15. Appendix B – Snyder Watershed Sediment Assessment 2012

Snyder Creek Watershed Sediment Assessment 2012

Simmons Creek (West Fork). Typical view of an incised channel. The historic channel meandered through the low-gradient meadows of this area.

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Note: Photos were taken by UCD staff, unless otherwise noted.

Abstract

Underwood Conservation District reports here on riparian erosion sites in the Snyder Creek watershed, a tributary to the Klickitat River, in south-central Washington state. Observations and data suggest that historically sediment-storing meadows in the upper watershed have experienced failure in numerous places due to incising stream channels. Data here allow comparative rankings of six chronic erosion sites in the upper watershed, and identification of another six potential project sites. This assessment also describes meadow areas and stream reaches that remain functional with regards to sediment storage, and opportunities to conserve these, as well as rehabilitate several hydrologically vital sites. This challenging and important work, if successful, would likely enhance base flow and lower sediment inputs. This assessment should help the District and partners create a strategic vision for prioritizing for further investigations, restoration project-development and ultimately enhanced natural stream function in the Snyder Creek watershed.

Introduction

Purpose

Under the SRFB agreement with Underwood Conservation District, the *Simmons Creek Restoration Project* includes this Special Condition:

> "The project is expanded to develop a strategic program that will help guide future development of projects in the Snyder Creek basin (or other higher priority basins) to reduce sediment delivery and improve base flows in the reaches that support ESA-listed salmonids. This strategic approach should be quantitative and consider all primary sources of sediment in the basin and evaluate their relative contribution to Snyder creek. A similar comprehensive evaluation of meadow areas and their potential role in improving base flows in Snyder Creek is also warranted."

This agreement, then, lays out an ambitious set of assessment goals for evaluating sediment delivery and compromised base flows, with the ultimate goal of creating an outline or plan to guide potential future stream-rehabilitation projects in the Snyder Creek basin. Below, we address specific points, definitions and working assumptions of how we carried out this assessment.

Researchers have shown that gravel/dirt roads, logging and other management activities can contribute fine sediment to watersheds, as do natural mass-wasting and storm events (Beschta 1978; Grant et al 1984; Sullivan et al 1986). Rather than attempt to measure those individual inputs (something which, properly done, requires a significant research effort), we focused our efforts on assessing stream reaches that showed evidence of active riparian erosion, especially those with evident anthropogenic impacts, as well as restoration opportunities[1]. Perhaps our foremost assumption was that stream morphology assessment metrics – quantifying entrenchment of stream channels, etc. – provide an accurate, basic understanding of sediment delivery and base flows. Creating sediment budgets, monitoring base flows and creating hydrologic models are all time-consuming endeavors, and beyond the scope of this assessment.

We approached this assessment in several steps, as suggested by sources such as the Washington Department of Natural Resources' watershed analysis manual (DNR 2011). Our first step was to develop a strategic overview of the watershed's primary sources of sediment. These sources include land uses (forestry, cattle-grazing, housing density), roads and soil types. This produced a coarse-scale look at the watershed as well as a few immediate insights. Given the limitations of staff time and the considerable amount of terrain to cover in the field, we did not conduct a GIS-based hazard matrix or mapping.

Similar watershed-level studies call for ground-truthing, and we spent the majority of our assessment time on step two, gathering data in the field. These field observations allowed us to complete an assessment that is fairly comprehensive: we walked 16 the watershed's approximately 25 miles perennial streams. The assessment is also strategic in its scope, by locating meadows and riparian sites actively eroding, and scoring them for comparison. We believe that measurements and observations of stream morphology is an effective rapid-assessment surrogate for overall stream health, including riparian sediment inputs. By walking the five perennial branches of Simmons and Snyder Creeks, we were able to locate many chronically eroding riparian sites, then measure and compare them. This has allowed us to develop a strategic program of future projects in the basin using both qualitative observations (ecological understanding, professional judgment) and a transparent, quantitatively prioritized site list.

The Snyder Creek Watershed

The Snyder Creek watershed is a tributary to the Klickitat River in Klickitat County, Washington. The Snyder Creek watershed covers an area of approximately 14,000 acres (22 sq. miles). The headwaters of the stream's branches originate from part of the watershed boundary separating the Klickitat River and White Salmon River drainages. The watershed includes approximately 1800 vertical feet, from an elevation of about 2,200 feet at the hilltops down to 450 feet at the town of Klickitat, site of the stream's confluence with the Klickitat River. The top of the watershed, where so much of its surface area is perched, receives an annual average precipitation of 32.7 inches, most of it as snow (80.1 inches) between November and March (WRCC 2006).

The watershed is composed of three distinctly different sections. Short (1,000-2,000 feet long), often seasonal, steep (2-8% gradient) headwaters feed into the several main branches (see Figure

[1] For this assessment, we use the term "restoration" loosely, as practitioners often do, to signify a range of erosion-reduction geomorphic treatments. These can range from engineering approaches to capture excess sediment, to some sort of rehabilitation of negative land-use effects, to attempts to regain natural ecological function.

1), which are much longer and low-gradient (0-2%) reaches, historically forming wet meadow complexes atop a hilltop plateau. These low-gradient main branches fall suddenly into parallel streams (Snyder and Simmons) which unite after a series of cascades at a confluence, then drop over a waterfall through a steep, dramatic canyon for 3.8 miles before bottoming out near an abandoned sawmill in the town of Klickitat and merging with the Klickitat River.

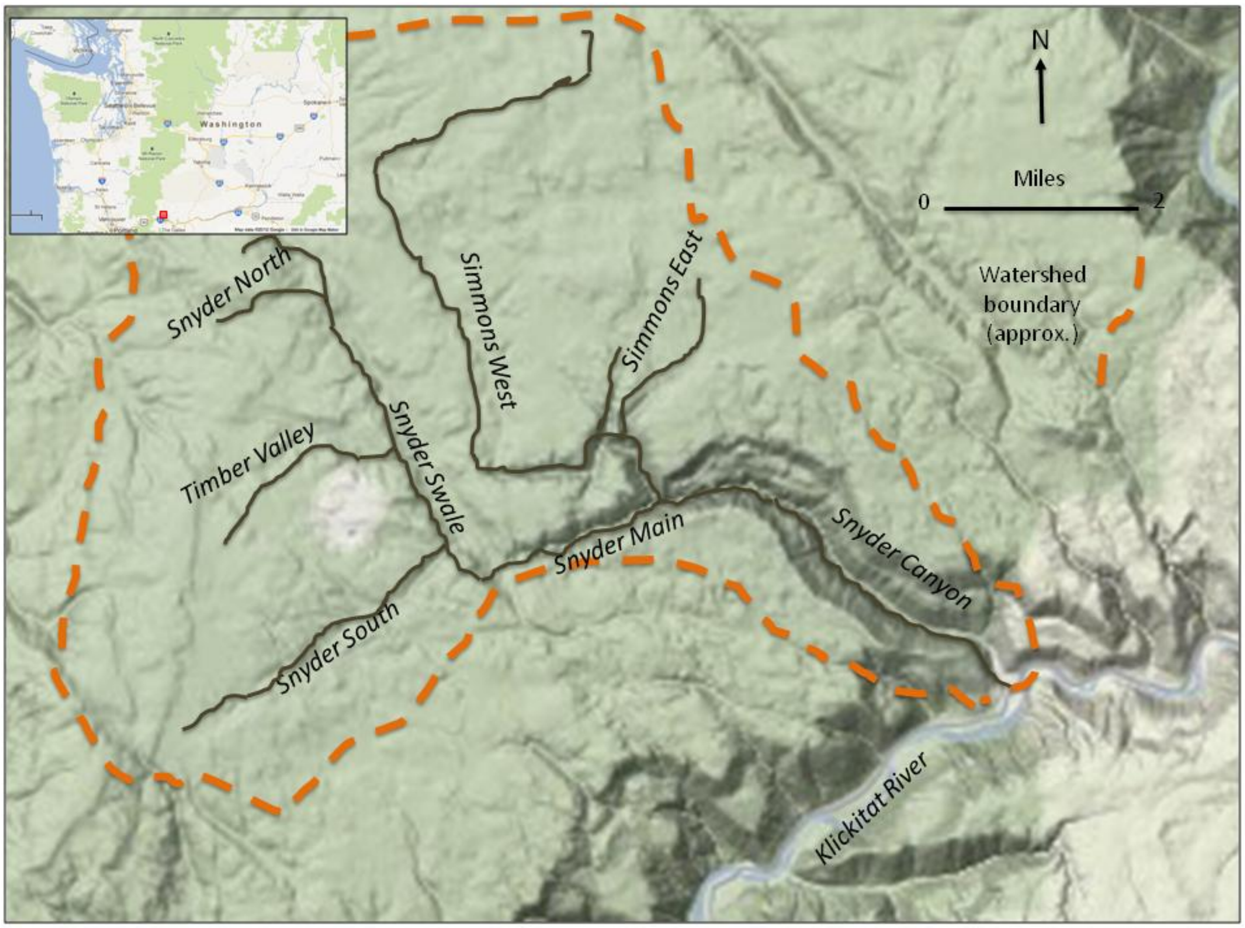

Figure 1: Snyder Creek Watershed boundary and main stream branches. (Background image: Google Maps 2012)

The Snyder Creek watershed, then, shows a stream reach pattern characteristic of the tall, rounded hills of this range, which differs from the popular Montgomery & Buffington model of Northwest mountain streams (1993). Stream channel reach slope is closely tied to its capacity to transport sediment.[2] Montgomery & Buffington's model describes typical Northwest streams with high-

[2] This is characterized in classic fashion by Lane's stream-balance relationship (Qs * ds ~ Qw * So; or, sediment discharge and particle size is directly related to stream discharge and slope. In other words, steeper and deeper moves more sediment). Despite being more than 60 years old, Lane's formulation remains useful and even fruitful in inspiring current research, e.g., Dust, D. and E. Wohl, 2012. Conceptual model for complex river responses using an expanded Lane's relation. Geomorphology, v. 139–140, pp. 109-121.

gradient headwater sediment source reaches, characterized by mass-wasting events that send sediment pulses downstream (Montgomery & Buffington 1998). In the model stream's middle, medium-gradient transport reaches, sediment is in some places deposited in bars and side-channels, but most is moved down to the stream's low-gradient depositional, or response, reaches. In the Snyder watershed, this model is upended somewhat. Rather than source -> transport -> response reaches, the watershed's stream branches resemble in their gradients and sediment relationships a pattern of source -> response -> transport -> into the Klickitat River.

