WASHINGTON STATE DEPARTMENT OF
Natural Resources

Landslide Hazard Zonation Project

Level I Assessment

Bacon Creek Watershed, Skagit County, Washington

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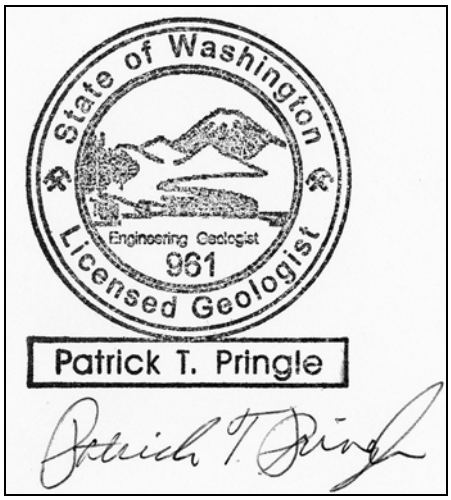

CONTENTS

1.0 Overview 3

2.0 Geologic and Physiographic Setting Pertinent to Mass-Wasting Interpretations 4

3.0 Summary of Methods 7

4.0 Summary of Analysis and Results 7

5.0 Description of Mass Wasting Map Units 8

6.0 Summary of Critical Questions 8

7.0 Confidence in Work Products 9

8.0 References 9

9.0 Appendices

9.1 Form A-2 (no A-1 or A-3) 11

9.2 Maps A-1, A-2 ..... contained in separate files

Figures

Figure 1. Map of the Bacon Creek WAU showing the location of lands reviewed during the mass wasting assessment 3

Figure 2. Map showing the areas being assessed in the Bacon Creek WAU and slopes steeper than 60% on limited portions of valley walls 5

Figure 3. Plot of annual maximum instantaneous peak streamflow of the Skagit River at Marblemount, Washington for the period 1944 to 2005 6

1.0 Overview

The purpose of this assessment is to identify the fee and state lands within the Bacon Creek WAU that have a moderate or high risk of mass wasting owing to the effects of natural instability and future forest practices. The Bacon Creek WAU[1] totals 51.7 mi^2, of which a mere 0.63 mi^2 (~400 ac, 1.22% of the total) is private or state owned (not federal or tribal) lands (Fig. 1); the basin headwaters are within North Cascades National Park, and most of the rest is part of the Mt. Baker–Snoqualmie National Forest.

The area under evaluation is predominantly a valley floor environment and adjacent small areas of lower valley wall. No landslides were identified in the evaluated area during review of aerial photographs. As a result, a single low-hazard-potential mass wasting map unit (MWMU) is delineated to cover the entire assessment area.

