Mass Wasting Assessment:
Landslide Hazard Inventory Project

West Fork Teanaway Watershed, Kittitas County, Washington

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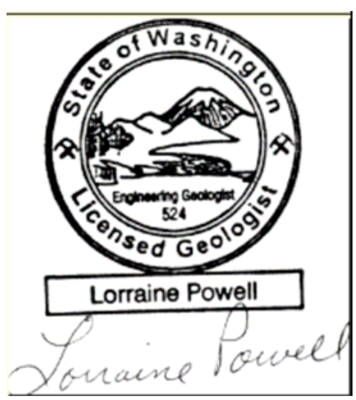
May 11, 2004



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1.0 Overview

The purpose of this mass wasting assessment is to identify non-federal non-tribal areas within the West Fork Teanaway WAU that have a moderate or high risk of landslides due to the effects of forest management (logging, roading, thinning, yarding, etc.). The Washington Forest Practices Board, Standard Methodology for Conducting Watershed Analysis, Version 4.0 (1997), adopted in part for use herein, requires that several critical questions are answered and that Mass Wasting Map Units (MWMU) are defined, both of which help assess the risk that landslide debris could be delivered to public resources (surface waters, public roads, and other infrastructure). **This is a reconnaissance study and its level of resolution must be kept in mind when using the document. For example, analysis of individual landslides or slopes is not an appropriate use of this report. Undoubtedly, some landslides have been accidentally omitted and some benign features may be improperly mapped as landslides herein**.

This assessment was conducted using aerial photographs, various maps, and field observations. Information is collected and compiled from these sources in a manner designed to respond to the critical questions or to suggest areas where more detailed information is necessary to do so have been completed. The objective of the data collection is to generate information sufficient to establish:

1. A generalized characterization of mass wasting processes active in the basin.

2. Portions of the landscape sharing similar physical characteristics relating to mass-movement behavior.

3. The relative potential for mass wasting within each landscape unit.

1.1 Introduction to Mass Wasting Processes and Terminology

Terminology used to describe mass wasting processes in this assessment follows the classification system established by the Washington Forest Practices Board (1997) as modified by Boyd and Vaugeois (2003). This system groups slope movement into nine types (shallow-rapid, debris flow, debris avalanche, shallow sporadic deep-seated, large persistent deep-seated, earth flow, rock topple/fall, and snow avalanche). Analysis is aided by designating landforms, slope shapes, land uses, and other observations associated with each group of landslides. (See Appendix A, Form A-1.) For the purposes of this study, most landslides that fail below rooting depth are categorized as deep-seated, consistent with the Forest Practices rules (WAC 222-16-050). For this reason, those deep-seated landslides that moved rapidly and clearly deliver are included in the analyses of sediment delivery.

2.0 Physical Setting Pertinent to Mass-Wasting Interpretations

The West Fork Teanaway watershed covers 25,063 acres in Kittitas County. Approximately 45% of the area in the upper portion of this watershed is managed by the U.S. Forest Service and is not included within this study (Map A-1). The remainder includes approximately 13,667 acres of private and State Trust land, the latter being managed by the Department of Natural Resources.

The headwaters of the West Fork Teanaway River lie just east of the Cascade crest and drain southeast past its confluence with the Middle Fork. Although there are three distinct geologic and topographic areas within the basin, most of the watershed is underlain by sedimentary rocks the Roslyn Formation which form gently rolling slopes, usually less than 50%. Glaciers originating in the local mountains have carved “U” shaped valleys in the upper portion of the basin (Frizzel and others 1984, Tabor and others 1982).

