APPENDIX A
MASS WASTING

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Table A-1. Required Module Work Products and Comparable Products for Onion Creek

Required Module Product	Onion Creek WAU Mass Wasting Analysis Product	Location in this Report
Map A-1, Landslide Inventory	Map A-1/A-2 combined	Map A-1/A-2
Map A-2, Mass Wasting Map Units and Hazard Ratings	Map A-1/A-2 combined	Map A-1/A-2
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APPENDIX A. MASS WASTING

1.0 INTRODUCTION

Mass wasting is the downslope movement of soil and rock material under the direct influence of gravity. Whether natural or management-induced, landslides can drastically alter the character of stream channels or adversely affect public resources, such as roads, bridges, or water supply.

The purpose of the mass wasting analysis is to evaluate the contribution of sediment delivered to stream channels by landslides. This is accomplished by inventorying historic and existing mass wasting features, identifying specific trigger mechanisms, and distinguishing among the types and rates of the processes active in the basin. In addition, the analysis attempts to distinguish between natural landslides (background) and landslides that are caused by land use activities or management activity, such as road building or logging.

The analysis methodology characterizes landscape areas that have produced landslides in the past and that have the potential to produce more landslides in the future. This is done by analyzing historical aerial photographs and conducting field surveys to create a landslide inventory; characterizing the geology underlying known landslides for its susceptibility to failure; and analyzing the geomorphic characteristics of the watershed that have produced landslides.

This assessment provides information based on geologic and terrain characteristics that will be used as guidance in developing forest management prescriptions for reducing mass wasting and the associated sediment delivery to streams. Information consists of maps and text that lead to ratings of delivered mass wasting hazard for geographic zones of the basin.

While the Onion Creek watershed has a complex geologic history, the most recent continental glaciation has left a subdued landscape. Glaciation has scraped weathered rock surfaces clean, rounded peaks and ridges, and deposited deep, well-drained soils throughout the watershed. Older Paleozoic rock and younger Mesozoic granite are competent, and not subject to rock fall or rock slide processes. The relatively dry climate, coupled with jointed bedrock and permeable soils, help reduce the hydrologic component driving mass wasting processes of the type and density associated with wetter areas of the state (i.e., western Cascades). In addition, many stream channels and swales are not connected throughout much of the lower portion and some of the upper portions of the watershed, providing little opportunity for mass wasting to adversely affect downstream resources.

1.1 Geologic Overview

The Onion Creek Watershed Administrative Unit (WAU) is located within the Northern Rocky Mountains physiographic province of northeast Washington (Easterbrook and Rahm, 1970), near Northport in Stevens County. The WAU is bounded on the north by the Columbia River, between nine and twenty-two river miles south of the Canadian border. It is bounded on the south by Gillette Mountain, and on the west by Staghorn Mountain, Grande Mountain and O'Toole Mountain. The Deep Creek drainage is adjacent to the Onion Creek WAU to the east. Total relief in the basin is about 4,285 feet, rising from a pond elevation of about 1,290 feet on Roosevelt Lake Reservoir on the Columbia River to about 5,575 feet on Gillette Mountain to the south. The area receives about 24 inches of precipitation per year, much of it in the form of snow.

The area is near the south end of the Kootenay Arc, a 250 mile-long arcuate belt of multiple deformation extending from north of Revelstoke, British Columbia to south of Hunters, Washington. The belt consists of metasedimentary rock deposited in a continental margin basin environment (Yates, 1970). Ages of the deformed rocks range from late Precambrian to Middle Jurassic. Dominant rock types in the WAU belonging to the Kootenay Arc include very competent Paleozoic sedimentary and metasedimentary rock consisting of limestone, dolomite, argillite, phyllite, slate and quartzite. These rocks are intruded by a batholith of granitic composition (the Spirit Pluton) over a large area of the central portion of the WAU.

Structural lineaments are generally oriented northeast, sympathetic with the trend expressed by the Columbia River in that region. Metasedimentary rocks in the northern portion of the WAU have been tightly folded, in places overturned to the north-northwest. Bedding strikes throughout the area are generally northeast, and dips are moderate to steep to the northwest and southwest. Major and minor folds and their associated lineations plunge southwesterly. The time during which deformation took place is only approximately known. Folded strata of Paleozoic age near the Northport area are cut by dikes about 50 million years old, and a few miles south folded strata are cut by the Spirit Pluton, which has been dated to about 100 million years old. Hence, the latest deformation reasonably occurred between 100 and 200 million years ago (Mills and Nordstrom, 1973). Following deformation, the region was subjected to a mild flexure deformation, extension in a northeast-southwest direction with development of joints, and by thrust faulting probably in response to compressive stresses acting in a north-south direction.

Rock outcrop of the Spirit pluton exhibits strong jointing that trends northeast. This jointing acts as a control on most western drainage tributaries to Onion Creek, which trend northeast. Porosity due to jointing in the granitic rock is likely concentrated along fracture zones and likely increases with the width of the joints at depth.

In many ways the landscape of the Onion Creek WAU is a legacy of the last great ice age. Continental glaciation overwhelmed the peaks and ridges, which were subdued under a load of moving glacier ice and subject to the rounding effects of glacial scour. Where exposed, bedrock surfaces are generally fresh and unweathered. As with other valleys in the Northern Rocky Mountain Province, the north-south orientation of the Onion Creek valley was a pathway for lobes of the Cordilleran Ice Sheet during successive glacial advances.

Glacial landforms are entirely of Wisconsin Age and are well preserved. At the time of maximum glaciation during the late Wisconsin, about 18,000 years ago (Kiver and Stradling, 1986), the area was completely covered by glaciers. Erosional details include polished outcrops and some rock-basin lakes. On some mountainslopes and foothills parallel to the north-south valley of Onion Creek the rock is locally eroded into streamlined forms. Bedrock surfaces in valleys above elevations of about 2,000 feet are extensively covered by a deep mantle of coarse to fine ablation till. Thin, discontinuous patches of till remain on mountain slopes and in the upper portions of tributary valleys. Glacial deposits also include large outwash terraces, and large terraces of ice-marginal lakes or kame terraces along the Columbia valley. The ice blocked off the Onion Creek tributary valley and provided conditions favorable to the development of terraces composed of low energy deposits of sands, silts and clays.

