Landslide Hazard Zonation Project

An Assessment of Landslide Potential on State-Managed Forestlands in the Clearwater and Warm Creek Basins, Whatcom County, Washington

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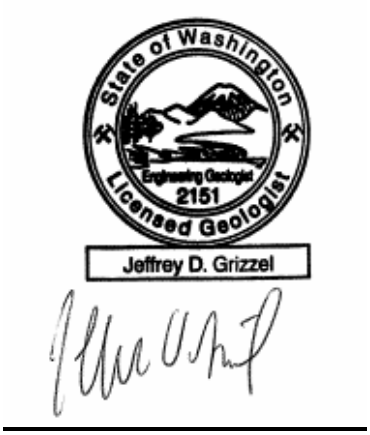

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Clearwater-Warm Landslide Hazard Zonation Project

1.0 Purpose and Scope

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

The basis of the Clearwater-Warm assessment is a landslide inventory compiled from aerial photographs spanning the period from 1970 through 2001. A primary assumption underlying the assessment is that the physical characteristics of sites where landslides have occurred in the past can be used to predict where landslides are likely to occur in the future. Therefore, factors that influence landslide occurrence such as landform type, slope gradient, slope form, and associated land use activity are quantified and/or described as part of the assessment. While some field validation of landslide data was conducted as part of the project, the assessment largely represents a reconnaissance level survey of landslides and associated hazard zones. End-users of this information should be aware of these limitations and exercise caution when translating map-based landslide hazard zone boundaries to field settings.

2.0 Project Area Overview

2.1 Physical Setting

The Clearwater-Warm project area is located in Townships 38 and 39 North, Ranges 06 and 07 East in central Whatcom County, Washington. The project area includes the western portion of the Clearwater Creek Watershed Administrative Unit (WAU) and the far western portion of the Marmot Ridge WAU north of the Middle Fork Nooksack River (MFNR). The project area is limited to DNR-managed forestlands in both WAUs but includes a few small parcels of private forestlands adjacent to or surrounded by DNR lands. Forestlands of the Mount Baker-Snoqualmie National Forest, which comprise the eastern portions of both WAUs, are not part of the project area.

The project area covers 10,197 acres, all of which is commercial forestland. The Washington DNR manages 98 percent of lands within the project area. The Clearwater Creek watershed encompasses approximately 14,000 acres, about half of which is located within the project area (6,986 acres). The Warm Creek watershed encompasses about 3,100 acres and only 5 percent of this total lies within the project area (498 acres). The

remaining 2,713 project area acres consist of several small, unnamed basins that drain into the MFNR.

2.2 Physiography

Elevations in the Clearwater-Warm project area range from 1,150 feet along the MFNR to nearly 4,300 feet along the western flank of Groat Mountain. Elevations in the eastern portions of the Clearwater and Warm Creek watersheds (outside the project area) are considerably higher, commonly exceeding 5,000 feet and reaching a maximum of just over 6,000 feet at the extreme eastern end of the Warm Creek basin.

Topography within the project area is rugged. Stream incision and glacial scour have cut deeply into this part of the North Cascades, producing high relief and steep slopes. Landforms include deep canyons, U-shaped glacial valleys, rounded foothills, and irregular glacial surfaces. Slope gradients within the project area commonly exceed 50 percent (27 degrees); low relief areas are generally limited to stream- and river-adjacent terraces or "benches".

Clearwater and Warm Creeks are typical of many streams draining the North Cascades, with steep channel gradients and coarse substrates. In their upper reaches, both Clearwater Creek and Warm Creek generally flow from east to west. The channels in these areas are mostly high-gradient (8 to 20 percent), exhibiting cascade and step-pool morphologies. The middle reaches of both streams flow from northeast to southwest and exhibit moderate-gradient (4 to 8 percent) longitudinal profiles associated with slightly broader, glaciated valleys. The northeast-southwest channel orientation continues in the lower reaches of both streams. The lower reach of Clearwater Creek exhibits a similar longitudinal profile to its middle reach (moderate gradient) while channel gradients along the lower reach of Warm Creek are extremely steep, commonly exceeding 20 percent. Due to their high stream power, both Clearwater and Warm Creeks are efficient transporters of coarse and fine sediments. Therefore, most sediment entering these channels is quickly transported to the MFNR; only small amounts (primarily coarser material) enter long-term storage within stream channels and adjacent floodplains.

2.3 Climate and Hydrology

Like the rest of western Washington, the Clearwater-Warm project area has a maritime-type climate with cool, wet winters and warm, dry summers. Average annual precipitation is estimated at between 60 and 110 inches (Federal Energy Regulatory Commission 2002) with about 75 percent falling between October and March. Most of this precipitation falls as snow, particularly above about 2,000 feet in elevation. Typically, snow first appears at higher elevations in October and snowpacks accumulate and melt several times each winter. Because the Clearwater-Warm project area is located in the "transient snow zone", streamflows typically remain high during the winter months and peak in response to rain-on-snow precipitation events. Mean monthly streamflows are estimated to range from 27 cubic feet/second (cfs) to 176 cfs for Clearwater Creek and from 8 cfs to 47 cfs for Warm Creek (Federal Energy Regulatory Commission 2002).

2.4 Geology and Erosion

The geology of the Clearwater-Warm project area has been mapped and described by Lapen (2000) and Tabor et al. (2003). In addition, Fiksdal and Brunengo (1981) developed a general overview of the geology as part of a slope stability assessment they conducted in the MFNR. These three reports are the basis for the following geologic overview of the project area.

Geomorphology and Mass Wasting (based on Fiksdal and Brunengo, 1981)

In 1981, Fiksdal and Brunengo conducted a landslide inventory and delineated landslide hazard zones for parts of five river basins in western Washington. The MFNR (where the Clearwater-Warm project area is located) was one of these basins. The authors produced a written report and landform maps "to assist forest managers in the identification of potential sediment sources…". Though the study was conducted using smaller scale aerial photos than were used in this assessment (1:24,000 as compared to 1:12,000), the resulting landslide hazard orthophoto maps provide insight into the different landforms present in the Clearwater-Warm project area, their relative stability, and their sensitivity to forest practices.

The authors identified four "terrain groups" in the Middle Fork Nooksack, each of which is present in the project area. The four terrain groups are: 1) alluvial-glacial terrain, 2) mature bedrock terrain, 3) sandstone-shale terrain, and 4) landslide terrain.

The alluvial-glacial terrain group consists of landforms shaped by glacial and fluvial processes and includes floodplains, terraces, valley benches, alluvial fans and cones, continental glacial deposits, glaciated valleys, cirque floors, and cirque headwalls. With the exception of cirque headwalls (which are subject to debris avalanche and rockfall), Fiksdal and Brunengo describe landforms in this terrain group as stable. Landforms in this terrain group include terrace surfaces along the mainstem MFNR, valley benches along the mainstem MFNR and Clearwater Creek, and scattered alluvial fans and cones, glaciated valleys, and cirque floors.

The mature bedrock terrain group consists of areas underlain by pre-Cenozoic rocks including phyllite, serpentinite, gabbro, blueschist, slate, metasandstone, and dunite. The landforms that developed on these rocks are locally variable and range from moderate-gradient toeslopes to near-vertical alpine crags. The authors identify four landforms within this terrain group, two of which are present in the Clearwater-Warm project area. These are: a) moderate-gradient (25 to 80 percent) slopes that are commonly stable, and b) steep-gradient (>70 percent) slopes underlain by bedrock including rocky knobs, undercut slopes, and craggy mountains that are subject to rockfall, debris avalanches, and snow avalanches.

The sandstone-shale terrain group consists of areas underlain by interbedded well-cemented sandstone and shale of the Chuckanut Formation of Paleocene age. The direction of dip, relative to the slope, strongly influences the dominant landforms and mass-wasting processes in this group. As a result, the landforms are defined on the basis

of bedding attitude. The authors identify four distinct landforms, all of which are present in the Clearwater-Warm project area. These are described in the Geology section below.

The landslide terrain group consists of landforms shaped predominantly by mass wasting processes and includes deposits of large landslides and zones of undercutting and mass wasting along major streams. The authors identify two landforms in this group, both of which are present in the Clearwater-Warm project area. They include: a) slump landforms that range widely in age and stability, and b) incised valleys where stream incision destabilizes adjacent slopes, making them subject to slumping and debris avalanches.

Fiksdal and Brunengo (1981) identified the following landforms as being most sensitive to forest practices:

1) All of the bedded sandstone-shale terrain where the potential for debris avalanches and torrents, rockslides, and slump-earthflows is high and where much of the harvestable timber is located;
2) Incised valleys where mass wasting is most active and has the most immediate impact on large streams;
3) Cirque headwalls (not present in the Clearwater-Warm project area), steep bedrock slopes, and Twin Sisters alpine zone (not present in the Clearwater-Warm project area) that have steep bare slopes subject to avalanches and rockfall but little timber.

Geology (based on Tabor et al. 2003; Lapen 2000; Fiksdal and Brunengo 1981)
The semischist and phyllite of Mount Josephine (Kjs) dominate the eastern and northern portions of the project area (Tabor et al. 2003). These pre-mid-Cretaceous rocks are foliated, folded, and faulted. Tabor et al. (2003) classified these rocks as one component of the Shuksan Nappe. In addition to the semischist and phyllite lithologies, Tabor et al. (2003) mapped smaller areas as part of the Bell Pass mélange, a mixed assemblage of foliated sandstone, phyllite, ribbon chert, basalt and very rare marble. Fiksdal and Brunengo (1981) classified areas underlain by the Shuksan Nappe and Bell Pass mélange as “Mature Bedrock Terrain” and described the associated landforms as “locally variable” ranging from “moderate footslopes (i.e., toeslopes) to alpine crags”. The authors mapped Groat Mountain (immediately east of the project area) and areas to the north, south, and west of this peak as Mature Bedrock Terrain. For slope stability purposes, they divided the unit into “mature topography” (Mm) and “steep mature topography” (Ms). Fiksdal and Brunengo (1981) described mature topography as “gentle to moderate, straight to rolling slopes” that are “stable to moderately stable”. In contrast, steep mature topography was described as unstable “steep bedrock knobs, free faces, alpine topography, and talus fields” where mass wasting processes include “major rockfall, debris avalanches, and snow avalanches”.

The Bellingham Bay Member of the Chuckanut Formation (Ec_{cb}) dominates the western and southern portions of the project area (Lapen 2000). The Bellingham Bay Member includes well-sorted sandstone, conglomerate, and mudstone, with small amounts of coal.

