: **Cliff-Dominated Slopes**
OVERALL HAZARD: **Very High**

Description:

Landform 14 comprises steep, mostly planar slopes composed of the igneous rocks located directly above the South Fork of South Prairie Creek, in its tributaries, and in alpine areas of the southern watershed. In the alpine areas, the cliffs appear to be composed of resistant lava flows that have been eroded by the major drainages and left as cliffs with a distinctive topographic map pattern.

Total Number and Cumulative Area of All Landslides: 11 4.6 acres.

Observed Slope on Failure (from DEM): Min: 59% Max: 151% Mean: 88%, s.d.= 26%

Slope Shape: Generally planar, but convex slopes are also present.

Materials:

Volcanic and lesser granitic rocks (Geologic Units Mva(fp), Mvt(pc), Mvc, Ovc(oh), Mian, and Migd(cr).

Elevation: Min: 229' Max: 5,796 Typical: 700'

Total Area: 135 acres

Mass Wasting Processes: Mostly shallow-rapid slides with minor debris flows.

Non-Road-Related Landslide Density: 814

Forest Practice Sensitivity: Very high for roading.

Mass Wasting Potential: High. 11 landslides have been identified in a relatively small area.

Number and Area of Delivering Landslides: 8 total 3.4 acres

Landslide Area Rate For Delivery: 899

Delivery Potential and Delivery Criteria Used:

Very High. Note however, that a large proportion is sidecast or cut-slope failures that do not travel substantial distances from the road on which they initiated.

Trigger Mechanisms:

Road building and maintenance. Roads that cut talus slopes inevitably create landslides because talus slopes develop at the angle of repose; any additional manmade steepening causes slope failure. Similarly, the thin soil in pockets on cliffs fail whenever disturbed.

Confidence: Moderate. Some aerial photographs are missing from DNR's collection.

Comments:

In the upper elevations of the watershed, cliffs appear to develop on stacked and horizontally layered lava flows of the Fifes Peak Formation. The flatter benches between these cliffs are used for roads. Unfortunately, soil build-ups on these benches are prone to failure, which commonly extend over lower cliffs and into the drainage network.

LANDFORM NUMBER: **15**
LANDFORM NAME: **Other Inner Gorges, Hollows, and Headwalls**
OVERALL HAZARD: **High (Rule Identified in part)**

Description:

Landform 15 comprises typical rule-identified landforms and many flatter features that are not included in the fourteen landforms described above.

Total Number and Cumulative Area of All Landslides: 7 1.0 acres.

Observed Slope on Failure (from DEM): Min: 36% Max: 149% Mean: 81%, s.d.= 37%

Slope Shape: Strongly convergent.

Materials:

These landforms occur in every rock and sediment unit except in the conglomerates of Landform 10.

Elevation: Min: 813' Max: 3,496' Typical: none

Total Area: 730 acres

Mass Wasting Processes:

Mostly shallow-rapid slides with minor debris flows and small sporadic deep-seated slides.

Non-Road-Related Landslide Density: 2,684

Forest Practice Sensitivity: Generally low, High where rule identified.

Mass Wasting Potential:

Moderate. These are strongly convergent landforms that mostly have some form of internal drainage or exit to drained slopes.

Number and Area of Delivering Landslides: 7 total 1.0 acres

Landslide Area Rate For Delivery: 50

Delivery Potential and Delivery Criteria Used:

Low. Typical shallow rapids and small debris flows, but the area of delivered sediment is low.

Trigger Mechanisms:

Harvest, roading, or yarding are all suspect, although too few slide exist to accurately characterize triggering mechanisms in Landform 15.

Confidence: Moderate. Some aerial photographs are missing from DNR's collection.

Comments:

These are typical rule identified landforms, although typical these slopes do not fail at less than 80%.

5.0 Hazard Ratings

Overall Hazard Ratings under this protocol may be determined from the following: 1) Specific criteria, such as rule-identified status (WAC 222-16-050), or 2) a combination of the Landslide Frequency Rate and the Landslide Area Rate For Delivery.