1.2 Geologic Map Units

Geology of the basin is displayed in Figure 4, Onion Creek Geology Map (Executive Summary, Section 2.2). The map was compiled from geologic maps and investigations by Joseph (1990), Kiver and Stradling (1986), and Yates (1964 and 1971). Unit Pmsu includes (from oldest to youngest): Cambrian Gypsy Quarzite, a thick-bedded quartzite interbedded with argillite; Cambrian Maitlen Phyllite, a fine-grained, thin bedded to medium-laminated phyllite interbedded with quartzite and limestone; Ordovician Ledbetter Slate, a slate and argillite with argillaceous limestone; and minor occurrences of Carboniferous phyllite and argillite. Unit Pl is comprised mostly of Cambrian to Ordovician Metaline Formation limestone and dolomite, that is subdivided into a lower thin-bedded limestone interbedded with shale and phyllite, a middle medium- to thick-bedded dolomite, and an upper massive limestone unit.

Unit Ki is Mesozoic granite of the Spirit pluton. The Spirit pluton regionally is elongate in an east-west direction, and locally cuts discordantly across northeast-trending folds in Paleozoic rock. The pluton consists of porphorytic biotite granodiorite and non-porphorytic granodiorite. Most exposures of the granite bedrock are fresh, having been scoured by recent glaciers. However, some exposures of the granite show its tendency to disintegrate rapidly into grus (angular, coarse-grained fragments derived from weathering of granitic rock). Where preserved, the accumulation of grus may be several yards thick. Much of the grus throughout the upper basin has been incorporated into till deposits mantling the foothills and mountain sideslopes and ridges.

Quaternary glacial units are mapped as glacial outwash (Qgo), glacio-lacustrine (Qgl), and till (Qgt). Glacial outwash and glacio-lacustrine units dominate the lower (northern) portion of the WAU along the Columbia River valley. Outwash is mostly crudely bedded, poorly sorted, fine to coarse sand, with rounded to well-rounded gravel, and silt with local inclusion of clay. Glacio-lacustrine deposits consists of very fine sand, silt, and clay interlaminated with silt in horizontal to wavy beds. Except for Five Mile Creek and drainages to Onion Creek, runoff drainages from hillslopes adjacent to the Columbia River valley do not extend down to the Columbia River; outwash terraces have high infiltration rates and contribute water to the ground-water systems. Much of the till (Qgt) in the valleys and footslopes of the upper portion of the watershed is deep ablation till, comprised of permeable fine to coarse sand. In tributary valleys on the eastern portion of the upper basin at about the 3,000 foot level, multiple more-or-less horizontal clayey beds are interbedded with coarse granular sands, suggesting probable ice-impounded drainage segments. Much of the deep till throughout the basin is permeable and well drained, but may locally have relatively impermeable boundaries of a more clay-rich composition.

1.3 Soil Unit Descriptions

The formation of geologic units has a strong control on the distribution and properties of soils in the WAU. One of the important properties of these soils is their permeability, enabling them to drain rapidly. Soils in the basin can be generally grouped into three main categories (USDA Soil Conservation Service, 1982): (1) soils on mountains; (2) soils on foothills; and (3) soils on terraces (please refer to Table B-1.1, Appendix B: Surface Erosion, for a tabular display of pertinent soil characteristics).

Soils on mountains include two sub-groups: the Spokane-Moscow-Rock outcrop group, and the Huckleberry-Raisio-Hartill group. The Spokane-Moscow-Rock outcrop soils are moderately deep, well drained, nearly level to very steep soils formed in material weathered from granite, with an admixture of loess and volcanic ash, and rock outcrop. This soil group is generally found on south aspect sideslopes in the northern portion of the upper basin, and on east aspect granite sideslopes in the western portion of the upper basin. The Huckleberry-Raisio-Hartill soils are moderately deep, well drained, nearly level to very steep soils formed in material weathered from shaly rock. This soil group is generally found on north aspect sideslopes in the south portion of the upper basin.

Soils on foothills include two sub-groups: the Aits-Newbell-Donavan group and the Belzar-Smackout-Maki group. The Aits-Newbell-Donavan soils are very deep, well drained, nearly level to very steep soils formed in mixed glacial till, with a mantle or admixture of volcanic ash and loess. These occur on all footslopes and valleys in the upper basin. The Belzar-Smackout-Maki soils are moderately deep and very deep, well drained, nearly level to very steep soils formed in glacial till from shaly rock and residuum and colluvium from limestone, with a mantle or admixture of volcanic ash and loess. These are generally found in the lower portion of the basin east of Onion Creek.

Soils on terraces and terrace escarpments include the Clayton-Cedonia-Martella group, which are very deep, well drained, and moderately well drained, nearly level to very steep soils formed in lake sediment and glaciofluvial material, and the Springdale-Spens-Bisbee group, which is a very deep, somewhat excessively drained, nearly level to very steep soils formed in glacial outwash.

1.4 Major Basin Landforms

Figure A-1 displays a landform map for the basin. Landform designations are assigned to surface features based on the origin and development of the landscape as it is expressed in the topography. Landforms are the basis of mass wasting unit descriptions due to similarities of mass wasting types and densities.

Principal landform divisions in the watershed consist of:

- Steep (greater than 70 percent) sideslopes on foothills and mountains. Generally on north aspects of Paleozoic rock (Pmsu and Pl) in the lower portion of the watershed east and west of Onion Creek, and in minor areas on north aspects of Paleozoic rock in the upper portion of the watershed.

- Folded and faulted Paleozoic sedimentary and metasedimentary rock on sideslopes and ridgetops of foothills and mountains. Includes rock outcrop, colluvial soils, and shallow till.

- Subdued hills of Mesozoic granitic rock on footslopes and sideslopes of foothills in the upper watershed. Includes rock outcrop, colluvial soils, and shallow till.

