Clallam River WAU

LANDSLIDE HAZARD ZONATION PROJECT

Clallam County, Washington

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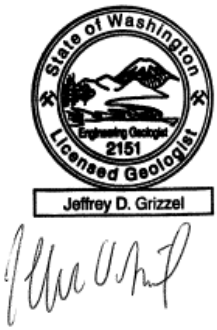

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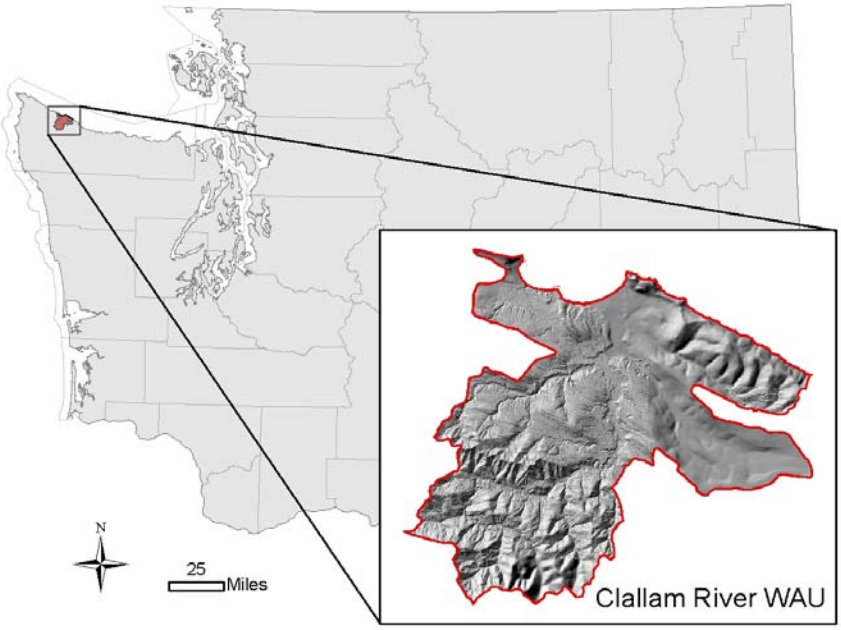

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Cover photo: Terrace face east of Clallam Bay on the Straits of Juan de Fuca. Photo from Washington Department of Ecology, 2004.

Contents

1.0 Purpose and Scope.....1

2.0 Project Area Overview.....1

3.0 Methods.....2

4.0 Results.....4

5.0 Limitations and Confidence in Work Products.....8

6.0 Literature Cited 9

Appendix A- A-1 Landslide Inventory
Appendix B- A-3 Mass Wasting Summary Tables
Appendix C- A-4 Landslide Area Hazard Rates

1.0 Purpose and Scope

This report describes the results of a mass wasting assessment for forestlands managed by the Washington Department of Natural Resources (DNR) in Clallam County, Washington. The assessment includes a landslide inventory and landslide hazard zones that describe the sensitivity of different parts of the landscape to forest practices such as timber harvest and road construction. The results of the assessment are intended for use by foresters, engineers, and other natural resource professionals involved in forest practices planning, review, implementation, and regulation in the project area. The assessment is part of a larger, statewide effort to map potentially unstable slopes on lands regulated under Washington's Forest Practices Act (RCW 76.09). This larger effort is known as the Landslide Hazard Zonation (LHZ) Project and is being conducted by the Washington Department of Natural Resources.

The basis of the Clallam Bay assessment is a landslide inventory compiled from aerial photographs spanning the period 1977 through 2003. A primary assumption underlying the assessment is that the physical characteristics of sites where landslides have occurred in the past can be used to predict where landslides are likely to occur in the future. Therefore, factors that influence landslide occurrence such as landform type, slope gradient, slope form, and associated land use activity are quantified and/or described as part of the assessment. While some field validation of landslide data was conducted as part of the project, the assessment largely represents a reconnaissance level survey of landslides and associated hazard zones. End-users of this information should be aware of these limitations and exercise caution when translating map-based landslide hazard zone boundaries to field settings.

2.0 Project Area Overview

2.1 Physical Setting

The Clallam Bay Watershed Administrative Unit (WAU) is located in Townships 31 and 32 North, Ranges 11, 12, and 13 West in Clallam County, Washington. The project area covers approximately 22,100 acres of which the Washington DNR manages 48 percent. The remaining lands are held by private landowners with less than 1 percent shared between the United States Forest Service, United States Coast Guard, Washington State Parks, and Washington State Department of Corrections.

2.2 Physiography

Elevations in the study area range from a high of 2670 feet on Ellis Mountain to sea level along the Strait of Juan de Fuca. Topography within the WAU is varied with a distinct physiographic change between the north and south portions of the project area. The primary geomorphic influence in the northern half of the study area was from glacial erosion and deposition from the Juan de Fuca lobe of the Cordilleran ice sheet (15,000 to 13,000 years ago). The glacial topography is characterized by gentle slopes, ridgelines, and valleys roughly trending east to west, reflecting the direction of glacial movement. In the southern half of the study area, deeply incised streams and narrow ridges are the

dominant topographic characteristics. Steep planar slopes and large convergent landforms are typical.

2.3 Climate and Hydrology

Like the rest of western Washington, the Clallam Bay project area has a maritime-type climate with cool, wet winters and warm, dry summers. Average annual precipitation averages 100 inches in the southwest corner to 70 inches in the northeast corner of the study area (DNR Mapping Tools: Climatology: Avg. Yearly Precipitation). Less than three percent of the area lies within the rain-on-snow precipitation zone (DNR Mapping Tools: Climatology: Rain on Snow layer), all of which is in the southern portion of the WAU.

2.4 Geology

Thorough discussions of the general bedrock geology in the vicinity of the study area are presented in Snavely and others (1993) and Schasse (2003). Bedrock in the study area represents a broad cross-section of Olympic Peninsula geology. Thinly-layered sedimentary rocks (15 to 45 million years) of the Olympic Core complex (Tabor and Cady, 1978; Gerstel and Lingley, 2000) dominate the study area. These are sandstone and siltstone with minor claystone, all of which weather readily to thick, gummy soils. The Crescent basalts (45 to 53 million years) are prominent in the southwestern part of the study area and are primarily pillow lava and breccias interbedded with sedimentary deposits (Schassee, 2003).

Valleys and areas proximal to the Strait of Juan de Fuca display a variety of Quaternary glacial deposits from the Cordilleran ice sheet (15,000 to 13,000 years ago), chiefly glacial till and drift. See Schassee (2003) for detailed descriptions of these units.

3.0 Methods

The Clallam Bay mass wasting assessment was conducted in accordance with the methods described in the Landslide Hazard Zonation Project Protocol (Washington Department of Natural Resources, 2006). 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 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.

The Clallam Bay landslide inventory was developed using 1:12,000 scale aerial photographs from 1977, 1985, 1990, and 2003 (Table 1). Color orthophotographs (18-inch pixels) flown from 2003 to 2005 were also reviewed as part of the inventory. Mapping was generally accomplished by digitizing the landslides directly from aerial photographs and/or orthophotographs into 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 Light Detection and Ranging (LiDAR) Digital Elevation Models (DEM) for Clallam County (flown 2001). 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 and landforms was performed at scales equal to or greater than 1:3000. The LiDAR DEM proved useful for identifying deep-seated landslides and smaller landforms that could not be identified through aerial photographs or 10-m DEMs. Also, landforms such as inner gorges, bedrock hollows, and more subtle convergent topography were easier to identify.

Table 1. Aerial photographs and orthophotographs used in developing the Clallam Bay landslide inventory.

Year	Scale	Image	Flight symbol	Reference/ ownership	Comment
1977	1:12,000	black & white	OL-77	DNR	No missing photos
1985	1:12,000	black & white	OL-85	DNR	No missing photos
1990	1:12,000	black & white	OL-90	DNR	No missing photos
2003	1:12,000	color	OL-C-03	DNR	No missing photos

Non-DNR managed lands lacked LiDAR DEM data, so available USGS 10-m DEMs were analyzed. The resolution of these data is much coarser than 6-ft LiDAR DEMs, so hazard polygons in these areas tend to be more broadly defined.