It's likely that the last mile or so of the stream above the Klickitat confluence historically exhibited sediment deposition and stream meandering expected in a response reach, based on the landform's widening canyon and a low gradient below a long series of steep reaches. The stream here, however, has been channelized for decades, and partially dammed, for convenience and industrial use by the former Champion International sawmill, which constructed its buildings and mill pond over the top of the stream (see Figure 3).

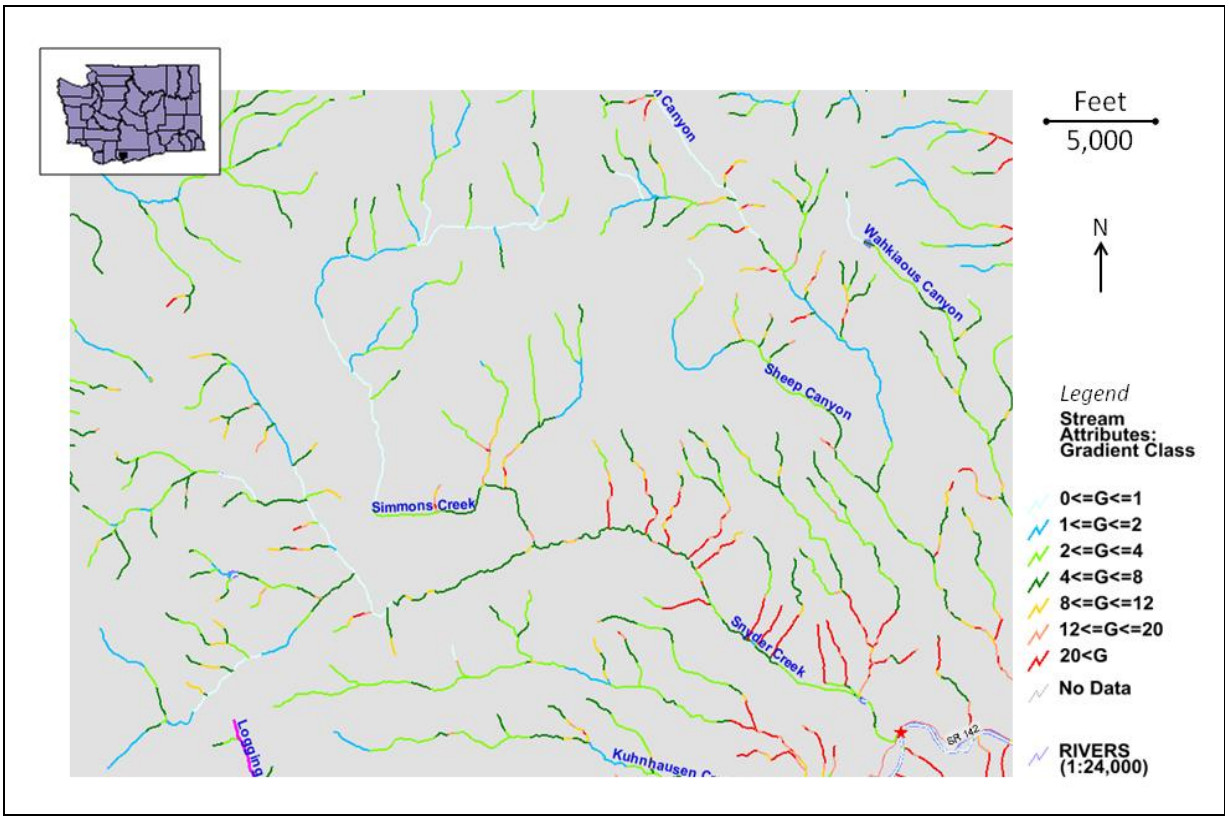

Figure 2: Snyder Watershed Gradients (Gradients map courtesy Washington Dept. of Fish & Wildlife online mapping program "SalmonScape" (http://wdfw.wa.gov/mapping/salmonscape/index.html).

The first quarter-mile of Snyder Creek upstream of the Klickitat River confluence – into the mill property – was the site of a significant, multi-agency restoration project in 2003-04. Personnel from the Yakama Nation Fisheries Program, Klickitat County, the Mid-Columbia Fisheries Enhancement Group and Washington Department of Fish and Wildlife (the project lead) removed two impassible culverts upstream of an old mill pond (MCFEG 2004). Downstream of the pond, the project created a weir step-ladder system to create fish-passable gradient, falls and pools. The result was restoration of passage for steelhead trout, which have historically spawned and reared in Snyder Creek watershed (Haring 2001).

Much of the watershed's headwater sediment was likely deposited into low-gradient marshy meadows, which have built up deep deposits of fine silt and clay. We speculate that rather than steep headwaters' mass-wasting events sending periodic, storm-driven sediment pulses down the watershed, historically there were small events in the several small, steep headwater tributaries, which tended to accumulate in the meadows, such as the Simmons Meadow, Legall Meadows and Snyder Swale. These would probably act as long-term sediment storage, releasing fine material downstream as a slow leakage transported by high spring runoff. Meadow areas were heavily logged and grazed in the early-twentieth century, with such a substantial volume of timber being harvested in the area that lumber companies were fed by a railroad line driven up Snyder Canyon and into Simmons Meadow.

A walk down Snyder Canyon in May 2012 continues to reveal railroad spikes and trestle ruins. Observations from these meadow areas show historically interweaving, sinuous stream patterns now mostly abandoned by straighter, often ditched and/or incised streambeds. Deep eroded channels in some of these presumably straightened reaches (e.g., Simmons West Fork) show deep deposits of a hard-packed, mucky fine gray soil underlying a hummic vegetation layer, both in current meadows and woodlands. These eroded channels lay directly atop bedrock with only minimal amounts of gravel and sand.

Figure 3: Snyder Canyon saw mill. This view is just upstream of the Snyder Stream confluence with the Klickitat River, a few hundred feet around the bend from the abandoned sawmill's smokestack, at photo center-left.

NRCS soil surveys describe the watershed's soil types as dominated by this amalgam of ashy loams, some atop clay loams, which is colluvium and residuum derived from basalt and loess, laying over basalt bedrock and outcrops (NRCS). In the Snyder Canyon and lower Simmons canyon reaches, this ashy-clay loam mixture represents no more than 35 percent of the soil area, the rest being gravel and rock outcrops on steep slopes and cliffs. The upper portion of the watershed, along the plateau, is generally of much lower gradient (<4%). Soils in these headwater and meadow areas are primarily ashy loams, composing 90 percent or more of the soil. These soils, being composed of fine material, are physically prone to erosion. Long stretches of certain stream branches (Simmons West Fork, and portions of Snyder Swale) have incised and been disconnected from their historic floodplains. Deeply incised streams (3-6 vertical feet in some places) can uncouple stream flow from groundwater recharge, creating a system much more prone to rapid runoff (flashiness) and increased erosion. This dynamic can be observed, for example, in neighboring parcels in Snyder Swale, where dry, ditched areas are situated adjacent to much wetter, marshy areas with less-defined stream channels.

Since at least 1990, Underwood Conservation District (UCD) has worked with agency partners and private landowners on projects along the West Fork of Simmons Creek and in Snyder Swale. These have included the creation of small check dams of heavy fabric in the upper reaches of Simmons to slow stream velocity and erosion; building medium-size check dams of wood and small rock in Simmons Meadow and installing livestake vegetation; and, building roughened crossings and fencing to reduce cattle impacts in Simmons Meadow and the upstream end of Snyder Swale.

The main thrust of this work has been an attempt to stabilize the two main stream branches' eroding banks of fine material, with the goals of increasing groundwater recharge and summer flow volume and reducing downstream sedimentation to salmonid habitat. Projects have been described in UCD's annual reports, plus Washington Conservation District reports and elsewhere.[3] Most recently, in the summers of 2009 and 2010, Washington Department of Natural Resources crews and private contractors (the land manager and project cooperator was Hancock Forest Management) built 17 small-log structures, three large-log structures and one hardened livestock crossing in a 4,000-foot-long reach of Simmons Meadow (Simmons West Fork).

