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The amount function and relationship to channel stability of large woody debris in minimally disturbed western Montana streams

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THE AMOUNT, FUNCTION, AND RELATIONSHIP TO CHANNEL
STABILITY OF LARGE WOODY DEBRIS,
IN MINIMALLY DISTURBED WESTERN MONTANA STREAMS.

by

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ABSTRACT

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The Amount, Function, and Relationship to Channel Stability of Large Woody Debris, in Minimally Disturbed Western Montana Streams.

Director: Donald F. Potts

Large Woody Debris (LWD) is recognized as an important component in natural stream systems. It contributes to many ecological functions both long and short term including: channel stability, fishery habitat enhancement, and sediment storage. However there is very little research or published information on LWD in Montana streams. Data were collected in 1993 from eight minimally disturbed second to fourth order western Montana watersheds to quantify the amount and function of LWD in these systems. Forty 100 meter reaches were sampled for the amount and functions of LWD, and its impact on channel stability, morphology, plus other stream data was collected and analyzed.

Study streams were classified into Rosgen stream types. Results from reaches were compared within and among streams. Statistical tests were done on sample means, comparing size and amount of LWD. Results were also compared with west coast and inland northwest studies to see how LWD in Montana streams compared in mean size and amount in these systems. Relative bed stability (RBS) calculations, using different formulas and bed-load particle size classes were done on study streams to rate the natural channel conditions.

The mean number of pieces of LWD per 100m reach was 37, with the average size of 21.6 cm and volume of 8.1 m^3/100m. An average of 58% of the pieces were serving some function for channel morphology, or stability. Number of pieces/meter were similar to numbers found in west coast studies but size and volume were considerably less. RBS calculations using the d_{84} size particle and either formula indicated the stream channels were stable.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

LIST OF APPENDICES

INTRODUCTION

The influence of large woody debris (LWD) on stream function and form is of great concern to forest managers, stream biologists, and hydrologists. LWD is an integral component of small and intermediate sized forest streams. LWD directly influences the physical form and stability of the channel (Swanson *et al.*, 1984; Andrus *et al.*, 1988; Bilby and Ward, 1989; Carlson *et al.*, 1990; Wood-Smith and Buffington, 1996), the movement of sediment (Beschta, 1979; Megahan, 1982; Bilby, 1984; Malanson and Butler, 1990), the retention of organic matter (Swanson *et al.* , 1976; Bilby and Likens, 1980; Bilby, 1981; Trotter, 1990), and the integrity of the biological community (Bilby and Likens, 1980; Bryant, 1983; Sedell *et al.*, 1984; Harmon *et al.* ,1986; Bisson *et al.* , 1987; Sedell and Maser, 1994) all of which influence water quality, fisheries, and aquatic ecology. These and other studies, in larger anadromous fisheries in the Pacific Northwest, have qualified and quantified these facts. This past research suggests that small streams draining moderately stable watersheds, have historically contained large amounts of woody debris (Swanson *et al.*, 1976; Bisson *et al.* ,1987; Sedell *et al.*, 1988) contributing to ecological processes potentially exceeding a century (Swanson and Lienkaemper, 1978; Sedell and Maser, 1994). However, whether LWD in second through fourth-order perennial streams, in western Montana function in the same ways, or serves the same purpose is debatable (Bilby and Wasserman, 1989). Little research has been done anywhere in the northern Rocky Mountains to document the roles that LWD plays in streams. Streams in the northern Rocky Mountain forests have a much lower biomass and far greater fire frequency; this would suggest that the role of LWD varies geographically. For example the characteristics and function of wood in rocky mountain streams may differ markedly from the Pacific northwest because of the drier climates and differences in geology, flow regimes, predominate tree species, and tree size.

Montana enacted a mandatory Streamside Management Zone law in 1993 which governs the practice of commercial timber management in streamside zones. In particular, this act addresses the retention of the number and size of trees in the streamside management zone, mainly for future woody debris recruitment. There is a definite lack of research and data for the northern Rockies. The reliability of extrapolating results of research from the west coast to set rules for the law is questionable at best. Recent high wind storms with large amounts of blown down timber, particularly in the streamside zones, has once again brought to the forefront the question of how much LWD is needed to have a properly functioning stream environment. Private landowners would like to salvage this valuable resource, but the regulations make it confusing on how much LWD should really be left in the streams. This study helps to provide a much needed reference standard for channel assessment and restoration efforts.

OBJECTIVES

There are two objectives of this study. The first objective is to determine if the amount and function of LWD in western Montana streams is similar to west coast streams or whether Montana needs to be treated as a separate and different system. This study will: (A) Determine LWD quantity and function in numerous minimally disturbed western Montana streams; (B) Compare the results with other research; (C) Evaluate whether the LWD frequencies and functions are similar enough to extrapolate west coast research to western Montana stream systems. The second objective of this study is to analyze these minimally disturbed head water streams and compare channel stability thresholds, using methods and indices developed by Olsen and Potts, (1993). This will be done by replicating methods used in the 1993 report to the Montana

Cumulative Watershed Effects Cooperative, and classifying these streams in relation to their "natural" channel stability thresholds. An assessment will be done to see if the amount of LWD present has an effect on the channel stability threshold.

STUDY AREA

The study was conducted in west central Montana (see map page 7), on the Lolo National Forest and Champion International, now Plum Creek Timber Company land. Forty stream reaches, located in eight watersheds, with drainage areas ranging from 1,685-11,155 hectares (ha), were sampled to determine the "naturally" occurring quantities of large woody debris, in pieces per 100 meters. The Lolo National Forest encompasses an area of 850,200 ha, an area bounded to the north by the Cabinet Mountains, to the east and south by the Sapphire and Bitterroot Ranges, and to the west by the Montana-Idaho state line. The Clark Fork river drainage is a dominate feature and bisects the forest from east to west. The major tributaries of the Clark Fork river are Rock Creek, Blackfoot, Bitterroot, St. Regis, Flathead, and Thompson Rivers (in order of confluence from east to west). Sampled watersheds are scattered throughout the forest (see map page 8). Ownership in the watersheds is mostly National Forest, with some Plum Creek Timber Company, (formerly Champion International), and the State of Montana.

Timber species on the forest include: ponderosa pine(*Pinus ponderosa*), western larch(*Larix occidentalis),* Douglas-fir(*Pseudotsuga menziesii*), lodgepole pine(*Pinus contorta*), western redcedar(*Thuja plicata*), grand fir(*Abies grandis*), subalpine fir(*Abies lasiocarpa*), Engelman spruce (*Picea engelmannii*) and western hemlock(*Tsuga heterophylla*). Deciduous species such as cottonwoods and aspens (*Populus spp.*), alder(*Alnus spp.*), willows(*Salix spp.*), and birch(*Betula spp.*), also occur in riparian areas.

Intense geological activity including; uplifting, volcanic activity, glaciation, and subsequent erosion occurred in the area forming the present landscape. The most predominate bedrock in the survey area are the partially metamorphosed ancient sedimentary rocks of the Belt basin supergroups; known as belt Metasedimentary rocks. Small areas of volcanic bedrock are exposed within the forest. The upper Lolo Creek drainage is composed of granites from the Idaho batholith. Other less decomposed, well weathered granites and associated gneiss and micaceous schists are present in transition areas at the contact between the Idaho batholith and the belt series.

The climate is dominated by Pacific maritime air masses and prevailing westerly winds. Temperatures in Missoula (elevation 960 meters) can be used as representative for the forest (U.S.F.S., 1989). Average daily temperature in Missoula from 1951-1978 ranged from -5.6°C in January to 19.6°C in July. Extreme temperatures for the same period were -15.5°C to 38.6°C. Annual precipitation ranges from an average 380 mm in the Missoula valley to over 2570 mm on mountain peaks around 2746 meters in elevation. The northwestern portion of the forest receives the highest amounts of precipitation while the southwestern portion receives the least (U.S.F.S., 1989). Over two-thirds of the annual precipitation falls as snow. Most precipitation occurs in a series of frontal systems moving east producing long duration, low intensity precipitation. Nearly half of the average annual 1070 mm of precipitation that falls on the Lolo National Forest's watersheds is released as stream flow (U.S.F.S., 1989).

Until the early 1900's most watersheds had little disturbance with the exception of natural events such as fires and floods. Periodic stand replacement wildfires would often burn large areas creating a patchwork pattern of various stand structures. A large conflagration burned over three million acres in Idaho and western Montana in 1910. Most of the watersheds in this study were affected by the 1910 fires.

