TFW-MAG1-00-002

TFW Effectiveness Monitoring Report

FUNCTIONS OF WOOD IN SMALL, STEEP STREAMS IN EASTERN WASHINGTON: SUMMARY OF RESULTS FOR PROJECT ACTIVITY IN THE AHTANUM, COWICHE, AND TIETON BASINS

by:

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February 2000

Prepared for
the Timber/Fish/Wildlife Monitoring Advisory Group
and the Northwest Indian Fisheries Commission.

This project was partially funded by
the Washington Department of Ecology through the Centennial Clean Water Fund.

ABSTRACT

Functions of Wood in Small, Steep Streams in Eastern Washington

A long term, ecological monitoring asset associated with the Channel Reference Site Network and the Wood In Small Streams Project was created in Eastern Washington. The monitoring goal is to describe the functional roles of wood in small, steep streams, and to document the relationship between riparian vegetation and in-channel **wood.** Detailed measurements were taken of both small and large woody debris, as well as channel morphometry, steps, sediment obstructions, and riparian stand conditions. Repeat measurements will test hypotheses about the roles of SWD in step face construction, hypotheses about sediment supply, step durability, and step functions over time, and hypotheses about the usability and information value of several experimental indicators (e.g., height:length ratios of sediment obstructions).

Comparing mean values from unmanaged (n=5) and managed (n=10) sites:

- Mean zone 1 wood volume was 3.5 times greater in unmanaged sites, zone 2 was similar, zone 3 was 4.2 times greater in unmanaged sites, and zone 4 was 1.8 times greater in unmanaged sites than managed sites.
- Mean SWD volume was 1.4 times greater in unmanaged sites than managed sites.
- Mean LWD volume was 2.5 times greater in unmanaged sites than managed sites.
- Mean SWD and LWD piece counts were 1.9 and 2.1 times greater in unmanaged sites
- Mean SWD drop and LWD drop in 100% wood faces were 1.7 and 1.3 times greater in unmanaged sites than managed sites.
- Mean drop in 100% rock faces was 1.4 times higher in managed sites than unmanaged sites.

From this initial dataset, it's evident that channel measurement sites in unmanaged forests have higher wood volumes and piece counts, regardless of piece size. This is consistent with higher stem densities in riparian forests surrounding unmanaged sites, particularly in large trees with numerous branch whorls. Branches are a major source of SWD. Fallen trees in densely shaded stands are often quite branchy; these branches can act as tines that comb out floating debris (rafts) or create wood piles. Branch wood was commonly found in many step faces.

Unmanaged stands have more trees in each of the four size classes that create conditions suitable for wood entry to channels. Mean values for trees per acre in four size classes (TPA <3" dbh, TPA 3-9", TPA 9-20", TPA >20") were 2.2, 1.6, 1.9, and 2.9 times greater in unmanaged sites compared to managed sites. Riparian stands recently disturbed by logging create structural conditions that can't produce channel wood until processes such as senescence, mortality, branch shedding, wind throw, bank erosion, wood decay, root rot, disease and insect effects can act on standing trees and cause wood to enter or fall near stream channels. Managed stands create structural conditions that maximize solar gain to canopies, reduce shading and competition for soil moisture, and maximize width and height growth rates. Without shading that occurs in stands with dense canopies, fewer branches senesce and shed to produce small woody debris for in-channel functions.

While dense, unmanaged stands create 2.4 times more in-channel and near-channel wood volume (zones l-2-3-4 mean volumes) per bankful width, sediment wedge volume (cubic yards per bankful width) and step quantity (number of steps per bankful width) are similar in unmanaged sites (n=5) compared to managed sites (n=10). Mean sediment wedge volume is nearly the same- 13% higher- in unmanaged sites compared to managed sites. Mean step quantity is only slightly higher- 18% higher- in unmanaged sites than in managed sites.

Crude methods used in measuring and calculating stored sediment volume may bias the initial results by forcing the assumption that all sediment obstructions are geometrically simple wedge shapes with simple-to-calculate obstruction volumes. Imperfect step measurement methods are likely to improve with repeat measurements and benefit from improvements in monitoring techniques and comprehension of fluvial processes.

The following performance targets are based on stand conditions providing self-replenishing supplies of wood to channels unaffected by land use activities:

Riparian forest characteristics:

TPA>20" dbh, 20-50;
TPA 9-20" dbh 70-l 10
TPA 3-9" dbh, 160-200
TPA <3" dbh, 200-400
Ratio of ~1:2:4:8 among the four diameter classes

Wood

A range of 7 to 13 SWD pieces/bfw and a range of l-2 LWD pieces/bfw are needed to retain sediment in small, steep streams. In terms of wood volumes, a range of 0.20-0.30 ft^3/bfw of SWD (all 4 zones), and a range of 7 to 18 ft^3/bfw of LWD (all four zones) are needed for sediment retention. For zones 1 and 2 (in-channel LWD and SWD), data indicates that a range of 3 to 5 ft^3/bfw provide functional sediment retention.

Overall, these performance criteria are based on information gathered on five unmanaged, reference sites, and seven managed sites with little significant alteration by human activity, and four managed sites affected by human activity in the Ahtanum, Cowiche, and Tieton basins. Extrapolation of these results to other mountainous forests requires prudence and caution. The assumptions underlying WISSP and CRSN may not apply to other situational categories.

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1. Introduction

In the context of unfinished LWD prescriptions for the Ahtanum watershed analysis, information was needed to understand the functional roles of wood in small, steep streams (type 4 and 5 streams, primarily first and second order channels).

The Channel Reference Site Network (CRSN, found in unmanaged landscapes) and Wood In Small Streams Project (WISSP, found in managed landscapes) are designed as long term experiments for measuring functions of in-channel wood in small, steep streams. The initial set of CRSN and WISSP sites are found in the Ahtanum, Cowiche and Tieton basins, west of Yakima, and include both fish- and non fish-bearing reaches of channel networks. This report summarizes findings of work performed for WDOE CCWF grant # G 9600333 during 1998. and of work performed in 1997 funded from other sources.

1.1 Strategy and rationale

The monitoring strategy includes selecting a representative sample of managed and unmanaged stream sites, establishing permanent measurement plots for repeat visits over time, collecting data in several reaches along the longitudinal profiles of selected streams, assuring data quality and integrity, generating information, and repotting the findings to stakeholders. Data sets in managed and unmanaged landscapes allow comparisons to reference or baseline environments that have natural disturbance regimes (i.e., a frequency, intensity, and duration of disturbances unaffected or minimally affected by human activity). This comparison assumes that small, steep channels with natural disturbance regimes, in unmanaged areas, have desirable performance characteristics (i.e.. ample functional wood in-channel, self-sustaining supplies of wood from upstream and near channel sources).

The rationale for this approach is to produce results that increase certainty and confidence, and directly support decision making to keep, change, or delete interim LWD prescriptions.

2. Project description

2.1 Project goal

The goal of the project is to 1) describe the functional roles of wood in small streams: 2) document the relationship, if any, between riparian vegetation and small stream channels, especially wood recruitment into channels: 3) support decisions for building consensus about the functional roles of wood in small streams; and 4) provide information that will help the prescription team come to closure on three interim prescriptions for CMRs 8. 12, and 13.

2.2 Monitoring questions and hypotheses

The approach for accomplishing the project goal is to pose a series of critical questions. Testable hypotheses have been developed for use in answering each question. The critical questions, hypotheses, and hypothesis testing procedures are summarized below.

1) How many functional pieces of channel wood are needed to provide the function of sediment retention in small, steep streams?

Null hypothesis: There is no significant relationship between in-channel wood parameters (wood volume per bankful width) and number of steps or volume of sediment storage.

Test procedure: Regression analysis will be used to test for significant relationships between: 1) in-channel wood volume and total number of steps, and 2) in-channel wood volume and total volume of sediment in storage, using pooled data from all study sites (except Pine).

2) How much riparian vegetation is needed to provide adequate wood input to the channel to maintain in-channel wood at levels needed to avoid loss of sediment retention function'?

Null hypothesis: There is no significant relationship between riparian stand condition parameters (TPA <3" dbh, TPA 3-9", TPA 9-20", TPA > 20", TPA all sizes) and number of steps or volume of sediment storage.

Test procedure: Regression analysis will be used to test for a significant relationships between riparian stand condition parameters and: 1) in-channel wood volume, 2) total number of steps, and 3) total volume of sediment in storage, using pooled data from all study sites (except Pine).

3) Is there a relationship between past timber harvest in riparian stands and riparian stand condition, in-channel wood loading, and sediment retention?

Null hypothesis: There is no significant difference between managed and unmanaged riparian stands and: 1) riparian stand condition parameters (TPA <3" dbh, TPA 3-9", TPA 9-20", TPA > 20", TPA all sizes), 2) and number of steps or volume of sediment storage.

Test procedure: Regression analysis will be used to test for a significant relationships between riparian stand condition parameters and: 1) in-channel wood volume, 2) total number of steps, and 3) total volume of sediment in storage, to compare data from unmanaged and managed study sites (except Pine).

2.3 Evaluation approach

The evaluation approach involves testing the first two hypotheses above to determine if there are significant relationships between the channel function of sediment retention, in-channel wood loading, and riparian stand conditions. Then, the third hypothesis will be evaluated to determine if there is a relationship with past management of riparian stands. Information on these relationships will then be used to develop recommendations for use by the prescription team.

3. Methods

Sixteen stream channels were measured during 1997 and 1998 following methods and procedures detailed below. Data were collected in digital form on channel geometry, channel longitudinal profile, in-channel wood, sediment obstructions, and riparian vegetation, Digital data collection was enabled using FieldWorker Pro mobile data collection software (Browne and Browne, 1998), running on Newton hand-held computers manufactured by Apple Computer, Inc. Use of enabling technologies eliminated the error prone step of creating machine-readable data from paper data forms.

3.1 Sampling design

3.1.1 Sampling locations

Both CRSN and WISSP sites are steep, narrow, and confined. with cobbly/bouldery beds and in-channel wood. CRSN sites will be found in areas with natural disturbance regimes. WISSP sites will have management-induced disturbance regimes.

Initially, CRSN sites were located near and within the boundary of the Ahtanum watershed analysis area (3 WAUs: Darland Mountain. Foundation Creek, Cowiche). Two CRSN sites were located in the nearby Tieton Basin, to the west of the three primary watershed administrative units. WISSP sites were located within the 3 WAUs of the Ahtanum watershed analysis area. Map 1 shows the locations of the measurement sites.

3.1.2 Site selection

Review of several information sources (e.g.. people. paper [maps. aerial photos]). followed by field reconnaissance yielded a superset of candidate segments. Visits to these potential segments provided inform&ion as to their suitability for inclusion into CRSN and WISSP. Segments selected for monitoring had to meet several criteria, including basin size (200-2000 acres). bankful width (<15 feet), valley width (<25 feet), confinement (tight), channel gradient (30% < S >5%), presence of wood steps (>2 per 10 CW), presence of wood (in zones I, 2, and 3). and cobbly bed materials (not bedrock controlled).

3.1.3 Sub-sampling

A single 150 foot reach was selected for taking measurements in each segment. Four potential measurement reaches are randomly chosen within a length of channel that is greater than 50% of the entire channel segment length. All the potential measurement reaches were visited by walking or wading through the channel and valley bottom. The purpose of this intensive reconnaissance is to determine representativeness of the four potential measurement reaches, compared to observed conditions of the entire length of channel segment. Each of the four potential measurement reaches had to meet the criteria listed above. While strong preference is given to the first reach that was randomly chosen to eliminate bias, the actual reach chosen for CRSN or WISSP was based on representativeness. Channel reaches that strongly represent typical conditions are preferred. Poorly representative reaches are not chosen for measurements.