The Landslide Frequency Rate For Delivery is simply the area of all landslides normalized for the period of study and the area of each Landform. These values are multiplied by one million to provide whole numbers. Landslide Area Rate For Delivery' is calculated in the same manner but includes only delivering all landslides (Table 5). The Area Rate for Delivery is especially useful for helping to quantify the potential for delivery of sediment to public resources where rule identified status may mis-characterize slope stability in the landform as outlined in Table A-2 of Washington Forest Practices Board (1997). Note that higher Landslide Area Rates For Delivery can be achieved by reducing the size of the Landform. While this may appear to be 'data gerrymandering', it has a favorable effect, which is to help limit the area of high-hazard mass wasting map units to those areas that are actually demonstrated to have high hazard.

Limited application suggests that Landslide Area Rates For Delivery less than 76 might be considered low; rates of 76 to 150 are probably moderate, rates of 151 to 799 are probably high, and rates greater than 799 are very high (Table 5). Frequency Rates less than 450 are probably low, rates of 451 to 999 are probably moderate, rates of 1,000 to 2,000 are probably high, and rates greater than 2,000 appear to be very high.

Table 5. Form A-4 Landslide Area Hazard Rates. The annualized rate of landslides that deliver to public resources in terms of Landslide Frequency Rates and Landslide Area Rates for Delivery during the 28-year study period. For the purposes of this analysis, 'delivering landslides' are taken to include those that move rapidly and have a 'probable' or 'yes' delivery rating. Landslide Frequency Rates include deep-seated failures, but Landslide Area Rates for Delivery generally do not include any deep-seated failures. The overall hazard rating system is modified from Table 4 and taken in part from Table 5 in Department of Natural Resources (2004).

LANDFORM	Landform 2	Landform 7	Landform 8	Landform 9	Landform 10	Landform 11	Landform 12	Landform 13	Landform 14	Landform 15	Study Area
Area of Landform (acres)	56	1146	525	46	1094	457	8	422	135	730	40149
Number of Landslides	0	6	8	0	29	9	1	14	11	7	85
Landslide Frequency Rate = (No. of slides x 1 million/Landform area/28 years)	0	187	544	0	947	703	4464	1185	2910	342	76
Number of 'Delivering' Landslides	0	5	7	0	16	3	1	9	8	7	62
Area of 'Delivering' Landslides (acres)	0	0.83	2.32	0	5.00	0.36	0.57	2.23	3.4	1.02	9.1
Landslide Area Rate for Delivery = (area of delivering landslides x 1 million/Landform area/28 years)	0	26	158	0	163	28	2545	189	899	50	8
Overall Rating from Frequency and Area Rates	Low	Low	High	Low	High	Low	Very High	High	Very High	Low	Low

Landslide Area Rates For Delivery for the fifteen South Prairie Creek landforms described herein are present in Table 5. The Landslide Area Rates For Delivery for the South Prairie Creek watershed are lower than corresponding landforms or mass wasting map units in most other watersheds studied to date (Table 6).

The overall study area inclusive of all mass wasting map units is rated as low hazard, consistent with the author's informal comparison with fourteen Priority 1 and three western Olympic Peninsula watersheds. South Prairie Creek in among the more stable watersheds that have been analyzed during the Landslide Hazard Zonation Project. In hindsight, it is clear that careful analysis of slopes within the deeply incised gorge system of South Prairie Creek and small areas of steep slopes in the southern part of the watershed prior to roading and harvest would have precluded most of the delivering landslides within the study area.

Table 6. Comparison of Landslide Area Rates For Delivery for parts of landforms in eight Washington State watersheds. Note that the landform categories tabulated herein include all such features regardless of the angle of the contained slope (i.e., rule-identified unstable slopes and lower angle features are both included).