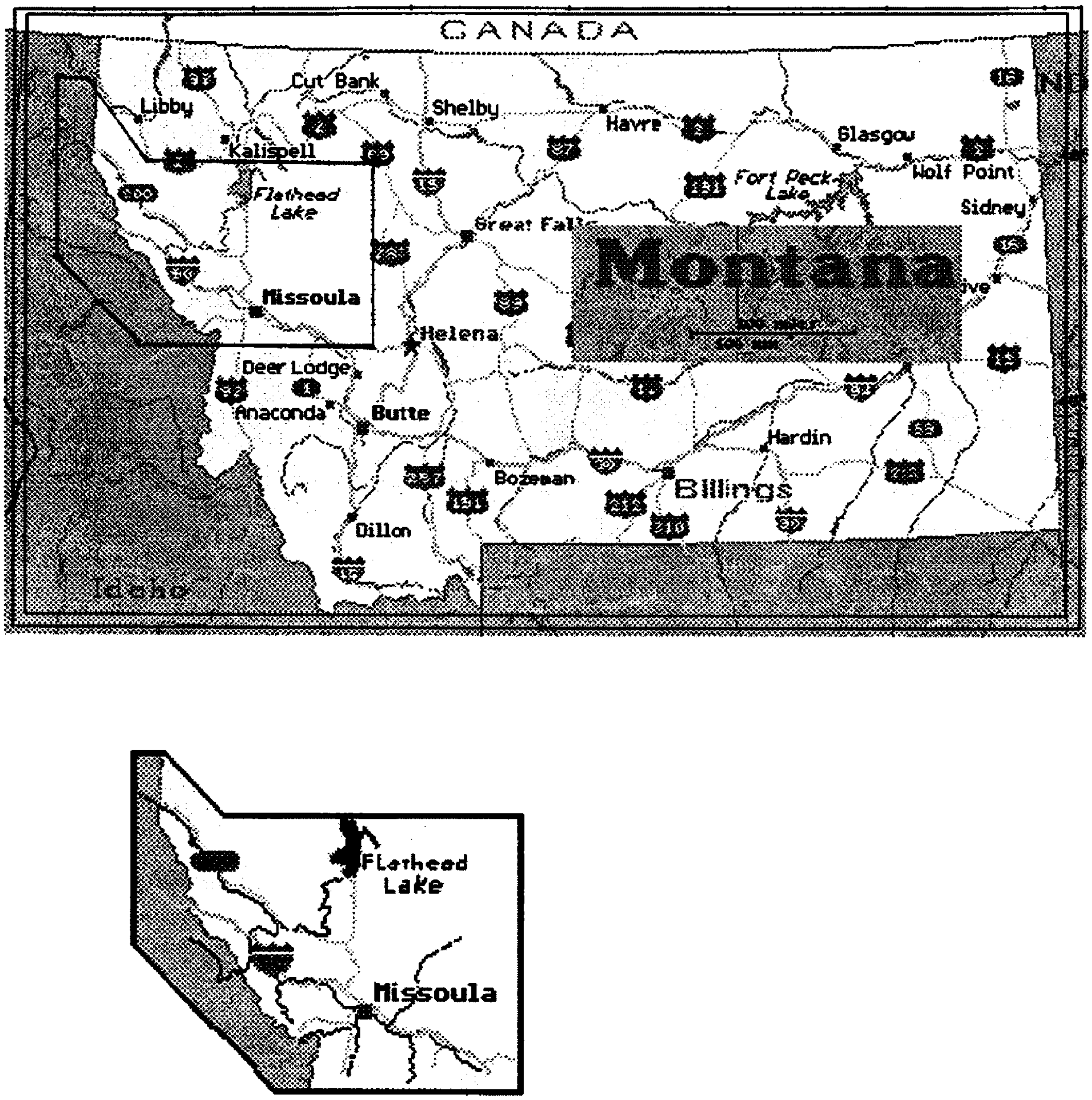
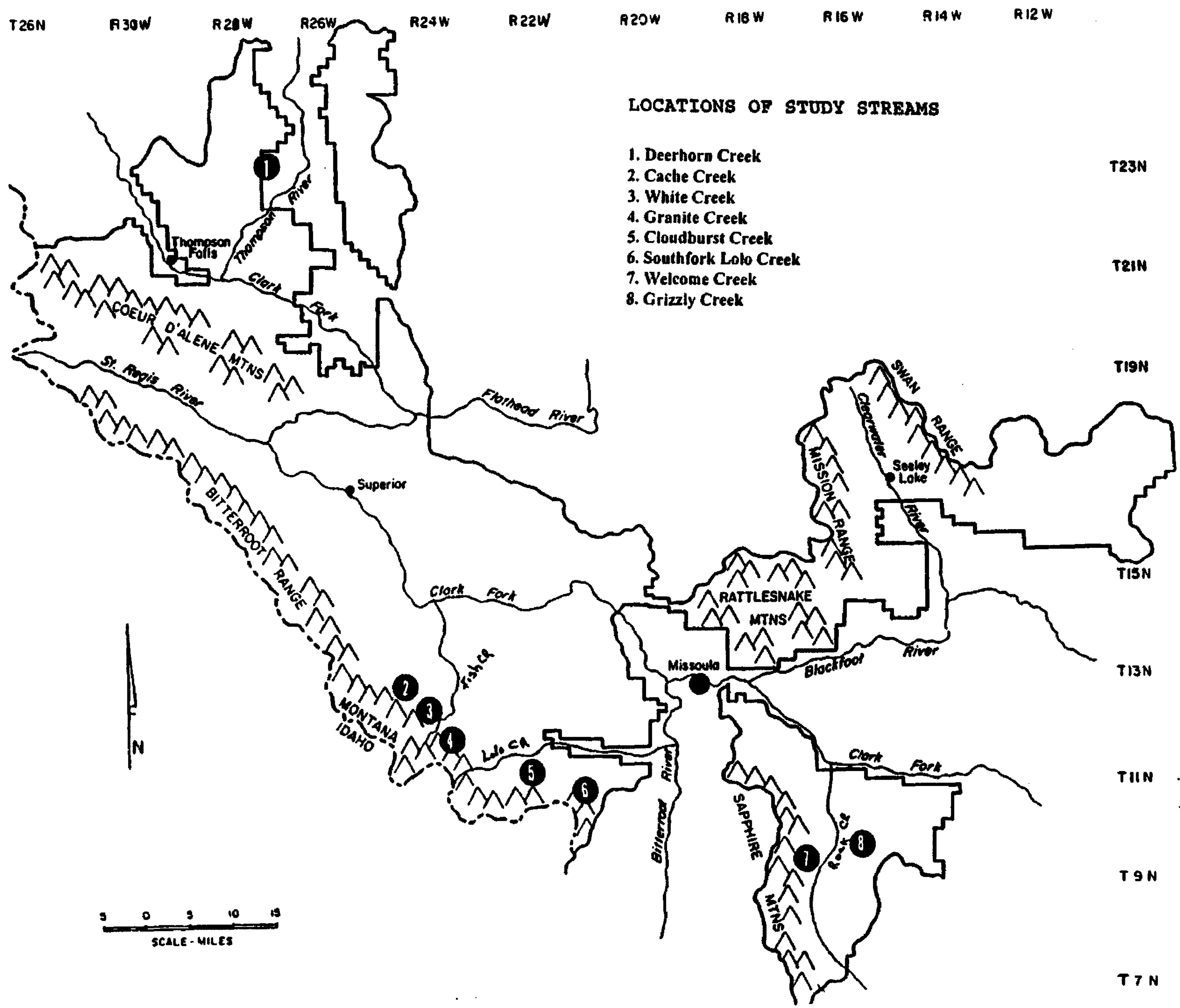

CANADA
Cut Bank
Libby
Shelby
Havre
Glasgow
Kalispell
Wolf Point
Fort Peck Lake
Flathead Lake
Sidney
Great Falls
Montana
Missoula
Helena
Deer Lodge
Anaconda
Butte
Hardin
Bozeman
Billings
Dillon
Idaho
Flathead Lake
Missoula

FIGURE 1


LOCATIONS OF STUDY STREAMS
1. Deerhorn Creek
2. Cache Creek
3. White Creek
4. Granite Creek
5. Cloudburst Creek
6. Southfork Lolo Creek
7. Welcome Creek
8. Grizzly Creek
T26N
R30W
R28W
R26W
R24W
R22W
R20W
R18W
R16W
R14W
R12W
T23N
T21N
T19N
T15N
T13N
T11N
T9N
T7N
Thompson Falls
Thompson River
Clark Fork
COEUR D'ALENE MTNS
St. Regis River
Flathead River
Superior
BITTERROOT RANGE
MONTANA
IDAHO
Fish Cr.
Lolo Cr.
Bitterroot River
Missoula
Blackfoot River
RATTLESNAKE MTNS
MISSION RANGE
SWAN RANGE
Clearwater River
Seeley Lake
SAPPHIRE MTNS
Rock Cr.
N
SCALE - MILES
5 0 5 10 15

METHODS

SITE SELECTION

Sample sites represent "minimally disturbed", headwater streams. Minimally disturbed sites are defined as: locations where man caused changes to the "natural" systems are not evident; or where if past disturbances have occurred, sufficient time has passed for LWD distribution and related channel features to redevelop. The study design included selecting streams of similar Rosgen type, similar drainage area, stream order, and other classifications for analysis purposes.

A Lolo Forest map, and air-photos were used to identify general areas that fit the description of "minimally disturbed". Discussions with knowledgeable professional land managers, familiar with the area also provided candidate streams. United States Geological Survey (USGS) 7.5 minute quadrangle maps of these streams were then reviewed, to classify streams and make final choices on study streams. Numerous streams were tentatively chosen, but with a field review did not meet study design of minimally disturbed, similar Rosgen type, similar drainage area, stream order etc., and were removed from consideration. Eight streams were sampled during the summer and fall of 1993. (table 1)

STREAM	ROSGEN TYPE	BASIN AREA	STREAM LENGTH	STREAM ORDER	ELEV. RANGE	STREAM SLOPE	AVERAGE PRECIP.	ASPECT OF FLOW
Cache Cr	B3	11,155 ha	18.5 km	4	1140-2135 m	3%	77-115 cm	S-NE
Cloudburst	A3	1,739 ha	8.1 km	2	1204-1980 m	5%	64-141 cm	S-N
Deerhorn	A3	2,519 ha	7.4 km	3	855-2134 m	7%	90-141 cm	W-E
Grizzly Cr	A3	1,951 ha	7.4 km	2	1190-2134 m	5%	51-115 cm	W-E
N.F. Granite	A3	1,685 ha	6.5 km	3	1340-1980 m	7%	77-205 cm	E-W
S.F. Lolo	B3	9,337 ha	20.5 km	4	1100-2440 m	4%	51-180 cm	S-N
Welcome Cr	A3	5,009 ha	12.0 km	3	1220-2195 m	4%	64-115 cm	NW-SE
White Cr	A3	2,721 ha	7.4 km	3	1175-2012 m	6%	90-141 cm	S-N

Table 1 Stream Summary

SAMPLING PROCEDURES

The exact location of the starting point for the sample reach was determined by an elevation designated in the office, however it turned out the hand held altimeter was not accurate enough to locate the desired elevation with any level of confidence. It was as accurate to locate the designated starting point on the 1:24,000 USGS quadrangle map, by comparing map and ground features. Once the starting point was located on the ground a string chain, measuring instrument was used to establish the sample reaches. Ten consecutive 100 meter reaches were delineated and ribboned. To reduce sampling bias, sample reaches were the even numbered reaches. Numerous site and stream classification variables were collected and recorded. A form adapted from a stream channel conditions assessment prepared for Weyerhaeuser Company by Jones & Stokes Associates (1992) was utilized for this purpose. (appendix F). Some of these variables collected include; stream type, (Rosgen 1985, Montgomery and Buffington 1992), stream order, (Strahler, 1952), modified Pfankuch rating, (Pfankuch, 1975) (appendix G), habitat type/riparian dominance type, (Hansen, *et al*, 1988), bankfull width, depth, gradient, width/depth ratio, bank texture, and sinuosity (table 2). These variables were collected using standard procedures and instruments as outlined in the Riparian, Aquatic, and Wetland Sampling Guide, (USDA-FS, 1990).

Large woody debris was counted and measured if it lay within the vertical extension of the streams bankfull width. This area coincides with zones 1, 2, and 3 identified by Robison and Beschta (1990b) (Figure 3).

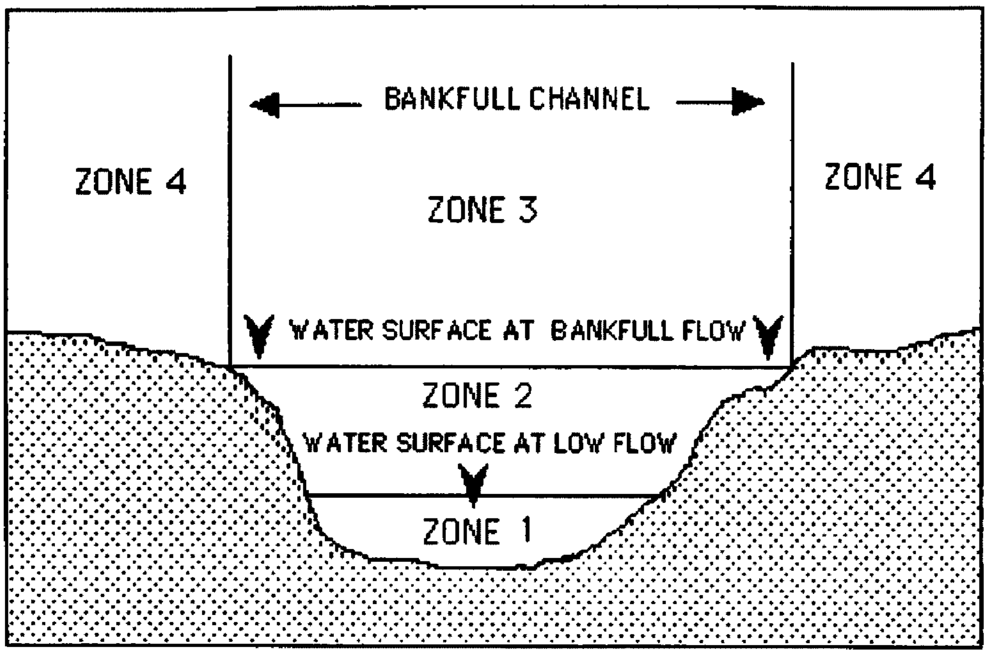


Figure 3. From Robison and Beschta (1990b)

The literature is inconsistent as to what size of wood constitutes LWD. The type and size of material seems to vary according to the objectives of the person measuring the debris. Some studies have included material as small as 2.5 cm in diameter (Harmon *et al.* ,1986). Studies of the effects of woody debris on channel morphology typically use a much larger minimum size for LWD usually 10 cm in diameter and 2 meter in length (Sedell *et al.*, 1988; Bilby and Ward, 1989). Small pieces may play important roles in small mountain streams, and LWD is likely to be smaller in Montana streams than Pacific northwest streams because of differences in tree species and growing conditions. For this study all woody debris meeting the criteria of $\geq$ 10 cm in diameter and $\geq$ 2 meters in length were measured and recorded (see plot form appendix E). The orientation and position of LWD pieces within the channel was recorded. Orientation affects stream flow characteristics and channel morphology, and both characteristics affect piece stability (Robison and Beschta 1990a). The orientation of each piece of LWD was recorded as being: a ramp; bridge; collapsed bridge; incorporated into the channel; part of a jam; parallel to the channel; or simply drift (drawing appendix D). Observations were made as to the function or effect the piece of LWD was having on the stream. These effects were recorded as: flow deflection; flow deflection plus bank stability; flow deflection plus sediment storage; pool formation; or no effect. These were the basic LWD information recorded.