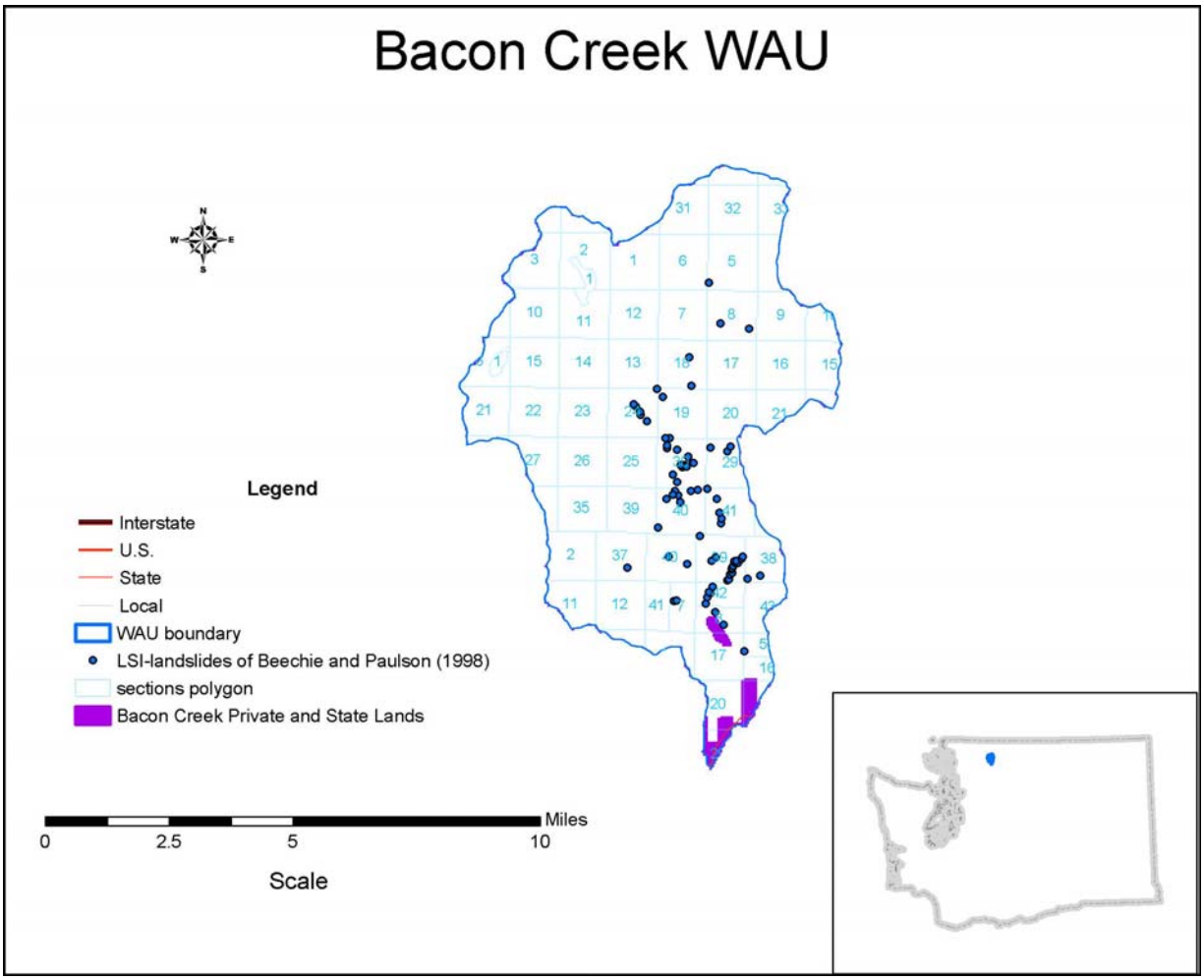

Figure 1. Map of the Bacon Creek WAU showing the location of lands reviewed during the mass wasting assessment. Note that none of the landslides mapped by Beechie and Paulson (1998) are in the areas being assessed.

[1] WAU boundaries and names were revised after this report was prepared, particularly on the south tip of the project area. Although the Bacon Creek WAU (#040127) remains almost as before, the small corner along the Skagit River between the mouths of Bacon and Diobsud creeks is now part of the Damfino WAU (#040126), located chiefly across the river. As a result, much of the land assessed in this project is now part of the Damfino basin.

The mass wasting methodology requires that several critical questions be answered by the analysis. These critical questions are listed and answered in Section 6.0 below.

This mass wasting assessment was conducted using aerial photographs, topographic and geologic maps, and GIS-based digital elevation data. Using this information, evidence of past mass wasting processes or potential for future mass wasting were evaluated relative to the aforementioned critical questions. A series of exercises designed to either confidently answer these critical questions, or identify more detailed information necessary to do so, is developed in this assessment. The objective of these exercises is to generate information sufficient to establish:

1. The mass wasting features and processes (e.g. shallow-rapid landslides, debris flows, and deep-seated failures) active in the basin;
2. Portions of the landscape having similar inherent physical characteristics relative to mass-movement behavior;
3. The relative potential for mass wasting impacts associated with the landscape units.

1.1 Introduction to Mass Wasting Processes and Terminology

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

2.0 Geologic and Physiographic Setting Pertinent to Mass-Wasting Interpretations

The lands reviewed in this assessment of the Bacon Creek WAU occupy primarily gently sloping to flat terrain, terraces, and lowermost valley walls within a small portion of the Skagit River valley and a short 2.4 mi (3.8 km) segment of lowermost Bacon Creek, a tributary (Fig. 2). In the Bacon Creek WAU, primarily recent alluvial deposits of lowermost Bacon Creek or Skagit River underlie the areas being assessed. Minor areas of till of Vashon age compose a small area of terraces along the Skagit River. A very small area consists of the lowermost valley walls of the Skagit River, which are composed of quartz diorite of the Marblemount Pluton (formally known as the Marblemount Meta-Quartz diorite). Mass wasting is generally not an issue of concern with the alluvial and glacial deposits underlying the overwhelming majority of the assessed lands in the WAU, because slopes are not steep enough for the initiation of slope failure. Where slopes are steep, they are composed of the relatively resistant rock of the Marblemount Pluton.