Fiksdal and Brunengo (1981) classified areas underlain by the Chuckanut Formation as "Sandstone-Shale Terrain". They noted that the direction of dip, relative to the slope, strongly influences landforms and mass wasting processes within this terrain. As a result, the authors defined three of the four units based on bedding attitude. The four units include: a) dip slopes (Sd) where the dip of bedding planes is in the same direction as the slope, b) scarp slopes (Sa) where the dip of bedding planes is into the slope, c) ribbed slopes (Sx) where the dip of bedding planes trends down and across the slope, and d) undercut slopes (Su) where stream action or mass movement undercuts the slope and influences slope form. Within the project area, dip slopes (Sd) and scarp slopes (Sa) comprise about 90 percent of the Sandstone-Shale Terrain. The remainder consists of approximately equal amounts of ribbed slopes (Sx) and undercut slopes (Su). The authors classified the Sd and Sa units as "unstable" and described dominant mass wasting processes as debris avalanche and debris torrent on steep slopes (both units) and slump-earthflow and rockslide along bedding planes (Sd unit).

Quaternary deposits, both glacial and non-glacial, cover most of the remaining portions of the project area. This includes terraces along the MFNR, nearly all of the Clearwater Creek valley and adjacent toeslopes, and the middle section of the Warm Creek valley and adjacent toeslopes (Lapen 2000; Tabor et al. 2003). Tabor et al. (2003) mapped areas adjacent to the MFNR as "older alluvium" (Qoal) of Holocene and Pleistocene age, noting that these deposits were above the modern floodplain and separated from it by a distinct topographic scarp. The authors noted this unit might also include lahar deposits from Mount Baker. Similarly, Lapen (2000) mapped this same part of the MFNR as "alluvium" (Qa) of Holocene age, noting that the unit might locally include older alluvium. Lapen (2000) mapped the lower Clearwater Creek valley as undifferentiated glacial deposits (Qgd). Similarly, Tabor et al. (2003) mapped the middle and upper Clearwater valley as undivided glacial deposits (Qgu) but noted that the unit consists mostly of morainal deposits or vegetated talus deposits including outwash. Tabor et al. (2003) mapped the middle Warm Creek valley as alpine glacial deposits (Qag) ranging from boulder till in uplands to gravel or sand outwash on broad valley floors.

Fiksdal and Brunengo (1981) classified the landforms associated with the aforementioned Quaternary deposits as either "Alluvial-Glacial Terrain" or "Landslide Terrain". Alluvial-Glacial Terrain generally includes the stable terraces and valley benches adjacent to the MFNR and Clearwater Creek (mapped as Qoal and Qa by Tabor et al. 2003 and Lapen 2000, respectively) while Landslide Terrain includes unstable slopes adjacent to the MFNR, Clearwater Creek and several of its larger tributaries, and Warm Creek (mapped as Qgd and Qgu by Lapen 2000 and Tabor et al. 2003, respectively).

3.0 Methods

The Clearwater-Warm mass wasting assessment was conducted in accordance with the methods described in the July 2005 Landslide Hazard Zonation Project Protocol (Washington Department of Natural Resources 2005). The LHZ protocol relies largely on information collected through an aerial photo-based landslide inventory. This information is used to develop landslide hazard zones that are unique in terms of their

mass wasting process(es), landform(s), sensitivity to forest practices, and the risk(s) to public resources and public safety. The LHZ protocol is essentially a reconnaissance-level survey with limited field validation of landslide and landform mapping. As a result, it is unlikely that all landslides have been identified and that all landforms have been properly classified and mapped. Users of this information should be aware of these limitations and should exercise caution when translating mapped hazard zone boundaries to field settings.

The Clearwater-Warm landslide inventory was developed using 1:12,000 scale aerial photographs from 1970, 1978, 1983, and 2001 (Table 1). Orthophotographs (1:12,000 scale) flown in 1998 were also reviewed as part of the inventory. The landslide inventory from Fiksdal and Brunengo (1981) served as an additional source of landslide information. LIght Detection And Ranging (LIDAR) images of the project area were not available at the time of inventory. Also, geologic maps covering the Bellingham (Lapen 2000) and Mount Baker (Tabor et al. 2003) 1:100,000 quadrangles provided background information on the geologic setting and the location of large-scale deep-seated landslides.

Table 1. Aerial photographs and orthophotographs used in developing the Clearwater-Warm landslide inventory.

Year	**Scale**	**Image**	**Flight ID**	**Origin**	**Coverage**
1970	1:12,000	Black/White	NW-69	WDNR	Partial
1978	1:12,000	Black/White	NW-78	WDNR	Complete
1983	1:12,000	Color	NW-C-83	WDNR	Complete
1998	1:12,000	Black/White	98 Orthos	WDNR	Complete
2001	1:12,000	Color	NW-C-01	WDNR	Complete

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

Accurately transferring the location of mass wasting features from aerial photographs to the computer sometimes proved difficult, particularly for small landslides where few, if any, nearby geographic references (e.g., roads or stream bends) were present. Where available, later aerial photographs were reviewed in order to provide a different spatial

perspective and improve the accuracy in locating the landslide. The 1998 orthophotographs often proved useful in this respect.

To develop the landslide hazard zones, commonalities among landscape and landslide attributes were identified. Portions of the project area where no (or very few) landslides occurred were grouped into a single "low hazard" landslide hazard zone. Portions of the project area with a high frequency of landslides were generally identified as "high hazard" areas. Within these generalized high hazard areas, discrete high hazard zones were delineated based on differences in landforms, slope forms, slope gradients, and mass wasting processes. Portions of the project area not identified as either "low hazard" or "high hazard" were initially classified as "moderate hazard". Validation of these preliminary hazard ratings was performed in accordance with the quantitative approach described in the Landslide Hazard Zonation Project Protocol (Washington Department of Natural Resources 2005).

The Digital Elevation Model- (DEM) derived slope map was used as a starting point for delineating the boundaries of the landslide hazard zones (Map A-2). Hazard zone boundaries were refined using the 1:12,000 aerial photographs. Consistent with the LHZ Project Protocol (Washington Department of Natural Resources 2005), all low hazard landforms were mapped first, followed by all forest practices rule-defined high hazard landforms. Low hazard landforms include terraces, valley benches, mid-slope benches, and ridges where no landslides were documented. Rule-defined high hazard landforms included convergent headwalls (including snow avalanche areas), bedrock hollows, and inner gorges with slope gradients in excess of 70 percent, deep-seated landslides in glacial materials, and the outer edges of meander bends along the MFNR. In addition, glacial river terrace faces along the MFNR were also identified as high-hazard because they have been closely associated with high frequencies of both deep-seated and shallow-rapid landslides in northwest Washington (see results of Regional Landform Identification Project for more information).

4.0 Results

A total of 354 landslides were documented to have occurred from 1970 through 2001 in the Clearwater-Warm project area (Map A-1). An additional 47 landslides were mapped on adjacent forestlands just east of the project area. These additional landslides were included in the landslide inventory and were used in developing the landslide hazard zones; however, they were not used in calculating the hazard rating for each landslide hazard zone. Doing so would have required that landform mapping be done for forestlands outside the project area, which was beyond the scope of the project.

The vast majority of project area landslides were translational, shallow-rapid debris avalanches and debris flows (334 landslides or 94 percent of landslides in the project area) (Table 2). Eighty percent (80%) percent of debris avalanches and debris flows were associated with bedrock hollow and inner gorge landforms.

Only 17 deep-seated landslides were identified within the project area (5% of all landslides within the project area) (Table 2). All but one of these landslides are associated with glacial or lahar deposits.

Table 2. Landslides mapped in the Clearwater-Warm project area during the period 1970-2001 listed by mass wasting process class.

Mass Wasting Process	Number of Landslides Within Project Area	Number of Landslides Outside Project Area	Total Number of Landslides
Debris Flow	132	10	142
Debris Avalanche	202	22	224
Deep-Seated	17	0	17
Rock Topple/Fall	1	0	1
Snow Avalanche	2	15	17
TOTAL	354	47	401

The landslide inventory results were used to develop six (6) Landslide Hazard Zones. One zone has a "LOW" overall hazard rating, one zone has a split "LOW/MODERATE" overall hazard rating, two zones have a "HIGH" overall hazard rating and the remaining two zones have a "VERY HIGH" overall hazard rating. The landslide hazard zones are illustrated on Map A-2 and detailed descriptions are included on Form A-2. Form A-3 reports the number of landslides by land use class and mass wasting process for each landslide hazard zone (except for Landslide Hazard Zone 3 which had no landslides within the project area). A brief overview of each zone is provided below.

Landslide Hazard Zone #1 – Benches and Ridges – LOW Hazard
This zone includes terraces along the MFNR, toeslope and midslope benches adjacent to Clearwater Creek, and prominent ridges between basins and sub-basins. Slope gradients are generally less than 40 percent (22 degrees) but may be as much as 50 percent (27 degrees) along major ridges. Slope form ranges from planar on benches to broadly divergent on ridges. Benches are mostly associated with glacial and lahar deposits while ridges are underlain by a variety of rock formations. The terraces and benches that comprise much of this unit include the "terraces (T)" and "benches (B)" described and mapped by Fiksdal and Brunengo (1981). This zone encompasses 2,117 acres, or 21 percent of the project area.

Landslide Hazard Zone #2 – Planar Valley Walls – LOW Hazard (timber harvest) MODERATE Hazard (road construction)
This zone includes valley walls within the Clearwater and Warm Creek basins as well as along the MFNR. Slope gradients are generally greater than 50 percent (27 degrees) and slope form is generally planar but may sometimes be broadly divergent. Large,

contiguous blocks of this zone lie between tributaries to Clearwater Creek in mid- to lower-slope positions and between Clearwater and Warm Creeks above the MFNR. Many of these blocks are located directly above midslope and toeslope benches in Clearwater Creek and terraces along the MFNR (i.e., above landforms that comprise Hazard Zone #1). Thirteen percent of landslides mapped within the project area lie within this zone; 68 percent of landslides within this hazard zone were road-related. This zone encompasses 5,209 acres, or 51 percent of the project area.

Landslide Hazard Zone #3 – Groat Mountain Headwall Complex – HIGH Hazard
This zone includes convergent headwalls along the upper flanks of Groat Mountain. Slope gradients exceed 70 percent (35 degrees) and slope form is convergent to broadly convergent. Many headwall landforms are unvegetated, owing to the high frequency of debris avalanches, rockfalls, and snow avalanches common in this zone. This entire zone was described and mapped by Fiksdal and Brunengo (1981) as "steep mature topography" (Ms). No landslides were mapped within this zone in the project area; however, 25 landslides within the same landform but outside the project area, were included in the landslide inventory (see Map A-1). This zone encompasses 17 acres, or less than 1 percent of the project area.

