Mass Wasting Module
Level II Assessment
Version 4.0

Quinault Lake, Quinault River, and Cook–Elk Watersheds,
Jefferson and Grays Harbor Counties, Washington

Prepared by:

Karl W. Wegmann

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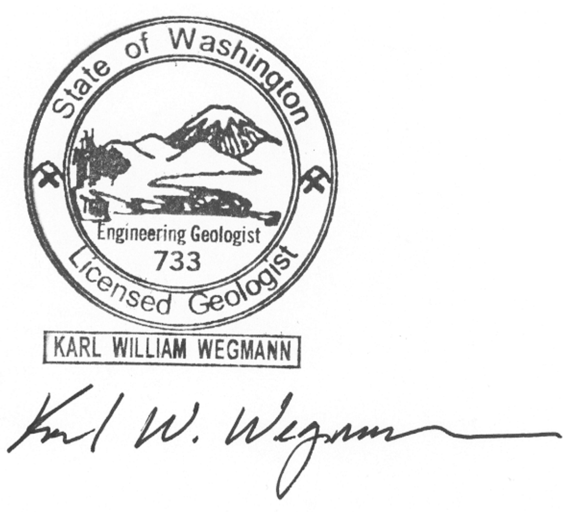

GEOLOGY AND EARTH RESOURCES ζ 1111 WASHINGTON ST SE ζ PO BOX 47007 ζ OLYMPIA, WA 98504-7007
FAX: (360) 902-1785 ζ TTY: (360) 902-1125 ζ TEL: (360) 902-1450
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1.0 Overview

The purpose of the assessment is to identify the fee and state land (non-federal and non-tribal) areas within the Quinault Lake, Quinault River, and Cook–Elk WAUs that have a moderate or high risk of landsliding due to the effects of future forest practices. Due to the relatively minor amount of non-tribal and non-federal lands within these three WAUs (slightly less than 10% of the land ownership), as well as similarities in their physiography, geology, and hydrology, it was decided that they would be analyzed together (Figure 1). Collectively, the Quinault Lake, Quinault River, and Cook-Elk WAUs total 267 mi^2, 26.1 mi^2 (~10%) of which is private or state owned (non-federal – non-tribal) lands. The Cook—Elk WAU has the largest amount of non-federal – non-tribal land ownership at 15.2 mi^2, or 35% of the WAU. Within the Quinault Lake WAU 9.8 mi^2, or 10.8% of the land area is in non-federal – non-tribal ownership. The Quinault River WAU has the smallest amount of non-tribal – non-federal land ownership at 1.1 mi^2, or 0.85% of the WAU area (Figure 1).

Mass wasting is of minimal concern for the study area, which is dominated by valley floor and glacial piedmont plain environments. No landslides were identified during review of aerial photographs. As a result, a single Low Hazard Potential Mass Wasting Map Unit (MWMU) covering the entire assessment area was delineated. However, alluvial debris fans, areas of high sediment delivery located at the transition in slope from steep confined channels to open flat valley floors, were delineated where the possibility of potential future impact to State or fee lands exists. These alluvial debris fans are recognized as *landforms of concern*, which may fall under Washington Forest Practice regulations for either "Sensitive Sites" or "Channel Migration Zones" (WAC-222-16-010).

The Mass Wasting methodology requires that several Critical Questions be answered by the analysis (see Section 5.0 for the Critical Questions).

This mass wasting assessment was conducted using aerial photographs and maps. Using this information, the geologist evaluates mass wasting processes relative to the critical questions. A series of exercises designed to either confidently answer the key questions, or identify more detailed information necessary to do so, is developed in this assessment. The objective of these exercises is to generate information sufficient to establish:

1. The mass wasting features and processes (e.g. shallow-rapid landslides, debris flows, and deep-seated failures) active in the basin.