2.1 Topography

The watershed area can be divided into three physiographic elements controlled by the underlying geology: 1) gently rolling slopes usually less than 40% formed in the Roslyn Formation, in the lower, southern, half of the basin between the junction of the West Fork and Middle Fork upstream to Corral Creek. The area experienced minor alpine glaciation that contributes to the flatter topography. 2) Steeper slopes often exceeding 70%. Teanaway Basalt is present in the middle portion of the basin from Corral Creek to below Hex Creek. Slopes within the basalt are considerably steeper than the lower basin. The West Fork forms a deeply incised gorge through the basalt. 3) Slopes ranging between 40% and 60%. Swauk Sandstone is found in the upper, northern, portion of the watershed. Local valley glaciers have carved many of the “U” shaped valleys in the upper basin (Frizzel and others 1984, Tabor and others 1982).

The study area occupies the southern 13,667 acres of the 25,063-acre West Fork Teanaway River watershed (Map A-1). Elevations range from about 2,240 feet above mean sea level at the confluence of the West and Middle Forks to 6,443 feet on Jolly Mountain. Major drainages include the Corral Creek (2,053 acres), Dingbat Creek (1,974 acres), Hex Creek (990 acres), Lower West Fork including Carlson Canyon (10,101 acres), Sandstone Creek (1,372 acres), Tumble Creek (591 acres), and the Upper West Fork (7,981 acres). The West Fork joins the Middle Fork Teanaway River at the southeastern edge of the watershed.

2.2 Geology

Bedrock

Three south dipping bedrock units, Swauk sandstone, Teanaway basalt, and Roslyn sandstone form the underlying geology within the West Fork Teanaway River basin. These units have been tilted southward although significant local variations in orientation of these layered rocks have been observed (Tabor, et al., 1982 and Frizzell, et al., 1984). North facing slopes are often scarp faces along the main stem of the Teanaway River. The LHZ study area is predominantly underlain by Lower Roslyn (Trl layered sandstone in beds to 15 cm thick with pebble layers) and Middle Roslyn (Trm –sandstone with some calcite cement containing only very minor thin bands of coal). Only minor occurrences of Upper Roslyn sandstone (Tru –sandstone with seams of bituminous coal) outcrop on the southern edge of the watershed. The Northern margin of the study area is underlain by Swauk sandstone (Tss- quartz rich sandstone).

Sediments

Draping the bedrock units are fluvial and glacial sediments. Ongoing river migration and flooding have developed the current broad, flat flood plain in the lower portion of the watershed. Soils in the lower half of the watershed are composed of residuum and colluvium from highly weathered Roslyn sandstone with minor components of volcanic ash. Soils are typically loam to sandy or silty loam with few rocks. The terrace face on the south side of the West Fork Teanaway River is composed of steeply dipping middle Roslyn sandstone on which a thin veneer of soil has developed. All soils in the southern half of the West Fork Teanaway watershed are well drained and have a high infiltration rate for water.

2.3 Summary of Previous Mass Wasting Investigations

Plum Creek prepared a draft Watershed Analysis for the West Fork Teanaway Basin, July 1997. This document was reviewed during the initial phase of the LHZ Project (L. Powell, 2003). During this review, opportunities to improve the interpretation were noted, hence this study. MWMU #5 has been revised to reflect the numerous failures identified on aerial photographs and through field examinations. MWMU # 6 has been revised to include two deep-seated landslides located in Section 20, Township 21 North, Range 15 Ease W.M. The other three MWMU's, # 4, 7, & 8, within the study area remain as described by Finn Krogstad (1997) without change from the Draft West Fork Teanaway Watershed Analysis (Plum Creek, 1997).

3.0 Summary of Methods

This assessment generally follows the Level II Mass Wasting methodology presented in the Standard Methods for Conducting Watershed Analysis Version 4.0 (Washington Forest Practices Board, 1997). However, the data-gathering period has been abbreviated and the synthesis and prescription phases have been omitted.

The 1985 stereo aerial photographs were viewed with a mirrored stereoscope with 3x magnification. The 2002 color ortho photos are available online at the DNR website (**http://www.wadnr.gov/eng/rm/psales/pho_map_prod_tim2.htm#bottom1**)(**/database/images/orthos/towns/*t29r43e*.tif)**

These sets include color images acquired in 1985 and 2002 (Table 1).