- Deep till in valleys and on toeslopes and footslopes of foothills. Includes some areas of deep till on mountain sideslopes and ridgetops.

- Glacio-fluvial and glacio-lacustrine terraces in the lower portion of the watershed; includes alluvial fans on toe slopes of foothills.

- Steep-walled escarpments in glacio-fluvial and glacio-lacustrine terraces, mainly in the lower portion of the watershed.

The general topography of the basin is an expression of the erosive effects of recent glaciation on competent rock; surfaces are generally fresh and ridges are rounded. The extent of steep lands is generally limited to tilted strata of competent metasedimentary rock and terrace escarpments. The landscape also reflects depositional effects of glaciation as a mantling of till on sideslopes and in valleys in the upper basin, and deposition of glacial outwash and glacio-fluvial terraces in the lower basin. Terraces in the lower watershed include two features of probable collapsed ice-walled lakebeds west of Onion Creek, kame terraces at about 1720', 1760', and 1600,' and glacio-lacustrine terraces at about 1560' to 1610', 1410' to 1490', and 1320' to 1360' (Kiver and Stradling, 1986)

2.0 METHODS

Methods used for data collection and analysis for this module are those described in the Watershed Analysis Manual, Version 3.0 (Washington Forest Practices Board, 1995). A landslide inventory was conducted by analyzing historical aerial photographs and by conducting field surveys to verify mapped landslides. From these surveys the geology underlying known landslides was characterized for its susceptibility to failure. Finally, the geomorphic characteristics of the watershed that have produced landslides were analyzed to determine mass wasting map units and hazard ratings. As the purpose of this report is to evaluate the effects of past and future land use activities on mass wasting processes, landslides on shorelines of the reservoir were not considered in the analysis.

2.1 Aerial Photograph Analysis

Black and white photo copies of aerial photographs from 1968, 1980, 1987, and 1992, and aerial photographs from 1977 and 1995, were examined to identify landslide scars and structural features. All photos except the 1977 and 1995 set were of approximate scale 1:12,000; the 1977 and 1995 sets were approximately 1:60,000 and 1: 63,360, respectively.

Potential landslide locations were recorded on USGS 1:24,000 7.5 minute topographic maps. Soil types were taken from the 1:24,000 SCS soils maps for Stevens County (USDA Soil Conservation Service, 1982). Bedrock and surficial deposit types were determined from geologic maps at scales of 1:100,000 (Joseph, 1990), 1:31,680 (Yates, 1964 and 1971), and 1:24,000 (Kiver and Stradling 1986).

2.2 Field Reconnaissance

Four days (September 30, October 1, 3, and 4, 1996) were spent in the field to verify photo-identified sites, and to assist with the surface erosion inventory along county and forest roads. Few photo-identified sites were verified as landslides; the other suspected sites were verified as benign surface scars at landings or were blemishes in the copy quality of the photo-copied sets of aerial photographs.

3.0 ANALYSIS AND RESULTS

3.1 Mass Wasting Inventories

A total of 16 landslides, three of which are ancient (inactive), were identified on the aerial photos and in the field. All slides occurred within glacially derived material; no slides were identified that are associated with bedrock failures. Ten landslides delivered sediment to streams. A brief summary is given below:

8 shallow-rapid landslides related to roads

4 shallow-rapid landslides with no forest-related land use identified

1 deep-seated landslide related to roads

3 deep-seated ancient landslides

Road building and harvest have occurred extensively in all MWMU's. No mass wasting was associated with harvest in any area, while roads (including non-forest roads) were associated with about 70 percent (9 of 13) of all active mass wasting features. Map A-1 shows the locations of the mass wasting features. Results are also summarized on Forms A-1, A-2, and A-3 (at the end of this appendix).

Each identified mass wasting feature displayed on Map A-1 was given a landslide identification number based on the location of its point of origin. The identification number consists of the Township, Range, Section, 1/16 Section, and number of feature. For example, 38/40E-33D1 is the first feature mapped in the "D" 1/16 Section in Section 33 of Township 38N, Range 40E. For simplicity, only the lettered 1/16 Section and feature number are displayed with the feature location on the map.

3.2 Observations

3.2.1 Field Verification

Of 21 potential features identified with aerial photos, 16 were visited in the field. Only three of the potential 21 features were verified as "real;" the other 13 were found to be cut slopes, landings, or blemishes on the photo copies. Five mass wasting features not visible on photos were found during field surveys, and five other photo-identified potential failures, excluding ancient deep-seated landslides, were not field checked.

3.2.2 Material Properties

All mass wasting in the WAU occurred in glacially derived sediments. These sediments exhibit a variety of properties, some of which are conducive to mass wasting and others of which are not. Till in the upper portion of the watershed consists of abundant amounts of coarse granitic sand, derived locally from grus and incorporated by the ice. For the most part, this till is well to very well drained. Portions of this till have a high sand, low clay content that maintains an angle of repose of less than about 35 degrees. Steeper slopes can be maintained with increasing clay content, but at the expense of reduced permeability. This can be problematic in areas of markedly contrasting permeability boundaries. In that case, groundwater can emerge as springs or seeps on cut banks of roads or stream channels, and induce shallow rapid landsliding as pore pressures are elevated.

Glacio-lacustrine and outwash sediments, generally on terraces and terrace escarpments in the lower portion of the WAU adjacent to the Columbia valley, consist of higher contents of silts and fine grained sand. Dry escarpments consisting mostly of silt and clay can retain steep slopes, but behave viscously when moist. They have lower permeability, and may retain moisture over extended periods of time, showing a tendency to cause saturation of overlying materials, with a consequent increase in pore pressures that can destabilize slopes.

3.2.3 Mass Wasting Processes

The inventory of landslides in the WAU shows that shallow rapid failures dominate, controlled in part by soils with contrasting permeabilities. It is a delicate balance at present; very little mass wasting occurs due to the lack of pore water pressure. Generally high permeabilities, coupled with deep soils and extensive jointing in the bedrock, help mitigate the tendency for landsliding in the Onion Creek WAU. If climate were to radically change for the wetter, we would expect to see more failures associated with prolonged saturation of soils and relatively greater duration of flood flows. A case can be made for expecting an increase in landsliding as a result of prolonged saturation by observing that a great number of landslides occur along the shore of Lake Roosevelt as a result of saturation by fluctuating reservoir levels (see Kiver and

Stradling, 1986, for an inventory of landslides included in their Lake Roosevelt Shoreline study).