3.1.4 Sample size

Ten sites were measured in 1998. During 1997, six sites were measured. In total, sixteen sites were measured. Five of the sixteen sites are CRSN sites, in unmanaged landscapes. Eleven of the sixteen sites are WISSP sites. in managed landscapes.

3.1.5 Frequency of measurements

Sites will be measured on five year intervals, or more frequently in response to events that trigger inputs of energy, sediment, water, and wood that could cause a significant change in riparian forest structure, in-channel wood functions, or channel conditions.

3.2 Sampling procedures

3.2.1 Woody debris

Sampling methods for large woody debris (LWD) conform to published literature [*Ambient Monitoring Program Manual* (Schuett-Hames et al., 1994)].

A 'new' sampling method was created for measurements of small woody debris (SWD). All channel wood was measured for wood pieces smaller than LWD, down to minimum dimensions of 1 inch diameter and 1 foot length.

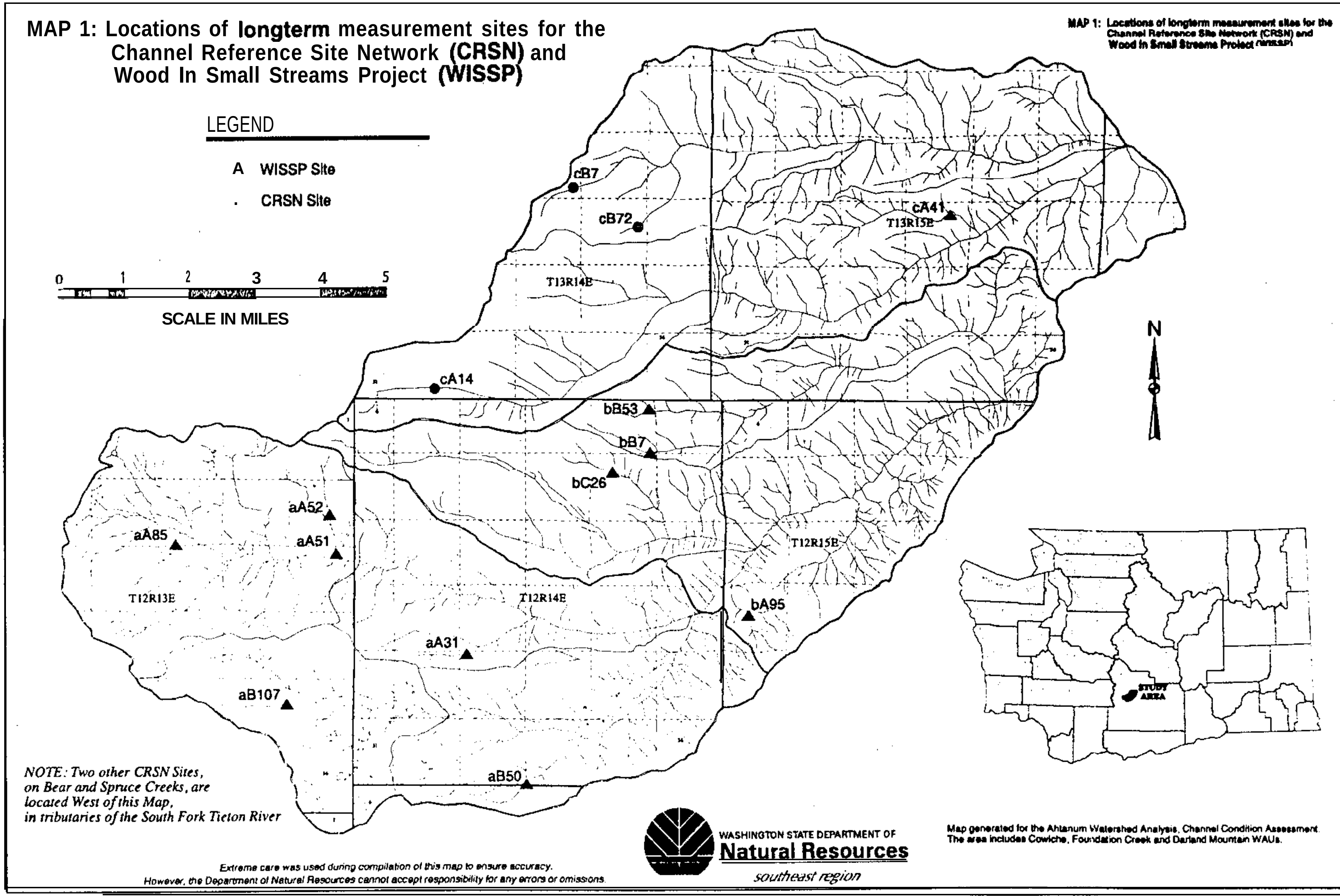
3.2.2 Sediment obstructions

In the context of this document, a 'step' refers to the vertical face or sloping riser found at the downstream edge of an obstruction. A step infers height (or elevation drop) and a mixture of building materials such as wood. rock, bedrock, soil. and other materials.

A 'wedge' refers to deposits of coarse and fine sediment collected behind (upstream of) step faces. A wedge infers volume. In the context of this document. a 'sediment obstruction' has the same meaning as the terms 'sediment wedge' or 'wedge'.

Each qualifying obstruction or wedge was categorized by face composition (e.g., percentage of step face height composed of wood, rock, or other materials), and the obstruction dimensions were recorded. The height, length, and average width of sediment obstructions were measured. Measurements of obstructions are based on methods proposed'by Platts et al. (1983). Platts et al. (1983) define an obstruction as any material in the channel causing sediment accumulations because of discontinuities in channel gradient, and include: logs (more than 5 cm in diameter), rocks, roots, stumps, and other debris including branches, twigs. and leaves. Volumes of

MAP 1: Locations of longterm measurement sites for the Channel Reference Site Network (CRSN) and Wood In Small Streams Project (WISSP)



sediment wedges were calculated as the product of step height, average width, and length, then halved (divided by two) to approximate the shape of a wedge.

To be classified as an obstruction and qualify for measurement and inclusion into the dataset, all of the following minimum dimensional criteria must be met:

- height (H) 20 cm (0.66 feet)
- length (L) 60 cm (1.97 feet)
- average width (W) 30 cm (0.98 feet)

While only measuring steps meeting all three dimensional criteria was initially intended, numerous low steps (not meeting the minimum height criterion) were measured and included in the dataset. The heights of steps labeled 'too low' in Table 4 ranged from 0.45 to 0.66 feet.

Some small, non-qualifying obstructions (not meeting the minimum height criterion) were measured and included in the dataset. "Small" sediment obstructions that span the entire channel width may play an important role in the overall dynamics of sediment storage and transport. Megahan reported that eliminating the smaller obstructions greatly reduces the work and causes a loss of only about 10 percent of the total volume of stored sediment (Platts et al., 1983).

Channel cross-sections were established with permanent surveying monuments at four permanent transects within each measurement reach. Tape distance and bed elevation were measured along each transect.

3.2.3 Riparian stand conditions

Riparian forest characteristics were measured in permanent plots, extending 75 feet (slope distance) away from the right and left channel edges. The total plot area is approximately 0.52 acres. Riparian forest mensuration includes double tagging each tree (at ground level and at breast height), determining location (distance up valley of downstream edge of measurement reach; hillslope distance away from the channel edge), measuring stem diameter, and classifying trees by species, recruitment potential, and vigor.

4. Results

The Pine data set was removed from consideration of the following regression analyses because it is deemed to be an outlier or anomaly: it has no steps, very little in-channel wood, and is found in a warm dry site (ponderosa pine, Douglas-fir plant association group). Over 160 regression analyses were performed on ten (n=10) managed sites and five (n=5) unmanaged sites. Data Desk statistical software. running on a G3 Macintosh PowerPC, enabled exploratory data analysis (Velleman, 1996).

4.1 Data presentation

Data on riparian vegetation, in-channel wood, steps, and sediment sedge volumes are presented in tabular form. The tabular displays are excerpts from Table A 1, the entire data matrix. Discussion of results from data analyses follow presentation of data.

4.1.1 Riparian vegetation

Table'1 describes stand structure at sixteen permanent sample plots. Table A2 presents summary statistics. Stand age structure and patterns result from past perturbations, influenced by site and soil quality characteristics.

Table 1. Riparian forest conditions at sixteen WISSP and CRSN sites.

	Gray	Tea	Meadow	Pine	Found	McClain	Darla	Trail	Cultus	Clover	Nass	Olds	Bear	Wren	Spruce	Cowiche
all[1]	300	385	292	64	389	471	1029	623	404	356	531	317	734	462	2146	786
>20"[2]	0	2	4	2	8	29	8	29	21	33	25	27	73	44	46	38
9-20"[3]	4	71	33	33	44	96	133	138	98	92	117	50	304	107	188	119
3-9"[4]	104	160	56	15	131	179	454	215	208	150	200	165	165	202	665	254
<3"[5]	192	152	200	14	69	167	435	240	77	80	188	71	192	107	1246	375
age[6]	10-20	15.70	2-50	15-50	20-100	60.100	40.100	40.90	40.140	60-100	40.100	80-140	80-140	80-140	80-140	80-140
site type[7]	W	W	W	W	W	W	W	W	W	W	W	C	c	c	c	c

[1] trees per acre, entire stand [2] trees per acre >20" dbh [3] trees per acre 9-20" dbh [4] trees per acre 3-9" dbh
[5] trees per acre <3" dbh [6] estimated age range, years [7] WISSP or CRSN

Pacific silver fir dominates plant association groups in all sites except Bear, Meadow and Pine. Pacific silver fir is the most abundant species in the tree regeneration layer in mixed conifer stands for cold and moist CRSN and WISSP sites. It is one of the most shade tolerant and environmentally restricted conifers in the investigation area and is found only in areas of strong maritime climatic influence, usually within a few miles of the Cascade Crest. Pacific silver fir is on sites that rarely if ever experience soil drought. Mature stands characteristically have two or more tree canopies. with species such as Douglas-fir and western larch forming a tall, emergent canopy above a layer made up of more shade-tolerant and slower-growing species such as Pacific silver fir, western hemlock, and grand fir. Heavily ground-shaded stands are characterized by very low understory plant cover, as in McClain. Very dense canopies, deep litter layers. and low light levels at the forest floor all appear to reduce the abundance of shrubs and herbs. Heavy grazing by elk (or cattle) reduces cover and species composition in at least some sparse stands. Catastrophic, stand replacing fires occur at intervals of 200-400 years (Agee, 1993).

Three sites were not dominated by Pacific silver fir. One site, Bear, was dominated by Alaska yellow cedar. The two remaining sites, Meadow and Pine were warm, dry sites growing ponderosa pine and Douglas-fir. Ponderosa pine is a major seral species in eastern Washington, and is usually restricted to warmer and drier sites, often in association with Oregon white oak and Douglas-fir. Tea was in a transitional area. with a fir, pine. Douglas-fir mixture. Douglas-fir is the climax tree species on habitats either too dry for, or beyond the geographic range of, more shade-tolerant species such as western hemlock. western redcedar, or subalpine fir.