The four sets of 1:12,000 scale aerial photographs listed above were viewed through a mirror stereoscope at 3x magnification. Translucent overlays were affixed to odd numbered exposures in each flight line. All visible mass wasting features were mapped and classified according to mass wasting process, year of occurrence, certainty of occurrence, landslide size, landform, slope shape, slope gradient, sediment/debris delivery, associated land use, and elevation. All mass wasting features and their attributes were electronically recorded using ArcInfo ArcMap software. The resulting landslide inventory map is included as Map A-1. Landslide inventory data (i.e., landslide attributes) are shown on Form A-1.

Accurately transferring the location of mass wasting features from aerial photographs to the computer sometimes proved difficult, particularly for small landslides where few, if any, nearby geographic references (e.g., roads or stream bends) were present. Where available, later aerial photographs were reviewed in order to provide a different spatial perspective and improve the accuracy in locating the landslide. The digital orthophotographs and LiDAR DEM often proved useful in this respect.

To develop the landslide hazard zones, commonalities among landscape and landslide attributes were identified. Portions of the project area where no (or very few) landslides occurred were grouped into a single “low hazard” landslide hazard zone. Portions of the project area with a high frequency of landslides were generally identified as “high hazard” areas. Within these generalized high hazard areas, discrete high hazard zones

were delineated based on differences in landforms, slope forms, slope gradients, and mass wasting processes. Portions of the project area not identified as either “low hazard” or “high hazard” were initially classified as “moderate hazard”. Validation of these preliminary hazard ratings was performed in accordance with the quantitative approach described in the Landslide Hazard Zonation Project Protocol (Washington Department of Natural Resources, 2006).

The LiDAR DEM derived slope map was used as a starting point for delineating the boundaries of the landslide hazard zones (Map A-2). Hazard zone boundaries were refined using the 1:12,000 aerial photographs. Consistent with the LHZ Project Protocol (Washington Department of Natural Resources 2006), all low hazard landforms were mapped first, followed by all forest practices rule-defined high hazard landforms. Low hazard landforms include terraces, valley benches, mid-slope benches, planar slopes, and ridges where no landslides were documented. Rule-defined high hazard landforms included convergent headwalls, bedrock hollows, and inner gorges with slope gradients in excess of 70 percent, the groundwater recharge areas of deep-seated landslides in glacial materials, and the outer edges of channel meander bends.

4.0 Results

A total of 145 landslides were documented to have occurred from 1977 through 2003 in the Clallam Bay project area (Map A-1). The majority of project area landslides were shallow-undifferentiated and debris flows (83 landslides or 57 percent of landslides in the project area). Ancient, deep-seated landslides, shallow-sporatic landslides, and earthflows made up the remaining mass wasting events (62 landslides or 43 percent of landslides in the project area). Eighty-two (82) percent of the shallow-undifferentiated and debris flows were associated with bedrock hollow, convergent headwalls, and inner gorge landforms.

Table 2. Landslides mapped in the Clallam Bay project area during the period 1977-2003 listed by mass wasting process class.

Landslide process	Number of landslides
Shallow undifferentiated	64
Debris flow	18
Debris slide/debris avalanche	1
Deep-seated	55
Earthflow	6
Rock topple/fall	1
Snow avalanche	0
Total	145

The landslide inventory results were used to develop nine (9) Landslide Hazard Zones with overall hazard ratings ranging from “LOW” to “VERY HIGH”. Due to the various DEM resolutions available for this project, some areas with similar physical characteristics were split into separate hazard zones to reflect varying confidence in the

available DEM data. For example, the LiDAR DEM allowed for very precise delineation of rule-identified landforms and large, deep-seated landslides whereas the 10-m DEM is better suited for landscape level mapping. Hazard Zones 1 through 6 were delineated using LiDAR with the exception of zone 3, which is the terrace face along the Strait of Juan de Fuca. The remaining Hazard Zones 10 to 12 were delineated with the 10-m DEM. These zones tend to be broadly delineated and the mapping accuracy and precision is expected to be low relative to those zones delineated using the LiDAR DEM. The landslide hazard zones are illustrated on Map A-2 and detailed descriptions are included on Form A-2. Form A-3 reports the number of landslides by land use class and mass wasting process for each landslide hazard zone. A brief overview of each zone is provided below.

Landslide Hazard Zone 1 – Probable Convergent Headwalls (101), Bedrock Hollows (102), and Inner Gorges (103) – VERY HIGH Hazard

This zone includes rule-identified convergent headwalls, bedrock hollows, and inner gorges. These features have been subdivided and coded as 101 for convergent headwalls, 102 for bedrock hollows, and 103 for inner gorges. Slope gradients exceed 70 percent (35 degrees). Slope form ranges from broadly convergent to strongly convergent for headwalls and bedrock hollows. Slope form within smaller inner gorges (e.g., first order streams) is almost always planar while slope form within larger inner gorges (e.g., third order streams) is generally planar but includes convergent, nested bedrock hollows and divergent spur ridges between hollows. Mass wasting within this zone is almost exclusively limited to shallow-rapid processes including debris avalanches, debris flows and long run-out debris torrents. Thirty-eight percent of all landslides mapped within the project area lie within this zone; 60 percent of all shallow-rapid (including shallow-undifferentiated, debris flow, and debris slide/avalanche) landslides mapped within the project area lie within this zone; and 43 percent of landslides within this hazard zone were road-related. This zone encompasses 1729 acres, or eight percent of the project area.

Landslide Hazard Zone 2 – Probable Meander Bends – HIGH Hazard

This zone contains rule-identified meander bends, which are the steep slopes (or cut bank) on the outer side of a curve in a stream. Slope gradients exceed 70 percent (35 degrees) but can be less above the cut bank. Slope form ranges from broadly convergent to strongly convergent on the cut bank of large streams, which is primarily on the Clallam River. Mass wasting within this zone is probably limited to shallow-rapid processes including debris avalanches and debris flows. No landslides were mapped within the project area within this zone. This zone encompasses 29 acres, or less than one percent of the project area.

Landslide Hazard Zone 3 – Probable Terrace Faces – MODERATE Hazard

Slope form ranges from broadly divergent to strongly convergent along the shoreline of the Strait of Juan de Fuca. This zone includes convergent headwalls, bedrock hollows, and inner gorges. Slope gradients exceed 70 percent (35 degrees) in many places. Mass wasting within this zone is almost exclusively limited to shallow-rapid processes including debris avalanches, and debris flows. Several ancient deep-seated landslides have been identified as well as small, sporadic deep-seated landslides. Mapping of

shallow landslides within this zone proved difficult because of the poor lighting conditions in aerial photographs due to the northern exposure of the slopes and the low angle lighting conditions necessary for high quality aerial photographs. Oblique aerial photographs taken by the Washington Department of Ecology (1994) reveal dozens of scars from shallow-undifferenated landslides, the majority of which were not identifiable with aerial photographs. Ten percent of all landslides mapped within the project area lie within this zone; 13 percent of all shallow-rapid (including shallow-undifferentiated, debris flow, and debris slide/avalanche) landslides mapped within the project area lie within this zone; and four percent of landslides within this hazard zone were road-related. This zone encompasses 654 acres, or three percent of the project area.

Landslide Hazard Zone 4 – Convergent to Planar Slopes greater than 60% – MODERATE Hazard

This zone includes broadly convergent to planar slopes greater than 60 percent and is dominant in the southern portion of the study area where streams have incised deeply into easily eroded bedrock. This zone is typically adjacent to HIGH and VERY HIGH hazard zones and rule-identified potentially unstable landforms. Six percent of all landslides mapped within the project area lie within this zone; 10 percent of all shallow-rapid (including shallow-undifferentiated, debris flow, and debris slide/avalanche) landslides mapped within the project area lie within this zone; and 18 percent of landslides within this hazard zone were road-related. This zone encompasses 770 acres, or four percent of the project area.