Snyder Creek's watershed is divided into a patchwork of ownership, with the most significant landowners including several active timber-management companies, the Washington Department of Natural Resources, and a number of smaller private parcels. Significant private, non-timber parcels include a key meadow area in Snyder Swale, private meadow property on the East Fork of Simmons Creek, a slowly developing residential area of several dozen ranchette lots in Timber Valley[4]; and, the private ownership of some former sawmill property above the Klickitat confluence.

Figure 4: Wreckage of an abandoned railroad line up Snyder Canyon. Historically, rail lines transported logs from productive flats at the top of the watershed to be milled near Klickitat, at the bottom.

Biologists report salmonids residing and spawning in portions of the Snyder Creek

[3] UCD reports are available online at the Washington State Conservation Commission website's search page, by searching for "Underwood Conservation District." The website address: http://www.scc.wa.gov/index.php/Search/newest-first.html

[4] There are 45 small (approximately 5-acre) lots along East Timber Valley Road, where the Timber Valley branch of Snyder Creek flows. Roughly 100 more similarly sized lots have been platted along West Timber Valley Road.

watershed, primarily in Snyder Canyon and below. There is a tall waterfall which poses an insurmountable fish-passage barrier at the confluence of Snyder and Simmons Creeks, at the head of the canyon. The creeks split here into separate canyon systems, each with its own cascades and additional passage-barriers. The watershed's salmon and steelhead are described in Table 1.

Table 1: Salmonids in Snyder Creek Watershed

Note: These data were gathered from Washington Dept Fish and Wildlife online mapping program "SalmonScape" (http://wdfw.wa.gov/mapping/salmonscape/index.html), accessed 6-29-12

Species	Stock	Watershed location	Presence	ESU [evolutionary significant unit] status
Coho	-	Lower Snyder Canyon (at Klickitat confluence)	Known spawning, documented	-
Coho	-	Snyder Canyon (upstream to falls at Simmons confluence)	Present, documented	-
Steelhead, Summer	Middle Columbia River	Snyder Canyon (Klickitat confluence to middle canyon)	Known spawning, documented	Threatened
Steelhead, Summer	Middle Columbia River	Snyder Canyon (upstream to Simmons confluence)	Presented, documented	Threatened
Steelhead, Winter	Middle Columbia River	Snyder Canyon (from Klickitat to Simmons confluence)	Present, documented	Threatened
Bull Trout	Lower Col River Basin	Upper watershed (Snyder and Simmons Creeks, above confluence)	Present, undetected	Threatened

The watershed has a history of resource-extraction (logging, cattle-grazing), which continues today at much more regulated and moderate levels, along with the attendant infrastructure such as logging roads; before that, spur railroads; and the straightening and ditching of streams. The resulting impacts of incision, flashiness and erosion have been considerable. Nonetheless, there are still significant wet-meadows and vegetated riparian areas in the upper Snyder Creek watershed, which are both worthy of conservation and serve as restoration models for other, impacted reaches. (See below for additional discussion of meadows.)

Methods

Assumptions

- The Snyder Creek Watershed can be effectively characterized by its 5 perennial branches, as shown by the US Geological Survey maps;

- The watershed has areas of streambank failure and resulting channel erosion ("erosion sites") which offer opportunities for restoration work;

- And, the erosion sites are sufficiently few and discrete that technicians can measure and document them.

Study approach

The watershed soil types, basic land-use history and fish presence were described through existing documents (soil surveys, watershed project reports, etc.) and some informal interviews with area resource practitioners and managers.

This assessment's efforts were spent principally in walking the watershed's stream reaches on the ground. We took basic morphological data and observations, and used the data to compare actively eroding riparian sites. This study's core purpose, after all, was to gain some understanding of the watershed's erosion patterns or sites and thus guide future conservation measures.

In walking the Snyder Creek watershed, efforts were focused on the principal perennial branches, as identified on USGS maps and by observation. Landowners were contacted for permission to access and measure riparian sites; permission was often granted, sometimes withheld, and in the case of SDS Lumber, granted only for physical passage (walking along the stream) with the proviso that technicians take no measurements or other data.

We calculate based on aerial imagery and ground observations that there are approximately 25 miles of perennial stream reaches in the Snyder Creek watershed. Of those stream-miles, half – an estimated 13.5 miles – are perennial, non-canyonized (i.e., not constrained by cliffs or bedrock) and less than 4 percent gradient. These stream reaches, in other words, can reasonably be expected to be sediment-source and –storage segments of stream.

During the course of this assessment, UCD technicians walked approximately 16 stream-miles of various terrain and sediment-capacity, and collected data from sites along approximately 6 miles of the sediment-storing reaches (see Figure 5.). We believe many or most of the key sediment-storage reaches, including most of the meadow areas, have been assessed or at least observed, and the major, actively-eroding sites noted.[5]

The purpose of walking a majority of the watershed – as much as could be accessed by permission in a reasonable period of effort – was to gain ground-observations and data based on measurements there, rather than identifying potential restoration projects solely on models and assumptions. We would have probably been able to complete the entire network of perennial branches but for lack of permission to access and/or take data, coupled with one reach (Timber Valley) with a significant number of small private owners. Any potential conservation project there would literally be in some people's backyards, and involve altering streamflow next to houses and removing in-stream structures and ponds built by residents – a project site with probably more limitations than potential.

Technicians' main task was to locate and document each major erosion point in the riparian areas. Technicians looked for evidence of significant ongoing riparian erosion, including failing banks, lack of saturated streamside meadows or riparian vegetation, perched water tables, evident turbidity, and obvious stream incision. An erosion site was defined as an area of actively eroding stream bank or riparian area, which exposes mineral soil, for at least 20 feet in length or 50 square feet in area (The "20/50 standard"). At each erosion site, technicians took a GPS point, made an estimated location mark on a field map, took photographs, measured the exposed soil's area and longitudinal length, made notes of apparent causes and possible restoration measures, and measured the sub-reach's physical habitat characteristics. Concomitant signs of ongoing erosion were also noted, such as a low-gradient stream segment lacking gravel and finer sediment, exposed bedrock and anthropogenic effects, including riparian cattle-grazing or logging, ditching, vehicle crossings and streamside road-building.

Technicians gathered data on several standard aspects of riparian vegetation and stream morphology along five cross-sections at each site, starting at the perceived upstream start of the erosion (cross-section 0) and 20 yards apart, for a total measured area of 240' stream-feet per site.

Data collected included:

- streambank slope (steeper banks are more likely to fail)
- sediment size
- bankfull height and width
- flood-prone area (as per Rosgen 1996)
- calculated W/D ratio and entrenchment (aka, stream channel incision)
- channel stability factors (abbreviated, from Rosgen)
- riparian vegetation types and root density (an attempt to quantify vegetation presence and rootedness, and thus its contribution to bank morphology and stability)
- proximal erosion hazards (unpaved roads, logging, cattle-grazing, camping, ATV/off-road vehicles within 500' of stream, and evident channel-straightening)

[5] Additional access permission would allow us to observe and collect pertinent data on two additional areas of interest: a private meadow area, north of Brewer Road, on the upper portion of East Simmons Creek; and, South Snyder fork through SDS property, south and west of Fisher Hill Road.

- and, an approximate erosion length (how long an area of the streambank is actively eroding; measured or else estimated by aerial imagery correlated with on-site observations)

These metrics are mostly standard in stream-science, and were chosen to balance the need for rapid assessment in the field with a reliable, repeatable protocol for quantifying the active erosion magnitude at each site. The specific metrics were informed by professional judgment, available field time and standard stream-assessment approaches.

Field data were transformed into comparable numbers back at the office to enable us to quantify the total erosion hazard at each site, as expressed as a single algebraic site score. This allows for transparent site comparisons. We determined a site's score with a formula that added together averaged data for each of bank angles, sediments and entrenchment, minus the combined W/D ratio and vegetation scores, and the results multiplied by an erosion length factor. The notion of a length factor was to weigh the longitudinal aspect of an eroding site in the total score. All other parameters being equal, a riparian site that's unraveling from increased erosion along 1000 feet ought not be scored the same as one that's only 100 feet long. See the Sub-Appendix to this assessment for complete data, definitions and scoring rationale.

Meadows

Riparian wet meadows are vital to the ecological health, biodiversity and ecosystem functions of most streams, including their sediment storage. For this assessment, we avoid the term *wetland*, which is synonymous in many regards (a transitional area between open water and uplands, characterized by at least seasonal inundation, riparian/wetland plants and hydric soils), but which carries certain legal ramifications and also cultural baggage. This assessment did not engage in wetland delineation. Delineation is based on legal restrictions; this assessment is based on gaining some understanding of watershed geomorphic function.

Nevertheless, it is useful to note previous, coarse-scale wetland delineations, as mapped by the US Fish & Wildlife Service (USFWS). The USFWS National Wetlands Inventory is a mapping program locating wetlands and classifying their various types. (For the Snyder Creek watershed, the primary wetland types are freshwater emergent and freshwater forested/shrub.) The Inventory depicts 62.85 acres of wetlands in the watershed – a tiny but important percentage of the whole watershed. Of these, half (31.77 acres) are located in Snyder Swale.

This suggests the centrality of Snyder Swale in the watershed's sediment storage and cycling. This delineation can be deceiving, though, or at least limited: The Inventory depicts only 2.9 acres of the Simmons Meadow area as wetlands. This may be currently accurate, given the site's disconnected floodplain and loss of wet meadow vegetation and hydrology, but historic stream meanders, gradient and soils suggest that the area was historically a wet meadow – an area up to 11.5 acres in extent. This represents a significant loss of meadow function to the watershed. Likewise, the Inventory doesn't show any of the Legall Road meadows – several of them saturated with a nearly indistinguishable stream channel and abundant wetland vegetation.