Considerable variation exists in the age-height-diameter relationship for riparian stands in the Ahtanum, Cowiche, and Tieton basins. Tree ring counts done on stumps at a very high elevation site (Bear) had trees that were small for their age and very old (0.25 feet dbh, 107 years: 1.7 ft dbh. 220 years: 2.2 feet dbh. 387 years: 3.3 feet dbh, 348 years: 3.4 ft dbh. 405 years). By contrast, tree growth was much more rapid at the Meadow site, in an intensively managed ponderosa pine-Douglas-fir plant association group (e.g., 0.41 ft diameier, 3 1 years: 0.8 ft, 27 years: 0.72, 44 years; 1.05ft, 43 years: 1.85 ft, 78 years: 1.93 feet, 91 years: 1.65 ft. 100 years).

4.1.2 Wood in channels

Piece counts are summarized in Table 2. Table A?. presents summary statistics for piece counts. The mean LWD pieces per bankful width was 2.10 for unmanaged sites compared to 0.98 for managed sites. Using the watershed analysis rating system (good > 2. fair 1-2. poor < 1), 3 of 5 CRSN sites rated good. and 2 fair. One WISSP site rated good, 5 fair. and 5 poor.

Six WISSP sites had LWD piece counts over 1 piece per unit length of bankful width that are comparable or slightly lower than that for the five CRSN sites. LWD piece counts in the five CRSN sites were similar to or above those of five heavily forested WISSP sites. SWD piece counts for the eleven WISSP sites were highly variable; four sites had the lowest SWD counts of all sixteen sites. The highest SWD piece count in a WISSP site was found in the Nass site:

numerous broken branches from a large tree laying on the channel bed, along the channel axis. accounted for this situation. SWD piece counts in the five CRSN sites were highly variable; the first and third highest SWD piece counts were found in Spruce and Cowiche sites; numerous broken branches from fallen trees over and in the channel accounted for this situation.

Wood counts by themselves lack information value as to current or future hydraulic function. Data that describe wood position within the channel's bankful wetted perimeter (i.e., zone 1 and 2) offer more information on wood function and usability, in a hydraulic or habitat sense, than wood data based only on piece counts.

Wood location is referenced in relation to four zones of influence. Zone one wood is in contact with the channel bed and flowing or standing water. Zone two wood is located above zone one wood, within the bankfull channel, and below the elevation of bankfull flow. Zone three wood is located directly above the wetted perimeter of the bankfull channel. Zone four wood is located to the left and right of the points of bankfull flow; zone four wood is near the wetted perimeter of the bankfull channel but not above it.

Table 2. Wood enumeration (LWD and SWD) for WISSP and CRSN sites.

moniker	Gray	Tea	Meadow	Pine	Found	McClain	Darla	Trail	Cultus	Clover	Nass	Olds	Bear	Wren	Spruce	Cowiche
SWD#/bfw[1]	1.4	5.7	7	0.79	1	3.6	9.5	4.1	1.8	6.6	29.3	3.2	6.6	2.3	29.7	24.2
LWD#/bfw	0.13	0.44	0.21	0.63	1.09	0.28	1.9	1.2	1.4	2.07	1.4	2.6	1.7	1.5	2.4	2.1
SWD #/ft[2]	.182	.633	.654	.125	.084	.507	1.01	.366	.132	.593	1.99	.427	1.05	.183	2.03	1.65
LWD #/ft	.017	.073	.02	0.1	.092	.037	.202	0107	.103	.143	.095	.373	.207	.119	.164	.143
SWD:LWD[3]	10.6	12.9	33.3	1.3	0.92	13.6	5.0	3.4	1.3	4.2	20.9	1.1	5.1	1.5	12.4	11.5
LWD:SWD	0.09	0.06	0.03	0.8	1.09	0.07	0.2	0.29	0.76	0.24	0.05	0.86	0.2	0.65	0.08	0.09

'pieces per bankful width 'pieces per unit channel length [3]ratio of piece counts

Wood volumes and channel locations are summarized in Table 3. Table A2 presents summary statistics for wood volume and location. The mean total wood volume was 18.02 ft^3 for unmanaged sites vs. 6.87 ft^3 for managed sites.

Total wood volumes (combined SWD and LWD volumes) were high in four of five unmanaged CRSN sites (Spruce. Bear. Wren, Olds); their wood volumes far exceeded that of most WISSP sites (e.g., Darla. Nass), except Clover. WISSP site Clover had the second highest total wood volume of the sixteen sites: this site also has a riparian forest stand similar in structure and composition to unmanaged stands. The four lowest total wood volumes occurred in recently logged sites (Gray, 0.95 ft^3/bfw; Tea, 2.3; Meadow, 2.1; Pine, 0.65). Skidding activities (in-channel or across channel) highly altered channel conditions of Meadow and Tea. The Gray site is highly affected by road proximity and may have been cleared of in-channel wood during timber harvest operations.

Values for comparative amounts of in-channel wood, as expressed by volumetric ratios (i.e.. LWD volume : SWD volume) had two channels exceeding 150 (Clover-166.2: Wren-184 [CRSN]), four channels exceeding a ratio of 50 (Trail-94. Found-55, Bear-88 [CRSN], Cowiche-50 [CRSN]), five channels with ratios between 30 and 45 (Olds-44 [CRSN]: Spruce-35 [CRSN]. Pine-35: McClain-38, Darla-29, Nass-33), and three channels with ratios of less than 10. Considered by themselves, these values indicate that large woody debris (i.e.. pieces with dimensions exceeding 4 inches [10 cm] diameter and 6 feet length [2 m]) appear to be the dominant piece types.

Table 3. Wood volume and zonation for WISSP and CRSN* sites.

moniker	Gray	Tea	Meadow	Pine	Found	McClain	Darla	Trail	Cultus	Clover	Nass	Olds	Bear	Wren	Spruce	Cowiche
total volume[1]	7.3	20.6	22.4	4.1	76.3	66.2	147.7	114.3	45.3	226.1	137.3	186.6	195.6	261.1	220.6	81
volume, ft^3/bfw	0.95	2.3	2.1	0.65	6.6	8.6	15.7	10.2	3.3	15.7	9.3	24.9	23.9	20.7	15.1	5.5
LWD ft^3/bfw[2]	0.73	0	1.9	0.62	6.5	8.6	15.2	10.1	3.2	15.6	9.1	24.3	23.6	20.6	14.7	5.4
SWD ft^3/bfw[2]	0.22	0.21	0.23	0.02	0.12	0.23	0.53	0.11	0.14	0.09	0.27	0.55	0.27	0.11	0.43	0.11
LWD:SWD[3]	3.3	10.1	7.9	35.1	54.9	37.9	26.5	94.4	22.97	166.7	33.33	43.9	88	104.2	34.6	49.6
Z1 vol, ft^3/bfw	0.16	0	0	0	0.56	0.15	1.15	0.96	0.235	2.66	0	0.16	1.76	3.99	3.27	0.50
Z2 vol, ft^3/bfw	0.34	1.96	1.89	0.27	2.59	1.71	6.5	0.56	0.24	1.17	6.64	2.6	2.65	5.07	2.62	1.2
Z3 vol, ft^3/bfw	0.09	0.02	0.09	0.10	1.33	1.03	0.76	1.65	0.93	1.66	0.35	6.77	2.99	3.41	2.01	0.52
Z4 vol, ft^3/bfw	0.34	0.26	0.11	0.27	2.11	5.95	7.29	6.64	1.93	10.0	2.12	15.1	16.3	6.2	7	3.29
Z1+Z2:TOTAL[3]	0.55	0.67	0.9	0.42	0.48	0.21	0.49	0.15	0.14	0.26	0.73	0.12	0.19	0.44	0.4	0.31
Z3+Z4:TOTAL[3]	0.46	0.13	0.09	0.56	0.52	0.79	0.51	0.65	0.66	0.74	0.27	0.66	0.61	0.56	0.6	0.69
Z1+Z2:Z3+Z4[3]	1.2	6.53	9.1	0.73	0.91	0.27	0.95	0.17	0.17	0.34	2.74	0.14	0.24	0.76	0.68	0.45
Z1+Z2+Z3:Z4[3]	1.63	7.2	17.7	1.42	2.12	0.48	1.16	0.49	0.73	0.57	3.39	0.64	0.47	1.51	1.16	0.68
Z1+Z2+Z3:TOT[3]	0.65	0.67	0.95	0.59	0.66	0.33	0.54	0.33	0.42	0.36	0.77	0.39	0.32	0.6	0.54	0.4

[1]volume units are cubic feel, and include wood of all sizes inzones 1, 2. 3, and 4

[2]volumes expressed for zones 1, 2, 3. and 4,in units of cubic feet wood per unit length (ft) of bankful width

[3]volumetric ratio, for all wood sizes(i.e., SWD and LWD)

*CRSN sites(unmanaged) include Olds, Bear. Wren, Spruce, and Cowiche. The eleven other sites are WISSP sites (managed)

The highest amounts of hydraulically active wood (ft^3/bfw. located in zones 1 and 2. within the channel's bankful wetted perimeter) are found in 3 managed sites (Darla, Clover, and Nass) and 3 unmanaged sites (Wren, Spruce, and Bear).

Wood is well organized or structured in Darla, Clover, and Nass (managed sites), and Bear, Wren. and Spruce (unmanaged sites) for providing channel functionality. These six sites had high zone 1 and 2 volumes, high wood piece counts in step faces, high number of steps, very high wood step elevation drops, and above average to high amounts of sediment wedge volumes compared to all other measurement sites,

In three unmanaged sites, Bear, Wren, and Spruce, wood is similarly well organized for providing channel functionality. A difference between Bear, Wren and Spruce compared to Darla; Clover, and Nass is higher total wood volumes in Bear, Wren and Spruce.

In addition, the organization of wood (piece types rafts, ramps, and bridges, and their spatial arrangement in zones 1, 2, 3. and 4) is measured by indicators such as step quantity. step elevation drop. and sediment wedge volume. Discussion of results from these indicators follows.

4.1.3 Step quantity and quality

Total numbers of steps ranged from 0 (Pine) to 28 (Bear). Gray had the most rock steps (100% rock step faces). Bear (3.41 stepsibfw, CRSN site) and Gray (3.25 steps/bfw, WISSP site) had the highest number of steps per bankful width. Table 4 summarizes step data. Table A2 presents summary statistics on steps.

Table 4. Step data for WISSP and CRSN sites

moniker	Gray	Tea	Meadow	Pine	Found	McClain	Darla	Trail	Cultus	Clover	Nass	Olds	Bear	Wren	Spruce	Cowiche
total # of steps[1]	25	14	14	0	8	15	21	17	11	20	16	22	26	12	23	7
steps too low[2]	4	4	7	0	1	3	4	2	4	5	2	2	a	4	3	2
steps/bfw[3]	3.25	1.56	1.31	0	0.67	2	2.23	1.52	0.61	1.36	1.09	2.93	3.41	0.95	1.56	0.46
100% wood[4]	1	2	0	0	1	5	9	5	2	6	6	10	9	3	8	5
100% rock[5]	11	1	0	0	1	3	2	6	. 2	1	0	1	4	2	6	0
% wood faces[6]	16.4	45.1	47.5	0	61	51	63.3	42.1	46	66	77.5	66	71.9	54	49.6	95
% rock laces	80.6	47.7	52.5	0	36	49	36.7	57.9	54	34	22.5	34	29.1	46	50.4	5
% other material	2.6	7.1	0	0	3	0	0	0	0	0	0	0	0	0	0	0
piecesinsteps	19	20	19	0	6	30	33	14	19	41	30	39	52	18	61	18
SWD % face[7]	64	65	100	0	17	60	64	36	68	68	70	54	72	44	72	56
LWD % face	16	35	0	0	83	40	36	64	32	32	30	46	26	56	28	44
decay in face[8]	4.95	4.6	3.42	0	4.67	4.6	4.26	4.21	4.11	3.56	4.23	3.59	3.89	3.36	4.16	3.78

'total number of steps in the measurement reach. Steps are structural features (also known as sediment wedges or sediment obstructions) located within the perimeter of the bankful channel, formed by wood, rock. bedrock. soil. other materials and structural features. Dimensional guidelines for classification as a step are. al a minimum, 0.66 feet height, 0.97 feet width, and 1.97 feet length.