Table 1. Photographic surveys used in this study.

Year	Scale	Image	Flight Number	Reference/Ownership	Comment
1985	1:12,000	color	SC-C	DNR	Complete coverage
2002	1:12,000	color	t20r14 & 15e.sid t21r14 & 15e.sid t22r14e.sid	DNR	Complete coverage

Nine 'definite' slides were located during a reconnaissance field investigation of part of the area on February 25 and 26, 2004. A Garmin V GPS unit was used to collect landslide location information. Location accuracy was only (+\- 55 feet) for the failure #140 (A-1 and Appendix A-1 spreadsheet). The failure appears located on the north side of the river when in reality it is near the toe of the slope on the south side of the West Fork Teanaway River. Thirty-five landslides were identified from aerial photos. Two were identified from USGS geologic maps.

The landslides were mapped directly in ArcGIS as a single Landslide shape file by registering the landslides on the Department of Natural Resources digital raster graphic ("drg75") topographic contours. This technique results in a maximum resolution of only 10 meters. A slope/convergence map (SLPSTAB; Vaugeois, 2000) and a slope-percent map derived from a USGS 10-meter digital elevation model (DEM) of the watershed aided in predicting areas of potential shallow-rapid slope failure and in assisting with the delineation of Mass Wasting Map Units (MWMUs).

The resulting landslide coverage is displayed as Map A-1. Pertinent attributes of the landslides are recorded on data sheets (Form A-1). These include: 1) the type of mass wasting process, (Lsi process 1=shallow-rapid, 2= debris flow, 3= debris avalanche, 4=deep-seated, 5=shallow, sporadic deep-seated, 6=large, persistent deep-seated, 7=earth flow, 8=rock topple, 9=snow avalanche)), 2) level of certainty of the observation (D-definite, P-probably, Q-questionable), 3) photo Identification Date (ID date), 4) landslide size (1=very small, 2=small, 3=medium, 4=large, 5=very large), (5) slope shape (convergent, divergent, planar), 6) field gradient as measured in the field, 7) map gradient measured from the 10m DEM, 8) delivery (Y-yes, N-no, P-probably, I-indeterminate), 9) land use (1=clear-cut, 2=young stands, 3=submature timber, 4=mature timber, 5=road, 6=partial cut, 7=yarding, 8=alpine, 9=other), 10) initiation elevation, 11) aerial photo identification number, 12) acreage as calculated for each polygon in acres, 13) the mass wasting map unit identification number.

Slope gradients were determined by exploring a DEM-derived slope percent map within each landslide polygon on the Landslide shape file. The slope angle cannot be reliably determined for small or narrow landslides where accuracy is limited by the 10-meter resolution of the DEM. Slope angle is understated where steep slopes and terrace faces are less than 60 feet high as the 10-meter resolution averages gentler slopes above and below the steep face into the calculation. Slopes derived from DEMs are generally lower than those measured in the field, but are less subjective, however, field measurements of slope angle were much steeper than those derived from the DEM-derived slope percent map. Conversely, the steepest slopes on rotational failures are on the failure plane and therefore steeper than the slope of the ground just before landslide initiation. As a result, the method of slope gradient estimation presented is an approximation.

Once the locations of mass wasting features were mapped and evaluated, areas of similar mass-wasting potential were grouped into Mass Wasting Map Units (MWMUs). These are shown on Map A-2 and described in Appendix B.

4.0 Summary of Analysis and Results

During this review, representative samples of 44 ‘definite’ landslides were inventoried using data obtained from color aerial photos taken in 1985 and 2004 (Form A-1). Of the landslides identified during this mass wasting assessment, 96% (44) were mapped as shallow rapid - undifferentiated failures and 4% (2) were deep-seated – undifferentiated. No secondary landslide features were observed on aerial photos associated with the two large deep-seated landslides.