Watershed	Gorges, headwalls, hollows	Inner gorges	Bedrock Hollows	Convergent headwalls	Superimposed on relict landslides	Cliff-dominated slopes	Lower hazard hills	Incised river	Glacial Outwash terraces	Valley floors	WAU or study area
S. Prairie Crk. (this study)	158	50			2545	899	3	163		0	8
S. Prairie Crk. (this study)	189					0	0	26			
L. Calawah Valley (Lingley, 2004a)	404						24	405		37	68
Jackman Corkindale (Lingley, 2004b)	1167				1217	213	24		35		461
Jackman Corkindale (Lingley, 2004b)	1142						10		19		
Nookachamps (Wegmann, 2004)		273	173	384					31		11
Lime and Dan Creeks (Wegmann, 2004)	119										4
Finney Miller (Lingley, 2004c)	1306	376			356	510	1		567		224
Finney Miller (Lingley, 2004c)					383	414			408		
West Fork Teanaway (Powell, 2004)									978		
Averages	**641**	**233**	**173**	**384**	**1125**	**407**	**10**	**198**	**340**	**19**	**129**

8.0 Note on Confidence in Work Products

The overall confidence in this mass wasting assessment is moderate. This moderate rating results because the Landslide Hazard Zonation Project is designed to provide a watershed-scale overview of slope stability throughout the State in the shortest reasonable period. It is to be used as a screening tool only. As a consequence, fieldwork and the number of aerial photograph sets examined are held to reasonable minimums and the work is performed rapidly with little time given to cross-checking results. **This assessment would be entirely insufficient and misleading if it is used as a stand-alone document for protecting private resources or for land-use planning. Keep in mind that some landslides may have been accidentally omitted or miscoded and some benign features may be improperly mapped as landslides herein**.

Another important source of potential error in this assessment is in the accuracy and precision of measurements of mass wasting features. Because only 20% of mapped landslides were actually visited in the field, it is not possible to report the degree to which location and measurement error in the GIS environment compares to on-the-ground field measurements. Given these sources of error, the confidence in the precise location and accuracy of measurements of individual landslides is considered moderate.

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Appendix A -- A-1 Form: Landslide Inventory

Mass Wasting Inventory Data for the South Prairie Creek WAU. Codes for this table are presented on the DNR Forest Practices website; except "f" which indicates the landslide in on land owned by the U.S. Forest Service.