Landslide Hazard Zone #4 – Middle Fork Nooksack River Terrace Face – HIGH Hazard
This zone includes the terrace face (or flank) adjacent to the MFNR. Slope gradients exceed 60 percent (31 degrees) and slope form is generally broadly to strongly convergent but includes planar and broadly divergent slopes. From a slope stability standpoint, convergent slope forms represent the highest hazard; planar slopes with no outward signs of instability are moderately stable and divergent slopes are generally stable. Deep-seated and shallow-rapid mass wasting processes occur within this zone, but deep-seated processes are more prevalent. While deep-seated slope movement may occur at relatively low slope angles (<31 degrees), shallow-rapid landslides generally occur at higher slope angles (>35 degrees). Five large deep-seated landslides are included within this zone; however, the associated groundwater recharge areas were not delineated. This zone also includes the outer edges of meander bends along the MFNR. This zone encompasses 167 acres, or less than 2 percent of the project area.

Landslide Hazard Zone #5 – Inner Gorge Slopes Adjacent to High-Order Streams – VERY HIGH Hazard
This zone includes inner gorge slopes immediately adjacent to fourth order streams including Clearwater Creek, Rocky Creek, and Warm Creek. Slope gradients exceed 70 percent (35 degrees) and slope form is generally planar but ranges locally from strongly convergent to strongly divergent. Strongly convergent areas generally represent colluvial hollows nested within the larger inner gorge landform; strongly divergent areas commonly represent spur ridges separating colluvial hollows. Shallow-rapid and deep-seated landslide processes occur within this zone, but shallow-rapid processes are more prevalent. Debris avalanches and short run-out debris flows are the predominant shallow-rapid landslide processes. Fiksdal and Brunengo (1981) described and mapped

this zone as "incised valleys" (Li). Thirty-one percent of project area landslides occurred within this zone. This zone encompasses 887 acres, or 9 percent of the project area.

Landslide Hazard Zone #6 – Convergent Headwalls, Bedrock Hollows, and Inner Gorges Adjacent to Low-Order Streams – VERY HIGH Hazard

This zone includes convergent headwalls, bedrock hollows, and inner gorges associated with first- through third-order headwater streams. Slope gradients exceed 70 percent (35 degrees). Slope form ranges from broadly convergent to strongly convergent for headwalls and bedrock hollows. Slope form within smaller inner gorges (e.g., first order streams) is almost always planar while slope form within larger inner gorges (e.g., third order streams) is generally planar but includes convergent, nested bedrock hollows and divergent spur ridges between hollows. Mass wasting within this zone is almost exclusively limited to shallow-rapid processes including debris avalanches, debris flows and long run-out debris torrents. Fifty-two percent (52%) of project area landslides occurred within this zone. This zone encompasses 1,800 acres, or 18 percent of the project area.

The quantitative approach described in the Landslide Hazard Zonation Project Protocol (Washington Department of Natural Resources 2005) was used to assign overall hazard ratings to three of the six landslide hazard zones (Table 3). Overall hazard ratings are based on the landslide frequency rate (number of landslides/acre/year) and the landslide area rate for delivery (area of delivering landslides/acre/year). Only landslides with definite or probable assigned delivery ratings (Form A-1) were included in the calculation of the landslide area rate for delivery.

Table 3. Landslide frequency rate (landslides/acre/year x 10^6), landslide area rate for delivery (area of delivering landslides/acre/year x 10^6), and overall hazard rating for Landslide Hazard Zones #2 (*Planar Valley Walls*), #5 (*Inner Gorge Slopes Adjacent to High-Order Streams*), and #6 (*Convergent Headwalls, Bedrock Hollows, and Inner Gorge Slopes Adjacent to Low-Order Streams*) in the Clearwater-Warm project area.

	Zone 2	Zone 5	Zone 6
Hazard Zone Area (acres)	5,209	887	1,800
Number of Delivering Landslides	17	88	160
Area of Delivering Landslides (acres)	7.1	22.3	79.7
Landslide Frequency Rate	102.0	3,100.3	2,777.8
Landslide Area Rate w/Delivery	42.6	785.7	1,383.7
Overall Hazard Rating	LOW/MOD[1]	VERY HIGH	VERY HIGH

1 – According to the Landslide Hazard Zonation Project Protocol, the Overall Hazard Rating for Zone 2 should be "LOW". However, due to the disproportionately high number of road-related landslides in this zone, a "split" hazard rating was assigned (68 percent of all landslides in this zone were road-related). The zone has a "LOW" hazard rating for timber harvest-related activities and a "MODERATE" hazard rating for road-related activities.

The quantitative approach described above was not used to assign overall hazard ratings for the remaining three hazard zones (zones #1, #3, and #4). Landslide Hazard Zone 1 (*Benches and Ridges*) was assigned a "LOW" overall hazard rating due to the very small number of landslides mapped within the zone (8 landslides distributed across 2,117 acres). Six of the eight mapped Zone 1 landslides were "questionable" and the remaining two were identified as "probable". It is possible that these landslides are associated with higher hazard inclusions (e.g., small bedrock hollows or inner gorges) embedded within the mapped low hazard area.

There were no mapped landslides within Landslide Hazard Zone 3 (*Groat Mountain Headwall Complex*) in the project area. Nevertheless, a "HIGH" overall hazard rating was assigned to this zone due to the high frequency and large size of landslides that occurred within similar terrain on adjacent lands managed by the United States Forest Service (e.g., landslides #96-110 on Form A-1).

Landslide Hazard Zone 4 (*Middle Fork Nooksack River Terrace Face*) was assigned a "HIGH" overall hazard rating due to the presence of two forest practices rule-identified unstable landforms (glacial deep-seated landslides and the outer edges of meander bends). In addition, similar river terrace landforms in other parts of northwest Washington have been identified as potentially unstable landforms through the Regional Landform Identification Project sponsored by the Cooperative Monitoring, Evaluation, and Research (CMER) Committee.

5.0 Limitations and Confidence in Work Products

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

Users should find a relatively high degree of correlation between the written hazard zone descriptions and the associated forest practices sensitivities and assigned hazard ratings. However, because landslide hazard zones are based on interpretations of remote imagery, users should expect to find discrepancies between the mapped hazard zone boundaries and actual ground conditions. For example, the true spatial extent of landforms such as inner gorges and bedrock hollows may differ somewhat from the mapped extent; in some cases hazard zones may be larger than depicted on Map A-2 while in other cases, they may be smaller.

In addition to the potential differences described above, some mapped hazard zones include "errors of omission" where undetected and unmapped high hazard landforms exist within moderate (or in rare cases low) hazard zones. Within the Clearwater-Warm project area, this is most likely to occur in Landslide Hazard Zone #2, where inclusions

of high hazard bedrock hollows or small inner gorges may be found within what has been mapped as moderate hazard planar slopes. While every attempt was made to minimize such errors, limitations associated with the project protocol make it impossible to completely eliminate them. Users should be aware of these limitations and view the map products as a coarse screen to help identify, in a general sense, portions of the landscape where forest practices have the potential to accelerate mass wasting.

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

6.0 Literature Cited

Federal Energy Regulatory Commission. 2002. Final Environmental Impact Statement – Warm Creek and Clearwater Creek Hydroelectric Projects, Washington. Report No. FERC/EIS-120F, Federal Energy Regulatory Commission, Office of Energy Projects, Division of Environmental and Engineering Review, Washington, D.C.

Fiksdal, A.J. and M.J. Brunengo. 1981. Forest slope stability project – phase II. Report No. WDOE 81-14, Washington Department of Natural Resources, Division of Geology and Earth Resources, Olympia, WA. Includes report (volume 1; 62 p.) and maps (volume 2).

Lapen, T.J. 2000. Geologic map of the Bellingham 1:100,000 quadrangle, Washington. Open File Report 2000-5, Washington Department of Natural Resources, Division of Geology and Earth Resources, Olympia, WA.

Tabor, R.W., R.A. Haugerud, W.Hildreth, and E.H. Brown. 2003. Geologic map of the Mount Baker 30- by 60-minute quadrangle, Washington. Geologic Investigation Series I-2660, United States Geologic Survey, Denver, CO.

Washington Department of Natural Resources. 2005. Landslide hazard zonation project protocol – version 2. Washington Department of Natural Resources, Forest Practices Division, Olympia, WA. 44 p.

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SLIDE_ID	HAZ_ZONE	SLIDE_PROC	CERTAINTY	ID_DATE	SLIDE_SIZE	SLIDE_AREA	ELEV	LANDFORM	SLP_SHP	GRADIENT	DELIVERY	LANDUSE	PHOT_NUMB
1	6	2	D	1970	2	1.6	3840	2	2	82	Y	5	NW-69-237-55F-10
2	6	2	D	1970	1	0.6	3720	2	1	95	Y	3	NW-69-237-55F-10
3	6	2	D	1970	1	0.7	3320	2	1	96	Y	3	NW-69-237-55F-10
4	6	2	D	1970	1	0.2	3160	2	1	78	Y	3	NW-69-237-55F-10
5	6	3	D	1970	1	0.1	2600	1	2	87	Y	3	NW-69-237-55F-10
6	6	3	D	1970	1	0.2	2360	1	3	79	Y	3	NW-69-237-55F-10
7	6	2	D	1970	2	1.1	4000	2	1	76	Y	5	NW-69-237-55F-10
8	6	3	D	1970	1	0.1	3160	1	2	91	Y	3	NW-69-237-55F-10
9	4	4	D	1970	5	7.0	1480	4	9	50	Y	4	NW-69-297-R56C-9
10	4	4	D	1970	5	5.4	1320	4	9	24	Y	4	NW-69-297-R56C-9
11	5	4	P	1970	4	0.8	1240	4	9	45	Y	5	NW-69-297-R56C-9
12	6	2	D	1970	1	0.4	1720	2	1	60	Y	3	NW-69-297-R56C-9
13	6	2	D	1970	1	0.8	1920	2	1	75	Y	3	NW-69-297-R56C-9
14	6	2	D	1970	1	0.8	1760	2	1	49	Y	3	NW-69-297-R56C-9
15	6	3	D	1970	1	0.2	2480	1	2	68	P	3	NW-69-297-R56C-9
16	6	2	P	1970	1	1.1	2680	2	1	71	Y	3	NW-69-297-R56C-9
17	6	3	D	1970	1	0.1	2360	2	2	52	P	5	NW-69-297-R56C-9
18	6	2	Q	1970	2	0.5	2600	9	1	53	Y	2	NW-69-297-R56C-9
19	6	2	D	1970	1	0.6	3000	2	1	75	Y	3	NW-69-297-R56C-10
20	6	3	D	1970	1	0.1	2840	1	2	93	Y	3	NW-69-297-R56C-10
21	6	3	D	1970	1	0.1	2720	1	2	89	Y	3	NW-69-297-R56C-10
23	6	2	D	1970	1	0.6	4160	9	1	81	Y	1	NW-69-297-R56C-12
24	6	2	D	1970	2	0.7	4040	2	1	59	Y	1	NW-69-297-R56C-12
25	6	2	D	1970	2	0.3	3760	5	1	76	Y	2	NW-69-297-R56C-12
26	6	3	D	1970	1	0.2	3560	2	2	84	Y	2	NW-69-297-R56C-12
27	6	2	D	1970	1	0.4	2840	2	1	89	Y	2	NW-69-297-R56C-12
28	6	2	D	1970	1	0.5	2920	2	1	102	Y	2	NW-69-297-R56C-12
29	6	2	D	1970	3	0.4	3600	2	1	87	Y	4	NW-69-297-R56C-12
30	6	2	D	1970	4	0.6	3760	2	1	80	Y	4	NW-69-297-R56C-12
31	6	2	D	1970	1	0.8	4600	5	2	55	Y	4	NW-69-297-R56C-12
32	6	2	D	1970	1	0.8	4640	5	2	61	Y	4	NW-69-297-R56C-12
33	6	3	D	1970	1	0.1	3120	1	2	59	Y	4	NW-69-297-R56C-12
34	6	3	D	1970	1	0.0	3200	1	3	70	Y	4	NW-69-297-R56C-12
35	6	2	D	1970	1	0.7	3560	2	1	71	Y	4	NW-69-297-R56C-12
36	6	2	D	1970	1	0.9	3760	2	1	84	Y	4	NW-69-297-R56C-12
37	5	4	D	1970	5	51.0	2080	8	9	50	Y	3	NW-69-297-R56C-12
38	6	3	D	1970	1	0.1	2180	1	2	55	Y	5	NW-69-297-R56C-12
39	6	3	D	1970	1	0.2	2100	1	2	40	Y	3	NW-69-297-R56C-12
40	6	3	P	1970	2	0.1	2120	1	2	50	P	3	NW-69-297-R56C-12
41	6	3	D	1970	1	0.1	2160	1	2	51	Y	3	NW-69-297-R56C-12
42	6	2	D	1970	1	0.9	3250	2	2	79	Y	2	NW-69-297-R56C-12
43	6	2	D	1970	1	0.9	3900	2	1	92	Y	2	NW-69-297-R56C-12
44	6	2	D	1970	1	0.2	3360	2	2	74	Y	2	NW-69-297-R56C-12
45	6	3	P	1970	2	0.3	2990	2	1	65	P	2	NW-69-297-R56C-12