'While these steps did not meet the minimum height requirement. 0.66 feet, these steps were measured for inclusion into CRSN and WISSP because of their potential for yielding useful information on the roles of small woody debris in step maintenance and sediment storage.

[3]number of steps per bankfull width

'number of steps that have faces 100% wood

'number of steps that have faces 100% rock

[6]the percentage of the entire population of step faces that are composed of wood

'the percentage of small woody debris in step faces that are composed of wood

'decay class values are averages. and range from 1 (fresh. least decayed) lo 5 (old, most decayed)

Three distinct sets of values are found for total pieces of wood in step faces (the steep risers forming the downstream edge of a step, wedge, or obstruction). CRSN sites Bear and Spruce had over 50 pieces forming step faces: their channel gradients and bankful widths are 19.2%8.2 feet. and 10.8%-14.2 ft, respectively. Four WISSP sites (Darla, McClain, Nass, Clover) and one CRSN site (Olds) had 30-40 pieces forming step faces. The remaining five measurement sites had piece counts forming step faces that ranged from 14 (Trail) to 20 (Tea). Only one site (Found) had LWD-dominated (83%) step faces, Trail had 64% of its wood step faces composed of LWD. Ten sites had >60% of their wood step faces composed of SWD. Meadow had 100% of its wood step faces composed of SWD.

Three CRSN sites showed a consistently high number of wood steps with 100% wood faces (R-Spruce; 9-Bear; 10-Olds). The widest range of step face materials composition (95% wood:5% rock) is found in the Cowiche site. on the mainstem of South Fork Cowiche Creek.

WISSP sites McClain. Darla. Trail, Cultus. Clover, Nass had similar step quantities and a similar number of steps constructed of 100% wood faces compared to the five unmanaged CRSN sites.

Seven channels had greater than two-thirds of step face heights formed by SWD. SWD appears to be a significant building material for wood step faces in most of the measurement sites. Created for this analysis to test the hypothesis that SWD is an important structural element of small. steep streams, the percent of step faces in SWD appears to be a valuable indicator. Repeat measurements over time will test the SWD-in-steps hypothesis.

Seven of sixteen sites had step face compositions that were nearly an even mix (50:50) of wood (small and large woody debris) and rock (gravels. cobbles. boulders). Table 4 shows this data summary. Very high percentages of wood step faces are found in three channels (95:5 for Cowiche. 77:23 for Nass. 71:29 for Bear) with channel gradients of 5.4, 11.8, and 19.2%.

respectively.

The highest percentage (81%) of rock faces is found in Gray, along with the highest number of rock steps (1 1). **Gray also has the highest amount of vertical drop (25 feet)** associated with rock steps forming at least 70% of step faces.

4.1.4 Sediment wedge volume

Values for stored sediment associated with sediment wedges ranged from 23 (Spruce) to 0 (Pine) cubic yards. Table 5 summarizes sediment obstruction data. Table A2 presents summary statistics.

Table 5. Sediment obstruction data for WISSP and CRSN sites.

moniker	Gray	Tea	Meadow	Pine	Found	McClain	Darla	Trail	Cultus	Clover	Nass	Olds	Bear	Wren	Spruce	Cowiche
total volume[1]	6.2	3.3	3.1	0	16.3	4.9	16.7	6.7	5.3	15.3	22.2	5.2	10.7	6.6	22.7	14.1
ave volume	0.39	0.56	0.17	0	2.22	0.33	1.17	0.39	0.24	0.94	1.39	0.4	0.45	0.42	0.99	2.35
max volume	0.65	1.75	2.09	0	5.67	1.32	4.2	1.44	0.62	3.07	13.7	1.31	1.15	1.15	4.16	5.64
min volume	0.05	0.02	0.01	0	0.13	0.05	0.3	0.09	0.08	0.06	0.07	0.04	0.04	0.03	0.03	0.19
volume/bfw[2]	0.61	0.37	0.29	0	1.54	0.65	1.99	0.59	0.39	1.06	1.51	0.69	1.31	0.63	1.56	0.96
ave H:L[3]	0.31	0.3	0.27	0	0.26	0.35	0.28	0.42	0.53	0.24	0.21	0.22	0.26	0.24	0.17	0.06
max H:L	0.67	0.7	0.64	0	0.49	0.95	0.7	1.65	1.6	0.46	0.46	0.66	0.5	0.66	0.46	0.15
min H:L	0.09	0.13	0.03	0	0.07	0.13	0.06	0.08	0.01	0.09	0.06	0.06	0.08	0.09	0.06	0.04

[1]expressed in units of cubic yards. Volume of sediment storage by obstructions or wedges is estimated by using the equation: sediment storage volume = [(Height at step face) x (average Width) x (Length)]/2

[2]total volume expressed in units of cubic yards per bankful width

[3]The Height:Length ratio is a dimensionless ratio that characterizes the shape of sediment wedges.

The highest volumes of sediment were found in four sites: Spruce (22.7 yd^3), Nass (22.2), Found (18.3), and Darla (18.7). The precise ages of these sediment wedges are unknown. Most steps appear to be 10-30 years old, based on the decay condition of wood step faces. The precise age of rock steps is unknown, but are likely to have higher longevity than wood steps (20-200 years?) due to the lack of deterioration, decay, and damage attributable to woody materials in step faces. While the state of our knowledge of sediment wedges is incomplete, repeat measurements of CRSN and WISSP sites can test hypotheses about sediment supply. step durability, and step functions over time.

4.2 Data analysis

Analyses of pooled data (15 sites without Pine) and split data (5 unmanaged sites, 10 managed sites without Pine) are presented in sections 4.2.1 and 4.2.2. Section 4.2.1 presents results for channel features. Section 4.2.2 presents results for riparian vegetation features. Section 4.2.3 presents multivariate results for channel and riparian vegetation features.

Comparisons of wood and riparian vegetation features and channel functions are presented in sections 4.2.3 and 4.2.4 for five unmanaged sites and ten managed sites.

4.2.1 Relationships between wood characteristics and quantity of steps and stored sediment

Exploratory data analyses were initially performed on pooled data (n=15, without Pine data) relationships between in-channel wood (zone 1 and zone 2 SWD and LWD, lumped together) predicting:
1) the number of steps per bankful width
2) the number of 100% wood-faced steps per bankful width
3) total obstructed sediment volume.

Overall, there were weak relationships for zone 1 and 2 wood predicting the number of steps per bankful width (adj. r^2 = -7.4%), the number of 100% wood-faced steps/bfw (adj. r^2 = 13.3%). and total obstructed sediment volume (adj. r^2 = 3 1.8%).

In-channel wood (zones 1 and 2) was a very poor predictor of number of steps and number of wood steps for 5 CRSN sites and 10 WISSP sites (without Pine).

Channel gradient alone in 10 WISSP sites was an excellent predictor of number of steps (adj. r^2 = 93.4%; F=129). For five CRSN sites, channel gradient was a fair predictor (adj. r^2 = 66.6%. F=8.97).

In- and near-channel wood (zones I, 2, 3) was a fair predictor (adj. r^2 = 61.2%; F=15.2) of the number of 100% wood-faced steps for 10 WISSP sites (without Pine). For five CRSN sites, zones 1.2, and 3 wood was a poor predictor.

In-channel wood (zones 1 and 2) was a fair predictor (adj. r^2 = 69.2%: F=21.2) of total obstructed sediment volume for 10 WISSP sites (without Pine). Zones 1, 2, and 3 wood was also a fair predictor (adj. r^2 = 72%; F=24.2). For five CRSN sites, in- and near-channel wood was a very poor predictor.

4.2.2 Relationships between riparian vegetation characteristics and in-channel wood, steps and sediment storage

Exploratory data analyses were initially performed on pooled data (n=15, without Pine data) relationships between total number of trees per acre (all four size classes) predicting:
1) the number of steps per bankful width
2) the number of all wood steps per bankful width
3) total obstructed sediment volume.

Overall, there were weak relationships for total trees per acre (all size classes) predicting zone 1 and 2 wood volume (adj. r^2 = 10.0%), the number of steps per bankful width (adj. r^2 = -7.7%), the number of 100% wood-faced steps/bfw (adj. r^2 = 13.6%). and total obstructed sediment volume (adj. r^2 = 32.0%).

Calculating regression equations for each of the four stand size classes (TPA>20" dbh, TPA 9-20" dbh, TPA 3-9" dbh. and TPA <3" dbh) also yielded weak relationships between dependent and independent variables.

The relationships between one predictor (total TPA) and three respondents (#steps. # 100% wood-faced steps. sediment volume) yielded initial results from which to launch other analyses.

Total trees per acre (all four size classes) was a poor predictor of number of steps and number of wood steps for 5 CRSN sites and 10 WISSP sites (without Pine).

Total trees per acre was a poor predictor (R^2 adj. = 33.1%: F=5.46) of total obstructed sediment volume for 10 WISSP sites (without Pine). For five CRSN sites, total trees per acre was a fait predictor (R^2 adj. = 65.7%: F=8.66).

4.2.3 Comparative relationships between wood characteristics and quantity of steps and stored sediment in managed and unmanaged sites

Multivariate analyses were performed on two datasets (managed sites, n=10; unmanaged sites, n=5), comparing relationships between in-channel wood and channel functions.

An additional sixty six tests were run with combinations of independent variables (zone 1 wood volume, or zone 2 wood volume, or various combinations of zones l-2-3-4) predicting step quantity (dependent or response variable).

The strongest regression relation (adj. r^2 = 99.9%) for unmanaged sites (n=5) involves number of steps as response variable and three predictors: channel gradient. TPA >20". and zone 2 wood volume.

The strongest regression relation (adj. r^2 = 96.4%) for managed sites (n=10) involves number of steps as response variable and three predictors: channel gradient, TPA >20", and zone 1 wood volume.

These results indicate that channels have steps where large trees (>20" dbh) and in-channel wood (zone 1 or zone 2 wood) exist. Steeper channels have more steps. This is consistent with higher energy dissipation functions required in channels with higher gradients to maintain stability.

Sixty four tests were run with combinations of independent variables predicting sediment volume (dependent or response variable).

The strongest regression relation (adj. r^2 = 99.7%) for unmanaged sites (n=5) involves sediment volume as response variable and two predictors: number of 100% rock steps and zone l-2-3 wood volume. These two predictors also yielded a strong relationship (adj. r^2 = 76.7%) for managed sites (n = 10).

These results indicate that rock (cobbles and boulders) exerts an important 'foundation' effect on sediment storage created, trapped, or forced by obstructions.

4.2.4 Comparative relationships between riparian vegetation characteristics and channel functions in managed and unmanaged sites

Multivariate analyses were performed on two datasets (managed sites, n=10; unmanaged sites, n=5), comparing relationships between riparian vegetation and channel functions.

An additional thirty two tests were run with combinations of independent variables testing prediction of in-channel wood volume.

The wood volume-riparian stand connection is exemplified by a very strong regression relation (adj. r^2 = 99.5%) between total wood volume (i.e.. wood in zones l-2-3-4) for unmanaged sites (n=5) and three predictors [basin size, TPA 3-9". TPA 9-20"].

