WASHINGTON STATE DEPARTMENT OF
Natural Resources

Mass Wasting Assessment for the State Lands Queets Block: Parts of Lower Queets River and Metheney Creek Watershed Administrative Units, Jefferson and Grays Harbor Counties, Washington

State Lands Landslide Hazard Block Mapping Project

State of Washington
Engineering Geologist
324
Licensed Geologist
WILLIAM S. LINGLEY JR.
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Prepared by:

Stephen L. Slaughter and William S. Lingley, Jr.

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LAND MANAGEMENT DIVISION • 1111 WASHINGTON ST SE • P O BOX 47018 • OLYMPIA, WA 985 04-7016

FAX: (360) 902-1789 • TTY: (360) 902-1125 • TEL: (360) 902-1177

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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 Lower Queets River and Metheney Creek Watershed Administrative Units (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 A-2 herein) will be used by the Department of Natural Resources (DNR) Region staff to identify those timber sales and Forest Practice Applications (see Chapter 222-20 WAC) that may require a site investigation prior to assigning the class of forest practice relative to potential unstable slopes and landforms (Chapter 222-16-050).

This is a reconnaissance study and its level of resolution must be kept in mind when using this document and Maps A-1 and A-2. For example, analysis of individual landslides or slopes is not an appropriate use of this report nor should it be used exclusively for zoning purposes. Moreover, the report was prepared according to the schedule necessary to produce a statewide State lands 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 may have been miscoded herein.

David Christiansen, Dave Parks, and Laura Vaugeois of DNR graciously reviewed this report and edited the text.

This assessment was conducted using aerial photographs, various maps, and field observations. Information was collected and compiled from these sources in a manner designed to respond to the critical questions or to suggest areas where more detailed information is necessary. The objective of the data collection is to generate information sufficient to establish:

- A generalized characterization of mass wasting processes active in the basin.
- Portions of the landscape sharing similar physical characteristics as these related to mass-movement behavior.
- The relative potential for mass wasting within each landscape unit.

1.2 Previous Investigations

Several papers and geologic maps cover the study area including detailed descriptions of the glacial geology along the Queets River by Thackray (1996), a detailed map of the Metheney Creek area (Lingley, W. and others, 1996), and a DNR 1:100,000 compilation of all local geology by Gerstel and Lingley, W. (2000). There is one slope stability map by Gerstel (1999); a preliminary 1:48,000 deep-seated landslide inventory of the west-central Olympic Peninsula. Several letter-reports on slope stability have been included with DNR Forest Practices Applications, but are not specifically referenced herein. In addition, Rau (1973) wrote an introductory level DNR geology bulletin covering the Washington coast

[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.

between Point Grenville and the Hoh River. Studies of slope stability in adjacent watersheds include Bilderback (*in preparation*) and Lingley, L. (2002).

1.3 Summary of Methods

This assessment generally follows the Landslide Hazard Inventory Protocol dated July 13, 2005 (Washington Department of Natural Resources, 2005), with minor modifications. The LHZ protocol relies largely on information collected through an aerial photo-based landslide inventory. This information is used to develop landslide hazard zones that are unique in terms of their mass wasting process(es), landform(s), sensitivity to forest practices, and the risk(s) to public resources and public safety. The LHZ protocol is essentially a reconnaissance-level survey with limited field validation of landslide and landform mapping. As a result, it is unlikely that all landslides have been identified and that all landforms have been properly classified and mapped. Users of this information should be aware of these limitations and should exercise caution when translating mapped hazard zone boundaries to field settings.

Seven sets of black and white aerial photographs (Table 1) acquired between 1967 and 1997 were viewed using a mirrored stereoscope with 3x magnification. Unfortunately, many key images were missing from DNR's collection and could not be viewed. In addition, 1998 orthophoto coverage (black and white, nonstereo) 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 in Appendix A are probably considerably older than the 1998 acquisition date of these data.

Field investigations to verify landforms and landslides were carried out on September 29 and November 7 and 8, 2005. Twenty percent of landslides mapped from aerial photographs were confirmed or rejected during field reconnaissance.

Mapping was generally accomplished by digitizing the landslides directly in ArcGIS. Control was established by rectifying most landslides with DNR digital orthophotographs as well as with topographic contours and a variety of hillshade layers created with USGS 10-meter digital elevation models (DEM). Lidar was not available for this area. Varying hillshade layers were used to provide optimal lighting conditions for different slope areas as different combinations of sun azimuth and slope orientations provide drastically different representations of the ground surface. Digitizing landslides was performed at scales equal to or greater than 1:3,000 and landforms were digitized at 1:5,000.

The resulting landslide mapping is displayed as Map A-1 and is available as PDF files or ArcInfo coverage from the DNR Forest Practices Division. Pertinent attributes of the landslides are recorded on data sheets (Appendices A and B). Slope gradients not measured in the field were determined by exploring DEM-derived slope percent pixels within the upper parts of each landslide polygon on the Map A-1 shapefile. These slope angle estimates are less than true slope angles where steep slopes or inner gorge faces are less than 60 feet wide, because the 10-meter resolution averages gentler slopes above and below the steep face into the calculation. Slopes derived from DEMs are generally lower than those measured in the field, but are less subjective. Conversely, the steepest slopes on rotational failures are on the failure plane and therefore steeper than the slope of the ground immediately before landslide initiation. As a result, the method of slope gradient estimation presented is an approximation. 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).

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.

Table 1. Photographic surveys used in this study.

Year	Scale	Image	Flight symbol	Flight number/ lines	Reference/ ownership	Comment
1967	1:12,000	black & white	GH-67	3A-1 to 10, 5B-1 to 11, 7B-1 to 12, 9B-1 to 11, 11D-1 to 12	DNR	No missing photos
1979	1:12,000	black & white	OBD-79	17A-11 to 14, 19A-32 to 40, 21A-35 to 41, 24A-34 to 39, 26A-26 to 34, 28A-25 to 35, 30-27 to 38	DNR	No missing photographs
1980	1:60,000	black & white	OL-H-80	10 1/2W-47 to 49, 11W-47 to 49, 12W-47A to 50	DNR	No missing photographs
1981	1:12,000	black & white	OL-81	15-21-148 to 156, 25-27-231 to 233, 10-29-283 to 286, 25-30-208 to 212, 25-31-193 to 200, 14-35-194 to 195, 25-33-163 to 195, 29-22-232 to 240	DNR	Missing 32 photographs
1985	1:12,000	black & white	OL-85	19-21-56 to 65, 19-22-40 to 49, 19-24-10 to 14, 10-26-133 to 140, 10-27-160 to 168, 10-29-175 to 181, 10-30-192 to 197, 38-31-60 to 71, 10-32-222 to 234, 15-33-33 to 42, 13-34-46 to 51	DNR	Missing 6 photographs
1990	1:12,000	black & white	OL-90	22-22-104 to 112, 26-22-5 to 11, 21-24-260 to 264, 12-26-177 to 182, 26-28-16 to 25, 22-30-146 to 153, 19-32-134 to 143, 19-34-164 to 174	DNR	Missing 2 photographs
1997	1:12,000	black & white	OL-97	2-21-138 to 147, 2-22-125 to 159, 2-23-164 to 167, 2-25-190 to 195, 5-27-125 to 134, 5-29-154 to 161, 5-30-168 to 176, 5-32-194 to 206, and 5-34-230 to 239	DNR	Missing 9 photographs

[2] Referred to simply as “landforms” hereafter.

2.0 Physical Setting

The field area is divided into two separate WAU's, the Lower Queets River and Metheney Creek. However, most of the lower Metheney WAU is dominated by glacial deposits from the Queets alpine glaciers, and shortly after each of at least eight ice advances, these WAUs shared a common floodplain.

2.1 Lower Queets River WAU

This WAU covers 44,177 acres and lies completely within Jefferson County. It is located about 25 miles south from the city of Forks (Figure 1). Federal land ownership is divided between the US Forest Service (3200 acres), and the National Park Service (9358 acres). The Quinault Indian Nation owns an additional 9973 acres for a total of 22,531 acres not included in this study (Table 2). The remaining 21,646 acres is divided between private ownership (5889 acres) and DNR-managed lands (15,757 acres).

The upstream end of the Queets River watershed lies approximately 18 miles due east of Kalaloch, and drains west to its confluence with the Pacific Ocean. Elevations range from a high of approximately 2600 feet along the eastern WAU boundary to sea level at the mouth of the Queets River.

2.2 Metheney Creek WAU

The watershed covers 24,027 acres and lies within Jefferson and Grays Harbor County. The WAU is about 25 miles south-southeast from the city of Forks (Figure 1). Federal land ownership is divided between the US Forest Service (20,337 acres) and the National Park Service (365 acres) totaling 20,702 acres (Table 2). These lands are not included within this study. The remaining 3325 acres are DNR managed lands.

The headwaters of the Metheney Creek watershed lies approximately 18 miles east-southeast of Kalaloch and drains to the west to its confluence with the Queets River. Elevations range from a high of approximately 3250 feet along the eastern boundary to 160 feet at its confluence with the Queets River.

Table 2. Land ownership divided by acres and percent.

	Lower Queets River WAU		Metheney Creek WAU	
	Acres	Percent	Acres	Percent
National Park Service	9358	21.2%	365	1.5%
US Forest Service	3200	7.2%	20,337	84.6%
DNR	15,757	35.7%	3325	13.8%
Quinault Indian Nation	9973	22.6%	-	-
Private	5889	13.3%	-	-
Total	44,177	100%	24,027	100%

2.3 Hydrology

Precipitation within both the watersheds is high, averaging 117 inches of rain annually (Western Regional Climate Center, 2005) with the highest precipitation occurring between October and April. Snow occasionally falls in the area; however rain-on-snow events are not a major concern.