4.0 MASS WASTING MAP UNITS

The basin landscape was partitioned into map units, based on physical characteristics contributing to slope instability and the potential for landslide sediment to enter streams or affect other public resources. Mass Wasting Map Units (MWMU) in the Onion Creek watershed are strongly related to landform. In addition to landslide processes, landslide densities, and landform, other criteria used to delineate MWMU's included slope gradients, bedrock type and structure, soil material, potential for sediment delivery to streams, and slope hydrology. Five MWMUs were delineated. These units are displayed on the combined Map A-1/A-2, and described below. In addition, a summary description of MWMU's is provided in Form A-2, and the number of mass wasting features associated with various land use activities is tabulated in Form A-3. Forms A-2 and A-3 can be found at the end of this report.

4.1 Mass Wasting Map Unit #1

MWMU # 1 is characterized by steep (greater than 60 percent), planar to concave slopes adjacent to confined stream channels within the 2,400 to 4,000 foot elevation range. These channels occupy relatively narrow valleys, with little or no intervening low-gradient flood plain or terrace between the channel and the valley slopes. The slopes generally steepen above the channel, and then break in gradient between the inner gorge slope and the lower gradient hillslope or footslope above.

Materials within MWMU # 1 are typified by moderately deep to deep (greater than 24") permeable sandy till overlying a relatively impermeable till with higher clay content, or lenses of horizontally bedded clay. Seeps and springs are not uncommon at these boundaries.

Five shallow rapid landslides were identified in this unit, at least one of which continued down the channel as a debris flow (landslide identification number 38/40E-33D1; photo year 1968). Slopes of mapped failures typically exceed 60 percent, and head scarps initiate at differential permeability boundaries. Erosion of toe slopes by stream incision may exacerbate failure on over-steepened slopes with long slope lengths. Four failures are associated with roads, at least one of which likely was triggered by concentrated surface water discharging onto a steep slope. The other three of the four slides may have been triggered by sidecast fill failures. A fifth slide was triggered at a seep as the sandy, dry overburden was saturated at an impermeable boundary (38/40E-19M1).

The hazard potential rating for MWMU # 1 is moderate. Failures indicate a moderate sensitivity to forest practices by roading. Sensitivity to harvesting is low, based on historical observation. Mass wasting potential under unmanaged conditions is low. The delivery potential is high, as steep slopes adjacent to stream channels have no where else to go when they fail.

4.2 Mass Wasting Map Unit #2

MWMU # 2 is characterized by planar, steep slopes (greater than 50 percent) on escarpments of glacio-lacustrine or outwash terraces. This landform occurs from 1,290 feet to about 2,000 feet. Materials are dominantly fine textured silty or sandy loams, or fine to coarse sand, interlayered with clay or fine silt.

A total of six landslides were observed in this unit. Three of the slides are ancient, very large, deep seated slides. Two of the three active slides are shallow rapid, one of which is (non-forest) road related. The road related slide (39/39E-28P1) appeared between aerial photo sets 1980 and 1987 following some small construction activity and development of a road at the escarpment crest. A third slide is a small, sporadic, chronic indication of a large persistent deep seated slide (39/39E-23L1).

Roading exacerbates the instability of steep escarpment slopes in several ways. Compaction of the surface by roading will allow surface water to concentrate, and discharge onto the steep slope. Road maintenance in the area of the large, persistent deep-seated slide continually removes the toe of the slumps by grading. Construction of roads at the top of this slide may further enhance instability by directing runoff onto the failure plane.

The hazard potential rating for MWMU # 2 is low, due to moderate mass wasting potential and a low delivery potential. Relative to its area, very few active slides were observed for this unit; however, with pressures of development and associated increase of road density, more frequent sliding could be a future concern. On the other hand, most terrace escarpments are remote from active streams. Only one active slide at present has the potential to deliver sediment to a stream (39/39E-23L1). Sediment delivered from this slide is routed through a gully developed from concentrated road runoff.

4.3 Mass Wasting Map Unit #3

MWMU # 3 is characterized by steep slopes (greater than 65 percent) on metasedimentary bedrock with dipslopes parallel to the hillslopes. These areas are further characterized by concave hollows adjacent to active stream channels, typically in the 1,800 feet to 5,000 feet elevation range. This unit delineates only those areas that could deliver sediment to streams.

Materials are dominantly shallow, fine to coarse colluvium or till overlying generally competent bedrock. The soils are moderately to very well-drained. In places these soils may be overlain by a mantle of volcanic ash, and so may be susceptible to puddling when compacted.

While no mass wasting was observed in this unit, concerns for failures in the future are justified by the presence of tension cracks in road tread and on fill, and by anecdotal evidence of a small fill failure at a stream crossing about fifteen years ago. In this case, trigger mechanisms relate to potential failure of saturated sidecast material placed on steep slopes, or to gullying of road fill at stream crossings due to undersized or blocked culverts.

The hazard potential rating for this unit is low due to low mass wasting potential. Sensitivity to harvesting is low, based on historical evidence that shows no discernible features in areas that have been harvested. However, the delivery potential is high everywhere, owing to the unit's mapped position in steep upland hollows adjacent to active streams.

4.4 Mass Wasting Map Unit #4

MWMU # 4 is characterized as relatively stable areas over a variety of landforms, slope gradients, and elevation ranges. This unit makes up the vast majority of the watershed, and so encompasses materials of all particle sizes of residuum, till, and rock outcrop.