A thorough inventory of wet meadows in the Snyder Creek watershed would prove fruitful, and should be considered as a follow-up to this assessment. Topographic forms, stream gradients and the Inventory suggest several areas of wet meadows we were unable to assess or observe, given limited field time and private property access restrictions. Principle among these are stretches of the Snyder Creek South Fork and the East Simmons Creek area. The latter site, which UCD was not allowed to assess, contains an area from approximately 5 (probable) to as many as 15 acres (less likely) of historically wet meadow.

In lieu of a more complete wet meadow assessment for the watershed, we made observations during field assessment time of various meadows, current and historic, and their perceived functionality. Setting up base-flow monitoring plans (peizometers, etc.) was beyond the scope of this project. However, stream scientists understand generally how meadows function, acting as sponges to soak up excess stream flow, then releasing it slowly as both surface and hyporheic flow. Meadows have an expected stream morphology (Rosgen stream types D and E), with a predictable range of slope, sinuosity, etc. A simple rapid assessment is to gauge whether a meadow is saturated by standing water during the early growing season (i.e., the seasonal high-water). Lacking this, a meadow adjacent to a stream is not likely functioning as a seasonal water- and sediment-storing area; possibly due to stream incision. For this assessment we defined a meadow as consisting of a minimum longitudinal stream reach of 300 feet. A meadow saturated during high-water periods was assumed to be functioning at its hydrologic capacity. Those that weren't were noted; and their associated erosion sites catalogued.

Results: Erosion Sites

Results of the field observations and data collection are summarized here. (Complete data are presented in the Sub-Appendix.) Identified erosion sites are shown in the map in Figure 5, while results are presented in brief, ranked form in Table 2. Following these items are brief narrative comments on the erosion sites. There are narrative descriptions of sites where technicians gathered data, as well as those sites that represent clear future erosion hazards or sediment-reducing restoration opportunities.

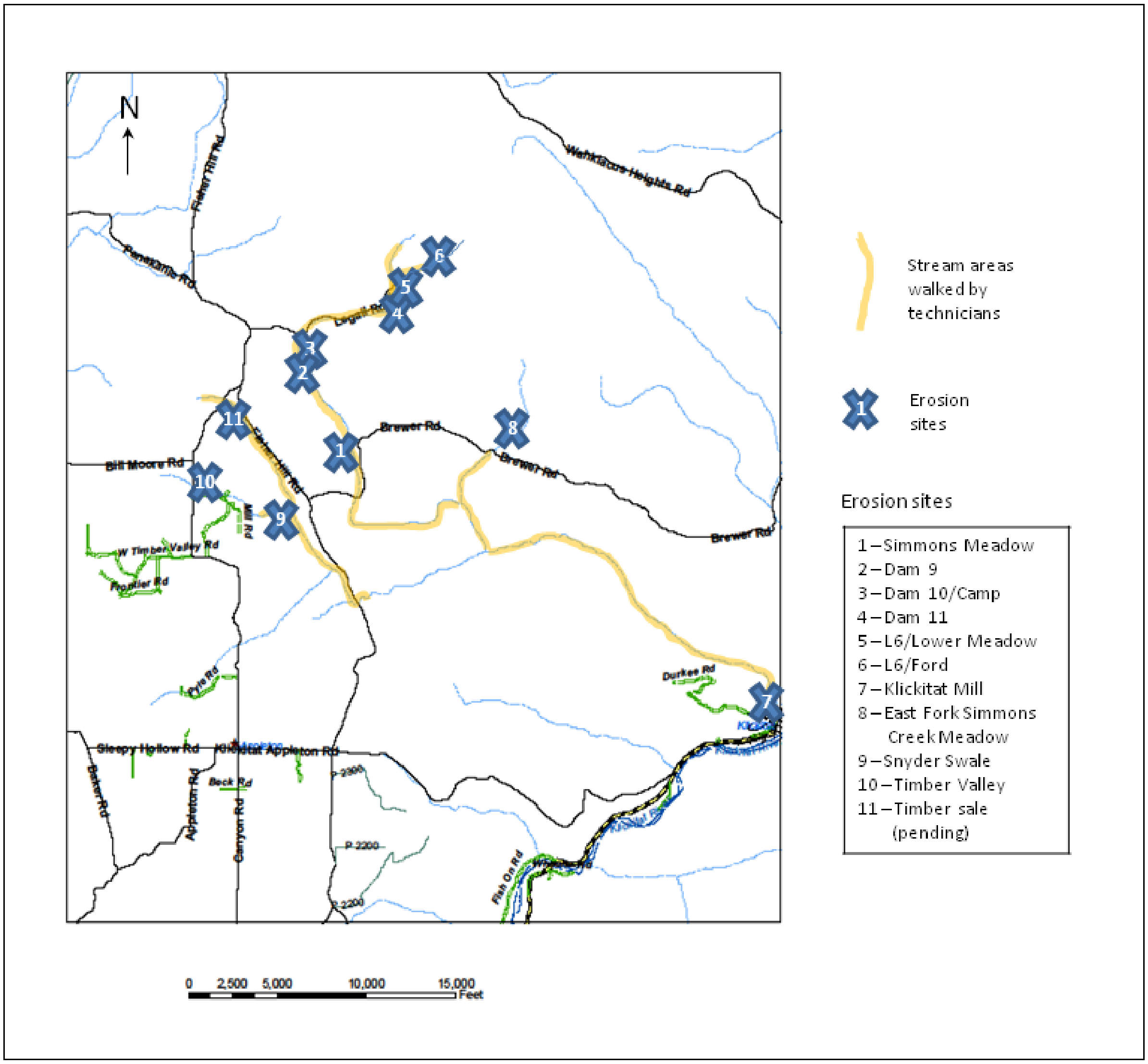

Figure 5: Snyder Watershed sites of concern. This map identifies the major reaches of the watershed, the areas walked by UCD technicians in spring 2012, and identified erosion sites. Some of these were measured as actively eroding riparian areas; others are unmeasured areas of concern. See notes for each, below.

Table 2: Riparian sites of erosion concern

Site name	Stream branch	Bankful W/D ratio *(lower = more incised or narrower channel)*	Estimated downstream length of bank erosion (feet)	Proximal erosion hazards #	Site's erosion hazard score +	Watershed erosion site rank
Simmons Meadow*	Simmons W. Fork	5.16	3,300	L, S	16.40	*Reference*
Dam 9	Simmons W. Fork	7.07	1,275	S	8.97	1
Dam 10/Camp	Simmons W. Fork	9.08	250	A	5.74	2
L6/Ford	Simmons W. Fork	16.61	300	R, L	4.60	3
L6/Lower Meadow	Simmons W. Fork	13.47	240	L	4.13	4
Check Dam 11	Simmons W. Fork	10.92	600	-	3.99	5
Klickitat Mill	Snyder Main	unknown	3,200	L, S, R	-	-
Simmons East Fork Meadow	Simmons E. Fork	unknown	unknown	unknown	-	-
Swale Meadow	Snyder Swale	stream channel being formed	stream channel being formed	L, S	-	-
Timber Valley	Snyder N. Fork	unknown	unknown	unknown	-	-
Timber Sale	Snyder Swale	future: unknown	future: unknown	(planned) L, R	-	-

** Simmons Meadow has been the subject of significant recent restoration measures. It is included here as a reference, thus is not ranked.*

 # These include roads (dirt/gravel within 500 feet) (R); cattle-grazing (C); logging within 500 feet (L); Camping/off-road vehicles (A); and channel-straightening (S).

+ The higher the riparian erosion score, the more advanced the evident, anthropogenically-affected erosion appears to be. Scoring is based on bankful W/D ratio, erosion length and other metrics: see sub-appendices for complete data and scoring rationale.

Simmons Meadow

Figure 6: Simmons Meadow. Looking downstream from the top of the measured erosion site.

One of the three large historic meadow complexes in the watershed, Simmons Meadow has experienced significant erosion, likely as a result of channel-straightening during previous logging periods. There is very little to no riparian vegetation except short grass, which grows on the meadow perched above the stream. The result is a deeply incised channel (approximately 5-6' deep, with an extremely narrow channel (its bankfull width/depth ratio averaging 5.16 in the measured portion, the lowest of any of the sites' ratios) running for approximately 3,300 feet of stream longitudinal distance. This meadow is a reference area for our protocol. This site has seen initial restoration measures by WA Dept. of Fish and Wildlife, Mid-Columbia Fisheries Enhancement Group, and Underwood Conservation District for the past several years, including log check dams, riparian exclusion fencing, two hardened cattle crossings and continued bank re-vegetation (primarily willow live-stakes, with some red-osier stakes, sedges and rushes). These efforts are preliminary, with hoped-for results in the next several seasons as vegetation takes root. Ownership: John Hancock Life Insurance.

Check Dam 9

Figure 7: Check dam 9 erosion site. The stream rapidly incises from a connected floodplain, a few yards upstream from the right-hand side of the image, to the deepening channel at the bend on the photo's left.