Within the 100 meter reach a site was chosen to sample features for the channel stability portion of the study. The Critical velocity, discharge, and shear stress equations are limited in application and require certain "uniform flow" conditions in which bed slope, water surface slope, and total energy gradients are parallel (Grant et al., 1992). The criteria for choosing these locations were as follows; in riffles of a non-braided channel with self-formed bed and banks, where streamlines are parallel to the bank, away from bends, changes in cross sectional geometry, backed-up water or obstructions to flow which include; channel bars, large boulders, or woody debris. These features disrupt uniform flow conditions by causing convergence, divergence, acceleration, or deceleration of stream flow (Grant *et al.,* 1992). A determination of channel geometry (area and roughness) at bankfull is needed for establishing channel stability thresholds. Channel dimensions were measured using a 20 meter fiberglass tape, meter rod, and a level. In all study reaches one side of the channel had a discernible bankfull height. A simple bubble level on a tight line stretched across the stream was used to locate the bankfull height on the opposite side. This method was used to determine the bankfull height and width. Depth from bankfull height was measured at a set interval at each cross section, depending on stream width. Water surface slope is required for critical discharge and velocity formulas. The slope of the riffle segment was measured using the level rod, 20 meter tape and a Spiegel-relaskop. Particle size distribution was obtained using the Wolman pebble count method (Wolman, 1954; Leopold et al., 1964). Within the representative area a grid pattern of sampling points was established to sample 100 pebbles systematically. Pebbles were randomly selected by closing your eyes, reaching down with one finger to a spot at the tip of your boot, and measuring the first pebble your finger comes in contact with. The intermediate, median, or b-axis diameter (not the shortest or longest axis of each pebble is measured). A ruler was used to measure the pebbles to the nearest cm.

STATISTICAL AND ANALYTICAL PROCEDURES

Analysis was performed using the statistical package Data Desk v. 5.0 (Data Description, Inc.), and Lotus 1-2-3. A Channel Cross-Section Analyzer: XSPRO (Grant et al. ,1992) was also used for the channel stability portion of the study. Data was summarized and displayed graphically to look for influential outliers that could limit the use of parametric tests. Non-normal distributions were log transformed in an attempt to get a near normal distribution for analysis. Many variables were tested with the null hypothesis that the sample means were equal ; ($H_ø: \mu 1 = \mu 2$) was tested against ($H_a: \mu 1 \neq \mu 2$) at an alpha level of 0.05. LWD piece volume was estimated from the equation in Platts *et al* (1987):

$$\text{Volume} = \frac{\Pi(D_1^2 + D_2^2)L}{8}$$

where D_1 and D_2 are end diameters (cm) and L is length (m).

Volumes were then converted to biomass estimates assuming an average wood density of 600 kg/m^3 (Harmon *et al*, 1986). Biomass totals are expressed in terms of weight per unit channel length and weight per unit of channel area.

The channel stability portion of the study was designed after the methods suggested by Olsen and Potts, (1993). Specifically two equations were used for critical bed velocities, one developed by the US Bureau of Reclamation, V_{c1}, and the other V_{c2}, from Costa (1983). Also needed for the analysis was velocity along the bottom at bankfull discharge V_b. The V, or mean velocity, for this equation was generated using XSPRO. The other variables were derived from information obtained at the sample reaches.

(1) $V_{c1} = 0.155 * \sqrt{d}$

(2) $V_{c2} = 0.18 * d^{0.49}$

(3) $V_b = 0.7 * V$

where,

V_{c1} = critical bed velocity (m/s)

V_{c2} = mean flow velocity (m/s)

V_b = velocity along bottom at dominant (bankfull) discharge

d = particle diameter (mm), either d_{50}, d_{84}

V = mean velocity (m/s)

Jowett (1989, in Gordon, et al., 1992) defines relative bed stability (RBS) as the ratio of the critical condition to the existing condition during dominant discharge. This was defined for use specifically with the Hjulstrom curve, which is widely used by hydrologists to predict particle transportation, erosion, and deposition in terms of velocity and particle size. Thus,

$$\text{Relative Bed Stability (RBS)} = V_c \,/\, V_b$$

where V_c and V_b, are the critical bed velocity and the velocity at dominant (bankfull) discharge, respectively.

RESULTS

Following is a synopsis of the results of the LWD survey and the channel stability analysis. Table 2 shows a summary of stream reach variables collected and used in the analysis.

Stream/ Reach		Bankful Width	width/ depth	Stream Gradient	Rosgen Type	Montg/Buff Type	Pfankuch Rating	Habitat Type
Cache Cr	1	11.0 m	15.53	3%	B3	Plane-bed	45	ABLA/MEFE
	2	12.5 m	20.27	4%	B3	Plane-bed	54	ABLA/MEFE
	3	11.5 m	15.50	3%	B3	Plane-bed	60	ABLA/VACA
	4	11.0 m	14.35	3%	B3	Plane-bed	49	ABLA/CLUN
	5	10.0 m	17.37	3%	B3	Plane-bed	55	THPL/CLUN
Cloudburst	1	3.3 m	7.59	4%	A3	Step-pool	35	PSME/PHMA
	2	3.0 m	6.36	4%	A3	Step-pool	37	PSME/CARU
	3	2.7 m	8.11	5%	A3	Step-pool	35	PSME/PHMA
	4	3.0 m	6.36	4%	A3	Step-pool	35	ABLA/VACA
	5	3.3 m	7.07	5%	A3	Step-pool	45	ABLA/VACA
Deerhorn	1	4.5 m	9.39	7%	A3	Step-pool	60	ABLA/VACA
	2	2.5 m	6.64	7%	A3	Step-pool	45	ABLA/MEFE
	3	4.0 m	8.33	7%	A3	Step-pool	47	ABLA/CLUN
	4	4.0 m	7.79	7%	A3	Step-pool	47	ABLA/CLUN
	5	4.0 m	7.23	7%	A3	Step-pool	51	THPL/CLUN
Grizzly Cr	1	3.0 m	9.46	5%	A3	Step-pool	45	PSME/CARU
	2	2.7 m	9.55	5%	A3	Step-pool	49	PSME/VAGL
	3	2.5 m	9.69	4%	A3	Plane-bed	45	PSME/PHMA
	4	2.3 m	5.75	4%	A3	Step-pool	51	PSME/VAGL
	5	2.8 m	8.96	4%	A3	Step-pool	51	PSME/VAGL
N.F. Granite	1	5.3 m	10.23	7%	A3	Step-pool	65	ABLA/MEFE
	2	6.0 m	12.28	7%	A3	Step-pool	55	ABLA/XETE
	3	5.5 m	10.12	8%	A3	Step-pool	48	ABLA/LUHI
	4	5.5 m	11.67	7%	A3	Step-pool	56	THPL/CLUN
	5	5.0 m	10.69	7%	A3	Step-pool	50	ABLA/VACA
S.F. Lolo Cr	1	10.5 m	11.5	3%	B3	Plane-bed	44	ABLA/VACA
	2	13.0 m	19.9	3%	B3	Plane-bed	47	ABLA/XETE
	3	11.0 m	12.55	4%	B3	Plane-bed	49	PSME/VAGL
	4	10.5 m	12.25	3%	B3	Plane-bed	48	THPL/CLUN
	5	12.0 m	13.97	3%	B3	Plane-bed	48	PSME/PHMA
Welcome Cr	1	5.5 m	7.08	4%	A3	Step-pool	27	ABLA/XETE
	2	3.5 m	11.47	4%	A3	Step-pool	33	PSME/PHMA
	3	6.0 m	8.09	4%	A3	Step-pool	47	PSME/VAGL
	4	5.5 m	7.33	4%	A3	Step-pool	39	PSME/CARU
	5	7.2 m	8.25	4%	A3	Step-pool	27	PSME/VAGL
White Cr	1	4.5 m	12.77	6%	A3	Step-pool	39	ABLA/VACA
	2	4.5 m	10.3	7%	A3	Step-pool	40	ABLA/CLUN
	3	4.0 m	14.3	6%	A3	Step-pool	41	ABLA/MEFE
	4	4.5 m	11.1	6%	A3	Step-pool	47	THPL/CLUN
	5	5.0 m	12.87	6%	A3	Step-pool	37	ABLA/VACA

Table 2 Summary of stream reach variables

The analysis of LWD loading in the sample reaches are listed in Appendix A along with piece counts and diameter information. The following table shows stream summary averages.

Stream	Mean # Pieces /100m	Mean Diam. cm	Mean Volume m^3	Mean Volume/m m^3/m	Mean wt/m kg/m	Mean wt/m^2 kg/m^2	Mean Functional Pieces/100	% Total Functional Pieces
CACHE CR	17	25.91	5.59	0.056	33.57	2.91	13	81%
CLOUDBURST	34	14.27	1.71	0.017	10.28	3.34	22	63%
DEERHORN CR	72	23.77	16.29	0.163	97.77	26.87	34	46%
GRIZZLY CR	22	13.32	0.85	0.008	5.10	1.90	8	39%
N.F. GRANITE	61	24.19	14.45	0.145	86.72	15.68	38	60%
S.F. LOLO CR.	44	25.79	13.49	0.135	80.94	6.89	36	70%
WELCOME CR.	13	24.43	5.43	0.054	32.56	5.95	7	61%
WHITE CR	36	21.30	6.89	0.069	41.40	9.24	16	48%
AVERAGE	37	21.62	8.09	0.081	48.54	9.10	22	58%

Table 3 Summary of LWD Sample streams

Sampled streams have wide natural ranges of LWD frequencies (table 3). The variation in most streams was less between reaches than between streams. There were 1493 pieces of LWD counted and measured in the sample reaches. Individual reaches had from a low of 5 pieces to a high of 121 pieces. The mean number was 37 pieces per 100 meter sample reach. The mean diameter of the LWD for all reaches was 21.6 cm (range 14.3-25.9 cm), the median diameter slightly lower at 18.6 cm. In almost all cases visual displays of frequency distributions showed skewed distributions, transformations were tried, but the distribution shape did not improve. Most of the skew was to smaller size classes with few points representing larger diameters. LWD loading in individual study reaches ranged from 0.36 kg/m^2 to 42.58 kg/m^2 with 9.10 kg/m^2 being the mean.