2. Portions of the landscape having similar inherent physical characteristics relative to mass-movement behavior.

3. The relative potential for mass wasting impacts associated with the landscape units.

1.1 Introduction to Mass Wasting Processes and Terminology

Terminology used to describe mass wasting processes in this assessment follows the classification system established by the Washington Forest Practices Board's standard methodology for conducting watershed analysis (1997) and updated by the landslide compilation of Boyd and Vaugeois (2003), which places slope movement into nine types (shallow-rapid, debris flow, debris avalanche, shallow sporadic deep-seated, large persistent deep-seated, earth flow, rock topple / fall, and snow avalanche). Geomorphic analysis is aided by designating landform, slope shape, and land use associated with landsliding. Other attributes related to landslide data analysis can also be collected and analyzed.

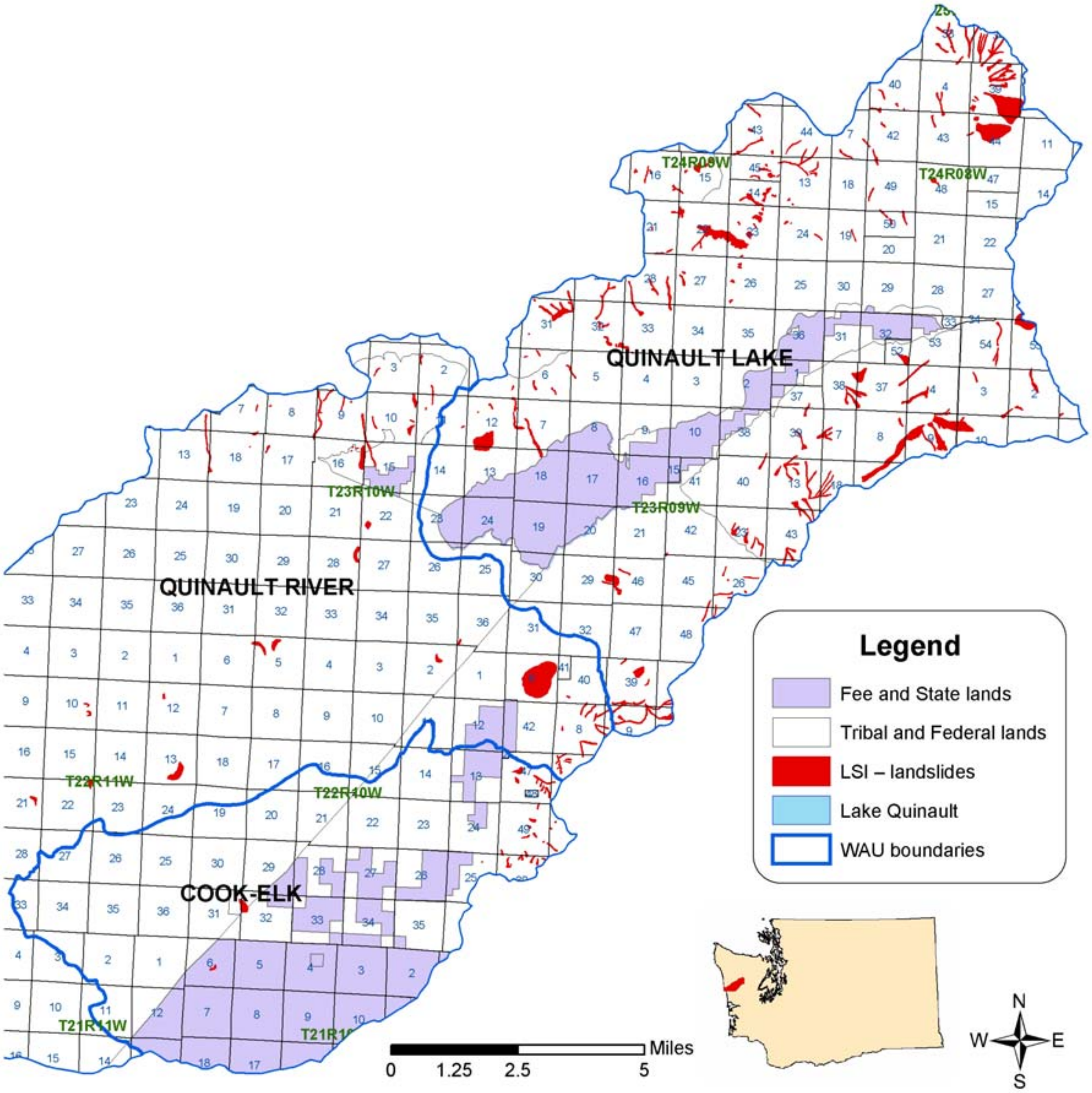

Figure 1. Map of the Quinault Lake, Cook—Elk, and eastern half of the Quinault River WAUs showing the location of private and State lands reviewed during the mass wasting assessment. Red landslide polygons are from Lingley (1999). Note that the only landslide located within lands reviewed during this assessment is in Section 6, Township 21 North, Range 10 West of the Cook—Elk WAU.

2.0 Summary of Geologic and Physiographic Setting Pertinent to Mass-Wasting Interpretations

The lands reviewed in this assessment occupy primarily gently sloping to flat terrain within the Quinault River valley and adjacent piedmont plain. Less than 5% of the assessed land occupies steeper valley-wall side slopes. In the Quinault Lake WAU, assessed lands are underlain primarily by recent alluvial deposits of the Quinault River and tributary streams. Steeper hillslope areas along the southern side of the Quinault valley are underlain by older glacial deposits (> 20,000 years; Moore, 1965) and sandstone and basaltic bedrock (Tabor and Cady, 1978). Assessed lands in the Quinault River and Cook–Elk WAUs are underlain almost entirely by older glacial drift (Chow Chow drift of Moore, 1965) consisting of silt, sand, gravel, and cobbles derived from the basalt and sedimentary rocks of the Olympic mountains. Mass wasting is generally not an issue with the alluvial and glacial deposits underlying the overwhelming majority of the assessed lands in the three WAUs, as slope angles are not steep enough for the initiation of slope failure.

2.1 Topography