Landslide Hazard Zone 5 – Probable Deep-seated Landslides – HIGH Hazard

This zone is entirely landscape-scale, ancient, deep-seated landslides that are apparent in LiDAR and rarely observable on aerial photography. Surface morphology is typically hummocky with deeply incised streams and oversteepened headscarps and toes. These features tend to be stable; however, field reconnaissance may be necessary when management activities are planned in this zone. Twenty-eight percent of all landslides mapped within the project area lie within this zone; no shallow-rapid (including shallow-undifferentiated, debris flow, and debris slide/avalanche) landslides are mapped within the project area lie within this zone; and no landslides within this hazard zone were road-related. This zone encompasses 664 acres, or three percent of the project area.

Landslide Hazard Zone 6 – Benches, Ridges, and Valley Walls (LiDAR DEM) – LOW Hazard

This zone includes terraces, valley walls, toeslope, and midslope benches, and prominent ridges between basins and sub-basins. Slope gradients (based on the LiDAR DEM) are less than 60 percent and slope form ranges from broadly convergent to planar on benches and slopes to broadly divergent on ridges. Large, contiguous blocks of this zone lie in the north half of the field area, especially where continental glaciers have scoured the landscape. Twelve percent of all landslides mapped within the project area lie within this zone; six percent of all shallow-rapid (including shallow-undifferentiated, debris flow, and debris slide/avalanche) landslides mapped within the project area lie within this zone; and seven percent of landslides within this hazard zone were road-related. This zone encompasses 10,329 acres, or 47 percent of the project area.

Landslide Hazard Zone 10 – Benches, Ridges, and Valley Walls (10-m DEM) – LOW Hazard

This zone includes terraces, valley walls, toeslope, and midslope benches, and prominent ridges between basins and sub-basins. Slope form ranges from broadly convergent to planar on benches and slopes to broadly divergent on ridges. Large, contiguous blocks of this zone lie in the north half of the field area, especially where continental glaciers have scoured the landscape. No landslides were mapped within this zone. This zone encompasses 6371 acres, or 29 percent of the project area.

Landslide Hazard Zone 11 – Planar to Convergent Slopes (10-m DEM) – MODERATE Hazard

This zone lies between ridge tops and valley bottoms. Slopes appear moderate; however LiDAR data adjacent to this area revealed convergent headwalls, bedrock hollows, and inner gorges not visible through the canopy. Slope gradients is typically 60 percent but can potentially exceed 70 percent (35 degrees) in some locations. Slope form ranges from broadly convergent to strongly convergent for headwalls and bedrock hollows. No landslides were mapped within the project area lie within this zone. This zone encompasses 1367 acres, or six percent of the project area.

Landslide Hazard Zone 12 – Probable Convergent Headwalls, Bedrock Hollows, and Inner Gorges (10-m DEM) – VERY HIGH Hazard

This zone includes convergent headwalls, bedrock hollows, and inner gorges. Slope gradients exceed 70 percent (35 degrees). Slope form ranges from broadly convergent to strongly convergent for headwalls and bedrock hollows. Slope form within smaller inner gorges (e.g., first order streams) is almost always planar while slope form within larger inner gorges (e.g., third order streams) is generally planar but includes convergent, nested bedrock hollows and divergent spur ridges between hollows. Mass wasting within this zone is almost exclusively limited to shallow-rapid processes including debris avalanches, debris flows and long run-out debris torrents. Less than two percent of all landslides mapped within the project area lie within this zone; less than three percent of all shallow-rapid (including shallow-undifferentiated, debris flow, and debris slide/avalanche) landslides mapped withing the project area lie within this zone; and seven percent of landslides within this hazard zone were road-related. This zone encompasses 209 acres, or one percent of the project area.

The quantitative approach described in the Landslide Hazard Zonation Project Protocol (Washington Department of Natural Resources, 2006) was used to assign overall hazard ratings to the hazard zones (Table 3). Overall hazard ratings are based on the landslide frequency rate (number of landslides/acre/year) and the landslide area rate for delivery (area of delivering landslides/acre/year). Only landslides with definite or probable assigned delivery ratings (Form A-1) were included in the calculation of the landslide area rate for delivery.

The quantitative approach described above was not used to assign overall hazard ratings for the remaining zones 6 and 10. Landslide Hazard Zone 6 (LiDAR) and 10 (10-m

DEM) were assigned a “LOW” overall hazard rating due to the very small number of landslides mapped within the zone (Zone 6 had 17 landslides distributed across 10,329 acres and zone 10 had no landslides across 6371 acres). It is possible that the zone 6 landslides are associated with higher hazard inclusions (e.g., small bedrock hollows or inner gorges) embedded within the mapped low hazard area.

Table 3. 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 26-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. Note that Landform 1 is subdivided into units (see above): 101, 102, and 103.

	Landform number									WAU
	1	2	3	4	5	6	10	11	12	
Area of Landform (acres)	1729	29	654	770	664	10,329	6371	1367	209	22122
Number of Landslides	61	0	14	8	41	17	0	0	2	143
Total number of photo years	28	28	28	28	28	28	28	28	28	28
Landslide Frequency Rate = (number of slides * 1,000,000 / Landform area / photo years)	1260	0	765	371	2204	59	0	0	341	231
Landslide Frequency Rate Qualtative Rating	**Very high**	**Low**	**High**	**High**	**Very high**	**Low**	**Low**	**Low**	**High**	**High**
Number of 'Delivering' Landslides	57	0	2	6	0	6	0	0	2	73
Area of 'Delivering' Landslides (acres)	24.4	0.0	0.6	3.2	0.0	1.8	0.0	0.0	6.6	36.6
Landslide Area Rate for Delivery = (area of delivering landslides * 1 million / Landform area / photo years)	504	0	35	147	0	6	0	0	1127	59
Landslide Area Rate for Delivery Qualitative Rating	**High**	**Low**	**Low**	**Moderate**	**Low**	**Low**	**Low**	**Low**	**Very high**	**Low**
Overall Hazard Rating	**Very High**	**High**	**Moderate**	**Moderate**	**Moderate**	**Low**	**Low**	**Moderate**	**Very High**	**Low**

5.0 Limitations and Confidence in Work Products

The results of this assessment are intended for use by foresters, engineers, and other natural resource professionals involved in the planning, review, implementation, and regulation of forest practices activities on forestlands in the project area. The hazard zones described in this assessment are based on landslide data specific to the project area and the author’s knowledge and experience working in similar terrain in other parts of the Olympic Peninsula.

Users should find a relatively high degree of correlation between the written hazard zone descriptions and the associated forest practices sensitivities and assigned hazard ratings. However, because landslide hazard zones are based on interpretations of remote imagery, users should expect to find discrepancies between the mapped hazard zone boundaries

and actual ground conditions. For example, the true spatial extent of landforms such as inner gorges and bedrock hollows may differ somewhat from the mapped extent; in some cases hazard zones may be larger than depicted on Map A-2 while in other cases, they may be smaller.

In addition to the potential differences described above, some mapped hazard zones include “errors of omission” where undetected and unmapped high hazard landforms exist within moderate (or in rare cases low) hazard zones. Within the project area, this is most likely to occur in Landslide Hazard Zones 4 and 11 where inclusions of high hazard bedrock hollows or small inner gorges may be found within what has been mapped as moderate hazard slopes. While every attempt was made to minimize such errors, limitations associated with the project protocol make it impossible to completely eliminate them. Users should be aware of these limitations and view the map products as a coarse screen to help identify, in a general sense, portions of the landscape where forest practices have the potential to accelerate mass wasting.