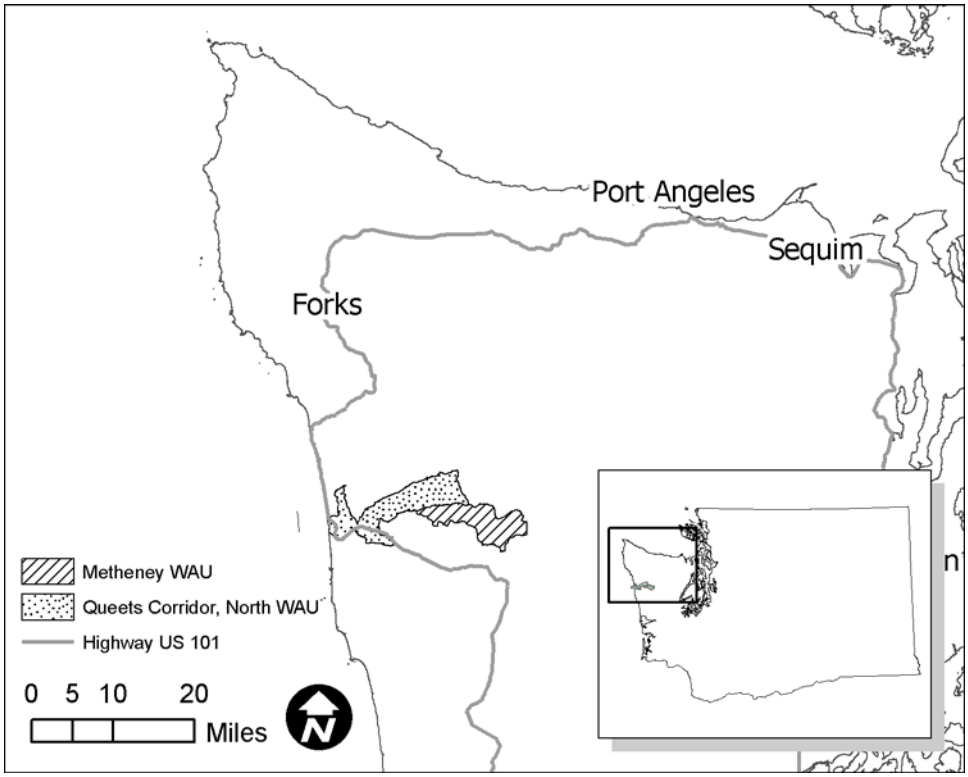

Figure 1. Map showing the location of the Metheney Creek and Lower Queets River WAU's.

The Queets River flows from glaciers and snowfields on Mount Olympus on the western slopes of the Olympic Mountains and has a drainage basin approximately 445 square miles. The annual mean discharge of the Queets is 4401 cubic feet per second (ft^3/s) with a recorded maximum discharge of 133,000 ft^3/s on December 15, 1999 and a minimum discharge of 300 ft^3/s recorded on October 21-25, 29, 1987 (US Geologic Survey, 2005).

Groundwater is critically important to understanding aspects of local slope stability throughout the study area; however, is not discussed in detail in this paper nor are areas of potential glacial recharge identified in maps A1 or A2. A cap of impermeable alpine glacial till forms a plain that separates groundwater from direct recharge in terraces proximal to the Queets River and Metheney Creek. Elsewhere, late Ice Age ice-scouring and stream incision have removed the till exposing the underlying sand to recharge from surface water. In these areas, and at the edges of the till-plain, surface water infiltrates downward into the underlying porous sand and gravel. During high precipitation periods, elevated groundwater level can cause instability and trigger deep-seated landslides.

2.4 Geology

2.4.1 Poorly-Consolidated Surficial Units

Surficial geology is based on 1:100,000 DNR maps of the Forks quadrangles by Gerstel and Lingley (2000). The majority of the lithology in both WAUs is derived from a series of large alpine glaciers that descended the modern day Queets River basin from the Olympic Mountains to the Pacific coastal lowlands. At least six small advances occurred between 54,000 to 18,300 years ago (Thackray, 2001), but two larger ice advances occurred earlier (Thackray, 1996). At least one of these over-topped hills in the northwest part of the Queets WAU. The second advance left a prominent ridge (lateral moraine) of glacial sediments north of the Queets River in the central and eastern parts of the Queets WAU.

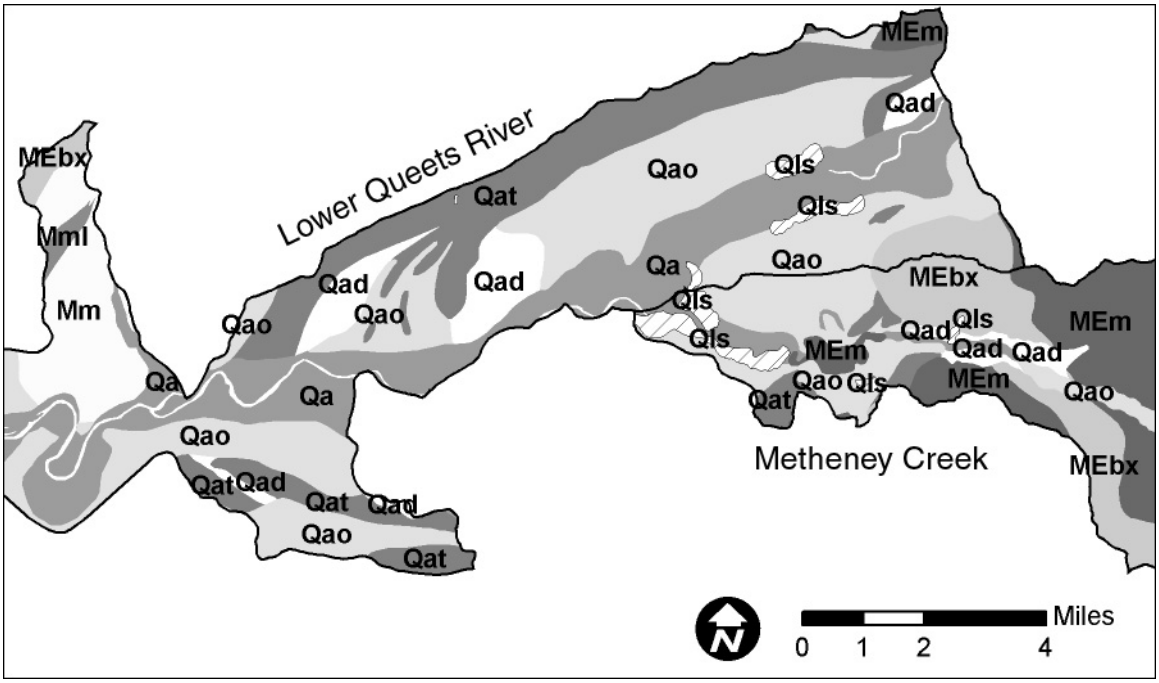

Figure 2. Generalized geologic map of the study area showing parts of the Lower Queets River (upper polygon) and Metheney Creek (polygon on lower right) WAU's. Note: The following map symbols include many very old glacial units lumped together with younger glacial units, such as unit Qat. For this reason, the symbology on this map is not consistent with 'state map' symbology. (See Dragovich and others, 2002.)

The 1:100,000 DNR geologic map depicts 35 individual geologic units within the WAU's, so for simplicity, geologic units have been grouped into similar categories based on their depositional and formation processes. (See Figure 2 for the approximate location of the geologic units.) For a more detailed description of geologic units, see Gerstel and Lingley (2000).

Qao *Quaternary alpine glacial outwash*. Surficial units in the study area consist of sediments[3] deposited mainly from the alpine glaciers. Streams carrying clay, sand, and gravel flowed from the leading edge of the advancing and receding glacier, deposited sand to pebble/cobble gravel.

Qat *Quaternary alpine glacial till*. As the glaciers advanced westward, they deposited layers of glacial '*Till*' beneath the ice. The glacial till consists of an unsorted, very compact, concrete-like mixture of clay, silt, sand, gravel, cobbles, and boulders supported by its matrix[4]. Till is resistant to erosion and low permeability, permitting stream water to slowly infiltrate into ground.

Qad *Quaternary alpine glacial drift*. The unit represents various depositional environments within an area too small to accurately map. Qad includes lake deposits and sediments similar to the aforementioned Qao and Qat.

[3] 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 glacial till.
[4] Matrix (as opposed to clast) support indicates that in a deposit of mixed sizes, the finer material carries the weight. Therefore, these deposits can flow. In clast-supported deposits, the weight is carried by grain-to-grain contacts between the larger particles, and these tend to be more resistant.

Qa *Quaternary alluvium*. These deposits consist of recent stream sediments within active channels, including the approximate areas of the 100-year flood plains. Composed entirely of sediments derived from the Olympic Mountains

Qls *Quaternary landslide deposits*. These deposits consist of unstratified and poorly sorted deposits of clay, silt, sand, gravel, and larger blocks often displaying a hummocky surface.

2.4.2 Bedrock Surficial Units

All of the bedrock in the study area is relatively soft, and thinly-layered units are common. For these reasons, the bedrock weathers easily and deep-seated landslides within the bedrock are common. The following geologic units were initially sediments that settled in deep-sea basins and compacted due to their own mass. These are described in more detail in Lingley (1995). These sedimentary rocks were subsequently folded, faulted, and accreted onto the North American plate by tectonic forces from the convergence of the Juan de Fuca and North American plates. They crop out throughout the western portions of the field area.

MEbx *Miocene/Eocene tectonic breccia*. Intensely sheared sedimentary rocks made up of volcanic and metamorphic mixes of broken rocks that have experienced extensive faulting due to plate tectonics. These rocks are generally unstable.

MEm *Miocene/Eocene marine sedimentary rocks*. Consists of both thick- and thin-bedded (layered) sandstone and conglomerate and thin-bedded siltstone, shale, or slate deposited in a marine environment.

Mml *Miocene marine clastic rocks*. Very thick (>10 feet) beds of sandstone with minor amounts of , siltstone and conglomerate, which formed in a marine environment.

Mm *Miocene marine sedimentary rocks*. Similar to Unit Mml, but dominated by siltstone and sandstone, which formed in a marine environment.

A large percentage of mapped landslides are present in the thinly bedded units (parts of Units MEm and Mm and the sheared rocks (Unit MEbx). (See Lingley and Lingley, 2002.)