2.1 Topography

The limited area of Bacon Creek that is being assessed here ranges in elevation from about 340 ft (100 m) (amsl) in the floodplain of the Skagit River 1.1 mi (1.8 km) downstream of Bacon Creek, to about 500 ft (150 m) elevation about 2.5 mi (4 km) upstream of the Skagit near the confluence of Oakes Creek with Bacon Creek. Valley walls adjacent to the Skagit River and lower Bacon Creek reach only to about 2200 ft (670 m) elevation around the areas being assessed.[2]

[2] Based on the U.S. Geological Survey topographic map for the Marblemount (1999) quadrangle.

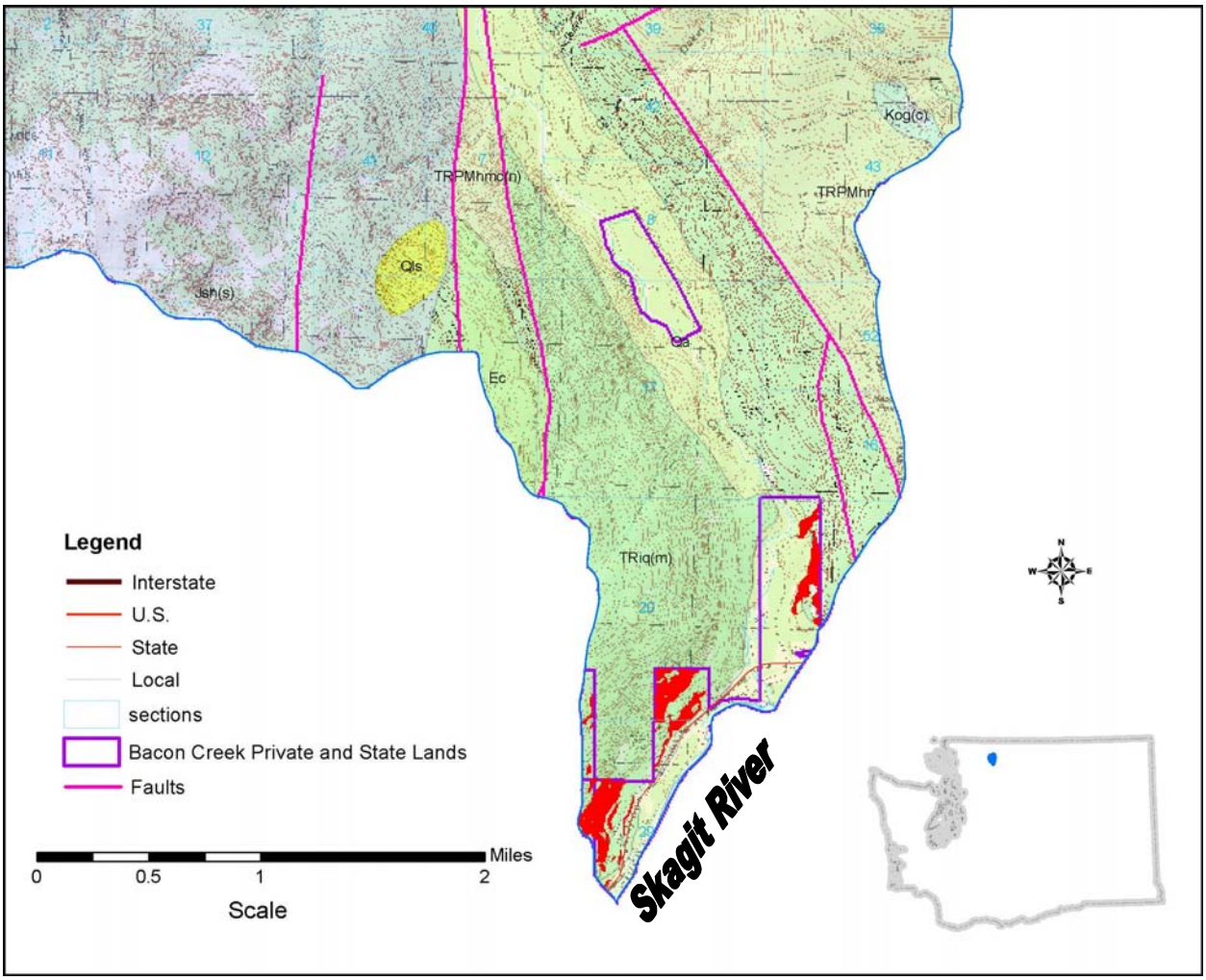

Figure 2. Map showing the areas being assessed in the Bacon Creek WAU (purple outline) and slopes steeper than 60% (red areas) on limited portions of valley walls. Colors show geologic units (after Dragovich and others, 2002): yellow is alluvium or glacial deposits; darker greens show rocks of the Marblemount Pluton; fuchsia lines are faults. Geologic units relevant to the lands being assessed are Qa, Quaternary alluvium; Qls, Quaternary landslide; and TRiq(m), Triassic Marblemount Pluton.

2.2 Geology

The most useful geologic information and maps for this assessment were Staatz and others (1972), Mc-Cleary and others (1978), Misch (1979), Fugro Northwest (1979, 1980a, b), Tabor and others (1994), and Dragovich and others (2002). For the purposes of this assessment, only one bedrock unit, the Marble-mount Pluton, and the glacial and alluvial sediments are of importance.

Alluvium includes fluvial deposits and terraces of postglacial age along Bacon Creek and along the Skagit River for 1 mi downstream of their confluence. Glacial deposits include terraces mapped as Vashon till along the Skagit River.