Aerial photos used to develop the landslide inventory were of high quality and provided good spatial and temporal coverage. However, photo-based landslide inventories inevitably underestimate landslide occurrence because many small landslides go undetected due to vegetation cover and/or topographic shading. Nevertheless, the author is confident the landslide inventory is representative of the landslide population within the project area. The author is also confident that the landslide hazard zones, the assigned hazard ratings, and their associated forest practices sensitivities reflect actual field conditions. However, as indicated above, mapped hazard zone boundaries will not always reflect actual field conditions and errors of omission are likely present in some hazard zones.

6.0 Literature Cited

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Form A-1 Landslide Inventory for Clallam River WAU Landslide Hazard Zonation Project

SLIDE_ID	LSI_PROCESS	CERTAINTY	ID_DATE	LS_SIZE	ID2_DATE	ID2_SIZE	INIT_ELEV	PHOTO_NUM	LANDFORM	LANDFORM_2	SLP_SHP	GRADIENT	DELIVERY	LANDUSE	GEOL_UNIT	WAU_LANDFORM	ACTIVITY_LEVEL	COMMENTS	Acres
2000	1	D	1985	5	0	0	1530	OL85 32-021-181	7	0	2	102	Y	5	Ev(cp)	0			3.35
2001	1	D	1985	3	0	0	985	OL85 35-021-181	5	0	1	85	Y	5	Em(1l)	1			0.21
2002	1	D	1985	4	1990	4	1570	OL85 35-021-181	7	1	2	95	Y	5	Ev(cp)	1		Channel appears scoured in 1990 photos	0.83
2003	1	P	1985	4	0	0	1280	OL85 35-021-181	2	1	1	90	Y	5	Em(1l)	1			1.02
2004	1	D	1985	2	0	0	1410	OL85 35-021-181	2	1	1	75	Y	5	Em(1l)	1		Scoured channel to bedrock in places; DF confined to IG	0.40
2005	1	D	1985	3	0	0	1610	OL85 35-021-181	2	1	1	70	Y	3	Ev(cp)	1		Scoured channel to bedrock in places; DF confined to IG	0.23
2006	1	D	1985	5	0	0	1510	OL85 35-021-181	2	1	1	110	Y	5	Ev(cp)	1		Several subsidary landslides combined into this feature	2.10
2007	1	P	1985	4	0	0	1050	OL85 35-021-181	2	1	1	155	Y	5	Em(1l)	1			0.91
2008	1	P	1985	4	1977	4	1030	OL85 35-021-181	2	1	1	85	Y	5	Em(1l)	2			0.74
2009	2	D	1985	3	0	0	1620	OL85 35-022-201	2	0	1	75	Y	2	Ev(cp)	6			0.11
2010	2	D	1977	5	0	0	1900	OL77 22C-77	2	1	1	150	Y	2	Ev(cp)	1			1.15
2011	2	D	1985	3	0	0	1700	OL85 35-022-201	2	1	1	115	Y	2	Ev(cp)	1			0.18
2012	2	D	1985	4	0	0	1950	OL85 35-022-201	2	1	1	115	Y	5	Ev(cp)	1			0.62
2013	2	D	1977	4	0	0	1950	OL77 22C-75	2	1	2	90	Y	2	Ev(cp)	1			0.76
2014	2	D	1985	4	0	0	1610	OL85 35-022-201	2	1	1	85	Y	5	Ev(cp)	1		May have blown out road in 1977	0.68
2015	2	D	1985	3	0	0	1650	OL85 35-022-201	2	1	1	77	Y	5	Ev(cp)	1			0.33
2016	2	D	1985	3	0	0	1630	OL85 35-022-201	2	1	1	100	Y	5	Ev(cp)	1			0.36
2017	2	D	1977	4	1990	5	2040	OL77 22C-75	2	1	1	112	Y	5	Ev(cp)	1		Numerous secondary faliures since 1985	4.45
2018	2	D	1985	4	0	0	1650	OL85 35-022-201	2	1	1	90	Y	5	Ev(cp)	1			0.42
2019	1	D	1985	4	0	0	1380	OL85 35-022-201	2	1	1	85	Y	3	Em(1l)	1		Channel is completely blown out	0.61
2020	1	D	1985	4	0	0	1520	OL85 35-022-201	7	0	2	100	Y	5	Ev(cp)	4			0.67

Form A-1 Landslide Inventory for Clallam River WAU Landslide Hazard Zonation Project

SLIDE_ID	LSI_PROCESS	CERTAINTY	ID_DATE	LS_SIZE	ID2_DATE	ID2_SIZE	INIT_ELEV	PHOTO_NUM	LANDFORM	LANDFORM_2	SLP_SHP	GRADIENT	DELIVERY	LANDUSE	GEOL_UNIT	WAU_LANDFORM	ACTIVITY_LEVEL	COMMENTS	Acres
2021	1	P	1985	3	0	0	1140	OL85 35-022-201	7	0	2	46	Y	3	Em(1l)	6			0.30
2022	1	D	1985	0	0	3	740	OL85 35-022-201	1	0	1	100	P	3	Em(1l)	1		Could be deposits from landslides upstream	0.31
2023	1	D	1985	2	0	0	770	OL85 35-022-201	1	4	2	140	Y	3	Em(1l)	1			0.10
2024	1	D	1985	2	0	0	680	OL85 35-022-201	4	0	2	125	Y	4	Qgd	1			0.13
2025	1	D	1985	2	0	0	610	OL85 35-022-201	4	0	2	151	Y	2	Qgd	1		Five small landslides lumped together	0.09
2026	1	P	1985	5	0	0	590	OL85 36-024-029	4	2	1	117	Y	4	Qgo	1		Mapped larger than in image; scarp is evident in LiDAR	1.47
2027	1	P	2001	4	0	0	530	LiDAR	4	2	1	140	N	4	Qgo	1			0.56
2028	1	P	1985	3	0	0	530	OL85 36-024-029	4	0	1	114	Y	4	Qgo	1			0.25
2029	1	P	1985	2	0	0	460	OL85 36-024-029	4	0	2	100	Y	4	Qgo	1			0.08
2030	1	D	1985	2	0	0	690	OL85 35-022-201	1	4	2	90	Y	4	Qgd	1			0.07
2031	1	D	1985	3	0	0	331		1	0	2	76	Y	2	Qgt	1			0.15
2032	1	D	1985	2	0	0	840	OL85 12-028-103	4	5	2	75	N	3	Mn(c)	3			0.10
2033	1	D	1985	2	0	0	710	OL85 12-028-103	4	5	2	75	N	3	Mn(c)	3			0.07
2034	1	D	1985	2	0	0	770	OL85 12-028-103	4	5	2	75	N	3	Mn(c)	3			0.07
2035	1	D	2003	4	0	0	570	Orthophotograph	4	0	2	61	N	1	Mn(c)	3			0.34
2036	1	D	1977	5	0	0	1570	OL77 21D-17	7	0	4	100	P	5	Ev(cp)	4		Very shallow landslide	1.67
2037	1	P	1977	4	0	0	1130	OL77 21D-17	2	1	1	96	Y	5	Em(1l)	1			0.55
2038	1	D	1977	1	0	0	950	OL77 21D-17	1	0	3	110	Y	1	Em(1l)	1			0.01
2039	3	P	1977	5	0	0	790	OL77 21D-17	4	9	1	130	Y	4	Em(2a)	1		Appears to be a natural meander bend that contains several shallow landslides	1.34
2040	5	D	1977	4	0	0	920	OL77 22C-80	2	1	1	136	Y	2	Em(2h)	1		Small landslides visible in photographs; larger scar evident with LiDAR	0.53

Form A-1 Landslide Inventory for Clallam River WAU Landslide Hazard Zonation Project