2.4.3 Regional Geologic Structure

Bedrock in the study area has been subject to severe and continuous faulting over a period of roughly 40 million years. These faults thoroughly shear wide areas parallel with the trend of each fault. This shearing weakens the soft bedrock resulting in: 1) increased erosion, 2) creation of valleys, and 3) initiation of many landslides. Most of these fault planes trend northwest, perpendicular to the direction of the incoming Juan de Fuca Plate and are tilted to the northeast. However, very young faults trend northeast and control the orientation of the Queets and central Clearwater River valleys (Gerstel and Lingley, 2000). Most of the strata in the bedrock is steeply dipping (standing on end) as a result of faulting.

The young northeast-trending fault zone that controls the orientation of the adjacent mid-Clearwater River valley cuts across the northern part of the study area. This faulting badly shears the bedrock forming wide zones of intensely fractured rock, which is depicted as the polygon of Unit MEbx in the northwestern part of the Queets WAU (T24N R13W). Unit MEbx is particularly susceptible to slope failure.

2.4.5 Geomorphology

The study area can be divided into four main physiographic elements and subdivided into eight watershed-specific landforms (hereafter, referred to as "Landforms"). The physiographic elements are:

1. Glacial Landforms. These include the upper plain and associated terraces of the Queets Valley and low ridges composed of till. The low ridges are moraines and include the gravel ridge north of the Queets River, which is depicted as polygon Qat on Fig. 2. This ridge is arguably the best-developed lateral moraine in Washington State. It formed along side the Queets glacier during the second huge ice advance. With the exception of gorges incised into the terraces by recent uplift and stream erosion, this physiographic element is quite stable.
2. Rounded Bedrock Hills. These are composed of marine sedimentary rocks, which are primarily located in T24N R13W. This physiographic element is characterized by very poor slope stability and includes numerous rule-identified unstable inner gorges, bedrock hollows, and convergent headwalls. (See WAC 222-050(1)(d)).
3. Large, Deep-Seated Landslides. This physiographic element consists of glacial, deep-seated landslides developed on terraces beside the Queets River and Metheney Creek. These landslides are considered unstable due to possible undercutting from the streams and rivers.
4. Alluvial Plains. These consists of the inner floodplains covered by reworked clay, silt, sand, and gravel mobilized and deposited by fluvial processes.

The eight watershed specific landforms are described throughout the remainder of this report, especially on Forms A2 and Map A2.

Rapid uplift of the entire study area during great subduction earthquakes occurs about every 600 years. This periodic uplift, which is on the order of 10-feet during every earthquake, causes streams to incise deeply and terraces to be abandoned by their subtended streams and rivers at a geologically rapid rate. The looping meanders of central Metheney Creek are good examples of such incision. Wegmann (2002) describes a northeastward progression of terrace abandonment through time. He demonstrates that older terraces are located at higher elevations from present day streams as one works further into the Olympic foothills.

3.0 Summary of Results

Aerial photograph analysis of the area proved sufficient to characterize landslide hazards throughout the field area. A minimum of 188 landslides were documented to have occurred from 1969 to 1998 in the study area (Map A-1). An additional 18 landslides were mapped on adjacent areas on Federal or Tribal lands in order to more accurately characterize the study area. With this information, nine Landforms having similar mass-wasting potential are identified and are displayed on Map A-2 and detailed descriptions are included on Form A-2. Pertinent attributes of individual landslide features were recorded on data sheets (Form A-1).

Of the landslides identified during this mass wasting assessment, 57 percent were mapped as shallow-undifferentiated failures, 26 percent as debris flows, 12 percent were small, sporadic deep-seated failures[5], and 4 percent were deep-seated landslides (Figure 3).

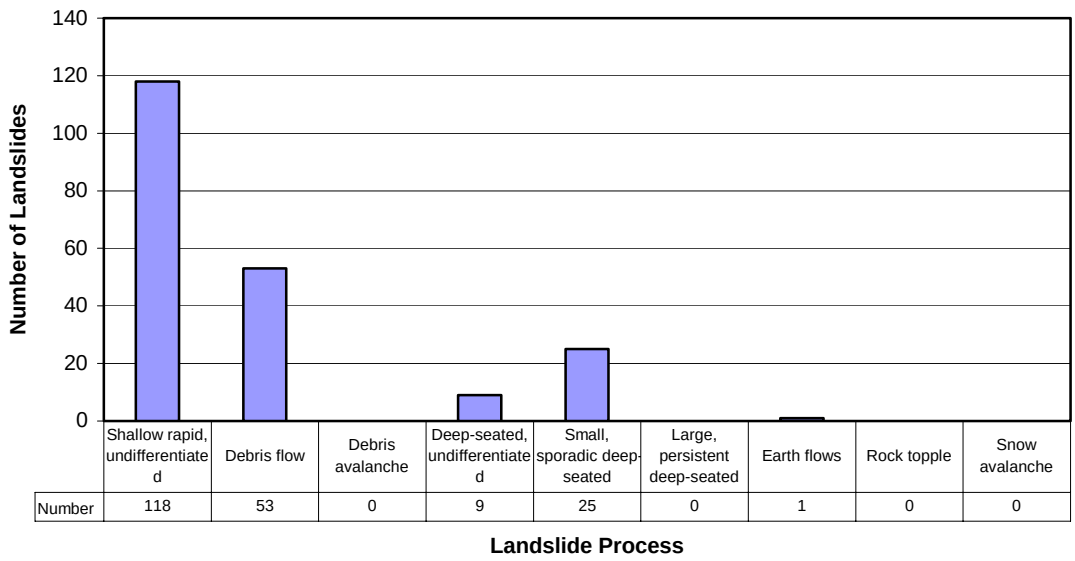

Figure 3. Distribution of landslides observed within the study area by mechanism.

On managed lands, 18 percent all of the landslides are road-related (Figure 4). Elsewhere, landslides associated with clear-cuts (0 to 5 years) include 36 percent of all recorded failures, young stands (5 to 15 years) include 11 percent, submature stands (15 to 50 years) include 11 percent, and mature stands include 10 percent of observed slope failures.

With the exception of road-related landslides, the majority of landslides are associated with rule-identified landforms[6] (Figure 5). Bedrock hollows contained 41 percent of the landslides followed by 32 percent from inner gorges. Terrace faces produced 19 percent of the landslides in the study area, convergent headwalls 3 percent, deep-seated landslides captured 2 percent, and stream influence accounted for almost 3 percent.

[5] Landslide process notation used herein is taken from earlier versions of the LHZ Protocol, which no longer includes in the process categories shallow sporadic deep-seated landslides, large persistent deep-seated landslides, and earthflows.
[6] See WAC 222-16-050(1).

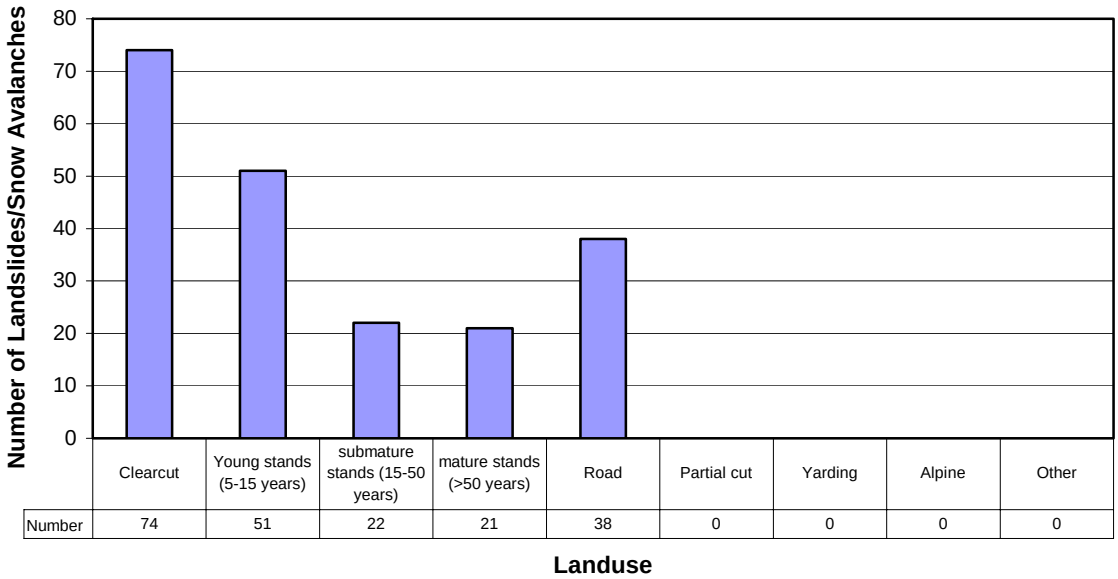

Figure 4. The distribution of landslides by land use association..

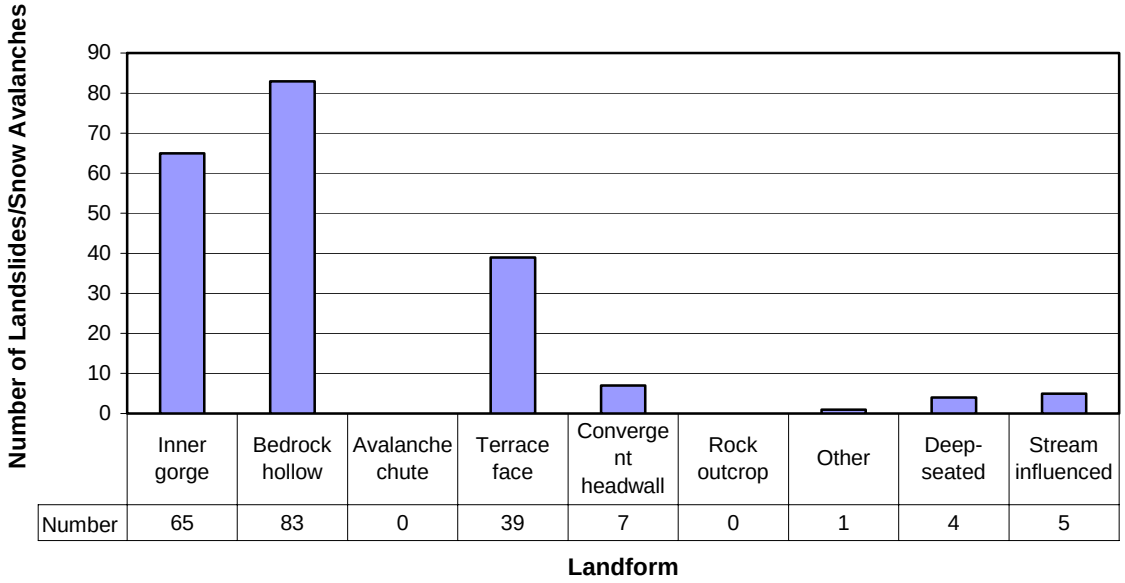

Figure 5. The distribution of landslides by individual small-scale landform association.