For managed sites (n=10), the strongest regression relation (adj. r^2 = 64.4%) is exemplified by zone 1 and 2 wood volume (response variable) and three predictors [basin size, bankful width. and total trees per acre]. In comparison. for unmanaged sites (n=5). another very strong regression relation (adj. r^2 = 97.1%) is exemplified by zone 1 and 2 wood volume (response variable) and three predictors [basin size. bankful width. and TPA 3-9"].

Less zone l-2-3 wood volume in managed sites is consistent with fewer standing and downed trees in managed riparian stands that. over time. produce less wood for in-channel functions.

Riparian stands recently disturbed by logging create structural conditions that can't produce channel wood until processes such as senescence, mortality. branch shedding, wind throw, bank erosion, wood decay, root rot, disease and insect effects can act on standing trees and cause wood to enter or fall near stream channels.

The results also indicate the importance of watershed area or bankful width and smaller trees (3" to 9" dbh) for production and introduction of wood to stream channels. For reference conditions. at five sites having small basin areas [200-1000 acres], or small bankful widths [6-15 feet], small [3-9" dbh] and medium [9-20" dbh] sized trees produce enough wood (SWD and LWD) to create channel complexity and satisfy a variety of channel functions.

Other data explorations predicting number of steps per bankful width yielded good relationships between number of steps/bfw and three predictors (channel gradient, TPA 9-20", TPA 3-9") for 5 CRSN sites (adj. r^2 = 82.5%) and 10 WISSP sites (adj. r^2 = 93.7%).

4.3 Comparisons of central tendency statistics for managed and unmanaged sites

These results focus on several comparisons made on mean values from managed (n = 10) and unmanaged (n = 10) sites. Table A2 contains a variety of other central tendency statistics such as mode, range, median, and standard deviation.

Comparing mean values from unmanaged and managed sites (seeTable A2 in the appendix), mean zone 1 wood volume was 3.5 times greater in unmanaged sites, zone 2 was similar, zone 3 was 4.2 times greater in unmanaged sites, and zone 4 was 1.8 times greater in unmanaged sites than managed sites.

In addition, mean SWD volume was 1.4 times greater in unmanaged sites, mean LWD volume was 2.5 times greater, and mean SWD and LWD piece counts were 1.9 and 2.1 times greater in unmanaged sites than managed sites. From this initial dataset. it's evident that channel measurement sites in unmanaged forests have higher wood volumes and piece counts, regardless of piece size. This is consistent with higher stem densities in riparian forests surrounding unmanaged sites. particularly in large trees with numerous branch whorls. Branches are a major source of SWD. Fallen trees in densely shaded stands are often quite branchy; these branches can act as tines that comb out floating debris (rafts) or create wood piles. Branch wood was commonly found in many step faces.

Comparing mean values from 5 unmanaged and 10 managed sites (see Table A2), mean SWD drop and LWD drop in 100% wood faces were 1.7 and 1.3 times greater in unmanaged sites than managed sites. Mean drop in 100% rock faces was 1.4 times higher in managed sites. In addition. in unmanaged sites, the mean number of 100% wood steps was 1.8 times higher. the mean number of steps per bankful width 1.2 times higher, and the mean number of wood pieces in steps was 1.6 times higher than in managed sites. Data from WISSP site Pine was dropped from this analysis because it is stepless and wood poor. located in a ponderosa pine and Douglas-fir plant association group.

Comparing mean values from unmanaged and managed sites (see Table A2), mean sediment wedge volume was 1.13 times greater in unmanaged sites. and mean number of steps per bankful width were 1.18 times greater in unmanaged sites compared to managed sites. Mores steps equate to more obstructed sediment if obstruction shapes are similar (height:length ratios similar overall). though the differences in sediment volume and step count are minor. Omitted are discussion implications of data on height:length ratios, or. form factors for sediment obstructions; height:length ratios of obstructions are an experimental indicator whose utility will be tested after repeat measurements. (See Table Al for a list of mean morphometric data for all measured obstructions.)

For unmanaged sites (n=5), very strong regression relations (adj. r^2 > 95%) exist among two sets of predictors: I) SWD pieces. % wood face. % rock face: 2) LWD pieces. TPA 9-20", TPA < 3". In addition, for unmanaged sites. the predictors SWD pieces. TPA 9-20", TPA < 3" yielded an adjusted r^2 of 91.7% when regressed against total sediment volume.

Unmanaged stands have more trees in each of the four size classes that create conditions suitable for wood entry to channels. Mean values for trees per acre in four size classes (TPA <3" dbh. TPA 3-9", TPA 9-20", TPA >20") were 2.2. 1.6. I .9, and 2.9 times greater in unmanaged sites compared to managed sites (see Table A2).

Riparian stands recently disturbed by logging create structural conditions that can't produce channel wood until processes such as senescence, mortality, branch shedding, wind throw, bank erosion, wood decay, root rot, disease and insect effects can act on standing trees and cause wood to enter or fall near stream channels. Managed stands create structural conditions that maximize solar gain to canopies, reduce shading and competition for soil moisture. and maximize width and height growth rates. Without shading that occurs in stands with dense canopies, fewer branches senesce and shed to produce small woody debris for in-channel functions.

While the results of Table A2 indicate that dense, unmanaged stands create 2.4 times more in-channel and near-channel wood volume (zones l-2-3-4 mean volumes) per bankful width, sediment wedge volume (cubic yards per bankful width) and step quantity (number of steps per bankful width) are similar in unmanaged sites (n=5) compared to managed sites (n=10). Mean sediment wedge volume is nearly the same-13% higher- in unmanaged sites compared to managed sites. Mean step quantity is only slightly higher-18% higher- in unmanaged sites than in managed sites.

These slight differences in stored sediment volume and step quantity may be explained by repeated, strong flushing that affected all channels due to the record flood flows in 1974, 1977, and 1996. These floods acted as significant stressors that promoted wood flotation and in-channel movement, as well as wood input through tree fall due to bank erosion or channel lateral movement. While channels respond differently to regimes of water, wood. sediment, and energy. CRSN and WISSP sites may be adjusting to a conditions of net wood loss.

While the mean number of 100% rock steps is similar for unmanaged and managed sites, the mean number of 100% wood steps is 1.8 times greater for unmanaged sites; and the mean number of wood pieces in steps is 1.6 times greater in unmanaged sites. It appears that rock steps remain the fundamental building material for steps. Where rock and wood interact as step face formers. wood on top of steps that is oriented and firmly positioned to catch bedload sediments can greatly increase sediment trapping efficiency and ultimately, the amount of transient or long term sediment storage. In effect, a few pieces of wood may greatly affect determinations of sediment storage with crude, simple methods used in this project. The trade-offs between speed and accuracy become more apparent with deeper consideration of measurement methods for steps.

Crude methods used in measuring and calculating stored sediment volume may bias the results by forcing the assumption that all sediment obstructions are geometrically simple wedge shapes with simple to calculate obstruction volumes.

Obstructions shaped like low, flat pancakes (height:length ratios of < 0.25) with vertical faces storing thick. uniform deposits of fine sediment (sand and gravel) may yield under estimates of stored sediment volumes. Obstructions shaped like ramps (height:length ratios of > I .0) with long, gently sloping faces storing deposits of mostly coarse. mixed sediments (sand and gravel. with many cobbles and boulders) may yield over estimates of stored sediment volumes. These imperfect step measurement methods are likely to improve with repeat measurements and benefit from improvements in monitoring techniques and comprehension of fluvial processes.

5. Discussion

Discussion of results includes an overview, followed by responses to three monitoring questions. In the context of unfinished LWD prescriptions for the Ahtanum watershed analysis, information from this monitoring project was provided to Ahtanum prescription team members regarding channel sensitivity to wood functions in certain small, steep channels.

5.1 Overview of responses to monitoring questions

Wood in and near the channel is important for preserving, enhancing and maintaining channel function, especially obstructed sediment volume. Channels show varied sensitivities to wood functions depending on wood characteristics (size, volume, wetted perimeter location, durability), wood type (raft, ramp, or bridge), wood supply (import, input, storage. export), sediment supply, and perturbation regime. All channels had at least one significant and major stressor in common: a set of three, very high peak flows that occurred within the past 25 years (1974, 1977, 1996).

It is likely that all WISSP and CRSN channels have historically low amounts of wood due to repeated, strong flushing. Unmanaged sites tend to have more well placed wood, with reliable multisized wood supplies (from upstream and upslope sources) than managed sites. More organized, well placed wood provides more channel functions such as roughness, sediment storage, diverse flow velocities leading to a variety of hydraulic and habitat conditions, complexity, and functional completeness.

5.2 How many functional pieces of channel wood are needed to provide the function of sediment retention in small, steep streams?

A range of 7 to 13 SWD pieces/bfw and a range of l-2 LWD pieces/bfw are needed to retain sediment in small, steep streams. In terms of wood volumes, a range of 0.20-0.30 ft^3/bfw of SWD (all 4 zones), and a range of 7 to 18 ft^3/bfw of LWD (all four zones) are needed for sediment retention. For zones 1 and 2 (in-channel LWD and SWD), data indicates that a range of 3 to 5 ft^3/bfw provide functional sediment retention. These ranges are based on data taken from Super Table 2.

Certain kinds of zone 4 wood are physically connected to zone 1.2, and 3 wood pieces and can offer the benefits of mass and ultimately stability for holding smaller wood pieces in place, and in some cases. pinning step face pieces in place. Large, high angle ramps have been observed to stabilize channel wood, sediments, and step faces. (Large, high angle ramps can also catch and release rafts and other floating debris over time.) In addition, the potential for these functions can be realized by zone 3 and 4 wood found in channel-spanning bridges. Numerous observations were made of zone 3 and 4 bridges in various states of collapse or 'failure' (mechanical breakage). Collapsed bridges form pairs of ramps, which, depending on their mode of emplacement into (zone 1 and 2) or near (zone 3 and 4) the channel, can offer hydraulic and habitat functions as ramp or raft pieces. These examples convey only two ways that zone 4 wood adds functional value to zone 1, 2. and 3 wood.

Statistical analysis indicates that wood alone is not a good predictor of sediment retention. This point-in-time dataset indicates that the number of 100% rock steps and zone l-2-3 wood volume affect obstructed sediment volume. Rock (cobbles, boulders) remains an important foundation element for sediment obstruction in small. steep streams.

5.3 How much riparian vegetation is needed to provide adequate wood input to the channel to maintain in-channel wood at levels needed to avoid loss of sediment retention function?

Riparian forest characteristics needed for self-replenishing wood supplies to channels for sediment retention are expressed as ranges of several quantitative measurements, with the values derived from stocking levels in the live unmanaged measurement sites.

- TPA>20" dbh, 20-50
- TPA 9-20" dbh 70- 110
- TPA 3-9" dbh, 160-200
- TPA <3" dbh, 200-400
- stem class ratio 1:2:4:8

The ranges of four tree diameter (or age) classes represent structural conditions in riparian forest stands that are assumed to produce self-replenishing supplies of wood to channels. The ratio of 1:2:4:8 approximates mid-points of ranges in values for stocking levels of five unmanaged reference sites. The assumption of 'self-replenishing conditions' will be tested over time through repeat measurements of stand conditions, falldown rates, conversion of fallen wood into in-channel forms, and evolution (formation/dissolution) of sediment obstructions.