SLIDE_ID	LSI_PROCESS	CERTAINTY	ID_DATE	LS_SIZE	ID2_DATE	ID2_SIZE	INIT_ELEV	PHOTO_NUM	LANDFORM	LANDFORM_2	SLP_SHP	GRADIENT	DELIVERY	LANDUSE	GEOL_UNIT	WAU_LANDFORM	ACTIVITY_LEVEL	COMMENTS	Acres
2041	5	D	2001	4	0	0	950	LiDAR	2	1	1	110	Y	3	Em(2h)	1		Slight evidence in photograph; scar evident in LiDAR	0.61
2042	1	D	1977	2	0	0	620	OL77 22C-77	4	0	3	95	Y	3	Qgd	1			0.02
2043	1	D	1977	1	0	0	600	OL77 22C-77	4	0	1	105	Y	1	Qgd	1			0.02
2044	1	D	1985	0	0	1	630	OL85 35-022-201	1	4	2	133	Y	4	Qgd	1			0.01
2045	1	D	1977	3	0	0	1310	OL77 22C-77	2	0	2	77	P	5	Ev(cp)	4			0.13
2046	1	D	1977	2	0	0	670	OL77 22C-77	4	0	2	100	Y	4	Qgd	1			0.03
2047	1	D	1977	2	0	0	690	OL77 22C-77	4	0	2	100	Y	4	Qgd	1			0.04
2048	1	D	1977	2	0	0	690	OL77 22C-77	4	0	2	100	Y	4	Qgd	1			0.04
2049	1	D	1977	2	0	0	660	OL77 22C-77	4	0	2	110	Y	4	Qgd	1			0.02
2050	6	P	2001	3	0	0	1400	LiDAR	1	0	2	88	Y	5	Ev(cp)	1		Small shallow-rapid in 1977 photographs	0.13
2051	2	D	1977	3	0	0	1260	OL77 22C-75	2	1	1	87	Y	5	Ev(cp)	1			0.25
2052	1	D	1977	3	0	0	1180	OL77 22C-75	2	0	2	95	P	1	Ev(cp)	4			0.32
2053	2	D	1977	4	0	0	1870	OL77 22C-75	2	1	1	90	Y	5	Ev(cp)	3			0.60
2054	1	D	1977	3	0	0	1610	OL77 22C-75	7	0	2	90	P	5	Ev(cp)	1			0.16
2055	4	P	2001	5	0	0	350	OL77 23C-86	7	0	2	120	N	4	OEm(m)	3			9.76
2056	1	D	1977	3	0	0	820	OL77 23C-80	2	0	2	115	Y	4	Em(2h)	1			0.09
2057	1	D	1977	3	0	0	840	OL77 23C-80	2	0	2	105	Y	4	Em(2h)	1			0.19
2058	2	D	1977	3	0	0	1360	OL77 23C-77	2	0	2	95	Y	5	Ev(cp)	4			0.27
2059	1	P	1977	1	0	0	840	OL77-23C-77	7	0	2	80	Y	5	Qgd	1			0.02
2060	2	D	1977	5	0	0	2375	OL77 23C-75	2	1	2	70	Y	5	Ev(cp)	12			3.82
2061	4	P	1977	5	0	0	0	OL77 24D-43	7	0	2	200	N	4	MOm(pc)	5	DD	South half contains LiDAR, north half is 10m DEM	59.93
2062	1	P	1977	0	0	0	470	OL77 24D-35	1	0	2	100	Y	4	Em(2h)	1			0.16
2063	1	P	1977	0	0	0	490	OL77 24D-35	1	0	2	100	Y	4	Em(2h)	1			0.30
2064	1	P	1977	0	0	0	450	OL77 24D-35	1	0	2	125	Y	4	Em(2h)	1			0.03
2065	1	D	1977	2	0	0	210	OL77 25D-70	7	0	3	70	N	1	Mn(c)	3			0.07

Form A-1 Landslide Inventory for Clallam River WAU Landslide Hazard Zonation Project

SLIDE_ID	LSI_PROCESS	CERTAINTY	ID_DATE	LS_SIZE	ID2_DATE	ID2_SIZE	INIT_ELEV	PHOTO_NUM	LANDFORM	LANDFORM_2	SLP_SHP	GRADIENT	DELIVERY	LANDUSE	GEOL_UNIT	WAU_LANDFORM	ACTIVITY_LEVEL	COMMENTS	Acres
2066	1	D	1977	2	0	0	120	OL77 25D-70	7	0	3	70	N	1	Mn(c)	3			0.03
2067	1	D	1977	2	0	0	140	OL77 25D-70	7	0	3	70	N	1	Mn(c)	3			0.05
2068	1	D	1977	4	0	0	220	OL77 25D-67	2	1	1	90	Y	3	MOm(p)	1			0.66
2069	1	D	1977	2	0	0	310	OL77 26D-75	1	9	2	90	Y	3	OEm(m)	1			0.03
2070	1	D	1977	2	0	0	310	OL77 26D-75	1	9	2	90	Y	3	OEm(m)	1			0.03
2071	1	D	1977	2	0	0	280	OL77 26D-75	1	9	2	90	Y	3	OEm(m)	1		Three smaller landslides combined into one	0.13
2072	1	D	1977	2	0	0	340	OL77 26D-75	1	9	2	90	Y	3	OEm(m)	1			0.03
2073	1	D	2003	4	0	0	830	Orthophotograph	4	0	3	60	I	1	Mn(c)	3			0.45
2074	4	P	1977	0	0	0	950	OL77 29E-33	4	0	7	90	N	4	Mn(c)	3	DD	Scarps apparent in photograph; hummocky body; probably two or more slides	54.81
2075	4	P	1977	5	0	0	1150	OL77 29E-33	4	0	1	100	N	4	Mn(c)	3	DD		27.38
2076	1	P	1990	2	0	0	700	OL90 14-22-238	1	2	1	127	Y	4	Qgd	1		Slide in in the shadows	0.08
2077	2	P	1990	3	0	0	1430	OL90 14-22-237	2	1	1	45	Y	2	Ev(cp)	6		May have initiated from ditch water from P1000	0.24
2078	2	D	1990	2	0	0	1520	OL90 14-22-237	2	0	2	90	Y	2	Ev(cp)	4			0.09
2079	2	D	1990	3	0	0	1790	OL90 14-22-237	2	1	1	95	Y	2	Ev(cp)	1			0.18
2080	1	P	1990	2	0	0	230	Ol90 14-23-214	2	0	1	40	P	1	OEm(m)	3			0.04
2081	1	P	1990	2	0	0	160	OL90 14-23-214	4	0	3	60	I	1	Om(mf)	3		Timber cut proximal to house to improve views?	0.03
2082	1	D	1990	2	0	0	940	OL90 14-23-205	2	1	1	120	Y	2	Qgt	6			0.08
2083	1	D	1990	3	1990	0	750	OL90 14-24-171	8	2	3	110	I	4	Em(2ls)	4			0.17
2084	1	D	2007	2	0	0	1550	Field	7	0	3	80	N	5	Ev(cp)	4			0.03
2085	5	D	2007	3	0	0	1500	Field	7	0	2	100	P	5	Ev(cp)	6	AR	Fresh cracks in road surface	0.31
2086	2	D	1985	5	0	0	1960	OL85 35-023-229	2	1	1	80	Y	5	Ev(cp)	12			2.79
2087	1	D	2007	2	0	0	1000	Field	7	0	2	90	Y	4	Em(2hb)	1			0.06
2088	4	P	2001	5	0	0	650	OL77 23C-86	7	0	2	220	N	4	Qgt	5	DD	Heavy human alteration of body	77.93

Form A-1 Landslide Inventory for Clallam River WAU Landslide Hazard Zonation Project