Slide_id	Lsi_process	Certainty	Id_date	Ls_size	Id2_date	Id2_size	init elev	Photo_number	Landform	Slp_shp	Gradient	Delivery	Landuse	South Prairie Landform	Deep-Seated Activity	Acreage	Geologic Unit (See Walsh and others, 1987)	Slope at Toe
1001	2	D	1996	3	1998	3	4154	NW96 59_62_210	1	1	98	Y	5	13		0.67	Mvt(fpc)	
1002	1	D	1996	4	1998	4	4137	NW96 59_62_210	2	2	96	P	5	14		1.74	Mvt(fpc)	
1004	1	D	1996	3	1998	3	4471	NW96 59_62_210	2	2	88	P	5	14		0.60	Mva(fp)	
1005	1	D	1996	3	1998	3	4171	NW96 59_62_210	2	2	121	I	5	13		0.93	Mvt(fpc)	
1006	1	D	1996	2	1998	2	4031	NW96 59_62_210	2	2	59	N	5	14		0.07	Mvt(fpc)	
1007	1	D	1996	3	1998	3	4003	NW96 59_62_210	2	2	71	P	5	14		0.40	Mvt(fpc)	
1008	1	D	1996	2	1998	2	3982	NW96 59_62_210	2	2	82	P	5	14		0.27	Mvt(fpc)	
1009	1	D	1996	2	1998	2	4032	NW96 59_62_210	2	2	86	N	5	14		0.16	Mvt(fpc)	
1011	1	P	1998	1			3656	NW-8-98	7	1	20	P	5	6		0.02	Mvt(fpc)	
1012	2	P	1998	2			3686	NW-8-98	1	1	86	Y	5	13		0.08	Mvt(fpc)	
1013	1	P	1998	1			3641	NW-8-98	1	1	29	Y	2	6		0.01	Mvt(fpc)	
1014	4	Q	1998	5			666	NW-8-98	9	2	74	N	4	11	C	139.60	Qgd	52
1015	4	Q	1998	5			554	NW-8-98	9	2	74	N	4	11	C	10.04	Qgd	37
1017	1	D	1998	3			1241	NW-8-98	9	1	69	Y	4	10		0.50	Mva(fp)	
1018	4	Q	1974	5			1201	NWH74_6E37	1	2	115	P	4	10	C	12.66	Ovc(oh)	90
1019	2	Q	1974	2			899	NWH74_6E37	1	1	118	P	3	8		0.12	$Ec_2(s)$	
1020	4	Q	1974	5			1211	NWH74_6E37	1	1	161	N	4	10	D	8.87	Ovc(oh)	138
1021	3	P	1974	2			1228	NWH74_6E37	1	1	122	Y	1	10		0.27	Ovc(oh)	
1022	3	P	1974	3			1367	NWH74_6E37	1	1	125	Y	1	10		1.19	Ovc(oh)	
1023	2	D	1974	2	1976	2	1190	NWH74_6E37	1	1	89	Y	2	10		0.10	Mva(fp)	
1024	2	D	1974	2	1976	2	1272	NWH74_6E37	1	1	92	Y	1	10		0.17	Ovc(oh)	
1025	2	D	1974	2	1976	2	1332	NWH74_6E37	1	1	102	Y	1	10		0.15	Ovc(oh)	
1026	1	D	1976	4			1475	NWC76 29-25	4	2	117	P	1	10		1.95	Ovc(oh)	
1027	1	P	1976	2			1136	NWC76 29-25	4	2	169	P	2	10		0.08	Ovc(oh)	
1028	4	Q	1976	4			1072	NWC76 29-25	4	2	108	N	4	10	C	2.22	Ovc(oh)	92
1029	2	D	1976	2			1233	NWC76 30A-25	1	1	94	Y	1	10		0.18	Ovc(oh)	
1030	2	P	1976	1			1111	NWC76 30A-25	1	1	104	I	1	10		0.04	Ovc(oh)	
1031	1	D	1976	2	2001	2	2332	NWC76 30A-24	1	2	64	P	5	7		0.21	Mva(fp)	
1032	1	Q	1976	2	1985	2	1715	NWC76 30A-22	1	2	121	P	3	8		0.13	Mva(fp)	
1033	2	Q	1976	3	1985	3	2058	NWC76 30A-22	1	1	90	Y	3	15		0.79	Mva(fp)	
1034	2	Q	1976	2			3220	NWC76 30A-22	1	1	36	Y	2	15		0.10	Mva(fp)	
1035	1	P	1976	2			4059	NWC76 30A-22	1	1	65	Y	5	14		0.13	Mva(fp)	
1036	1	P	1976	1			2301	NWC76 31A_26	2	1	83	Y	5	7		0.05	Mva(fp)	
1037	2	P	1976	3			3360	NWC76 31A_26	1	1	61	Y	2	13		0.61	Mva(fp)	