Three mass wasting features were identified for this unit; all shallow rapid. One non-forest road related shallow landslide occurred in an unmanaged forest area, in shallow, fine- to coarse-textured colluvium and till overlying bedrock, with no sediment delivery to stream channel (40/40E-33N1). Two forest road related failures at stream crossings are included in this unit (37/40E-5J1 and 37/40E-5C1). They occurred at stream crossings and were probably caused by gullying of road fill resulting from culvert failure or overtopping of plugged culverts, contrasted to over-saturation and mass failure of the fill. The channels were incised for short distances downstream from the ripped culverts, but no degradation was observed upstream of the culverts.

Assuming standard forest practice rules are followed, the forest practice sensitivity is none, mass wasting potential is low (very low historical activity), delivery potential is low (very low historical activity), and the overall hazard potential rating is low.

4.5 Mass Wasting Map Unit #5

MWMU # 5 comprises 186 acres of lands in the Headwaters sub-basin that have been altered by mining activity. While other mining operations have historically occurred within the WAU, MWMU # 5 identifies only the operations of the Van Stone Mine because these are the only operations known to have a potential sediment delivery hazard.

The two tailings ponds are the mine features that have had historical mass wasting. These ponds have steep (greater than 60 percent), planar slopes constructed of relatively impermeable silt-sized material from mining waste. The northern and western walls of both the upper and lower ponds are proximal to streams with fish-bearing potential. The walls of the upper pond are adjacent to MWMU #1 (Map A-1).

Three shallow rapid landslides were identified in this unit. Evidence for one slide (38/40E-30A1) was observed during the 1996 field visit. This was a small shallow rapid slide of about 30 m^3 that initiated from the tailings wall of the lower pond, and deposited sediment into a sensitive stream. Evidence for a second probable slide that initiated on the upper tailings pond was observed from the 1968 aerial photos (38/40E-33D2). The slide may have been triggered by rapid surface runoff from upland slopes that surged through the pond, breached the wall and discharged onto the slopes below. A third slide included in this unit is based on anecdotal evidence of a large, catastrophic rapid landslide having occurred in 1958, ten years prior to the earliest photo record. Triggering mechanisms for this slide are probably associated with rapid surface runoff and wall breach, either from rapid storm runoff or from ruptured slurry pipes.

A moderate hazard potential rating is assigned to MWMU # 5. There is a high potential for delivery of sediment to streams. The mass wasting potential, while high in the past, is rated moderate under present conditions. These conditions include actions taken by the owner to prevent rupture of slurry lines that deliver to the ponds. In the past, the slurry lines were above-ground, wooden pipes, and subject to rupture that would spill slurry into streams. These have been upgraded to high strength, flexible poly-fibre pipes. The owner has also regraded the area between the upper pond and the hillslope behind it, so that surface water will be diverted around the pond instead of through it. In addition, the owner is taking measures to stabilize the pond walls (see Appendix B for more discussion of mining management).

5.0 CONFIDENCE DISCUSSION

While the Onion Creek watershed has a complex geologic history, the most recent continental glaciation has left a subdued impression on the landscape. Glaciation has scraped weathered rock surfaces clean, rounded peaks and ridges, and deposited deep, well drained soils throughout the watershed. Older Paleozoic rock and younger Mesozoic granite are competent, and not subject to rock fall or rock slide processes. The relatively dry climate, coupled with jointed bedrock and permeable soils, help reduce the soil saturation potential associated with mass wasting. A low stream density (about 1.9 mi/mi^2) is also associated with a reduced mass wasting potential. In addition, stream channels and swales are not connected throughout much of the lower portion and some of the upper portions of the watershed, providing little opportunity for mass wasting to adversely affect stream resources.

An extensive road network provided adequate access for field verification of suspect landslides identified in aerial photos. Aerial photo coverage was available starting in 1968, but photo sets other than high altitude flights were of poor copy quality. Dense forest cover in the steeper, upper basin may have obscured small mass wasting failures.

5.1 Mass Wasting Inventory

Of 21 potential features identified with aerial photos, 16 were visited in the field. Only three of the potential 21 features were verified as actual mass wasting. The other 13 features were found to be cut slopes, landings, or blemishes on the photo copies. Five mass wasting features were found during field surveys, and five other photo-identified potential failures, excluding ancient deep-seated landslides, were not field checked.

Although some small features or healed mass wasting features could have been overlooked in the photo survey, field inventory provided confidence in defining mass wasting units and characterizing types, densities, and trigger mechanisms of features. In addition to the mass wasting analyst, the surface erosion, riparian, channel, and fish analysts were on the lookout for features. A total of five (5) mass wasting features were found during 20 person-days of field time. Examples of all MWMU's were visited by the mass wasting analyst.

5.2 Analysis and Results

There were few opportunities for observing naturally occurring landslides under unmanaged conditions. Nearly all forested areas in the WAU have been cut over at least once.

Opportunities for observing the effects of forest practices on mass wasting activity did not vary much between MWMU's. Road building and harvest have occurred extensively in all MWMU's. No mass wasting was associated with harvest in any area, while roads (including non-forest roads) were associated with about 70 percent (9 of 13) of all active mass wasting features.

MWMU polygons were delineated on the map using characteristics gleaned from 1:24,000-scale topographic and soils maps; geologic maps of 1:100,000 and 1:31,680 and 1:24,000 scale; and aerial photos of about 1:12,000 and 1:63,000 scale. Confidence in mapping accuracy is high for all mass wasting features, due to the limited number of features (one-half of which were visited in the field), and due to excellent control on reference features such as roads.

Moderate to high confidence overall is estimated for map resolution for delineation of the MWMU polygons. Again, this is attributed to the paucity of landslides observed by all analysts in the field, over a wide portion of the basin. Moderate confidence is given for MWMU # 1, due to the characteristically small nature of the slides observed stream-side, and due to the forest cover in the upper portions of the watershed. Any error in mapping would likely fall on the side of excluding small areas of moderate (or high) hazard polygons contained within mapped low-hazard polygons.

6.0 MONITORING RECOMMENDATIONS

Most landsliding is initiated as shallow rapid failures associated with roading. Effects on stability from changes in road construction methods (reducing risk of gullying and landsliding by reducing concentrated drainage discharge onto steep slopes) and management practices (maintaining culverts) should be seen over time by comparison of the existing mass wasting inventory with subsequent events, and by inventorying events that occur in areas of new road construction. New and existing roads in MWMU # 3 in particular should be monitored by observation for signs of incipient failure, such as tension cracks on road surfaces.