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2089	4	P	2005	5	0	0	570	LiDAR	7	0	7	90	N	4	Em(2h)	5	DD		38.31
2090	4	P	2005	5	0	0	688		7	0	7	90	N	4	Em(2h)	5	DD		1.42
2091	4	Q	2005	5	0	0	350	LiDAR	7	0	7	120	N	4	OEm(m)	5			9.51
2092	4	P	2005	5	0	0	810	LiDAR	7	0	7	80	N	4	Qgd	5	DD		9.31
2093	4	D	2005	5	0	0	710	LiDAR	9	7	7	100	N	4	Em(2h)	5	DD		6.39
2094	7	P	2005	5	0	0	510	LiDAR	9	7	7	75	N	4	Qgo	5	DD		3.39
2095	4	D	2005	5	0	0	240	LiDAR	9	7	2	110	N	4	MOm(p)	5	DD		1.16
2096	4	P	2005	5	0	0	285	LiDAR	9	7	2	110	N	4	MOm(p)	5	DD	Several small deep-seated slides mapped as one	8.69
2097	4	D	2005	5	0	0	730	LiDAR	1	9	2	130	N	4	OEm(m)	5	DD	Hummocky ground; incised channels	42.49
2098	4	P	2005	4	0	0	240	LiDAR	9	7	2	100	N	4	OEm(m)	5	DD		9.33
2099	4	P	2005	5	0	0	330	LiDAR	9	7	7	115	N	4	MOm(p)	5	DD	Probably a landslide complex	37.24
2100	4	D	2005	5	0	0	246	LiDAR	7	0	2	90	N	4	MOm(p)	5	DD	Debris fan extends into flood plain	5.13
2101	4	P	2005	5	0	0	400	LiDAR	7	9	2	100	N	4	OEm(m)	5	DI		8.02
2102	4	P	2005	5	0	0	290	LiDAR	9	7	7	100	N	4	MOm(p)	5	DD	Probably a landslide complex	15.38
2103	7	P	2005	5	0	0	810	LiDAR	9	7	7	70	N	4	Qgt	5	DD		36.53
2104	4	Q	2005	5	0	0	570	LiDAR	9	7	2	100	N	4	OEm(m)	5	DD		7.07
2105	4	P	2005	5	0	0	525	LiDAR	9	7	7	100	N	4	OEm(m)	5	DD		18.03
2106	4	P	2005	5	0	0	280	LiDAR	7	0	7	80	N	4	MOm(p)	5	DD	Surface appears anthropogenically modified	25.53
2107	5	P	2005	5	0	0	420	LiDAR	7	7	2	120	N	4	MOm(pc)	6	DD		1.37
2108	4	D	2005	5	0	0	540	LiDAR	9	7	3	110	N	4	MOm(pc)	5	DD		22.59
2109	4	P	0	0	0	0	0		0	0	0	0		0		5			89.82
2110	1	D	2007	4	0	0	630	LiDAR	7	0	0	95	Y	5	Mn(c)	6			0.78
2111	4	P	2005	5	0	0	545	LiDAR	9	7	2	100	N	4	Em(2h)	6	DD		2.01
2112	4	Q	2005	5	0	0	440	LiDAR	9	7	2	70	N	4	Qgt	5	DD	Could be abandoned terrace	4.63

Form A-1 Landslide Inventory for Clallam River WAU Landslide Hazard Zonation Project

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2113	4	P	2005	5	0	0	455	LiDAR	9	7	7	70	N	4	OEm(m)	5	DD	Landslide complex	9.14
2114	4	D	2005	5	0	0	600	LiDAR	9	7	4	80	N	4	OEm(m)	5	DD		12.08
2115	4	Q	2005	5	0	0	1055	LiDAR	7	0	3	110	N	4	Em(2hs)	6	DI	Hummocky surface; no channelization	12.70
2116	4	Q	2005	5	0	0	585	LiDAR	9	7	2	110	N	4	OEm(m)	6	DD	Possible fluvial/glacial terrace	2.76
2117	4	P	2005	5	0	0	575	LiDAR	9	7	2	115	N	4	OEm(m)	5	DD	Landslide complex	6.82
2118	4	P	2005	5	0	0	540	LiDAR	4	9	2	99	N	4	Qgt	6	DD		1.40
2119	4	P	2005	5	0	0	630	LiDAR	9	7	2	90	N	4	Em(2h)	6	DI		2.75
2120	4	P	2005	5	0	0	1040	LiDAR	9	7	4	110	N	4	Em(2a)	6	DI		5.84
2125	4	P	2005	5	0	0	360	LiDAR	9	7	2	90	N	4	OEm(m)	5	DD		17.41
2126	4	P	2005	5	0	0	285	LiDAR	9	7	4	100	N	4	OEm(m)	5	DI		10.85
2127	4	P	2005	5	0	0	310	LiDAR	9	7	7	90	N	4	MOm(p)	5	DD	Landslide complex	31.89
2128	5	P	2005	5	0	0	460	LiDAR	4	9	3	115	N	4	OEm(m)	5	R		1.77
2129	4	Q	2005	5	0	0	460	LiDAR	9	7	3	90	N	4	OEm(m)	5	DI		2.25
2130	4	P	2005	5	0	0	450	LiDAR	4	9	3	80	N	4	OEm(m)	5	DD		1.25
2131	4	D	2005	5	0	0	650	LiDAR	4	9	7	150	N	4	Qgt	6	DD		13.30
2132	5	D	2007	3	0	0	1000	LiDAR	1	0	1	80	N	4	EM(2hb)	1	DD		0.19
2134	4	D	2005	5	0	0	640	LiDAR	1	9	2	100	N	4	EOm(m)	6	DD		5.16
2135	4	P	2005	5	0	0	370	LiDAR	9	0	4	100	N	4	OEm(m)	5	DI		4.38
2136	4	P	2005	5	0	0	280	LiDAR	9	7	4	100	N	4	OEm(m)	5	DD		2.85
2137	4	P	2005	5	0	0	0	LiDAR	4	9	2	80	N	4	OEm(m)	5	DD		6.23
2138	4	P	2005	5	0	0	380	LiDAR	9	7	2	100	N	4	OEm(mk)	5	DI		2.82
2139	4	Q	2005	5	0	0	490	LiDAR	4	9	3	85	N	4	OEm(m)	5	DI		1.20
2140	4	P	2005	5	0	0	525	LiDAR	4	7	3	100	N	4	OEm(m)	5	DD		1.73
2141	4	P	2005	5	0	0	500	LiDAR	4	9	4	100	N	4	OEm(m)	5	DD		2.44
2142	4	P	2005	5	0	0	500	LiDAR	9	7	7	90	N	4	Qgd	5	DD	Landslide complex	55.63
2143	4	P	2005	5	0	0	400	LiDAR	9	7	3	100	N	4	OEm(m)	5	DI		1.58
2145	7	P	2005	5	0	0	690	LiDAR	4	7	3	70	N	4	OEm(m)	6	DD		31.09

Form A-1 Landslide Inventory for Clallam River WAU Landslide Hazard Zonation Project

SLIDE_ID	LSI_PROCESS	CERTAINTY	ID_DATE	LS_SIZE	ID2_DATE	ID2_SIZE	INIT_ELEV	PHOTO_NUM	LANDFORM	LANDFORM_2	SLP_SHP	GRADIENT	DELIVERY	LANDUSE	GEOL_UNIT	WAU_LANDFORM	ACTIVITY_LEVEL	COMMENTS	Acres
2146	4	P	2005	5	0	0	1020	LiDAR	4	9	2	75	N	4	Em(2h)	6	DD		11.31
2147	7	P	2005	5	0	0	950	LiDAR	9	7	3	100	N	4	Em(2hb)	1	DD		2.82
2148	4	P	2005	5	0	0	510	LiDAR	4	9	2	100	N	4	OEm(m)	1	DD		1.35
2149	1	D	1985	2	0	0	610	OL85 35-022-201	4	0	3	95	Y	4	Qgd	1			0.02
2150	1	D	1977	2	0	0	620	OL77 22C-77	4	0	3	118	Y	3	Qgd	1			0.02

Form A-2 Landform Assessment Description

Landform (Hazard Zone) Number – 1 (mapped as 101, 102, and 103)

Landform (Hazard Zone) Description – Probable convergent headwall (Landform 101), bedrock hollows (Landform 102), and inner gorges (Landform 103)

Slope – slopes greater than 70 percent

Slope Shape – convergent to strongly convergent

Lithology – all geology types

Elevation – sea level to 2600 feet

Total Area – 1729 acres, 8 percent of project area

Mass Wasting Processes – shallow-undifferentiated, debris flows, and debris slides are typical

Forest Practices Sensitivity – HIGH for timber harvesting; HIGH for roads

Mass Wasting Potential – Landslide Frequency Rating: 1260; Landslide Area Rating: 504; Hazard potential: VERY HIGH

Delivery Potential – HIGH

Delivery Criteria Used – slope gradient; presence of surface waters

Hazard Potential Rating – HIGH (road construction); HIGH (timber harvest)

Trigger Mechanisms – Under natural conditions, the dominant mass wasting triggering mechanism is high soil pore water pressure associated with high intensity rainfall. Forest practices can accelerate the debris avalanche rate within this unit through: 1) increased soil pore water pressure associated with concentrated road surface water drainage, 2) reduced root strength associated with clearcut timber harvest, and 3) reduced soil structural strength associated with soil disturbance caused by log yarding.