Slide_id	Lsi_process	Certainty	Id_date	Ls_size	Id2_date	Id2_size	init elev	Photo_number	Landform	Slp_shp	Gradient	Delivery	Landuse	South Prairie Landform	Deep-Seated Activity	Acreage	Geologic Unit (See Walsh and others, 1987)	Slope at Toe
1038	4	Q	1976	5			3689	NWC76 31A_26	5	2	78	N	4	11	C	15.67	Mva(fp)	41
1039	2	P	1976	3	1985	3	3620	NWC76 30A_21	1	1	65	Y	2	12		0.57	Mvt(fpc)	
1041	2	P	1976	4	1985	4	3294	NWC76 30A_21	1	1	68	Y	1	6		1.46	Mvt(fpc)	
1042	1	P	1981	1			618	SP81 22_69_195	1	3	60	N	1	8		0.03	Ec_2(c)	
1045	5	Q	1981	3			997	SP81 28_70_14	2	2	94	N	4	10	C	0.58	Ec_2(s)	38
1046	1	D	1981	2	1985	2	1110	SP81 33_72_246	9	1	131	Y	2	10		0.12	Ovc(oh)	
1047	1	P	1981	2			1092	SP81 33_72_246	9	1	92	Y	2	10		0.09	Ovc(oh)	
1048	1	D	1981	1	1985	1	1337	SP81 33_72_246	8	1	160	P	3	10		0.04	Ovc(oh)	
1049	2	P	1981	3			1932	SP81 9_73_172	1	1	102	Y	5	8		0.42	Qap	
1050	1	P	1981	2			1228	SP81 9_73_171	9	2	101	Y	3	7		0.28	Mva(fp)	
1051	1	Q	1981	1			1242	SP81 9_73_172	9	1	34	Y	3	10		0.05	Mva(fp)	
1052	1	Q	1981	1			1203	SP81 9_73_172	9	2	73	P	3	10		0.03	Mva(fp)	
1054	1	Q	1981	1			3900	SP81 33_74_223	1	1	44	I	1	6		0.01	Mvt(fpc)	
1055	2	P	1981	1			3616	SP81 33_74_225	1	1	60	Y	5	6		0.02	Mian	
1056	1	P	1981	1			3592	SP81 33_74_225	9	1	44	Y	1	15		0.01	Mian	
1057	9	P	1981	3			4621	SP81 33_75_209	5	1	131	P	8	13		0.89	Migd(cr)	
1058	9	P	1981	3			4144	SP81 33_75_209	5	2	80	P	8	13		0.78	Mva(fp)	
1059	1	P	1981	2	1985	2	3806	SP81 33_75_209	2	1	86	P	5	14		0.07	Mvt(fpc)	
1060	2	D	1981	3			3310	SP81 21_77_187	1	1	71	Y	1	f		0.87	Mva(fp)	
1061	1	D	1981	2			3088	SP81 21_77_187	1	1	100	Y	5	f		0.10	Mva(fp)	
1062	2	D	1981	3	1996	3	3805	SP81 21_77_187	1	1	119	Y	5	f		1.00	Mva(fp)	
1063	1	D	1981	3			3238	SP81 21_77_187	1	1	102	Y	5	f		0.42	Mva(fp)	
1064	2	P	1981	2			3578	SP81 21_77_187	1	1	52	Y	5	f		0.12	Mva(fp)	
1065	1	P	1981	3			2805	SP81 21_77_187	5	1	87	Y	5	f		0.52	Mva(fp)	
1066	2	P	1981	3	1985	3	4134	SP81 21_77_187	1	1	113	Y	5	f		0.70	Mva(fp)	
1067	1	Q	1981	2			3670	SP81 21_77_187	5	1	104	Y	1	f		0.16	Mva(fp)	
1068	1	Q	1981	2			3389	SP81 21_77_187	1	1	108	Y	1	f		0.13	Mva(fp)	
1069	1	P	1981	1			3149	SP81 21_77_187	1	1	55	P	1	f		0.03	Mva(fp)	
1070	2	P	1985	2			3287	SP85 30_076_270	1	1	120	Y	1	f		0.39	Mva(fp)	
1071	2	P	1985	2			3216	SP85 30_076_270	1	1	91	Y	1	f		0.23	Mva(fp)	
1072	2	P	1985	2			3120	SP85 30_076_270	1	1	127	Y	1	f		0.19	Mva(fp)	
1073	1	D	1985	2			3139	SP85 30_076_270	1	1	131	Y	5	f		0.15	Mva(fp)	
1074	1	P	1985	2			3179	SP85 30_076_270	2	2	70	N	5	f		0.13	Mva(fp)	
1075	1	P	1985	2			3213	SP85 30_076_270	2	2	56	N	5	f		0.10	Mva(fp)	
1076	1	P	1985	2			4391	SP85 30_076_270	2	2	90	N	5	f		0.13	Mva(fp)	
1077	1	D	1985	3	1996	3	4230	SP85 30_076_270	2	2	116	N	5	f		0.78	Mva(fp)	
1078	2	Q	1985	1			4055	SP85 30_077_122	1	1	54	Y	5	13		0.02	Mvt(fpc)	
1079	1	P	1985	2			2142	SP85 30_074_144	1	2	66	I	3	7		0.07	Mva(fp)	
1080	1	D	1985	3	1996	1	3881	SP85 30_075_122	9	2	117	N	5	14		0.99	Mvt(fpc)	
1081	1	P	1996	1			3647	NW96 59_62_211	2	2	66	P	5	f		0.07	Mva(fp)	
1082	2	P	1996	2			3691	NW96 59_62_211	1	1	77	P	5	f		0.21	Mva(fp)	