This is not to imply that managed riparian forest stands cannot produce adequate amount of wood for channels. Seven WISSP sites (Found, McClain, Darla, Trail, Cultus, Clover, Nass) have good to excellent stocking levels for most of the four size classes. While the stands in the Found and Darla measurement sites are suboptimal for trees >20 inches dbh, most of the seven other well stocked WISSP sites offer good LWD recruitment potential over the next 100 years.

The rates of tree fall, tree fall over channels, and conversion of fallen wood into hydraulically active forms are unknown. Currently there is a lack of data from small, steep streams on the conversion rate of fallen trees to hydraulically effective in-channel wood. and its significance on channel functions and aquatic habitat.

The decomposition of fallen wood in the investigation area is unknown, but it is likely to be slow and highly variable. The breakdown, and conversion of zone 3 and 4 wood (near channel wood) into zone 1 and 2 forms (in-channel wood) depends on many factors including tree species, temperature. moisture. substrate quality, log size, and decomposer type (Harmon et al., 1986: Caza, 1993). Only recently have long term experiments been established to follow the decay of fallen wood through time from documented starting conditions (Harmon, 1992).

Currently, forest practices generally attempt to reduce senescence-related mortality of large canopy trees through the selective retention of vigorous trees (Goodburn and Lorimer, 1998). Short intervals between harvests enable efficient salvage of any low vigor trees from a variety of size classes before or shortly after death. This intensive forest management is now occurring in at least five WISSP sites (Tea, Meadow, Pine. Found. Cultus). Repeat measurements at WISSP and CRSN sites over several decades will test the hypothesis that reduction of senescence-related mortality causes reduction of snags, falldown. and wood recruitment potential to stream channels.

5.4 Is there a relationship between past timber harvest in riparian stands and riparian stand condition, in-channel wood loading, and sediment retention?

From this initial dataset, higher amounts of wood (SWD and LWD) in unmanaged forests provide a wider range of budding materials for step faces. Unmanaged sites had mot-e wood pieces in steps. and elevation drop from SWD- and LWD-built steps, than in managed sites. This finding is consistent with higher stem densities in riparian forests surrounding unmanaged sites. particularly in large trees with numerous branch whorls. Branches are a common source of SWD found in many step faces. However. elevation drop from rock-built steps was higher in managed sites than unmanaged sites. compensating for energy dissipation functions lost from less wood in managed sites.

The lack of information on bedload transport rates contributes to an uncertain interpretation of comparatively similar obstructed sediment volumes for managed and unmanaged sites. No sediment budgets were constructed or analyzed. Intuitively, one could argue that higher amounts of zone 1 and zone 2 wood (SWD and LWD) found in unmanaged sites would contribute to higher sediment trapping and retention. Though engaging, such speculation lacks data from which to draw data-driven conclusions. Repeat measurements can provide data-driven insights on sediment obstruction functions of multisized wood and rock found in small, steep streams.

Slight differences in stored sediment volume and step quantity may be explained by repeated, strong flushing that affected all channels due to the record flood flows in 1974, 1977, and 1996. These floods acted as significant stressors that promoted wood flotation and in-channel movement, as well as wood input through tree fall due to bank erosion or channel lateral movement. While channels respond differently to regimes of water, wood, sediment, and energy, CRSN and WISSP sites may be adjusting to a conditions of net wood loss.

Unmanaged stands have more trees in each of the four size classes that create conditions suitable for wood entry to channels. Riparian stands recently disturbed by logging create structural conditions that can't produce channel wood until processes such as senescence, mortality, branch shedding, wind throw, bank erosion, wood decay, root rot, disease and insect effects can act on standing trees and cause wood to fall into or near stream channels. Managed stands create structural conditions that maximize solar gain to canopies, reduce shading and competition for soil moisture, and maximize width and height growth rates. Without shading that occurs in stands with dense canopies, fewer branches senesce and shed to produce small woody debris for forest floor and in-channel functions. Without shading, fewer snags form to produce standing and fallen wood for a variety of forest and channel functions.

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7. Acknowledgments

No monitor is an island, or solitary raft. Special thanks go to a bevy of stream workers who waded through and collected a great data stream: Susan Hattrup, Russell Langshaw. Joe Schmitt, Larry Dominguez, Richard Visser. Ann Stephenson. Jack Powell, Andrew Strolis, Mark Teske. Jim Stephenson, John LaManna, Joe Hattrup, Venice Goetz, George Wilhere, Aram Langhans. Charlie McKinney, Joe Snyder, Mike Jones, Sabina Schievelbein, Grace Anderson, Ben Hayward, Diana Woods, Sallie Herman, Angela Schafer, Scott Sebring, Brian Young. Tara Hicks, and Mark Golliet. Bravo! Good work! They earned my respect and deep gratitude.

Nancy Sturhan (WDNR) provided consistent encouragement and needed support. Tami Grant and Nikki Housh (WDNR) kept resources flowing.

Dave Schuett-Hames (NWIFC) deserves high praise for persistent project support and numerous astute reviews that led to successive refinements of this information product.

Doug Rushton and Helen Bresler (WDOE) are acknowledged for their initial reviews. Jim Matthews (Yakama Nation) and Joe Wernex (WDNR) deserve thanks for use of surveying gear. Bill Garrigues, Scott Hoefer, and Karen Lindhorst (WNF), and Jim Matthews offered many site location suggestions.

APPENDIX

Al. Additional Information Displays

Tables Al and A2 (compendium of all data and a summary of central tendency statistics) are included for review and further consideration.

In Table Al, the data galaxy, columns for the sixteen measurement sites are matched with numerous rows of data in ten major themes:

1. place
2. geometry
3. trees
4. wood volume
5. wood pieces
6. wedge
7. elevation
8. notes
9. thanks
10. author

In Table A2, the statistics summary, nine central tendency statistics are matched with fifty-one monitoring indicators:

1. mean
2. median
3. mid range
4. variance
5. standard deviation
6. range
7. skewness
8. kurtosis
9. standard error

Table A1 The data galaxy, a compendium of all data collected in Wood In Small Streams Project and Channel Reference Site Network.

	site name	aA52	bB53	bA95	cA41	bC26	aA31	aA85	aA51	aB50	aB107	bB7	cB72	Bear	cB7	Spruce	cA14
PLACE	moniker	Gray	Tea	Meadow	Pine	Found	McClain	Darla	Trail	Cultus	Clover	Nass	Olds	Bear	Wren	Spruce	Cowiche
	site type	WISSP	WISSP	WISSP	WISSP	WISSP	WISSP	WISSP	WISSP	WISSP	WISSP	WISSP	CRSN	CRSN	CRSN	CRSN	CRSN
	water type	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
	elevation, feet	5220	4480	3480	3280	4520	4560	5160	4400	4280	5400	4720	5160	5000	5200	3600	5220
	source area, acres	600	200	200	800	500	150	200	900	450	350	300	200	150	400	1000	1000
	management history	L, R, G	L, R, G	L, S, G	L, R	L, R	NL, R	L, S	NL, R	L, R, G	L	L, S, G	none	none	none	none	G
	plant association group	ABAM	ABAM/PIPO	PIPO	PIPO	ABAM	ABAM	ABAM	ABAM	ABAM	ABAM	ABAM	ABAM	CHNO	ABAM	ABAM/PIPO	ABAM
GEOMETRY	bankful depth, feet	2.3	1.5	0.89	1.2	1.9	1.3	1.63	2.1	1.9	1.4	2.3	1.6	1.8	1.7	3.5	1.9
	bankful width, feet	7.7	9	10.7	6.3	11.9	7.5	9.4	11.2	13.6	14.5	14.7	7.5	8.2	12.6	14.6	14.7
	width:depth ratio	3.4	6	11.9	5.3	6.1	5.8	5.8	5.2	7	10.5	6.5	4.8	4.5	7.3	4.2	7.5
	channel gradient, %	20.6	14.9	13	6.9	11	16.3	17.5	15.5	11.1	15.1	11.7	26.4	19.8	14	13.2	5.2
	confinement	mc	mc	c	c	c	c	c	c	c	c	c	c	c	c	c	mc
	meas. reach length, ft	174	166.3	153.5	150	150	164.5	153	160	150	157	160.1	150	165.9	151	165	161
	meas reach length (BFWs)	22.60	18.48	14.35	23.81	12.61	21.93	16.28	14.29	11.03	10.83	10.89	20.00	20.23	11.98	11.30	10.95
TREES	trees per acre, all sizes	300	385	292	64	389	471	1029	623	404	356	531	317	734	462	2146	786
	TPA >20" dbh	0	2	4	2	8	29	8	29	21	33	25	27	73	44	46	38
	TPA 9-20" dbh	4	71	33	33	44	96	133	138	98	92	117	50	304	107	186	119
	TPA 3-9" dbh	104	160	56	15	131	179	454	215	208	150	200	165	165	202	665	254
	TPA <3" dbh	192	152	200	14	69	167	435	240	77	80	188	71	192	107	1246	375
	estimated stand age, yrs	10-20	15-70	2-50	15-50	20-100	60-100	40-100	40-90	40-140	60-100	40-100	80-140	80-140	80-140	80-140	80-140
WOOD	total wood volume, ft^3	7.3	20.6	22.4	4.1	78.3	66.2	147.7	114.3	45.3	228.1	137.3	186.6	195.8	261.1	220.6	81
	LWD volume, ft^3	5.6	18.7	19.9	3.9	77.9	64.5	142.7	113.3	43.4	226.8	133.3	182.4	193.6	259.7	214.4	79.5
	SWD volume, ft^3	1.7	1.85	2.5	0.1125	1.42	1.7	5	1.2	1.89	1.36	4	4.15	2.2	1.41	6.2	1.5
	total wood volume, ft^3/ft	0.042	0.124	0.146	0.027	0.522	0.402	0.965	0.714	0.302	1.453	0.858	1.240	1.180	1.730	1.340	0.503
	LWD volume, ft^3/ft	0.032	0.112	0.130	0.026	0.519	0.392	0.933	0.708	0.289	1.450	0.833	1.220	1.170	1.720	1.290	0.493
	SWD volume, ft^3/ft	0.010	0.011	0.016	0.001	0.009	0.010	0.033	0.007	0.013	0.009	0.025	0.028	0.013	0.009	0.038	0.010
	total wood volume, ft^3/bfw	0.95	2.30	2.10	0.65	6.60	8.80	15.70	10.20	3.30	15.70	9.30	24.90	23.90	20.70	15.10	5.50
	LWD volume, ft^3/bfw	0.73	0.00	1.9	0.62	6.5	8.6	15.2	10.1	3.2	15.6	9.1	24.3	23.6	20.6	14.7	5.4
	SWD volume, ft^3/bfw	0.221	0.206	0.234	0.018	0.119	0.227	0.532	0.107	0.139	0.094	0.272	0.553	0.268	0.112	0.425	0.109
	LWD:SWD volumetric ratio	3.3	10.1	7.9	35.1	54.9	37.9	28.5	94.4	22.97	166.7	33.33	43.9	88	184.2	34.6	49.6
	Zone 1 volume, ft^3	1.4	0	0	0	6.7	1.1	10.8	10.8	3.2	41.4	0	1.2	14.6	50.3	47.8	7.4
	Zone 2 volume, ft^3	2.6	17.8	20.2	1.7	30.8	12.8	61.1	6.3	3.3	16.9	100.6	21	23.4	63.9	41.2	17.7
	Zone 3 volume, ft^3	0.76	0.22	0.98	0.65	15.8	7.7	7.3	20.7	12.68	24.1	5.1	50.78	24.5	42.98	29.4	7.6
	Zone 4 volume, ft^3	2.6	2.5	1.2	1.69	25.1	44.6	68.6	76.6	26.2	145.7	31.2	113.6	133.3	103.9	102.2	48.3
	Zones 1, 2, 3 volume, ft^3	4.76	18	21.2	2.4	53.3	21.6	79.2	37.8	19.2	82.4	105.7	72.9	62.5	157.2	118.4	32.7
	Zones 1, 2, 3 volume, ft^3/bfw	0.620	2.000	1.980	0.380	4.480	2.880	8.430	3.380	1.410	5.680	7.190	9.720	7.620	12.480	8.110	2.220
	Zone 4 volume, ft^3/bfw	0.338	0.278	0.112	0.268	2.110	5.950	7.290	6.840	1.930	10.050	2.120	15.100	16.300	8.200	7.000	3.290
	Z1+Z2+Z3:Z4 (vol) ratio	1.83	7.20	17.70	1.42	2.12	0.48	1.16	0.49	0.73	0.57	3.39	0.64	0.47	1.51	1.16	0.68
	Z1+Z2+Z3: total (vol) ratio	0.65	0.87	0.95	0.59	0.68	0.33	0.54	0.33	0.42	0.36	0.77	0.39	0.32	0.60	0.54	0.40
	Zone 1 volume, ft^3/bfw	0.18	0.00	0.00	0.00	0.56	0.15	1.15	0.96	0.23	2.86	0.00	0.16	1.78	3.99	3.27	0.50
	Zone 2 volume, ft^3/bfw	0.34	1.98	1.89	0.27	2.59	1.71	6.50	0.56	0.24	1.17	6.84	2.80	2.85	5.07	2.82	1.20
	Zone 3 volume, ft^3/bfw	0.10	0.02	0.09	0.10	1.33	1.03	0.78	1.85	0.93	1.66	0.35	6.77	2.99	3.41	2.01	0.52
	Zone 4 volume, ft^3/bfw	0.34	0.28	0.11	0.27	2.11	5.95	7.29	6.84	1.93	10.05	2.12	15.10	16.30	8.20	7.00	3.29
	Z1+Z2 volume, ft^3	4	17.8	20.2	1.7	37.5	13.9	71.9	17.1	6.5	58.3	100.6	22.2	38	114.2	89	25.1
	Z1+Z2 volume, ft^3/ft	0.023	0.107	0.132	0.011	0.250	0.084	0.470	0.107	0.043	0.317	0.628	0.148	0.229	0.756	0.539	0.156
	Z1+Z2 volume, ft^3/bfw	0.519	1.980	1.890	0.270	3.150	1.850	7.650	1.530	0.478	4.020	6.840	2.960	4.630	9.060	6.100	1.710