4.0 Landform Descriptions (Form A-2)

4.1 Introduction

The eight landforms specific to the two WAUs are defined herein and have been delineated to show areas having similar mass-wasting potential and potential to deliver to public resources and threaten public safety. The eight watershed specific landforms are based on landslide process, geology, failure density, lithology, hydrology, geomorphology, and topography. The following sections characterize these landforms; 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 mostly moderate as the study is designed to provide representative samples rather than exhaustive analyses. In the following sections, low hazard landforms are described with an abbreviated description (Form A-2), whereas moderate, high, and very high hazard landforms that will trigger a field investigation by Department of Natural Resources Region personnel are described with a complete Form A-2.

LANDFORM NUMBER	10
LANDFORM NAME	Convergent and rule-identified features
OVERALL HAZARD	Very high
Description of mass-wasting unit	Convergent features including rule-identified bedrock hollows, inner gorges, and convergent headwalls. Rule identified features contain slope angles 70% and greater.
Number and cumulative area of landslides	84 landslides; 20.8 acres
Observed slope of Landform	70% and greater
Slope shape	Concave convergent and concave-planar
Materials	Mm(r), Mml, MEbx, and in some glacial geologic units
Elevation of landslide initiation	123 to 626 feet; average 401 feet
Total area of Landform	648 acres
Mass-wasting processes	Shallow-rapid, debris flow, and shallow, sporadic deep-seated landslides
Forest Practice sensitivity	Landform is sensitive to any forest practice activity that reduces root strength, undercuts or oversteepens, or loads these slopes, and/or redirects water onto these slopes. Runoff or shallow groundwater that channel it to point locations that saturate road or landing fill and/or thin soils draping bedrock, triggering landslides.
Mass-wasting potential	High
Number of delivering landslides	83
Area of delivering landslides	20.5 acres
Landslide area rate for delivery	1022; very high
Delivery potential and delivery criteria used	High, direct observation of delivery to typed waters.
Trigger mechanisms	Saturation of soils during heavy precipitation events, diverted streams/channels, over-steepening from roading, and others.
Confidence	High. Field verification revealed convergent areas in marine sedimentary rocks are very susceptible to mass wasting.
Comments	The DEM lacked sufficient detail to identify convergent features in the marine sedimentary rock in T24N R13W. **We assigned areas surrounding the convergent features as moderate hazard due to poor DEM resolution and insufficient aerial photograph coverage, which together suggest that we may not have been able to identify all convergent terrain.**

LANDFORM NUMBER	11
LANDFORM NAME	Incised glacial sediments
OVERALL HAZARD	Very high
Description of mass-wasting unit	Incision in glacial sediments from streams. Slopes are typically 70 percent or greater.
Number and cumulative area of landslides	80 landslides; 60 acres
Observed slope of Landform	Typically greater than 70 percent
Slope shape	All slope shapes
Materials	All glacial and interglacial geologic units
Elevation of landslide initiation	152 to 520 feet; average 328 feet
Total area of Landform	1475 acres
Mass-wasting processes	Shallow-rapid, debris flow, deep-seated, and shallow-sporadic deep-seated landslides.
Forest Practice sensitivity	Landform is sensitive to **any forest Practice activity that reduces root strength**, or otherwise disturbs the ground.
Mass-wasting potential	High
Number of delivering landslides	64 landslides
Area of delivering landslides	21.8 acres
Landslide area rate for delivery	477; high
Delivery potential and delivery criteria used	High; direct observation of delivery to typed waters
Trigger mechanisms	Saturation of soils during heavy precipitation events, diverted streams/channels, over-steepening from roading, and others.
Confidence	High
Comments	This landform is very susceptible to mass wasting and because these incised drainages are sharply v-shaped, delivery in inevitable.

LANDFORM NUMBER	12
LANDFORM NAME	Deep-seated landslides within incised glacial sediments
OVERALL HAZARD	High (rule-identified)
Description of mass-wasting unit	Deep-seated landslides proximal to the Queets River and Metheney Creek separated by sections of incised glacial sediments. These are located on prominent terrace faces.
Number and cumulative area of landslides	2 landslides; 56 acres
Observed slope of Landform	Greater than 50 percent
Slope shape	All slope shapes
Materials	Qao (alpine glacial outwash)
Elevation of landslide initiation	300 to 370 feet
Total area of Landform	365 acres
Mass-wasting processes	Deep-seated
Forest Practice sensitivity	While these appear to be natural failures, logging or roading that might increase recharge should be carefully assessed.
Mass-wasting potential	Moderate and on-going
Number of delivering landslides	2
Area of delivering landslides	1.8 acres
Landslide area rate for delivery	159; high
Delivery potential and delivery criteria used	Incision at the toe from lateral migration of streams could reactivate these slides
Trigger mechanisms	Natural, but may be accelerated by roading or increased recharge. On going river erosion will probably cause these to fail naturally in the future.
Confidence	Moderate
Comments	There are several glacial deep-seated landslides along the Queets River and are primarily on federal lands. The associated glacial deep-seated recharge areas for these landslides that have not been mapped.

LANDFORM NUMBER	13
LANDFORM NAME	Slopes in marine sedimentary rocks
OVERALL HAZARD	Moderate
Description of mass-wasting unit	Slopes approximately greater than 20% (on the DEM) in marine sedimentary units.
Number and cumulative area of landslides	20 landslides; 3 acres
Observed slope of Landform	Greater than 20% according to DEM
Slope shape	All slope shapes
Materials	Mm(r), MEbx, and Mml (all marine sedimentary rocks)
Elevation of landslide initiation	115 to 716 feet; average 420 feet
Total area of Landform	1,885 acres
Mass-wasting processes	Shallow-rapid, debris flows, shallow sporadic deep-seated, and large-persistent deep-seated landslides.
Forest Practice sensitivity	Landform is sensitive to any forest Practice activity that reduces root strength, undercuts or oversteepens or loads these slopes, and/or redirects water onto these slopes.
Mass-wasting potential	High in convergent areas
Number of delivering landslides	19 landslides
Area of delivering landslides	2.8 acres
Landslide area rate for delivery	48; low (see Comments)
Delivery potential and delivery criteria used	Low, except where convergent topography was missed during this study.
Trigger mechanisms	Saturation of soils during heavy precipitation events, diverted streams/channels, over-steepening from roading, and others.
Confidence	Moderate
Comments	Landform 10 normally captures the convergent areas in marine sedimentary rocks; **however, due to poor DEM resolution and incomplete aerial photograph coverage some convergent features have not been identified and are in Landform 13. Knowing this, the overall hazard for Landform 13 has been upgraded from low to moderate to identify areas of high hazard not located in this study.**

LANDFORM NUMBER	14
LANDFORM NAME	Glacial terraces and subdued moraines
OVERALL HAZARD	Low
Description of mass-wasting unit	Flat and low-relief (less than 60% from DEM) glacial sediments consisting of clay, silt, sand, and gravel.
Comments	This Landform contains 18,556 acres and the Landslide area rate for delivery is 0. Areas incised from small streams not evident on the DEM, may be much steeper than 60% and are not identified on this landform.

LANDFORM NUMBER	16
LANDFORM NAME	Low relief convergent features on glacial sediments
OVERALL HAZARD	Low
Description of mass-wasting unit	Landform consists of small Type N_P and N_S streams incised into glacial sediments consisting of clay, silt, sand, and gravel. Slopes are typically less than 70 percent.
Comments	This Landform is 479 acres and the Landslide area rate for delivery is 0.

LANDFORM NUMBER	17
LANDFORM NAME	Low gradient marine sediments
OVERALL HAZARD	Low
Description of mass-wasting unit	Landform consists of areas under approximately 15 percent on marine sedimentary rocks or on more indurated (stronger) marine sedimentary rocks.
Comments	This Landform is 361 acres and the Landslide area rate for delivery is 0.

LANDFORM NUMBER	18
LANDFORM NAME	Alluvial plains
OVERALL HAZARD	Low
Description of mass-wasting unit	Includes sand, gravel, and boulders deposited recently on floodplains (inclusive of channel migration zones) by creeks and rivers
Comments	This Landform is 1081 acres and the Landslide area rate for delivery is 0.

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 landslides (Table 3). The Area Rate for Delivery is especially useful for helping to quantify the potential for delivery of sediment where rule-identified status may mischaracterize slope stability in the landform as outlined in Table A-2 of Washington Forest Practices Board (2005). 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.

Table 3. Form A-4 Landslide Area Hazard Rates. The annualized rate of landslides that deliver to public resources and threaten public safety in terms of Landslide Frequency Rates and Landslide Area Rates for Delivery during the 31-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.

	Landform number								WAU
	10	11	12	13	14	16	17	18	
Area of Landform (acres)	648	1475	365	1864	18556	480	361	1081	24829
Number of Landslides	84	80	2	20	0	0	0	0	186
Total number of photo years	31	31	31	31	31	31	31	31	31
Landslide Frequency Rate = (number of slides * 1,000,000 / Landform area / photo years)	4180	1750	177	346	0	0	0	0	242
Landslide Frequency Rate Qualtative Rating	Very high	Very high	Moderate	High	Low	Low	Low	Low	High
Number of 'Delivering' Landslides	82	64	2	18	0	0	0	0	166
Area of 'Delivering' Landslides (acres)	20.5	21.8	1.8	2.8	0.0	0.0	0.0	0.0	46.9
Landslide Area Rate for Delivery = (area of delivering landslides * 1 million / Landform area / photo years)	1022	477	159	48	0	0	0	0	61
Landslide Area Rate for Delivery Qualitative Rating	Very high	High	High	Low	Low	Low	Low	Low	Low
Overall Hazard Rating	Very High	Very High	High	Moderate	Low	Low	Low	Low	Low

6.0 Confidence in Work Product

The confidence in this mass wasting assessment is moderate. This rating is based on the Landslide Hazard Zonation Project design to provide a watershed overview of slope stability in a timely manner with minimal field verification. As a consequence, fieldwork and the number of aerial photograph sets examined are held to reasonable minimums. Omissions will be present due to the limited field verification of individual features, particularly in heavy canopy forested areas.