7.0 REFERENCES AND BIBLIOGRAPHY

Easterbrook, Don J., and David A. Rahm. 1970. Landforms of Washington. Western Washington State College (Western Washington University), Bellingham, Washington.

Joseph, Nancy L. 1990. Geologic Map of the Colville 1:100,000 Quadrangle, Washington-Idaho. Washington Division of Geology and Earth Resources, Open File Report 90-13.

Kesten, S. Norman. 1970. The Van Stone Mine, Stevens County, Washington. *In* Weissenborn, A.E., editor, Lead-Zinc Deposits in the Kootenay Arc, Northeastern Washington and Adjacent British Columbia. State of Washington Department of Natural Resources, Bulletin No. 61.

Kiver, E.P., and Stradling, D.F. 1986. Lake Roosevelt Shoreline Study; Glacial Geology, Terraces, Landslides, and Lineaments. U.S. Bureau of Reclamation unpublished report.

Mills, Joseph W., and Harold E. Nordstrom. 1973. Multiple Deformation of Cambrian Rocks in the Kootenay Arc, near Northport, Stevens County, Washington. Northwest Science 47(3):185-202.

Sidle, R.C. 1985. Factors Influencing the Stability of Slopes. *In* Proceedings of a Workshop on Slope Stability: Problems and Solutions in Forest Management, USDA Forest Service, Pacific Northwest Forest and Range Experiment Station. General Technical Report PNW-180.

USDA SCS. 1982. Soil Survey of Stevens County, Washington. US Department of Agriculture, Soil Conservation Service.

Washington Forest Practices Board. 1995. Standard Methodology for Conducting Watershed Analysis. In Chapter 222-22 WAC, Version 3.0.

Yates, R. G. 1964. Geologic Map and Sections of the Deep Creek Area, Stevens and Pend Oreille Counties, Washington. U.S. Geological Survey Miscellaneous Geologic Investigations Map I-412, 1 sheet, scale 1:31,680.

Yates, Robert G. 1970. Geologic Background of the Metaline and Northport Mining Districts, Washington. *In* Weissenborn, A.E., editor, Lead-Zinc Deposits in the Kootenay Arc, Northeastern Washington and Adjacent British Columbia. State of Washington Department of Natural Resources, Bulletin No. 61.

Yates, R. G. 1971. Geologic Map of the Northport Quadrangle, Washington. U.S. Geological Survey Miscellaneous Geologic Investigations Map I-603, 1 sheet, scale 1:31,680.

Form A-1. Mass Wasting Inventory Data

	a	b	c	d	e	f	g	h	i	j	k	l	m
	Sub-basin	Landslide I.D. and (photo year)	MWMU	Type	Landslide size (cubic meters)	Sediment delivered to stream? Y/N, (Type)	Surface erosion of scar (percent)	Associated land use activity	Slope gradient and type	Soil type and texture	Bedrock or parent material	Initiation elevation	Comment
1	Headwaters	37/40E-5J1 (92+)	4	G/d	170	Y (p)	100	FR	--	stoney till	Pmsu	3680	gullying (washout) of road fill from culvert at stream crossing
2	Headwaters	37/40E-5C1 (92+)	4	G/d	60	Y (f)	100	FR	--	stoney till	Pmsu	3200	gullying (washout) of road fill from culvert at stream crossing
3	Headwaters	38/40E-27N1 (68)	1	SR/q	640	Y (fp)	100	FR (?)	--	sandy till	Ki	3720	questionable side cast failure; more than 60% revegetated by 1980
4	Headwaters	38/40E-28Q1 (68)	1	SR/q	640	Y (fp)	100	FR (?)	60 % concave	sandy till	Ki	3400	questionable side cast failure; more than 60% revegetated by 1980
5	Headwaters	38/40E-28N1 (68)	1	SR/q	210	Y (fp)	100	FR (?)	--	sandy till	Ki	3180	questionable side cast failure; more than 60% revegetated by 1980
6	Headwaters	38/40E-33D1 (68)	1	SR/d	1360	Y (fp)	100	R	60 % concave	sandy till	Ki	3160	chronic source of sediment to channel, visible in all aerial photo sets and '96 field visit. 1968 shows evidence of 3,000 + feet of deposition in channel; initiation may be attributed to road culvert/ drainage failure.
7	Headwaters	38/40E-33D2 (68)	5	SR/p	680	Y (fp)	100	M	>60% concave, converging	fine-textured tailings	-	3160	probable failure in tailing pond wall; contribution to deposition in #6 above
8	Headwaters	38/40E-30A1 (92+)	5	SR/d	30	Y (fp)	100	M	35% planar	fine-textured tailings	-	2680	failure in tailing pond wall; silty tailings deposits on grassey vegetated bars in the channel below the slide
9	Headwaters	38/40E-19M1 (96)	1	SR/d	50	Y (fp)	95	N	100% concave	sandy till	Ki	2460	failure initiated at soil boundary between dry silty till and moist pebbley till with clay matrix
10	Lower Onion	39/39E-23L1 (96)	2	LPD/d	Very Large (see comments)	Y (f)	15	R	70% planar	silt loam	glacial terrace escarpment	1640	translational slump block exposed along road alignment; bare, planar cutslope reveals insipient failure lineament; no catastrophic failure, but small sporadic slumps give evidence to LPD classification; regrading of inboard road continually weakens toe of slide
11	Lower Onion	39/39E-23N1 Ancient	2	LAD/d	Very Large (greater than 5,000)	na	--	N	35% concave	fine sand	glacial terrace escarpment	1650	collapse in terrace at probable ice-wall contact