	Z3+Z4 volume, ft^3	3.36	2.72	2.18	2.34	40.9	52.3	75.9	97.3	38.9	169.8	36.3	164.4	157.8	146.9	131.6	55.9
	Z3+Z4 volume, ft^3/ft	0.019	0.016	0.014	0.016	0.273	0.318	0.496	0.608	0.259	1.080	0.227	1.090	0.551	0.973	0.798	0.347
	Z3+Z4 volume, ft^3/bfw	0.436	0.302	0.204	0.371	3.440	6.970	8.070	8.690	2.860	11.700	2.470	21.900	19.200	11.700	9.000	3.800
	Z1+Z2:TOTAL ratio (vol)	0.55	0.87	0.9	0.42	0.48	0.21	0.49	0.15	0.14	0.26	0.73	0.12	0.19	0.44	0.4	0.31
	Z3+Z4:TOTAL ratio (vol)	0.46	0.13	0.09	0.58	0.52	0.79	0.51	0.85	0.86	0.74	0.27	0.88	0.81	0.56	0.6	0.69
	Z1+Z2:Z3+Z4 ratio (vol)	1.2	6.53	9.1	0.73	0.91	0.27	0.95	0.17	0.17	0.34	2.74	0.14	0.24	0.78	0.68	0.45
	SWD pieces/ft	0.182	0.633	0.654	0.125	0.084	0.507	1.010	0.366	0.132	0.593	1.990	0.427	1.050	0.183	2.030	1.650
	LWD pieces/ft	0.017	0.073	0.020	0.100	0.092	0.037	0.202	0.107	0.103	0.143	0.095	0.373	0.207	0.119	0.164	0.143
	SWD pieces/bfw	1.4	5.7	7	0.79	1	3.8	9.5	4.1	1.8	8.6	29.3	3.2	8.6	2.3	29.7	24.2
	LWD pieces/bfw	0.13	0.44	0.21	0.63	1.09	0.28	1.9	1.2	1.4	2.07	1.4	2.8	1.7	1.5	2.4	2.1
	SWD:LWD piece ratio	10.77	12.950	33.33	1.26	0.92	13.57	5	3.42	1.29	4.15	20.93	1.14	5.06	1.53	12.38	11.52
	LWD:SWD piece ratio	0.09	0.08	0.03	0.8	1.09	0.07	0.2	0.29	0.78	0.24	0.05	0.88	0.2	0.65	0.08	0.09
WEDGE	total volume, cubic yards	6.2	3.3	3.1	0	18.3	4.9	18.7	6.7	5.3	15.3	22.2	5.2	10.7	8.6	22.7	14.1
	total volume, yd^3/bfw	0.805	0.367	0.290	0.000	1.540	0.653	1.990	0.598	0.390	1.060	1.510	0.693	1.310	0.683	1.560	0.959
	average volume, yd^3	0.39	0.56	0.17	0	2.22	0.33	1.17	0.39	0.24	0.94	1.39	0.4	0.45	0.42	0.99	2.35
	maximum volume, yd^3	0.65	1.75	2.09	0	5.67	1.32	4.2	1.44	0.82	3.07	13.7	1.31	1.15	1.15	4.18	5.84
	minimum volume, yd^3	0.05	0.02	0.01	0	0.13	0.05	0.3	0.09	0.08	0.08	0.07	0.04	0.04	0.03	0.03	0.19
	ave Height:Length ratio	0.31	0.3	0.27	0	0.26	0.35	0.28	0.42	0.53	0.24	0.21	0.22	0.28	0.24	0.17	0.08
	maximum Height:Length ratio	0.87	0.7	0.64	0	0.49	0.95	0.7	1.65	1.6	0.48	0.46	0.68	0.5	0.86	0.46	0.15
	minimum Height:Length ratio	0.09	0.13	0.03	0	0.07	0.13	0.08	0.08	0.01	0.09	0.08	0.06	0.08	0.09	0.06	0.04
	total number of steps	25	14	14	0	8	15	21	17	11	20	16	22	28	12	23	7
	steps per bfw	3.25	1.56	1.31	0.00	0.67	2.00	2.23	1.52	0.81	1.38	1.09	2.93	3.41	0.95	1.58	0.48
	not meeting minimum height	4	4	7	0	1	3	4	2	4	5	2	2	8	4	3	2
	number of steps/bfw	3.25	1.56	1.31	0.00	0.67	2.00	2.23	1.52	0.81	1.38	1.09	2.93	3.41	0.95	1.58	0.48
	number of 100% wood steps	1	2	0	0	1	5	9	5	2	8	6	10	9	3	8	5
	number of 100% rock steps	11	1	0	0	1	3	2	6	2	1	0	1	4	2	6	0
	pieces of wood in steps	19	20	19	0	6	30	33	14	19	41	28	39	52	18	61	18
	percent of step face in SWD	84	65	100	0	17	60	64	36	68	68	71	54	72	44	72	56
	percent of step face in LWD	16	35	0	0	83	40	36	64	32	32	29	46	28	56	28	44
	wood decay state in steps	4.95	4.8	3.42	0	4.67	4.6	4.26	4.21	4.11	3.56	3.93	3.59	3.89	3.36	4.18	3.78
	percent of wood step faces	16.4	45.1	47.5	0	61	51	63.3	42.1	46	66	87.5	66	71.9	54	49.6	95
	percent of rock step faces	80.8	47.7	52.5	0	36	49	36.7	57.9	54	34	12.5	34	28.1	46	50.4	5
	% of other materials in step faces	2.8	7.1	0	0	3	0	0	0	0	0	0	0	0	0	0	0
ELEVATION	total bed drop, feet	35.8	24.8	20	10.4	16.6	26.8	27.8	25.6	16.6	22.7	18.7	39.58	32.8	21.2	21.7	8.3
	total step drop, feet	30.6	12.6	8.9	0	15.5	17.2	26.8	22.1	10.4	24.5	20.1	13.6	32.3	19.8	27.8	6.4
	step to bed drop, %	85	51	45	0	93	64	114	86	63	108	108	34	99	97	128	77
	drop from faces 100% SWD, %	2.1	0	0	0	0	11.6	12.9	4.7	0	3.5	20.1	0	17.1	9.7	3.7	16.9
	drop from faces 100% LWD, %	0	3.8	0	0	12	9.3	17.6	6.2	4.2	28.4	7.8	7.5	1.5	34.4	5.1	11
	drop from faces 70-100% SWD, %	0	0	0	0	0	4.5	4.9	0	0	6.2	0	4.8	9.5	5.9	0	0
	drop from faces 70-100% LWD, %	0	3	0	0	53.6	0	0	0	0	0	39	0	0	8	3.7	9.6
	drop from mixed wood, %	5.9	2.8	0	0	0	1.9	0	3.7	3.1	21.1	2.7	0	7.3	3.1	41	39.2
	drop from faces 100% rock, %	36.6	2.6	0	0	9.6	11.7	15.5	27.5	6.2	4	0	2.7	11.3	3.3	23.3	0
	drop from faces 70-100% rock, %	33.2	16.5	0	0	0	14.9	11.2	20.3	8.7	14.3	0	0	20.4	9	16.7	0
	other drop, %	7.7	22.2	44.5	0	18.1	12.3	47.8	23.8	36.3	30.4	35.3	19.5	31.7	23.6	35	0

NOTES This super table summarizes data collected during field seasons 1997 and 1998 for the Channel Reference Site Network (CRSN) and Wood In Small Streams Project (WISSP). Here's the entire data matrix. It's only a galaxy, a Milky Way in the universe...

THANKS Special thanks go to a bevy of stream workers who collected this data stream:
Susan Hattrup, Russell Langshaw, Joe Schmitt, Larry Dominguez, Richard Visser, Ann Stephenson, Jack Powell, Andrew Strolis, Mark Teske, Jim Stephenson, John LaManna, Joe Hattrup, Venice Goetz, George Wilhere, Aram Langhans, Charlie McKinney, Joe Snyder, Mike Jones, Sabina Schievelbein, Grace Anderson, Ben Hayward, Diana Woods, Sallie Herman, Angela Schafer, Scott Sebring, Brian Young, Tara Hicks, and Mark Golliet. Bravo! Good work + Good people = Great dataset!

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Table A2. Summary of central tendency statistics for 51 monitoring indicators, for CRSN (n=5) and WISSP (n=10) sites.