Slide_id	Lsi_process	Certainty	Id_date	Ls_size	Id2_date	Id2_size	init elev	Photo_number	Landform	Slp_shp	Gradient	Delivery	Landuse	South Prairie Landform	Deep-Seated Activity	Acreage	Geologic Unit (See Walsh and others, 1987)	Slope at Toe
1083	1	D	1998	2			4229	NW-8-98	2	2	76	P	5	f		0.16	Mva(fp)	
1084	1	P	1996	3			5023	NW96 59_62_208	1	1	101	P	5	13		0.51	Migd(cr)	
1085	1	P	1996	1			4149	NW96 59_62_212	2	2	118	N	5	13		0.03	Mva(fp)	
1086	2	P	1996	2			3762	NW96 59_62_212	1	1	151	Y	4	14		0.08	Mva(fp)	
1087	2	P	1996	1			2271	NW96 59_62_213	1	1	75	Y	5	15		0.06	Mian	
1088	2	P	1996	1			2218	NW96 59_62_213	1	1	83	Y	5	15		0.06	Mian	
1089	2	Q	1996	2			2261	NW96 59_62_219	1	1	68	Y	1	7		0.10	Mva(fp)	
1090	4	Q	1996	5			3546	NW96 59_64_179	5	2	61	N	3	11	C	22.48	Mva(fp)	38
1091	2	Q	2001	3			1919	NWC2001 65_60_12	1	1	98	Y	2	8		0.63	Mva(fp)	
1092	2	Q	2001	3			1901	NWC2001 65_60_12	1	1	77	Y	2	8		0.82	Mva(fp)	
1093	4	Q	2001	5			1919	NWC2001 10_58_3	1	2	121	N	4	10	D	14.22	Ovc(oh)	116
1094	4	Q	2001	5			971	NWC2001 10_58_3	1	2	96	N	4	10	C	3.17	$Ec_2(s)$	90
1095	2	Q	2001	1			859	NWC2001 10_58_3	1	1	130	P	3	10		0.03	$Ec_2(s)$	
1096	4	Q	2001	5			1203	NWC2001 10_58_3	1	2	74	N	4	10	D	7.65	Ovc(oh)	27
1097	1	Q	2001	1			1026	NWC2001 10_58_3	8	2	59	P	4	10		0.03	Ovc(oh)	
1098	5	Q	2001	3			1049	NWC2001 10_58_3	1	2	129	N	4	10	D	0.66	Ovc(oh)	106
1099	4	Q	2001	5			1313	NWC2001 10_58_3	1	2	149	N	4	10	D	13.80	$Ec_2(pg)$	129
1100	7	Q	1998	5			1715	NW-8-98	1	2	174	N	4	10	A	34.16	Ovc(oh)	99
1101	7	Q	1998	4			1449	NW-8-98	1	2	128	N	4	10	A	2.30	Ovc(oh)	128
1102	1	Q	2001	2			3707	NWC2001 55_64_181	2	2	48	I	5	6		0.07	Mva(fp)	
1103	1	P	2001	1			3841	NWC2001 55_63_156	1	1	45	Y	5	f		0.05	Mva(fp)	
1104	2	P	2001	3			4222	NWC2001 55_63_156	1	1	102	Y	5	f		0.19	Mva(fp)	
1105	1	Q	2001	1			3478	NWC2001 55_63_156	2	2	98	I	1	f		0.06	Mva(fp)	
1106	1	D	2001	2			4708	NWC2001 55_63_156	2	1	89	P	5	f		0.08	Mva(fp)	
1107	1	D	2001	3			4178	NWC2001 55_63_156	2	2	67	P	5	f		0.44	Mva(fp)	
1108	1	P	2001	2			4176	NWC2001 55_63_156	2	2	70	Y	5	f		0.10	Mva(fp)	
1109	2	D	2001	2			4933	NWC2001 55_63_154	1	1	91	Y	8	13		0.14	Migd(cr)	
1110	2	D	2001	1			4690	NWC2001 55_63_154	1	1	109	P	8	13		0.03	Migd(cr)	
1111	2	D	2001	1			4792	NWC2001 55_63_154	1	1	129	P	8	13		0.03	Migd(cr)	
1112	2	D	2001	2			3379	NWC2001 55_63_154	1	1	72	Y	1	14		0.11	Migd(cr)	
1113	8	P	2001	2			4699	NWC2001 55_62_137	1	1	130	I	5	13		0.07	Migd(cr)	
1115	1	P	2001	2			4138	NWC2001 55_62_140	2	2	76	Y	5	11		0.10	Mva(fp)	
1116	1	D	2001	2			3846	NWC2001 55_62_140	2	2	110	Y	5	11		0.24	Mvt(fpc)	
1117	1	D	2001	1			4019	NWC2001 55_62_140	2	2	81	Y	5	11		0.01	Mva(fp)	
1118	2	Q	2001	2			1944	NWC2001 62_61_16	1	1	55	Y	5	8		0.10	Mva(fp)	
1119	2	Q	2001	2			1896	GIS hillslope model	1	1	112	Y	5	7		0.20	Mva(fp)	
1120	2	Q	2001	2			1885	NWC2001 62_61_14	1	1	110	Y	5	8		0.10	Mva(fp)	
1121	4	P	1998	5			1555	NW-8-98	1	2	174	N	4	10	C	11.21	Ovc(oh)	92
1122	1	P	2004	2			4069	FIELD	3	1	122	Y	4	13		0.13	Migd(cr)	
1123	5	D	2004	3			2219	FIELD	1	1	91	Y	1	15		1.06	Mva(fp)	
1124	1	Q	1998	1			3251	NW-8-98	1	1	87	Y	5	f		0.49	Mva(fp)	

