Kalaloch Ridge
LANDSLIDE HAZARD ZONATION PROJECT
Jefferson County, Washington

Prepared By
Eric L. Bilderback and Matthew J. Brunengo

Forest Practices Division
Adaptive Management Program
in coordination with the Washington Division
of Geology and Earth Resources

Priority 3
Mass Wasting Assessment
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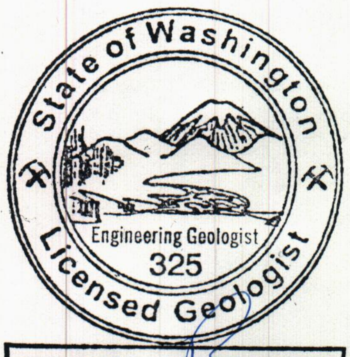


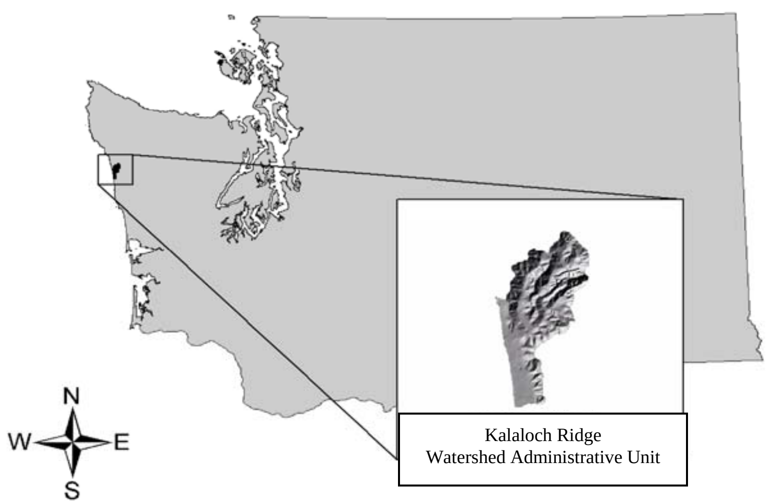
MATTHEW J. BRUNENGO

Washington State Department of Natural Resources

Forest Practices Division
PO Box 47012
Olympia, WA 98504-7012
Phone: 360-902-1400
Fax: 360-902-1428

Division of Geology and Earth Resources
PO Box 47007
Olympia, WA 98504-7007
360-902-1450
360-902-1785

Websites: http://www.dnr.wa.gov/forestpractices/lhzproject
http://www.dnr.wa.gov/forestpractices/adaptivemanagement
http://www.dnr.wa.gov/geology/



Cover photo: View westward across the terrain of the Kalaloch Ridge WAU; debris slide–debris flow from a colluvium-filled bedrock hollow.

CONTENTS

1.0 Project Summary

The Kalaloch Ridge watershed administrative unit (WAU) is located on the western margin of the Olympic Mountains. The WAU has a total area of 14,180 ac (22.2 mi^2), 3,153 ac of which is federally regulated national park land, leaving 11,027 ac reviewed in this study. The WAU is part of a mountain block called Kalaloch Ridge rising between the deep valleys of the Hoh (north) and Clearwater–Queets (east and south) rivers. About 80% of the WAU is within the watershed of Kalaloch Creek, but the study area also encompasses the basins of many small streams draining to the Pacific, between the outlet of Kalaloch Creek and the mouth of the Queets.

The wet temperate maritime climate of the WAU is typical of Northwest coastal mountain ranges. Annual precipitation ranges from about 100–120 in. at the western mountain front, to about 140 in. on the ridges to the east. Most of the precipitation falls between October and April; rainfall is more common at this basin's elevations, although a few inches of snow falls in most winters even in the lowlands. The region is also susceptible to strong winds that cause significant blowdown of forest trees. Heavy and/or intense precipitation is significant in triggering landslides.

Mountain soils in the Kalaloch area are generally thin, due to rapid downslope movement of materials on steep slopes. Water from storms tends to perch at the soil-bedrock surfaces. This combination of high relief, low cohesion, and abrupt strength changes related to both groundwater boundaries and the soil-rock interface makes these slopes highly susceptible to debris slides and flows. Timber harvest can increase mass wasting by both loss of root strength and increasing hydraulic pressure in the soil from loss of canopy interception and transpiration on these slopes.

Slope failures in the Kalaloch Ridge WAU were observed on five sets of 1:12,000 aerial photographs (1979 to 1997). Slope failures were classified and cataloged according to the mass wasting feature type. During this review, a representative sample of 477 mass-wasting features was inventoried from air-photo and field investigation. Of the landslides identified, about 29% were mapped as shallow-undifferentiated failures, 22% were debris flows, 35% were debris slides and debris avalanches, and 15% were deep-seated landslides. The landslides mapped in the Kalaloch WAU are presented on Map A-1 and listed in Appendix A.

The air-photo survey and landslide inventory were also used to determine land use and to map rule-identified (inner gorges, bedrock hollows, etc.) and analyst-described landforms[1]. USGS digital elevation models and other GIS products were used to map low-hazard flat and low gradient areas according to the Landslide Hazard Zonation (LHZ) Protocol. The remaining land in the WAU was divided into analyst-described landforms. These landforms have been delineated to identify areas that have similar mass-wasting potential, potential to deliver wood, water and sediment to public resources, and potential to adversely affect public safety. They have been developed from a series of iterative statistical analyses of landslide attributes including gradient, elevation, lithology, and slope shape at locations of landslide initiation. Each landform was assigned a landslide frequency rate (LFR), a landslide area rate for delivery (LAR), and an overall hazard rating as called for by the LHZ protocol (Appendix D).

The distributions of the landforms identified during the Kalaloch Ridge LHZ study are shown on Map A-2, and they are described in Forms A-2 (Appendix C). Rule-identified landforms that are present in the Kalaloch WAU include inner gorges, bedrock hollows, and active deep-seated landslides. Analyst-defined landforms in the study area include two units, both rated very high

[1] *Landforms* as defined herein can be more inclusive than the small-scale unstable landforms commonly defined in rule (WAC 222-16-050(1)), referred to as "rule-identified landforms".

hazard. (1) Slopes steeper than 55% include all slope forms (convergent, divergent and planar) that are steeper than that slope angle. Thin soils that are not strongly anchored to bedrock and abundant rainfall make steep slopes in the Kalaloch WAU susceptible to debris slides, debris flows, and other shallow landslides. While slides start on all slope forms in this landform, areas where surface or groundwater is concentrated (contributing to increased hydraulic pressure in the soil) are particularly susceptible to slope failure. Roots from trees that stand on steep slopes play a significant role in stabilizing the thin soils mantling bedrock in this landform. (2) Highly convergent slopes include steep swales on otherwise planar slopes; the headwater basins of small streams; and other types of channeled and unchanneled basins, swales, and hollows. This landform concentrates abundant water, deeply weathering the bedrock of the WAU and potentially producing areas of positive pore-pressures during intense or prolonged precipitation events. Convergence of surficial and shallow groundwater make this landform highly susceptible to slope failure; debris slides, debris flows, and other shallow landslides frequently start within highly convergent slopes. Both these analyst-defined units may contain unmapped inner gorges and bedrock hollows.

2.0 Introduction and Summary of Methods

2.1 Use of this report

The purpose of this mass wasting assessment is to identify non-federal, non-tribal areas within the Kalaloch Ridge WAU that have moderate to high risk of landsliding due to both natural phenomena and the effects of human forest practices (harvest, roading, yarding, etc.). All lands within the WAU have been divided into designated mass-wasting hazard landforms. Maps of these landforms are designed for use by landowners in determining the areas likely to create landslide hazard, and by Department of Natural Resources regional staff to identify sites where future forest practice applications may require detailed investigation prior to classification (WAC Chapters 222-16-050 and 222-20).

This assessment is a reconnaissance survey, and its relatively broad resolution must be considered when using this document and its accompanying maps. Moreover, the survey was conducted within a constrained timeline that was budgeted to produce a statewide unstable-slopes screening tool as quickly as possible. For this reason, it is likely that some landslides or unstable landforms have been overlooked, some benign features have been mistakenly mapped as landslides, and some landslides have been classified improperly. Thus, the landslide inventory presented in this report (Map A-1 and Form A-1) is intended to be representative but not necessarily complete.

This analysis was largely conducted remotely using the best map and image-based resources available, supplemented by field visits to verify mapping results. However, we note that landslide inventories that are conducted primarily using air photos have been demonstrated to omit up to 85% of the landslides that actually exist on the ground in heavily forested terrain; furthermore, they tend to skew the majority of landslide occurrences toward clear-cuts because they are easier to spot on air-photos in these areas than under canopy (Brardinoni and others, 2003).

Information was collected and compiled in a manner that was designed to respond to the critical questions that are outlined in Section II of the Landslide Hazard Zonation Protocol, and to direct attention to areas where more detailed analysis is necessary. The objective of the data collection was to generate information sufficient to establish:

- A generalized characterization of mass-wasting processes that are active in the WAU;

- Areas of the landscape that share similar physical characteristics related to mass-wasting behavior (landform units);
- The relative potential for mass wasting to occur among the various landform units.

No comprehensive analysis of slope stability had been conducted in the Kalaloch watershed prior to this investigation.[2]

2.2 Methods

The procedures described below follow the Landslide Hazard Zonation Protocol (version 2.0, http://www.dnr.wa.gov/forestpractices/lhzproject/lhz_protocol_v2_final.pdf), with minor modifications. Five sets of 1:12,000 aerial photographs, acquired from 1979 to 1997, were analyzed with a mirror stereoscope under 3x magnification (Appendix E); a set of 1:60,000 air-photos from 1967 was inspected but not mapped. Other photo flight years were available from DNR's collection in Olympia, but these sets were missing many key photos and were therefore not reviewed.

Table 1. Aerial photographs used in this study.

Year	Project ID	Scale	Image Type	Coverage of WAU
1967	WFPA-66	1:60,000	black and white stereo	complete
1979	OBD-79	1:12,000	black and white stereo	near complete
1981	OL-81	1:12,000	black and white stereo	near complete
1985	OL-85	1:12,000	black and white stereo	near complete
1990	OL-90	1:12,000	black and white stereo	near complete
1997	OL-97	1:12,000	black and white stereo	near complete

Landslides observed on the stereo photos were classified and catalogued according to the mass wasting feature type. For the purposes of this analysis, landslides that failed below rooting depth are categorized as deep-seated landslides (per the Forest Practices Board Manual); all remaining slides are classified as shallow landslides. The mass wasting feature types include shallow-undifferentiated landslides, debris flows, debris slides and avalanches, rock topple and fall, deep-seated landslides (including earthflows), and snow avalanches.

The mapped landslides were ranked according to their relative level of certainty as questionable, probable, or definite. Features with some combination of distinct headscarps, lateral margins, scoured run-outs, oversteepened toes, obvious deposits with hummocky topography, or vegetation patterns that indicate landslide disturbance were considered to be definite landslides. Those that were more subdued or concealed by vegetation made identification of them as landslides less than certain, and were thus considered to be probable landslides. Features that resemble degraded landslides but could have been formed by non-mass movement processes were considered questionable (following Wieczorek, 1984; also Turner and Schuster, 1996). Most landslides were mapped from air photos, but several were identified in the field that were not evident on the photos, most of them in areas of heavy canopy or postdating the most recent photo set.

Following stereo air-photo analysis, all observed landslides were mapped directly into GIS. Transfer of mapped features to a digital database was accomplished by "heads-up" digitization of landslides into a GIS map with layers that included streams, roads, townships, geology, and a

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[2] Previously, some landslides in this region have been identified during geologic mapping (see section 3.2) and broad-scale slope-stability studies (Fiksdal and Brunengo, 1980, 1981; Gerstel, 1999).

USGS 10-meter digital elevation model (DEM) with DEM-derived contours, slope gradients, and hillshades. The landslides mapped in the Kalaloch Ridge WAU are presented on Map A-1.

Slope gradients for shallow landslides were determined by calculating the maximum DEM-derived slope angle within each landslide initiation polygon. For deep-seated landslides, the average angle over the entire landslide polygon was calculated. We found that using the average gradient for deep-seated landslides provides the quickest and most reasonable representation of the pre-failure slope surface compared to other GIS slope measurement methods (Bilderback, 2006).

Because lidar was not yet available for this area, the maximum resolution of this map base is about 10 m (33 ft). Slope gradients and elevations of small slope failures that were identified on high-resolution air photos are not accurately estimated by the 10 m DEM due to raster smoothing. Typically, DEM-derived slope gradients are underestimated by at least 10% relative to field-measured gradients (Dragovich and others, 1993), and more so on smaller features that are smoothed over by the DEM's coarse resolution. However, despite these limitations, the 10 m DEM was used in place of field measurements for the sake of expeditiousness to estimate the gradients of landslides. It should be emphasized that all slope gradient estimates presented in this report are likely minimum approximations.

The air-photo survey was also used to determine land use and to map rule-identified landforms (inner gorges, bedrock hollows, etc.). The 10 m DEM and other GIS products were used to map low-hazard flat areas, low-gradient hillslopes, and ridgetops, as prescribed by the LHZ protocol. The remaining land was divided into analyst-described landforms that were established from a series of statistical analyses of the mapped landslides in the basin. These analyses were focused on identifying the primary driving forces of mass wasting in the WAU based on such physical attributes of the landscape as slope gradient and convergence, elevation, annual precipitation, and lithology. We used a combination of data types in the designation of landform units, including slope gradient and elevation (from the 10 m DEM); slope convergence (from the DNR SLPSTAB model; Shaw and Johnson, 1995); geologic information (from DGER 1:100,000 mapping); and precipitation and rain-on-snow magnitudes (from DNR GIS coverages). These landforms are intended to identify areas that might be at particular hazard of mass wasting in the future. The landforms mapped in the Kalaloch Ridge WAU are presented on Map A-2 and described in Appendix C. Each landform was assigned a landslide frequency rate (LFR), a landslide area rate for delivery (LAR), and an overall hazard rating as called for by the LHZ protocol (Appendix D).

3.0 Study Area

3.1 Location, Physiography, Climate

The Kalaloch[3] Ridge WAU is located on the western margin of the Olympic Mountains physiographic province (Fig. 1; Galster and others, 1989). It covers a total area of 14,180 ac (22.2 mi^2), in a mountain block called Kalaloch Ridge rising between the deep valleys of the Hoh (north) and Clearwater–Queets (east and south) rivers. About 80% of the WAU is within the watershed of Kalaloch Creek, but the study area also encompasses the basins of many small streams draining to the Pacific between the outlet of Kalaloch Creek and the mouth of the Queets. About 3,153 ac of low-lying costal land in the WAU are part of Olympic National Park; this federally regulated parkland is not included in this landslide hazard analysis.

[3] The name is from a Quinault word (*K-e-le-ok*) meaning "good place to land canoes", referring to the sheltered beach near the mouth of Kalaloch Creek (Hitchman, 1985).

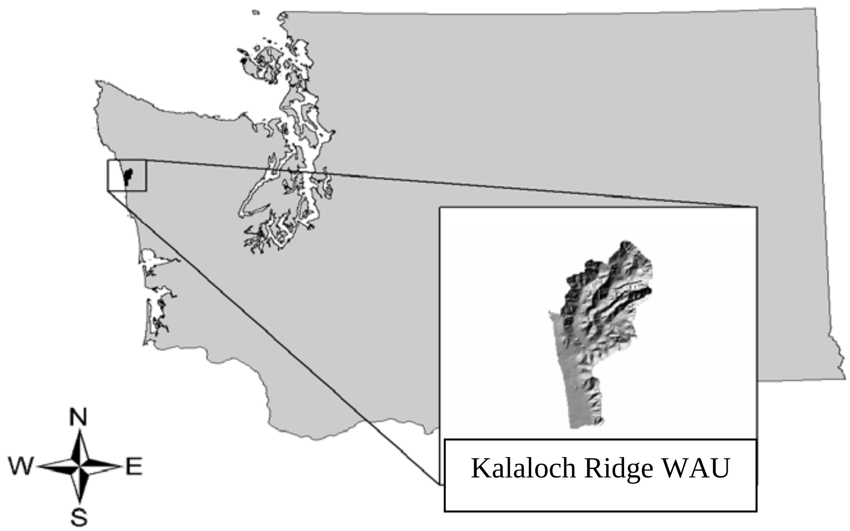

Figure 1: General location map of the Kalaloch Ridge WAU.

The Olympics have a core of lower Cenozoic sedimentary rocks, thrust under the western margin of North America in the Cascadia subduction zone; and a peripheral band of oceanic basalts and overlying sedimentary rocks around the north, east, and south sides of the range. The topography of the Olympics is generally high and rugged, particularly in the central part of the range and in the peripheral basalts, a function of rapid Tertiary to Quaternary uplift and high rates of erosion by fluvial, mass movement, and glacial processes. Mass wasting in the Olympic region includes small landslides and debris flows, large rock-based landslides, gravitational sagging of bedrock, and snow avalanches in alpine areas.

Bedrock of the Kalaloch Ridge massif consists of mid-Tertiary sedimentary rocks, overlain with unconsolidated glacial and fluvial sediments along the coastal terrace and river valleys. Ridges and summits are fairly accordant, at about 500–700 ft elevation at the west end, to about 1200–1500 ft on the high divides; local relief can reach 1000 ft even in the upper tributary canyons. The coastal terrace and the valley bottoms of the larger forks of Kalaloch Creek rise to about 200 ft elevation.