Form A-1, continued

	a	b	c	d	e	f	g	h	i	j	k	l	m
	Sub-basin	Landslide I.D. and (photo year)	MWMU	Type	Landslide size (cubic meters)	Sediment delivered to stream? Y/N, (Type)	Surface erosion of scar (percent)	Associated land use activity	Slope gradient and type	Soil type and texture	Bedrock or parent material	Initiation elevation	Comment
12	Lower Onion	39/39E-23M1 Ancient	2	LAD/d	Very Large (greater than 5,000)	na	--	N	35% concave	fine sand	glacial terrace escarpment	1600	collapse in terrace at probable ice-wall contact
13	Crown Creek	39/39E-28P1 (87)	2	SR/p	910	N	50	N (R)	60% concave	fine sand	glacial terrace escarpment	1600	slide evident following small construction activity
14	Five Mile Creek	39/40E-4M1 (87)	2	SR/p	510	N	--	N	30% converging	till	Pmsu	1760	in drainage; under canopy and poor photo = uncertainty
15	Five Mile Creek	39/40E-4G1 Ancient	2	LAD/d	Very Large (greater than 5,000)	na	--	N	15 % concave	fine sand	glacial terrace escarpment	1800	ancient landslide
16	Five Mile Creek	40/40E-33N1 (87)	4	SR/d	510	N	100	N (R)	65% planar	till and colluvium	Pz limestone	1520	30 % revegetated; dipslope into hillside; paved road at toe; railroad grade below that.

Footnotes:

column d:
G = road crossing gully
SR = shallow rapid
LPD = large persistent deep-seated failure
LAD = large ancient deep-seated failure
d = definite
p = probable
q = questionable

column f:
f = fish bearing
fp = potential fish bearing
p = perennial, non-fish bearing

column h:
FR = forest road
R = road
M = mining
N = no associated forest land use

Form A-2 Mass Wasting Map Unit Description

MWMU Number:	1
Description:	Steep (>60%) planar to concave slopes adjacent to stream channels.
Materials:	Moderately deep to deep (>24") permeable sandy till overlying relatively impermeable, more clay-rich till.
Landform:	Inner gorge: a narrow valley characterized by steepening of slope gradient above stream channels, with break in gradient between the inner-gorge slope and lower gradient hillslope or footslope above. Inner gorge delivers directly to the active stream channel with little or no intervening low-gradient flood plain or terrace.
Slope:	> 60% measured on site.
Elevation Range:	2,400 ft. to 4,000 ft.
Total Area:	0.75 acres
Mass Wasting Processes:	Three road-related shallow rapid landslides (probable side-cast failures); 1 definite debris flow initiated from a down-slope shallow rapid landslide associated with concentrated surface-water discharge from road; 1 non-road, non-forest related shallow rapid landslide;
Forest Practice Sensitivity:	Moderate sensitivity to roading; low to moderate sensitivity to harvesting based on no historical harvest-related slides observed.
Mass Wasting Potential:	Moderate potential under forest practices related to roading; Low potential under unmanaged conditions.
Delivery Potential:	High
Delivery Criteria:	Steep slopes adjacent to stream channels; historical delivery observed.
Hazard Potential Rating:	Moderate
Trigger Mechanisms:	Discharge of surface waters onto steep slopes, and saturation of overburden increasing pore water pressure at relatively impermeable boundary.

Form A-2 Mass Wasting Map Unit Description

MWMU	1 (continued)
Confidence:	High confidence that the potential hazard rating for this MWMU is moderate; Low confidence that entire area mapped as MWMU 1 is unstable. The poor copy quality of aerial photos provides low confidence for interpretation of three road-related shallow rapid landslides (probable side-cast failures).
Comment:	The shallow rapid failure from which the debris flow originated is a persistent source of sediment to the stream channel by sloughing and surface runoff from oversteepened slopes in the failure plane.

Form A-2 Mass Wasting Map Unit Description

MWMU Number:	2
Description:	Steep slopes of glacio-fluvial terrace escarpments
Materials:	Fine textured silty or sandy loams, or fine to coarse sand, interlayered with clay or fine silt
Landform:	Escarpments of glacio-lacustrine or outwash terraces
Slope:	> 50%
Elevation Range:	1,290 ft to 2,000 feet
Total Area:	993 acres
Mass Wasting Processes:	2 shallow rapid slides and 1 small sporadic slide related to persistent deep seated (excludes numerous shallow rapid slide at the reservoir); 3 ancient, very large deep-seated landslides
Forest Practice Sensitivity:	Road construction, especially in areas of active, large deep-seated slides
Mass Wasting Potential:	Moderate
Delivery Potential:	Low
Delivery Criteria:	Most terrace escarpments are remote from active streams; observed delivery is routed through a gully over long distances on slopes of decreasing gradient
Hazard Potential Rating:	Low
Trigger Mechanisms:	Road cuts across the base of a pre-existing slide, and continual removal of toe by road maintenance; compaction of surface by roading may concentrate discharge of water into (incipient) failure planes at impermeable boundaries
Confidence:	High, based on historical activity
Comment:	Where delivering to stream(s), the surface erosion of recent landslide scars is a persistent source of fine sediment

Form A-2 Mass Wasting Map Unit Description

MWMU Number:	3
Description:	Steep slopes (> 65%) on metasedimentary bedrock with dipslopes of bedding paralleling the hillslope
Materials:	Shallow to moderately deep fine to coarse colluvium and till
Landform:	Steep mountain sideslopes with concave hollows adjacent to active stream channels
Slope:	>65 %
Elevation Range:	1,800 ft to 5,000 ft.
Total Area:	1,420 acres
Mass Wasting Processes:	Shallow rapid failures possible (none observed)
Forest Practice Sensitivity:	Road construction
Mass Wasting Potential:	Low
Delivery Potential:	High
Delivery Criteria:	Steep slopes adjacent to active stream channels with few intervening depositional areas.
Hazard Potential Rating:	Low
Trigger Mechanisms:	Potential failure of saturated sidecast material placed on steep slopes (greater than 65%), and potential fill failures at stream crossings
Confidence:	Moderate; no discernible historical activity other than observed tension cracks on a few road surfaces on fill. Most of these areas are roaded and have been harvested in the past.