On managed lands, all landslides are associated with sub-mature timber (15 to 50 years). Natural failures resulting from erosion on the outside of meanders and incision along West Fork Teanaway River are common, reoccurring, and usually deliver directly to typed waters. The terrace face is composed of a steeply dipping sandstone bedrock unit on which a thin veneer of soil has developed. After a failure occurs, the soils slowly rebuild and revegetate. This instability would be exacerbated by harvest and/or roading.

5.0 Mass Wasting Units

The distribution of the five Mass Wasting Map Units (MWMUs) for the West Fork Teanaway study area are shown on Map A-1, and are described in the Forms A-2. These units have been delineated to depict areas having similar mass wasting potential and potential to deliver to public resources. Mass wasting potential is based mainly on landslide process, failure density, lithology, geomorphology, and topography. Hydrogeology is not considered as a critical variable for delineating MWMUs in this watershed. Three of the mass wasting map units within the study area, MWMU #4, MWMU #7, MWMU #8, as delineated in the 1997 Draft West Fork Teanaway Watershed Analysis (Plum Creek, 11997) have not been altered. Slight modification was made to MWMU#6. MWMU#5 was remapped and reevaluated due to the number of landslide features found on aerial photo and field reconnaissance. The following sections briefly describe the characteristics of each MWMU's with additional information given in Appendix B.

5.1 MWMU4: Lower Basin Headwalls:

MWMU #4 involves the broad, moderate to steep, concave slopes forming the headwaters of lower elevation basins. Slopes locally exceed 50 to 70% but flatten down slope before reaching streams. This MWMU is rated low hazard for harvest as evidence of failure is absent and streams are not actively undercutting these slopes. Roads are rated as medium hazard. Potential delivery is low due to distance from the mainstem, low gradient and lack of confinement in lower order streams (Krogstad, 1997).

5.2 MWMU5: Lower Basin Valley Walls/Gorges

MWMU #5 includes steep, mainstem valley walls with steep planar or dissected slopes above tributaries. The defining landform is steep, unbroken slopes directly above large or steep confined channels. Hazard ratings for harvest and roads are high as is the delivery potential due to the number of historic failures directly adjacent to the mainstem West Fork Teanaway River. Slope failure initiation areas derived from the 10-meter DEM are typically lower than rule-identified thresholds and other WAUs. Field measured slopes for these failures were found to be 70% to greater than 100%. The variance in accuracy of the DEM-derived slope measurements is due to the 10m resolution of the maps.

5.3 MWMU6: Lower Basin Flatter Slopes

MWMU #6 contains a wide range of slope forms, steepness, and materials. Generally slopes are less than 50% but steeper areas are contained within this unit. This unit was separated from MWMU #4 by an arbitrary slope break. Two large deep-seated landslides were mapped in Section 20, Township 21 North, Range 15 East W.M. The potential hazard delivery rating is low for harvest, roads and delivery (Krogstad, 1997). The condition of the toes and a road located under one of the toes was not field verified. Both landslides are stream adjacent.

5.4 MWMU7: Glacio-fluvial Plateaus

This unit is a plateau tens of meters above the current valley bottom. The few streams crossing this unit locally steepen and incise near the edges of the unit. Mass wasting potential is low for harvest, roads, and delivery (Krogstad, 1997)

5.5 MWMU8: Active Alluvial Valley

Flat floodplain deposits located beside the river. Deposits can include terraces several feet above the current floodplain and steep slopes several feet high between and along the stream banks. The mass wasting hazard delivery rating is low for harvest, roads and delivery potential (Krogstad, 1997)

6.0 Delivery

Delivery susceptibility factors for five Lower West Fork Teanaway MWMUs described above are zero or nearly zero except for MWMU # 5. Most landforms within the West Fork Teanaway watershed are stable due to low slope angles, stable geologic units, the high porosity of sediments, and low annual precipitation. MWMU # 5 is unique in the generally consistent steep slopes created by scarp faces on the southern dipping Roslyn Sandstone bedrock unit, thin draping soils overlying the steep bedrock outcrops, and location adjacent to either the mainstem West Fork Teanaway River or side streams delivering to the mainstem. Slope failures on these steep faces deliver directly to the river or its floodplain.