The wet temperate maritime climate of the WAU is typical of Northwest coastal mountain ranges. Figure 2 shows a time series of water-year precipitation at three long-term weather stations near Kalaloch. Annual precipitation amounts range from about 100–120 in. at the western mountain front, to about 140 in. on the ridges to the east.[4] Most of the precipitation falls between October and April; rainfall is more common at this basin's elevations, although a few inches of snow falls in most winter months even in the lowlands. The region is also susceptible to strong winds that cause significant blowdown of forest trees.

Heavy and/or intense precipitation is significant in triggering landslides. The graph (Fig. 2) shows that some years, and some periods, can be much wetter than average (e.g., 1965–76, 1981–84, the late 1990s), and others are relatively dry (1977, 1985–94, 2001). As much as 40+ in. of rain can fall

[4] Data from Western Regional Climate Center, http://www.wrcc.dri.edu; and OSU Spatial Climate Analysis Service, PRISM precipitation maps, http://mistral.oce.orst.edu/www/mapserv.

during individual months, and storms can deliver >10 in. in 24 hr. Because of the steep terrain and typically shallow soils over bedrock, the mountains shed runoff quickly during storms or snowmelt, and so are susceptible to landslides and flooding.

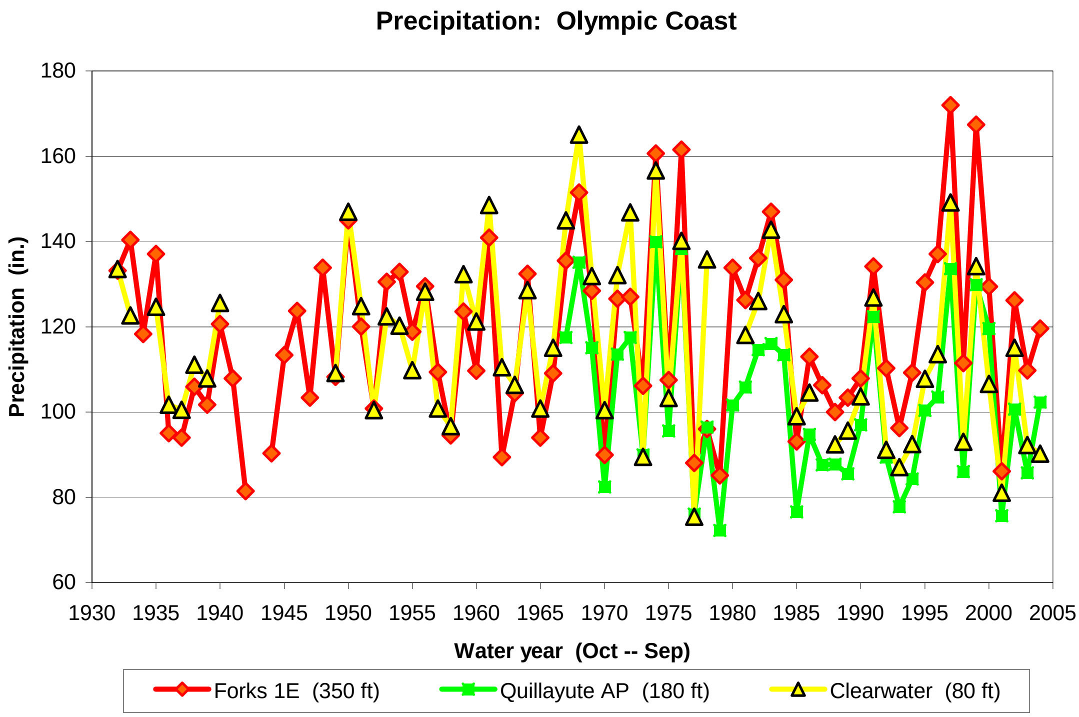

Figure 2: Time series of water-year precipitation at three long-term weather stations near Kalaloch.

3.2 Geology

A. Bedrock and Structure

The geology of the western Olympics has been dominated by plate convergence at the Cascadia subduction zone for at least 35 Ma.[5] Subduction, uplift and deformation have created a complex mountain structure; hydroclimatic and geomorphic processes have carved it into an intricate land-scape over a long history of erosion by mass wasting, water, and ice.

The Olympic Peninsula is built of Tertiary marine sedimentary rocks deposited over submarine and subaerial oceanic-island basalts, which have been lifted due to convergence and subduction of the Juan de Fuca plate beneath the North American plate. The Olympics are distinctive in that the subduction complex has been exposed above sea level since about 18 Ma (see Pazzaglia and others, 2002, 2003). From east to west, the Olympic core and coastal mountains expose older (Eocene–Oligocene) to younger (Miocene–Pliocene) sedimentary rocks that have been pushed beneath the continental margin, subjected to compression causing lithification (the hardening of sediment into rock) and low-grade metamorphism, and uplift.

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[5] The Kalaloch area was mapped by Rau (1975), with additional work in compilation of the 1:100,000 Forks quadrangle (Gerstel and Lingley, 2000). More detailed information can be found in these sources; discussions of regional geology are also contained in the field-trip guides of Pazzaglia and others (2003).

The region around Kalaloch Ridge is considered part of the currently active Olympic subduction complex. The rocks in the study area are marine sedimentary rocks, deposited in the early to middle Miocene (25–14 Ma) by turbidity currents on submarine fans on the continental margin (Hoh rock assemblage or formation; Rau, 1973, 1975; Gerstel and Lingley, 2000). Some are rhythmically bedded sandstones and shales, interpreted as interchannel and levee facies; others are thicker-bedded but laterally discontinuous sandstones (rare conglomerates), interpreted as deposits of submarine debris flows. These two kinds of rocks are mapped as interbedded throughout most of the area. A third rock type, intensely sheared tectonic breccia of mixed sedimentary rocks and basalts, was emplaced as mud diapirs or piercement structures[6] along a fault zone in the ridge southeast of Kalaloch (Elk Creek mélange zone of Rau, 1975).

Complex structural patterns have formed due to the compression and folding related to the aforementioned subduction, metamorphism and uplift. The bedded rock layers strike from N–S to E–W, and the dips range from moderate to vertical to overturned. A broad NE–SW trending fold has been inferred from coastal exposures to cross the area, centered near Kalaloch with raised limbs north of Brown's Point and south of the Queets River. The area is cut by several mapped faults, including three NNW–NNE trending high-angle reverse faults[7]; the East Fork valley, in particular, seems to have been eroded along one of these faults. The Clearwater River shear zone trends SW across the southern ridge.

B. Surficial

Several periods of colder climate and glaciation affected western Washington during the Quaternary. The latest episode (Fraser glaciation) is generally the best understood and dated, and the sequence was probably typical. However, conditions during at least three previous events were more extreme in the Olympics, judging from the greater extents of valley glaciers during earlier advances (Thackray, 1996; Pazzaglia and others, 2002, 2003).

During the Fraser glaciation, alpine glaciers expanded as global climate cooled, starting about 30 thousand years ago (ka), until they reached their maximum extent by about 20 ka and then began to generally retreat, although some later minor readvances have been inferred (Hoh Oxbow and Twin Creeks drifts of Thackray, 1996). The Cordilleran ice sheet was growing in British Columbia at the same time, and its Juan de Fuca lobe flowed westward down the Straits, eventually covering the northwest corner of the peninsula to the Quillayute River. During this time, sea level was depressed >300 ft, so the shoreline was many miles west of its current location. The region experienced maximum continental ice extent (Vashon stade) about 18–13 ka, after which continental ice rapidly wasted from the Straits of Juan de Fuca as sea level rose.

Large valley glaciers from the western Olympics occupied the Hoh, Queets, and other major valleys several times, most extensively during pre-Fraser advances (perhaps about 70, 160 and 200 ka). During glacial-age low-stands, deposition extended onto the exposed continental shelf: Destruction Island is a remnant of that once-continuous depositional surface.

The Hoh valley glacier did advance into the Kalaloch WAU over a low spot in the northern ridge separating the Hoh drainage and the west fork of Kalaloch Creek, depositing a small amount of glacial drift on the ridge tops there. The Queets and Hoh valley glaciers seem to have built large

[6] Diapirs commonly intrude vertically upward along fractures or zones of structural weakness through overlying rocks due to the density contrast (manifest as a buoyant force) between lighter rocks below and overlying denser rocks. The products of diapirism are also referred to as piercement structures.
[7] A fault resulting from compressive stresses, in which the hanging wall appears to have moved upward relative to the footwall.

proglacial fans outward from the ice margins in the lower valleys, across the adjacent lowlands and onto the exposed continental shelf. These fans probably coalesced toward the structural low around Kalaloch. There does not seem to be any strong evidence that small alpine glaciers existed in the Kalaloch Ridge area, as there are no apparent cirques in the WAU, and the maximum elevations of 1500 ft seem too low. However, small glaciers are within the range of possibility, based on a projection of Porter's (1964) trend of elevations of Pleistocene cirque floors.

The period during and immediately after glaciation was commonly a time of rapid erosion and sediment transport. The recently deglaciated hillslopes were susceptible to rapid wasting, and mass movement and surface erosion were probably significantly faster than during full glacial or since revegetation. As sea levels neared current elevations (most recently, about 5 ka), sedimentation filled the valleys with modern alluvium, and the rising ocean waves eroded landward. The wave-cut surface created during the previous major interglacial transgression (about 122 ka) is a prominent unconformity between Hoh bedrock or older drift and younger unconsolidated sediments, exposed north and south of Kalaloch.[8]

3.3 Land-Use History of Kalaloch WAU and Vicinity

A. Vegetation and Disturbance

Most of Kalaloch Ridge and the adjacent valleys are within the *Picea sitchensis* Zone, with the higher ridges and eastern slopes in the *Tsuga heterophylla* Zone (Franklin and Dyrness, 1973; Henderson and others, 1989). Sitka spruce and western hemlock are the climax tree species in these vegetation zones, but Douglas-fir and western redcedar are codominant conifers in old forests. Angiosperm trees and shrubs (red alder, bigleaf maple, vine maple, huckleberry, salal, devils club, etc.) are common in the understory and in younger stands (particularly in disturbed areas), as are a great variety of fern, forb, and herb species.

Despite the wet climate, the Olympics have been susceptible to forest fires of various sizes and intensities, caused by agents both natural (lightning) and human, usually during the hotter and drier summers (Henderson and others, 1989; Agee, 1993). The study area seems to have escaped major fires, at least in the past few centuries. Forest mapping by the USGS[9] showed burned lands in the Sol Duc and Queets valleys, but none in the Kalaloch area. But these maps also indicate a few stands in the lower Clearwater and Hoh valleys that had lower estimated timber volumes than the surrounding areas; it is likely that these stands were recovering from much earlier fires.

B. Settlement and Land Use

This part of western Jefferson County was originally occupied by members of the Queets (Quiatso) tribe, closely related to fellow Salishan-speaking Quinaults (Quinaelt or Kwle-ni-lth) to the south.[10] Together they numbered a few thousand people in pre-contact times, living in villages located near the mouths of major rivers, but they utilized the lands and resources of the valleys and mountains as well as the ocean (Ruby and Brown, 1992).

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[8] The unconformity (a substantial break or gap in the stratigraphic succession) is exposed near the foot of Beach Trail 4 near Brown's Point, where Quaternary sediments overlie overturned Hoh turbidites. The unconformity dips below sea level in the syncline axis near Kalaloch, but rises into view to the south.

[9] A survey of the Olympic Forest Reserve (originally including most of the west side of the peninsula) was performed in 1898–1900 and published in USGS Professional Paper 7 (Dodwell and Rixon, 1902); that work was incorporated into the map of Washington in Professional Paper 5 (Gannett, 1902).

[10] The Hoh and Quileute people to the north spoke distantly related Chimakuan languages. All these tribes were participants in the Quinault River Treaty in 1855–56, which led to the establishment, expansion, and allotment of the Quinault, Hoh and Quileute reservations through the 1890s.

Despite early exploration by Euro-Americans (beginning with Spanish and English mariners in the 1770–80s), the remoteness of this part of the Olympic coast delayed settlement. The Grays Harbor area was occupied in the 1850s, and the region around Forks Prairie in the 1860s–70s, but whites did not appear in Queets and Quinault lands until the late 1880s (Ruby and Brown, 1992). Townships were surveyed in the Kalaloch area by about 1900; Dodwell and Rixon's 1902 forest map indicated settlement sites at Clearwater (Post Office established 1895); Queets and Evergreen (founded 1890) on the Queets River; and "Pins" on the Hoh. Trails were shown from Lake Quinault to Queets, thence up the Clearwater Valley toward the Hoh, and an apparent road from the Hoh north to Forks Prairie. No paths were shown on the coastal terrace around Kalaloch, and perhaps the swampy ground, dense vegetation, and hills to the north made it an unattractive route; most travel along the coast was probably by boat. A wagon road was built in the Queets Valley in about 1910. Becker's Ocean Resort[11] was built in the mid–1920s, and hosted the ribbon-cutting ceremony for the opening of the Olympic Loop Highway (U.S. 101) in 1931.

The Olympic Forest Reserve was created by Grover Cleveland in 1897, encompassing most of the unappropriated federal land remaining on the Olympic Peninsula.[12] Administration was transferred to the Forest Service in 1905; Mount Olympus National Monument was carved out by Theodore Roosevelt in 1909, and became a national park in 1938. About 50,000 ac in the Hoh and Clearwater areas were transferred from Olympic National Forest to the state of Washington as trust land in about 1935. The coastal strip of the ONF was added to the park in 1953.

C. Logging and Roading

As mentioned above, none of the Kalaloch Ridge WAU was shown as either logged or burned in early forest maps (Dodwell and Rixon, 1902); mature timber stands were indicated throughout the area. No roads or trails were mapped in the WAU, only a trail up the Clearwater valley to the east.

The first topographic map published of the area, the 1956 Destruction Island 15' quadrangle (based on 1952 air-photos), indicated almost all of the WAU as forested, with the exception of about 200 ac on the slopes southeast of Kalaloch in Section 10. Other cleared patches were shown in the Clearwater basin and north of the WAU. Likewise, the only primitive (logging) roads shown extend from the highway in Section 10, up to the ridge above Elk Creek and over to the Clearwater. Apparently, almost none of the Kalaloch WAU had been roaded or logged by the early 1950s. Based on 1960 air photos, large sections of the westernmost low-lying areas of the WAU were clearcut during the late 1950s. The 1967 1:60,000 air photos show that the basic ridge-top road system of the Kalaloch WAU was in place by that time and that timber harvest had commenced on the easternmost ridges. Harvest also began in the DNR Clearwater block in about 1966. An American Automobile Association tourist map published in 1976, and the USGS 7.5' topographic maps published in 1982, show many roads throughout the Kalaloch WAU and the region in general.

3.4 Landforms and Slope Processes

A. Geology, Structure and Shallow Landslides

The rock types, structure, and geologic history of the Olympics have great importance for current landforms. Uplift patterns and the orientations of rock units and structural elements (folds and faults) affect ridge and valley forms and trends. The intrinsic rock strength, as well as stratigraphic and structural juxtaposition, influences the patterns of resistance to erosion and thus the form of

[11] See the Kalaloch area web site, from http://www.freewebs.com/onphistory.

[12] In 1893 Congress allowed the president to reserve forested federal lands for protection from fire and illegal exploitation. Initially the forest reserves were administered by the Interior Department (surveyed by the USGS); under Theodore Roosevelt, they were transferred to the Agriculture Department as national forests.

rock-based landforms. Weaker rock types, such as some sheared and subduction-complex rocks, usually form lower mountains with gentler slopes, and some undergo gravitational sagging. Resistant rock types commonly stand highest in the landscape, holding up ridges and craggy peaks. Fluvial and glacial erosion has preferentially removed the weaker rocks, commonly leaving the more resistant layers exposed as spurs and bluffs in the topography. But this high, steep terrain is susceptible to many forms of mass movement, from shallow soil slips to rare large rockslides (see Turner and Schuster, 1996). The various movement processes are influenced by different combinations of rock and soil resistance (strength), versus gravitational stress and triggering events such as storms and earthquakes.

Shallow landslides occur mostly within the mantle of soil or regolith. The marine sandstones typically weather into sandy, low-cohesion soils with little internal strength; the shales form soils with somewhat more clay. In either case, mountain soils in the Kalaloch area are generally thin, due to rapid movement on steep slopes. Water from storms tends to perch on the soil-bedrock surfaces. This combination of high relief, low cohesion, and abrupt strength and groundwater boundaries at the soil-rock interface makes these slopes highly susceptible to debris slides and flows. Harvesting of trees causes loss of the component of strength contributed by tree roots, which can be critical on marginally stable slopes.

The attitudes of bedding planes and joint surfaces also affect mass-movement processes. Discontinuities in the rock, whether sandstone-shale contacts or joint openings, are major strength boundaries. Thus, the strength available to resist downslope stress varies depending on the orientation and steepness of the discontinuities. However, Fiksdal and Brunengo (1981) did not identify any bedding-controlled landforms in the upper Clearwater basin to the east.