In combination, the three watersheds range in elevation from sea level at the mouth of the Quinault River to 4,495 feet above mean sea level (amsl) at the summit of Colonel Bob in the Quinault Lake WAU. The assessed lands, on the other hand, only range in elevation from 173 feet to 803 feet (amsl). West of Lake Quinault, the topography is flat to gently undulating. With the exception of the Quinault River, stream incision into the older glacial deposits west of Lake Quinault is minimal. East of lake Quinault, the topography is characterized by a broad flat alluvial valley floor that transitions abruptly into steep bedrock valley-side slopes. Numerous alluvial debris fans are located where streams exit the steep valley margins onto the flat valley floor.

2.2 Geology

The three watersheds are composed of three, generally east-northeast trending, major geologic units that have markedly different weathering and erosion characteristics: 1) late Quaternary sediments (sand, gravel, and clay) deposited in the valley of the Quinault River, some of its tributaries, and across the broad piedmont plain west of Lake Quinault by several advances of Pleistocene alpine glacial ice, 2) The Tertiary volcanic rocks of the Crescent Formation cropping out on Quinault Ridge south of the Quinault valley, and 3) Tertiary sandstones with minor amounts of shale and other rock types that form the highlands north of the Quinault Valley (Lingley and others, 1996; Quinault Indian Nation, 1999). For the purposes of this assessment, only the glacial and alluvial sediments are of significant importance. During the past 160,000 years there have been at least 4 major glacial advances in the Quinault basin, based upon correlation of glacial deposits with the Queets and Hoh basins to the north (Moore, 1965, Thackray, 1996). The Quinault lowlands contain up to several hundred feet of glacial deposits (silt, sand and gravel), as well as lake and swamp deposits laid down during interglacial periods (Quinault Indian Nation, 1999). The glaciers pushed up low gravel ridges (terminal moraines) that dammed Lake Quinault and formed several sets of convex-to-the-west ridges across the piedmont plain. The glacial deposits are stable from a mass wasting perspective, except along exposed river bluffs and stream banks, where fluvial erosion may undermine the slope.

2.3 Hydrology

Precipitation within the three watersheds is extreme, ranging from 80 inches per year along the Pacific coast to over 200 inches per year in the upper elevation reaches (DNR, 2003). The average annual rainfall at Lake Quinault is 146 inches (Quinault Indian Nation, 1999). Most of the annual rainfall occurs between October and May with a pronounced summer dry season. During the winter months, elevations between about 1,000 and 3,000 feet are susceptible to rain-on-snow hydrologic events (DNR, 1991), which, if they occur, often trigger widespread mass wasting along the steep Quinault valley margins. Above 3,000 feet, a winter snow pack may develop from December through March.