The total area of delivering landslides, failures with a delivery identified as 'yes' or 'probable' in Appendix A, A-1, in the study area is approximately 9.18 acres. The area of MWMU # 5 is 238 acres.

7.0 Summary of Critical Questions

In order to address the critical questions posed by the Standard Methods for Conducting Watershed Analysis, which have been adopted as part of the Landslide Hazard Zonation project protocols, the following summaries are included:

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

During this review of the West Fork Teanaway WAU, a total 46 landslides have been identified over a 17-year photo history. Most of these are relatively small shallow rapid failures, but two deep-seated landslides are also present. Five Mass Wasting Map Units are defined on the basis of similarities in slope form, landslide frequency, geology, and other factors. Within this WAU, only MWMU#5, is identified as having both high mass wasting potential and high delivery potential. The overall mass wasting potential of the West Fork Teanaway WAU is low when compared with other watersheds in other regions of Washington (e.g. Parks, 2000, Lingley, 1998, 2002;)

What mass wasting processes are active?

Shallow rapid and deep-seated landslides are active mass wasting processes in the West Fork Teanaway WAU (Form A-1).

How are mass wasting features distributed throughout the landscape?

See Map A-1. The majority of landslides inventoried in this mass wasting assessment are located in MWMU #5, an unstable landform that is sensitive to forest practice management activities as defined in WAC 222-16-050. Two deep-seated landslides are present in and were added to MWMU #6.

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

Yes. About 80% of landslides observed in MWMU #5 probably or definitely delivered sediment to the mainstem West Fork Teanaway or its tributaries (Form A-1). Damage to other public resources has been minimal. A high percentage of landslides initiate on steep scarp faces in bedrock draped with thin soils. These deliver directly to the West Fork Teanaway River or to the floodplain. Despite the high delivery frequency, the volumes of delivered sediment are relatively low, owing to short slope distances and thin soils covering bedrock.

How do forest management activities create or contribute to instability?

Any disturbance of the soils on the steep scarp slopes that would causes loss of root strength will destabilize the soils and contribute to slope failures. Road building, yarding, harvest, skidding would all impact slope stability in MWMU #5.

What areas of the landscape are susceptible to slope instability?

Most landslides in this watershed are associated with steep, scarp slopes draped with a thin veneer of soil located adjacent to the mainstem or a tributary of the West Fork Teanaway River in MWMU #5.

8.0 Confidence in Work Products

The confidence in this mass wasting assessment is moderate. This moderate rating results because the Landslide Hazard Zonation Project is designed to provide a watershed overview of slope stability in a timely manner. As a consequence, fieldwork and the number of aerial photograph sets examined are held to reasonable minimums.

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

In addition, there are several sources of systematic error that reduce the confidence in the work products of this analysis, those being omission, misinterpretation, accuracy, and precision. Omission occurs when mass wasting features are not identified on aerial photographs or in the field due to canopy cover, gaps in the aerial photo record, quality of aerial photos, or interpreter errors. Misinterpretation occurs when a mass-wasting feature is identified but incorrectly classified or data are transposed, and where unrecognized software/file instability occurs. Accuracy involves the degree to which the physical parameters of a mass-wasting feature are correctly measured, and precision describes how variability within an assessment can be controlled when making multiple measurements over varying time and spatial scales (Parks, 2000).

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

Because many deep-seated landslide features are quite large, remain heavily vegetated during movement, and may not have obvious scars visible through the vegetation canopy, misinterpretation is more likely. A recent detailed study in Cowlitz County, Washington, suggests that up to 25 percent of inferred deep-seated landslides identified from aerial photograph analysis are misinterpreted (Wegmann, 2003). Therefore confidence in work products related to classification of landslide process is low to moderate.