Slide_id	Lsi_process	Certainty	Id_date	Ls_size	Id2_date	Id2_size	init elev	Photo_number	Landform	Slp_shp	Gradient	Delivery	Landuse	South Prairie Landform	Deep-Seated Activity	Acreage	Geologic Unit (See Walsh and others, 1987)	Slope at Toe
1125	4	P	1998	1			1306	GIS hillslope model	4	2	98	N	4	11	B	0.05	Ovc(oh)	34
1126	4	D	1998	1			4160	Tabor et al., 2000	5	2	149	N	4	15	B	0.02	Mvt(fpc)	77
1127	7	Q	2004	5			2811	GIS	5	2	105	N	4	f	C	8.85	Mva(fp)	52
1128	4	Q	1998	5			3249	Tabor et al., 2000	8	2	68	N	4	11	C	115.10	Mvt(fpc)	78

8.0 Appendix C -- Mass Wasting Summary Tables

Mass Wasting Summary Table: Landform 6

Activity	Shallow Rapid Landslides	Debris Flows	Debris Avalanches	Deep-Seated Landslides	Shallow Sporadic Deep-seated Landslides	Large Persistent Deep-seated Landslides	Earthflows	Totals
Clear Cut (timber 0-5 Yrs.)	1	1						2
Young Timber (5-15 yrs.)	1							1
Submature Timber (15-50 yrs.)								0
Mature Timber (>50 yrs.)								0
Road Related	2	1						3
Partial Cut								0
Yarding								0
Alpine								0
Other (e.g., housing)								0

Mass Wasting Summary Table: Landform 7

Activity	Shallow Rapid Landslides	Debris Flows	Debris Avalanches	Deep-Seated Landslides	Shallow Sporadic Deep-seated Landslides	Large Persistent Deep-seated Landslides	Earthflows	Totals
Clear Cut (timber 0-5 Yrs.)		1						1
Young Timber (5-15 yrs.)								0
Submature Timber (15-50 yrs.)	2							2
Mature Timber (>50 yrs.)								0
Road Related	2	1						3
Partial Cut								0
Yarding								0
Alpine								0
Other (e.g., housing)								0