This site represents the upstream initiating site of the long incised channel down to Simmons Meadow, separated only by a few hundred feet of functioning wet meadow, attached floodplain and aspen groves. An earlier generation of watershed-restoration measures identified ongoing erosion of the Simmons West Fork as a primary need and attempted to address that in part through small check-dams made of fence posts and heavy fabric. At least 14 were installed, by field observation. Most appear to have held back sediment temporarily: only small amounts (<1 cubic yard) generally remains in situ. This site is the ninth dam upstream of Simmons Meadow. It's located at a sharp S-bend in the stream, where the West Fork of Simmons Creek rapidly descends from a somewhat-functioning meadow and connected floodplain into a deep incised channel which runs downstream through historic woods and meadows to Simmons Meadow. There is current evidence of a perched water-table here, with percolation observed from the side of the incised channel, 2-3' above the spring stream-flow. The ongoing erosion, in other words, appears to have incised the stream channel below the surrounding water table. Atop the perched floodplain/wet meadow area are mixed stands of ponderosa pine, grand fir and aspen; their roots reach only about half-way down the incised bank toward the bottom of the measured site (and downstream). Like Simmons Meadow half a mile downstream, this site has no stream-bottom vegetation. Given its longitudinal impact, this site represents the beginning, not totality, of an incised stream reach. Ownership: Washington Department of Natural Resources.

Check Dam 10/ Camp

Figure 8: Check dam 10 /Camp erosion site. This view looks downstream from the hardened crossing at the site's head. Eroded banks are evident, especially on the photo's left, immediately downstream of the crossing.

Located at the tenth observed fabric check dam upstream of Simmons Meadow, this short erosion site is located a few dozen yards east of an informal but popular camping site on DNR property along Legall Road. The Dam 10 site was measured at the check dam (and apparent hardened crossing), downstream. The banks are shallowly incised (1.5-2'), but appear to be deepening. There are functional, attached wet-meadow areas upstream and downstream of Dam 10, which suggests the possibility that restoration work here could be successful. There is also evidence of occasional cattle and off-road vehicle use; an important first step would be to strengthen the fence and gate near the informal camp area. Ownership: Washington Department of Natural Resources.

L5 / Check Dam 11

Figure 9: L5 / Check Dam 11. Looking upstream from the downstream end of the site. Heavily vegetated in places, especially toward the downstream portion, with aquatic vegetation, but also featuring sloughing banks.

This erosion site is located in an area we're calling the Legall meadows complex: a long string of wet meadows and meandering stream channels amid saturated woodlands (cottonwoods, aspen) situated near Legall Road in the upper reaches of the West Fork of Simmons Creek. This string of meadows is approximately 1.4 miles long, from the Check Dam 10 site upstream to the "L6" sites. Technicians labeled six wet meadow areas of various size, ending upstream at the L6 area (see Figure 6). At L5/Check Dam 11, a downstream wet meadow area in a ponderosa pine plantation of ~20-year-old trees, to a short section of 2-3' eroded banks. A few shrubs and stream-bottom grasses are present. Given its distance from Legall Road and lower elevation, restoration at this site could include a thinning of the pines, replanting riparian shrubs and trees, and adding large-woody debris jams. This site is within a few dozen yards of the L6/Lower Meadow site, separated by a small attached floodplain, a copse of mature cottonwood trees and small logjam, and a boundary line. Restoration work at this site could, probably should, be combined with work at the L6/Lower Meadow site, approximately 200 feet upstream. Ownership: Washington Department of Natural Resources.

L6 / Lower Meadow

Figure 10: L6/Lower Meadow. The view downstream, where the channel is both meandering and incising. The edge of a pine plantation is visible in the upper left portion of the photo.

At approximately 4.75 acres, L6 is a substantial wet meadow area (~4.75 acres), and the Lower Meadow erosion site is situated nearly at its outlet. At the downstream end of L6 (i.e., upstream of the Dam 11 site), the stream splits into two headwaters forks, watering two arms of the Y-shaped meadow area. The northerly fork drains down from meadows and forests, through a 0.3-acre holding pond, and then in a narrow channel along the base of rising ground, to the Y confluence. Much of this is thinly vegetated, being apparently previously logged, and now planted as a timber plantation. Above the confluence, the Lower Meadow erosion site is located where the stream bends at an apparent overflow channel, and incises to approximately 1' before regaining, for a short distance, an active flood plain. Restoration efforts here could be conducted with a minimum of disturbance to the timber being grown by adding riparian vegetation.

Also, technicians observed evidence of fishing and fish-stocking in the pond; in addition to abandoned fishing tackled at the pond, two small (4-6") apparent catfish were seen in the stream. Ecological services would be well served by removing non-native species here. Ownership: John Hancock Life Insurance.

L6 / Ford

Figure 11: L6/Ford. Looking across the ford (photo left), and immediately downstream. The stream, representing a small volume of flow in this headwater reach, is percolating through/over the cobbles of the ford.

The Ford erosion site is located at the upstream end of the westerly stream fork that flows through L6, and is slightly higher than the meadow area. The site is located immediately downstream of an access road ford, between a pine plantation area and forest. The ford acts as a check-dam, backing up a small ponded area and creating downstream scour. Erosion here is reminiscent of the Lower Meadow site with a few small meanders and a low amount of entrenchment. Riparian vegetation is present but scarce, but grasses and small plants show significant (50%) stream-channel rootedness. And unlike many reaches downstream, there are cobbles, gravels and sand present in the substrate. A clump of willows is present mid-reach. An abandoned channel is evident immediately north of the current channel. This is probably the least significant of the identified erosion sites, both by score and observation. Restoration efforts here could potentially lower the erosion while maintaining the ford and nearby timber plantation potentially by reconnecting the historic channel, and/or adding riparian shrubs: more willows here would be an obvious candidate. Ownership: John Hancock Life Insurance.

Klickitat Mill

Unscored. (See Figure 3 for photo.) The former sawmill property, upstream of the recent fish-passage work at the Snyder-Klickitat confluence, is not necessarily an erosion site (it was not measured due to access restrictions) – it should be considered more of a restoration opportunity than an erosion risk. The stream empties out of its long canyon here into a narrow floodplain, which was reworked as the site of a long-running sawmill. In 2003-04, several agencies undertook a reconstruction of the stream mouth from the confluence up into the mill site proper; above the mill buildings, however, the stream remains channelized in a deep, straight cobble bed against one side of the canyon. It's likely that the change from high- to moderate-gradient here resulted historically in a more meandering or braided stream and floodplain. Restoring that function would be enormously expensive, given likely mill-cleanup costs, but could recreate a sediment-trapping stream reach and backwater areas for salmon spawning and rearing. Ownership: Confluence proper – Klickitat County. Upstream of mill buildings – Private individual.

East Fork Simmons Creek Meadow

Unscored, due to lack of owner permission for project data-collection. Located immediately north of Brewer Road, and east of Simmons Meadow, the East Fork of Simmons Creek Meadow site is approximately 5-15 acres on the upper end of Simmons East Fork. Given its lack of access, this meadow is not a known erosion site per se, but rather a site of erosion concern due to ongoing cattle use and lack of riparian vegetation rootedness/canopy. A small pond on the downstream end of the site may be acting to trap sediment. One potential partial option to reduce erosion concerns might be the creation of several additional vegetated ponds along the approximately 2300-foot-long stream area: This would erect a series of sediment traps, slowing and storing water, while preserving active cattle-range and other agrarian land-uses. Other potential approaches to discuss with the landowner, in conjunction with ponds or as an alternate, could be riparian fencing and off-stream trough-watering; and, a partial-restoration project of, say, the lower one-third of the meadow area, with exclusion fencing, native-species planting and seasonal "flash grazing" of cattle to encourage greater riparian vegetation growth and recovery. Ownership: Private individual.

Timber Valley

Unscored. This site is another one of concern, rather than one that's necessarily actively an excessive erosion hazard. There are warning signs, however: There are 45 lots and several dozen owners in this upstream reach of Snyder Creek above Snyder Swale, as well as a newly logged parcel upstream. Properly assessing this stream reach will require a community outreach effort and successful negotiation of numerous property owner concerns and permission. This may well be a worthwhile project – one that results in significant local interest and participation, if landowners see its value, but requiring a concerted outreach and education effort for what are currently unknown ecological benefits. Ownership: Multiple private individuals.

Swale Meadow

Figure 12: Swale Meadow: newly incising stream. This historic wetland was ditched and drained, but the stream (Snyder South Fork) here is escaping its ditch at the base of a steep reach, and is meandering across the Swale toward the main stem of Snyder Creek (below trees in photo).

Unscored. “Swale Meadow” is a site name given to an identified portion of lower Snyder Swale that represents an active channel-forming area where a stream appears to have recently escaped a ditch. This does represent a “hazard” in the sense that carving new channels is exposing considerable mineral, and no doubt exporting it as sediment. However, we believe this process is a natural one: a reassertion of stream dynamics long pent up by previous ditching efforts and land-uses, and representing as much an opportunity as an erosion problem. Furthermore, there are multiple (2-3) active, sinuous stream channels: the stream appears to have no single established channel yet.

Snyder Swale is a series of meadows, wetlands, woodlands and ditched fields. Much of the 2.5-mile-long swale was not accessible for data-gathering purposes for this assessment. One private owner (an individual, not a timber company) has two significant parcels of the lower half of the Swale. The upstream parcel, opposite Brewer Road, is covered mainly in grasses and sedges. This parcel is approximately 2300’ long; 500’ downstream of the property line, the Timber Valley fork of Snyder Creek enters, and downstream of this confluence is a complex, often saturated floodplain that alternates between a defined stream channel and semi-defined channel areas. There are ditches on both the east and west sides of the Swale valley.