Confidence – HIGH for landform description and associated sensitivity/hazard; HIGH for landform mapping

Comments – This landform was delineated entirely with LiDAR.

Form A-2 Landform Assessment Description

Landform Number – 2

Landform Description – Probable meander bends

Slope – greater than 70 percent

Slope Shape – mostly convergent but locally variable including planar and divergent slopes

Lithology – all geology types

Elevation – 40 feet to 400 feet

Total Area – 29 acres, less than 1 percent of the project area

Mass Wasting Processes – shallow undifferentiated and debris avalanche

Forest Practices Sensitivity – HIGH for timber harvesting; HIGH for roads

Mass Wasting Potential - Landslide Frequency Rating: 0; Landslide Area Rating: 0; Hazard potential: HIGH (rule-identified)

Delivery Potential - HIGH

Delivery Criteria Used – slope gradient; presence of surface waters

Hazard Potential Rating – HIGH (road construction); HIGH (timber harvest)

Trigger Mechanisms – Under natural conditions, undercutting of the outside bend of a stream channel undermines the upper slopes triggering shallow-undifferentiated and/or debris avalanches from the upper slopes. Forest practices can accelerate the mass wasting rate within this unit through: 1) increased soil pore water pressure associated with concentrated road surface water drainage, 2) reduced root strength associated with clearcut timber harvest, and 3) reduced soil structural strength associated with soil disturbance caused by log yarding.

Confidence – HIGH for landform description and associated sensitivity/hazard; HIGH for landform mapping

Comments – This landform was delineated entirely with LiDAR.

Form A-2 Landform Assessment Description

Landform Number – 3

Landform Description – terrace face along the Strait of Juan de Fuca

Slope – typically greater than 70 percent but can be less in places

Slope Shape – variable; ranges from convergent to divergent, but convergent slopes represent greatest landslide hazard

Lithology – all geology types, especially continental glacial sediments

Elevation – sea level to 600 feet

Total Area – 654 acres, 3 percent of project area

Mass Wasting Processes – shallow-undifferentiated, debris flows, and large rotational deep-seated landslides

Forest Practices Sensitivity – HIGH for timber harvesting; HIGH for roads

Mass Wasting Potential - Landslide Frequency Rating: 803; Landslide Area Rating: 37; Hazard potential: MODERATE (see comments)

Delivery Potential - HIGH

Delivery Criteria Used – slope gradient; presence of surface waters

Hazard Potential Rating – MODERATE (road construction); MODERATE (timber harvest)

Trigger Mechanisms – Under natural conditions the oversteepend slopes facing the Straits of Juan de Fuca are continually eroded by tidal and storm processes. Undercutting of the steep slopes trigger shallow-undifferentiated, debris flows, deep seated landslides. Forest practices may increase the rate of shallow-rapid landsliding within this unit through: 1) increased soil pore water pressure associated with concentrated road surface water drainage, 2) reduced root strength associated with clearcut timber harvest, and 3) reduced soil structural strength associated with soil disturbance caused by log yarding.

Confidence – HIGH for landform description and associated sensitivity/hazard; MODERATE to HIGH for landform mapping

Comments – Aerial photograph coverage was inadequate due to poor lighting conditions from the north facing slopes. Oblique aerial photographs from the Washington Department of Ecology(see text for details) revealed dozens of shallow-undifferentiated landslides not visible in aerial photographs. Because of this, the zone was artificially upgraded to MODERATE overall hazard potential. This landform was delineated entirely with 10-m DEMs.

Form A-2 Landform Assessment Description

Landform Number – 4

Landform Description – Moderate to steep gradient, planar to moderately convergent slopes

Slope – greater than 60 percent

Slope Shape – planar to moderately convergent

Lithology – all geology types

Elevation – sea level to 2600 feet

Total Area – 770 acres, 4 percent of project area

Mass Wasting Processes – shallow-undifferentiated and debris flows

Forest Practices Sensitivity – MODERATE for timber harvesting; MODERATE for roads

Mass Wasting Potential - Landslide Frequency Rating: 371; Landslide Area Rating: 147; Hazard potential: MODERATE

Delivery Potential - HIGH

Delivery Criteria Used – slope gradient; presence of surface waters downslope

Hazard Potential Rating – MODERATE (road construction); MODERATE (timber harvest)

Trigger Mechanisms – Under natural conditions, the dominant triggering mechanism for this unit is high soil pore water pressure associated with high intensity rainfall. Forest practices can accelerate the landslide rate within this unit through: 1) increased soil pore water pressure associated with concentrated road surface water drainage, 2) reduced root strength associated with clearcut timber harvest, and 3) reduced soil structural strength associated with soil disturbance caused by log yarding.

Confidence – HIGH for landform description and associated sensitivity/hazard; HIGH for landform mapping

Comments – This zone is typically proximal to HIGH and VERY HIGH hazard zones and rule-identified potentially unstable landforms and may contain these features with this zone. This landform was delineated entirely with LiDAR.

Form A-2 Landform Assessment Description

Landform Number – 5

Landform Description – Probable deep-seated landslides

Slope – all slope angles

Slope Shape – all slope shapes

Lithology – all geology types

Elevation – sea level to 2600 feet

Total Area – 664 acres, 3 percent of project area

Mass Wasting Processes – shallow-undifferentiated and debris flows on toes and headscarps; potential for reactivation of deep-seated landslide if toe is disturbed

Forest Practices Sensitivity – MODERATE for timber harvesting; MODERATE for roads
Mass Wasting Potential - Landslide Frequency Rating: 2204; Landslide Area Rating: 0; Hazard potential: MODERATE

Delivery Potential - HIGH

Delivery Criteria Used – slope gradient; presence of surface waters downslope

Hazard Potential Rating – MODERATE (road construction); MODERATE (timber harvest)

Trigger Mechanisms – Under natural conditions, the dominant triggering mechanism for these deep-seated landslides are probably large-magnitude earthquakes. Smaller deep-seated landslide can reinitiate movement when the toe is modified or removed. Forest practices might accelerate the shallow slope movement along the toes or headscarps of these landslides through: 1) increased soil pore water pressure associated with concentrated road surface water drainage, 2) reduced root strength associated with clearcut timber harvest, and 3) reduced soil structural strength associated with soil disturbance caused by log yarding.

Confidence – HIGH for landform description and associated sensitivity/hazard; HIGH for landform mapping

Comments – This landform was delineated entirely with LiDAR.