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SLIDE_ID	HAZ_ZONE	SLIDE_PROC	CERTAINTY	ID_DATE	SLIDE_SIZE	SLIDE_AREA	ELEV	LANDFORM	SLP_SHP	GRADIENT	DELIVERY	LANDUSE	PHOT_NUMB
46	6	2	D	1970	1	1.0	3650	2	1	74	Y	2	NW-69-297-R56C-12
47	6	2	D	1970	1	0.8	3720	2	1	81	Y	2	NW-69-297-R56C-12
48	2	4	D	1970	5	1.0	3440	8	9	81	Y	4	NW-69-297-R56C-14
49	6	2	D	1970	2	1.4	4120	2	2	90	Y	4	NW-69-297-R56C-14
50	5	2	D	1970	1	0.3	1760	2	1	71	Y	3	NW-69-223-57B-65
51	6	3	D	1970	5	6.2	4130	5	2	78	Y	9	NW-69-223-57B-65
52	6	3	D	1970	2	0.1	2090	1	3	34	P	5	NW-69-223-57B-67
53	6	3	D	1970	2	0.1	2220	1	2	41	P	5	NW-69-223-57B-67
54	2	3	D	1970	2	0.3	2580	1	3	46	Y	5	NW-69-223-57B-67
55	6	3	D	1970	2	0.1	2460	1	3	56	Y	2	NW-69-223-57B-67
56	6	3	D	1970	2	0.1	2180	1	2	41	Y	3	NW-69-223-57B-67
57	6	3	D	1970	2	0.1	2160	1	3	34	Y	3	NW-69-223-57B-67
58	6	3	D	1970	2	0.1	2120	1	2	40	Y	3	NW-69-223-57B-67
59	6	2	D	1970	5	1.1	2960	7	2	64	Y	4	NW-69-223-57B-69
60	6	3	D	1970	3	0.1	3160	1	2	31	Y	4	NW-69-223-57B-69
61	6	3	D	1970	3	0.1	3240	1	2	41	Y	4	NW-69-223-57B-69
62	6	3	D	1970	3	0.1	3320	1	3	49	Y	4	NW-69-223-57B-69
63	6	2	D	1970	5	0.8	3760	7	2	85	P	4	NW-69-223-57B-69
64	6	3	D	1970	4	0.4	3200	7	4	71	P	4	NW-69-223-57B-69
65	6	3	D	1970	2	0.1	2450	1	1	48	Y	3	NW-69-223-57B-69
66	6	3	D	1970	2	0.1	2440	1	2	45	Y	3	NW-69-223-57B-69
67	6	3	D	1970	3	0.2	2400	1	2	61	Y	3	NW-69-223-57B-69
68	6	3	D	1970	2	0.1	2380	1	2	41	Y	3	NW-69-223-57B-69
69	6	3	D	1970	2	0.1	2360	1	2	37	Y	3	NW-69-223-57B-69
70	6	3	D	1970	2	0.1	2340	1	2	33	Y	3	NW-69-223-57B-69
71	6	3	D	1970	2	0.1	2320	1	2	40	Y	3	NW-69-223-57B-69
72	6	3	D	1970	2	0.1	2290	1	2	28	Y	3	NW-69-223-57B-69
73	5	3	D	1970	3	0.5	2160	1	1	52	Y	3	NW-69-223-57B-69
74	6	2	D	1970	5	0.7	3280	7	1	67	Y	4	NW-69-223-57B-71
75	6	2	D	1970	5	0.6	3120	7	2	69	Y	4	NW-69-223-57B-71
76	5	2	D	1970	3	0.2	2840	7	1	60	Y	4	NW-69-223-57B-71
77	6	2	D	1970	4	1.9	3680	7	2	50	Y	4	NW-69-223-57B-71
78	6	2	D	1970	3	0.3	3690	2	1	91	P	4	NW-69-223-57B-71
79	6	2	D	1970	3	2.1	2560	7	2	51	P	4	NW-69-223-58D-6
80	1	3	P	1970	1	0.1	2320	1	2	42	P	5	NW-69-223-58D-10
81	6	3	D	1970	3	0.5	2400	1	2	43	Y	2	NW-69-223-58D-10
82	5	2	D	1970	2	0.1	2280	1	1	43	P	3	NW-69-223-58D-12
83	5	2	D	1970	2	0.1	2320	1	1	39	P	3	NW-69-223-58D-12
84	2	3	D	1970	2	0.0	2430	7	3	45	P	5	NW-69-223-58D-12
85	2	3	D	1970	1	0.1	2420	7	1	43	P	5	NW-69-223-58D-12
86	1	2	Q	1970	2	0.5	1630	9	1	20	Y	4	NW-69-223-59D-5
88	5	3	D	1970	3	0.1	1760	1	1	65	Y	4	NW-69-223-59D-5
89	5	3	D	1970	2	0.1	2200	1	1	62	Y	4	NW-69-223-59D-5
90	5	3	D	1970	2	0.1	2320	1	1	81	Y	4	NW-69-223-59D-5

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SLIDE_ID	HAZ_ZONE	SLIDE_PROC	CERTAINTY	ID_DATE	SLIDE_SIZE	SLIDE_AREA	ELEV	LANDFORM	SLP_SHP	GRADIENT	DELIVERY	LANDUSE	PHOT_NUMB
91	5	3	D	1970	2	0.1	2640	1	1	60	Y	4	NW-69-223-59D-5
92	5	3	D	1970	2	0.1	2600	1	1	18	Y	4	NW-69-223-59D-7
93	5	3	D	1970	2	0.1	2680	1	2	64	Y	4	NW-69-223-59D-7
94	5	3	D	1970	3	0.2	2720	1	1	49	Y	4	NW-69-223-59D-7
95	6	3	D	1970	3	0.1	3320	1	1	39	Y	4	NW-69-223-59D-7
96	999	9	D	1970	5	2.8	4320	5	1	56	Q	4	NW-69-223-59D-7
97	999	9	D	1970	5	2.7	4680	5	1	105	Q	4	NW-69-223-59D-7
98	999	9	D	1970	5	7.1	5160	5	1	107	Q	4	NW-69-223-59D-7
99	999	9	D	1970	4	0.7	4600	5	1	74	Q	4	NW-69-223-59D-7
100	999	9	D	1970	3	0.2	3960	2	1	87	Q	4	NW-69-223-59D-7
101	999	9	D	1970	5	1.0	4880	5	1	86	Q	4	NW-69-223-59D-7
102	999	9	D	1970	5	2.3	5200	5	1	91	Q	4	NW-69-223-59D-7
103	999	9	D	1970	5	6.1	5400	5	1	79	Q	4	NW-69-223-59D-9
104	999	9	D	1970	6	13.0	5480	5	1	79	Y	8	NW-69-223-59D-9
105	999	9	D	1970	6	15.0	5440	5	1	106	Y	8	NW-69-223-59D-9
106	999	9	D	1970	6	21.2	5320	5	1	88	Y	8	NW-69-223-59D-9
107	999	9	D	1970	6	6.1	5120	5	1	45	Y	8	NW-69-223-59D-9
108	999	9	D	1970	6	12.6	4360	5	1	120	Y	8	NW-69-223-59D-11
109	999	9	D	1970	6	11.9	4560	5	1	165	Y	8	NW-69-223-59D-11
110	999	9	D	1978	5	4.0	4480	5	1	125	Y	8	NW-69-223-59D-11
111	2	9	D	1970	3	0.6	3960	5	2	75	P	4	NW-69-223-59D-11
112	2	9	D	1970	3	0.6	4000	5	2	146	P	4	NW-69-223-59D-11
113	999	2	D	1970	2	0.8	3240	2	1	59	Y	4	NW-69-223-59D-11
114	999	2	P	1970	2	0.8	3320	2	2	68	P	4	NW-69-223-59D-13
115	5	3	D	1970	3	0.4	2880	1	1	75	Y	4	NW-69-223-59D-15
116	6	2	D	1970	1	1.2	3440	2	2	84	Y	8	NW-69-223-59D-16
117	5	3	D	1970	3	0.3	2960	1	2	66	Y	9	NW-69-223-59D-16
118	6	3	P	1983	2	0.2	2560	2	1	81	P	3	NW-C-83-19-55-374
119	6	2	D	1983	3	0.2	2960	5	2	77	P	5	NW-C-83-19-55-374
120	6	2	D	1983	3	1.0	3760	2	1	81	Y	2	NW-C-83-19-55-374
121	6	2	D	1983	3	0.8	4160	5	2	90	Y	1	NW-C-83-19-55-374
122	6	2	D	1983	4	1.4	3840	5	1	57	Y	1	NW-C-83-27-56-099
123	6	3	P	1983	2	0.1	3280	1	2	65	Y	1	NW-C-83-27-56-099
124	6	2	D	1983	3	1.0	3000	2	1	83	Y	1	NW-C-83-27-56-099
125	6	2	D	1983	3	1.4	3000	2	1	81	Y	1	NW-C-83-27-56-099
126	6	3	D	1983	2	0.8	3120	1	2	57	Y	2	NW-C-83-27-56-101
127	6	3	P	1983	2	0.3	3120	2	2	47	I	2	NW-C-83-27-56-101
128	6	3	P	1983	1	0.4	3280	2	2	54	I	2	NW-C-83-27-56-101
129	1	3	Q	1983	2	0.3	1320	4	2	47	P	5	NW-C-83-23-56-121
130	5	3	D	1983	2	0.3	1540	1	2	34	P	5	NW-C-83-23-56-121
131	5	3	D	1983	1	0.2	1580	1	2	38	P	5	NW-C-83-23-56-121
132	5	3	D	1983	1	0.1	1760	7	2	49	I	5	NW-C-83-23-56-121
133	5	3	D	1983	1	0.1	1760	7	2	48	I	5	NW-C-83-23-56-121
134	5	3	D	1983	1	0.1	1800	1	2	33	Y	4	NW-C-83-23-56-121
135	6	2	D	1983	2	0.2	3400	2	2	98	Y	1	NW-C-83-23-56-123