Mass Wasting Summary Table: Landform 8

Activity	Shallow Rapid Landslides	Debris Flows	Debris Avalanches	Deep-Seated Landslides	Shallow Sporadic Deep-seated Landslides	Large Persistent Deep-seated Landslides	Earthflows	Totals
Clear Cut (timber 0-5 Yrs.)	1							1
Young Timber (5-15 yrs.)		2						2
Submature Timber (15-50 yrs.)	1	1						2
Mature Timber (>50 yrs.)								0
Road Related		3						3
Partial Cut								0
Yarding								0
Alpine								0
Other (e.g., housing)								0

Mass Wasting Summary Table: Landform 10

Activity	Shallow Rapid Landslides	Debris Flows	Debris Avalanches	Deep-Seated Landslides	Shallow Sporadic Deep-seated Landslides	Large Persistent Deep-seated Landslides	Earthflows	Totals
Clear Cut (timber 0-5 Yrs.)	1	4	2					7
Young Timber (5-15 yrs.)	3	1						4
Submature Timber (15-50 yrs.)	3	1						4
Mature Timber (>50 yrs.)	1			8	2			11
Road Related					0			0
Partial Cut								0
Yarding								0
Alpine								0
Other (e.g., housing)								0

Mass Wasting Summary Table: Landform 11

Activity	Shallow Rapid Landslides	Debris Flows	Debris Avalanches	Deep-Seated Landslides	Shallow Sporadic Deep-seated Landslides	Large Persistent Deep-seated Landslides	Earthflows	Totals
Clear Cut (timber 0-5 Yrs.)								0
Young Timber (5-15 yrs.)								0
Submature Timber (15-50 yrs.)				1				1
Mature Timber (>50 yrs.)				5				5
Road Related	3							3
Partial Cut								0
Yarding								0
Alpine								0
Other (e.g., housing)								0

Mass Wasting Summary Table: Landform 12

Activity	Shallow Rapid Landslides	Debris Flows	Debris Avalanches	Deep-Seated Landslides	Shallow Sporadic Deep-seated Landslides	Large Persistent Deep-seated Landslides	Earthflows	Totals
Clear Cut (timber 0-5 Yrs.)								0
Young Timber (5-15 yrs.)		1						1
Submature Timber (15-50 yrs.)								0
Mature Timber (>50 yrs.)								0
Road Related								0
Partial Cut								0
Yarding								0
Alpine								0
Other (e.g., housing)								0

Mass Wasting Summary Table: Landform 13

Activity	Shallow Rapid Landslides	Debris Flows	Debris Avalanches	Deep-Seated Landslides	Shallow Sporadic Deep-seated Landslides	Large Persistent Deep-seated Landslides	Earthflows	Totals
Clear Cut (timber 0-5 Yrs.)								0
Young Timber (5-15 yrs.)		1						1
Submature Timber (15-50 yrs.)								0
Mature Timber (>50 yrs.)	1							1
Road Related	3	3	1					7
Partial Cut								0
Yarding								0
Alpine	2	3						5
Other (e.g., housing)								0

Mass Wasting Summary Table: Landform 14

Activity	Shallow Rapid Landslides	Debris Flows	Debris Avalanches	Deep-Seated Landslides	Shallow Sporadic Deep-seated Landslides	Large Persistent Deep-seated Landslides	Earthflows	Totals
Clear Cut (timber 0-5 Yrs.)		1						1
Young Timber (5-15 yrs.)								0
Submature Timber (15-50 yrs.)								0
Mature Timber (>50 yrs.)		1						1
Road Related	9							9
Partial Cut								0
Yarding								0
Alpine								0
Other (e.g., housing)								0

Mass Wasting Summary Table: Landform 15

Activity	Shallow Rapid Landslides	Debris Flows	Debris Avalanches	Deep-Seated Landslides	Shallow Sporadic Deep-seated Landslides	Large Persistent Deep-seated Landslides	Earthflows	Totals
Clear Cut (timber 0-5 Yrs.)	1				1			2
Young Timber (5-15 yrs.)		1						1
Submature Timber (15-50 yrs.)		1						1
Mature Timber (>50 yrs.)				1				1
Road Related		2						2
Partial Cut								0
Yarding								0
Alpine								0
Other (e.g., housing)								0

10-21-04