The Marblemount Pluton unit, formally known as the Marblemount Meta-Quartz Diorite, is a low-grade metamorphic rock with massive to weakly gneissic texture. Mattinson (1972) determined it was Late

Triassic in age based on U-Pb analyses of zircons. It was probably metamorphosed in the Late Cretaceous and early Tertiary (Tabor and others, 2002). This rock unit is fairly resistant to mass wasting.

2.3 Hydrology

Precipitation within the Bacon Creek watershed is extreme, ranging up to more than 170 in/yr in the upper elevations to the north; however, the range in the areas being assessed near the Skagit River is about 70 to 80 in/yr (WDNR, 2003). Most of the annual rainfall occurs between October and May with a pronounced summer dry season. During winter months, elevations between about 1,000 and 3,000 ft are susceptible to rain-on-snow events (WDNR, 1991), which can trigger widespread mass wasting along the steep Bacon Creek valley margins; however, all the lands assessed here are considered rain-dominated ("RD").

The major floods of record on the Skagit since 1943 occurred in 1950, 1989, 1990, 1995, 1996, and 2003 (Fig. 3; USGS, 2007; Jon Riedel, National Park Service, personal comm., 2004). Erosion was observed in air photographs, probably triggered by a debris flow in the inner gorge of Oakes Creek; that debris flow likely reached the alluvial fan at the confluence of Oakes and Bacon creeks during a large storm, such as the one in 1995. The Oakes Creek alluvial debris fan abuts the north boundary of the land being assessed here. Future debris flows at that location may affect the area being assessed, but would not originate on it. The lack of identified mass wasting features on lands encompassed by this assessment indicates that extreme precipitation events do not have a significant impact on triggering mass wasting in these lands.