It is critical for the reader to understand that while these decisions are sufficient to characterize aspects of the slope failure as functions of forest management, this assessment would be entirely insufficient and misleading if it is used as a stand alone document for protecting private and public resources or for land use planning. Keep in mind that this is only a reconnaissance study, and undoubtedly, some landslides have been accidentally omitted and some benign features may be improperly mapped as landslides herein.

In addition, there are several sources of systematic error that reduce the confidence in the work products of this analysis, those being omission, misinterpretation, accuracy, and precision. Omission occurs when mass wasting features are not identified on aerial photographs or in the field due to canopy cover, gaps in the aerial photo record, quality of aerial photos, or interpreter errors. Misinterpretation occurs when a mass-wasting feature is identified but incorrectly classified or data are transposed, and where unrecognized software/file instability occurs. Accuracy involves the degree to which the physical parameters of a mass-wasting feature are correctly measured, and precision describes how variability within an assessment can be controlled when making multiple measurements over varying time and spatial scales (Parks, 2000).

This mass wasting assessment was primarily conducted with aerial photographs, and as a result, there is a high likelihood that errors of omission occurred primarily in areas covered by mature forest canopies, steep north facing slopes always in shadow at any given time, and those areas covered with extensive glacial deposits. The scarcity of mass wasting features identified under mature canopy and steep north slope aspect shadow conditions is not necessarily an indication of the relative stability of slopes with mature vegetation regimes or steep north face aspects.

Because many deep-seated landslide features are quite large, remain heavily vegetated during movement, and may not have obvious scars visible through the vegetation canopy, misinterpretation is more likely. A detailed study in Cowlitz County, Washington, suggests that up to 25 percent of inferred deep-seated landslides identified from aerial photograph analysis are misinterpreted (Wegmann, 2003). Confidence in work products related to classification of deep-seated landslide processes in this watershed is high due to visibility and completeness of photo coverage.

Another important source of potential error in this assessment is in the accuracy and precision of measurements of mass wasting features. Because very few 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. Similarly, measurements of slope angle from digital elevation models typically misrepresent the true hill slope angle. Given these sources of error, the confidence in the precise location and accuracy of measurements of individual landslides is considered moderate.

6.0 References

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Appendix A. Form A-1: Landslide Inventory

Mass-Wasting Inventory Data for the study area that includes parts of the Lower Queets River and Metheney Creek WAU's. Codes for this table are presented on the DNR Forest Practices website. Under Photo_number column "FIELD" indicates that the landslide was discovered in the field and "ORTHO" indicates the landslide was found in the 1998 digital orthophotographs GIS layer.

Slide_id	Lsi_process	Certainty	Id_date	Ls_size	Id2_date	Id2_size	Init_elev	Photo_number	Landform	Slp_shp	Gradient (%)	Delivery	Landuse	Siouxon_landform	Deep_seated_activity	Acres	Geol_unit	Comment
1000	1	P	1981	0	0	0	383	OL-81 25-33-165	2	2	70	N	1	11		0.09	Qao	
1001	1	P	1981	0	0	0	396	OL-81 25-33-165	2	2	69	N	1	11		0.07	Qao	
1002	1	P	1981	0	0	0	358	OL-81 25-33-165	2	2	76	N	1	11		0.06	Qao	
1003	1	P	1981	0	0	0	361	OL-81 25-33-165	2	2	72	N	1	11		0.07	Qao	
1004	1	P	1981	0	0	0	390	OL-81 25-33-165	2	2	73	N	1	11		0.07	Qao	
1005	1	P	1981	0	0	0	366	OL-81 25-33-165	2	2	71	Y	1	11		0.06	Qao	
1006	1	P	1981	0	0	0	375	OL-81 25-33-165	2	1	55	Y	1	11		0.11	Qao	
1007	1	P	1981	0	0	0	363	OL-81 25-33-165	2	2	82	N	1	11		0.06	Qao	
1008	1	P	1981	0	0	0	415	OL-81 25-33-165	2	2	55	Y	1	11		0.14	Qao	
1009	2	P	1981	0	1985	0	392	OL-81 25-33-166	2	1	70	Y	1	11		0.24	Qao	
1010	1	D	1979	0	0	0	368	ODB-79 23A-38	4	2	34	Y	1	11		0.05	Qapw(2)	
1011	1	D	1979	0	0	0	365	ODB-79 23A-38	4	2	45	Y	1	11		0.08	Qapw(2)	
1012	1	P	1979	0	1985	0	306	ODB-79 23A-38	4	2	75	P	1	11		0.13	Qapo	
1013	4	D	1979	0	0	0	122	ODB-79 21A-42	4	3	51	N	4	0	DD	14.57	Qapwo(2)	Possibly undercut by Queets River
1014	1	D	1979	0	0	0	125	ODB-79 21A-42	4	2	31	P	4	0		0.15	Qapwt(2m)	
1015	1	D	1979	0	0	0	152	ODB-79 21A-42	4	2	43	N	4	0		0.37	Qapwt(2m)	
1016	1	D	1979	0	0	0	152	ODB-79 21A-42	4	2	42	N	4	0		0.32	Qapwt(2m)	
1017	1	D	1979	0	0	0	231	ODB-79 21A-42	4	2	46	N	4	0		0.73	Qapwt(2m)	
1018	1	D	1979	0	0	0	247	ODB-79 21A-42	4	2	58	N	4	0		0.18	Qapwt(2m)	
1019	1	D	1979	0	1985	0	272	ODB-79 21A-42	4	2	64	N	4	11		0.37	Qapwt(2m)	

Slide_id	Lsi_process	Certainty	Id_date	Ls_size	Id2_date	Id2_size	Init_elev	Photo_number	Landform	Slp_shp	Gradient (%)	Delivery	Landuse	Siouxon_landform	Deep_seated_activity	Acres	Geol_unit	Comment
1020	1	D	1979	0	0	0	328	ODB-79 21A-42	4	2	42	Y	4	11		0.38	Qapwt(2m)	
1021	5	D	1981	0	1985	0	574	OL-81 15-21-149	2	2	85	Y	5	10		0.46	Mm(r)	< 5 year old falure; PIP near head
1022	2	D	1967	0	1981	0	477	GH-67-5B-5	1	2	50	Y	5	10		0.46	Mm(r)	
1023	2	D	1981	0	0	0	617	OL-81 15-21-151	4	2	38	Y	2	10		0.11	Mml	
1024	1	P	1981	0	1985	0	626	OL-81 15-21-151	4	1	50	Y	2	10		0.60	Mml	
1025	2	D	1981	0	1985	0	584	OL-81 15-21-151	4	1	36	P	2	10		0.15	Mml	
1026	1	D	1981	0	1985	0	558	OL-81 15-21-153	4	1	48	Y	5	10		0.34	MEbx	
1027	1	P	1981	0	0	0	532	OL-81 15-21-153	4	1	40	Y	1	10		0.14	MEbx	
1028	1	D	1979	0	1985	0	508	OBD-79 17A-13	1	2	44	Y	5	10		0.23	MEbx	
1029	1	D	1979	0	0	0	517	OBD-79 17A-13	1	3	51	Y	1	10		0.22	MEbx	
1030	1	D	1979	0	0	0	525	OBD-79 17A-13	1	3	40	Y	5	10		0.20	MEbx	Pond upstream of landslide deposit in 1981 aerial photograph
1031	2	P	1985	0	0	0	424	OL-85 19-021-059	4	2	40	Y	5	10		0.46	Mml	
1032	2	D	1985	0	0	0	578	OL-85 19-021-061	1	1	45	Y	5	10		0.18	MEbx	
1033	2	D	1985	0	0	0	604	OL-85 19-021-061	1	1	35	Y	5	10		0.29	MEbx	
1034	2	D	1985	0	0	0	517	OL-85 19-021-061	1	1	30	Y	5	10		0.27	MEbx	
1035	2	D	1985	0	0	0	317	OL-85 19-022-041	1	1	40	Y	5	10		0.52	Mm(r)	
1036	1	D	1985	0	0	0	190	OL-85 19-024-011	8	2	51	P	2	0		0.84	Qls	
1037	2	P	1985	0	0	0	314	OL-85 19-024-011	1	2	46	P	1	11		0.19	Qapwt(2m)	
1038	2	D	1985	0	0	0	408	OL-85 10-026-134	1	2	48	Y	1	11		0.13	Qapwt(2m)	
1039	2	D	1985	0	0	0	319	OL-85 10-026-134	1	2	59	Y	1	11		0.10	Qapw(2)	
1040	1	D	1985	0	0	0	363	OL-85 10-026-134	1	1	58	Y	1	11		0.11	Qapw(2)	
1041	1	D	1985	0	0	0	365	OL-85 10-026-134	1	2	61	P	5	11		0.05	Qapw(2)	