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SLIDE_ID	HAZ_ZONE	SLIDE_PROC	CERTAINTY	ID_DATE	SLIDE_SIZE	SLIDE_AREA	ELEV	LANDFORM	SLP_SHP	GRADIENT	DELIVERY	LANDUSE	PHOT_NUMB
136	6	3	D	1983	1	0.1	2820	1	3	80	Y	1	NW-C-83-23-56-123
137	2	3	D	1983	2	0.1	2080	7	2	40	I	5	NW-C-83-23-57-059
138	2	2	Q	1983	2	0.6	2390	7	3	51	I	5	NW-C-83-23-57-059
139	2	3	D	1983	2	0.4	2640	7	3	69	I	5	NW-C-83-23-57-059
140	2	3	P	1983	3	2.9	2600	7	3	58	I	5	NW-C-83-23-57-059
141	2	3	D	1983	2	0.4	3000	7	2	71	N	5	NW-C-83-23-57-061
142	6	2	D	1983	2	0.4	2880	1	1	72	Y	1	NW-C-83-23-57-061
143	6	8	D	1983	4	4.3	3570	6	5	67	I	4	NW-C-83-23-57-061
144	6	3	D	1983	1	0.2	3000	2	2	52	N	1	NW-C-83-23-57-061
145	6	3	P	1983	2	0.3	3480	2	2	79	I	3	NW-C-83-23-57-063
146	6	2	P	1983	2	0.3	2560	1	1	30	Y	5	NW-C-83-23-57-063
147	6	2	D	1983	3	1.2	2640	2	1	64	Y	5	NW-C-83-23-57-065
148	6	2	D	1983	2	0.2	2840	2	1	54	Y	3	NW-C-83-23-57-065
149	6	3	D	1983	1	0.1	2320	1	2	40	Y	3	NW-C-83-23-57-065
150	2	2	D	1983	3	0.6	2800	2	1	128	P	4	NW-C-83-23-57-065
151	2	2	D	1983	3	0.4	2720	2	1	100	P	4	NW-C-83-23-57-065
152	5	2	D	1983	2	1.0	2760	1	1	57	Y	2	NW-C-83-23-57-067
153	5	2	D	1983	2	0.2	2440	2	1	50	Y	2	NW-C-83-23-57-067
154	5	2	D	1983	2	0.1	2360	1	1	27	Y	2	NW-C-83-23-57-067
155	5	2	D	1983	2	0.1	2420	1	1	54	Y	2	NW-C-83-23-57-067
156	5	3	D	1983	1	0.0	2760	1	2	61	I	2	NW-C-83-23-57-067
157	5	3	D	1983	1	0.1	2760	1	2	67	I	2	NW-C-83-23-57-067
158	1	3	Q	1983	1	0.0	2900	1	2	49	I	2	NW-C-83-23-57-067
159	1	3	Q	1983	1	0.1	2900	1	2	49	I	2	NW-C-83-23-57-067
160	5	2	D	1983	2	0.8	2840	1	2	48	Y	5	NW-C-83-23-57-067
161	5	2	D	1983	2	0.7	2860	1	2	62	Y	5	NW-C-83-23-57-067
162	5	2	D	1983	2	0.3	2680	1	1	72	I	2	NW-C-83-23-57-067
163	5	2	D	1983	2	0.3	2680	1	1	65	Y	2	NW-C-83-23-57-067
164	5	2	D	1983	2	0.2	2660	1	1	62	Y	2	NW-C-83-23-57-067
165	5	3	D	1983	3	0.9	2900	1	2	42	Y	1	NW-C-83-23-57-067
166	5	3	D	1983	1	0.0	2840	1	2	41	P	1	NW-C-83-23-57-067
167	5	3	D	1983	1	0.0	2820	1	2	39	P	1	NW-C-83-23-57-067
168	5	3	D	1983	1	0.1	2980	2	1	64	P	1	NW-C-83-23-57-069
169	5	3	D	1983	2	0.1	2740	2	1	42	Y	1	NW-C-83-23-57-069
170	5	3	D	1983	1	0.1	2840	2	1	32	Y	1	NW-C-83-23-57-069
171	6	3	D	1983	1	0.1	3000	1	2	65	Y	1	NW-C-83-23-57-069
172	6	2	D	1983	2	0.8	4200	2	1	27	Y	1	NW-C-83-23-57-069
173	6	3	P	1983	1	0.1	3240	2	1	49	I	5	NW-C-83-23-57-069
174	6	3	P	1983	1	0.1	4200	2	2	51	I	5	NW-C-83-23-57-069
175	2	2	D	1983	3	2.6	4160	2	2	68	Y	5	NW-C-83-23-57-069
176	6	3	D	1983	1	0.1	3440	2	1	52	Y	1	NW-C-83-23-57-069
177	6	3	D	1983	1	0.1	3200	2	1	40	Y	1	NW-C-83-23-57-069
178	5	3	D	1983	1	0.1	3190	1	1	35	Y	1	NW-C-83-23-57-069
179	5	3	D	1983	2	0.2	3150	1	1	45	Y	1	NW-C-83-23-57-069
180	5	3	D	1983	1	0.0	3120	1	1	55	Y	1	NW-C-83-23-57-069

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SLIDE_ID	HAZ_ZONE	SLIDE_PROC	CERTAINTY	ID_DATE	SLIDE_SIZE	SLIDE_AREA	ELEV	LANDFORM	SLP_SHP	GRADIENT	DELIVERY	LANDUSE	PHOT_NUMB
181	5	3	D	1983	2	0.1	3040	1	1	54	Y	1	NW-C-83-23-57-069
182	6	3	D	1983	1	0.1	2960	1	2	26	Y	1	NW-C-83-23-58-198
183	6	3	D	1983	1	0.1	2880	1	2	26	Y	1	NW-C-83-23-58-198
184	2	2	P	1983	1	0.3	2980	1	1	30	Y	5	NW-C-83-23-58-198
185	2	3	D	1983	2	0.2	3050	7	1	59	I	5	NW-C-83-23-58-198
186	2	3	D	1983	1	0.2	2950	7	2	39	P	5	NW-C-83-23-58-198
187	2	3	D	1983	1	0.1	3340	7	3	60	I	5	NW-C-83-23-58-200
188	2	3	D	1983	1	0.1	3420	7	3	55	I	5	NW-C-83-23-58-200
189	2	2	D	1983	2	0.3	3800	8	2	95	I	5	NW-C-83-23-58-200
190	2	2	D	1983	2	0.6	3800	8	2	78	I	5	NW-C-83-23-58-200
191	2	3	D	1983	2	0.1	3600	8	2	58	I	5	NW-C-83-23-58-200
193	2	3	Q	1983	2	0.1	3920	7	2	63	I	5	NW-C-83-23-58-204
194	1	3	Q	1983	1	0.1	2650	2	1	35	I	1	NW-C-83-23-58-204
195	6	2	D	1983	1	0.2	2750	1	1	44	Y	1	NW-C-83-23-58-204
196	6	3	D	1983	1	0.1	2620	2	1	35	I	1	NW-C-83-23-58-204
197	6	2	D	1983	2	0.6	2720	2	1	36	Y	1	NW-C-83-23-58-204
198	5	2	D	1983	2	0.3	2500	2	1	38	Y	5	NW-C-83-23-58-206
199	5	2	D	1983	1	0.2	2460	2	1	63	Y	2	NW-C-83-23-58-206
200	5	2	D	1983	2	0.1	2650	2	1	64	Y	1	NW-C-83-23-58-206
201	5	2	D	1983	2	0.5	2760	2	1	51	Y	1	NW-C-83-23-58-206
202	5	2	D	1983	2	0.3	2650	2	1	64	Y	1	NW-C-83-23-58-206
203	5	2	Q	1983	2	0.4	2720	2	1	71	Y	1	NW-C-83-23-58-206
204	5	2	D	1983	2	0.7	2850	2	1	41	Y	1	NW-C-83-23-58-206
205	5	2	D	1983	2	0.3	2680	2	1	58	Y	1	NW-C-83-23-58-206
206	5	2	D	1983	2	0.2	2600	2	1	54	Y	1	NW-C-83-23-58-206
207	5	2	D	1983	2	0.2	2650	2	1	73	Y	1	NW-C-83-23-58-206
208	5	2	D	1983	2	0.1	2640	2	1	45	Y	1	NW-C-83-23-58-206
209	5	3	D	1983	1	0.1	2560	1	2	59	P	1	NW-C-83-23-59-275
210	5	3	D	1983	1	0.1	2600	1	2	75	P	1	NW-C-83-23-59-275
211	5	4	D	1983	2	0.2	2700	8	2	44	P	1	NW-C-83-23-59-275
212	5	3	D	1983	1	0.1	2760	1	2	41	Y	1	NW-C-83-23-59-275
213	999	3	D	1983	2	0.1	3010	1	2	41	Y	3	NW-C-83-23-59-285
214	999	3	D	1983	1	0.1	3250	1	2	53	Y	3	NW-C-83-23-59-285
215	999	3	D	1983	2	0.3	3500	2	2	30	I	1	NW-C-83-23-59-285
216	999	3	P	1983	2	0.6	3460	2	1	28	I	1	NW-C-83-23-59-285
217	5	4	P	2001	3	0.3	1200	1	2	24	Y	4	NW-C-01-73-56-127
218	6	3	D	2001	2	0.2	1680	1	1	45	Y	3	NW-C-01-73-56-127
219	6	3	D	2001	1	0.0	2840	1	2	76	I	3	NW-C-01-73-56-131
220	6	3	D	2001	1	0.0	2870	1	2	62	I	3	NW-C-01-73-56-131
221	6	3	D	2001	1	0.0	2930	1	2	75	P	3	NW-C-01-73-56-131
222	6	3	D	2001	1	0.0	2870	1	2	54	Y	3	NW-C-01-73-56-131
223	6	3	D	2001	1	0.0	2930	1	2	72	Y	3	NW-C-01-73-56-131
224	6	3	D	2001	2	0.1	3210	1	2	70	Y	3	NW-C-01-73-56-131
225	6	2	D	2001	2	0.3	3920	2	1	80	P	3	NW-C-01-73-56-131