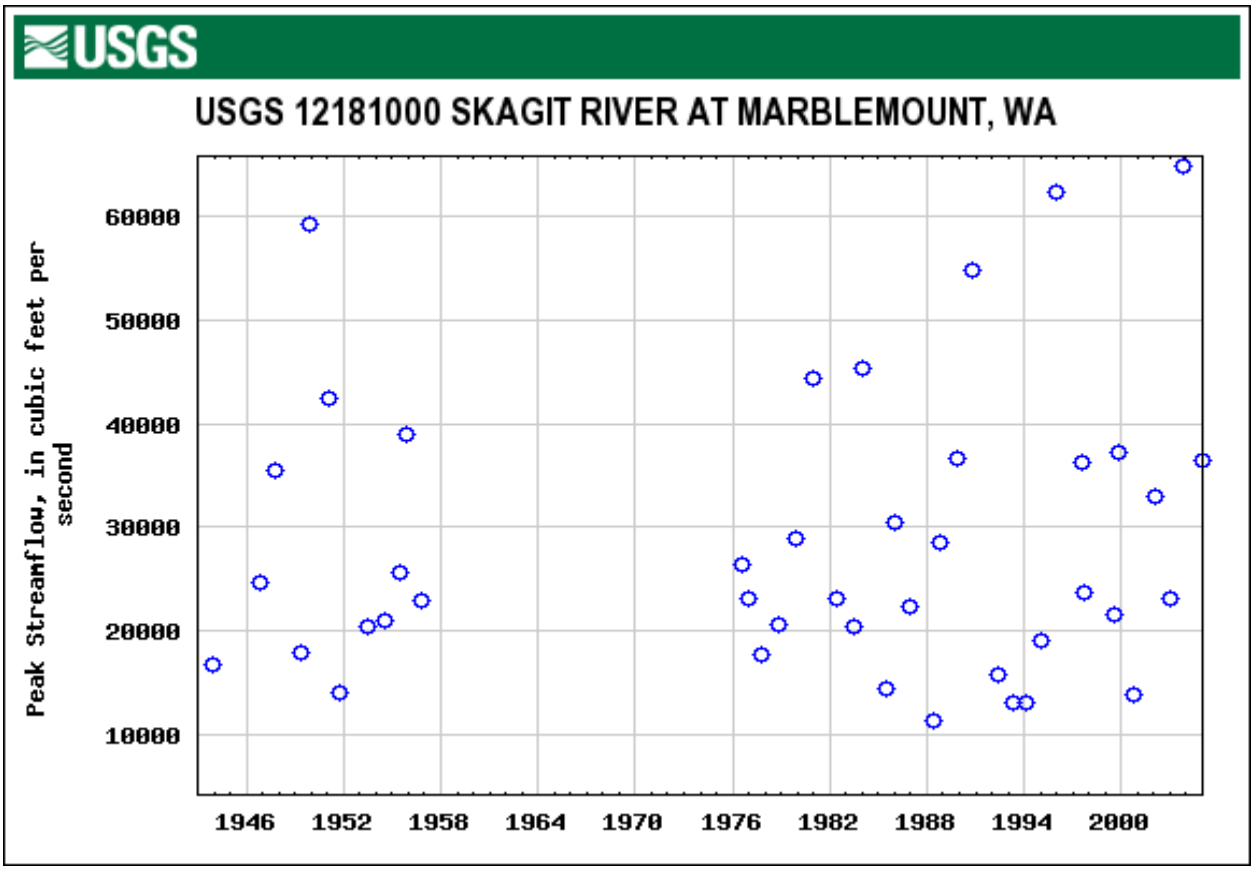

Figure 3. Plot of annual maximum instantaneous peak streamflow of the Skagit River at Marblemount, Washington for water years 1944 to 2005 (USGS, 2007). The peak flow on October 20, 2003 was 64,800 cfs, the highest recorded at this gauge since flows have been regulated by dams upstream (about 1930).

2.4 Summary of Previous Mass Wasting Investigations

McCleary and others (1978), Misch (1979), and Dragovich and others (2002) identified landslides as well as sackung features (ridge-parallel troughs caused by spreading associated with gravitational creep of a mountain flank) during their geologic mapping. Schuster and others (2000) and Riedel and others (2001) described a large rock slide-debris avalanche along the Skagit River upstream of the Bacon Creek watershed, mapped earlier by Fugro Northwest (1979, 1980a, b; see Map A–1). This landslide dammed the Skagit about 7,000 yr ago and created a temporary lake that probably lasted several centuries. This slide occurred in Cascade River Schist, which crops out in upper Bacon Creek, but does not directly influence the probability of mass wasting in the assessed lands.