The major floods of known record occurred in 1909, 1949, 1955, 1961, and 1997 (USGS 2004), with the largest, a 50-year event, occurring in 1909 (Quinault Indian Nation, 1999). Sedimentation on alluvial debris fans was observed in aerial photographs following large hydrologic events, such as in 1997. The lack of identified mass wasting events on lands encompassed by this assessment indicates that extreme precipitation events do not have a significant impact on triggering mass wasting events.

2.4 Summary of Previous Mass Wasting Investigations

Lingley (1999) completed an extensive landslide inventory for the Quinault watershed, which includes the three watershed analysis units reviewed in this assessment. In total, Lingley identified 306 mass wasting features over a 58-year photo history for the Quinault Lake, Quinault River, and Cook–Elk WAUs. Of the mass wasting features identified by Lingley, only one, a large persistent deep-seated landslide located along an unnamed tributary to Elk Creek in Section 6, Township 21 North, Range 10 West of the Cook–Elk WAU falls within the lands assessed under this study. Based upon photographic evidence collected during this assessment, this single landslide does not appear to deliver sediment to public resources and is not believed to be active. The other 305 identified mass wasting features are located entirely within tribal or federal lands. The conclusion reached during this review, that there are no areas of mass wasting concern within the assessed land, is further supported by the fact that: 1) only one landslide was identified in any of the fee and State lands in these three WAUs over a 58 year-photo review by another analyst; and 2) that this landslide does not impact public resources and is believed to be inactive.

3.0 Summary of Methods

This assessment follows the Level II Mass Wasting methodology presented in the Standard Methods for Conducting Watershed Analysis Version 4.0 (WFPB 1997), with the exception of a field visit. As no mass wasting features were identified during the aerial photograph review, it was decided that a field assessment was unwarranted. Available geology, topography, soils, and hydrology information was reviewed for the assessment area. Aerial photographs taken in 1962 (DNR 1:12,000 black and white), 1967 (DNR 1:12,000 black and white), 1972 (DNR 1:12,000 black and white), 1981 (DNR 1:12,000 black and white), 1990 (DNR 1:12,000 black and white), 1997 (DNR, 1:12,000 black and white), and 2000 (DNR 1:32,000 black and white) were viewed with a mirrored stereoscope with 3x magnification. A slope/convergence map (SLPSTAB; Vaugeois, 2000) and a slope-percent map derived from a USGS 10-meter digital elevation model (DEM) of the watershed aided in predicting areas of potential shallow-rapid slope failure (Vaugeois, 2000). Interpretation of aerial photographs, topographic maps, and a DEM, as well as previous field inspections by the author, aided in the delineation of alluvial debris fans as 'landforms of concern'. These landforms were digitized into an ESRI shapefile utilizing ArcGIS. Bill Lingley, Washington Division of Geology and Earth Resources, reviewed the assessment.

4.0 Summary of Analysis and Results

For the fee and State lands of the Quinault Lake, Quinault River, and Cook—Elk WAUs, no mass wasting features were identified during this assessment across a 35-year photo period. A previous landslide inventory for the Quinault watershed found only one landslide within the assessment area (Map

A-1; Lingley, 1999), and this landslide, considered to be inactive, does not impact public resources. Based upon these findings, a single Mass Wasting Map Unit of Low Hazard Potential rating was delineated for the entire assessment area. Adherence to Washington Forest Practice rules concerning potentially unstable slopes or landforms should be adequate for resource protection (e.g. WAC 222-16-010).