B. Deep-Seated Landslides

Rocks of the Olympics are somewhat susceptible to large deep-seated landslides. Fiksdal and Brunengo (1980, 1981) did not map any big slides on Kalaloch Ridge, but did identify several in detailed mapping of the upper Clearwater basin. Gerstel (1999) mapped six large deep-seated landslide features within the Kalaloch WAU, although at middle to low levels of confidence.

Long-term weathering, uplift, and incision can alter the balance of stress and strength toward slope movement, but there is usually some triggering event that provides the final push to initiate it. With small debris slides, it is typically a big storm that saturates the mantle and increases pore-water pressures, reducing the effective strength of the mass. For larger landslides, increased water input due to several months or years of above-normal precipitation (or significant land-use changes) can be enough to initiate, accelerate, or reactivate deep-seated movement. For these large slides, though, more serious triggers would seem to be required, because they have not been observed to move after large storms or abnormally wet winters. Seismic acceleration is a likely cause of some landslides, especially in a tectonically active area such as the Olympic coast.

4.0 Summary of Landslide Inventory

During this review, a representative sample of 477 mass-wasting features was inventoried from air-photo and field investigation. Of the landslides identified, 29% were mapped as shallow-undifferentiated failures, 22% were debris flows, 35% were debris slides and debris avalanches, and 15% were deep-seated landslides (Table 2). The resulting landslide inventory is presented in Map A-1. Pertinent attributes of individual features were compiled onto Form A-1 (Appendix A).

Table 2: Summary of the type and number of LHZ protocol-specified mass-wasting features mapped in the Kalaloch Ridge WAU.

Mass Wasting Feature Type	Number Mapped	Area (acres)
Shallow undifferentiated landslides	136	46.6
Debris flows	105	77.4
Debris slides/avalanches	166	99.0
Rock topples/falls	0	0.0
Snow avalanches	0	0.0
Deep-seated landslides	70	323.1
Totals	**477**	**546.1**

Land use was determined for each feature inventoried and is recorded in the inventory spreadsheet (Form A-1, Appendix A) and summary tables (Form A-3, Appendix B). As mentioned, almost none of the Kalaloch WAU had been roaded or logged by the early 1950s. Based on 1960 air photos, large sections of the low-lying western parts of the WAU were clearcut during the late 1950s, and more intense harvest and road-building occurred during the late 1960s and '70s. About 18% of identified shallow landslides were road-caused failures that occurred within the past 26 years; 62% of mapped shallow landslides were located in clear-cuts.

5.0 Landforms

We identified eight landform units during the Kalaloch Ridge landslide hazard study. Their distributions are shown on Map A-2, and they are described in Forms A-2 (Appendix C). These map units have been delineated to identify areas that have similar mass-wasting potential, potential to deliver wood, water and sediment to public resources, and/or potential to adversely affect public safety. They have been developed from a series of iterative statistical analyses of landslide attributes including gradient, elevation, lithology, and slope shape at locations of slide initiation. Since 2005, all rule-identified landforms (as described in the LHZ protocol and WAC 222-16-050) and other standard high-hazard landforms (such as active deep-seated landslides) have been assigned a uniform numbering system (1–9) as part of the LHZ protocol; other landforms receive numbers greater than 9. Not all common landforms occur in a given watershed, so the identifying numbers of landforms in any basin may not be listed as consecutive.

6.0 Hazard Ratings

Pursuant to the LHZ protocol, hazard ratings for mass-wasting landforms were determined based upon one or more of the following criteria: 1) rule-identified status (WAC 222-16-050); 2) the landslide frequency rate (LFR) and landslide area rate for delivery (LAR); or 3) the professional judgment of the analyst. Form A-4 (Appendix D) shows the values of area, landslide numbers and frequency, and hazard ratings for each of the landform units and the full Kalaloch Ridge WAU.

The LFR is used to quantify the landslide density in each landform. As described in the LHZ protocol, it is calculated from the total number of shallow landslides, excluding all questionable slides and the probable slides recognized on the first photo set, normalized for the period of study and the area of each landform, i.e., divided by record length (26 years, 1979–2005) and map unit acreage. The values are then multiplied by one million for easier interpretation. The LAR is the area of delivering shallow landslides normalized for the period of study and the area of each landform, also excluding all questionable slides and the probable slides recognized on the first photo set, and multiplied by one million. The LAR is used as a proxy for the volume of sediment that might be delivered to public resources. Limited application suggests that areas with certain ranges of LFR and LAR values have the hazard levels shown in Table 3 (from Lingley, 2004), and these qualitative ratings are in use as of the writing of this report.

Table 3: **Qualitative rating system for the LFR and LAR.**

Qualitative Ratings	Landslide Frequency Rate	Landslide Area Rate for Delivery
Low	< 100	< 76
Moderate	100 to 199	76 to 150
High	200 to 999	151 to 799
Very high	> 999	> 799

In the Kalaloch WAU, low-hazard landforms include ridge tops with slopes 0–10% (LF #19), valley bottoms and low-lying flat areas with slopes 0–10% (LF #20), and divergent and planar slopes 10–55% (LF #12). These low-hazard landforms cover about 77% of the land area of the WAU. Rule-identified landforms present in this WAU include inner gorges (LF #1) and bedrock hollows (LF #2); these are rated very high hazard, as are the active deep-seated landslides (LF #8), with a rating assigned by professional judgment. Two analyst-described landform units in the study area, slopes steeper than 55% (LF #10) and highly convergent slopes (LF #11), were also both rated very high hazard.

Note that higher LFR and LAR rates can be achieved by reducing the area of the landform. While this may appear to be "data gerrymandering", it helps limit the area of high-hazard landforms to those areas that are actually demonstrated to have high hazard.

7.0 Confidence in Work Products

The confidence in this mass wasting assessment is generally high. 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; this is particularly problematic in forested areas with heavy canopy.

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

In addition, there are several sources of systematic error that reduce the confidence in the accuracy and/or precision of the work products of this analysis. Omission occurs when mass-wasting features are not identified on air-photos or in the field due to canopy cover, gaps in the photo record, poor photo quality, or interpreter errors. Misinterpretation can occur when a mass-wasting feature is identified but incorrectly classified, when data are transposed, or when unrecognized software/file instability occurs.

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

Because many deep-seated landslides are quite large, remain heavily vegetated during movement, and may not have obvious scars visible through the canopy, misinterpretation is more likely. A recent detailed study in Cowlitz County suggests that up to 25% of inferred deep-seated landslides identified solely from air-photo analysis are misinterpreted (Wegmann, 2006). However, our 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 hillslope angles from digital elevation models typically misrepresent the true slope gradients. Given these sources of error, the confidence in the precise location and accuracy of measurements of individual landslides is considered moderate.

8.0 Acknowledgments

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Appendix A - Form A-1: Landslide Inventory

lsiuniquid	Slide_id	source_idno	Lsi_process	Certainty	ld_date	Ls_size	ld2_date	ld2_size	init elev	Photo_number	Landform	Slp_shp	Gradient	Field Gradient	Delivery	Landuse	Deep-Seated Activity	Deep Seated Type	Slope at Toe	Acreage	Geologic Unit	Comments
	1001	992	3	D	1979	4	1985	4	681	OBD-79_19A-31	7	1	54		Y	3				0.91	Mml	
	1002	992	4	P	1979	5	1990	5	495	OBD-79_19A-30	8	1	16		Y	3	R	T	20	31.74	Mml	
	1003	992	3	D	1979	5			696	OBD-79_18A-11	7	1	62		P	5				3.23	Mml	
	1004	992	2	D	1979	4			610	OBD-79_19A-29	7	1	53		P	5				0.99	Mml	
	1005	992	3	D	1979	3			473	OBD-79_19A-29	2	3	73		I	1				0.20	Mml	
	1006	992	3	D	1979	3			540	OBD-79_19A-29	2	4	60		P	1				0.14	Mml	
	1007	992	3	D	1979	4			552	OBD-79_19A-29	7	4	72		P	5				1.02	Mml	
	1008	992	2	D	1979	4			722	OBD-79_19A-29	7	3	59		Y	5				0.44	Mml	
	1009	992	3	D	1979	4			558	OBD-79_19A-29	9	1	64		Y	1				0.75	Mml	
	1010	992	2	D	1979	5			960	OBD-79_19A-27	2	1	83	95	Y	1				1.64	Mml	
	1011	992	1	D	1979	4			770	OBD-79_19A-27	7	3	99		Y	5				0.84	Mml	
	1012	992	1	D	1979	3			576	OBD-79_19A-27	9	2	40		Y	1				0.18	Mml	
	1013	992	2	D	1979	5			1116	OBD-79_19A-27	2	1	66		Y	1				2.05	Mml	
	1014	992	2	D	1979	5			1158	OBD-79_19A-27	2	1	67		Y	5				1.79	Mml	
	1015	992	1	D	1979	3			702	OBD-79_19A-27	7	3	34		N	1				0.32	Mmr	
	1016	992	1	D	1979	4			733	OBD-79_19A-27	7	3	65		P	1				0.68	Mmr	
	1017	992	3	D	1979	5			900	OBD-79_19A-27	2	1	71		Y	1				1.47	Mmr	
	1018	992	1	D	1979	3			582	OBD-79_19A-27	7	3	61		Y	1				0.12	Mml	
	1019	992	1	D	1979	3			611	OBD-79_19A-27	7	1	50		Y	1				0.14	Mml	
	1020	992	3	D	1979	4	1985	4	492	OBD-79_19A-30	2	3	86		Y	1				0.56	Mml	
	1021	992	1	D	1979	4			444	OBD-79_19A-30	9	2	78		Y	1				0.63	Mmr	
	1022	992	1	D	1979	3			482	OBD-79_19A-30	2	3	52		I	1				0.36	Mmr	
	1023	992	1	D	1979	3			657	OBD-79_19A-30	2	2	70		Y	1				0.23	Mmr	
	1024	992	1	D	1979	2			513	OBD-79_19A-30	9	2	70		Y	1				0.04	Mmr	
	1025	992	1	D	1979	2			464	OBD-79_19A-30	9	2	70		Y	1				0.07	Mmr	
	1026	992	1	D	1979	2			498	OBD-79_19A-30	9	2	38		Y	1				0.04	Mmr	
	1027	992	3	D	1979	5			1048	OBD-79_19A-26	7	4	63		Y	1				2.49	Mml	
	1029	992	3	D	1979	5			806	OBD-79_19A-26	9	2	57		Y	1				1.06	Mmr	
	1031	992	1	D	1979	4			810	OBD-79_19A-26	7	2	46		Y	5				0.67	Mmr	
	1032	992	1	D	1979	5			776	OBD-79_19A-26	7	2	80		Y	5				2.05	Mmr	
	1033	992	1	D	1979	3			652	OBD-79_19A-26	7	2	73		Y	5				0.20	Mmr	
	1034	992	1	D	1979	4			615	OBD-79_19A-26	7	2	101		Y	5				0.42	Mmr	
	1035	992	1	D	1979	3			615	OBD-79_19A-26	7	2	88		Y	5				0.24	Mmr	
	1036	992	3	D	1979	5	1985	2	603	OBD-79_19A-26	2	3	63		Y	5				2.09	Mmr	
	1037	992	1	D	1979	3			469	OBD-79_19A-26	7	2	40		N	1				0.30	Mmr	
	1038	992	1	D	1979	3			650	OBD-79_19A-29	9	1	51		Y	1				0.36	Mmr	
	1039	992	1	D	1979	3			580	OBD-79_19A-29	9	2	26		Y	1				0.21	Mmr	
	1040	992	1	D	1979	3			564	OBD-79_19A-29	9	3	67		Y	1				0.14	Mml	
	1041	992	1	D	1979	4			486	OBD-79_19A-29	9	3	44		Y	1				0.44	Mml	
	1042	992	1	D	1979	3			567	OBD-79_19A-29	9	2	55		Y	1				0.19	Mml	

Appendix A - Form A-1: Landslide Inventory

lsiuniquid	Slide_id	source_idno	Lsi_process	Certainty	ld_date	Ls_size	ld2_date	ld2_size	init elev	Photo_number	Landform	Slp_shp	Gradient	Field Gradient	Delivery	Landuse	Deep-Seated Activity	Deep Seated Type	Slope at Toe	Acreage	Geologic Unit	Comments
	1043	992	2	D	1979	3			614	OBD-79_19A-29	2	2	87		Y	1				0.39	Mml	
	1044	992	1	D	1979	5			698	OBD-79_18A-10	1	1	89		Y	1				2.80	Mml	
	1045	992	2	D	1979	5			1084	OBD-79_19A-29	2	1	39		Y	1				1.61	Mml	
	1046	992	2	D	1979	5			1063	OBD-79_19A-29	2	1	61		Y	1				1.58	Mml	
	1048	992	1	D	1979	3			1284	OBD-79_19A-25	2	2	49		I	5				0.22	Mml	
	1049	992	3	D	1979	4	1981	4	817	OBD-79_19A-25	7	2	47		Y	3				0.54	Mml	
	1051	992	1	P	1979	3			1210	OBD-79_19A-25	9	1	38		Y	1				0.23	Mml	
	1052	992	2	P	1979	4			1293	OBD-79_19A-24	1	1	29		Y	1				0.77	Mml	
	1053	992	1	P	1979	4			982	OBD-79_19A-24	7	3	37		N	5				0.53	Mml	
	1054	992	2	P	1979	4			899	OBD-79_19A-24	2	1	44		Y	1				0.57	Mmr	
	1055	992	1	P	1979	4			718	OBD-79_19A-24	1	1	40		Y	1				0.85	Mmr	
	1056	992	2	P	1979	4	1985	4	1019	OBD-79_19A-24	1	1	45		Y	1				0.46	Mml	
	1057	992	1	D	1979	4			824	OBD-79_19A-24	1	1	37		Y	1				0.60	Mmr	
	1058	992	1	D	1979	3			854	OBD-79_19A-24	2	2	60		Y	1				0.30	Mmr	
	1059	992	2	D	1979	3			825	OBD-79_19A-24	7	1	67		Y	5				0.26	Mmr	
	1060	992	3	D	1979	4			806	OBD-79_19A-24	1	2	48		Y	7				1.03	Mmr	
	1061	992	1	D	1979	3			789	OBD-79_19A-24	1	1	72		Y	1				0.24	Mml	
	1062	992	3	P	1979	4			840	OBD-79_19A-24	1	1	47		Y	1				0.54	Mml	
	1063	992	1	P	1979	3			1000	OBD-79_19A-24	9	1	40		Y	1				0.23	Mmr	
	1064	992	1	D	1979	4			1127	OBD-79_19A-24	7	4	59		Y	5				0.69	Mml	
	1065	992	1	D	1979	4			1180	OBD-79_19A-24	7	1	60		Y	5				0.61	Qapwt1	
	1066	992	1	D	1979	3			1101	OBD-79_19A-24	7	1	26		P	5				0.14	Qapw1	
	1067	992	1	D	1979	2			711	OBD-79_19A-24	1	1	22		Y	1				0.04	Mmr	
	1069	992	1	D	1979	4	1985	3	531	OBD-79_18A-15	7	2	43	60	N	5				0.45	MEbx	
	1070	992	3	P	1979	4			542	OBD-79_18A-15	1	1	42		Y	1				0.70	MEbx	
	1071	992	3	D	1979	5			441	OBD-79_18A-15	2	1	32	45	Y	5				1.43	MEbx	
	1072	992	1	D	1979	5			366	OBD-79_18A-15	2	2	35	65	Y	5				1.22	Mmr	
	1073	992	1	D	1979	3			362	OBD-79_18A-15	2	2	31	70	P	1				0.23	MEbx	
	1075	992	2	P	1979	5			506	OBD-79_18A-15	1	1	34	60	Y	5				1.73	MEbx	
	1076	992	1	P	1979	4			424	OBD-79_18A-14	1	1	62		Y	2				0.72	MEbx	
	1077	992	1	P	1979	3			683	OBD-79_18A-14	1	1	52		Y	2				0.26	MEbx	
	1078	992	1	P	1979	3			616	OBD-79_18A-14	1	1	47		Y	2				0.29	MEbx	
	1079	992	1	P	1979	5			292	OBD-79_18A-14	2	2	39		Y	1				1.06	Mmr	
	1080	992	1	Q	1979	3			212	OBD-79_18A-14	1	1	31		N	1				0.23	Mmr	
	1084	992	1	Q	1979	3			147	OBD-79_18A-14	9	2	17		Y	1				0.20	Mmr	
	1085	992	1	P	1979	3			167	OBD-79_18A-14	9	4	21		N	1				0.40	Mmr	
	1086	992	4	P	1979	5			411	OBD-79_18A-13	8	1	28		I	1	R	C	21	18.53	Mmr	
	1087	992	4	Q	1979	5			341	OBD-79_18A-13	8	2	27		I	1	R	R	20	8.04	Mmr	
	1088	992	2	P	1979	4	1985	3	445	OBD-79_18A-13	2	1	47		Y	1				0.89	Mml	
	1089	992	3	D	1979	5			345	OBD-79_18A-13	1	1	34		Y	1				1.21	MEbx	