A statistical F-test of multiple μs was done for individual streams as well as for all the streams together (results are in appendix B) . Tests were done for the hypothesis that all the means for LWD diameter, and volume were the same, the results of these F-tests are summarized in table 4 . Ho: All means are equal. Ha: One or more means is different. At alpha level = 0.05.

TABLE 4. F-Test Results

STREAM	F-TEST DIAM.	F-TEST VOL.
CACHE CREEK	FAIL TO REJECT	FAIL TO REJECT
CLOUDBURST	FAIL TO REJECT	FAIL TO REJECT
DEERHORN	FAIL TO REJECT	FAIL TO REJECT
GRIZZLY	FAIL TO REJECT	FAIL TO REJECT
N.F. GRANITE	REJECT	REJECT
S.F. LOLO	FAIL TO REJECT	FAIL TO REJECT
WELCOME CR	FAIL TO REJECT	FAIL TO REJECT
WHITE CR	FAIL TO REJECT	FAIL TO REJECT
ALL	REJECT	REJECT
A3	REJECT	REJECT
B3	FAIL TO REJECT	FAIL TO REJECT

The results of the F-test were consistent for all but one stream, N.F. Granite Creek. For this stream the Ho: All means are equal, had to be rejected, for both mean diameter, and volume. In all the other streams the F-tests results were; fail to reject the null hypothesis that all means are equal, for both diameter and volume. When the F-tests were done comparing the means of diameter, and volume for all the streams the Ho: All means are equal, was rejected, for both.

The orientation and function of the LWD for each reach is summarized in appendix C, a summary by stream is in tables 5 and 6. Orientation was fairly well represented in each stream. The function of the LWD varied mostly with orientation. Close to 60% of the LWD fell into the ramp, bridge, and the drift categories, evenly distributed in each. The remaining 40% were distributed in the parallel, jam, collapsed bridge, and in channel categories listed from most frequent to least.

TABLE 5 ORIENTATION

STREAM	RAMP	BRIDGE	COLLAPSED BRIDGE	INCHANNEL	PARALLEL	JAM	DRIFT
CACHECR	28%	4%	1%	7%	24%	19%	18%
CLOUDBURST	25%	28%	21%	5%	14%	0%	8%
DEERHORN CR	11%	20%	9%	5%	23%	0%	33%
GRIZZLY CR	17%	41%	8%	6%	6%	0%	21%
N.F. GRANITE	15%	10%	5%	11%	13%	20%	27%
S.FK. LOLO	20%	7%	1%	3%	7%	53%	9%
WELCOME CR	30%	33%	14%	2%	5%	0%	17%
WHITE CR	18%	24%	4%	5%	11%	7%	31%
AVERAGE	20%	21%	8%	5%	13%	12%	21%

It seemed appropriate to look at what portion of LWD present was serving a function in relation to channel morphology or stream processes. Categories of function include: flow deflection, flow deflection contributing to bank stability, flow deflection with sediment trapping, pool formation, or no function, as shown in table 6. The percent of functioning LWD was quite variable from individual reach to reach. It ranged from a high of 99% to a low of 20%, with an overall study average of 58%.

TABLE 6 FUNCTION

STREAM	FLOW DEFLECT.	FLOWDEF BANKSTAB	FLOWDEF SEDTRAP	POOL	NONE
CACHECR	15%	44%	7%	12%	22%
CLOUDBURST	0%	17%	40%	8%	35%
DEERHORNCR	0%	24%	17%	5%	53%
GRIZZLY CR	4%	7%	20%	6%	62%
N.F. GRANITE	0%	12%	39%	11%	38%
S.FK. LOLO	0%	8%	21%	55%	17%
WELCOME CR	8%	28%	13%	9%	42%
WHITE CR	4%	17%	18%	6%	55%
AVERAGE	4%	20%	22%	14%	41%

Of the 58% functioning LWD pieces, most often flow deflection was a component of the function. Secondly, the LWD also was contributing to either bank stability, or sediment, and organic debris trapping. Only 14% of the time the LWD was creating a pool. In some cases it was in conjunction with large boulders, or had been incorporated into the channel. There were basically four types of pools formed from the LWD present; scour, plunge, dammed, and backwater. All four types appeared to be equally represented, depending on stream width, and LWD size. Sediment storage was observed with all but the scour pools. The ramps rarely served to trap sediment, but often were associated with small scour pools caused by flow deflection. The LWD parallel to the channels wasn't associated with sediment storage or pool development, but mostly with bank stability.

The relative bed stability (RBS) for each study reach, are summarized in table 7. The first two columns are the particle sizes represented at d_{50} and d_{84}. The definition of d_{50} being that 50% of the particles sampled were smaller than this size, d_{84} consequently, 84% of the particles are smaller than this size. The next three columns are the RBS values generated by the different equations. RBS/USBR is the formula from the bureau of reclamation, and RBS/COSTA is from Costa (1983). The last column shows the number of functioning pieces of LWD measured in the corresponding study reach. Correlation and regression analysis using RBS values and the number and volume of LWD present in each reach was done to look at the potential relationship between RBS and LWD.

Stream/ Reach		PARTICLE D50	PARTICLE D84	RBS USBR D50	RBS USBR D84	RBS COSTA	# Funct Pieces LWD
Cache Cr	1	100	170	1.58	2.06	5.45	9
	2	100	170	1.77	2.31	6.11	15
	3	100	180	1.51	2.03	5.37	24
	4	90	170	1.47	2.02	5.33	11
	5	70	100	1.52	1.82	4.83	7
Cloudburst	1	75	130	2.10	2.76	7.32	32
	2	80	130	2.17	2.76	7.32	19
	3	80	120	2.71	3.32	8.80	30
	4	70	120	2.03	2.65	7.04	16
	5	80	130	2.10	2.67	7.09	13
Deerhorn	1	60	120	1.61	2.27	6.04	40
	2	50	110	1.98	2.93	7.79	40
	3	60	100	1.66	2.14	5.68	42
	4	60	100	1.61	2.08	5.52	17
	5	70	120	1.69	2.21	5.87	30
Grizzly Cr	1	50	100	1.98	2.79	7.43	10
	2	60	90	2.45	3.00	7.98	12
	3	40	70	2.30	3.04	8.11	7
	4	60	90	2.08	2.55	6.79	8
	5	45	90	2.03	2.87	7.64	4
N.F. Granite	1	60	170	1.61	2.71	7.16	24
	2	60	170	1.56	2.63	6.96	79
	3	50	170	1.28	2.37	6.26	27
	4	70	140	1.84	2.60	6.90	36
	5	50	140	1.51	2.53	6.70	24
S.F. Lolo Cr	1	110	200	1.44	1.94	5.12	11
	2	90	160	1.57	2.09	5.53	120
	3	100	180	1.35	1.80	4.77	17
	4	110	200	1.47	1.98	5.22	27
	5	110	190	1.41	1.85	4.90	7
Welcome Cr	1	85	130	1.43	1.76	4.67	6
	2	90	130	1.68	2.02	5.36	9
	3	80	130	1.38	1.76	4.67	4
	4	90	130	1.47	1.76	4.67	8
	5	70	120	1.22	1.59	4.22	10
White Cr	1	100	180	2.69	3.61	9.54	25
	2	100	170	2.27	2.96	7.83	12
	3	80	130	2.95	3.76	9.99	15
	4	80	150	2.32	3.18	8.42	11
	5	80	150	2.32	3..18	8.42	18

TABLE 7. RBS for all study reaches

DISCUSSION

The literature contains many articles addressing the benefits of LWD, its many roles and functions. The great majority of these studies were conducted in the Pacific Northwest and Alaska, with one study done in Eastern Washington, and one from Colorado. Direct comparison of LWD characteristics among studies are complicated by different criteria for minimum size among researchers. Although a 10 cm diameter and 1 meter length have often been used (Long 1987; Andrus et al. 1988; Fausch and Northcote 1992), minimum criteria commonly range from 10 cm to 20 cm in diameter and from 1 meter to 3 meters in length. However, tree species in Montana are not as large as those in the Pacific Northwest, so excluding LWD pieces <20 cm in diameter would eliminated a considerable number of pieces in each sample reach. Small pieces play important roles in small Montana mountain streams (Potts and Anderson, 1990), so it is inappropriate to exclude them from analysis, but differences in criteria must be considered when comparing studies.

Comparisons are also complicated by the use of different descriptive statistics (i.e., mean, geometric mean, median). In this study, there was relatively little difference when viewing these three statistics. Because of the skewed distributions to the smaller size arithmetic means were used, since these tend to be a slightly larger.

There were four studies reviewed which listed LWD pieces/ 100 meters and were used for comparison. The studies from Coastal Alaska, (Harmon et al ,1986), and British Columbia, (Fausch and Northcote, 1992) to eastern Washington, (Bilby and Wasserman, 1989), and Colorado, (Richmond and Fausch, 1995). Figure 4 shows a graphical comparison of the number of LWD pieces found in these studies. The number of pieces was surprisingly similar given the physical differences in the various regions. The piece count ranged from 26 pieces/100 meters in eastern Washington, this number was calculated from measured data, by Bilby and Wasserman, to 43 pieces/100 meters in the Colorado study. The Montana number was an average of 37 pieces/ 100 meter stream reach.

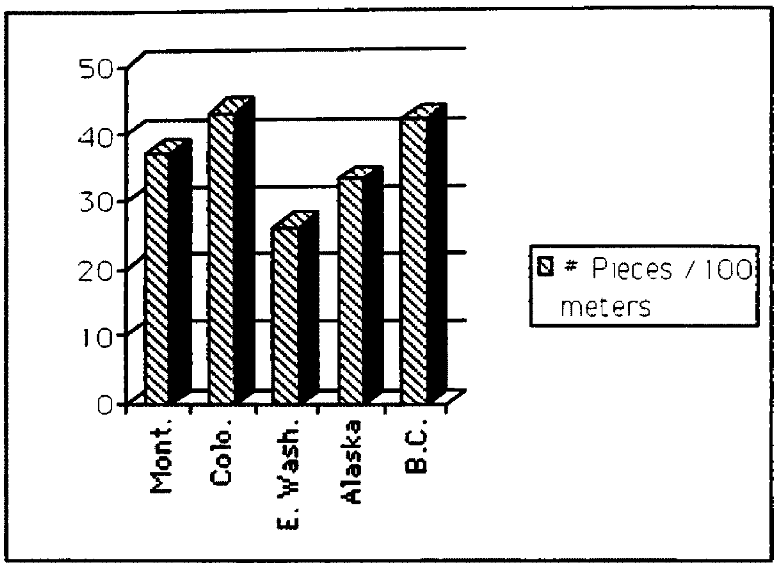


Figure 4 (Number of pieces per 100 meters)

Despite differences in criteria and statistics. LWD in the Montana streams was smaller than that in the wet coastal forests of the pacific northwest and Alaska (Harmon et al, 1986). (**Figure 5**). This possibly owing to differences in predominate tree species and climate between the two regions. The differences are less when comparing similar species and climatic regions like Colorado, and eastern Washington. On average, mean diameter LWD was 21.6 cm in Montana, compared with median of 19 cm in Colorado, and 53 cm average diameter in five undisturbed streams in coastal southeast Alaska. Similarly, LWD in relatively undisturbed reaches of a coastal British Columbia stream had a geometric mean diameter of 26 cm, while Bilby and Wasserman (1989) predicted from measured data in eastern Washington that you could expect to find in a 2-15 m wide stream, LWD with a mean diameter of 45 cm.