Slide_id	Lsi_process	Certainty	Id_date	Ls_size	Id2_date	Id2_size	Init_elev	Photo_number	Landform	Slp_shp	Gradient (%)	Delivery	Landuse	Siouxon_landform	Deep_seated_activity	Acres	Geol_unit	Comment
1042	1	D	1985	0	0	0	391	OL-85 10-026-134	1	2	64	Y	1	11		0.08	Qapw(2)	
1043	1	D	1985	0	0	0	281	OL-85 10-026-134	1	2	61	P	1	11		0.09	Qapo	
1044	1	D	1985	0	0	0	211	OL-85 10-026-134	1	2	69	I	1	11		0.07	Qapo	
1045	1	D	1985	0	0	0	189	OL-85 10-026-134	1	2	60	N	1	11		0.06	Qapo	
1046	1	D	1985	0	0	0	152	OL-85 10-026-134	1	2	63	N	1	11		0.03	Qapo	
1047	1	D	1985	0	2005	0	257	OL-85 10-026-134	1	1	83	P	1	11		0.10	Qapo	Post-havest slide; may have occurred on fluvial terrace on Qapo
1048	1	P	1985	0	0	0	240	OL-85 10-026-134	1	1	39	I	1	11		0.11	Qapo	
1049	1	D	1985	0	1990	0	356	OL-85 10-026-134	1	2	53	Y	1	11		0.06	Qapw(2)	
1050	1	D	1985	0	0	0	284	OL-85 10-026-134	1	2	77	Y	1	11		0.08	Qapo	
1051	2	D	1985	0	0	0	364	OL-85 10-026-134	1	1	53	Y	1	11		0.13	Qapw(2)	
1052	5	P	1985	0	0	0	296	OL-85 10-032-227	4	2	30	Y	1	12		1.83	Qao	Possibly initiated by meandering river or clearcut or both
1053	5	D	1985	0	0	0	250	OL-85 10-032.227	8	2	38	Y	3	0		4.28	Qls	
1054	5	D	1985	0	2005	0	422	OL-85 15-033-037	2	2	71	Y	4	11		1.01	Qao	Landslide is older than image; delivered into wetland
1055	5	D	1985	0	0	0	430	OL-85 15-033-037	2	1	105	Y	4	11		0.98	Qao	Landslide is older than image; appears as abandoned meander bend; 3 ft vert headscarp; 80 ft wide; 11" DBH fir on body; smaller subsidary slides midslope
1056	5	D	1985	0	0	0	434	OL-85 15-033-037	2	1	75	N	4	11		0.90	Qao	Landslide is older than image; abandoned meander bend
1057	1	D	1985	0	1990	0	238	OL-85 10-027-161	4	3	34	N	5	11		0.56	Qapo	

Slide_id	Lsi_process	Certainty	Id_date	Ls_size	Id2_date	Id2_size	Init_elev	Photo_number	Landform	Slp_shp	Gradient (%)	Delivery	Landuse	Siouxon_landform	Deep_seated_activity	Acres	Geol_unit	Comment
1058	1	D	1985	0	0	0	232	OL-85 10-027-161	4	2	43	Y	1	11		0.04	Qapo	
1059	1	P	1997	0	0	0	238	OL-97 5-32-204	2	2	62	P	3	0		0.42	Qao	Canopy hole
1060	1	D	1990	0	1998	0	447	OL-90 19-34-168	2	2	53	Y	1	11		0.23	Qapo	
1061	1	P	1990	0	1998	0	439	OL-90 19-34-168	2	2	49	Y	1	11		0.27	Qapo	
1062	1	P	1990	0	1998	0	427	OL-90 19-34-168	2	2	57	Y	1	11		0.27	Qapo	
1063	1	D	1998	0	0	0	467	ORTHO	2	2	103	Y	2	10		0.27	Qapo	
1065	2	D	1990	0	0	0	314	OL-90 26-28-19	1	1	34	Y	1	11		0.17	Qapo	
1066	1	P	1990	0	0	0	263	OL-90 26-28-19	1	1	43	N	1	11		0.03	Qapo	
1067	1	P	1990	0	0	0	274	OL-90 26-28-19	4	2	57	P	5	11		0.12	Qapo	
1068	1	D	1990	0	0	0	248	OL-90 26-28-19	4	2	51	Y	1	11		0.15	Qapo	
1069	1	P	1990	0	0	0	210	OL-90 26-28-19	4	2	49	Y	1	11		0.12	Qapo	
1070	2	D	1990	0	0	0	360	OL-90 26-28-19	4	2	58	Y	1	11		0.19	Qapo	
1071	1	D	1990	0	0	0	247	OL-90 12-26-179	2	2	62	Y	1	11		0.22	Qapo	
1072	1	P	1990	0	0	0	317	OL-90 12-26-179	2	2	52	Y	1	11		0.12	Qapw(2)	
1073	1	P	1990	0	0	0	322	OL-90 12-26-179	2	2	40	Y	1	11		0.07	Qapw(2)	
1074	1	P	1990	0	0	0	329	OL-90 12-26-179	2	2	25	Y	1	11		0.11	Qapw(2)	
1075	1	P	1990	0	0	0	293	OL-90 12-26-179	2	2	63	Y	1	11		0.07	Qapw(2)	
1076	1	P	1990	0	0	0	352	OL-90 12-26-179	2	2	24	Y	2	11		0.07	Qapw(2)	
1077	1	D	1990	0	0	0	327	OL-90 12-26-179	2	2	35	Y	2	11		0.10	Qapw(2)	
1082	2	D	1967	0	1990	0	341	GH-67-5B-5	2	1	85	Y	1	13		0.57	Mm(r)	10 ft vert scarp

Slide_id	Lsi_process	Certainty	Id_date	Ls_size	Id2_date	Id2_size	Init_elev	Photo_number	Landform	Slp_shp	Gradient (%)	Delivery	Landuse	Siouxon_landform	Deep_seated_activity	Acres	Geol_unit	Comment
1083	2	D	1967	0	1981	0	257	GH-67-5B-5	2	1	31	Y	1	10		0.18	Mm(r)	Debris dam and pond at base of landslide in 1981 photographs; field evidence shows numerous subsidary failures all about 6 ft x 6 ft; entire feature consists of verticle sidewalls and rule ID'ed bedrock hollow
1084	1	D	1967	0	0	0	231	GH-67-5B-5	2	2	42	Y	5	10		0.26	Mm(r)	
1085	2	D	1967	0	2005	0	285	GH-67-5B-5	1	1	50	Y	5	10		0.23	Mm(r)	Destroyed road; 30 ft vert headwall; 60 ft wide
1085	2	P	1967	0	0	0	327	GH-67-58-8	2	2	31	Y	1	13		0.22	Mm(r)	
1086	2	P	1967	0	0	0	294	GH-67-5B-8	2	2	30	Y	1	10		0.24	Mm(r)	
1087	1	P	1998	0	0	0	466	ORTHO	0	2	32	Y	2	0		1.30	Qa	
1088	2	D	1981	0	0	0	310	OL-81 29-22-234	1	2	48	Y	5	10		0.35	Mm(r)	
1089	1	D	1981	0	0	0	123	OL-81 29-22-234	2	2	15	P	1	10		0.02	Mm(r)	
1090	1	D	1981	0	0	0	115	OL-81 29-22-234	2	2	16	P	1	13		0.01	Mm(r)	
1091	5	P	1981	0	0	0	260	OL-81 29-22-234	2	2	46	Y	3	10		0.86	Mm(r)	Marginal streams; disturbed canopy; ponded water at base; probable headwall visible
1092	2	D	1981	0	0	0	316	OL-81 29-22-234	2	1	28	Y	2	10		0.48	Mm(r)	Bedrock hollow initiation; debris flow visible to stream; ponds at base of debris flow
1093	2	D	1981	0	0	0	338	OL-81 29-22-234	2	1	49	Y	2	10		0.50	Mm(r)	Bedrock hollow initiation; debris flow channel visible final 200 ft to stream; debris dam visible at base
1094	2	P	1981	0	0	0	204	OL-81 29-22-234	1	2	38	Y	2	10		0.10	Mm(r)	Possible bedrock hollow initiation not visible

Slide_id	Lsi_process	Certainty	Id_date	Ls_size	Id2_date	Id2_size	Init_elev	Photo_number	Landform	Slp_shp	Gradient (%)	Delivery	Landuse	Siouxon_landform	Deep_seated_activity	Acres	Geol_unit	Comment
1095	2	D	1981	0	0	0	373	OL-81 29-22-234	2	1	51	Y	2	10		0.42	Mm(r)	Bedrock hollow initiation; debris flow travelled to stream; debris dam possible; pond visible upstream of debris flow
1096	2	P	1981	0	0	0	246	OL-81 29-22-234	1	1	50	Y	2	10		0.28	Mm(r)	Initiation not apparent
1097	1	D	1981	0	0	0	339	OL-81 29-22-234	2	1	95	Y	2	10		0.16	Mm(r)	Bedrock hollow initiation; runout not apparent; debris dam at base; probably initiated as earthflow
1098	1	P	1981	0	0	0	320	OL-81 29-22-234	2	1	47	I	2	10		0.10	Mm(r)	
1099	2	Q	1981	0	0	0	293	OL-81 29-22-234	1	2	21	Y	2	10		0.27	Mm(r)	Initiation point not visible; questionable landslide
1100	2	P	1980	0	0	0	1272	OL-H-80 11W-48	1	1	75	Y	5	0		0.19	MEbx	
1101	2	P	1980	0	0	0	1277	OL-H-80 11W-48	1	1	75	Y	5	0		0.66	MEbx	
1103	4	Q	1980	0	0	0	348	OL-H-80 11W-48	4	3	14	N	4	0	C	75.14	Qao	
1106	4	D	1980	0	0	0	589	OL-H-80 10.5W-48	4	3	105	N	4	0	B	147.95	Qao	
1107	1	Q	1980	0	0	0	348	OL-H-80 12w-49	1	2	62	P	1	11		0.18	Qapw(2)	
1108	2	P	1980	0	0	0	1515	OL-H-80 10.5W-48	1	1	84	Y	5	0		0.94	MEbx	
1109	2	P	1980	0	0	0	1453	OL-H-80 10.5W-48	1	1	70	Y	5	0		1.90	MEbx	
1111	1	Q	1998	0	0	0	896	ORTHO	1	1	67	Y	3	0		0.19	MEbx	
1112	1	P	1998	0	0	0	1207	ORTHO	1	2	77	I	5	0		0.02	MEbx	
1113	1	P	1997	0	0	0	461	OL97_2_21_141	5	1	31	P	5	10		0.50	Mm(r)	
1114	5	Q	1997	0	0	0	498	OL97_2_21_141	5	2	48	P	2	10		1.50	Mm(r)	
1115	1	Q	1997	0	0	0	497	OL97_2_21_141	5	1	42	P	2	10		0.19	Mm(r)	
1116	2	Q	1997	0	0	0	511	OL97_2_21_141	5	1	40	P	1	13		0.13	Mm(r)	
1117	5	Q	1997	0	0	0	441	OL97_2_22_153	2	1	33	P	3	10		0.35	Mm(r)	