Appendix A - Form A-1: Landslide Inventory

lsiuniquid	Slide_id	source_idno	Lsi_process	Certainty	ld_date	Ls_size	ld2_date	ld2_size	init elev	Photo_number	Landform	Slp_shp	Gradient	Field Gradient	Delivery	Landuse	Deep-Seated Activity	Deep Seated Type	Slope at Toe	Acreage	Geologic Unit	Comments
	1090	992	1	P	1979	3			202	OBD-79_18A-13	2	2	27		N	1				0.33	MEbx	
	1091	992	1	P	1979	3			189	OBD-79_18A-13	2	2	26		N	1				0.28	MEbx	
	1092	992	3	D	1979	5	1981	3	332	OBD-79_18A-13	1	1	35		Y	2				2.25	Mmr	
	1093	992	3	P	1979	5			325	OBD-79_18A-13	1	1	28		P	2				1.10	Mmr	
	1094	992	2	P	1979	5			484	OBD-79_18A-13	1	2	41		Y	3				1.42	Mml	
	1095	992	1	P	1979	4			780	OBD-79_18A-13	2	1	70		Y	3				1.01	Mml	
	1096	992	4	P	1979	5			382	OBD-79_18A-12	8	2	31		I	2	R	R	22	4.39	Mmr	
	1097	992	2	D	1979	5			408	OBD-79_18A-12	1	2	46		Y	2				1.51	Mmr	
	1098	992	1	D	1979	3			168	OBD-79_18A-12	7	3	15		Y	5				0.22	Mmr	
	1099	992	3	D	1979	4			346	OBD-79_18A-12	1	1	40		Y	1				0.72	Mmr	
	1100	992	1	D	1979	3			332	OBD-79_18A-12	2	1	40		N	1				0.31	Mmr	
	1101	992	1	P	1979	3			249	OBD-79_18A-12	2	4	30		N	1				0.18	Mmr	
	1102	992	1	P	1979	2			259	OBD-79_18A-12	2	2	39		I	1				0.10	Mmr	
	1103	992	4	Q	1979	5			374	OBD-79_18A-12	8	2	40		N	1	DI	R	43	1.59	Mmr	
	1104	992	1	D	1979	3			369	OBD-79_18A-12	2	1	76		N	1				0.33	Mmr	
	1105	992	1	D	1979	2			288	OBD-79_18A-12	2	1	55		N	1				0.10	Mmr	
	1106	992	1	P	1979	3			288	OBD-79_18A-12	2	1	57		N	1				0.16	Mmr	
	1107	992	1	D	1979	2			473	OBD-79_18A-12	2	2	53		N	1				0.09	Mmr	
	1108	992	1	D	1979	2			339	OBD-79_18A-12	2	2	39		N	1				0.05	Mmr	
	1109	992	1	D	1979	3			323	OBD-79_18A-12	2	2	64		Y	1				0.16	Mml	
	1110	992	1	D	1979	2			322	OBD-79_18A-12	1	2	43		Y	2				0.08	Mmr	
	1111	992	1	D	1979	3			374	OBD-79_18A-12	1	2	46		Y	2				0.21	Mmr	
	1112	992	2	D	1979	5			650	OBD-79_18A-11	2	1	55		P	1				1.11	Mml	
	1113	992	1	P	1979	4			724	OBD-79_18A-11	7	2	70		N	5				0.46	Mml	
	1114	992	1	P	1979	4			482	OBD-79_18A-11	1	1	44		P	1				0.53	Mml	
	1115	992	1	P	1979	2			630	OBD-79_18A-11	2	2	48		N	5				0.04	Mml	
	1116	992	1	P	1979	2			645	OBD-79_18A-11	2	2	50		N	1				0.07	Mml	
	1117	992	1	Q	1979	2			698	OBD-79_18A-11	7	2	67		N	1				0.07	Mml	
	1118	992	2	P	1979	5			519	OBD-79_18A-11	2	1	42		P	1				1.74	Mmr	
	1119	992	1	D	1979	4			427	OBD-79_18A-11	2	1	57		P	1				0.48	Mml	
	1120	992	2	D	1979	4			605	OBD-79_18A-11	2	1	57		Y	1				0.67	Mml	
	1121	992	3	D	1979	4			561	OBD-79_18A-11	2	1	66		Y	1				0.71	Mmr	
	1122	992	3	D	1979	4			583	OBD-79_18A-11	2	1	85		Y	1				0.78	Mml	
	1123	992	1	P	1979	3			560	OBD-79_18A-11	2	2	56		N	1				0.33	Mmr	
	1124	992	1	D	1979	4			529	OBD-79_18A-11	2	1	61		Y	1				0.70	Mmr	
	1125	992	3	D	1979	5			328	OBD-79_18A-11	2	1	38		Y	1				1.56	Mmr	
	1126	992	2	D	1979	5			568	OBD-79_18A-10	2	1	69		Y	1				1.78	Mmr	
	1127	992	1	D	1979	3			365	OBD-79_18A-11	9	1	25		Y	1				0.24	Mmr	
	1128	992	1	P	1979	3			405	OBD-79_18A-11	7	2	20		P	5				0.29	Mmr	
	1129	992	1	P	1979	3			328	OBD-79_18A-11	1	2	38		I	1				0.24	Mmr	

Appendix A - Form A-1: Landslide Inventory

lsiuniquid	Slide_id	source_idno	Lsi_process	Certainty	ld_date	Ls_size	ld2_date	ld2_size	init elev	Photo_number	Landform	Slp_shp	Gradient	Field Gradient	Delivery	Landuse	Deep-Seated Activity	Deep Seated Type	Slope at Toe	Acreage	Geologic Unit	Comments
	1130	992	2	D	1979	5			614	OBD-79_18A-10	1	1	68		Y	1				1.25	Mmr	
	1131	992	2	D	1979	4			581	OBD-79_18A-10	2	1	66		Y	5				0.77	Mmr	
	1132	992	2	D	1979	4			406	OBD-79_17A-9	2	2	41		P	5				0.76	Mmr	
	1133	992	4	P	1979	5			475	OBD-79_18A-10	8	3	41		Y	1	DI	C	36	1.61	Mml	
	1134	992	4	D	1979	5			606	OBD-79_18A-10	8	2	47		Y	1	DD	C	42	1.98	Mml	
	1135	992	3	D	1979	4			804	OBD-79_18A-10	2	2	60		P	1				0.64	Mml	became a debris flow
	1136	992	1	P	1979	4			448	OBD-79_18A-10	7	3	50		P	5				0.70	Mml	
	1137	992	1	P	1979	3			405	OBD-79_18A-10	2	2	52		I	5				0.35	Mml	
	1138	992	1	P	1979	4			457	OBD-79_18A-10	2	2	53		Y	5				0.53	Mml	
	1139	992	1	D	1979	4			653	OBD-79_18A-10	2	1	69		Y	1				0.47	Mml	
	1140	992	1	D	1979	3			568	OBD-79_18A-10	2	1	67		I	1				0.20	Mml	
	1141	992	3	D	1979	4			452	OBD-79_18A-10	7	3	63		I	5				0.43	Mml	became a debris flow
	1142	992	3	D	1979	4			581	OBD-79_18A-10	2	1	83		Y	1				0.57	Mml	
	1143	992	4	D	1979	5			896	OBD-79_18A-9	8	2	50		Y	1	AR	C	58	3.02	Mmr	
	1144	992	4	D	1979	5			563	OBD-79_18A-9	8	4	50		P	1	DD	C	40	1.81	Mml	
	1145	992	3	D	1979	5			868	OBD-79_18A-9	7	1	89	70	Y	5				2.98	Mml	became a debris flow
	1146	992	4	P	1979	5			833	OBD-79_18A-9	8	3	42		Y	1	DI	T	32	2.86	Mml	
	1147	992	3	D	1979	5			560	OBD-79_18A-9	2	2	56		Y	1				1.27	Mml	became a debris flow
	1148	992	3	D	1979	4			493	OBD-79_18A-9	2	2	60		Y	1				0.62	Mml	became a debris flow
	1149	992	1	D	1979	4			465	OBD-79_18A-9	9	2	58		Y	1				0.47	Mml	
	1150	992	1	Q	1979	3			654	OBD-79_18A-9	9	3	68		Y	1				0.26	Mml	
	1151	992	3	D	1979	4			869	OBD-79_18A-9	2	2	65		Y	1				0.61	Mml	
	1152	992	1	D	1979	3			656	OBD-79_18A-9	2	2	67		Y	1				0.19	Mml	
	1153	992	1	P	1979	3	1981	3	538	OBD-79_18A-8	2	3	71		Y	1				0.23	Mmr	
	1154	992	1	D	1979	4			557	OBD-79_18A-8	1	2	40		Y	1				0.92	Mmr	
	1155	992	4	P	1979	5			963	OBD-79_18A-8	8	2	44		Y	1	DD	C	21	4.93	Mml	
	1156	992	4	P	1979	4	1985	4	907	OBD-79_18A-8	8	2	49		Y	1	DD	T	43	0.65	Mml	
	1157	992	3	P	1979	4			872	OBD-79_18A-7	2	2	40		Y	1				0.84	Mml	
	1159	992	3	D	1979	4			545	OBD-79_17A-10	7	2	84		Y	5				0.83	Mml	
	1160	992	3	Q	1979	4			324	OBD-79_17A-10	9	1	58		Y	1				0.67	Mml	
	1161	992	3	D	1979	5			336	OBD-79_17A-10	2	3	47		Y	1				1.79	Mml	became a debris flow
	1162	992	4	P	1979	5			488	OBD-79_17A-9	8	2	40		Y	1	R	C	32	11.77	Mml	
	1163	992	4	P	1979	5			732	OBD-79_17A-8	8	2	43		Y	1	R	C	47	8.59	Mml	
	1164	992	3	D	1979	4			690	OBD-79_17A-8	2	1	66	105	Y	5				1.00	Mml	
	1165	992	3	D	1979	4			491	OBD-79_17A-8	7	3	37		P	5				0.96	Mml	
	1166	992	4	D	1979	3			699	OBD-79_17A-8	8	2	48		Y	1	DD	T	40	0.29	Mml	
	1167	992	4	D	1979	4	1985	5	696	OBD-79_17A-8	8	2	70		Y	1	AR	T	79	0.51	Mml	
	1168	992	4	Q	1979	5			856	OBD-79_17A-8	8	2	44		Y	1	R	C	34	4.47	Mml	
	1169	992	4	Q	1979	5			623	OBD-79_17A-7	8	3	45		Y	1	DI	T	32	2.12	Mml	
	1170	992	1	D	1979	3	1985	3	971	OBD-79_17A-6	2	2	59		I	1				0.35	Mml	

Appendix A - Form A-1: Landslide Inventory

lsiuniquid	Slide_id	source_idno	Lsi_process	Certainty	ld_date	Ls_size	ld2_date	ld2_size	init elev	Photo_number	Landform	Slp_shp	Gradient	Field Gradient	Delivery	Landuse	Deep-Seated Activity	Deep Seated Type	Slope at Toe	Acreage	Geologic Unit	Comments
	1171	992	3	D	1979	5			1177	OBD-79_17A-6	9	2	58		Y	5				1.18	Mmr	
	1172	992	4	P	1979	5			723	OBD-79_18A-10	8	1	46		Y	1	DI	T	41	3.93	Mml	
	1173	992	4	P	1979	5			418	OBD-79_18A-10	8	4	30		Y	1	DI	T	30	2.47	Mml	
	1174	992	4	Q	1979	5			643	OBD-79_18A-10	8	2	39		Y	1	DI	C	45	1.46	Mml	
	1175	992	4	Q	1979	5			426	OBD-79_18A-10	8	3	29		Y	1	R	C	20	7.53	Mmr	
	1176	992	4	Q	1979	5			327	OBD-79_17A-12	8	3	32		P	1	R	T	40	2.15	MEbx	
	1177	992	4	P	1979	5			425	OBD-79_17A-12	8	2	30		I	1	DI	T	32	1.85	MEbx	
	1178	992	4	Q	1979	5			364	OBD-79_17A-11	8	3	24		Y	1	R	T	23	4.31	Mmr	
	1179	992	4	P	1979	5			412	OBD-79_17A-11	8	2	26		Y	1	R	C	20	5.63	Mmr	
	1180	992	4	D	1979	5			601	OBD-79_18A-110	8	3	42		Y	1	AR	R	60	1.23	Mml	
	1181	992	1	Q	1979	4			578	OBD-79_18A-110	7	3	94		I	5				0.77	Mml	
	1182	992	4	P	1979	5			414	OBD-79_17A-13	8	2	45		Y	1	DI	T	37	1.51	MEbx	
	1183	992	3	P	1979	5	1985	5	614	OBD-79_17A-13	2	2	46	65	Y	1				1.10	MEbx	became a debris flow
	1184	992	3	D	1979	4			598	OBD-79_17A-13	2	2	38	55	Y	1				0.84	MEbx	became a debris flow
	1185	992	2	D	1979	4			432	OBD-79_17A-13	2	3	32	65	Y	1				0.89	MEbx	
	1186	992	3	P	1979	3			303	OBD-79_17A-13	2	2	43		Y	1				0.38	MEbx	became a debris flow
	1187	992	3	Q	1979	4			284	OBD-79_17A-13	2	2	30		Y	1				0.59	MEbx	became a debris flow
	1188	992	3	P	1979	4			218	OBD-79_17A-13	1	2	31		Y	1				0.47	Mmr	became a debris flow
	1189	992	3	P	1979	4			230	OBD-79_17A-13	2	3	35		Y	1				0.47	MEbx	
	1190	992	3	D	1979	4			305	OBD-79_17A-12	2	1	38	40	Y	1				0.90	Mmr	became a debris flow
	1191	992	1	Q	1979	4			305	OBD-79_17A-12	2	1	45		Y	1				0.74	Mmr	became a debris flow
	1192	992	3	D	1979	5			491	OBD-79_17A-12	2	1	52	75	Y	5				1.38	MEbx	
	1193	992	1	Q	1979	4			398	OBD-79_17A-11	7	2	22		I	5				0.86	Mml	
	1194	992	4	D	1979	4			291	OBD-79_17A-11	8	2	5		Y	1	AR	T	28	0.90	Mml	
	1195	992	3	D	1979	4			285	OBD-79_17A-11	2	1	40		Y	1				0.79	Mmr	became a debris flow
	1196	992	1	P	1979	5			268	OBD-79_17A-11	2	3	38		Y	1				1.27	Mmr	
	1197	992	2	D	1979	5			408	OBD-79_17A-11	2	2	55		Y	5				1.32	Mmr	became a debris flow
	1198	992	3	D	1979	5	1981	5	411	OBD-79_17A-11	2	2	74		Y	5				1.09	Mml	
	1199	992	3	D	1979	4	1981	4	411	OBD-79_17A-11	2	2	72		Y	1				0.79	Mml	
	1200	992	3	D	1979	5	1981	5	407	OBD-79_17A-11	2	2	71		Y	1				1.11	Mml	
	1201	992	3	Q	1979	4			191	OBD-79_17A-11	2	2	30		Y	1				0.67	Mmr	
	1202	992	4	Q	1979	5			503	OBD-79_17A-8	8	2	23		Y	3	R	T	20	14.53	Mml	
	1203	992	4	D	1979	5			291	OBD-79_16A-12	8	3	21		Y	1	AR	T	15	3.95	Mml	
	1204	992	1	D	1979	3			237	OBD-79_16A-12	9	2	21		Y	2				0.16	Mmr	
	1205	992	1	P	1979	2			195	OBD-79_16A-12	2	3	34		I	2				0.03	Mml	
	1206	992	4	P	1979	5			616	OBD-79_16A-11	8	1	30		Y	1	DI	T	31	3.12	Mml	
	1207	992	4	D	1979	3			312	OBD-79_16A-11	8	3	32		Y	1	DD	E	26	0.37	Mml	
	1208	992	1	D	1979	3			343	OBD-79_16A-11	9	2	37		Y	1				0.16	Mml	
	1209	992	4	D	1979	5			517	OBD-79_16A-10	8	2	36		Y	1	DI	T	20	9.62	Mmr	
	1210	992	1	D	1979	4			443	OBD-79_16A-10	4	3	44		Y	1				0.48	Mml	