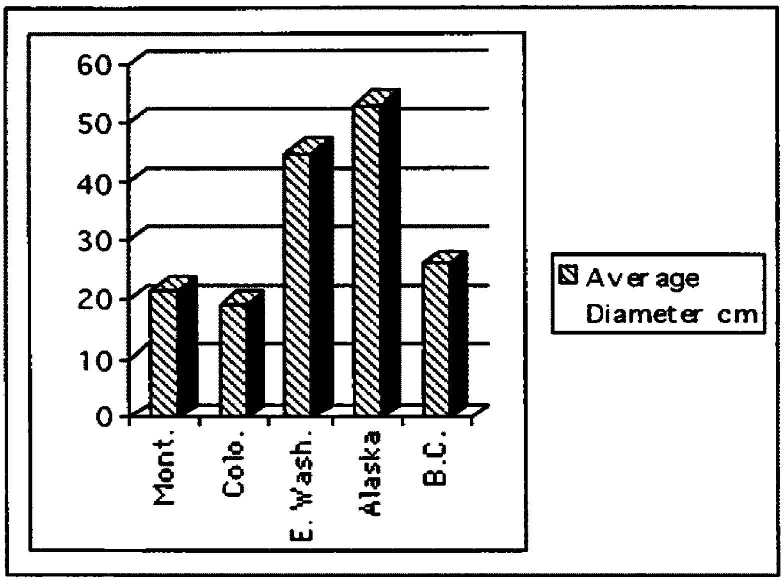


Figure 5 (Average diameter in CM)

LWD volume per 100 m of stream (Figure 6) averaged 58 m^3 in the five Alaska streams and 43.2 m^3 in the British Columbia streams, compared with 13.3 m^3 in the 11 reaches in Colorado. Andrus et al (1988), reported an average woody debris volume per 100 m, in a constricted, high gradient, gravel or cobble based interior Oregon stream being 32.8 m^3, the Montana data ranged from a low of 0.6 m^3 to 32 m^3 with an average of 8.1 m^3.

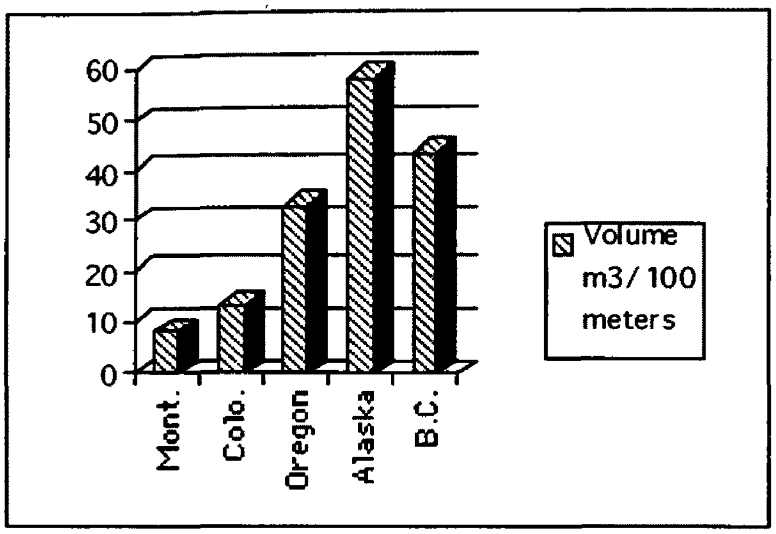


Figure 6 (Volume in m^3 per 100 meters)

Bilby and Wasserman (1989) also found that riparian tree density is positively related to the amount of LWD in streams. This Bilby and Wasserman (1989) study was to be used to formulate riparian management regulations in Washington State. It was conducted in both eastern and western Washington, and they concluded from their results that eastern Washington was so unlike western Washington, that an entirely different set of guidelines was required. The same situation exists here in western Montana, it is so different than the west coast, that different guideline are needed here. Perhaps based on regions with similar climatic and vegetative characteristics.

Channel stability can be directly related to LWD presence or absence (Adenlof and Wohl, 1994, Wood-Smith and Buffington, 1996). LWD impact can be either positive or detrimental depending on its orientation, and function, it can safely dissipate energy or it could cause local scour and instability. The simple interpretation of the RBS index as stated in Olsen and Potts (1993) is that when V_c equals V_b (RBS =1), then the stream is at the threshold of stability. They further proposed that when the RBS ratio >1 but <1.5 the stream is approaching its stability threshold, when 1.5 <RBS < 2 the stream was vulnerable to damage from increased peak discharge, and when RBS >2 the stream channel is very stable. In other words the d_i size fraction will not be mobilized with normally expected flows and stream-bed instability should not result. Olsen and Potts, found a disproportionate number of stream reaches very near or beyond their threshold when they used the d_{50} results. They stated that this conservative estimate of critical conditions seemed unrealistic, and recommended using the d_{84} as the measure of channel stability. Numerous other studies also recommend using the d_{84} size particle in channel stability analysis (Pickup 1976, Jackson and Beschta 1982, Carling 1988, Sidle 1988, Booth 1990, and Kappesser 1992). Similar results were found using the d_{50} in this study with 65 percent of the reaches being near their thresholds, or vulnerable to damage from increases in peak discharges. When the

d_{84} was used, only 20 percent, mostly in two streams, fell into the category of being vulnerable to damage from increases in peak discharges. Using the equation found in Costa all reaches were rated very stable.

CONCLUSIONS

This study provides answers to how much LWD you can expect to find in minimally disturbed Montana streams. The numbers of pieces and loading can be used as a reference standard on which channel assessment and restoration efforts can be based. It is obvious that streams in Montana are different enough that west coast data really does not transfer well to this area. General trends do however show up in both regions. The research in Colorado produced similar results on size and amount of LWD. These two intermountain regions are similar in other characteristics also. The amount of LWD in stream channels depends on a variety of factors. Stream size is an important determinant, with smaller streams usually containing more wood than larger streams (Swanson et al., 1982; Bilby and Ward, 1987). Stream size plays a major role in determining the size of LWD in stream channels as well as the amount of LWD. Generally, the average size (diameter, length, or volume) of LWD in a stream channel increases with increasing stream size (Bilby and Ward, 1987). This increase is caused by the increased capacity of larger channels to move material downstream. Thus, in larger channels, smaller wood is selectively flushed from the system or deposited on the flood plains, leaving only the larger pieces. This causes a decrease in the amount of LWD, but an increase in average piece size.

It is important to remember the role and effects that LWD has on stream systems. There are a few basic ones which also seem to be present in both regions. One of the biggest roles LWD seems to have, is in storing and regulating fine sediment and organic material, which in turn provides habitat for aquatic organisms fish use as a food source. Another role LWD plays is in dissipating energy, and altering channel morphology (Hallisey and Belt, 1996). Finally, LWD provides and maintains aquatic habitat and cover for fish. So, even though the volume and numbers are greatly different between Montana and west coast streams, the functions are consistent in both regions. The rational and reasoning for maintaining functional LWD is just as important to both regions.

Further inventories of LWD should be done in the Rockies to build upon the data found in this research. There could be LWD differences in stream classes, or land types that become obvious with future study.

More work is needed to refine the Relative Bed Stability technique. The method is a sound, well thought out procedure and merits further research. With current technology and better understanding of the processes that occur during bankfull flow, a specific equation designed for the inherently stable stream channels associated with the geomorphic formations found in western Montana can be formulated and tested.

MANAGEMENT IMPLICATIONS

The Streamside Management Zone (SMZ) regulations require that a specific number of trees be retained to provide for future woody debris recruitment. In class 1 streams , which would include the second to fourth order perennial streams in this study, the regulations require that you retain at least 50% of the trees ≥ 20 cm DBH on each side of the stream or 10 trees per 30 meter segment, whichever is greater. Some of the other requirements include; leave species and sizes that represent the original stand, and protect and leave shrubs and sub-merchantable trees. When conducting harvest activities in the SMZ, individual trees that have a high probability of becoming LWD in the stream should be designated for retention. The retention requirements of the SMZ law are consistent with the numbers of LWD per area of stream length found in this study. This should provide adequate tree numbers to provide for future LWD recruitment to the stream.

A problem occurs when a lot of wind thrown trees are present in a stream. If a landowner wants to salvage the wind thrown timber, and recover this valuable resource, the SMZ regulations provide for this situation. A site specific alternative practice can be granted, even though the regulations suggest leaving all trees which have fallen across or in the stream. This is inconsistent with LWD numbers found in this study and could overload the system and cause resource damage. At this point common sense on the part of the State regulator and landowner should be used. A quick inventory, using similar methodology from this study of existing LWD, its amount and function could be done. An agreement could be made as to what the needs of the stream are in relation to LWD loading. Information gained from this research can be used as a basis or reference to design a plan that provides for more, or enhances existing LWD, while protecting against potential problems of having too much debris in the stream. Some of these problems could include induced flooding and damage to improvements like culverts, bridges, and roads. The important factor is the streams needs for LWD can be met, as well as the landowners objectives and resource values can be preserved.

The benefit of having a channel stability rating technique for land managers, is the ability to assess a streams capacity for handling increased flows. Using sampling techniques similar to the ones used in this study can provide data useful in rating formulas. This can assist in planning for stream rehabilitation, and for designing projects that potentially could increase critical flows, for example timber harvesting. Having a tool to better predict impacts could not replace experience and knowledge of stream processes, but would help in screening those streams at risk, and identify those that are in good condition.