Another important source of potential error in this assessment is in the accuracy and precision of measurements of mass wasting features. Because very few landslides were actually visited in the field, it is not possible to report the degree to which location and measurement error in the GIS environment compares to on-the-ground field measurements. Similarly, measurements of slope angle from digital elevation models typically misrepresent the true hill slope angle. Given these sources of error, the confidence in the precise location and accuracy of measurements of individual landslides is considered moderate.

9.0 Acknowledgement

This report was written using a format developed by Dave Parks (2000). Laura Vaugeois edited this text and provided administrative support. Tom Boyd helped develop the mass wasting layers and final map layouts, creating order from the chaos of slivers. Jack Powell field checked mapped slope failures. Bill Lingley contributed greatly through his patience in bringing me through the programmatic text revisions and GIS map format updates to the LHZ program.

10.0 References

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11.0 Appendix A -- A-1 Form: Landslide Inventory

Form A-1 Mass Wasting Inventory Data for the West Fork Teanaway WAU

Landslide IDN	GPS_ID	Lsi_process	Certainty	Id_date	Ls_size	Id2_date	Id2_size	Landform	Slp_shp	Field Gradient	Map Gradient	Delivery	Landuse	Init_elev	Photo_num	Acreage	MWMU
101		1	D	1985	3			4	3		73	Y	3	2390	SC_C_85_43_036_135	0.21	5
102		1	D	1985	3			4	3		61	P	3	2360	SC_C_85_43_036_135	0.31	5
103		1	D	1985	4			4	3		73	Y	3	2345	SC_C_85_46_053_154	0.77	5
104		1	D	1985	4			4	3		76	Y	3	2425	SC_C_85_46_053_154	0.77	5
105		1	D	1985	4			4	3		73	P	3	2420	SC_C_85_46_053_154	0.51	5
106		1	D	1985	3			4	3		50	P	3	2380	SC_C_85_46_053_154	0.16	5
107		1	D	1985	2			4	3		49	Y	3	2405	SC_C_85_46_053_154	0.08	5
108		1	D	1985	3			4	3		56	Y	3	2435	SC_C_85_46_034_167	0.34	5
109		1	D	1985	2			4	3		83	Y	3	2435	SC_C_85_46_034_167	0.09	5
110		1	D	1985	4			4	3		92	Y	3	2580	SC_C_85_46_034_167	0.56	5
111		1	D	1985	3			4	3		92	Y	3	2565	SC_C_85_46_034_167	0.43	5
112		1	D	1985	3			4	3		85	Y	3	2500	SC_C_85_46_034_167	0.16	5
113		1	D	1985	3			4	3		74	Y	3	2480	SC_C_85_46_034_167	0.21	5
114		1	D	1985	3			4	3		77	P	3	2485	SC_C_85_46_034_167	0.32	5
115		1	D	1985	2			4	3		67	Y	3	2435	SC_C_85_46_034_167	0.06	5
116		1	D	1985	3			4	3		71	Y	3	2470	SC_C_85_46_034_167	0.27	5
117		1	D	1985	3			4	3		55	P	3	2450	SC_C_85_46_034_167	0.24	5
118		1	D	1985	4			4	3		70	P	3	2485	SC_C_85_46_034_167	0.54	5
119		1	D	1985	3			4	3		64	P	3	2515	SC_C_85_46_033_177	0.42	5
120		1	D	1985	5			4	3		64	N	3	2575	SC_C_85_46_033_177	1.5	5
121		1	D	1985	3			4	3		71	N	3	2460	SC_C_85_46_033_177	0.18	5
122		1	D	1985	3			4	3		52	N	3	2490	SC_C_85_46_033_177	0.28	5
123		1	D	1985	2			4	3		63	Y	3	2470	SC_C_85_46_033_177	0.11	5
124		1	D	1985	3			4	3		64	N	3	2600	SC_C_85_46_033_177	0.15	5
125		1	D	1985	3			4	3		60	Y	3	2520	SC_C_85_46_032_188	0.12	5
126		1	D	1985	3			4	3		73	Y	3	2560	SC_C_85_46_032_188	0.19	5
127		1	D	1985	2			4	3		66	Y	3	2560	SC_C_85_46_032_188	0.13	5
128		1	D	1985	3			4	3		61	Y	3	2650	SC_C_85_46_032_188	0.32	5
129		1	D	1985	3			4	3		82	Y	3	2640	SC_C_85_46_032_188	0.22	5
130		1	D	1985	3			4	3		77	P	3	2658	SC_C_85_46_032_188	0.29	5
131		1	D	1985	3			4	3		63	Y	3	2640	SC_C_85_46_032_188	0.27	5
132		1	D	1985	3			4	3		57	Y	3	2660	SC_C_85_46_032_188	0.33	5
133		1	D	1985	3			4	3		99	Y	3	2740	SC_C_85_46_032_188	0.13	5
134		1	D	1985	2			4	3		71	P	3	2680	SC_C_85_46_032_188	0.11	5
135		1	D	1985	3			4	3		62	Y	3	2660	SC_C_85_46_032_188	0.38	5
136		6	D	1000	5			8	2		42	N	2	3100	USGS map	104	6
137		6	D	1000	5			8	5		27	N	3	2995	USGS map	52	6
138	T-1	1	D	2003	1			4	3	100	46	Y	3	2365	Field Observation	0.02	5
139	T-3	1	D	2003	2			4	3	100	48	Y	3	2380	Field Observation	0.04	5
140	T-4	1	D	2003	2			4	3	90		I	3	2392	Field Observation	0.01	5
141	T-5	1	D	2003	3			4	3	85	79	N	3	2345	Field Observation	0.23	5
142	T-6	1	D	2003	3			4	3	90	48	N	3	2425	Field Observation	0.17	5
143	T-7	1	D	2003	1			4	3	83	79	N	3	2370	Field Observation	0.02	5
144	T-8	1	D	2003	2			4	3	80	78	N	3	2300	Field Observation	0.07	5
145	T-9	1	D	2003	2			4	3	80	77	Y	3	2310	Field Observation	0.06	5
146	T-10	1	D	2003	2			4	3	105	60	N	3	2340	Field Observation	0.06	5