Paulson (1997) and Beechie and Paulson (1998) conducted reconnaissance landslide mapping of this area as part of a broader study of the upper Skagit River basin. They identified 78 mass-wasting features within a 30-yr air-photo record, and calculated a landslide rate of about 0.02/km^2/yr (~0.05/mi^2/yr), among the lowest of the 10 basins they examined. (Locations of their inventoried slides and their five MWMUs, are shown in Maps A–1 and A–2.) Vaugeois (2000) significantly updated existing landslide mapping as part of a western Washington slope modeling studies (see also Shaw and Vaugeois, 1999; Boyd and Vaugeois, 2003). No areas of mass wasting or landforms of concern were noted by any of the previous studies within the limited boundaries of the lands being assessed here.

3.0 Summary of Methods

This assessment follows the Level II mass wasting module presented in the *Standard Methods for Conducting Watershed Analysis* (Version 4.0, WFPB, 1997), with the exception of a field visit; consequently, this is considered a Level I assessment.

Available geologic, topographic, soils, and hydrologic information was reviewed for the lower Bacon Creek basin, focusing on the small assessment areas. Aerial photographs acquired by WDNR in 1962 (1:12,000 black and white), 1983 (1:12,000 color), 1996 (1:12,000 black and white), 1998 (1:63,360 black and white), and 2001 (1:12,000 color) were viewed with a mirror stereoscope with 3x magnification. A slope/convergence map (SLPSTAB; Vaugeois, 2000) and a slope-gradient map derived from a USGS 10-m digital elevation model (DEM) of the watershed aided in predicting areas of potential shallow-rapid slope failure (Vaugeois, 2000). Interpretation of air-photos, topographic maps, geologic maps, and the DEM aided in the analysis. Because no mass wasting features were identified within the limited assessment area during review of photos and other information, it was decided that field work was unwarranted.

4.0 Summary of Analysis and Results

Map A–1 shows the locations of landslide features in and around the southern Bacon Creek WAU. Most of them were identified in the previous watershed analysis of the Upper Skagit by Paulson (1997) and Beechie and Paulson (1998); inventory data can be found in those documents, and in the WDNR LSI and Hazone datasets. Another 30 slides were mapped or remapped in this project; these are indicated by a second identification number in parentheses (e.g., number 565(2)).

On the small area of fee and state lands in the Bacon Creek WAU assessed here, no mass wasting features were identified across a 40-yr photo period (although a few are nearby).

5.0 Description of Mass Wasting Units

The distribution of mass wasting map units for the Bacon Creek WAU are shown on Map A–2. The five MWMUs designated by Beechie and Paulson (1978) are shown across the basin, including two rated as high hazard (dominantly inner gorges, of limited area) and one of moderate hazard (other slopes steeper than 30° or 58%). However, based on the findings that no landslides had been identified in the small areas being examined in detail here, a single MWMU was delineated covering the entire assessment area, having a low hazard-potential rating.

MWMU1: Low Hazard Areas
MWMU1 is characterized by alluvial valley bottoms and glacial drift terrace surfaces having minimal dissection, all with gentle slope gradients; and a limited area of moderate to steep planar hillslopes along valley margins. MWMU1 (in the area being assessed) is composed of alluvial deposits along the Skagit and lowermost Bacon Creek; glacial drift consisting of silt, sand, gravel and cobbles composing a terrace along the Skagit; and valley walls of gneissic to massive meta-diorite of the Marblemount Pluton. Slopes range from 0 to 278%, with an average of 17.5%; elevation ranges from about 350 to 2000 ft (about 100 to 600 m).

MWMU1 is considered to have low potential for mass wasting and delivery, thus a low hazard potential rating. Adherence to Washington Forest Practices rules concerning potentially unstable slopes or landforms should be adequate for resource protection (e.g. WAC 222-16-050). Note that most of the area in this unit overlaps with the two low-hazard MWMUs mapped by Beechie and Paulson (1998). However, part coincides with their moderate-hazard MWMU 3. Steeper slopes on the valley sides might be susceptible to unrecognized or infrequent mass movement; some of these lie just upslope of the North Cascades Highway (S.R. 20) and the Skagit River. Among the 30 landslides inventoried within the southern Bacon Creek WAU in this project, most[3] occurred on slopes steeper than about 65%. Although these include features on a variety of landforms, slopes steeper than that gradient (suggested by areas mapped as >60% on Fig. 2) might serve as a minimal threshold for field checking of proposed roads and harvest units in this basin.