The downstream parcel starts approximately 700 feet above the Snyder South Fork and continues down to Fisher Hill Road. The lower two-thirds of this parcel are actively saturated well into the spring or later, with multiple stream channels, standing water, wetland vegetation and aspen groves over much of the land. The upper third is somewhat drier, lacking significant numbers of trees. However, there is clear observable evidence here that the incoming Snyder South Fork has partially jumped its previous ditch on the valley’s west side and is now actively creating new channels, in an open meadow. This area appears previously heavily impacted by management (likely, timber-harvested and grazed by cattle).

There appears to be substantial potential for stream and meadow restoration here: The landowner has taken a hands-off management approach and granted UCD access; future timber harvest is unlikely; there's a stream confluence with active channel-formation (multiple newly created channels); and there are functional wet meadows / wetlands downstream to expand. The area immediately upstream and downstream of the Snyder South confluence represents a meadow area of approximately 3 acres. These two private Snyder Swale parcels, and particularly the downstream one, hold excellent potential for maximizing sediment- and water-storage capacity. Owners: Private individual.

Timber sale

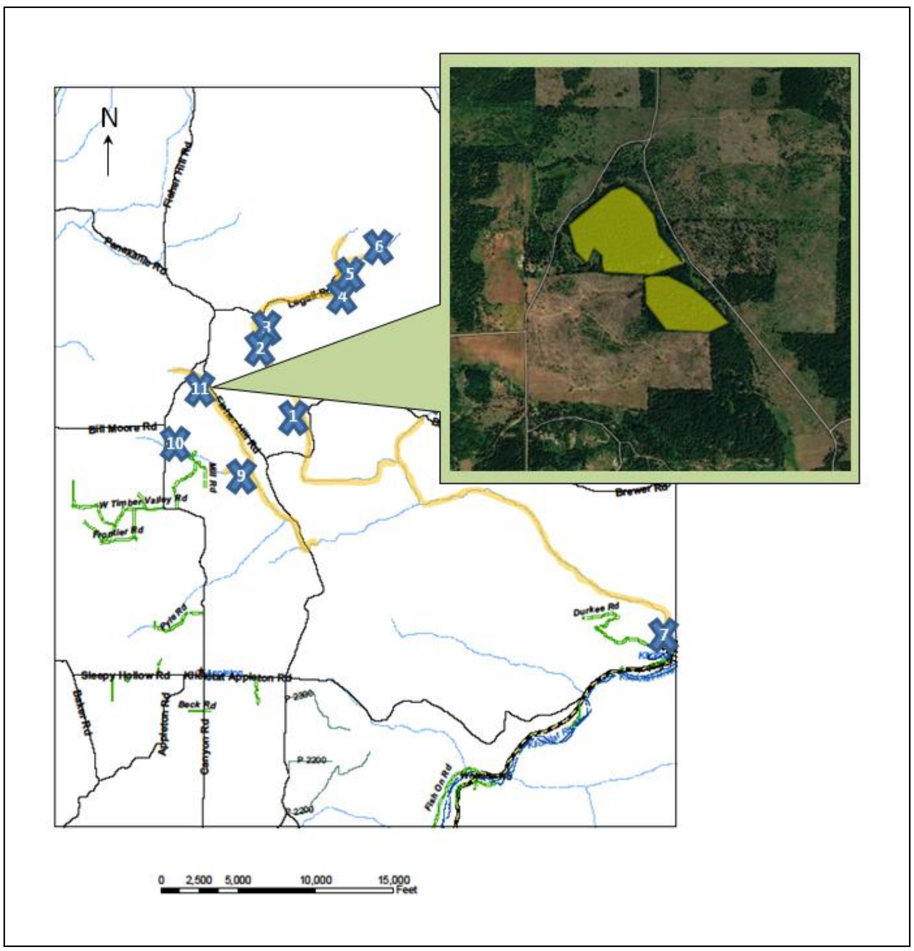

Figure 13: Timber sale planned area. A superimposed aerial photo and approximate areas of a DNR-planned timber sale at erosion site 11. This is south of the Fisher Hill Road and Canyon Road intersection, and represents 100 acres to be logged at the head of Snyder Swale.

The Washington Department of Natural Resources is conducting a 100-acre timber sale of forest at the intersection of Fisher Hill Road and Canyon Road (DNR 2012a, b), which represents a large stand at the head of Snyder Swale. As with harvests that clear timber generally, this site can be expected to decrease base flow and increase the rapidity of overland runoff into area streams, along with the attendant rise in sediment-inputs to those streams. Conservation efforts to work with the timber-purchaser and, if possible, DNR prior to the sale's completion could be expected to lower some amount of future sediment increases into the Swale. At the very least, all parties should make energetic efforts to rapidly reforest the site and assess/increase riparian vegetation buffers. Ownership: Washington Department of Natural Resources.

Discussion: "Next Steps"

Sediment erosion and deposition are natural, necessary functions of all streams. Excessive erosion, however, can be harmful to a watershed's fish and other organisms and its other hydrologic and ecosystem functions, especially when human land-use management creates chronic conditions not otherwise experienced by the stream system. Observations strongly suggest there are a number of these chronic erosion sites in the Snyder Creek watershed. Some are historical, while others are newer – and some of the largest are probably both.

The erosion-site scoring system introduced above is one way to rank sites where technicians collected data at actively eroding sites in the watershed (see Table 2). This can inform conservation agencies and partners where to consider placing efforts for erosion-reduction and stream restoration generally.

Not all sites that could be were measured, however, due to access issues. Also, there are other factors to consider, chief among them the limits of funding and UCD staff resources, and the fact that UCD is a non-regulatory agency which works with landowners on a voluntary basis. Creating and cultivating working relationships with landowners is a critical preliminary step to the conservation projects in which UCD engages. Stream restoration projects therefore proceed where there is an intersection of available resources (grant funding, District personnel), a willing landowner and appropriate timing (e.g., in-water work windows or seasonal plantings).

Still, not all watershed sites where significant restoration work could be performed were measured in this assessment. Consider the Klickitat Mill site, for example: By any reasonable measure, it would be a high-priority location for restoration work, given that it's closest to the Klickitat River, would likely function naturally as a sediment trap or buffer were the floodplain reconnected to the stream, and would be expected to host spawning or rearing salmon (given its low gradient and position below the Snyder-Simmons confluence falls. Yet there is currently no landowner relationship in place (the owner failed to return repeated communications for this assessment), and the site is polluted and problematic. If resources were not a limiting factor, this would be an ideal place to rehabilitate; but without very significant resources, liability resolved and willing owner, it's not feasible at this time.

So a second way to gain a sense of project priorities is to check which ones are feasible, in terms of having a likely-cooperative landowner, physical access, etc. One attempt at assembling these factors is given in Table 3:

Table 3: Restoration project potential of riparian sites

Site name	Stream branch	Riparian erosion data measured?	Public land?	Physical access?	Cooperator likely?	Restoration ready?
Dam 9	Simmons W. Fork	Y	Y	Y	Y	Y
Dam 10/Camp	Simmons W. Fork	Y	Y	Y	Y	Y
Dam 11	Simmons W. Fork	Y	Y	Y	Y	Y
Klickitat Mill	Snyder Main	N	N	Y	N	N
L6/Lower Meadow	Simmons W. Fork	Y	N	Y	Y	Y
L6/Ford	Simmons W. Fork	Y	N	Y	Y	Y
Swale Meadow	Snyder Swale	N	N	Y	Y	Y
Timber Valley	Snyder North	N	N	Y	N	N
Simmons Meadow	Simmons W. Fork	Y	N	Y	Y	Y
East Fork Simmons Meadow	Simmons E. Fork	N	N	Y	N	N

Notes: Physical access means readily walkable with supplies, work crews, etc.
Restoration ready = physical access + likely cooperator or public land.

Ultimately, though, this feasibility approach lacks a sense of priorities. Those will develop when and if conservation workers pursue a list of feasible projects, as initially outlined in Table 3.

Taking these approaches into account, we offer a short list of feasible, high-priority watershed projects that will be expected to be successful in maintaining base flow and reducing excessive erosion or sediment inputs to the lower watershed. This list is not given in a ranked order and assumes a cooperating landowner.

High-priority proposed projects

- Restoration project of lower Swale Meadow private parcels.
- Greater study of the Check Dam 9 and the long incised downstream reach, with renewed restoration efforts.
- Preservation of existing functional meadows along Legall Road (L1-L6) by agreement, easements or other protections.
- Restoration planting and potential check-dam construction or multi-channel braiding at Check Dam 10, Check Dam 11 and L6/Lower Meadow sites.
- Additional monitoring and upstream planting of the Simmons Meadow restoration project, in progress.
- Landowner-outreach efforts to allow access for assessments, especially for riparian meadows, on Simmons Creek East Fork and Snyder Creek South Fork.

Taken together, these recommended high-priority projects compose a three-prong strategy to conservation work in the Snyder Creek Watershed:

1) **Restoring functional conditions** at erosion hazard sites. A combination of larger and smaller (more practical) projects in areas of compromised riparian function; especially since these are primarily either on public land or on property maintained by a generally cooperative and ecologically astute private landowner.