12.0 Appendix B -- A-2 Form: Mass Wasting Map Unit Descriptions

MWMU Number: 4 Lower Basin Headwalls (Krogstad, 1997) Unchanged from original Watershed Analysis.

Description: Broad, moderate to steep concave-up slopes forming headwaters in the lower basin. Slope angles locally exceed that of other MWMUs but slopes flatten before reaching streams.

Materials: Thin to thick colluvial and residual soils

Slopes: 50% - 70%

Elevation: 2400’ to 3600’

MW Processes: Potentially susceptible to shallow rapid failures

Mass Wasting Potential: Harvest – Low. Slopes are steep but evidence of failures is absent and streams are not actively undercutting these slopes.

Roads; Moderate. Slopes are steep but evidence of failures is absent

Delivery Potential: Low. Distance to mainstem, low gradient and lack of confinement in lower order streams.

Hazard Potential Rating: Low

Trigger Mechanisms: These are generally agreed upon trigger mechanisms, but there is no evidence that they are operating in this landscape.

Confidence: Delineation, High. The topography of this unit is very distinctive and is easily identified on topographic maps and air photos.

Stability, Moderate: While many sections of this unit have been harvested without evidence of failure, road builders have generally avoided this unit.

MWMU Number: 5 Lower Basin Valley Walls/Gorges

Description: Unit combines both steep mainstem walls with steep planar or dissected slopes above tributaries and is defined by steep unbroken slopes underlain by south dipping Roslyn Sandstone bedrock draped with thin veneers of residual soil.

Materials: Thin residual soils

Slope: 50% to greater than 100%

Elevation: 2300' to 5200'

Total Area:

MW Processes: Shallow rapid failures and small deep-seated landslides.

Mass Wasting Potential: High – steep planar failing slopes above mainstem or tributaries of the West Fork Teanaway River.