APPENDIX A

Stream/ Reach		TOTAL# PIECES	MEDIANDI AMETE	TOTAL VOLUME m^3	VOL./M m^3/m	wt/m kg/m	wt/m^2 kg/m^2	Total Functional Pieces	% Total Functional Pieces
Cache	1	10	16.51	0.654	0.007	3.92	0.36	9	90%
	2	26	25.4	8.973	0.090	53.84	4.31	15	58%
	3	28	20.32	9.766	0.098	58.60	5.10	24	86%
	4	13	30.48	6.174	0.062	37.04	3.37	11	85%
	5	8	38.1	2.407	0.024	14.44	1.44	7	88%
TOTALS		**85**		**27.97**	**0.280**	**167.84**	**14.7**	**66**	**78%**
AVERAGE		**17**	**26.16**	**5.59**	**0.056**	**33.57**	**2.91**	**13**	**81%**
Cloudburst	1	41	10.16	1.918	0.019	11.51	3.49	32	78%
	2	31	10.16	1.609	0.016	9.65	3.22	19	61%
	3	43	10.16	1.591	0.016	9.55	3.47	30	70%
	4	32	10.16	1.495	0.015	8.97	2.99	16	50%
	5	23	10.16	1.957	0.020	11.74	3.56	13	57%
TOTALS		**170**		**8.57**	**0.086**	**51.42**	**16.2**	**110**	**65%**
AVERAGE		**34**	**10.16**	**1.71**	**0.017**	**10.28**	**3.34**	**22**	**63%**
Deerhorn	1	79	20.32	22.969	0.230	137.81	30.63	40	51%
	2	80	20.32	17.742	0.177	106.45	42.58	40	50%
	3	92	21.59	22.347	0.223	134.08	33.52	42	46%
	4	51	17.78	9.672	0.097	58.03	14.51	17	33%
	5	59	20.32	8.749	0.087	52.49	13.12	30	51%
TOTALS		**361**		**81.47**	**0.815**	**488.87**	**134.36**	**169**	**47%**
AVERAGE		**72**	**20.07**	**16.29**	**0.163**	**97.77**	**26.8**	**34**	**46%**
Grizzly	1	30	10.16	1.169	0.012	7.01	2.34	10	33%
	2	30	10.16	1.186	0.012	7.12	2.59	12	40%
	3	14	15.24	0.697	0.007	4.18	1.67	7	50%
	4	15	10.16	0.603	0.006	3.62	1.61	8	53%
	5	20	10.16	0.593	0.006	3.56	1.29	4	20%
TOTALS		**109**		**4.248**	**0.042**	**25.49**	**9.50**	**41**	**38%**
AVERAGE		**22**	**11.18**	**0.850**	**0.008**	**5.10**	**1.90**	**8**	**39%**
N.F.Granite	1	63	15.24	6.886	0.069	41.32	7.87	24	38%
	2	83	25.4	18.184	0.182	109.10	18.18	79	95%
	3	50	30.48	25.172	0.252	151.03	27.46	27	54%
	4	65	20.32	14.089	0.141	84.53	15.37	36	55%
	5	43	20.32	7.934	0.079	47.60	9.52	24	56%
TOTALS		**304**		**72.26**	**0.723**	**433.59**	**78.4**	**190**	**63%**
AVERAGE		**61**	**22.35**	**14.45**	**0.145**	**86.72**	**15.7**	**38**	**60%**
S.F. Lolo	1	28	30.48	14.696	0.147	88.18	8.40	11	39%
	2	121	22.86	31.969	0.320	191.81	14.75	120	99%
	3	27	25.4	10.474	0.105	62.84	5.71	17	63%
	4	28	20.32	6.256	0.063	37.54	3.57	27	96%
	5	14	15.24	4.055	0.041	24.33	2.03	7	50%
TOTALS		**218**		**67.45**	**0.67**	**404.7**	**34.47**	**182**	**83%**
AVERAGE		**44**	**22.86**	**13.49**	**0.13**	**80.94**	**6.89**	**36**	**70%**
Welcome	1	13	22.86	2.155	0.022	12.93	2.35	6	46%
	2	14	30.48	3.949	0.039	23.69	6.77	9	64%
	3	5	10.16	8.827	0.088	52.96	8.83	4	80%
	4	18	20.32	6.401	0.064	38.41	6.98	8	44%
	5	14	20.32	5.799	0.058	34.79	4.83	10	71%
TOTALS		**64**		**27.13**	**0.271**	**162.79**	**29.8**	**37**	**58%**
AVERAGE		**13**	**20.83**	**5.426**	**0.054**	**32.56**	**5.95**	**7**	**61%**
White	1	30	10.16	6.306	0.063	37.84	8.41	25	83%
	2	53	19.05	13.579	0.136	81.47	18.11	12	23%
	3	36	20.32	5.452	0.055	32.71	8.18	15	42%
	4	29	16.51	3.895	0.039	23.37	5.19	11	38%
	5	34	10.16	5.264	0.053	31.58	6.32	18	53%
TOTALS		**182**		**34.49**	**0.345**	**206.98**	**46.2**	**81**	**45%**
AVERAGE		**36**	**15.24**	**6.899**	**0.069**	**41.40**	**9.24**	**16**	**48%**

APPENDIX B

F-TEST SUMMARIES

LWD DIAMETER ALL STREAMS

Summaries
No Selector

Variable	Count	Sum	Mean	Median	Variance	StdDev	Range	StdErr
cache	85	879	10.3412	9	34.0846	5.83820	26	0.633242
cloudburst	181	999	5.51934	4	8.07324	2.84134	16	0.211195
deerhorn	366	3462	9.45902	8	33.4764	5.78588	44	0.302433
grizzly	145	755	5.20690	4	4.56801	2.13729	15	0.177492
nf granite	309	2927	9.47249	8	21.3280	4.61822	28	0.262721
sf lolo	222	2264	10.1982	9	25.7071	5.07022	26	0.340291
welcome	76	739.500	9.73026	8.50000	32.5563	5.70581	28	0.654501
white	186	1581	8.50000	6	27.8730	5.27949	24	0.387111

F- TEST ALL STREAMS

F-Test of Multiple μ's

No Selector

Total Alpha Level 0.0500

Ho: All means are equal. Ha: One or more mean is different.

F-Test for cache...white
F-Ratio = 28.97134
Degrees of Freedom = 7 (top),1562 (bottom)
Reject Ho at Alpha = 0.0500
$p \leq 0.0001$

F- TEST B3 STREAMS

F-Test of Multiple μ's

No Selector

Total Alpha Level 0.0500

Ho: All means are equal. Ha: One or more mean is different.

F-Test for cache and sf lolo
F-Ratio = 0.04485
Degrees of Freedom = 1 (top),305 (bottom)
Fail to reject Ho at Alpha = 0.0500
p=0.8324

F- TEST A3 STREAMS

F-Test of Multiple μ's

No Selector

Total Alpha Level 0.0500

Ho: All means are equal. Ha: One or more mean is different.

F-Test for cloudburst...white
F-Ratio = 34.10412
Degrees of Freedom = 5 (top), 1257 (bottom)
Reject Ho at Alpha = 0.0500
$p \leq 0.0001$

LWD VOLUMES ALL STREAMS

Summaries
No Selector

Variable	Count	Sum	Mean	Median	Variance	StdDev	Range	StdErr
cache	85	27.9742	0.329108	0.231667	0.190197	0.436115	2.46617	0.047303
cloudburst	181	8.56950	0.047345	0.022240	0.007156	0.084591	0.750600	0.006288
deerhorn	365	81.4804	0.223234	0.083400	0.174888	0.418196	5.56000	0.021889
grizzly	129	4.24830	0.032933	0.022240	0.001634	0.040423	0.299931	0.003559
nf granite	307	72.2650	0.235391	0.123556	0.289803	0.538334	6.25500	0.030724
sf lolo	216	67.2309	0.311254	0.177920	0.202967	0.450519	3.11360	0.030654
welcome	72	27.1325	0.376840	0.111200	1.17282	1.08297	8.69831	0.127629
white	186	34.4959	0.185462	0.058071	0.082577	0.287362	1.80885	0.021070

F-TEST VOLUMES ALL STREAMS

F-Test of Multiple μ's

No Selector

TotalAlpha Level 0.0500

Ho: All means are equal. Ha: One or more mean is different.

F-Test for cache...white

F-Ratio = 10.27028

Degrees of Freedom = 7 (top),1533 (bottom)

Reject Ho at Alpha = 0.0500

$p \leq 0.0001$

F-TEST VOLUMES B3 STREAMS

F-Test of Multiple μ's

No Selector

TotalAlpha Level 0.0500

Ho: All means are equal. Ha: One or more mean is different.

F-Test for cloudburst...white

F-Ratio = 10.14505

Degrees of Freedom = 5 (top),1234 (bottom)

Reject Ho at Alpha = 0.0500

$p \leq 0.0001$

F-TEST VOLUMES A3 STREAMS

F-Test of Multiple μ's

No Selector

TotalAlpha Level 0.0500

Ho: All means are equal. Ha: One or more mean is different.

F-Test for cache and sf lolo

F-Ratio = 0.09752

Degrees of Freedom = 1 (top),299 (bottom)

Fail to reject Ho at Alpha = 0.0500

$p = 0.7550$

CACHE CREEK

Summaries
No Selector

Variable	Count	Sum	Mean	Median	Variance	StdDev	Range	StdErr
dia1	10	63	6.30000	6.50000	3.34444	1.82878	5	0.578312
dia2	26	291	11.1923	10	30.5615	5.52825	22	1.08418
dia3	28	288	10.2857	8	43.7672	6.61568	26	1.25025
dia4	13	133	10.2308	12	24.6923	4.96914	16	1.37819
dia5	8	104	13	15	50.2857	7.09124	20	2.50713

F-Test of Multiple μ's

No Selector

Total Alpha Level 0.0500

Ho: All means are equal. Ha: One or more mean is different.

F-Test for dia1, dia2, dia3, dia4, and dia5

F-Ratio = 1.82112

Degrees of Freedom = 4 (top),80 (bottom)

Fail to reject Ho at Alpha = 0.0500

p = 0.1329

Summaries
No Selector

Variable	Count	Sum	Mean	Median	Variance	StdDev	Range	StdErr
vol1	10	0.654227	0.065423	0.065639	0.001918	0.043798	0.133440	0.013850
vol2	26	8.97291	0.345112	0.231667	0.097405	0.312098	1.02428	0.061207
vol3	28	9.76583	0.348780	0.256996	0.260015	0.509917	2.46617	0.096365
vol4	13	6.17376	0.474905	0.242169	0.432241	0.657450	2.45134	0.182344
vol5	8	2.40748	0.300935	0.395378	0.045905	0.214255	0.585653	0.075751

F-Test of Multiple μ's

No Selector

Total Alpha Level 0.0500

Ho: All means are equal. Ha: One or more mean is different.

F-Test for vol1, vol2, vol3, vol4, and vol5

F-Ratio = 1.32899

Degrees of Freedom = 4 (top),80 (bottom)

Fail to reject Ho at Alpha = 0.0500

p = 0.2664

CLOUDBURST CREEK

Summaries
No Selector

Variable	Count	Sum	Mean	Median	Variance	StdDev	Range	StdErr
dia1	43	231	5.37209	4	6.38206	2.52627	8	0.385253
dia2	35	194	5.54286	4	7.60840	2.75833	10	0.466243
dia3	44	225	5.11364	4	3.82400	1.95550	8	0.294803
dia4	35	188	5.37143	4	6.06387	2.46249	10	0.416237
dia5	24	161	6.70833	4	22.3025	4.72256	16	0.963988

F-Test of Multiple μ's

No Selector

Total Alpha Level 0.0500

Ho: All means are equal. Ha: One or more mean is different.

F-Test for dia1, dia2, dia3, dia4, and dia5

F-Ratio = 1.33809
Degrees of Freedom = 4 (top),176 (bottom)
Fail to reject Ho at Alpha = 0.0500
p = 0.2577

Summaries
No Selector

Variable	Count	Sum	Mean	Median	Variance	StdDev	Range	StdErr
vol1	43	1.91820	0.044609	0.022240	0.005312	0.072886	0.348427	0.011115
vol2	35	1.60885	0.045967	0.019306	0.005371	0.073286	0.358311	0.012388
vol3	44	1.59093	0.036158	0.022240	0.001652	0.040651	0.222400	0.006128
vol4	35	1.49502	0.042715	0.029653	0.004197	0.064786	0.333600	0.010951
vol5	24	1.95650	0.081521	0.014827	0.027559	0.166008	0.750600	0.033886

F-Test of Multiple μ's

No Selector

Total Alpha Level 0.0500

Ho: All means are equal. Ha: One or more mean is different.

F-Test for vol1, vol2, vol3, vol4, and vol5

F-Ratio = 1.21740
Degrees of Freedom = 4 (top),176 (bottom)
Fail to reject Ho at Alpha = 0.0500
p=0.3051

Summaries
No Selector

Variable	Count	Sum	Mean	Median	Variance	StdDev	Range	StdErr
dia1	79	756	9.56962	8	38.0944	6.17207	26	0.694412
dia2	83	817	9.84337	8	47.6459	6.90260	44	0.757659
dia3	94	927	9.86170	8.50000	34.0344	5.83390	22	0.601721
dia4	51	460	9.01961	7	23.2196	4.81867	18	0.674749
dia5	59	502	8.50847	8	15.9094	3.98866	20	0.519279

F-Test of Multiple μ's

No Selector

Total Alpha Level 0.0500

Ho: All means are equal. Ha: One or more mean is different.