Form A-2 Mass Wasting Map Unit Description

MWMU Number:	4
Description:	Stable areas
Materials:	Rock outcrop, and all particle sizes of residuum and till
Landform:	Variable
Slope:	Variable
Elevation Range:	1,290 ft. to 5,575 ft.
Total Area:	53,862 acres
Mass Wasting Processes:	1 non-forest, road-related shallow rapid in shallow fine- to coarse-textured colluvium and till overlying bedrock (no delivery); (2 forest road related failures at stream crossings due to probable gullying of the fill caused by overtopping of debris-dammed culverts).
Forest Practice Sensitivity:	None, assuming standard forest practice rules are followed
Mass Wasting Potential:	Low
Delivery Potential:	Low
Delivery Criteria:	Minimal historical activity
Hazard Potential Rating:	Low
Trigger Mechanisms:	Undercutting or removal of toes at base of steep slopes, or concentrated drainage from roads, or blocked or failed culverts
Confidence:	High, based on historical activity

Form A-2 Mass Wasting Map Unit Description

MWMU Number:	5
Description:	Lands modified by mine works, especially mine tailings areas known to have contributed sediment to streams by mass wasting.
Materials:	Deep, relatively impermeable silt-sized material derived from mining tailings in limestone.
Landform:	Tailings ponds are constructed over deposits of till on toe slopes and footslopes of foothills and mountains. The ponds have a form characteristic of terraces, with steep-walled escarpments.
Slope:	The ponds are contained by steep (greater than 60%) walls constructed of silt-sized tailings.
Elevation Range:	2,680 ft. to 3,950 ft.
Total Area:	186 acres
Mass Wasting Processes:	Two observed shallow rapid landslides associated with concentrated surface-water discharge, probably from over-topping of the pond walls. (Anecdotal evidence for one very large catastrophic rapid landslide having occurred in the same way in 1958, 10 years prior to the photo history).
Forest Practice Sensitivity:	n/a
Mass Wasting Potential:	Moderate
Delivery Potential:	High
Delivery Criteria:	Steep slopes of tailings walls adjacent to stream channels; historical delivery.
Hazard Potential Rating:	Moderate
Trigger Mechanisms:	Discharge of surface waters from upslope hillslopes during storm events causing overtopping of tailings walls and gullying or washout.
Confidence:	High, based on historical activity and anecdotal evidence.

Form A-3. Mass Wasting Summary Table, MWMU #1

MASS WASTING FEATURE

Activity	Shallow Rapid LS	Large Persistent Deep-Seated Failures	Small Sporadic Deep-Seated Failures	Debris Torrents/ Debris Flows	Totals
Clear Cut 0-20 years	0	0	0	0	0
Clear Cut 20-50 years	0	0	0	0	0
Partial Cut	0	0	0	0	0
Road	3	0	0	1 (debris flow)	4
Stream Crossing	0	0	0	0	0
Landing	0	0	0	0	0
Other Forest Practices	0	0	0	0	0
Wildfire	0	0	0	0	0
Mature Forest	0	0	0	0	0
Non-Forest Land Use	1	0	0	0	1
Totals	4	0	0	1	5

Form A-3. Mass Wasting Summary Table, MWMU #2

MASS WASTING FEATURE

Activity	Shallow Rapid LS	Large Persistent Deep-Seated Failures	Small Sporadic Deep-Seated Failures	Debris Torrents/ Debris Flows	Totals
Clear Cut 0-20 years	0	0	0	0	0
Clear Cut 20-50 years	0	0	0	0	0
Partial Cut	0	0	0	0	0
Road	0	0	0	0	0
Stream Crossing	0	0	0	0	0
Landing	0	0	0	0	0
Other Forest Practices	0	0	0	0	0
Wildfire	0	0	0	0	0
Mature Forest	0	0	0	0	0
Non-Forest Land Use	2	0	1	0	3
Totals	2	0	1	0	3

Form A-3. Mass Wasting Summary Table, MWMU #3

MASS WASTING FEATURE

Activity	Shallow Rapid LS	Large Persistent Deep-Seated Failures	Small Sporadic Deep-Seated Failures	Debris Torrents/ Debris Flows	Totals
Clear Cut 0-20 years	0	0	0	0	0
Clear Cut 20-50 years	0	0	0	0	0
Partial Cut	0	0	0	0	0
Road	0	0	0	0	0
Stream Crossing	0	0	0	0	0
Landing	0	0	0	0	0
Other Forest Practices	0	0	0	0	0
Wildfire	0	0	0	0	0
Mature Forest	0	0	0	0	0
Non-Forest Land Use	0	0	0	0	0
Totals	0	0	0	0	0

Form A-3. Mass Wasting Summary Table, MWMU #4

MASS WASTING FEATURE

Activity	Shallow Rapid LS	Large Persistent Deep-Seated Failures	Small Sporadic Deep-Seated Failures	Debris Torrents/ Debris Flows	Totals
Clear Cut 0-20 years	0	0	0	0	0
Clear Cut 20-50 years	0	0	0	0	0
Partial Cut	0	0	0	0	0
Road	0	0	0	0	0
Stream Crossing	0	0	0	2 *	2
Landing	0	0	0	0	0
Other Forest Practices	0	0	0	0	0
Wildfire	0	0	0	0	0
Mature Forest	0	0	0	0	0
Non-Forest Land Use	1	0	0	0	1
Totals	1	0	0	2	3

* These failures are road fill failures caused by gullying of the road are classified here for convenience (see text in Section 4.4)

Form A-3. Mass Wasting Summary Table, MWMU #5

MASS WASTING FEATURE

Activity	Shallow Rapid LS	Large Persistent Deep-Seated Failures	Small Sporadic Deep-Seated Failures	Debris Torrents	Totals
Clear Cut 0-20 years	0	0	0	0	0
Clear Cut 20-50 years	0	0	0	0	0
Partial Cut	0	0	0	0	0
Road	0	0	0	0	0
Stream Crossing	0	0	0	0	0
Landing	0	0	0	0	0
Other Forest Practices	0	0	0	0	0
Wildfire	0	0	0	0	0
Mature Forest	0	0	0	0	0
Non-Forest Land Use	3	0	0	0	3
Totals	3	0	0	0	3