2) **Reaching out to landowners** of other potential sites (specifically of the East Fork Simmons Creek Meadow, Snyder South Fork and Timber Valley areas). New, trust-based relationships could allow greater access and understanding, especially in portions of Snyder Swale, Snyder South Fork and East Fork Simmons Creek Meadow, where access for data-collection was not given or was limited.

3) **Enacting conservation projects** where existing opportunities present themselves (e.g., lower Swale Meadow). Conservation – that is, protection of existing natural conditions – is preferred above restoration efforts, because conservation preserves ecosystem functions, is more certain than trying to re-establish lost functions, and is generally less expensive. The most obvious example is the lower Swale Meadow, just upstream of Fisher Hill Road.

Conclusion

There are several moderate-to-large riparian erosion sites in the Snyder Creek watershed that appear to be contributing significant and unnaturally large amounts of fine sediment into the Klickitat River watershed. Given that there appear to be no functional sediment-storage reaches between the erosion sites and the Klickitat River, these sites are assumed to be contributing fine sediments into that system at a higher rate than would be assumed from a functional, undisturbed tributary watershed.

The Snyder Creek Watershed Sediment Assessment can be a useful step toward addressing these erosion sites. Of course, additional data-collection[6] would deepen our understanding of the system's dynamics. Still, this assessment quantifies several major erosion sites and allows Underwood Conservation District and partners to identify potential restoration and conservation projects in the watershed.

With the observations in this assessment, Underwood Conservation District and partners can focus future sediment-based stream restoration on known problem sites in the watershed, selecting between several sites of various magnitudes and opportunities for supporting naturally-sustaining, sediment- and water-storing capacity.

Acknowledgements

Underwood Conservation District wishes to thank Hancock Forest Management and the other private landowners, named and unnamed, who gave their consent for UCD technicians to access their property and learn more about the Snyder Creek Watershed and its current conditions.

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[6] including permanent cross-sections; systemic measurement of the watershed's sediment budget; a careful assessment of initial restoration efforts; and a fine-resolution GIS analysis.

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Sub-Appendix A: Data

Erosion site	Cross-section	Bank angle L (deg)	Bank angle R (deg)	Sediments	Sed score, avg	BW (ft)	BH (ft)	FPA (ft)	W/D Ratio	Entrenchment
Simmons Meadow										
	0	35	30	S,F,F,S,F	4.2	11.5	2.5	16.1	6.57	1.40
Erosion hazard score	1	40	45	F,S,F,S,S	3.8	7.5	1.95	9.85	5.49	1.31
16.40	2	35	50	F,F,F,F,F	5	6.8	2.45	10.2	3.97	1.50
	3	50	45	F,F,F,F,F	5	8.2	3	9.8	3.90	1.20
	4	50	40	F,S,S,F,F	4.2	8.2	2	11.25	5.86	1.37
	Site average	42	42	-	4.44	8.44	2.38	11.44	5.16	1.36

Erosion site	Cross-section	Bank angle L (deg)	Bank angle R (deg)	Sediments	Sed score, avg	BW (ft)	BH (ft)	FPA (ft)	W/D Ratio	Entrenchment
Check Dam 9										
	0	10	30	C,C,C,GC,GC	0.4	14.85	1.75	34	12.12	2.29
Erosion hazard score	1	20	55	F,GF,GF,C,C	1.8	9.3	2.55	42	5.21	4.52
8.97	2	35	30	F,S,S,S,S	3.4	9.75	2.35	15.45	5.93	1.58
	3	40	45	GF,F,S,M,M	2	8.75	2.15	13.6	5.81	1.55
	4	55	50	F,F,GC,GC,C	2.8	9.45	2.15	11.95	6.28	1.26
	Site average	32	42	-	2.08	10.42	2.19	23.40	7.07	2.24

Erosion site	Cross-section	Bank angle L (deg)	Bank angle R (deg)	Sediments	Sed score, avg	BW (ft)	BH (ft)	FPA (ft)	W/D Ratio	Entrenchment
Check Dam 10 / Campsite										
	0	65	55	S,M,C,C,F	1.6	12.7	1.35	20.5	13.44	1.61
Erosion hazard score	1	35	15	S,S,GF,S,S	2.8	12.5	1.92	20.3	9.30	1.62
5.74	2	45	75	F,S,S,S,S	3.4	8.8	2.05	37	6.13	4.20
	3	15	40	S,S,F,S,S	3.4	11.6	1.75	15.1	9.47	1.30
	4	50	40	S,F,S,F,F	4.2	10.6	2.15	17.4	7.04	1.64
	Site average	42	45	-	3.08	11.24	1.844	22.06	9.08	2.08

Erosion site	Cross-section	Bank angle L (deg)	Bank angle R (deg)	Sediments	Sed score, avg	BW (ft)	BH (ft)	FPA (ft)	W/D Ratio	Entrenchment
Check Dam 11 / L5										
	0	35	60	F,C,W,C,S	1.6	16.3	1.45	17.95	16.06	1.10
Erosion hazard score	1	60	25	S,S,S,S,GF	2.8	14.1	1.5	19	13.43	1.35
3.99	2	20	45	F,F,S,S,S	3.8	13.4	1.55	22	12.35	1.64
	3	35	30	S,F,F,F,F	4.6	18.1	1	21.25	25.86	1.17
	4	30	35	S,F,S,S,F	3.8	14.3	1.33	21.5	15.36	1.50
	Site average	36	39	-	3.32	15.24	1.366	20.34	16.61	1.35

Erosion site	Cross-section	Bank angle L (deg)	Bank angle R (deg)	Sediments	Sed score, avg	BW (ft)	BH (ft)	FPA (ft)	W/D Ratio	Entrenchment
L6 / Lower Meadow										
	0	35	45	S,S,S,GC,BR	2	5.55	0.48	7.9	16.52	1.42
Erosion hazard score	1	90	35	F,S,S,S,S	3.4	6.8	1	9.55	9.71	1.40
4.13	2	30	50	S,S,S,S,S	3	7.23	1.02	11.5	10.13	1.59
	3	12	50	S,S,S,S,S	3	8	0.6	20.5	19.05	2.56
	4	25	20	S,S,S,S,S	3	6.7	0.8	24.2	11.96	3.61
	Site average	38.4	40	-	2.88	6.856	0.78	14.73	13.47	2.12

Erosion site	Cross-section	Bank angle L (deg)	Bank angle R (deg)	Sediments	Sed score, avg	BW (ft)	BH (ft)	FPA (ft)	W/D Ratio	Entrenchment
L6 / Ford										
	0	15	10	C,C,C,S,S	1.2	9.7	0.8	62	17.32	6.39
Erosion hazard score	1	75	35	C,S,S,S,S	2.4	7.9	1.08	10.4	10.45	1.32
4.60	2	40	55	S,S,S,S,GC	2.6	7.65	1.45	10.75	7.54	1.41
	3	20	80	GF,S,S,S,S	2.8	8	1.15	13.72	9.94	1.72
	4	90	20	GF,S,S,S,F	3.2	7.2	1.1	12.4	9.35	1.72
	Site average	48	40	-	2.44	8.09	1.116	21.85	10.92	2.51

Erosion site	Cross-section	Root density %, top	Root density %, bottom	Riparian vegetation, top	Riparian vegetation, bottom	Vegetation score	Proximal erosion hazards	Proximal erosion score	Erosion length, feet	Erosion length factor
Simmons Meadow										
	0	100	3	4c	1	0.56	-	-	-	-
Erosion hazard score	1	-	-	-	-	-	-	-	-	-
16.40	2	100	3	4c	1	0.56	-	-	-	-
	3	-	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-	-
	Site average	100	3	-	-	0.56	L, S	2.5	3300	1.5

Erosion site	Cross-section	Root density %, top	Root density %, bottom	Riparian vegetation, top	Riparian vegetation, bottom	Vegetation score	Proximal erosion hazards	Proximal erosion score	Erosion length, feet	Erosion length factor
Check Dam 9										
	0	25	10	9a	4b	0.325	-	-	-	-
Erosion hazard score	1	-	-	-	-	-	-	-	-	-
8.97	2	100	0	9a	1	0.25	-	-	-	-
	3	-	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-	-
	Site average	62.5	5	-	-	0.2875	S	1.5	1275	1.5

Erosion site	Cross-section	Root density %, top	Root density %, bottom	Riparian vegetation, top	Riparian vegetation, bottom	Vegetation score	Proximal erosion hazards	Proximal erosion score	Erosion length, feet	Erosion length factor
Check Dam 10 / Campsite										
	0	3	3	5a	4a	0.06	-	-	-	-
Erosion hazard score	1	-	-	-	-	-	-	-	-	-
5.74	2	25	50	6a	4c	1.125	-	-	-	-
	3	-	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-	-
	Site average	14	26.5	-	-	0.5925	A	0.25	250	1

Erosion site	Cross-section	Root density %, top	Root density %, bottom	Riparian vegetation, top	Riparian vegetation, bottom	Vegetation score	Proximal erosion hazards	Proximal erosion score	Erosion length, feet	Erosion length factor
Check Dam 11 / L5										
	0	90	25	11b	2a	0.95	-	-	-	-
Erosion hazard score	1	-	-	-	-	-	-	-	-	-
3.99	2	80	100	11a	5c	1.8	-	-	-	-
	3	-	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-	-
	Site average	85	62.5	-	-	1.375	-	0	600	1.25

Erosion site	Cross-section	Root density %, top	Root density %, bottom	Riparian vegetation, top	Riparian vegetation, bottom	Vegetation score	Proximal erosion hazards	Proximal erosion score	Erosion length, feet	Erosion length factor
L6 / Lower Meadow										
	0	100	25	5a	4c	1	-	-	-	-
Erosion hazard score	1	-	-	-	-	-	-	-	-	-
4.13	2	75	50	5a	4c	1.375	-	-	-	-
	3	-	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-	-
	Site average	87.5	37.5	-	-	1.1875	L	1	240	1

Erosion site	Cross-section	Root density %, top	Root density %, bottom	Riparian vegetation, top	Riparian vegetation, bottom	Vegetation score	Proximal erosion hazards	Proximal erosion score	Erosion length, feet	Erosion length factor
L6 / Ford										
	0	100	50	4c	5b	1.5	-	-	-	-
Erosion hazard score	1	-	-	-	-	-	-	-	-	-
4.60	2	100	50	4c	9a	1.5	-	-	-	-
	3	-	-	-	-	-	-	-	-	-
	4	-	-	-	-	-	-	-	-	-
	Site average	100	50	-	-	1.5	R, L	1.5	300	1

DEFINITIONS

Cross-sections: 5 cross-sections, measured 20 yards apart, starting at the perceived upstream starting point of an erosion site.