Appendix A - Form A-1: Landslide Inventory

lsiuniguid	Slide_id	source_idno	Lsi_process	Certainty	ld_date	Ls_size	ld2_date	ld2_size	init elev	Photo_number	Landform	Slp_shp	Gradient	Field Gradient	Delivery	Landuse	Deep-Seated Activity	Deep Seated Type	Slope at Toe	Acreage	Geologic Unit	Comments
	1211	992	2	D	1979	4			615	OBD-79_16A-10	2	1	39		Y	1				0.92	Mml	
	1212	992	2	D	1979	4			604	OBD-79_16A-10	2	1	52		Y	1				0.74	Mml	
	1213	992	2	P	1979	5			753	OBD-79_16A-9	1	1	81		Y	1				1.19	Mmr	
	1214	992	1	Q	1979	3			680	OBD-79_16A-9	2	2	54		P	1				0.22	Mmr	
	1215	992	1	P	1979	4			762	OBD-79_16A-9	1	2	47		Y	1				0.69	Mmr	
	1216	992	3	P	1979	4			705	OBD-79_16A-9	2	1	47		Y	1				0.48	Mmr	became a debris flow
	1217	992	3	D	1979	4			772	OBD-79_16A-9	2	1	52		Y	1				1.00	Mmr	became a debris flow
	1218	992	3	D	1979	3			703	OBD-79_16A-9	2	2	69		Y	2				0.35	Qapw2	
	1219	992	3	P	1979	4			569	OBD-79_16A-9	7	1	65		Y	2				0.50	Qapw2	
	1220	992	2	D	1979	5			487	OBD-79_16A-9	1	1	40		Y	1				1.31	Mmr	
	1221	992	3	D	1979	4	1990	4	522	OBD-79_16A-9	2	2	66		I	1				0.43	Mml	became a debris flow
	1222	992	2	D	1979	4	1990	3	464	OBD-79_16A-9	1	2	33		P	1				0.43	Mml	
	1223	992	3	D	1979	4			560	OBD-79_16A-9	2	2	60	75	Y	1				0.48	Mml	became a debris flow
	1224	992	3	D	1979	3			589	OBD-79_16A-9	2	2	61	85	Y	1				0.37	Mml	became a debris flow
	1225	992	2	P	1979	5			840	OBD-79_16A-8	1	1	72		Y	1				2.37	Qapw2	
	1226	992	3	D	1979	3	1985	3	767	OBD-79_16A-8	7	3	54		I	5				0.37	Qapw2	
	1227	992	2	D	1979	4			623	OBD-79_16A-8	2	1	45		Y	1				0.61	Mml	
	1228	992	4	D	1979	5			360	OBD-79_16A-8	8	2	25		Y	1	DD	E	20	1.10	Mml	
	1229	992	4	D	1979	4			365	OBD-79_16A-8	8	2	21		I	1	AR	E	20	0.83	Mml	
	1230	992	3	P	1979	5	1985	5	726	OBD-79_16A-8	2	2	44		Y	1				1.06	Mmr	became a debris flow
	1231	992	3	D	1979	5			615	OBD-79_16A-8	7	2	54		Y	5				1.54	Mml	became a debris flow
	1232	992	4	P	1979	5			827	OBD-79_16A-7	8	3	40		Y	1	R	T	38	8.87	Qapw2	
	1233	992	3	D	1979	4			657	OBD-79_16A-7	2	2	46		Y	1				0.79	Mmr	
	1234	992	3	P	1979	4			521	OBD-79_16A-7	2	3	50		Y	1				0.54	Mml	
	1235	992	2	P	1981	4			992	OL-81_11-23-269	2	2	27		Y	5				0.98	Mml	became a debris flow
	1236	992	3	D	1981	4			1019	OL-81_11-23-269	2	2	33	75	Y	5				0.58	Mml	became a debris flow
	1237	992	3	D	1981	3			763	OL-81_11-23-269	2	3	67		Y	1				0.27	Mmr	
	1238	992	3	P	1981	3			811	OL-81_11-23-269	2	1	75		Y	1				0.38	Mmr	
	1239	992	1	P	1981	3			729	OL-81_11-23-269	2	2	72		P	1				0.18	Mmr	
	1240	992	3	D	1981	4			1358	OL-81_11-23-269	2	2	59		Y	1				0.50	Mml	became a debris flow
	1241	992	2	P	1981	3	1981	3	397	OL-81_12-22-3	1	2	40		Y	1				0.41	Mml	
	1242	992	3	D	1981	3	1981	3	438	OL-81_12-22-3	2	2	55	80	Y	1				0.35	Mml	
	1243	992	1	P	1981	3			449	OL-81_12-22-4	2	2	62		I	1				0.18	Mmr	
	1244	992	1	P	1981	3			341	OL-81_12-22-4	2	1	54		I	1				0.18	Mmr	
	1245	992	2	D	1981	4			889	OL-81_12-22-4	2	1	53		Y	1				0.65	Mml	
	1246	992	3	D	1981	3			405	OL-81_15-21-151	7	2	24		Y	5				0.31	Mmr	
	1247	992	1	D	1981	3			515	OL-81_15-21-152	7	2	10		N	5				0.14	Mmr	
	1248	992	1	D	1981	2			428	OL-81_15-21-154	9	2	28		Y	1				0.03	MEbx	
	1249	992	3	D	1981	3			346	OL-81_15-21-156	2	2	68		Y	1				0.30	Mml	
	1250	992	3	D	1981	4			319	OL-81_12-21-55	7	2	34		Y	5				0.98	Mml	

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lsiuniquid	Slide_id	source_idno	Lsi_process	Certainty	Id_date	Ls_size	Id2_date	Id2_size	init elev	Photo_number	Landform	Slp_shp	Gradient	Field Gradient	Delivery	Landuse	Deep-Seated Activity	Deep Seated Type	Slope at Toe	Acreage	Geologic Unit	Comments
	1251	992	3	P	1981	3	1985	3	413	OL-81_12-21-55	2	2	23		Y	1				0.14	Mml	
	1252	992	2	D	1981	3			321	OL-81_12-21-55	1	1	28		Y	1				0.31	Mmr	
	1253	992	3	D	1981	3			332	OL-81_12-21-55	1	2	28		Y	1				0.28	Mmr	
	1254	992	4	P	1981	3			1010	OL-81_12-21-59	8	3	44		N	1	AR	T	40	0.34	Mml	
	1255	992	1	D	1981	2			841	OL-81_12-21-59	1	1	30		Y	1				0.09	Mml	
	1256	992	1	D	1981	2			801	OL-81_12-21-59	1	1	42		Y	1				0.10	Mml	
	1257	992	1	D	1981	4	1990	4	847	OL-81_12-21-59	1	1	49		Y	1				0.54	Mml	
	1258	992	1	D	1981	2			587	OL-81_12-21-59	7	5	6		Y	1				0.10	Mml	
	1259	992	3	P	1981	3			355	OL-81_15-20-165	2	1	36		Y	1				0.25	Mmr	
	1260	992	3	D	1981	3			387	OL-81_15-20-170	2	2	49		Y	1				0.30	Mml	became a debris flow
	1261	992	2	D	1981	4			388	OL-81_15-20-170	2	1	44		Y	1				0.70	Mml	became a debris flow
	1262	992	2	D	1985	4			452	OL-85_23-20-161	2	2	50		Y	1				0.66	Mmr	
	1263	992	2	D	1985	5			521	OL-85_23-20-161	2	1	48		Y	1				1.04	Mmr	
	1264	992	3	D	1985	3			445	OL-85_23-20-161	2	2	61		Y	1				0.38	Mmr	became a debris flow
	1265	992	1	P	1985	2			149	OL-85_23-20-161	9	3	22		P	1				0.06	Qapwo2	
	1266	992	3	P	1985	3			592	OL-85_23-20-164	2	2	28		Y	1				0.26	Mml	became a debris flow
	1267	992	1	D	1985	3			782	OL-85_20-20-079	1	1	51		Y	1				0.17	Mml	
	1268	992	1	D	1985	3			715	OL-85_20-20-079	7	2	60		I	1				0.17	Mml	
	1269	992	3	D	1985	3			416	OL-85_20-21-141	2	2	72		Y	1				0.26	Mml	became a debris flow
	1270	992	1	P	1985	3			511	OL-85_20-21-141	2	2	60		Y	1				0.17	Mml	
	1271	992	3	D	1985	3			318	OL-85_20-21-140	2	2	42		I	1				0.18	Mml	
	1272	992	1	D	1985	2			170	OL-85_20-21-140	9	3	40		Y	1				0.07	Qapwo2	
	1273	992	1	D	1985	2			105	OL-85_20-21-140	9	3	5		Y	1				0.10	Mmr	
	1274	992	1	D	1985	3			696	OL-85_20-21-142	7	2	52		Y	5				0.32	Mml	
	1275	992	1	D	1985	3			742	OL-85_20-21-142	2	2	48		Y	5				0.22	Mml	
	1276	992	3	D	1985	3			809	OL-85_20-21-143	2	1	57		Y	1				0.14	Mml	
	1277	992	3	D	1985	3			363	OL-85_20-21-143	2	2	27		Y	1				0.30	Mml	
	1278	992	3	D	1985	4			683	OL-85_20-21-143	2	2	68		Y	1				0.57	Mml	became a debris flow
	1279	992	3	D	1985	3			475	OL-85_20-21-143	2	3	56		Y	1				0.39	Mml	
	1280	992	3	D	1985	4			741	OL-85_20-21-143	2	2	60		Y	1				0.51	Mml	became a debris flow
	1281	992	1	D	1985	3			592	OL-85_20-21-143	2	1	37	90	Y	1				0.19	Mml	
	1282	992	3	D	1985	3			724	OL-85_20-21-143	2	2	36		P	1				0.13	Mml	
	1283	992	4	P	1985	5			759	OL-85_20-21-144	8	3	57		P	1	DD	E	45	1.10	Mml	
	1284	992	1	D	1985	3			690	OL-85_20-21-144	9	4	53		Y	1				0.24	Mml	
	1285	992	3	D	1985	4	1990	4	1048	OL-85_20-21-145	2	2	58		Y	5				0.63	Mmr	
	1286	992	2	D	1985	3			467	OL-85_19-21-64	2	2	52		Y	1				0.28	Mml	
	1287	992	3	D	1985	3			345	OL-85_19-21-64	2	1	33		Y	1				0.17	Mml	
	1288	992	1	D	1985	2			244	OL-85_19-21-64	1	2	33		Y	1				0.04	Mml	
	1289	992	1	D	1985	2			307	OL-85_19-21-63	9	3	44		Y	1				0.09	Mml	
	1290	992	1	P	1985	3			246	OL-85_19-21-63	2	3	37		Y	1				0.25	Mmr	

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lsiuniquid	Slide_id	source_idno	Lsi_process	Certainty	ld_date	Ls_size	ld2_date	ld2_size	init elev	Photo_number	Landform	Slp_shp	Gradient	Field Gradient	Delivery	Landuse	Deep-Seated Activity	Deep Seated Type	Slope at Toe	Acreage	Geologic Unit	Comments
	1291	992	1	D	1985	3			448	OL-85_19-21-58	1	2	37		I	1				0.18	Mmr	
	1292	992	1	Q	1985	3			445	OL-85_19-21-57	1	1	34		Y	1				0.13	Mmr	
	1293	992	2	D	1985	4			507	OL-85_19-21-56	2	3	48		Y	1				0.70	Mmr	
	1294	992	2	D	1985	5			1112	OL-85_20-22-203	2	1	58		Y	1				1.05	Mml	
	1295	992	3	D	1985	4			949	OL-85_20-22-203	2	2	42		Y	1				0.42	Mml	
	1296	992	3	D	1985	4			846	OL-85_20-22-203	2	2	41		Y	1				0.47	Mml	
	1297	992	3	D	1985	3			739	OL-85_20-22-203	2	2	53		Y	1				0.21	Mmr	
	1298	992	2	D	1985	3			1004	OL-85_20-22-203	1	1	41		Y	1				0.27	Mml	
	1299	992	1	P	1985	2			745	OL-85_20-22-202	9	3	29		Y	1				0.03	Mml	
	1300	992	1	D	1985	3			585	OL-85_20-22-202	2	2	26		Y	1				0.13	Mmr	
	1301	992	1	P	1985	1			510	OL-85_20-22-202	9	2	13		Y	1				0.02	Mmr	
	1302	992	3	D	1985	3			431	OL-85_20-22-202	2	2	26		Y	1				0.11	Mmr	became a debris flow
	1303	992	2	D	1985	3			554	OL-85_20-22-201	2	2	44		Y	1				0.39	Mmr	
	1304	992	2	D	1985	3			547	OL-85_20-22-201	1	1	46		Y	1				0.22	Mmr	
	1305	992	1	P	1985	3			452	OL-85_20-22-200	9	3	29		Y	1				0.35	Mmr	
	1306	992	2	P	1985	2			434	OL-85_20-22-199	1	2	47		Y	5				0.05	Mmr	
	1307	992	3	D	1985	5			1247	OL-85_20-22-199	2	1	46	50	Y	1				2.72	Mml	became a debris flow
	1308	992	2	D	1985	4			814	OL-85_20-22-199	1	1	61		Y	1				0.43	Mml	became a debris flow
	1309	992	2	D	1985	4			1054	OL-85_20-22-199	2	1	56		Y	1				0.87	Mml	
	1310	992	2	P	1985	3			829	OL-85_20-22-199	2	2	64		Y	1				0.35	Mml	
	1311	992	3	D	1985	1			521	OL-85_20-22-199	2	3	113		I	1				0.02	Mml	
	1312	992	3	P	1985	3			521	OL-85_20-22-199	2	2	60		Y	1				0.12	Mml	
	1313	992	1	P	1985	2			461	OL-85_20-22-199	9	2	32		Y	1				0.03	Mml	
	1314	992	3	D	1985	3			564	OL-85_20-22-199	2	2	70		Y	1				0.18	Mml	
	1315	992	3	D	1985	3			451	OL-85_20-22-198	7	2	39		Y	5				0.30	Mml	
	1316	992	3	D	1985	3			464	OL-85_20-22-198	7	2	27		Y	5				0.31	Mml	
	1317	992	2	P	1985	3			576	OL-85_20-22-198	2	2	61		Y	1				0.13	Mml	
	1318	992	3	P	1985	1			511	OL-85_20-22-198	1	2	52		Y	1				0.02	Mml	
	1319	992	3	P	1985	3			587	OL-85_20-22-198	2	2	57		Y	1				0.11	Mml	
	1320	992	3	D	1985	3			423	OL-85_20-22-198	7	2	28		Y	5				0.30	Mml	
	1321	992	3	D	1985	3			419	OL-85_20-22-198	7	2	28		Y	5				0.31	Mml	became a debris flow
	1322	992	2	D	1985	4			534	OL-85_20-22-198	2	1	67		P	1				0.63	Mml	
	1323	992	3	D	1985	3			524	OL-85_20-22-198	2	3	82		P	1				0.12	Mml	
	1324	992	2	D	1985	5			725	OL-85_20-22-198	2	3	57		P	1				1.45	Mml	
	1325	992	3	D	1985	4			633	OL-85_20-22-198	2	1	62		Y	1				0.63	Mmr	
	1326	992	1	D	1985	4			568	OL-85_20-22-198	1	9	75		Y	1				0.77	Mml	became a debris flow
	1327	992	2	P	1985	5			621	OL-85_20-22-197	1	2	49		Y	3				1.94	Mml	
	1328	992	2	P	1985	5			586	OL-85_20-22-197	1	2	40		Y	3				1.37	Mml	
	1329	992	3	D	1985	2			583	OL-85_20-22-196	2	3	33		Y	1				0.05	Mml	
	1330	992	3	D	1985	2			502	OL-85_20-22-196	2	3	27		Y	1				0.07	Mml	

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lsiuniquid	Slide_id	source_idno	Lsi_process	Certainty	ld_date	Ls_size	ld2_date	ld2_size	init elev	Photo_number	Landform	Slp_shp	Gradient	Field Gradient	Delivery	Landuse	Deep-Seated Activity	Deep Seated Type	Slope at Toe	Acreage	Geologic Unit	Comments
	1331	992	3	D	1985	3			604	OL-85_20-22-195	2	2	39		Y	1				0.11	Mml	
	1332	992	2	D	1985	4			790	OL-85_20-22-195	2	1	69		Y	2				0.66	Mml	became a debris flow
	1333	992	1	D	1985	2			493	OL-85_20-22-194	9	2	39		Y	2				0.07	MEbx	
	1334	992	1	D	1985	2			787	OL-85_20-22-194	2	2	50		Y	1				0.06	Mml	
	1335	992	2	D	1985	3			940	OL-85_20-22-203	2	3	53		Y	1				0.34	Mml	
	1336	992	3	D	1985	4			586	OL-85_20-23-253	2	2	82	65	Y	1				0.43	Mml	
	1337	992	1	P	1985	3			602	OL-85_20-23-253	2	3	71		Y	1				0.13	Mml	
	1338	992	3	D	1985	3			668	OL-85_20-23-255	2	1	77		Y	1				0.33	Mml	became a debris flow
	1339	992	3	D	1985	3			646	OL-85_20-23-255	9	1	79		Y	1				0.12	Mml	
	1340	992	3	P	1985	4			852	OL-85_20-23-255	2	1	51		Y	5				0.62	Mml	became a debris flow
	1341	992	3	D	1985	3			849	OL-85_20-23-255	2	1	79		Y	1				0.23	Mml	became a debris flow
	1342	992	1	D	1985	3			850	OL-85_20-23-255	1	1	126		Y	1				0.34	Mml	
	1343	992	3	P	1985	3			865	OL-85_20-23-256	2	2	56		Y	5				0.33	Mml	became a debris flow
	1344	992	2	D	1985	4			869	OL-85_20-23-256	2	1	74		Y	1				0.50	Mml	
	1345	992	3	D	1985	4			891	OL-85_20-23-256	2	2	90	85	Y	5				0.70	Mml	became a debris flow
	1346	992	3	D	1985	4			849	OL-85_20-23-256	2	2	57		Y	5				0.67	Mml	became a debris flow
	1347	992	3	D	1985	2			673	OL-85_20-23-256	1	2	54		Y	1				0.06	Mml	
	1348	992	2	D	1985	5			1153	OL-85_20-23-257	2	1	82	70	Y	1				3.07	Mml	became a debris flow
	1349	992	3	P	1985	3			454	OL-85_20-23-258	2	1	48		Y	1				0.18	Mmr	
	1350	992	2	D	1985	4			775	OL-85_20-23-258	2	1	77		Y	1				0.78	Mmr	became a debris flow
	1351	992	4	P	1985	3			394	OL-85_20-23-258	8	4	28		I	1	DI	T	22	0.32	Mmr	
	1352	992	3	D	1985	5			986	OL-85_20-23-258	2	2	48		Y	5				1.24	Mml	
	1353	992	3	D	1985	4			848	OL-85_20-23-258	1	1	46		Y	1				0.82	Mml	became a debris flow
	1354	992	1	P	1985	3			1231	OL-85_20-23-259	2	2	47		Y	1				0.20	Mml	
	1355	992	3	P	1985	4			1204	OL-85_20-23-259	2	1	43		Y	1				0.57	Mml	became a debris flow
	1356	992	3	D	1985	5			1211	OL-85_20-23-259	2	1	56		Y	1				1.11	Mml	
	1357	992	3	D	1985	4			1376	OL-85_20-23-259	2	1	45		Y	5				0.81	Mml	
	1358	992	3	D	1985	3			490	OL-85_20-23-259	2	2	29		Y	1				0.33	Mmr	became a debris flow
	1359	992	2	D	1985	5			1210	OL-85_20-23-260	2	2	49		Y	1				1.22	Mml	became a debris flow
	1360	992	3	D	1985	4			1162	OL-85_20-23-260	2	3	51		Y	1				0.54	Mml	
	1361	992	4	D	1985	4			655	OL-85_20-23-260	8	3	34		Y	1	DD	T	32	0.93	Mmr	
	1362	992	4	D	1985	5			858	OL-85_20-23-260	8	2	42		Y	1	DI	T	45	1.16	Mmr	
	1363	992	2	D	1990	3			398	OL90_20-20-202	1	2	38		Y	2				0.14	Mml	
	1364	992	2	D	1990	3			491	OL90_20-20-202	1	2	6		Y	5				0.28	Mml	
	1365	992	2	D	1990	2			392	OL90_20-20-202	2	2	23		Y	2				0.10	Mml	
	1366	992	3	P	1990	2			345	OL90_20-20-202	2	3	30		Y	1				0.05	Mml	
	1367	992	3	D	1990	3			262	OL90_20-20-202	2	2	15		Y	1				0.21	Mml	
	1368	992	2	D	1990	4			571	OL90_20-20-203	1	1	35		Y	2				0.43	Mml	
	1369	992	3	D	1990	3			537	OL90_20-20-204	2	2	40		Y	5				0.15	Mml	
	1370	992	3	D	1990	3			519	OL90_20-20-204	2	2	48		Y	5				0.21	Mml	