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226	6	3	D	2001	1	0.2	3840	2	1	77	I	3	NW-C-01-73-56-131
227	6	3	D	2001	1	0.0	3280	7	1	67	I	5	NW-C-01-73-56-131
228	6	3	D	2001	1	0.1	3360	2	2	71	I	3	NW-C-01-73-56-131
229	6	3	D	2001	2	0.1	2960	1	1	55	Y	3	NW-C-01-73-56-166
230	5	3	P	2001	2	0.1	1900	1	1	40	Y	4	NW-C-01-79-57-180
231	5	3	P	2001	2	0.0	1900	1	1	48	Y	4	NW-C-01-79-57-180
232	5	3	D	2001	1	0.2	2000	1	1	54	Y	4	NW-C-01-79-57-180
233	5	2	P	2001	2	0.4	2120	1	1	35	P	4	NW-C-01-79-57-180
234	5	3	D	2001	2	0.2	2000	1	1	41	Y	4	NW-C-01-79-57-180
235	5	4	D	2001	3	0.7	1990	1	2	43	Y	4	NW-C-01-79-57-180
236	5	4	P	2001	3	1.6	2070	1	2	55	Y	4	NW-C-01-79-57-180
237	5	3	D	2001	2	0.3	2100	1	1	48	I	4	NW-C-01-79-57-180
238	5	3	D	2001	2	0.2	2100	1	1	50	I	4	NW-C-01-79-57-180
239	5	3	D	2001	2	0.2	2100	1	1	43	I	4	NW-C-01-79-57-180
240	6	3	Q	2001	1	0.1	2100	1	2	49	Y	3	NW-C-01-79-57-180
241	5	2	P	2001	2	0.1	2080	1	1	60	Y	4	NW-C-01-79-57-180
242	5	2	P	2001	2	0.2	2110	1	1	58	I	4	NW-C-01-79-57-182
243	6	3	D	2001	1	0.1	3140	7	3	59	I	5	NW-C-01-79-57-182
244	6	2	D	2001	2	0.3	3360	2	1	71	P	3	NW-C-01-79-57-182
245	2	3	D	2001	1	0.1	3490	2	1	76	I	5	NW-C-01-79-57-182
246	6	2	D	2001	2	0.3	3380	2	1	76	P	3	NW-C-01-79-57-182
247	6	3	D	2001	1	0.1	2800	1	2	50	Y	3	NW-C-01-79-57-182
248	2	2	D	2001	2	0.3	3970	2	1	64	P	1	NW-C-01-79-57-182
249	6	3	D	2001	2	0.1	3290	1	1	66	Y	3	NW-C-01-79-57-182
250	5	3	Q	2001	1	0.1	2880	1	2	57	Y	3	NW-C-01-79-57-182
251	5	3	D	2001	3	0.2	2820	1	1	56	Y	3	NW-C-01-79-57-182
252	6	2	D	2001	2	0.1	3220	1	1	63	Y	3	NW-C-01-79-57-182
253	5	4	D	2001	4	0.6	2800	1	2	48	Y	3	NW-C-01-79-57-182
254	5	3	D	2001	2	0.1	2860	1	1	38	Y	3	NW-C-01-79-57-184
255	5	3	D	2001	1	0.1	2960	1	1	51	Y	3	NW-C-01-79-57-184
256	5	3	D	2001	1	0.1	3040	1	1	54	Y	3	NW-C-01-79-57-184
257	5	3	D	2001	1	0.1	3060	1	1	54	Y	3	NW-C-01-79-57-184
258	5	3	D	2001	1	0.1	3080	1	1	52	Y	3	NW-C-01-79-57-184
259	5	3	D	2001	2	0.2	3100	1	1	39	Y	3	NW-C-01-79-57-184
260	5	3	D	2001	3	0.6	3220	1	2	34	Y	3	NW-C-01-79-57-184
261	6	3	D	2001	1	0.2	3360	7	1	55	I	3	NW-C-01-79-57-184
262	6	4	P	2001	3	0.9	3510	7	1	27	I	4	NW-C-01-79-57-184
263	6	3	D	2001	1	0.1	3710	1	1	48	Y	2	NW-C-01-79-57-184
264	6	3	D	2001	1	0.1	3780	1	1	52	Y	2	NW-C-01-79-57-184
265	5	3	D	2001	1	0.1	1740	1	1	46	I	5	NW-C-01-73-57-172
266	5	3	D	2001	1	0.1	1740	1	1	57	I	5	NW-C-01-73-57-172
267	5	3	D	2001	1	0.1	1720	1	1	46	I	5	NW-C-01-73-57-172
268	6	3	D	2001	1	0.2	2390	1	1	43	Y	3	NW-C-01-73-57-174

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271	6	3	D	2001	1	0.2	2580	1	1	52	Y	3	NW-C-01-73-57-174
272	2	3	D	2001	1	0.1	3220	4	3	66	N	5	NW-C-01-73-58-201
273	2	3	D	2001	1	0.1	3220	4	3	66	N	5	NW-C-01-73-58-201
274	6	3	D	2001	1	0.2	3540	1	2	42	Y	2	NW-C-01-73-58-203
281	6	3	D	2001	2	0.2	2340	1	1	42	Y	3	NW-C-01-73-58-205
283	6	3	P	2001	1	0.1	2450	1	2	22	Y	3	NW-C-01-73-58-205
284	6	3	P	2001	2	0.2	2480	7	2	29	I	3	NW-C-01-73-58-207
285	6	3	D	2001	1	0.1	2620	7	2	34	I	3	NW-C-01-73-58-207
287	2	2	P	2001	2	0.4	2360	1	1	44	P	3	NW-C-01-73-58-207
288	6	2	D	2001	2	0.4	3000	2	1	45	Y	3	NW-C-01-73-58-207
289	6	3	D	2001	2	0.1	2820	1	2	29	Y	2	NW-C-01-73-58-207
290	5	2	D	2001	2	0.3	2830	2	1	54	Y	2	NW-C-01-73-58-207
293	999	3	D	2001	1	0.2	2870	1	1	23	Y	4	NW-C-01-73-58-209
294	999	3	D	2001	1	0.1	2890	1	1	27	Y	4	NW-C-01-73-58-209
295	999	3	D	2001	1	0.2	2930	1	1	46	Y	4	NW-C-01-73-58-209
296	999	3	P	2001	2	0.2	2780	1	2	46	Y	4	NW-C-01-73-58-209
297	5	3	P	2001	1	0.2	2780	1	1	31	Y	4	NW-C-01-73-59-235
298	2	3	D	2001	1	0.2	3320	2	1	82	I	2	NW-C-01-73-59-235
299	2	3	D	2001	1	0.1	3350	1	1	48	Y	3	NW-C-01-73-59-235
300	999	2	D	2001	2	0.3	4000	2	1	82	Y	2	NW-C-01-73-59-235
301	999	2	D	2001	1	0.2	3720	2	1	62	Y	2	NW-C-01-73-59-235
302	999	2	D	2001	1	0.2	3740	2	1	57	Y	2	NW-C-01-73-59-235
303	999	3	Q	2001	2	0.1	4440	1	2	82	Y	4	NW-C-01-73-59-235
304	999	3	P	2001	2	0.1	4560	1	2	84	Y	4	NW-C-01-73-59-235
305	999	3	D	2001	2	0.2	2620	1	1	38	Y	4	NW-C-01-73-59-239
306	999	2	P	2001	2	0.2	3080	2	2	58	I	4	NW-C-01-73-59-239
307	999	2	P	2001	2	0.1	3140	2	2	59	I	4	NW-C-01-73-59-239
308	999	2	P	2001	2	0.1	3140	2	1	54	I	4	NW-C-01-73-59-239
309	6	3	D	2001	2	0.1	2980	1	3	36	Y	2	NW-C-01-73-59-242
310	999	3	D	2001	2	0.3	3140	1	2	58	Y	4	NW-C-01-73-59-242
312	999	3	P	2001	1	0.2	3520	1	2	43	Y	4	NW-C-01-73-59-242
400	4	4	D	1978	3	3.5	1380	4	1	45	Y	4	NW-78-69D-22
401	6	2	D	1978	2	0.6	1520	1	1	25	Y	5	NW-78-69D-22
402	6	2	D	1978	3	1.9	2440	1	1	62	Y	5	NW-78-69D-22
403	6	2	D	1978	3	3.5	2880	1	1	51	Y	5	NW-78-69D-22
404	5	3	D	1978	1	0.3	1780	1	1	78	Y	4	NW-78-69D-22
405	6	2	D	1978	3	3.3	3020	2	1	65	Y	5	NW-78-69D-22
406	6	2	D	1978	2	2.1	3040	2	1	66	Y	5	NW-78-69D-22
407	6	2	D	1978	1	0.7	3100	2	1	62	Y	2	NW-78-69D-22
408	6	2	D	1978	2	0.6	3650	2	1	67	Y	2	NW-78-69D-24
409	6	2	D	1978	1	0.3	3400	2	1	90	Y	2	NW-78-69D-24