6.0 Summary of Critical Questions

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

What evidence is present for mass wasting or mass wasting potential in the watershed?
No mass wasting features were identified during this assessment of non-federal lands. Based upon this lack of evidence and the nature of the evaluated landforms, the mass wasting potential for the assessed lands is considered to be negligible.

What mass wasting processes are active?
No mass wasting has been documented in the area under assessment.

How are mass wasting features distributed throughout the landscape?
No mass wasting has been documented in the area under assessment.

[3] Among the landslides, 28 have gradients in the 60 to 70% range, with two at 90%. Using various ways of calculation, one standard deviation below the mean, or approximately the 84th percentile, gives a break at ~62 to 65%.

Do landslides deliver sediment to stream channels or other waters, or threaten public works or safety?
No.

How do forest management activities create or contribute to instability?
Forest management activities were not observed to create or contribute to slope instability on the assessed lands. Current Washington forest practices regulations should be adequate to insure resource protection with respect to potential slope instability.

What areas of the landscape are susceptible to slope instability?
There were no portions of the assessed landscape deemed susceptible to slope instability (Map A–2). However, an alluvial debris fan from Oakes Creek (a tributary to Bacon Creek) that abuts the northern margin of the area being assessed, may deliver sediment to the area in the future. Sediment deposition and changes in channel location could result from debris flows that begin higher in the channel network. In addition, steeper slopes on the valley walls in and adjacent to the lands assessed in this project might be susceptible to infrequent or unrecognized slope instability. Proposals for roading or harvest on slopes steeper than 65%, especially above S.R. 20 and/or major streams, should receive initial field evaluation for potentially unstable landforms.

7.0 Confidence in Work Products

The overall confidence in this mass wasting assessment is high. This is due in large part to the low relief, absence of evidence for landsliding, and apparent lack of potentially unstable landforms within the limited fee and state land portions of the Bacon Creek WAU. The only limitation on this appraisal comes from the lack of field checking in this project.

8.0 References

Beechie, T. and Paulson, K.M., 1998, Upper Skagit Watershed Analysis: unpublished study by the Skagit System Cooperative, Sedro–Woolley, WA.

Boyd, T. G. and Vaugeois, L. M., 2003, On the development of a statewide landslide inventory [abstract]: Geological Society of America Abstracts with Programs, v. 35, no. 6, p. 18.

Dragovich, Joe D.; Logan, Robert L.; Schasse, Henry W.; Walsh, Timothy J.; Lingley, William S., Jr.; Norman, David K.; Gerstel, Wendy J.; Lapen, Thomas J.; Schuster, J. Eric; Meyers, Karen D., 2002, Geologic map of Washington–Northwest quadrant: Washington Division of Geology and Earth Resources Geologic Map GM-50, 3 sheets, scale 1:250,000, 72 p.

Fugro Northwest, Inc., 1979, Interim report on geologic feasibility studies for Copper Creek dam: Seattle City Light, 152 p., 2 plates.

Fugro Northwest, Inc., 1980a, Report on additional geologic studies for proposed Copper Creek dam: Fugro Northwest, Inc. [under contract to Seattle City Light], 1 v.

Fugro Northwest, Inc., 1980b, Executive summary of geologic feasibility studies for proposed Copper Creek dam: Fugro Northwest, Inc. [under contract to Seattle City Light], 19 p.

Mattinson, J. M., 1972, Ages of zircons from the northern Cascade Mountains, Washington: Geological Society of America Bulletin, v. 83, no. 12, p. 3769-3783.

McCleary, J. R.; Dohrenwend, J. C.; Cluff, Lloyd; Hanson, K. L., 1978, 1872 Earthquake studies, Washington Public Power Supply System, Nuclear projects nos. 1 and 4, Straight Creek fault zone study: Woodward-Clyde Consultants, 72 p.

Misch, Peter, 1979, Geologic map of the Marblemount quadrangle, Washington: Washington Division of Geology and Earth Resources Geologic Map GM-23, 1 sheet, scale 1:48,000.