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lsiuniquid	Slide_id	source_idno	Lsi_process	Certainty	ld_date	Ls_size	ld2_date	ld2_size	init elev	Photo_number	Landform	Slp_shp	Gradient	Field Gradient	Delivery	Landuse	Deep-Seated Activity	Deep Seated Type	Slope at Toe	Acreage	Geologic Unit	Comments
	1371	992	4	P	1990	5			903	OL90_20-20-204	8	2	35		Y	1	DD	T	40	1.04	Mmr	
	1372	992	3	P	1990	4			1075	OL90_20-20-205	2	2	61		Y	2				0.65	Mmr	
	1373	992	3	P	1990	4			1071	OL90_20-20-205	2	2	53		Y	2				0.62	Mmr	
	1374	992	2	D	1990	3			943	OL90_20-20-205	1	1	35		Y	2				0.24	Mmr	
	1375	992	2	D	1990	4			955	OL90_20-20-205	2	1	67		Y	2				0.64	Mml	
	1376	992	3	D	1990	3			604	OL90_22-20-286	2	2	40		Y	5				0.21	MEbx	
	1377	992	1	D	1990	2			292	OL90_20-21-150	7	2	25		Y	2				0.04	Mml	
	1378	992	2	P	1990	4			738	OL90_20-21-153	2	1	41		Y	2				0.43	Mml	
	1379	992	2	D	1990	3			686	OL90_20-21-153	2	1	45		Y	2				0.29	Mml	
	1380	992	2	D	1990	3			690	OL90_20-21-153	2	2	59		Y	2				0.15	Mml	
	1381	992	2	P	1990	3			624	OL90_20-21-153	2	2	61		Y	2				0.19	Mml	
	1382	992	3	D	1990	3			475	OL90_20-21-153	2	1	40		Y	2				0.17	Mml	
	1383	992	3	P	1990	2			349	OL90_20-21-153	9	2	33		Y	2				0.06	Mmr	
	1384	992	2	D	1990	4			583	OL90_20-21-153	2	1	61		Y	2				0.49	Mml	
	1385	992	1	P	1990	3			534	OL90_20-21-153	2	1	53		Y	2				0.18	Mml	
	1386	992	2	P	1990	3			379	OL90_20-21-153	1	2	24		Y	2				0.15	Mml	
	1387	992	2	P	1990	3			560	OL90_20-21-153	2	2	64		Y	2				0.18	Mml	
	1388	992	2	P	1990	2			558	OL90_20-21-153	2	2	49		Y	5				0.08	Mml	
	1389	992	1	D	1990	4			852	OL90_20-21-153	2	1	60		Y	5				0.70	Mml	
	1390	992	2	D	1990	4			723	OL90_20-21-153	2	1	70		Y	1				0.45	Mml	
	1391	992	2	P	1990	3			694	OL90_20-21-153	2	2	53		Y	1				0.18	Mml	
	1392	992	3	D	1990	3			785	OL90_20-21-154	2	2	24		Y	1				0.30	Mml	
	1393	992	2	D	1990	3			642	OL90_20-21-154	2	2	77		Y	1				0.19	Mml	
	1394	992	2	D	1990	4			814	OL90_20-21-154	2	1	73		Y	3				0.70	Mml	
	1395	992	4	D	1990	5			447	OL90_20-21-154	8	2	23		Y	1	AR	T	44	2.07	Mml	
	1396	992	4	D	1990	4			639	OL90_20-21-154	8	2	42		Y	1	AR	T	44	0.90	Mml	
	1397	992	1	P	1990	3			646	OL90_20-21-154	2	2	54		N	1				0.12	Mml	
	1398	992	3	D	1990	3			734	OL90_20-21-155	2	2	55		Y	2				0.14	Mml	
	1399	992	3	D	1990	3			695	OL90_20-21-155	2	2	48		Y	2				0.23	Mml	
	1400	992	3	D	1990	2			660	OL90_20-21-155	2	2	32		Y	2				0.09	Mml	
	1401	992	4	P	1990	5			580	OL90_20-21-155	8	3	15		Y	1	DD	T	15	1.50	Mml	
	1402	992	4	P	1990	5			733	OL90_20-21-155	8	2	35		Y	1	AR	T	50	1.15	Mml	
	1403	992	2	D	1990	5			938	OL90_20-21-155	1	1	28		Y	5				1.06	Mml	
	1404	992	4	P	1990	5			918	OL90_20-21-155	8	3	32		Y	1	R	T	33	17.12	Mml	
	1405	992	3	D	1990	4			617	OL90_20-21-155	2	2	38		Y	1				0.60	Mml	
	1406	992	1	D	1990	2			739	OL90_20-21-155	9	1	30		Y	1				0.08	Mml	
	1407	992	2	P	1990	4			695	OL90_20-21-155	1	1	37		Y	2				0.58	Mml	
	1408	992	2	D	1990	3			686	OL90_10-22-186	2	2	53		Y	2				0.22	Mml	
	1409	992	3	P	1990	3			653	OL90_10-22-186	2	2	47		Y	2				0.21	Mml	
	1410	992	3	P	1990	2			646	OL90_10-22-186	2	2	58		P	2				0.08	Mml	

Appendix A - Form A-1: Landslide Inventory

lsiuniquid	Slide_id	source_idno	Lsi_process	Certainty	ld_date	Ls_size	ld2_date	ld2_size	init elev	Photo_number	Landform	Slp_shp	Gradient	Field Gradient	Delivery	Landuse	Deep-Seated Activity	Deep Seated Type	Slope at Toe	Acreage	Geologic Unit	Comments
	1411	992	2	P	1990	4			751	OL90_10-22-186	2	2	47		Y	2				0.56	Mml	
	1412	992	2	P	1990	4			666	OL90_10-22-186	2	2	58		Y	2				0.72	Mml	
	1413	992	3	P	1990	3			649	OL90_10-22-186	2	2	59		Y	2				0.15	Mml	
	1414	992	3	D	1990	3			390	OL90_10-22-186	2	2	43		Y	2				0.21	Mml	
	1415	992	4	P	1990	4			743	OL90_10-22-187	8	3	55		N	1	DD	T	41	0.80	Mml	
	1417	992	3	P	1990	4			442	OL90_10-22-188	2	2	76		Y	2				0.57	Mmr	
	1418	992	3	D	1990	3			405	OL90_10-22-188	2	2	55		Y	2				0.38	Mmr	
	1419	992	4	D	1990	4			650	OL90_10-22-189	8	2	47		I	1	AR	T	38	1.00	Mml	
	1420	992	3	D	1990	5			459	OL90_10-22-189	2	2	53		Y	5				2.57	Mml	
	1421	992	1	P	1990	4			654	OL90_10-22-189	7	3	66		N	5				0.45	Mml	
	1422	992	4	P	1990	5			768	OL90_10-22-191	8	2	40		P	1	R	T	29	8.24	Mml	
	1423	992	1	P	1990	3			578	OL90_10-22-192	2	2	35		Y	2				0.13	Mmr	
	1424	992	3	P	1990	3			575	OL90_10-22-192	2	2	54		Y	2				0.20	Mmr	
	1425	992	2	D	1990	4			988	OL90_10-22-193	2	1	35		Y	5				0.81	Mml	
	1426	992	4	P	1990	5			328	OL90_10-23-154	8	3	15		Y	1	DD	T	14	2.94	Mml	
	1427	992	4	P	1990	4			246	OL90_10-23-155	8	3	17		N	1	DD	T	16	0.77	Mmr	
	1428	992	4	P	1990	4			251	OL90_10-23-155	8	3	19		Y	1	DD	T	17	0.44	Mmr	
	1429	992	3	D	1990	4			1006	OL90_10-23-155	2	1	78		Y	1				0.81	Mml	
	1430	992	2	D	1990	3			1035	OL90_10-23-155	2	1	63	85	Y	1				0.41	Mml	
	1431	992	3	D	1990	4			1278	OL90_10-23-158	2	2	47		Y	5				0.70	Mml	
	1432	992	4	P	1997	5			266	OL97_26-20-122	8	4	34		N	1	DD	T	23	3.66	Mmr	
	1433	992	4	P	1997	5			332	OL97_26-20-122	8	2	33		Y	1	DD	T	30	3.32	Mmr	
	1434	992	2	D	1997	4			421	OL97_26-20-122	2	1	60		Y	5				0.67	Mml	
	1435	992	4	P	1997	5			265	OL97_26-20-123	8	4	15		Y	2	DI	T	15	3.26	Mml	
	1436	992	4	D	1997	5			604	OL97_26-20-123	8	2	26		Y	1	DD	T	40	3.24	Mmr	
	1437	992	4	Q	1997	5			779	OL97_26-20-125	8	4	23		Y	1	DI	T	25	3.60	Mml	
	1438	992	4	P	1997	5			740	OL97_26-20-125	8	2	24		Y	1	DI	E	33	10.40	Mml	
	1439	992	2	D	1997	3			303	OL97_26-21-59	9	2	44		Y	3				0.19	Mmr	
	1440	992	4	P	1997	5			455	OL97_26-21-60	8	2	32		Y	3	R	T	20	14.73	Mmr	
	1441	992	4	D	1997	5			353	OL97_26-21-60	8	2	29		Y	3	AR	T	27	3.49	Mmr	
	1442	992	4	D	1997	5			402	OL97_26-21-60	8	3	27		Y	3	AR	T	30	3.08	Mmr	
	1443	992	3	D	1997	3			828	OL97_26-21-65	2	2	44		Y	2				0.12	Mml	
	1444	992	3	P	1997	4			609	OL97_26-21-65	2	2	48		P	2				0.73	Mml	
	1445	992	2	D	1997	3			668	OL97_26-22-3	2	2	69		Y	2				0.23	Mml	
	1446	992	3	D	1997	3			582	OL97_26-22-3	2	2	63		Y	2				0.13	Mml	
	1447	992	2	D	1997	3			531	OL97_26-22-3	2	2	41		Y	2				0.27	Mml	
	1448	992	2	P	1997	3			590	OL97_26-22-3	2	2	39		Y	2				0.39	Mml	
	1449	992	4	P	1997	5			451	OL97_26-22-3	8	3	45		Y	2	AR	T	60	1.49	Mml	
	1450	992	4	P	1997	5			399	OL97_26-22-3	8	3	16		Y	2	DD	T	17	3.89	Mml	
	1451	992	2	D	1997	4			962	OL97_26-22-4	2	1	79		Y	5				0.62	Mml	

Appendix A - Form A-1: Landslide Inventory

lsiuniquid	Slide_id	source_idno	Lsi_process	Certainty	ld_date	Ls_size	ld2_date	ld2_size	init elev	Photo_number	Landform	Slp_shp	Gradient	Field Gradient	Delivery	Landuse	Deep-Seated Activity	Deep Seated Type	Slope at Toe	Acreage	Geologic Unit	Comments
	1452	992	3	P	1997	3			407	OL97_26-22-4	2	2	49		Y	2				0.19	Mml	
	1453	992	3	D	1997	3			625	OL97_26-22-4	2	2	45		Y	2				0.18	Mml	
	1454	992	3	D	1997	3			715	OL97_26-22-4	2	2	62		Y	2				0.27	Mml	
	1455	992	1	D	1997	3			520	OL97_26-22-4	7	3	104		N	5				0.34	Mml	
	1456	992	4	P	1997	4			969	OL97_30-23-132	8	2	65		N	1	AR	T	50	0.78	Mml	
	1457	992	2	D	1997	3			1039	OL97_30-23-135	2	1	58	120	Y	2				0.38	Mml	
	1458	992	3	D	1997	3			1163	OL97_30-23-135	2	2	98	115	Y	2				0.32	Mml	
	1459	992	2	D	1997	3			1144	OL97_30-23-135	2	2	91	65	Y	2				0.37	Mml	
	1460	992	2	D	1997	3			1110	OL97_30-23-135	2	2	78	85	Y	2				0.31	Mml	
	1461	992	3	D	1997	3			762	OL97_30-23-135	2	2	110		Y	2				0.18	Mml	
	1462	992	2	D	1997	5			1196	OL97_30-23-135	2	2	77	65	Y	5				2.45	Mml	
	1463	992	3	D	1997	4			1337	OL97_30-23-135	2	1	54	55	Y	2				0.85	Mml	
	1464	992	2	P	1997	4			989	OL97_30-23-137	1	1	33		Y	2				0.76	Mml	
	1465	992	3	P	1997	3			584	OL97_30-23-137	2	2	33		Y	4				0.29	Mmr	
	1466	992	2	P	1997	3			1063	OL97_30-23-138	2	2	52		Y	2				0.28	Mml	
	1467	992	2	P	1997	4			1097	OL97_30-23-138	2	2	40		Y	2				0.91	Mml	
	1468	992	4	P	1997	5			947	OL97_30-23-138	8	3	67		Y	2	AR	T	65	1.33	Mmr	
	1469	992	2	D	1997	3			845	OL97_30-23-138	2	2	46		Y	2				0.20	Mmr	
	1470	992	2	D	1997	3			764	OL97_30-23-138	2	2	10		Y	5				0.23	Mmr	
	1471	992	2	D	1997	3			737	OL97_30-23-138	2	2	9		Y	5				0.22	Mmr	
	1472	992	2	D	1997	2			719	OL97_30-23-138	2	2	16		Y	2				0.06	Mmr	
	1473	992	3	D	1997	2			676	OL97_30-23-138	2	2	27		Y	2				0.06	Mmr	
	1474	992	3	D	1997	2			690	OL97_30-23-138	2	2	26		Y	2				0.05	Mmr	
	1475	992	4	P	1979	5			672	OBD79_17A-8	8	3	41		Y	1	AR	T	55	6.19	Mml	
	1476	992	3	D	2005	3			845	observed in field	2	1	51		I	3				0.19	Mml	
	1477	992	3	D	2005	3			500	observed in field	2	1	25	105	Y	5				0.38	Mml	
	1478	992	3	D	2005	3			857	observed in field	2	2	64	75	Y	5				0.32	Mml	
	1479	992	3	D	2005	2			860	observed in field	2	1	32		Y	3				0.10	Mml	
	1480	992	3	D	2005	2			715	observed in field	7	2	102		N	3				0.08	Mml	
	1481	992	3	D	2005	3			483	observed in field	2	2	74	85	Y	3				0.16	Mmr	
	1482	992	4	D	2005	5			911	observed in field	8	2	27		Y	3	DI	C	33	27.78	Mml	
	1483	992	4	D	2005	5			911	observed in field	8	2	29		I	3	AR	C	40	6.74	Mml	
	1484	992	3	D	1979	4			1047	OBD-79_19A-27	2	1	66	95	Y	1				0.61	Mml	
	1485	992	2	D	1979	4			776	OBD-79_19A-27	2	1	64		Y	5				0.56	Mml	
	1486	992	2	D	1979	4			1084	OBD-79_19A-27	2	1	76		Y	5				0.89	Mml	
	1487	992	2	P	1979	3	1985	3	469	OBD-79_18A-13	2	1	49		Y	1				0.31	Mml	
	1488	992	3	P	1979	4			532	OBD-79_18A-11	2	1	62		Y	1				0.62	Mml	

Appendix C A-2 Landform Descriptions

Kalaloch Creek – Form A-2

Landform # 1 – Inner Gorges – Very High Hazard

Description: Rule-identified inner gorges are steep-sided (>70%), typically flat-bottomed canyons or gullies that are formed by a combination of fluvial and mass-wasting processes. The upper boundary of an inner gorge is the first break in slope of at least 10° at the crests of their inner walls. Inner gorges can be symmetrical or asymmetrical in cross-section and are commonly discontinuous in lateral extent (See Forest Practice Board Manual Section 16). Debris slides, debris flows, slope ravel, and small rotational failures frequently originate within inner gorges. In addition, colluvial evacuations from bedrock hollows or other convergent slopes upstream from inner gorges can evolve into scouring debris flows during major hydrologic events. Inner gorge walls can revegetate rapidly, often masking recent slope failures on air photos and on the ground.