Form A-2 Landform Assessment Description

Landform Number – 11

Landform Description – Steep planar to convergent slopes

Slope – greater than 60 percent

Slope Shape – planar to convergent

Lithology – all geology types

Elevation – sea level to 2600 feet

Total Area – 1367 acres, 6 percent of project area

Mass Wasting Processes – shallow-undifferentiated and debris flows

Forest Practices Sensitivity – HIGH for timber harvesting; HIGH for roads

Mass Wasting Potential - Landslide Frequency Rating: 0; Landslide Area Rating: 0; Hazard potential: MODERATE (see comments)

Delivery Potential - HIGH

Delivery Criteria Used – slope gradient; presence of surface waters downslope

Hazard Potential Rating – MODERATE (road construction); MODERATE (timber harvest)

Trigger Mechanisms – Under natural conditions, the dominant triggering mechanism for this unit is high soil pore water pressure associated with high intensity rainfall. Forest practices can accelerate the landslide rate within this unit through: 1) increased soil pore water pressure associated with concentrated road surface water drainage, 2) reduced root strength associated with clearcut timber harvest, and 3) reduced soil structural strength associated with soil disturbance caused by log yarding.

Confidence – MODERATE for landform description and associated sensitivity/hazard; MODERATE for landform mapping

Comments – Due to very poor 10-m DEM coverage in this area, landform analysis was almost entirely based on aerial photographs. In the southern portion of the study area, little or no timber harvest throughout the study period (hence, very few management-related landslides) provided scant views of bare ground, so landforms had to be interpreted from proximal areas with LiDAR. These areas were given an overall hazard potential of MODERATE to ensure that areas of steep ground are walked by a slope stability expert to identify potentially unstable landforms.

Form A-2 Landform Assessment Description

Landform Number – 12

Landform Description – Probable convergent headwalls, bedrock hollows, and inner gorges (10-m DEM)

Slope – greater than 70 percent

Slope Shape – convergent to strongly convergent

Lithology – all geology types

Elevation – sea level to 2600 feet

Total Area – 209 acres, 1 percent of project area

Mass Wasting Processes – shallow-undifferentiated and debris flows

Forest Practices Sensitivity – HIGH for timber harvesting; HIGH for roads

Mass Wasting Potential - Landslide Frequency Rating: 341; Landslide Area Rating: 1127; Hazard potential: VERY HIGH

Delivery Potential - HIGH

Delivery Criteria Used – slope gradient; presence of surface waters downslope

Hazard Potential Rating – HIGH (road construction); HIGH (timber harvest)

Trigger Mechanisms – Under natural conditions, the dominant triggering mechanism for this unit is high soil pore water pressure associated with high intensity rainfall. Forest practices can accelerate the landslide rate within this unit through: 1) increased soil pore water pressure associated with concentrated road surface water drainage, 2) reduced root strength associated with clearcut timber harvest, and 3) reduced soil structural strength associated with soil disturbance caused by log yarding.

Confidence – MODERATE for landform description and associated sensitivity/hazard; MODERATE for landform mapping

Comments – Due to very poor 10-m DEM coverage in this area, landform analysis was almost entirely based on aerial photographs. In the southern portion of the study area, little or no timber harvest throughout the study period provided scant views of bare ground, so landforms had to be interpreted from proximal areas with LiDAR.

Form A-3 – Mass Wasting Summary Table
Landslide Hazard Zone #1 (coded as 101, 102, and 103)

Activity	Shallow-undifferentiated	Debris flows	Debris avalanches/debris slide	Deep-seated	Earthflow	Rock topple/falls	Snow avalanche	Totals
Clear cut (timber 0-5 Yrs.)	2	-	-	-	-	-	-	2
Young timber (5-15 yrs.)	2	4	-	-	-	-	-	6
Submature timber (15-50 yrs.)	11	-	-	-	-	-	-	11
Mature timber (>50 yrs.)	19	-	1	1	1	-	-	22
Road related	9	7	-	-	-	-	-	16
Partial cut	-	-	-	-	-	-	-	0
Yarding	-	-	-	-	-	-	-	0
Alpine	-	-	-	-	-	-	-	0
Other (e.g., housing)	-	-	-	-	-	-	-	0

Form A-3 – Mass Wasting Summary Table
Landslide Hazard Zone #2

Activity	Shallow-undifferentiated	Debris flows	Debris avalanches/debris slide	Deep-seated	Earthflow	Rock topple/falls	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.)	-	-	-	-	-	-	-	0
Road related	1	-	-	-	-	-	-	1
Partial cut	-	-	-	-	-	-	-	0
Yarding	-	-	-	-	-	-	-	0
Alpine	-	-	-	-	-	-	-	0
Other (e.g., housing)	-	-	-	-	-	-	-	0

Form A-3 – Mass Wasting Summary Table
Landslide Hazard Zone #3

Activity	Shallow-undifferentiated	Debris flows	Debris avalanches/debris slide	Deep-seated	Earthflow	Rock topple/falls	Snow avalanche	Totals
Clear cut (timber 0-5 Yrs.)	7	-	-	-	-	-	-	7
Young timber (5-15 yrs.)	-	-	-	-	-	-	-	0
Submature timber (15-50 yrs.)	3	-	-	-	-	-	-	3
Mature timber (>50 yrs.)	-	-	-	3	-	-	-	3
Road related	-	1	-	-	-	-	-	1
Partial cut	-	-	-	-	-	-	-	0
Yarding	-	-	-	-	-	-	-	0
Alpine	-	-	-	-	-	-	-	0
Other (e.g., housing)	-	-	-	-	-	-	-	0

Form A-3 – Mass Wasting Summary Table
Landslide Hazard Zone #4

Activity	Shallow-undifferentiated	Debris flows	Debris avalanches/debris slide	Deep-seated	Earthflow	Rock topple/falls	Snow avalanche	Totals
Clear cut (timber 0-5 Yrs.)	1	-	-	-	-	-	-	1
Young timber (5-15 yrs.)	-	1	-	-	-	-	-	1
Submature timber (15-50 yrs.)	-	-	-	-	-	-	-	0
Mature timber (>50 yrs.)	1	-	-	-	-	-	-	1
Road related	4	1	-	-	-	-	-	5
Partial cut	-	-	-	-	-	-	-	0
Yarding	-	-	-	-	-	-	-	0
Alpine	-	-	-	-	-	-	-	0
Other (e.g., housing)	-	-	-	-	-	-	-	0

Form A-3 – Mass Wasting Summary Table
Landslide Hazard Zone #5

Activity	Shallow-undifferentiated	Debris flows	Debris avalanches/debris slide	Deep-seated	Earthflow	Rock topple/falls	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.)	-	-	-	38	2	-	-	40
Road related	-	-	-	-	-	-	-	0
Partial cut	-	-	-	-	-	-	-	0
Yarding	-	-	-	-	-	-	-	0
Alpine	-	-	-	-	-	-	-	0
Other (e.g., housing)	-	-	-	-	-	-	-	0

Form A-3 – Mass Wasting Summary Table
Landslide Hazard Zone #6

Activity	Shallow-undifferentiated	Debris flows	Debris avalanches/debris slide	Deep-seated	Earthflow	Rock topple/falls	Snow avalanche	Totals
Clear cut (timber 0-5 Yrs.)	-	-	-	-	-	-	-	0
Young timber (5-15 yrs.)	1	2	-	-	-	-	-	3
Submature timber (15-50 yrs.)	1	-	-	-	-	-	-	1
Mature timber (>50 yrs.)	-	-	-	10	1	-	-	11
Road related	1	-	-	-	-	-	-	1
Partial cut	-	-	-	-	-	-	-	0
Yarding	-	-	-	-	-	-	-	0
Alpine	-	-	-	-	-	-	-	0
Other (e.g., housing)	-	-	-	-	-	-	-	0

Form A-3 – Mass Wasting Summary Table
Landslide Hazard Zone #12

Activity	Shallow-undifferentiated	Debris flows	Debris avalanches/debris slide	Deep-seated	Earthflow	Rock topple/falls	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.)	-	-	-	-	-	-	-	0
Road related	2	-	-	-	-	-	-	2
Partial cut	-	-	-	-	-	-	-	0
Yarding	-	-	-	-	-	-	-	0
Alpine	-	-	-	-	-	-	-	0
Other (e.g., housing)	-	-	-	-	-	-	-	0