Delivery Potential: High – Failures on steep slopes above the mainstem or tributaries commonly deliver directly to typed waters. Multiple failures currently active and in the past have deliver directly to the river, its tributaries, or to it's floodplain.

Hazard Potential Rating: High

Trigger Mechanisms: Any disturbance on steep slopes that reduces root strength or loads the slope including harvest and road location.

Confidence: High. Observed failures with debris delivered to the river, its tributaries, and floodplain.

MWMU Number: 6 Lower Basin Flatter Slopes

Description: Unit includes a wide range of slope forms, steepness, and materials. Generally flatter than 50%, but can include steeper sections that flatten down slope. Channels are not confined, except in a few low gradient reaches. Separated from MWMU 4 by an arbitrary break in slope. This unit also includes two deep-seated landslides.

Materials: colluvium and residual soils

Slopes: generally less than 50%, but locally steeper

Elevation: 2300’ to 5500’

MW Processes: None observed but includes possible earth flow features and reactivation of toes of deep seated landslides in streams.

Mass Wasting Potential: Low - shallow to moderate slopes with no evidence of failures

Delivery Potential: Generally low but high where streams undercut toes of deep-seated landslides.

Hazard Potential Rating: Low

Trigger Mechanisms: Clear-cutting that reduces root strength holding unstable soils on slopes. Roads may increase failure rates in this unit. Woody debris in streams can block culverts, leading to fill saturation and failure. Stream crossings appear to contain large amounts of fill that might cause small culvert failures and debris flows. Side cast road fills can become unstable if placed on organic materials, not compacted, or keyed into the slope. Steep road cuts can result in cut-slope failures. Long distances between culvert spacing allow small cut slope failure to direct large volumes of water onto unstable slopes. Infrequent road maintenance can allow minor fill cracks and drainage problems to evolve into a more significant instability. Reactivation of toes of deep-seated landslides due to road construction and/or harvest resulting in loss of rooting strength.

Confidence: Delineation, moderate. The topography of this unit includes flatter slopes at low elevations and steeper slopes in the upper part of the MWMU, but the functional consequence of these distinctions is limited by low delivery potential.

Stability, moderate. The unit includes small sections of up to 70% slopes, but the overall low gradient of slopes and channels tend to inhibit delivery of sediment to fish-bearing waters. Deep-seated landslides appear to be dormant and are somewhat indistinct.

MWMU Number: 7 Glacio-fluvial Plateaus (Krogstad, 1997)

Description: A nearly flat plateau tens of meters above the current valley bottom. Few streams crossing this unit can steepen and incise near the edges of the unit.

Materials: thin to thick alluvially derived soils

Slopes: nearly flat

Elevation: 2400’ to 2800’

MW Processes: none observed

Mass Wasting Potential: Harvest – Low. These units are flat.

Roads; Low. These units are flat.

Delivery Potential: Low.

Hazard Potential Rating: Low

Trigger Mechanisms: none

Confidence: Delineation, High. The topography of this unit is very distinctive and is easily identified on topographic maps and air photos.

Stability, high. Topographic flatness precludes failure.

Comments: These plateaus are so flat that they are of no concern.

MWMU Number: 8 Active Alluvial Valley (Krogstad, 1997)

Description: Flat floodplain deposits near the current river elevation. Can include terraces several feet above the current floodplain and steep slopes several feet tall between them and along the stream bank.

Materials: alluvially derived channel and over bank deposits

Slopes: nearly flat

Elevation: 2200' to 2500'

MW Processes: none observed

Mass Wasting Potential: Harvest – Low. Unit is nearly flat.

Roads; Low. Unit is nearly flat.

Delivery Potential: Low. Near river but streams in unit are nearly flat.

Hazard Potential Rating: Low

Trigger Mechanisms: none

Confidence: Delineation, High. The topography of this unit is very distinctive and is easily identified on topographic maps and air photos.

Stability, High. Topographic flatness precludes failure.

Comments: These plateaus are so flat that they are of no concern.