Gradient of Sidewall: >70% field-measured, or >65% DEM-measured; field-measured slopes are commonly steeper than those determined from the DEM.
Material: Inner gorges form in soil and other unconsolidated surficial deposits over all rock types within this watershed.
Elevation: Variable, between 97 and 1308 ft
Total Landform Area: 147 acres

Mass Wasting Process: Inner gorges form due to a combination of incision by streams, scouring by debris flows, and sidewall slope failures. Over-steepened walls of inner gorges often fail as debris flows, debris slides, slope ravel, or small rotational failures. Slope failure most often occurs within unconsolidated surficial deposits or at the soil-bedrock interface.

Forest Practice Sensitivity: Roots from trees that stand in and along inner gorges can extend into the gully walls and significantly impede mass wasting by providing increased soil strength (Krogstad, 1995). Timber harvest, road (and landing) construction, and other activities that result in loss of root strength on steep slopes can greatly reduce slope stability. Timber harvest can also increase hydraulic pressure in the soil by loss of canopy intercept and transpiration. Roads and landings can destabilize inner gorge walls by undercutting and oversteepening them; sidecast and road (or landing) fill can also load slopes excessively. Furthermore, roads and landings can trigger landslides by capturing surface runoff and shallow groundwater, causing saturation of road fill or thin soils.

Mass Wasting Potential: **<u>Very High</u>**, 33 landslides were mapped in 147 acres of inner gorges over a 26 year air photo period, yielding an overall Landslide Frequency Rate of 8630; 232 for road related landslides, and a Landslide Frequency Rate of 8373 for all other land uses (see LHZ protocol).

Delivery Potential/Criteria: **<u>Very High</u>**, 33 landslides (100%) with a total area of 21 acres delivered from inner gorges in this watershed. Inner gorges commonly contain steep slopes that are proximal to water; therefore, it is likely that landslides in these features will deliver sediment to streams and/or other public resources. Delivery criteria are based on field and photo observations of visible sedimentation, proximity of streams, and unobstructed routes of delivery. This unit has an overall Landslide Area Rate for delivery of 5419; 16 for road related landslides and a Landslide Area Rate for delivery of 5403 for all other land uses (see LHZ protocol).

Overall Hazard Rating: **<u>Very High</u>**, based on LHZ Protocol, LHZ Overall Landform Hazard Ratings and standard Forest Practices Rules.

Trigger Mechanisms: Mass wasting on these naturally unstable slopes is triggered by intense precipitation events (including rain-on-snow), and is accelerated by forest management activities that causes loss of root strength, oversteepening and loading of slopes and soil saturation resulting from loss of canopy or artificial diversion of surface and groundwater.

Confidence: **<u>High</u>**, based on excellent photo quality and coverage, and adequate field verification.

Comments:

Kalaloch Creek – Form A-2

Landform # 2 – Bedrock Hollows – Very High Hazard

Description: Rule-identified bedrock hollows are steep (>70% at the steepest point), spoon- or elongate inverted tear-drop-shaped areas of convergent topography with concave profiles. These features can exist on any hillslope and within other landforms. Bedrock hollows seldom contain channels but commonly drain directly into inner gorges or other channels downslope. Gradual accumulation of colluvial debris over long periods and convergence of shallow groundwater make bedrock hollows highly susceptible to slope failure; debris slides, debris flows, and other shallow landslides frequently initiate within bedrock hollows. Hollows can revegetate and fill rapidly, which often masks their presence on air photos and on the ground. However, even subdued hollows can be prone to destructive landslides.

Gradient at Steepest Slope: >70% field-measured, or >65% DEM-measured; field-measured slopes are commonly steeper than those determined from the DEM.
Material: Bedrock hollows can form in soil and other unconsolidated surficial deposits over all rock types within this watershed.
Elevation: Variable, between 161 and 1414 ft
Total Landform Area: 170 acres

Mass Wasting Process: Gradual accumulation of colluvial debris over long periods, and convergence of shallow ground-water make bedrock hollows highly susceptible to slope failure. Soil saturation, loss of root strength, and/or over-steepening of slopes in hollows can cause evacuations as debris slides, debris flows, and other shallow landslides. Slope failure occurs within unconsolidated surficial deposits or at the soil-bedrock interface.

Forest Practice Sensitivity: Roots from trees that stand adjacent to and within bedrock hollows can significantly impede mass wasting by providing increased soil strength (Krogstad, 1995). Timber harvest, road (and landing) construction, and other activities that degrade root strength on steep slopes can greatly reduce slope stability. Roads and landings can destabilize bedrock hollows by over-steepening them and by channeling water into them; sidecast and road (or landing) fill can also load slopes excessively. Great care should be taken not to channel excess water into bedrock hollows.

Mass Wasting Potential: **Very High**, 162 landslides were mapped in 170 acres of bedrock hollows over a 26-year air photo period, yielding an overall Landslide Frequency Rate of 36585; 6549 for road related landslides, and a Landslide Frequency Rate of 30036 for all other land uses (see LHZ protocol).

Delivery Potential/Criteria: **Very High**, 151 landslides (93%) with a total area of 85 acres delivered to public resources from bedrock hollows in this watershed. Bedrock hollows contain steep slopes that are commonly upstream from water; therefore, it is likely that landslides in theses features will deliver sediment to streams and/or other public resources. Delivery criteria are based on field and photo observations of visible sedimentation, proximity of streams, and unobstructed routes of delivery. This unit has am overall Landslide Area Rate for delivery of 19162; 5126 for road related landslides and a Landslide Area Rate for delivery of 14024 for all other land uses (see LHZ protocol).

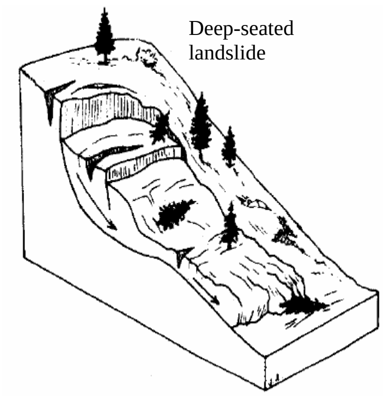
Overall Hazard Rating: **Very High**, based on LHZ Protocol, LHZ Overall Landform Hazard Ratings and standard Forest Practices Rules.

Trigger Mechanisms: Landslides can be triggered in this landform by soil saturation (particularly by artificial diversion of surface and ground water), loss of root strength, and over-steepening and loading of slopes. These mechanisms can be caused by timber harvest, road and landing construction or improper drainage especially during periods of intense precipitation events (including rain-on-snow).

Confidence: **High**, based on excellent photo quality and coverage, and adequate field verification.

Comments:

Landform # 8 – Active Deep-Seated Landslides – Very High Hazard



Description: Landform #8 consists of 18 deep-seated landslides that have evidence of recent movement such as fresh head scarps, oversteepened toes, crevassed ground, jack-strawed or split trees, recent shallow landsliding, and distinct lateral boundaries (side scarps). This landform includes both rotational and translational landslides with slip planes that are below maximum tree rooting depth. Deep-seated landslides can be further destabilized or reactivated by forest practices that undercut or oversteepen their toes, channel water onto them, change their hydrology, or load them excessively. Weakened, fractured, and recently mobilized soil and bedrock materials of deep-seated landslides are also extremely susceptible to shallow landslides. Many active deep-seated landslides extend directly into stream channels and have the potential to deliver large volumes of sediment to streams and other public resources.

Gradient: 21 to 70% (39% average)
Material: Deep-seated landslides can form in all rock types within this watershed.
Elevation: Variable, between 143 and 1021 ft
Total Area: 37.2 acres

Mass Wasting Process: Deep-seated landslides can mobilize large amounts of sediment by failing along slip surfaces that are tens to hundreds of feet deep. These large-scale slope failures can occur extremely quickly (seconds to minutes) or they can occur gradually over many years, moving either continuously or sporadically. While deep-seated landslides most commonly occur independently of human influence, they can be destabilized or reactivated by forest practices that undercut or oversteepen their toes, increasing saturation by canopy removal or channeling water onto them, or load them to excess. Furthermore, the weakened, fractured, and recently mobilized soils and bedrock materials that compose deep-seated landslides are extremely susceptible to shallow landslides, such as debris slides and debris flows.

Forest Practice Sensitivity: The bodies of many deep-seated landslides are supported from below by their toes; any forest practice that undercuts or oversteepens these toes can dramatically increase mass wasting rates. Dumping of road material (e.g. end-haul, sidecast, etc.) or other artificial loading of deep-seated landslides can increase mass movement or otherwise destabilize these features. In addition, diversion of water onto deep-seated landslides can increase hydraulic pressure within the landslide, effectively lubricating slip surfaces and potentially loading the landslide mass. Furthermore, timber harvest can potentially increase hydraulic pressure within a landslide by decreasing the canopy's capacities to intercept rain and transpire water vapor.

Mass Wasting Potential: **<u>High</u>**, 18 landslides were identified as active or recently active mass wasting features, although there were no shallow landslides identified on these deep-seated features.

Delivery Potential/Criteria: **<u>High</u>**, deep-seated landslides can mobilize large amounts of sediment through large-scale slope failure. Furthermore, many deep-seated landslides extend directly into stream channels. Delivery criteria are based on field and photo observations of proximity to streams and unobstructed routes of delivery.

Overall Hazard Rating: **<u>Very High</u>**, based on analyst professional judgment and the LHZ Protocol.

Trigger Mechanisms: Movement of these inherently unstable features can be triggered by both natural causes (such as earthquakes or intense precipitation/rain-on-snow events); undercutting by streams; or by human forest practices that change landslide hydrology (such as surface water diversion or canopy removal) or landslide structure (such as under-cutting or oversteepening of slopes, or loading of slopes).

Confidence: **<u>Moderate</u>**, based on excellent photo quality and coverage, but minimal field verification.

Comments:

Kalaloch Creek – Form A-2

Landform # 10 – Slopes Steeper than 55% – Very High Hazard

Description: Steep slopes steeper than 55% include all slope forms, convergent, divergent and planar, that are steeper than 55%. Thin soils that are not strongly anchored to incompetent, poorly consolidated, and weathered bedrock units and abundant rainfall make steep slopes in the Kalaloch Creek watershed susceptible to debris slides, debris flows, and other shallow landslides. While landslides initiate on all slope forms in this landform, areas where surface or groundwater is concentrated, contributing to increased hydraulic pressure in the soil, are particularly susceptible to slope failure. Roots from trees that stand on steep slopes play a significant role in stabilizing the thin soils mantling bedrock in this landform. This unit contains unmapped inner gorges and bedrock hollows.

Gradient: >55% (DEM-measured). Field-measured slopes are commonly steeper than those determined from the DEM.
Material: Steep slopes occur in all rock types within this watershed.
Elevation: Variable, between 62 and 1436 ft
Total Landform Area: 843 acres

Mass Wasting Process: Debris slides, debris flows, and other shallow landslides occur on the steep, thin soil mantled slopes of the Kalaloch watershed commonly sliding on the soil-bedrock interface. While landslides initiate on all slope forms in this landform, areas where surface or groundwater is concentrated are particularly susceptible to slope failure. Rock types with in the watershed are commonly weakened by fracturing and deep weathering, all of which contributes to mass wasting on these slopes (>55%).

Forest Practice Sensitivity: Roots from trees that stand on slopes >55% can significantly impede mass wasting by forming an interwoven root mat, providing greatly increased slope strength (Krogstad, 1995). Timber harvest, road (and landing) construction, and other activities that reduce root strength on these slopes can greatly reduce slope stability. Timber harvest can also increase hydraulic pressure in the soil by loss of canopy intercept and evapotranspiration. Roads and landings can destabilize steep slopes by undercutting and oversteepening them; sidecast and road (or landing) fill can also load slopes excessively. Furthermore, roads and landings can trigger landslides by capturing surface runoff and shallow groundwater, causing saturation of road fill or thin soils.

Mass Wasting Potential: **Very High**, 53 landslides were mapped in 843 acres of steep slopes greater than 55% over a 26 year air photo period, yielding an overall Landslide Frequency Rate of 2417; 867 for road related landslides, and a Landslide Frequency Rate of 1551 for all other land uses (see LHZ protocol).

Delivery Potential/Criteria: **Very High**, 45 landslides (85%) with a total area of 28 acres delivered from steep slopes greater than 55% in this watershed. The Kalaloch creek watershed has a high drainage density (8.6 miles of streams per square mile), because of this attribute, steep slopes are commonly upstream from water; therefore, it is likely that landslides in theses features will deliver sediment to streams and/or other public resources. Delivery criteria are based on field and photo observations of visible sedimentation, proximity of streams, and unobstructed routes of delivery. This unit has an overall Landslide Area Rate for delivery of 1273; 639 for road related landslides and a Landslide Area Rate for delivery of 639 for all other land uses (see LHZ protocol).

Overall Hazard Rating: **Very High**, based on LHZ Protocol.

Trigger Mechanisms: Mass wasting on these naturally unstable slopes is triggered by loss of root strength, soil saturation (particularly by artificial diversion of surface and ground water), and oversteepening and loading of slopes. These triggering mechanisms can be caused by timber harvest, road and landing construction, improper drainage, and intense precipitation events.

Confidence: **High**, based on excellent photo quality and coverage, and adequate field verification.

Comments: This landform was delineated by selecting all slopes greater that 55% based on a 10m DEM derived slope map. DEM derived slope maps commonly underestimate landslide initiation point slopes by 10% or more (Dragovich and others, 1993) and by as much as 80% in this study (see A-1 table).

Kalaloch Creek – Form A-2

Landform # 11 – Highly Convergent Slopes – Very High Hazard

Description: Highly convergent slope features include: steep swales on otherwise planar slopes; the headwater basins of small streams; and other types of channeled and unchanneled basins, swales, and hollows. This landform concentrates abundant water potentially producing areas of positive pore pressure during intense or long lasting precipitation events and deeply weathering the bedrock of the Kalaloch Creek watershed. Convergence of surficial and shallow ground water make this landform highly susceptible to slope failure; debris slides, debris flows, and other shallow landslides frequently initiate within highly convergent slopes. This unit contains unmapped inner gorges and bedrock hollows.

Gradient: >40% **-** field observed slope failures initiated on slopes as low as 40%. As mapped, this landform contains slopes between 25% and 55% (DEM-measured) and over half (57%) of the air-photo observed landslides initiated on slopes with DEM-measured gradients of less than 40%. It is important to note however, that field-measured gradients are commonly steeper than those determined from DEMs and that DEMs often omit isolated areas of steep slopes.
Material: Highly convergent slopes-related failures occur in unconsolidated surficial deposits, at the soil-bedrock interface or within highly weathered zones of the poorly consolidated, fractured bedrock units of this watershed.
Elevation: Variable, between 73 and 1394 ft
Total Landform Area: 1305 acres

Mass Wasting Process: Debris slides, debris flows, and other shallow landslides occur where water is concentrated in small drainages on convergent slopes. Slope failure mechanisms in this landform are similar to bedrock hollows and inner gorges; however, landslides initiate on gentler slopes than in these rule-identified landforms.

Forest Practice Sensitivity: Many of the observed landslides in this landform were related to concentration of water caused by both forest practices activity and natural processes. Roads and yarding scars channel and concentrate water. Timber harvest can increase mass wasting by both loss of root strength and increasing hydraulic pressure in the soil from loss of canopy intercept and transpiration. Roots from trees on highly convergent slopes can significantly impede mass wasting by providing greatly increased slope strength (Krogstad, 1995). Roads and landings were further observed to destabilize this landform by under-cutting or over steeping slopes and loading slopes with sidecast.

Mass Wasting Potential: **Very High**, 77 landslides were mapped in 1305 acres of highly convergent slopes over a 26 year air photo period, yielding an overall Landslide Frequency Rate of 2269; 472 for road related landslides, and a Landslide Frequency Rate of 1798 for all other land uses (see LHZ protocol).

Delivery Potential/Criteria: **Very High**, 73 landslides (95%) with a total area of 34 acres delivered from highly convergent slopes in this watershed. Highly convergent slopes contain slopes that are commonly upstream from water; therefore, it is likely that landslides in theses features will deliver sediment to streams and/or other public resources. Delivery criteria are based on field and photo observations of visible sedimentation, proximity of streams, and unobstructed routes of delivery. This unit has an overall Landslide Area Rate for delivery of 992; 327 for road related landslides and a Landslide Area Rate for delivery of 665 for all other land uses (see LHZ protocol).