Slide_id	Lsi_process	Certainty	Id_date	Ls_size	Id2_date	Id2_size	Init_elev	Photo_number	Landform	Slp_shp	Gradient (%)	Delivery	Landuse	Siouxon_landform	Deep_seated_activity	Acres	Geol_unit	Comment
1118	2	Q	1997	0	0	0	461	OL97_2_22_153	1	1	31	P	3	10		0.25	Mm(r)	
1119	5	Q	1997	0	0	0	362	OL97_2_22_153	2	1	15	P	3	10		0.15	Mm(r)	
1120	5	P	1997	0	0	0	385	OL97_2_22_153	2	1	27	P	3	10		0.10	Mm(r)	
1121	1	P	1997	0	0	0	391	OL97_2_22_153	1	1	32	P	3	10		0.06	Mm(r)	
1122	5	P	1997	0	0	0	557	OL97_2_22_153	2	1	65	P	3	10		0.26	Mm(r)	
1123	1	Q	1997	0	0	0	472	OL97_2_21_141	1	1	42	Y	2	10		0.17	Mm(r)	
1124	1	Q	1997	0	0	0	446	OL97_2_21_141	1	1	48	Y	2	10		0.10	Mm(r)	
1125	2	Q	1997	0	0	0	481	OL97_2_21_145	1	1	40	Y	2	13		0.18	Mm(r)	
1126	1	Q	1997	0	0	0	448	OL97_2_22_157	2	1	33	P	2	13		0.13	Mm(r)	
1127	5	Q	1997	0	0	0	605	OL97_2_22_157	2	0	23	P	2	10		0.13	MEbx	
1128	1	Q	1997	0	0	0	538	OL97_2_22_157	1	0	39	Y	2	10		0.46	MEbx	
1129	1	Q	1997	0	0	0	471	OL97_2_22_155	1	1	28	Y	5	13		0.20	Mm(r)	
1130	1	Q	1997	0	0	0	464	OL97_2_22_155	1	1	25	P	5	10		0.04	Mm(r)	
1131	1	Q	1997	0	0	0	469	OL97_2_22_155	1	1	45	Y	2	10		0.31	Mml	
1132	2	Q	1997	0	0	0	365	OL97_2_22_155	1	1	20	Y	2	13		0.13	Mm(r)	
1133	2	Q	1997	0	0	0	348	OL97_2_22_155	1	1	38	Y	2	13		0.07	Mm(r)	
1134	5	Q	1997	0	0	0	371	OL97_2_22_155	5	1	42	Y	2	13		0.14	Mm(r)	
1135	1	Q	1997	0	0	0	393	OL97_2_22_155	5	1	47	Y	2	10		0.06	Mm(r)	
1136	2	P	1997	0	0	0	492	OL97_2_22_155	1	1	52	Y	5	10		0.08	Mm(r)	
1137	1	P	1997	0	0	0	568	OL97_2_22_155	5	1	50	Y	2	13		0.11	Mm(r)	
1138	1	Q	1997	0	0	0	568	OL97_2_22_155	1	1	46	Y	2	10		0.25	Mm(r)	
1139	1	P	1997	0	0	0	232	OL97_2_25_193	2	1	45	Y	3	11		0.20	Qapwt(2m)	
1140	5	Q	1997	0	0	0	262	OL97_2_25_193	2	2	37	Y	3	11		0.13	Qapwt(2m)	

Slide_id	Lsi_process	Certainty	Id_date	Ls_size	Id2_date	Id2_size	Init_elev	Photo_number	Landform	Slp_shp	Gradient (%)	Delivery	Landuse	Siouxon_landform	Deep_seated_activity	Acres	Geol_unit	Comment
1141	5	Q	1997	0	0	0	278	OL97_2_25_193	2	2	29	Y	2	11		0.44	Qapwt(2m)	
1142	1	P	1997	0	0	0	308	OL97_2_25_193	2	1	44	Y	2	11		0.14	Qapwt(2m)	
1143	5	P	1997	0	0	0	318	OL97_2_25_193	2	1	44	Y	2	11		0.11	Qapwt(2m)	
1144	1	P	1997	0	0	0	300	OL97_2_25_193	1	2	50	Y	2	11		0.05	Qapwt(2m)	
1145	1	P	1997	0	0	0	300	OL97_2_25_193	1	2	37	Y	2	11		0.05	Qapwt(2m)	
1146	1	P	1997	0	0	0	327	OL97_2_25_193	1	2	78	I	1	11		0.01	Qapwt(2m)	
1147	1	P	1997	0	0	0	321	OL97_2_25_193	2	1	84	Y	5	11		0.06	Qapwt(2m)	
1148	1	P	1997	0	0	0	352	OL97_2_25_193	2	1	85	Y	2	11		0.07	Qapwt(2m)	
1149	5	P	1997	0	0	0	378	OL97_2_25_193	2	1	68	Y	2	11		0.09	Qapwt(2m)	
1150	1	Q	1980	0	0	0	380	OL-H-80 12-47A	4	1	63	Y	1	11		0.10	Qapwt(2m)	
1151	5	P	1997	0	0	0	357	OL97_2_25_193	2	2	66	P	3	11		0.08	Qapwt(2m)	
1152	1	Q	1997	0	0	0	357	OL97_2_25_193	4	1	52	Y	1	11		0.02	Qapwt(2m)	
1153	1	P	1997	0	0	0	204	OL97_5_27_128	4	2	33	N	1	11		0.01	Qapo	
1154	1	D	1997	0	0	0	227	OL97_5_27_128	4	2	39	P	1	11		0.24	Qapo	
1155	1	D	1997	0	0	0	260	OL97_5_27_128	4	2	36	P	1	11		0.01	Qapo	
1156	1	D	1997	0	0	0	286	OL97_5_27_128	4	1	37	P	1	11		0.15	Qapo	
1157	1	D	1997	0	0	0	236	OL97_5_27_128	4	2	33	Y	1	11		0.01	Qapo	
1158	4	Q	1997	0	0	0	364	OL97_5_32_200	4	3	33	Y	4	12		54.34	Qao	
1159	1	P	1997	0	0	0	330	OL97_5_34_233	9	2	101	Y	4	10		0.34	Qao	
1160	1	D	1997	0	0	0	437	OL97_5_34_233	9	3	88	Y	2	10		0.21	Qapo	
1161	4	Q	1997	0	0	0	520	OL97_5_34_233	4	3	71	N	4	11		4.81	Qapo	
1162	1	D	1997	0	0	0	403	OL97_5_34_233	9	4	44	Y	2	11		0.11	Qapo	
1163	5	Q	1997	0	0	0	1000	OL97_5_34_232	2	2	31	N	4	15		3.45	Qapt(m)	

Slide_id	Lsi_process	Certainty	Id_date	Ls_size	Id2_date	Id2_size	Init_elev	Photo_number	Landform	Slp_shp	Gradient (%)	Delivery	Landuse	Siouxon_landform	Deep_seated_activity	Acres	Geol_unit	Comment
1250	2	D	1981	0	0	0	396	OL-81 29-22-234	1	1	51	Y	5	10		0.11	Mm(r)	Road appears abandoned by 1981
1251	1	P	1981	0	0	0	375	OL-81 29-22-234	2	2	40	P	2	10		0.09	Mm(r)	Canopy hole reveals visible scar; probable bedrock hollow initiation
1253	2	P	1981	0	0	0	365	OL-81 29-22-234	2	2	38	Y	2	10		0.34	Mm(r)	
1254	1	Q	1981	0	0	0	254	OL-81 29-22-234	2	2	28	I	2	10		0.14	Mm(r)	Canopy hole
1255	2	P	1981	0	1998	0	267	OL-81 29-22-234	2	1	32	Y	2	10		0.27	Mm(r)	Canopy hole only reveals initiation in 1981; orthophotograph reveals enlongate canopy hole to main drainage; sub-vert limbs; 2 subsidary shallow-rapids too small to map; PIP
1256	2	P	1981	0	0	0	228	OL-81 29-22-234	2	1	60	Y	2	10		0.15	Mm(r)	Canopy hole; debris dam at base created pond; PIP
1257	2	P	1981	0	0	0	219	OL-81 29-22-234	2	1	45	Y	2	10		0.14	Mm(r)	Canopy hole; tension cracks at head of hollow; PIP
1258	1	Q	1981	0	0	0	196	OL-81 29-22-234	2	2	35	Y	2	10		0.14	Mm(r)	Canopy change; decidious canopy appears to extend into channel, possibly pushing stream to the north
1259	1	P	1981	0	0	0	325	OL-81 29-22-234	2	2	33	I	2	13		0.05	Mm(r)	Bedrock hollow failure; runout not evident
1260	2	P	1981	0	0	0	485	OL-81 29-22-234	2	1	49	Y	1	10		0.32	Mm(r)	
1264	2	P	1981	0	0	0	318	OL-81 29-22-234	2	1	56	Y	5	10		0.07	Mm(r)	
1265	2	P	1981	0	0	0	514	OL-81 29-22-234	2	1	59	P	3	10		0.37	Mm(r)	Canopy hole