Alluvial debris fans, zones of coarse sediment deposition along valley margins resulting from up-channel debris flows, were delineated in the assessment area. Although these landforms are not areas of mass wasting per se, they often represent the rapid deposition of large volumes of coarse sediment and woody debris resulting from debris flows that initiate higher in the channel network. Several of these alluvial debris fans exhibit evidence, both from aerial photographs and field observations, of active sediment deposition and channel position changes within the past 10 years, and are thus noted as 'landforms of concern' in this assessment (Map A-2). Forest practice activities on alluvial debris fans may be regulated under Washington Forest Practices regulations for *Sensitive Sites* or *Channel Migration Zones* (WAC 222-16-010).

5.0 Description of Mass Wasting Units

The distribution and area of Mass Wasting Map Units (MWMUs) for the fee and State land portions of the Quinault Lake, Quinault River, and Cook—Elk WAUs are shown on Map A-2. A single MWMU, with a Low Hazard Potential rating, covering the entire assessment area, was delineated.

MWMU1: Low Hazard Areas

This unit encompasses all of the fee and State lands reviewed during this assessment. MWMU1 is characterized by low gradient alluvial valley bottoms, low gradient glacial piedmont plain and outwash surfaces of minimal to moderate dissection, and moderate to steep planar hillslopes along valley margins. MWMU1 is composed of alluvial deposits of the Quinault River and tributaries, glacial drift, consisting of silt, sand, gravel and cobbles, and minor amounts of Tertiary sandstone and basaltic bedrock. A single deep-seated landslide was previously identified within MWMU1 (Lingley, 1999). This inactive landslide does not impact public resources. Slopes range from 0 to 125% with an average slope of 3.5%. The elevation of MWMU1 ranges from 173 to 803 feet. Only one landslide is identified within MWMU1, in the Cook—Elk WAU (Lingley, 1999).

6.0 Summary of Critical Questions

In order to explicitly address the critical questions posed by the Standard Methods for Conducting Watershed Analysis, the following summaries are included:

What evidence is present for mass wasting or mass wasting potential in the watershed?

No mass wasting features were identified during this assessment of fee and State Lands. One large persistent deep-seated landslide was identified in the Cook—Elk WAU by Lingley (1999). Based upon these findings, the mass wasting potential for the assessed lands is negligible.

What mass wasting processes are active?

The only documented mass wasting process is deep-seated landsliding. The morphology of this lone landslide indicates that it is probably an old or relict feature.

How are mass wasting features distributed throughout the landscape?

See Map A-1. Mass wasting features are almost completely absent from the landscape of the assessed areas.

Do landslides deliver sediment to stream channels or other waters, or threaten public works or safety?

No.

How do forest management activities create or contribute to instability?

Forest management activities were not observed to create or contribute to slope instability on the assessed lands. Current Washington Forest Practice regulations should be adequate to insure resource protection as impacted by potential slope instability.

What areas of the landscape are susceptible to slope instability?

There were no portions of the assessed landscape deemed susceptible to slope instability (Map A-2). However, alluvial debris fans, situated at channel mouths along valley margins may be areas of rapid sediment delivery, deposition, and changes in channel location due to debris flows initiating higher in the channel network.

7.0 Confidence in Work Products

The overall confidence in this mass wasting assessment is high; this is due in large part to the overall low numbers of mass wasting features and rates of landsliding observed within the fee and State land portions of the Quinault Lake, Quinault River, and Cook—Elk WAUs, and the experience of the analyst in working with slope stability issues. There are several sources of systematic error that may reduce the confidence in the typical mass wasting work products, those being omission, misinterpretation, accuracy, and precision. However, as no mass wasting features were identified during this analysis, only omission and misinterpretation are relevant to this assessment. Omission occurs when mass wasting features are not identified on aerial photographs or in the field due to canopy cover, gaps in the aerial photo record, quality of aerial photos, or user errors. Misinterpretation occurs when a mass-wasting feature is identified but incorrectly classified.

This mass wasting assessment was primarily conducted via remotely sensed data (aerial photograph interpretation), and as a result, there is a high likelihood that errors of omission occurred primarily in areas covered by mature forest canopies. However, the oldest photos used in this analysis were from 1962, after most of the old growth timber in the watershed had been removed. Therefore, the resulting assessment of mass wasting processes is rated with a high level of confidence.