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410	5	3	D	1978	1	0.2	1900	1	1	48	Y	5	NW-78-69D-24
411	6	3	D	1978	1	0.4	2260	1	1	38	Y	5	NW-78-69D-24
412	6	2	D	1978	2	1.7	3630	2	2	67	Y	2	NW-78-69D-26
413	6	2	D	1978	2	0.9	3540	2	1	75	Y	2	NW-78-69D-26
414	4	4	D	1978	3	5.3	1480	4	2	21	Y	4	NW-78-70D-55
415	4	4	D	1978	3	9.4	1470	4	2	23	Y	4	NW-78-70D-55
416	1	2	Q	1978	1	0.6	1490	1	1	15	Y	4	NW-78-70D-55
417	6	3	D	1978	1	0.1	2820	1	2	64	Y	5	NW-78-70D-55
418	6	3	D	1978	1	0.1	2820	1	2	64	Y	5	NW-78-70D-55
419	5	3	D	1978	1	0.1	1840	1	1	46	Y	3	NW-78-70D-55
420	6	2	D	1978	1	0.2	3060	2	1	68	Y	3	NW-78-70D-55
421	6	3	D	1978	1	0.1	3140	1	1	68	Y	2	NW-78-70D-55
422	6	3	D	1978	1	0.1	3140	2	1	65	N	2	NW-78-70D-55
423	6	3	D	1978	1	0.1	4020	7	2	66	N	5	NW-78-70D-55
424	6	3	D	1978	1	0.1	4130	7	2	63	N	5	NW-78-70D-55
425	6	3	D	1978	1	0.1	3720	7	2	64	I	5	NW-78-70D-55
426	6	3	D	1978	1	0.2	2750	7	2	73	I	5	NW-78-70D-55
427	2	3	D	1978	2	0.3	3120	2	2	61	N	2	NW-78-70D-55
428	5	2	D	1978	2	0.5	1900	8	1	52	P	3	NW-78-70D-57
429	5	2	D	1978	2	0.7	1920	8	1	56	P	3	NW-78-70D-57
430	5	2	D	1978	2	0.8	2020	8	1	50	Y	3	NW-78-70D-57
431	5	2	D	1978	2	0.7	2000	8	1	51	Y	3	NW-78-70D-57
432	5	2	D	1978	1	0.3	1900	8	1	41	Y	3	NW-78-70D-57
433	5	2	D	1978	1	0.2	1870	8	1	42	P	3	NW-78-70D-57
434	5	2	D	1978	2	0.4	1920	8	1	50	Y	3	NW-78-70D-57
435	5	2	D	1978	2	0.4	1920	8	1	45	Y	3	NW-78-70D-57
436	5	3	D	1978	1	0.1	1940	8	1	45	P	3	NW-78-70D-57
437	5	3	D	1978	1	0.3	1940	8	1	31	P	3	NW-78-70D-57
438	5	4	P	1978	3	1.2	1860	1	2	32	Y	3	NW-78-70D-57
439	6	3	D	1978	1	0.1	2040	1	1	25	Y	3	NW-78-70D-57
440	6	2	D	1978	1	0.4	3080	2	1	55	Y	5	NW-78-70D-59
441	2	3	D	1978	2	0.2	2640	1	1	69	Y	5	NW-78-70D-59
442	6	3	D	1978	2	0.1	3320	1	2	68	Y	4	NW-78-70D-61
443	6	3	D	1978	1	0.0	3240	1	2	35	Y	4	NW-78-70D-61
444	6	3	D	1978	1	0.0	3200	1	2	32	Y	4	NW-78-70D-61
445	6	3	D	1978	1	0.1	3180	1	2	54	Y	4	NW-78-70D-61
446	6	3	D	1978	1	0.1	3080	1	2	70	Y	4	NW-78-70D-61

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447	2	3	D	1978	2	0.1	3420	7	2	70	I	4	NW-78-70D-61
448	2	3	D	1978	1	0.1	3500	7	2	78	I	4	NW-78-70D-61
449	2	3	D	1978	1	0.0	3640	7	2	76	I	4	NW-78-70D-61
450	6	2	D	1978	2	0.2	3560	7	2	74	Y	4	NW-78-70D-61
451	6	2	D	1978	3	0.4	3760	7	2	65	Y	4	NW-78-70D-61
452	6	2	D	1978	2	0.9	3520	1	2	67	Y	4	NW-78-70D-61
453	6	3	D	1978	2	0.1	3460	1	2	70	Y	4	NW-78-70D-61
454	5	2	D	1978	1	0.2	2980	2	1	52	Y	5	NW-78-70D-61
455	5	2	D	1978	1	0.3	2980	2	1	58	Y	5	NW-78-70D-61
456	5	2	Q	1978	1	0.3	2940	2	1	53	Y	5	NW-78-70D-61
457	6	3	D	1978	1	0.0	2140	1	2	48	Y	3	NW-78-71C-48
458	2	2	D	1978	1	0.1	3020	7	2	49	Y	5	NW-78-71C-48
459	2	3	D	1978	1	0.0	3070	7	2	65	I	5	NW-78-71C-48
460	2	3	D	1978	1	0.0	3260	7	2	63	I	5	NW-78-71C-48
461	2	3	D	1978	1	0.2	3320	2	1	47	P	2	NW-78-71C-48
462	6	3	D	1978	1	0.1	2560	5	1	37	I	3	NW-78-71C-48
463	2	3	Q	1978	1	0.1	3020	7	2	30	I	5	NW-78-71C-48
464	2	3	D	1978	1	0.0	2980	7	2	31	I	5	NW-78-71C-48
465	2	3	D	1978	1	0.0	2980	7	2	31	I	5	NW-78-71C-48
466	2	3	D	1978	1	0.0	2980	7	2	36	I	5	NW-78-71C-48
467	2	3	D	1978	1	0.0	2980	7	2	36	I	5	NW-78-71C-48
468	6	3	D	1978	1	0.0	2480	1	1	41	Y	1	NW-78-71C-50
469	6	2	D	1978	2	0.5	3720	5	2	75	Y	4	NW-78-71C-50
470	6	2	D	1978	2	0.8	3850	5	2	85	Y	4	NW-78-71C-50
471	6	2	D	1978	2	0.3	3500	5	2	68	Y	4	NW-78-71C-50
472	2	3	D	1978	2	0.1	3780	7	2	40	I	5	NW-78-71C-50
473	6	3	D	1978	1	0.1	3860	7	3	41	I	5	NW-78-71C-50
474	2	2	D	1978	1	0.1	3610	7	2	57	I	5	NW-78-71C-50
475	1	3	P	1978	1	0.1	3420	7	2	32	I	5	NW-78-71C-50
476	6	2	D	1978	1	0.6	2840	2	1	39	Y	5	NW-78-71C-50
478	6	3	D	1978	2	0.3	2880	1	2	45	Y	2	NW-78-71C-50
479	6	3	D	1978	1	0.0	2740	1	1	43	Y	2	NW-78-71C-52
480	6	3	D	1978	1	0.0	2720	1	1	50	Y	2	NW-78-71C-52
481	6	3	D	1978	1	0.0	2660	1	1	54	Y	2	NW-78-71C-52
482	6	3	D	1978	1	0.0	2640	1	1	39	Y	2	NW-78-71C-52
483	6	3	D	1978	1	0.0	2540	1	2	38	Y	3	NW-78-71C-52
484	5	2	D	1978	1	0.2	2220	1	1	41	Y	3	NW-78-71C-54
485	5	2	D	1978	2	0.5	2460	1	1	75	Y	3	NW-78-71C-54
486	5	4	P	1978	3	3.5	2120	1	2	57	Y	3	NW-78-71C-54
487	5	4	P	1978	3	4.5	2200	1	2	45	Y	3	NW-78-71C-54
488	5	2	D	1978	1	0.3	2420	1	1	50	Y	2	NW-78-71C-56
489	5	3	D	1978	1	0.1	2320	1	1	37	Y	2	NW-78-71C-56
490	5	3	D	1978	1	0.1	2340	1	1	42	Y	2	NW-78-71C-56
491	999	2	D	1978	1	0.4	3010	2	1	61	Y	4	NW-78-71C-56

Form A-1: Landslide Inventory for Clearwater-Warm Landslide Hazard Zonation Project

SLIDE_ID	HAZ_ZONE	SLIDE_PROC	CERTAINTY	ID_DATE	SLIDE_SIZE	SLIDE_AREA	ELEV	LANDFORM	SLP_SHP	GRADIENT	DELIVERY	LANDUSE	PHOT_NUMB
492	999	2	D	1978	2	0.7	3080	2	1	56	Y	4	NW-78-71C-56
493	999	3	D	1978	1	0.1	3260	1	1	43	Y	4	NW-78-72C-51
494	2	3	D	1978	1	0.1	3440	8	1	47	Y	4	NW-78-72C-51
495	999	3	D	1978	2	0.2	3780	8	1	36	Y	4	NW-78-72C-51
496	999	3	D	1978	1	0.1	3800	8	1	38	Y	4	NW-78-72C-51
497	999	3	D	1978	1	0.1	3700	8	1	47	Y	4	NW-78-72C-51
498	999	3	D	1978	1	0.1	3860	1	2	42	Y	4	NW-78-72C-51
499	999	3	D	1978	2	0.2	4140	1	2	25	Y	4	NW-78-72C-51
500	999	3	Q	1978	2	0.3	3580	1	1	36	Y	4	NW-78-72D-1
501	999	3	D	1978	1	0.1	3620	7	2	27	I	5	NW-78-72D-1
502	999	3	D	1978	1	0.1	3600	7	2	23	I	5	NW-78-72D-1
504	6	2	D	1978	2	0.6	3500	5	2	85	Y	4	NW-78-69D-26
505	6	2	D	1978	3	2.7	3900	5	2	85	Y	4	NW-78-69D-26
506	6	2	D	1978	1	0.2	3090	2	1	61	Y	5	NW-78-70D-59

Form A-2 Landform Assessment Description

Landform (Hazard Zone) Number - 1

Landform (Hazard Zone) Description – Low-gradient, planar to divergent slopes associated with terraces, mid-slope and toeslope benches, and ridges.

Slope - <50 percent

Slope Shape – planar (terraces and benches); divergent to planar (ridges)

Lithology – Terraces and toeslope benches are generally underlain by modern and older alluvium (lower elevations) and glacial sediments (higher elevations); mid-slope benches and ridges are underlain by the Chuckanut Formation (western part of project area) and Easton Metamorphic Suite (eastern part of project area).

Elevation – 1,600 feet to 5,500 feet

Total Area – 2,117 acres (21 percent of project area)

Mass Wasting Processes – not applicable

Non-road-related Landslide Density – not applicable

Forest Practices Sensitivity – LOW

Mass Wasting Potential - LOW

Delivery Potential - LOW

Delivery Criteria Used – slope gradient; presence of surface waters

Hazard Potential Rating - LOW

Trigger Mechanisms – not applicable

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

Comments – Stream channels within this unit are locally incised, creating small-scale inner gorge features similar to those included in Landslide Hazard Zone #6. While slopes adjacent to these streams sometimes exceed 70 percent gradient, the channel gradients are generally lower (<10 percent), making the risk of debris flow initiation low relative to streams associated with Landslide Hazard Zone #6. Nevertheless, where stream-adjacent slopes exceed 70 percent, the landform is considered an “inner gorge” and should be assigned the same sensitivity and hazard ratings as Landslide Hazard Zone #6.