Slide_id	Lsi_process	Certainty	Id_date	Ls_size	Id2_date	Id2_size	Init_elev	Photo_number	Landform	Slp_shp	Gradient (%)	Delivery	Landuse	Siouxon_landform	Deep_seated_activity	Acres	Geol_unit	Comment
1266	1	D	1981	0	0	0	514	OL-81 29-22-234	2	1	80	P	3	10		0.37	Mm(r)	Canopy hole; very unstable ground; 2 observed subsidary failures both ~6 ft wide and ~10 ft long; neither delivered
1267	1	D	1981	0	0	0	503	OL-81 29-22-234	2	1	80	P	3	10		0.27	Mm(r)	Canopy hole; 2 old growth stumps at head of LS
1268	1	D	1981	0	0	0	450	OL-81 29-22-234	2	1	22	P	5	10		0.20	Mm(r)	Possible sidecase faliure
1269	2	P	1981	0	0	0	326	OL-81 29-22-236	2	1	23	Y	5	10		0.48	Mm(r)	
1270	2	P	1981	0	0	0	221	OL-81 29-22-236	1	1	23	P	3	10		0.14	Mm(r)	
1271	2	P	1981	0	0	0	309	OL-81 29-22-236	2	1	27	Y	5	13		0.40	Mm(r)	
1272	2	P	1981	0	0	0	334	OL-81 29-22-236	2	1	39	Y	5	10		0.42	Mm(r)	
1273	2	P	1981	0	0	0	246	OL-81 29-22-236	2	1	34	Y	5	10		0.19	Mm(r)	
1274	2	P	1981	0	0	0	387	OL-81 29-22-236	2	2	30	P	5	10		0.12	Mm(r)	
1275	1	D	1981	0	0	0	413	OL-81 29-22-236	2	1	69	Y	1	10		0.26	Mm(r)	
1276	1	D	1981	0	0	0	403	OL-81 29-22-236	2	1	34	Y	1	10		0.06	Mml	Heavily scarred ground from cable logging
1277	1	D	1981	0	0	0	305	OL-81 29-22-236	1	2	33	P	1	10		0.01	Mml	Heavily scarred ground from cable logging
1278	1	D	1981	0	0	0	328	OL-81 29-22-236	1	2	30	P	1	10		0.01	Mml	Heavily scarred ground from cable logging
1279	1	D	1981	0	0	0	323	OL-81 29-22-236	1	2	29	P	1	10		0.01	Mml	Heavily scarred ground from cable logging
1280	1	D	1981	0	0	0	294	OL-81 29-22-236	1	2	27	P	1	10		0.01	Mml	Heavily scarred ground from cable logging
1281	1	D	1981	0	0	0	355	OL-81 29-22-236	1	2	37	P	1	10		0.01	Mml	Heavily scarred ground from cable logging
1282	1	D	1981	0	0	0	434	OL-81 29-22-236	1	2	45	P	1	13		0.01	Mml	Heavily scarred ground from cable logging

Slide_id	Lsi_process	Certainty	Id_date	Ls_size	Id2_date	Id2_size	Init_elev	Photo_number	Landform	Slp_shp	Gradient (%)	Delivery	Landuse	Siouxon_landform	Deep_seated_activity	Acres	Geol_unit	Comment
1283	1	D	1981	0	0	0	378	OL-81 29-22-236	2	2	36	P	1	10		0.01	Mml	Heavily scarred ground from cable logging
1284	2	P	1981	0	0	0	417	OL-81 29-22-236	1	1	35	Y	5	13		0.12	Mm(r)	
1285	1	P	1981	0	0	0	387	OL-81 29-22-238	9	3	20	Y	2	13		0.05	Mm(r)	
1286	1	P	1981	0	0	0	390	OL-81 29-22-238	9	3	20	Y	2	13		0.05	Mm(r)	
1287	1	P	1981	0	0	0	403	OL-81 29-22-234	1	2	35	Y	1	10		0.01	Mm(r)	
1288	1	P	1998	0	0	0	1305	ORTHO	7	2	38	I	5	15		1.09	Qapwt(2m)	Road at initiation point appears abandoned
1289	4	P	1981	0	0	0	399	OL-81 25-33-166	4	2	57	N	4	11	DI	30.53	Qao	Bocy of DSLS. In 1981 photograph, forest partially covers west half of landslide. Field: humocky body with standing water, but could be root holes
1289	4	P	1981	0	0	0	399	OL-81 25-33-166	4	2	57	Y	4	11	DI	6.40	Qao	Headwall of DSLS. In 1981 photograph, forest partially covers west half of landslide. Field: prominent 10 ft wide horizontal bench near top of scarp
1290	4	D	1981	0	0	0	399	OL-81 25-33-166	4	1	90	Y	4	11	DI	4.49	Qao	Spring at base of head; approx 2 gpm; arcuate scarp
1291	5	P	1981	0	0	0	399	OL-81 25-33-166	4	2	66	P	4	11	DI	1.76	Qao	
1292	2	D	2005	0	0	0	347	FIELD	8	2	90	N	3	11		0.05	Qls	<5 years old; 18 ft wide; 3 ft vert headscarp
1293	1	D	2005	0	0	0	262	FIELD	8	2	90	Y	2	11		0.01	Qls	<10 year old; 30 feet wide; on toe of LS 1289

Slide_id	Lsi_process	Certainty	Id_date	Ls_size	Id2_date	Id2_size	Init_elev	Photo_number	Landform	Slp_shp	Gradient (%)	Delivery	Landuse	Siouxon_landform	Deep_seated_activity	Acres	Geol_unit	Comment
1294	1	D	2005	0	0	0	257	FIELD	1	1	90	P	1	11		0.10	Qapo	Post-havest slide; may have occurred on fluvial terrace on Qapo
1295	1	D	2005	0	0	0	565	FIELD	2	1	80	P	3	13		0.10	Mm(r)	Failed between roots; 5 ft deep failure
1296	5	D	2005	0	0	0	472	FIELD	2	2	70	Y	3	10		0.06	Mm(r)	Translational slide; PIP 1-2 gpm
1297	5	D	2005	0	0	0	469	FIELD	2	2	70	Y	3	10		0.04	Mm(r)	Translational slide
1298	5	D	2005	0	0	0	272	FIELD	2	1	75	Y	3	10		0.43	Mm(r)	Possible earthflow; alder in scarp 12" dbh
1299	5	D	2005	0	0	0	516	FIELD	2	2	72	Y	1	13		0.13	Mm(r)	Possible dip slope or joining plane initiation; 10 ft deep x 60 ft by 100 ft; clay-rich; sits immediately upslope of leave tree buffer
1300	1	D	2005	0	0	0	405	FIELD	1	2	70	Y	1	10		0.04	Mm(r)	Ocurred possibly due to blowdown of leave trees; fallen trees are all flagged similar to standing leave trees
1301	7	D	2005	0	0	0	425	FIELD	2	1	120	Y	5	10		0.61	Mm(r)	
1302	4	D	2005	0	0	0	716	FIELD	2	2	75	N	5	13	AR	0.16	Mm(r)	~10 12" DBH trees on translated/rotated block; 10 ft vert scarp parallel to road

Appendix B -- Mass-Wasting Summary Tables

Table B-1: Mass-Wasting Summary of Landform 10

Activity	Shallow-rapid landslides	Debris flows	Debris avalanches	Deep-seated	Shallow sporadic deep-seated	Earthflows	Rock topple	Snow avalanche	Totals
Clear cut (timber 0-5 Yrs.)	13	3	-	-	-	-	-	-	16
Young timber (5-15 yrs.)	15	12	-	-	2	-	-	-	29
Submature timber (15-50 yrs.)	3	3	-	-	8	-	-	-	14
Mature timber (>50 yrs.)	1	-	-	-	-	-	-	-	1
Road related	7	15	-	-	1	1	-	-	24
Partial cut	-	-	-	-	-	-	-	-	0
Yarding	-	-	-	-	-	-	-	-	0
Alpine	-	-	-	-	-	-	-	-	0
Other (e.g., housing)	-	-	-	-	-	-	-	-	0

Table B-2: Mass-Wasting Summary of Landform 11

Activity	Shallow-rapid landslides	Debris flows	Debris avalanches	Deep-seated	Shallow sporadic deep-seated	Earthflows	Rock topple	Snow avalanche	Totals
Clear cut (timber 0-5 Yrs.)	44	7	-	-	-	-	-	-	51
Young timber (5-15 yrs.)	8	-	-	-	3	-	-	-	11
Submature timber (15-50 yrs.)	1	1	-	-	2	-	-	-	4
Mature timber (>50 yrs.)	2	-	-	4	4	-	-	-	10
Road related	4	-	-	-	-	-	-	-	4
Partial cut	-	-	-	-	-	-	-	-	0
Yarding	-	-	-	-	-	-	-	-	0
Alpine	-	-	-	-	-	-	-	-	0
Other (e.g., housing)	-	-	-	-	-	-	-	-	0

Table B-3: Mass-Wasting Summary of Landform 12

Activity	Shallow-rapid landslides	Debris flows	Debris avalanches	Deep-seated	Shallow sporadic deep-seated	Earthflows	Rock topple	Snow avalanche	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	-	-	-	-	-	-	-	-	0
Partial cut	-	-	-	-	-	-	-	-	0
Yarding	-	-	-	-	-	-	-	-	0
Alpine	-	-	-	-	-	-	-	-	0
Other (e.g., housing)	-	-	-	-	-	-	-	-	0

Table B-4: Mass-Wasting Summary of Landform 13

Activity	Shallow-rapid landslides	Debris flows	Debris avalanches	Deep-seated	Shallow sporadic deep-seated	Earthflows	Rock topple	Snow avalanche	Totals
Clear cut (timber 0-5 Yrs.)	2	3	-	-	1	-	-	-	6
Young timber (5-15 yrs.)	5	3	-	-	1	-	-	-	9
Submature timber (15-50 yrs.)	1	-	-	-	-	-	-	-	1
Mature timber (>50 yrs.)	-	-	-	-	-	-	-	-	0
Road related	1	2	-	1	-	-	-	-	4
Partial cut	-	-	-	-	-	-	-	-	0
Yarding	-	-	-	-	-	-	-	-	0
Alpine	-	-	-	-	-	-	-	-	0
Other (e.g., housing)	-	-	-	-	-	-	-	-	0

Table B-4: Mass-Wasting Summary of Landform 15

Activity	Shallow-rapid landslides	Debris flows	Debris avalanches	Deep-seated	Shallow sporadic deep-seated	Earthflows	Rock topple	Snow avalanche	Totals
Clear cut (timber 0-5 Yrs.)	-	-	-	-	-	-	-	-	0
Young timber (5-15 yrs.)	-	-	-	-	-	-	-	-	0
Submature timber (15-50 yrs.)	-	-	-	-	-	-	-	-	0
Mature timber (>50 yrs.)	-	-	-	-	1	-	-	-	1
Road related	1	-	-	-	-	-	-	-	1
Partial cut	-	-	-	-	-	-	-	-	0
Yarding	-	-	-	-	-	-	-	-	0
Alpine	-	-	-	-	-	-	-	-	0
Other (e.g., housing)	-	-	-	-	-	-	-	-	0