Overall Hazard Rating: **Very High**, based on LHZ Protocol.

Trigger Mechanisms: Mass wasting on these naturally unstable slopes is triggered by loss of root strength, soil saturation (particularly by canopy removal and artificial diversion of surface and ground water), and oversteepening and loading of slopes. These triggering mechanisms can be caused by timber harvest, road and landing construction, improper drainage, and intense precipitation events.

Confidence: **High**, based on excellent photo quality and coverage, and adequate field verification.

Comments: This landform was delineated by selecting highly convergent (concave) slopes sections from the Washington Department of Natural Resources slope stability model (Shaw and Johnson, 1995). These slopes can have DEM-derived gradients as low as 25% in the Kalaloch watershed; however, based on field investigations, it is reasonable to assume that most slope failures in this landform are initiating on slopes steeper than about 40%.

Kalaloch Creek – Form A-2

Landform # 12 – Divergent and Planar Slopes between 10% and 55% – Low Hazard

Description: This landform is composed of low to moderate gradient divergent and planar slopes that exhibit a low landslide potential, and/or are not likely to deliver sediment to streams, impact public safety or impact public resources. This unit may contain unmapped inner gorges and bedrock hollows or other higher hazard map units that have been erroneously included in landform #12.

Gradient: between 10% and 55%
Material: Low gradient divergent and planar slopes can form in all rock types within this watershed. Slope failure most often occurs within unconsolidated surficial deposits or at the soil-bedrock interface.
Elevation: Between 32 and 1454 ft
Total Landform Area: 6523 acres

Mass Wasting Process: Debris slides, Debris flows, shallow undifferentiated landslides and deep-seated landslides may occur within this landform.

Forest Practice Sensitivity: Mass wasting on these naturally stable slopes tends to be influenced by human interference. Timber harvest, road (and landing) construction, and other activities that undermine root strength can greatly reduce slope stability. Timber harvest can also increase hydraulic pressure in the soil by loss of canopy intercept and transpiration. Roads and landings can destabilize slopes by undercutting and oversteepening them; sidecast and road (or landing) fill can also load slopes excessively. Furthermore, roads and landings can trigger landslides by capturing surface runoff and shallow groundwater, causing saturation of road fill or thin soils.

Mass Wasting Potential: **Moderate**, 23 landslides were mapped in 6523 acres of low gradient divergent and planar slopes over a 26 year air photo period, yielding an overall Landslide Frequency Rate of 136; 65 for road related landslides, and a Landslide Frequency Rate of 71 for all other land uses (see LHZ protocol).

Delivery Potential/Criteria: **Low**, 19 landslides (82%) with a total area of 5 acres delivered from low gradient divergent and planar slopes in this watershed. This landform has a low delivery potential because it has a relatively low mass wasting potential and most landslides initiating on this landform are small, shallow landslides. Delivery criteria are based on field and photo observations of visible sedimentation, proximity of streams, and unobstructed routes of delivery. This unit has an overall Landslide Area Rate for delivery of 31; 18 for road related landslides and a Landslide Area Rate for delivery of 14 for all other land uses (see LHZ protocol).

Overall Hazard Rating: **Low**, based on LHZ Protocol.

Trigger Mechanisms: Mass wasting triggering mechanisms vary; however, landslides are unlikely to initiate on this landform or deliver to public resources unless engineered (plugged culvert, side cast fill failure, overused skidding trail, etc.). This type of mass wasting event can be engineered on any type of landform with any type of slope gradient even if the landform is not commonly unstable.

Confidence: **High**, based on excellent photo quality and coverage, and adequate field verification.

Comments:

Kalaloch Creek – Form A-2

Landform # 19 – Ridge Tops – Low Hazard

Description: This landform includes all ridge tops and ridge noses that have gradients gentler than 11% and have a low landslide potential, with low likelihood of delivering sediment to streams or otherwise impacting public resources. This unit may contain unmapped inner gorges and bedrock hollows, or other higher hazard map units that have been erroneously included in this landform.

Gradient: Variable 0 to 10%
Material: Ridge tops can form in all rock types within this watershed.
Elevation: Variable, between 3200 and 4600 ft
Total Landform Area: 456 acres

Mass Wasting Process: Although rare, shallow landslides, deep-seated landslides, and unmapped high hazard landforms may occur within this landform.

Forest Practice Sensitivity: Mass wasting on these naturally stable slopes is unlikely, but possible if caused by human interference. Forest harvest related activities that could contribute to landslides developing on this landform would generally be the result of poor management practices and are likely to be in violation of forest practices rules. These activities might include damming streams with road fill or with blocked culverts, diverting streams from their channels, creating large undrained areas that could saturate fill material or hillslopes, sidecasting excessive amounts of uncompacted material, or channeling runoff large distances in drainage ditches.

Mass Wasting Potential: **Low**, no landslides were found to have initiated within this landform during this investigation. LHZ protocol presumes this landform will have a low mass wasting potential.

Delivery Potential/Criteria: **Low**, based on LHZ protocol level one analysis and air-photo analysis. Distance from stream channels and nearly flat topography inhibits the transport of landslide debris to public resources.

Overall Hazard Rating: **Low**, based on LHZ Protocol.

Trigger Mechanisms: Mass wasting triggering mechanisms vary; however, landslides are unlikely to initiate on this landform or deliver to public resources unless there has been failure of roads, drainage structures, etc. (plugged culvert, side cast fill failure, overused skidding trail, etc.). This type of mass wasting can happen on any type of landform with any type of slope gradient even if the landform is not commonly unstable.

Confidence: **High**, based on excellent photo quality and coverage, GIS tools, and adequate field verification.

Comments:

Kalaloch Creek – Form A-2

Landform # 20 – Valley Bottoms and Low Lying Flat Areas – Low Hazard

Description: This map unit includes all slope forms that are gentler than 11% in gradient, such as valley bottoms, stream flood plains, flat terraces, and prairies that have low landslide potential, and are not likely to deliver sediment to streams or otherwise impact public resources. This unit may contain unmapped inner gorges, bedrock hollows, or other high hazard map units that have been erroneously included in the landform.

Gradient: Variable 0 to 10%
Material: Valley bottoms can form in all rock types within this watershed, although the surficial unit is typically Quaternary alluvium.
Elevation: Variable, between 400 and 3500 ft
Total Landform Area: 1545 acres

Mass Wasting Process: Although rare, debris slides, debris flows, shallow undifferentiated landslides, and deep-seated landslides may occur within this landform.

Forest Practice Sensitivity: Mass wasting on these naturally stable slopes is unlikely, but possible if caused by human interference. Forest harvest related activities that could contribute to landslides developing on this landform would generally be the result of poor management practices and are likely to be in violation of forest practices rules. These activities might include damming streams with road fill or with blocked culverts, diverting streams from their channels, creating large undrained areas that could saturate fill material or hillslopes, sidecasting excessive amounts of uncompacted material, or channeling runoff large distances in drainage ditches.

Mass Wasting Potential: **Low**, no landslides were found to have initiated within this landform during this investigation. LHZ protocol presumes this landform will have a low mass wasting potential.

Delivery Potential/Criteria: **Low**, based on LHZ protocol level I analysis and air-photo analysis. Distance from stream channels and nearly flat topography inhibits the transport of landslide debris to public resources.

Overall Hazard Rating: **Low**, based on LHZ Protocol.

Trigger Mechanisms: Mass wasting triggering mechanisms vary; however, landslides are unlikely to initiate on this landform or deliver to public resources unless there has been failure of roads, drainage structures, etc. (plugged culvert, side cast fill failure, overused skidding trail, etc.). This type of mass wasting can happen on any type of landform with any type of slope gradient even if the landform is not commonly unstable.

Confidence: **High**, based on excellent photo quality and coverage, GIS tools, and adequate field verification.

Comments:

Appendix B - A-3 Mass Wasting Summary Tables

Landslides used for Appendix B exclude all questionable mass wasting features, all deep-seated landslides, and all probable mass wasting features from the oldest (1979) photo set, as per the LHZ protocol.

Mass Wasting Summary table: Landform 1 - Inner gorges

Activity	Shallow-undifferentiated Landslides	Debris Flows	Debris Slides	Rock Topple and Fall	Snow avalanche	Total Number of Landslides	Total Failure Area of Landslides (Acres)	Total 'Delivering' Landslides	Total Failure Area of 'Delivering' Landslides (Acres)
Clear Cut (timber 0-5 Yrs.)	13	8	4			**25**	**14.4**	**25**	**14.4**
Young Timber (5-15 yrs.)	1	4	1			**6**	**4.4**	**6**	**4.4**
Submature Timber (15-50 yrs.)		1				**1**	**1.4**	**1**	**1.4**
Mature Timber (>50 yrs.)						**0**			
Road Related		1				**1**	**0.6**	**1**	**0.6**
Partial Cut						**0**			
Yarding						**0**			
Alpine						**0**			
Other						**0**			
Landform Totals	**14**	**14**	**5**	**0**	**0**	**33**	**20.8**	**33**	**20.8**

Mass Wasting Summary table: Landform 2 - Bedrock hollows

Activity	Shallow-undifferentiated Landslides	Debris Flows	Debris Slides	Rock Topple and Fall	Snow avalanche	Total Number of Landslides	Total Failure Area of Landslides (Acres)	Total 'Delivering' Landslides	Total Failure Area of 'Delivering' Landslides (Acres)
Clear Cut (timber 0-5 Yrs.)	19	32	43			**94**	**50.2**	**84**	**48.2**
Young Timber (5-15 yrs.)		20	17			**37**	**13**	**37**	**13**
Submature Timber (15-50 yrs.)		2				**2**	**0.9**	**2**	**0.9**
Mature Timber (>50 yrs.)						**0**			
Road Related	3	9	17			**29**	**22.9**	**28**	**22.7**
Partial Cut						**0**			
Yarding						**0**			
Alpine						**0**			
Other						**0**			
Landform Totals	**22**	**63**	**77**	**0**	**0**	**162**	**87**	**151**	**84.8**

Appendix B - A-3 Mass Wasting Summary Tables

Mass Wasting Summary table: Landform 10 - Slopes steeper than 55%									
Activity	Shallow-undifferentiated Landslides	Debris Flows	Debris Slides	Rock Topple and Fall	Snow avalanche	Total Number of Landslides	Total Failure Area of Landslides (Acres)	Total 'Delivering' Landslides	Total Failure Area of 'Delivering' Landslides (Acres)
Clear Cut (timber 0-5 Yrs.)	14	1	14			**29**	**14.1**	**25**	**13.3**
Young Timber (5-15 yrs.)		1	1			**2**	**0.4**	**2**	**0.4**
Submature Timber (15-50 yrs.)			3			**3**	**0.3**	**2**	**0.3**
Mature Timber (>50 yrs.)						**0**			
Road Related	9	4	6			**19**	**15.2**	**16**	**14**
Partial Cut						**0**			
Yarding						**0**			
Alpine						**0**			
Other						**0**			
Landform Totals	**23**	**6**	**24**	**0**	**0**	**53**	**30**	**45**	**28**

Mass Wasting Summary table: Landform 11 - Highly convergent slopes									
Activity	Shallow-undifferentiated Landslides	Debris Flows	Debris Slides	Rock Topple and Fall	Snow avalanche	Total Number of Landslides	Total Failure Area of Landslides (Acres)	Total 'Delivering' Landslides	Total Failure Area of 'Delivering' Landslides (Acres)
Clear Cut (timber 0-5 Yrs.)	20	3	16			**39**	**15.9**	**36**	**15.1**
Young Timber (5-15 yrs.)	6	4	7			**17**	**3.9**	**17**	**3.9**
Submature Timber (15-50 yrs.)		1	3			**4**	**2.7**	**3**	**2.5**
Mature Timber (>50 yrs.)						**0**			
Road Related	2	4	10			**16**	**11.1**	**16**	**11.1**
Partial Cut						**0**			
Yarding			1			**1**	**1**	**1**	**1**
Alpine						**0**			
Other						**0**			
Landform Totals	**28**	**12**	**37**	**0**	**0**	**77**	**34.6**	**73**	**33.6**

Appendix B - Form A-3: Mass Wasting Summary Tables

Mass Wasting Summary table: Landform 12 - Divergent and planar slopes (10 - 55%)									
Activity	Shallow-undifferentiated Landslides	Debris Flows	Debris Slides	Rock Topple and Fall	Snow avalanche	Total Number of Landslides	Total Failure Area of Landslides (Acres)	Total 'Delivering' Landslides	Total Failure Area of 'Delivering' Landslides (Acres)
Clear Cut (timber 0-5 Yrs.)	6		5			**11**	**2.2**	**10**	**2.1**
Young Timber (5-15 yrs.)						**0**			
Submature Timber (15-50 yrs.)						**0**			
Mature Timber (>50 yrs.)			1			**1**	**0.3**	**1**	**0.3**
Road Related	6	4	1			**11**	**3.9**	**8**	**3**
Partial Cut						**0**			
Yarding						**0**			
Alpine						**0**			
Other						**0**			
Landform Totals	**12**	**4**	**7**	**0**	**0**	**23**	**6.4**	**19**	**5.4**

Appendix D - Form A-4: Landform Hazard Rating Table

Landslides used for Appendix B exclude all questionable mass wasting features, all deep-seated landslides, and all probable mass wasting features from the first (1979) photo set, as per the LHZ protocol.

LANDFORMS	**1** - Inner Gorges	**2** - Bedrock Hollows	**8** - Active Deep-seated Landslides	**10** - Slopes steeper than 55%	**11** - Highly Convergent Slopes	**12** - Divergent and planar slopes between 10 & 55%	**19** - Ridge Tops	**20** - Valley Bottoms and Low Lying Flat Areas	KALALOCH WATERSHED ADMINISTRATIVE UNIT
Area of Landform (acres)	147	170	37	843	1305.1	6523	456	1545.2	11027
Number of Shallow Landslides	33	162	0	53	77	23	0	0	348
Landslide Frequency Rate (Number of slides/Landform Area/26 Years) x 10^6	8630.1	36585	0	2417	2269.3	136	0	0	1215
Number of 'Delivering' Landslides	33	151	0	45	73	19	0	0	321
Area of 'Delivering' Landslides (acres)	21	85	0	28	34	5	0	0	172
Landslide Area Rate for Delivery (Area of Delivering Landslides/Landform Area/26 Years) x 10^6	5418.7	19162	0	1273.3	991.99	31	0	0	602
Overall Hazard Rating	**VERY HIGH**					**LOW**			**VERY HIGH**
Area of Hazard Rating	2503 acres					8524 acres			11027
% or WAU Area	22.70%					77.30%			100%

Appendix E - Detailed Air Photo List

County: Jefferson

Year: 1966
Scale: 1:60,000
Image: Black and White
Flight: WFPA 66
Ownership: DNR

Flight Line	Photo #'s	Missing Photos
63B	2-5	

Year: 1979
Scale: 1:12,000
Image: Black and White
Flight: OBD-79
Ownership: DNR

Flight Line	Photo #'s	Missing Photos
14A	5-8	
15A	4-14	
16A	4-15	
17A	2-14	
18A	4-16	
19A	22-41	28
20A	25-44	30,42

Year: 1981
Scale: 1:12,000
Image: Black and White
Flight: OL-81
Ownership: DNR

Flight Line	Photo #'s	Missing Photos
13-18	135-138	
13-19	81-91	Entire Flight Line
28-19	211-215	
13-20	30-40	Entire Flight Line
15-20	161-171	
12-21	52-61	53,56,57,60,61
15-21	145-156	
12-22	1-11	5-11
29-22	230-240	235
29-23	223-227	
11-23	262-272	62,63,65,66,67,70,71
25-23	294-297	294-296
11-24	211-220	212-220

Year: 1985
Scale: 1:12,000
Image: Black and White
Flight: OL-85
Ownership: DNR

Flight Line	Photo #'s	Missing Photos
19-18	161-164	161
19-19	102-111	
19-19	84-94	
23-20	159-167	162
20-20	79-82	
19-20	66-79	
20-21	138-148	138
19-21	52-65	
20-22	194-205	
17-22	161-163	Entire Flight Line
19-22	36-50	
17-23	235-237	
20-23	252-263	
19-23	27-34	
23-24	188-198	

Year: 1990
Scale: 1:12,000
Image: Black and White
Flight: OL-90
Ownership: DNR

Flight Line	Photo #'s	Missing Photos
22-18	24-27	
22-19	70-79	
22-19	86-96	
20-20	199-208	199
22-20	279-290	283-285
20-21	149-159	152,157
22-21	197-198	
22-21	100-112	
22-22	221-222	
10-22	185-196	
26-22	1-13	2, 4, 6
22-23	245-247	
10-23	151-162	151
21-23	270-281	274-276
10-24	92-100	

Year: 1997
Scale: 1:12,000
Image: Black and White
Flight: OL-97
Ownership: DNR

Flight Line	Photo #'s	Missing Photos
26-18	236-239	
26-19	176-186	
2-19	126-134	126-127
26-20	119-129	
2-20	92-104	94
2-21	124-125	
26-21	57-69	
2-22	82-83	
26-22	1-12	
2-22	149-160	151
2-22	58-60	Entire Flight Line
30-23	130-140	
2-23	163-174	
30-24	90-101	