F-Test for dia1, dia2, dia3, dia4, and dia5

F-Ratio = 0.68187

Degrees of Freedom = 4 (top),361 (bottom)

Fail to reject Ho at Alpha = 0.0500

p = 0.6049

Summaries
No Selector

Variable	Count	Sum	Mean	Median	Variance	StdDev	Range	StdErr
vol1	79	22.9699	0.290758	0.133440	0.481209	0.693692	5.55012	0.078046
vol2	82	17.7421	0.216367	0.121084	0.089158	0.298593	1.92500	0.032974
vol3	94	22.3469	0.237733	0.079076	0.140027	0.374202	1.77920	0.038596
vol4	51	9.67224	0.189652	0.079076	0.049535	0.222564	0.882187	0.031165
vol5	59	8.74928	0.148293	0.059307	0.045367	0.212995	1.32204	0.027730

F-Test of Multiple μ's

No Selector

Total Alpha Level 0.0500

Ho: All means are equal. Ha: One or more mean is different.

F-Test for vol1, vol2, vol3, vol4, and vol5

F-Ratio = 1.10585

Degrees of Freedom = 4 (top),360 (bottom)

Fail to reject Ho at Alpha = 0.0500

p = 0.3535

GRIZZLY CREEK

Summaries
No Selector

Variable	Count	Sum	Mean	Median	Variance	StdDev	Range	StdErr
dia1	31	155	5	4	7	2.64575	15	0.475191
dia2	35	178	5.08571	4	5.55126	2.35611	11	0.398255
dia3	24	146	6.08333	6	5.38406	2.32036	11	0.473641
dia4	29	144	4.96552	4	2.17734	1.47558	6	0.274009
dia5	26	132	5.07692	4	2.07385	1.44009	4	0.282424

F-Test of Multiple μ's

No Selector

Total Alpha Level 0.0500

Ho: All means are equal. Ha: One or more mean is different.

F-Test for dia1, dia2, dia3, dia4, and dia5

F-Ratio = 1.23418

Degrees of Freedom = 4 (top),140 (bottom)

Fail to reject Ho at Alpha = 0.0500

p = 0.2992

Summaries
No Selector

Variable	Count	Sum	Mean	Median	Variance	StdDev	Range	StdErr
vol1	31	1.16992	0.037739	0.024711	0.002066	0.045458	0.246030	0.008165
vol2	35	1.18598	0.033885	0.015444	0.002926	0.054093	0.299931	0.009143
vol3	14	0.696544	0.049753	0.036449	0.001752	0.041862	0.177457	0.011188
vol4	29	0.602797	0.020786	0.012356	0.000211	0.014516	0.053129	0.002696
vol5	20	0.593067	0.029653	0.024711	0.000516	0.022705	0.069191	0.005077

F-Test of Multiple μ's

No Selector

Total Alpha Level 0.0500

Ho: All means are equal. Ha: One or more mean is different.

F-Test for vol1, vol2, vol3, vol4, and vol5

F-Ratio = 1.42675

Degrees of Freedom = 4 (top),124 (bottom)

Fail to reject Ho at Alpha = 0.0500

p = 0.2290

Summaries
No Selector

Variable	Count	Sum	Mean	Median	Variance	StdDev	Range	StdErr
dia4	66	571	8.65152	8	19.4613	4.41150	18	0.543018
dia1	64	480	7.50000	6	12.6984	3.56348	16	0.445435
dia2	83	823	9.91566	10	14.2489	3.77477	18	0.414335
dia3	52	678	13.0385	12	30.9005	5.55882	28	0.770869
dia5	44	375	8.52273	8	17.4181	4.17350	18	0.629178

F-Test of Multiple μ's

No Selector

TotalAlpha Level 0.0500

Ho: All means are equal. Ha: One or more mean is different.

F-Test for dia1, dia2, dia3, dia4, and dia5

F-Ratio = 13.81985

Degrees of Freedom = 4 (top),304 (bottom)

Reject Ho at Alpha = 0.0500

$p \leq 0.0001$

Summaries
No Selector

Variable	Count	Sum	Mean	Median	Variance	StdDev	Range	StdErr
vol1	63	6.88575	0.109298	0.037839	0.033549	0.183165	1.22320	0.023077
vol2	83	18.1841	0.219086	0.154444	0.127918	0.357656	2.97522	0.039258
vol3	52	25.1717	0.484070	0.200160	1.14908	1.07195	6.25129	0.148653
vol4	66	14.0900	0.213484	0.109656	0.150544	0.388000	2.99004	0.047759
vol5	43	7.93350	0.184500	0.108111	0.079514	0.281981	1.70383	0.043002

F-Test of Multiple μ's

No Selector

Total Alpha Level 0.0500

Ho: All means are equal. Ha: One or more mean is different.

F-Test for vol1. vol2. vol3. vol4. and vol5

F-Ratio = 3.92517

Degrees of Freedom = 4 (top),302 (bottom)

Reject Ho at Alpha = 0.0500

$p = 0.0040$

SOUTH FORK LOLO CREEK

Summaries
No Selector

Variable	Count	Sum	Mean	Median	Variance	StdDev	Range	StdErr
dia1	30	357	11.9000	12	38.2310	6.18312	26	1.12888
dia2	121	1223	10.1074	9	20.4134	4.51811	26	0.410738
dia3	28	294	10.5000	10	35.1481	5.92859	20	1.12040
dia4	29	260	8.96552	8	19.9631	4.46800	14	0.829687
dia5	14	130	9.28571	6	36.0659	6.00549	14	1.60504

F-Test of Multiple μ's

No Selector

Total Alpha Level 0.0500

Ho: All means are equal. Ha: One or more mean is different.

F-Test for vol1, vol2, vol3, vol4, and vol5

F-Ratio = 2.03574

Degrees of Freedom = 4 (top),217 (bottom)

Fail to reject Ho at Alpha = 0.0500

p = 0.0905

Summaries
No Selector

Variable	Count	Sum	Mean	Median	Variance	StdDev	Range	StdErr
vol1	30	14.6960	0.489867	0.265644	0.520165	0.721224	3.10124	0.131677
vol2	121	31.9689	0.264206	0.177920	0.101141	0.318026	2.49212	0.028911
vol3	28	10.4738	0.374064	0.091122	0.335595	0.579305	2.59652	0.109478
vol4	29	6.25624	0.215732	0.055600	0.129063	0.359254	1.75140	0.066712
vol5	14	4.05509	0.289650	0.043244	0.199169	0.446283	1.28436	0.119274

F-Test of Multiple μ's

No Selector

Total Alpha Level 0.0500

Ho: All means are equal. Ha: One or more mean is different.

F-Test for vol1, vol2, vol3, vol4, and vol5

F-Ratio = 2.03574

Degrees of Freedom = 4 (top),217 (bottom)

Fail to reject Ho at Alpha = 0.0500

p = 0.0905

WELCOME CREEK

Summaries
No Selector

Variable	Count	Sum	Mean	Median	Variance	StdDev	Range	StdErr
dia1	15	135	9	9	19.8571	4.45614	12	1.15057
DIA2	15	169	11.2667	12	13.7810	3.71227	12	0.958504
DIA3	6	52	8.66667	4	130.667	11.4310	28	4.66667
dia4	22	214	9.72727	8	30.5887	5.53071	20	1.17915
dia5	18	169.500	9.41667	8	36.6544	6.05429	20	1.42701

F-Test of Multiple μ's

No Selector

Total Alpha Level 0.0500

Ho: All means are equal. Ha: One or more mean is different.

F-Test for dia1, DIA2, DIA3, dia4, and dia5
F-Ratio = 0.38597
Degrees of Freedom = 4 (top),71 (bottom)
Fail to reject Ho at Alpha = 0.0500
p=0.8180

Summaries
No Selector

Variable	Count	Sum	Mean	Median	Variance	StdDev	Range	StdErr
vol1	15	2.15527	0.143685	0.092667	0.026309	0.162200	0.578240	0.041880
vol2	15	3.94914	0.263276	0.242169	0.037984	0.194895	0.644033	0.050322
vol3	6	8.82681	1.47113	0.027182	12.5361	3.54063	8.69831	1.44546
vol4	19	6.40141	0.336916	0.098844	0.364024	0.603344	2.12268	0.138417
vol5	18	5.79985	0.322214	0.111200	0.294212	0.542413	2.11280	0.127848

F-Test of Multiple μ's

No Selector

Total Alpha Level 0.0500

Ho: All means are equal. Ha: One or more mean is different.

F-Test for vol1, vol2, vol3, vol4, and vol5
F-Ratio = 1.87249
Degrees of Freedom = 4 (top),68 (bottom)
Fail to reject Ho at Alpha = 0.0500
p=0.1253

WHITE CREEK

Summaries
No Selector

Variable	Count	Sum	Mean	Median	Variance	StdDev	Range	StdErr
dia1	30	236	7.86667	4	41.9126	6.47400	24	1.18198
dia2	54	499	9.24074	7.50000	29.1674	5.40068	20	0.734940
dia3	37	329	8.89189	8	16.5991	4.07420	14	0.669794
dia4	32	263	8.21875	6.50000	17.0151	4.12494	14	0.729193
dia5	33	254	7.69697	4	37.4678	6.12109	24	1.06555

F-Test of Multiple μ's

No Selector

Total Alpha Level 0.0500

Ho: All means are equal. Ha: One or more mean is different.

F-Test for dia1, dia2, dia3, dia4, and dia5
F-Ratio = 0.63316
Degrees of Freedom = 4 (top), 181 (bottom)
Fail to reject Ho at Alpha = 0.0500
p = 0.6395

Summaries
No Selector

Variable	Count	Sum	Mean	Median	Variance	StdDev	Range	StdErr
vol1	30	6.30628	0.210209	0.040156	0.151585	0.389340	1.80638	0.071083
vol2	54	13.5791	0.251464	0.083400	0.097711	0.312587	1.32452	0.042538
vol3	37	5.45189	0.147348	0.111200	0.031801	0.178329	0.900720	0.029317
vol4	32	3.89524	0.121726	0.050040	0.016214	0.127334	0.467040	0.022510
vol5	33	5.26347	0.159499	0.030889	0.112345	0.335179	1.80391	0.058347

F-Test of Multiple μ's

No Selector

Total Alpha Level 0.0500

Ho: All means are equal. Ha: One or more mean is different.