Portions of this unit lie within the groundwater recharge area of glacial deep-seated landslides along the MFNR and Clearwater Creek.

Form A-2 Landform Assessment Description

Landform Number - 2

Landform Description – Moderate to steep gradient, planar to divergent slopes located between headwater stream channels and headwater basins

Slope – >50 percent (mostly 50 to 80 percent)

Slope Shape – planar to divergent

Lithology – Chuckanut Formation (western part of project area) and Easton Metamorphic Suite (eastern part of project area)

Elevation – 1,400 feet to 5,000 feet

Total Area – 5,209 acres (51 percent of project area)

Mass Wasting Processes – debris avalanches (most commonly); debris flows (rare)

Non-road-related Landslide Density – 0.00009 landslides/acre/year

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

Mass Wasting Potential - LOW

Delivery Potential - HIGH

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

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

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

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

Comments – Unmapped inclusions of Hazard Zone #1 and Hazard Zone #6 exist within this zone. Inclusions of Hazard Zone #1 are commonly small spur ridges and mid-slope benches less than 10 acres in size. Inclusions of Hazard Zone #6 are commonly bedrock hollows and inner gorges associated with first- or second-order stream channels. Hazard Zone #6 inclusions within this zone represent the greatest “false negative” risk within the project area.

Portions of this unit lie within the groundwater recharge area of a large, glacial deep-seated landslide along the middle reach of Clearwater Creek (#37 in the landslide inventory).

Form A-2 Landform Assessment Description

Landform Number - 3

Landform Description – Steep, convergent headwalls on the upper slopes of Groat Mountain

Slope - >70 percent

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

Lithology – Easton Metamorphic Suite

Elevation – 2,600 feet to 5,400 feet

Total Area – 17 acres (<1 percent of the project area)

Mass Wasting Processes – snow avalanche, rock topples and falls, and debris avalanche

Non-road-related Landslide Density – not applicable (no landslides mapped within project area)

Forest Practices Sensitivity – HIGH (see Trigger Mechanisms below)

Mass Wasting Potential - HIGH

Delivery Potential - HIGH

Delivery Criteria Used – slope gradient; presence of surface waters

Hazard Potential Rating - HIGH

Trigger Mechanisms – Under natural conditions, the dominant debris avalanche triggering mechanism is high soil pore water pressure associated with high intensity rainfall and/or rain-on-snow precipitation events. Freeze/thaw processes drive rockfall and topples. Forest practices can accelerate the debris avalanche rate within this unit through: 1) increased soil pore water pressure associated with concentrated road surface water drainage, 2) reduced root strength associated with clearcut timber harvest, and 3) reduced soil structural strength associated with soil disturbance caused by log yarding. Forest practices may also accelerate the rate of snow avalanching by increasing snow accumulation and melt rates in harvested areas.

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

Comments – Only a small portion of this hazard zone is located within the project area. Most of this zone lies north and east of the project area on forestlands managed by the United States Forest Service.

Form A-2 Landform Assessment Description

Landform Number - 4

Landform Description – moderate to steep slopes along the MFNR terrace face; includes the outer edges of meander bends along the MFNR

Slope – >60 percent

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

Lithology – glacial and lahar deposits; older alluvium

Elevation – 1,200 to 1,600 feet

Total Area – 167 acres (2 percent of project area)

Mass Wasting Processes – rotational deep-seated landslides (dominant process); debris avalanches (less common and limited to >70 percent/>35 degree slopes)

Non-road-related Landslide Density – not applicable

Forest Practices Sensitivity – HIGH (see Trigger Mechanisms below)

Mass Wasting Potential - HIGH

Delivery Potential - HIGH

Delivery Criteria Used – slope gradient; presence of surface waters

Hazard Potential Rating - HIGH

Trigger Mechanisms – Under natural conditions, the triggering mechanism for deep-seated landslide movement is high soil pore water pressure associated with high intensity rainfall and/or rain-on-snow precipitation events and above-average seasonal and/or annual precipitation. Channel incision associated with tributary streams that flow across the body of landslides or along their margins may also reduce stability. Forest practices may accelerate deep-seated movement by increasing soil pore water pressures through: 1) concentrated road surface water runoff, and 2) reductions in evapotranspiration associated with timber harvest.

Forest practices may also increase the rate of shallow-rapid landsliding within this unit through: 1) increased soil pore water pressure associated with concentrated road surface water drainage, 2) reduced root strength associated with clearcut timber harvest, and 3) reduced soil structural strength associated with soil disturbance caused by log yarding.

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

Comments – The groundwater recharge area for glacial deep-seated landslides within this zone (i.e., landslides #9, #10, #400, #414, and #415) extend outside this zone into Hazard Zone #1.

Form A-2 Landform Assessment Description

Landform Number - 5

Landform Description – Steep inner gorge slopes adjacent to high-order streams

Slope – >70 percent

Slope Shape – Convergent to planar; divergent spur ridges separate convergent areas

Lithology – Mostly glacial deposits; some areas may be underlain by the Chuckanut Formation (Clearwater Creek) or the Easton Metamorphic Suite (Warm Creek)

Elevation – 1,400 to 3,000 feet

Total Area – 887 acres (9 percent of project area)

Mass Wasting Processes – debris avalanche and short-run out debris flows (dominant); rotational deep-seated landslides (present but less common)

Non-road-related Landslide Density – 0.00327 landslides/acre/year

Forest Practices Sensitivity – HIGH (see Trigger Mechanisms below)

Mass Wasting Potential - HIGH

Delivery Potential - HIGH

Delivery Criteria Used – slope gradient; presence of surface waters

Hazard Potential Rating – VERY HIGH

Trigger Mechanisms – Forest practices may increase the rate of shallow-rapid landsliding in this unit through: 1) increased soil pore water pressure associated with concentrated road surface water drainage, 2) reduced root strength associated with clearcut timber harvest, and 3) reduced soil structural strength associated with soil disturbance caused by log yarding.

Deep-seated landslide movement is triggered by high soil pore water pressure associated with high intensity precipitation events and above-average seasonal and/or annual precipitation. Channel incision associated with streams that flow across landslide body or along its margins may also reduce stability. Forest practices may accelerate deep-seated movement by increasing soil pore water pressures through: 1) concentrated road runoff, and 2) reductions in evapotranspiration associated with timber harvest.

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

Comments – A single, large deep-seated landslide lies within this unit along the middle section of Clearwater Creek (landslide #37). The groundwater recharge area for this landslide encompasses parts of Hazard Zones #1 and #2 and has not been delineated/mapped.

Form A-2 Landform Assessment Description

Landform Number - 6

Landform Description – Steep slopes associated with convergent headwalls, bedrock hollows, and inner gorges adjacent to low-order streams

Slope – >70 percent

Slope Shape – Convergent to planar

Lithology – Chuckanut Formation (western part of project area) and Easton Metamorphic Suite (eastern part of project area)

Elevation – 1,600 to 4,400 feet

Total Area – 1,800 acres (18 percent of project area)

Mass Wasting Processes – debris avalanche, debris flow, and long run-out debris torrents (dominant); rotational deep-seated landslides (present but rare)

Non-road-related Landslide Density – 0.00267 landslides/acre/year

Forest Practices Sensitivity – HIGH (see Trigger Mechanisms below)

Mass Wasting Potential - HIGH

Delivery Potential - HIGH

Delivery Criteria Used – slope gradient; presence of surface waters

Hazard Potential Rating – VERY HIGH

Trigger Mechanisms – Forest practices may increase the rate of shallow-rapid landsliding in this unit through: 1) increased soil pore water pressure associated with concentrated road surface water drainage, 2) reduced root strength associated with clearcut timber harvest, and 3) reduced soil structural strength associated with soil disturbance caused by log yarding.

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

Comments – Due to the high gradient and confined nature of many headwater streams draining this hazard zone, there is a high potential for debris avalanches to translate into long run-out debris torrents.

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

Land Use Activity	Shallow Landslides	Debris Flows	Debris Avalanches	Deep-Seated Landslides	Snow Avalanche	TOTAL
Clearcut (0-5 yrs)	0	1	0	0	0	1
Young Forest (5-15 yrs)	0	0	3	0	0	3
Submature Forest (15-50 yrs)	0	1	1	0	0	2
Mature Forest (>50 years)	0	2	4	1	2	9
Road	0	7	25	0	0	32
Partial Cut	0	0	0	0	0	0
Yarding	0	0	0	0	0	0
Alpine	0	0	0	0	0	0
Other	0	0	0	0	0	0
TOTAL	0	11	33	1	0	47

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

Land Use Activity	Shallow Landslides	Debris Flows	Debris Avalanches	Deep-Seated Landslides	Earthflows	TOTAL
Clearcut (0-5 yrs)	0	0	0	0	0	0
Young Forest (5-15 yrs)	0	0	0	0	0	0
Submature Forest (15-50 yrs)	0	0	0	0	0	0
Mature Forest (>50 years)	0	0	0	4	0	4
Road	0	0	0	0	0	
Partial Cut	0	0	0	0	0	0
Yarding	0	0	0	0	0	0
Alpine	0	0	0	0	0	0
Other	0	0	0	0	0	0
TOTAL	0	0	0	4	0	4

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

Land Use Activity	Shallow Landslides	Debris Flows	Debris Avalanches	Deep-Seated Landslides	Earthflows	TOTAL
Clearcut (0-5 yrs)	0	9	13	1	0	23
Young Forest (5-15 yrs)	0	10	4	0	0	14
Submature Forest (15-50 yrs)	0	13	13	5	0	31
Mature Forest (>50 years)	0	4	18	3	0	25
Road	0	6	8	1	0	15
Partial Cut	0	0	0	0	0	0
Yarding	0	0	0	0	0	0
Alpine	0	0	1	0	0	1
Other	0	0	0	0	0	0
TOTAL	0	42	57	10	0	109

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

Land Use Activity	Shallow Landslides	Debris Flows	Debris Avalanches	Deep-Seated Landslides	Rockfall	TOTAL
Clearcut (0-5 yrs)	0	11	10	0	0	21
Young Forest (5-15 yrs)	0	15	19	0	0	34
Submature Forest (15-50 yrs)	0	15	47	0	0	62
Mature Forest (>50 years)	0	22	13	1	1	37
Road	0	13	16	0	0	29
Partial Cut	0	0	0	0	0	0
Yarding	0	0	0	0	0	0
Alpine	0	1	1	0	0	2
Other	0	0	0	0	0	0
TOTAL	0	77	106	1	1	185

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