Paulson, K.M., 1997, Estimating changes in sediment supply due to forest practices: a sediment budget approach applied to the Skagit River basin in northwestern Washington: MS thesis, University of Washington, Seattle, 156 p.

Riedel, J. L.; Pringle, P. T.; Schuster, R. L., 2001, Deposition of Mount Mazama tephra in a landslide-dammed lake on the upper Skagit River, Washington, USA. *in* White, J. D. L.; Riggs, N. R., editors, Volcaniclastic sedimentation in lacustrine settings: International Association of Sedimentologists Special Publication 30, p. 285-298.

Schuster, R. L.; Riedel, J. L.; Pringle, P. T., 2000, Early Holocene Damnation Creek landslide dam, Washington State, U.S.A. *in* Bromhead, E.; Dixon, N.; Ibsen, M.-L., editors, Landslides in research, theory and practice: Thomas Telford, v. 3, p. 1333-1338.

Shaw, S. and Vaugeois, L.M., 1999, Comparison of GIS-based models of shallow landsliding for application to watershed management. Timber/Fish/Wildlife draft publication #118, 104p, 14 plates.

Staatz, M. H.; Tabor, R. W.; Weis, P. L.; Robertson, J. F.; Van Noy, R. M.; Pattee, E. C., 1972, Geology and mineral resources of the northern part of North Cascades National Park, Washington: U.S. Geological Survey Bulletin 1359, 132 p., 2 plates.

Tabor, R. W.; Haugerud, R. A.; Booth, D. B.; Brown, E. H., 1994, Preliminary geologic map of the Mount Baker 30- by 60-minute quadrangle, Washington: U.S. Geological Survey Open-File Report 94-403, 55 p., 2 plates.

Tabor, R. W.; Booth, D. B.; Vance, J. A.; Ford, A. B., 2002, Geologic map of the Sauk River 30- by 60-minute quadrangle, Washington: U.S. Geological Survey Geologic Investigations Series Map I-2592, 2 sheets, scale 1:100,000, 67 p.

U.S.G.S., 2007, Peak streamflow for the Skagit River at Marblemount, WA for the period Dec. 1943 to Jan. 2005: http://nwis.waterdata.usgs.gov/wa/nwis/peaks/?site_no=12181000&agency_cd=USGS [accessed on 4/17/2009].

Vaugeois, Laura, 2000, Creation of a slope stability screening tool from landslide prediction models: Forest Practices Board presentation, Washington Department of Natural Resources, Olympia, Washington.

Washington Department of Natural Resources, Forest Practices Division, 1991, ROS: ARC / INFO spatial coverage, accessed on 1/7/2003.

Washington Department of Natural Resources, Geographic Information Systems, 2003, PRECIP: ARC / INFO spatial coverage, accessed on 1/7/2003.

Washington Forest Practices Board, 1997, Standard methodology for conducting watershed analysis, Version 4.0: Washington Department of Natural Resources Olympia Washington, 1 v.

9.0 Appendices

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

MWMU Number: 1 — Low Hazard Areas

Description:
Low gradient alluvial valley bottoms; low gradient terraces composed of glacial drift and having minimal dissection; and a smaller area of moderate to steep planar hillslopes along valley margins.

Materials:
Low hazard areas include alluvial deposits of Bacon Creek and the Skagit River; glacial drift deposits of Vashon age comprising silt, sand, cobbles, and boulders; and gneissic to massive meta-quartz diorite of the Marblemount Pluton.

Landform:
Low to moderate gradient valley floors and terraces; some moderate to steep planar valley sidewalls.

Slope (determined via DEM):
Min: 0.0% Max: 278% Mean: 17.5%

Elevation (determined via DEM):
Min: 350 ft Max: 2000 ft

Total Area:
0.63 mi^2 (403 ac); covers 100% of the surface area of lands assessed in the Bacon Creek WAU.

MW Processes:
No further mass wasting features were identified during this assessment.

Forest Practice Sensitivity:
Low.

Mass Wasting Potential:
Low.

Delivery Potential:
Low.

Delivery Criteria Used:
Proximity and direction of visible landslide scars in relation to surface water features.

Hazard Potential Rating:
Low

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

Confidence:
High, given limitations of remote assessment; no field checking.