Misinterpretation, or incorrect identification and classification, of mass wasting features is another source of error in the assessment. This source of error is considered minimal for shallow rapid, debris flow, debris avalanche, and rock fall features and a source of moderate error with respect to deep-seated landslides processes. Because many deep-seated landslide features are quite large, remain heavily vegetated during movement, and may not have obvious scars visible through the vegetation canopy, misinterpretation of these features is more likely. A recent study in Cowlitz County, Washington, suggests that up to 25 percent of inferred deep-seated landslides identified from aerial photograph analysis are misinterpreted (Wegmann, 2003). Therefore confidence in work products related to classification of landslide process is moderate.

8.0 Appendix A-1

8.1 References

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8.2 Forms

Form A-2 Descriptions of Mass Wasting Map Units and Landforms of Concern

MWMU Number: 1 — Low Hazard Areas

Description:

Low gradient alluvial valley bottoms, low gradient glacial piedmont plain and outwash surfaces of minimal to moderate dissection, and moderate to steep planar hillslopes along valley margins.

Materials:

Low hazard areas include alluvial deposits of the Quinault River and tributaries as well as glacial drift deposits from advances of Pleistocene glaciers down the Quinault valley; including silt, sand, cobbles, and boulders in terminal moraines, till sheets, and outwash.

Landform:

Low-to-moderate gradient valley floors, piedmont plain, moderate to steep planar valley sidewalls.

Slope (Determined via DEM):

Min: 0.0% Max: 125% Mean: 3.5% Standard Deviation: 6.5

Elevation (Determined via DEM):

Min: 173’ Max: 803’ Mean: 336’ Standard Deviation: 87

Total Area:

13,063 acres. MWMU5 covers 100% of the surface area of the fee and State lands assessed in the Quinault Lake, Quinault River, and Cook—Elk WAUs.

MW Processes:

Lingley (1999) identified only one deep-seated inactive-to-relict landslide during her review of the Cook—Elk WAU. No further mass wasting features were identified during this assessment.

Forest Practice Sensitivity:

Low.

Mass Wasting Potential:

Low.

Delivery Potential:

Low.

Delivery Criteria Used:

Proximity and direction of visible landslide scars in relation to surface water features.

Hazard Potential Rating:

Low

Trigger Mechanisms:

Background mass wasting processes, high intensity rainfall, soil accumulations and natural disturbance.

Confidence:

High.

Landform Number: 1 — Alluvial Debris Fan

Description:

Cone-shaped depositional landform located where steep confined streams transition onto broad, relatively flat, valley bottoms. Alluvial debris fans have a gradient intermediate between the nearly flat valley floor and much steeper hillslope bedrock stream channels. In the Quinault valley, these debris fans are commonly forested. Trees growing on these fans often have sediment piled against them on the uphill side, and many exhibit impact scars on their trunks.

Materials:

Alluvial debris fans are composed of poorly sorted, poorly rounded alluvial sands, gravels, cobbles and boulders. Deposits are generally dominated by cobble to boulder-sized clasts, some of which may be the size of cars. Woody debris is also common within and upon these deposits.

MW Processes:

Alluvial debris fans represent the area of deposition for the coarse sediment load transported during high-energy debris flow events.

Forest Practice Sensitivity:

Variable. It is unknown to what extent the presence of large trees rooted on alluvial debris fans act as traps for debris flow sediment. It is possible that sediment and debris would move further out onto the valley floor in the absence of large living trees.

Mass Wasting Potential:

Low. Alluvial debris fans are not sites of mass wasting, rather they represent the depositional, or receiving area from up-basin mass wasting events.

Delivery Potential:

High. By definition, alluvial debris fans are locations for delivery and deposition of coarse sediment. The finer sediment fraction may be routed further down the channel network. Because alluvial debris fans are active geologic landforms, human structures and roads sited on or across these features may be in harms way.

Delivery Criteria Used:

Proximity and direction of up-basin debris flow failures; historical delivery observed.

Hazard Potential Rating:

Moderate. Due to the potentially damaging volumes and rate of coarse sediment deposition on alluvial debris fans, they are assigned a Moderate Hazard Potential Rating as a 'landform of concern'.

Confidence:

High.

8.3 Maps A-1, A-2