Bank angles: Measured in degrees, both banks, per cross-section, then averaged for the site.

Sediments:

In the field, sediments were sampled using the modifed Wolman "first-touch" method described in Rosgen (p.5-25) and the EPA wadeable streams manual.

Particles were not measured with a gravelometer, but were described with the EPA wadeable subjective approach.

Particles were then assigned a score, based on size (erodability).

Sediment type	Abbreviation	Score
Fines	F	5
Sand	S	3
Gravel, fine	GF	2
Gravel, coarse	GC	1
Cobbles	C	0
Boulders	Bo	0
Bedrock	BR	0
Wood	W	0
Manmade	M	0

For sediment assessment, sediment is scored (5 per cross-section x 5 cross-sections = 25 scores/site) with resulting average.

Higher the score, greater the likelihood of washing fine materials downstream.

"Hardpan" (condensed mud and fines) was treated as Fines (F).

Bankfull Width, Height:

Bankfull points were found at each cross-section, using standard clues (change of vegetation, height of deposition bars, etc.).

Width was measured bank to bank with horizontal stadia rod and hand-level.

Bankfull height (as per Rosgen) is elevation, in feet, from stream thalweg bottom to level stadia rod across bankfull width.

Following bankfull width, a second rod was placed perpendicular to stadia rod to gain a measurement of the maximum depth, or height, of water at bankfull stage.

Flood-Prone Area:

The width of the stream's "flood-prone" stage, defined as twice bankfull height. Taken at the same point bankfull, per cross-section, using a stadia rod (vertical) and a clinometer level at eye-level to find the resulting width on the riparian area. Entrenched (incised) streams have much narrower FPA widths than streams actively connected to a floodplain, such as a wet meadow.

FPA is used to calculate a stream's entrenchment.

Width/Depth Ratio:

Rosgen calls this ratio the "most sensitive and positive indicator of…channel instability" at this level of field assessment.

This is calculated as bankfull surface width / bankfull mean depth. For this assessment, mean depth was calculated as bankfull depth at the thalweg (BH, in the data table), * 0.7.

Entrenchment Ratio:

Based on a dimensionless rating curve for streams, the ratio is used as a comparison or check on W/D ratio as calculated for a given site.

Entrenchment describes a stream's incision, or vertical containment of its streamflow.

Calculated as the FPA / BW.

Root Density:

An estimated percentage of riparian area covered in vegetative roots -- an estimate of riparian structure and resistance to chronic erosion.

Riparian Vegetation:

As per Rosgen (Table 6-1) for riparian vegetation code.

This is a qualitative description of existing vegetation.

Taken at cross-sections 0 and 2 (ie, twice per erosion site), at the top and bottom of the streambank.

Vegetation category	Code	
Bare ground	1	*(Codes are given*
Forbs only	2	*further values of a, b or c*
Annual grass w/forbs	3	*to denote "low," "moderate"*
Perennial grass	4	*or "high" density)*
Rhizomatous grasses	5	
Low brush	6	
High brush	7	

Combination grass/brush	8
Deciduous overstory	9
Deciduous w/brush/grass understory	10
Perennial overstory	11
Wetland vegetation community	12

Vegetation Score

An attempt to quantify riparian vegetation presence and rootedness, and thus its contribution to bank morphology and stability.

Calculated from vegetation types and root density estimates. Used in an erosion site's score (see Sub-Appendix B).
The score is a formula, which accounts for root density (top, bottom), with bottom vegetation heavily weighted due to the significance of toe erosion in failing banks, and vegetation type (as per Rosgen codes).
So: ((Root density, top * 1) + (Root density, bottom * 4))/200 * vegetation type [where 2a to 4c = 1, and 5a and higher = 2]
The lower the score, the lower the rootedness and presumed strength of riparian vegetation (and thus, a higher likely erosion rate).

Proximal Erosion Hazards

A qualitative description of likely nearby contributors of fine sediment, if any.

Proximal hazards	**Abbrev**	**defined**	**score**
Roads	R	dirt/gravel road within 200 feet, unless buffered by mature forest	0.5
Cattle-grazing	C	evidence of cattle in riparian area	0.5
Logging	L	recent, with significant ground disturbance, or historic with lost	1
Camping/Off-road vehicles	A	within 200 feet	0.25
Channel-straightening	S	or ditching, of the stream at site	1.5

Proximal Erosion Score

As with vegetation and other scores, this is an attempt to quantify observed sediment/erosion influences for purposes of comparing or ranking sites, for UCD's internal consideration of potential conservation projects.
Higher score = higher the proximal sediment inputs presumed to be.
Scoring: add the total. Example: a site with R (= 0.5) and L (= 1) has a Proximal Erosion Score of 1.5.

Erosion Length

A calculated approximate longitudinal stream-length of incised/eroding banks, starting at the apparent upstream erosion point (bare soil). Approximated based on field measurement, or field observations plus aerial imagery.

Erosion Length Factor

A transformation of the Erosion Length into a simple number for the sake of the site's total erosion hazard score.
The idea is to (moderately) stress the longitudinal aspect of the site as a factor in its total score.
Is the site unraveling along hundreds or thousands of feet?

Erosion length	Factor
0-500'	1
500-750'	1.25
750'+	1.5

Erosion Hazard Score

This is a tota of the site's erosion and morphology metrics, scored as a means of site-to-site comparison.
The higher the score, the more presumed bank failures, erosion and export of fine sediment from the site.
See scoring method and rationale in Sub-Appendix B.

Sub-Appendix B: Site Scoring

One requirement of this assessment was to draw up a quantitative comparison between erosion sites; a second goal of Underwood Conservation District was to do so in a way that encouraged thoughtful project-identification. The result for this assessment is the "Erosion hazard score" for each site, shown in Table 2 and in Sub-Appendix A.

Method:

The erosion hazard score is a score of an identified site's total morphology metrics (bankfull W/D ratio, entrenchment ratio, etc.) measured during this assessment, with each factor weighted with best-judgment and through experimentation. The goal was to calculate scores based on a single algebraic formula.

Creating that formula was an experiment. Many of the metrics have unique units. One example: Stream substrate sediment is commonly categorized into boulders, cobbles, fine gravel, etc., based on generally accepted size-ranges (in mm), or else categorized directly by those size ranges. This tells stream scientists and geomorphologists much about a site's condition, habitat and sediment regime. The goal with this metric was to include sediment size averages into a formula that sensibly weighed that number, along with the others gathered at each site. Sediments, therefore, were transformed from sizes into scores: bedrock was rated at 0 (highly unlikely to be exported as sediment down-stream), while fines were rated at 5 (highly subject to stream transport).

Each metric was averaged per site, and transformed into a unit-less score for the purpose of inclusion within the erosion hazard score. Specifics for each metric are included with the definitions in Sub-Appendix A.

We tried several different scoring formula attempts, with each component number given different weights. The resulting scores gave different numbers, of course, but were generally consistent rankings of the various sites. Simmons Meadow site, the longest and generally most incised, for example, always resulted in the highest erosion hazard score. The formula we settled upon seems to accurately capture the differences in magnitudes between the various sites.

The formula we used for calculating the erosion hazard score was:

((0.1 bank angles) + sediments + (3 – entrenchment))

– ((0.25 W/D ratio) + vegetation)

* erosion length factor

Utility:

The purpose for scoring the sites, besides being an assessment requirement, is not to put forward a definitive ranking. Rather, we hope the rankings are useful in thinking about natural resource enhancement and project-identification. An erosion score is not the last word, but the first in a conversation on restoring natural stream conditions (especially sediment-cycling) in the Snyder Creek watershed.

Underwood Conservation District works with land-owners on voluntary basis. Our hope is to create long-term relationships built on trust and effectiveness. Armed with an initial list of recommended priorities and site scores, the Conservation District hopes to better identify feasible, pertinent watershed projects. The Washington Department of Natural Resources, in its watershed assessment manual (see references), outlines an iterative process of watershed field assessments and project-identification, driven by field teams, policy officials, land managers and other stakeholders. This is the same essential approach taken by Underwood Conservation District. We hope our initial list of priorities and site-scoring helps make future conversations possible for the health of the Snyder Creek watershed.