CASN sites, statistical summary (n = 5)

Statistic	bankful depth, feet	bankful width, feet	W:D	cha" grad	reach length (bfws)	TPA, all sizes	TPA >20" dbh	TPA 9-20" dbh	TPA 3-9" dbh	TPA <3" dbh	total wood volume ft^3/bfw	LWD volume ft^3/bfw	SWD volume ft^3/bfw
Mean	2.10	11.52	5.66	15.72	14.89	889.00	45.60	153.60	290.20	398.20	18.02	17.72	0.29
Median	1.80	12.60	4.80	14.00	11.98	734.00	44.00	119.00	202.00	192.00	20.70	20.60	0.27
MidRange	2.55	11.10	5.85	15.80	15.59	1231.50	50.00	177.00	415.00	658.50	15.20	14.85	0.33
Variance	0.62	11.99	2.57	62.67	22.87	531049.00	289.30	9476.30	45228.70	238420.00	63.59	61.77	0.04
StdDev	0.79	3.46	1.60	7.92	4.78	728.73	17.01	97.35	212.67	488.28	7.97	7.86	0.20
Range	1.90	7.20	3.30	21.20	9.28	1829.00	46.00	254.00	500.00	1175.00	19.40	18.90	0.44
Skewness	1.43	-0.26	0.36	0.06	0.39	i.24	0.78	0.66	1.39	1.30	-0.79	-0.80	0.26
Kurtosis	0.15	-1.75	-1.79	-0.96	-1.82	-0.08	-0.44	-0.79	0.10	-0.05	-0.83	-0.85	-1.47
StdErr	0.35	1.55	0.72	3.54	2.14	325.90	7.61	43.53	95.11	218.37	3.57	3.51	0.09

WISSP sites, statistical summary (without Pine, n = 10)

Statistic	bankful depth, feet	bankful width, feet	W:D	cha" grad	reach length (bfws)	TPA, all sizes	TPA >20" dbh	TPA 9-20" dbh	TPA 3-9" dbh	TPA <3" dbh	total wood volume ft^3/bfw	LWD volume ft^3/bfw	SWD volume ft^3/bfw
Mean	1.722	11.02	6.82	14.67	15.33	478	15.9	82.6	185.7	180	7.495	7.093	0.2151
Median	1.765	10.95	6.05	15	14.32	396.5	14.5	94	169.5	177.5	7.7	7.55	0.2135
MidRange	1.595	11.1	7.65	15.8	16.71	660.5	16.5	71	255	252	8.325	7.8	0.313
Variance	0.21	7.04	6.34	9.40	19.46	47854.90	161.88	1951.16	11334.90	11457.30	29.36	31.86	0.02
StdDev	0.46	2.65	2.52	3.07	4.41	218.76	12.72	44.17	106.47	107.04	5.42	5.64	0.13
Range	1.41	7.20	8.50	9.60	11.77	737.00	33.00	134.00	398.00	366.00	14.75	15.60	0.44
Skewness	-0.29	0.11	0.98	0.45	0.58	1.73	0.06	-0.44	1.59	1.27	0.35	0.24	1.57
Kurtosis	-0.88	-1.32	0.06	-0.57	-1.05	2.13	-1.68	-0.93	2.31	1.33	-1.16	-1.20	1.98
StdErr	0.15	0.84	0.80	0.97	1.40	69.18	4.02	13.97	33.67	33.85	1.71	1.78	0.04

Table A2. Summary of central tendency statistics for 51 monitoring indicators, for CRSN (n=5) and WISSP (n=10) sites. (continued)

CRSN sites, statistical summary (n = 5)

LWD:SWD (volume)	Z1+Z2+Z3:Z4 (volume)	Z1+Z2+Z3:TOT (volume)	Zone 1 volume ft^3/bfw	Zone 2 volume ft^3/bfw	Zone3 volume ft^3/bfw	Zone4 volume ft^3/bfw	Z1+Z2 volume ft^3/bfw	Z3+Z4 volume ft^3/bfw	Z1+Z2:TOT (volume)	Z3+Z4:TOT (volume)	Z1+Z2:Z3+Z4 (volume)	SWD pieces/bfw	LWD pieces/bfw
80.06	0.89	0.45	1.94	2.95	3.14	9.98	4.89	13.12	0.29	0.71	0.46	13.60	2.10
49.60	0.68	0.40	1.78	2.62	2.99	8.20	4.63	11.70	0.31	0.69	0.45	8.60	2.10
109.40	0.99	0.46	2.08	3.13	3.64	9.79	5.38	12.85	0.28	0.72	0.46	16.00	2.15
3802.54	0.19	0.01	2.81	1.90	5.36	30.74	8.19	54.98	0.02	0.02	0.08	158.10	0.28
61.66	0.43	0.12	1.68	1.38	2.31	5.54	2.86	7.41	0.14	0.14	0.27	12.57	0.52
149.60	1.04	0.28	3.63	3.87	6.25	13.01	7.35	18.10	0.32	0.32	0.64	27.40	1.30
1.14	0.54	0.28	0.14	0.45.	0.64	0.09	0.41	0.01	-0.16	0.16	0.02	0.38	0.17
-0.31	-1.28	-1.47	-1.61	-0.44	-0.58	-1.55	-1.04	-1.43	-1.53	-1.53	-1.59	-1.64	-1.33
27.56	0.19	0.05	0.75	0.62	1.04	2.48	1.28	3.32	0.06	0.06	0.12	5.62	0.23

WISSP sites, statistical summary (without Pine, n = 10)

46	3.567	0.59	0.6101	2.3623	0.8141	3.7018	2.9907	4.5142	0.478	0.522	2.238	7.22	1.012
30.915	1.495	0.595	0.2085	1.8	0.8545	2.115	1.935	3.15	0.465	0.515	0.93	4.9	1.145
85	9.09	0.64	1.43	3.5415	0.937	5.081	4.064	5.952	0.52	0.475	4.635	15.15	1.1
2512.97	28.88	0.05	0.79	5.70	0.44	12.46	6.19	16.53	0.08	0.08	9.59	68.93	0.50
50.13	5.37	0.23	0.89	2.39	0.67	3.53	2.49	4.07	0.29	0.29	3.10	8.30	0.71
163.40	17.22	0.62	2.86	6.60	1.83	9.94	7.17	11.50	0.76	0.77	8.93	28.30	1.94
1.56	2.07	0.22	1.77	1.14	0.21	0.55	0.92	0.46	0.24	-0.26	1.44	2.07	0.07
1.40	2.99	-1.34	2.15	-0.21	-1.30	-1.12	-0.49	-1.13	-1.34	-1.31	0.53	3.27	-1.38
15.85	1.70	0.07	0.28	0.75	0.21	1.12	0.79	1.29	0.09	0.09	0.98	2.63	0.22

Table A2. Summary of central tendency statistics for 51 monitoring indicators, for CRSN (n=5) and WISSP (n=10) sites. (continued)

CRSN sites, statistical summary (n = 5)

SWD:LWD piece ratio	LWD:SWD piece ratio	sediment wedge wolume yd^3/bfw	if of steps per bfw	# of 100% wood steps	# of 100% rock steps	pieces of wood in steps	% of step face in SWD	% of step face in LWD	wood decay state in steps	% of wood step faces	%t of rock step faces	% of other materials in step faces
6.33	0.38	1.04	1.87	7.00	2.60	37.60	59.60	40.40	3.76	67.30	32.90	0.00
5.06	0.20	0.96	1.58	8.00	2.00	39.00	56.00	44.00	3.78	66.00	34.00	0.00
6.76	0.48	1.12	1.95	6.50	3.00	39.50	58.00	42.00	3.77	72.30	27.70	0.00
28.78	0.13	0.15	1.60	8.50	5.80	381.30	148.80	148.80	0.10	320.08	317.98	0.00
5.36	0.36	0.39	1.26	2.92	2.41	19.53	12.20	12.20	0.31	17.89	17.83	0.00
11.24	0.80	0.88	2.94	7.00	6.00	43.00	28.00	28.00	0.82	45.40	45.40	0.00
0.20	0.51	0.34	0.19	-0.41	0.40	0.03	-0.03	0.03	0.07	0.66	-0.70	.
-1.75	-1.50	-1.48	-1.60	-1.40	-1.24	-1.63	-1.48	-1.48	-1.02	-0.81	-0.75	.
2.40	0.16	0.17	0.57	1.30	1.08	6.73	5.46	5.46	0.14	8.00	7.97	0.00

WISSP sites, statistical summary (without Pine, n = 10)

10.633	0.292	0.9203	1.58115	3.9	2.7	22.9	63.3	36.7	4.251	52.59	46.11	1.29
7.885	0.145	0.729	1.44858	3.5	1.5	19.5	66.5	33.5	4.235	49.25	48.35	0
17.125	0.56	1.14	1.95951	4.5	5.5	23.5	58.5	41.5	4.185	51.95	46.65	3.55
104.73	0.13	0.34	0.57	9.88	11.57	102.77	531.34	531.34	0.26	347.96	324.82	5.62
10.23	0.36	0.58	0.76	3.14	3.40	to.14	23.05	23.05	0.51	18.65	18.02	2.37
32.41	1.06	1.70	2.57	9.00	11.00	35.00	83.00	83.00	1.53	71.10	68.30	7.10
1.12	1.45	0.62	0.97	0.35	1.65	0.19	-0.58	0.58	-0.27	-0.05	0.05	1.66
0.36	0.61	-0.96	0.38	-1.25	1.61	-0.55	0.13	0.13	-1.07	0.33	0.26	1.58
3.24	0.11	0.18	0.24	0.99	1.08	3.21	7.29	7.29	0.16	5.90	5.70	0.75

Table A2. Summary of central tendency statistics for 51 monitoring indicators, for CRSN (n=5) and WISSP (n=10) sites. (continued)

CRSN sites, statistical summary (n = 5)

total bed drop feet	total step drop feet	step to bed drop %	SWD drop in 100% wood faces, %	LWD drop in 100% wood faces, %	SWD drop in 70-100% wood faces, %	LWD drop in 70-100% wood faces, %	mixed drop in 100% wood faces, %	drop in 100% rock faces, %	drop in 70.100% rock faces, %	all other drop %
24.72	19.98	87.00	9.48	11.90	4.04	4.26	18.12	8.12	9.22	21.96
21.70	19.80	97.00	9.70	7.50	4.80	3.70	7.30	3.30	9.00	23.60
23.94	19.35	81 .00	8.55	17.95	4.75	4.80	20.50	11.65	10.20	17.50
144.31	109.52	1208.50	59.11	170.21	16.62	19.78	409.72	89.77	07.75	jl38.97
12.01	10.47	34.76	7.69	13.05	4.08	4.45	20.24	9.47	9.37	13.75
31.28	25.90	94.00	17.10	32.90	9.50	9.60	41.00	23.30	20.40	35.00
-0.11	-0.10	-0.52	-0.12	1.24	0.16	0.16	0.36	0.89	0.08	-0.80
-1.11	-1.37	-0.70	-1.61	-0.08	-1.38	-1.67	-1.90	-0.71	-1.65	-0.63
5.37	4.68	15.55	3.44	5.83	1.82	1.99	9.05	4.24	4.19	6.15

WISSP sites, statistical summary (without Pine. n = 10)

23.54	16.87	81.7	5.49	8.93	1.56	9.56	4.12	11.37	11.91	27.84
23.75	18.65	85.5	2.8	7	0	0	2.75	7.9	12.75	27.1
26.2	19.75	79.5	10.05	14.2	3.1	26.8	10.55	18.3	16.6	27.75
35.32	52.08	615.12	49.15	75.64	6.48	387.67	39.15	148.17	110.64	177.76
5.94	7.22	24.80	7.01	8.70	2.55	19.69	6.26	12.17	10.52	13.33
19.20	21.70	69.00	20.10	28.40	6.20	53.60	21.10	36.60	33.20	40.10
0.64	0.14	-0.14	1.03	1.14	0.96	1.60	2.24	1.05	0.53	0.03
-0.19	-1.15	-1.37	-0.25	0.53	-0.93	0.76	3.77	-0.10	-0.26	-1.14
1.88	2.28	7.84	2.22	2.75	0.81	6.23	1.98	3.85	3.33	4.22