F-Test for vol1, vol2, vol3, vol4, and vol5
F-Ratio = 1.40356
Degrees of Freedom = 4 (top),181 (bottom)
Fail to reject Ho at Alpha = 0.0500
p = 0.2346

APPENDIX C

LWD ORIENTATION AND FUNCTION SUMMARY

LWD ORIENTATION/FUNCTION SUMMARY

	RAMP	BRIDGE	COLL BRIDGE	INCHANNEL	PARALLEL	JAM	DRIFT	TOTALS
CACHE CR	24	3	1	6	20	16	15	85
CLOUDBURST	42	47	35	9	24	0	13	170
DEERHORN CR	38	71	31	19	82	0	120	361
GRIZZLY CR	19	45	9	7	6	0	23	109
N.F. GRANITE	46	30	14	32	38	62	82	304
S.FK. LOLO	44	15	2	6	16	115	20	218
WELCOME CR	19	21	9	1	3	0	11	64
WHITE CR	32	44	8	9	20	12	57	182
TOTAL	264	276	109	89	209	205	341	1493
	18%	18%	7%	6%	14%	14%	23%	

	RAMP	BRIDGE	COLL BRIDGE	INCHANNEL	PARALLEL	JAM	DRIFT
CACHE CR	28%	4%	1%	7%	24%	19%	18%
CLOUDBURST	25%	28%	21%	5%	14%	0%	8%
DEERHORN CR	11%	20%	9%	5%	23%	0%	33%
GRIZZLY CR	17%	41%	8%	6%	6%	0%	21%
N.F. GRANITE	15%	10%	5%	11%	13%	20%	27%
S.FK. LOLO	20%	7%	1%	3%	7%	53%	9%
WELCOME CR	30%	33%	14%	2%	5%	0%	17%
WHITE CR	18%	24%	4%	5%	11%	7%	31%
AVERAGE	20%	21%	8%	5%	13%	12%	21%

	FLOW DEF	FLOW DEF BANKSTAE	FLOW DEF SEDTRAP	POOL	NONE	TOTALS
CACHE CR	13	37	6	10	19	85
CLOUDBURST	0	29	68	13	60	170
DEERHORN CR	0	87	63	19	192	361
GRIZZLY CR	4	8	22	7	68	109
N.F. GRANITE	1	36	120	33	114	304
S.FK. LOLO	0	17	45	120	36	218
WELCOME CR	5	18	8	6	27	64
WHITE CR	7	31	32	11	101	182
TOTAL	30	263	364	219	617	1493
AVERAGE	2%	18%	24%	15%	41%	

	FLOW DEF	FLOW DEF BANKSTAE	FLOW DEF SEDTRAP	POOL	NONE
CACHE CR	15%	44%	7%	12%	22%
CLOUDBURST	0%	17%	40%	8%	35%
DEERHORN CR	0%	24%	17%	5%	53%
GRIZZLY CR	4%	7%	20%	6%	62%
N.F. GRANITE	0%	12%	39%	11%	38%
S.FK. LOLO	0%	8%	21%	55%	17%
WELCOME CR	8%	28%	13%	9%	42%
WHITE CR	4%	17%	18%	6%	55%
AVERAGE	4%	20%	22%	14%	41%

CACHE CR		RAMP	BRIDGE	COLL BRIDGE	INCHANNEL	PARALLEL	JAM	FLOAT	TOTAL
	1	7				2			9
	2	5	1	1	1	2	7	9	26
	3	7	1		2	8	7	2	27
	4	5	1		2	3	1	2	14
	5				1	5	1	2	9
TOTALS		24	3	1	6	20	16	15	85
		28%	4%	1%	7%	24%	19%	18%	

CLOUDBURST		RAMP	BRIDGE	COLL BRIDGE	INCHANNEL	PARALLEL	JAM	FLOAT	TOTAL
	1	15	7	14		3		2	41
	2	7	10	4		8		2	31
	3	11	12	9	4	6		1	43
	4	6	10	3	2	5		6	32
	5	3	8	5	3	2		2	23
		42	47	35	9	24	0	13	170
		25%	28%	21%	5%	14%	0%	8%	

DEERHORN CR		RAMP	BRIDGE	COLL BRIDGE	INCHANNEL	PARALLEL	JAM	DRIFT	TOTAL
	1	6	16	5	1	28		23	79
	2	9	14	11	3	17		26	80
	3	11	12	7	8	17		37	92
	4	3	20	4	2	8		14	51
	5	9	9	4	5	12		20	59
		38	71	31	19	82	0	120	361
		11%	20%	9%	5%	23%	0%	33%	

GRIZZLY CR		RAMP	BRIDGE	COLL BRIDGE	INCHANNEL	PARALLEL	JAM	DRIFT	TOTAL
	1	8	14			2		6	30
	2	5	8	3	3	1		10	30
	3	3	6	2	1	1		1	14
	4	3	7	3	1	1			15
	5		10	1	2	1		6	20
		19	45	9	7	6	0	23	109
		17%	41%	8%	6%	6%	0%	21%	

N.F. GRANITE

		RAMP	BRIDGE	COLL BRIDGE	INCHANNEL	PARALLEL	JAM	DRIFT	TOTAL
N.F. GRANITE	1	4	5		12	5	3	34	63
	2	12	3	3	7	11	47		83
	3	14	2	3	5	5		21	50
	4	11	5	6	5	14		24	65
	5	5	15	2	3	3	12	3	43
		46	30	14	32	38	62	82	304
		15%	10%	5%	11%	13%	20%	27%	

		RAMP	BRIDGE	COLL BRIDGE	INCHANNEL	PARALLEL	JAM	DRIFT	TOTAL
S.FK. LOLO	1	8	8	1	2		1	8	28
	2	4	1			2	114		121
	3	12	3	1	2	2		7	27
	4	14	1		1	12			28
	5	6	2		1			5	14
		44	15	2	6	16	115	20	218
		20%	7%	1%	3%	7%	53%	9%	

		RAMP	BRIDGE	COLL BRIDGE	INCHANNEL	PARALLEL	JAM	DRIFT	TOTAL
WELCOME CR	1	3	5	2	1			2	13
	2	4	5	4		1			14
	3	2	1			1		1	5
	4	6	5	2				5	18
	5	4	5	1		1		3	14
		19	21	9	1	3	0	11	64
		30%	33%	14%	2%	5%	0%	17%	

		RAMP	BRIDGE	COLL BRIDGE	INCHANNEL	PARALLEL	JAM	DRIFT	TOTAL
WHITE CR	1	12	5			5	8		30
	2	2	17	1	2	6	1	24	53
	3	7	9	2	3	3		12	36
	4	2	10	2	2	3	2	8	29
	5	9	3	3	2	3	1	13	34
		32	44	8	9	20	12	57	182
		18%	24%	4%	5%	11%	7%	31%	

SUMMARY

RAMP	BRIDGE	COLL BRIDGE	INCHANNEL	PARALLEL	JAM	DRIFT	
264	276	109	89	209	205	341	1493
18%	18%	7%	6%	14%	14%	23%	

		FLOW DEF	FLOW DEF BANKSTAB	FLOW DEF SEDTRAP	POOL	NONE	TOTAL
CACHE CR	1	2	7			1	10
	2	2	8	1	4	11	26
	3	6	13	2	3	4	28
	4	1	6	3	1	2	13
	5	2	3		2	1	8
		13	37	6	10	19	85
TOTALS							
		15%	44%	7%	12%	22%	

		FLOW DEF	FLOW DEF BANKSTAB	FLOW DEF SEDTRAP	POOL	NONE	TOTAL
CLOUDBURST	1		3	27	2	9	41
	2		8	11		12	31
	3		9	15	6	13	43
	4		6	8	2	16	32
	5		3	7	3	10	23
		0	29	68	13	60	170
		0%	17%	40%	8%	35%	

		FLOW DEF	FLOW DEF BANKSTAB	FLOW DEF SEDTRAP	POOL	NONE	TOTAL
DEERHORN CR	1		30	9	1	39	79
	2		17	20	3	40	80
	3		20	15	7	50	92
	4		8	7	2	34	51
	5		12	12	6	29	59
		0	87	63	19	192	361
		0%	24%	17%	5%	53%	

		FLOW DEF	FLOW DEF BANKSTAB	FLOW DEF SEDTRAP	POOL	NONE	TOTAL
GRIZZLY CR	1	4	2	4		20	30
	2		1	8	3	18	30
	3		1	5	1	7	14
	4		4	3	1	7	15
	5			2	2	16	20
		4	8	22	7	68	109
		4%	7%	20%	6%	62%	

		FLOW DEF	FLOW DEF BANKSTAB	FLOW DEF SEDTRAP	POOL	NONE	TOTAL
N.F. GRANITE	1	1	5	6	12	39	63
	2		12	58	9	4	83
	3		5	17	5	23	50
	4		12	19	5	29	65
	5		2	20	2	19	43
		1	36	120	33	114	304
		0%	12%	39%	11%	38%	

		FLOW DEF	FLOW DEF BANKSTAB	FLOW DEF SEDTRAP	POOL	NONE	TOTAL
S.FK. LOLO	1		1	8	2	17	28
	2		2	4	114	1	121
	3		2	13	2	10	27
	4		12	14	1	1	28
	5			6	1	7	14
		0	17	45	120	36	218
		0%	8%	21%	55%	17%	

		FLOW DEF	FLOW DEF BANKSTAB	FLOW DEF SEDTRAP	POOL	NONE	TOTAL
WELCOME CR	1		3	1	2	7	13
	2		5	1	3	5	14
	3		3	1		1	5
	4	3	3	2		10	18
	5	2	4	3	1	4	14
		5	18	8	6	27	64
		8%	28%	13%	9%	42%	

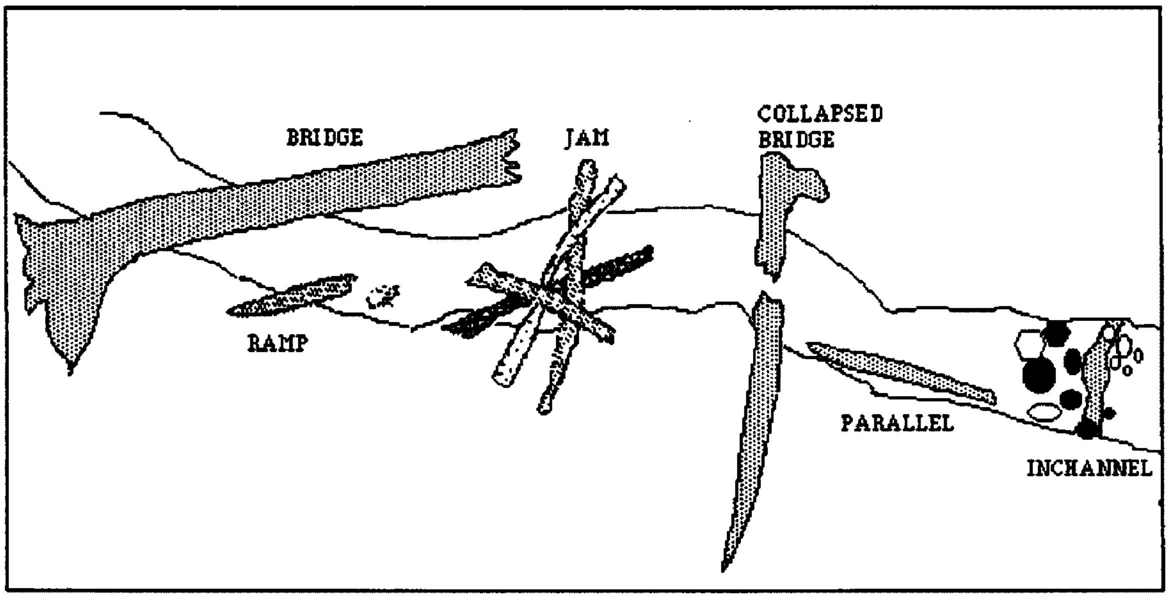
		FLOW DEF	FLOW DEF BANKSTAB	FLOW DEF SEDTRAP	POOL	NONE	TOTAL
WHITE CR	1	6	17		2	5	30
	2	1	7	2	2	41	53
	3		3	9	3	21	36
	4		1	8	2	18	29
	5		3	13	2	16	34
		7	31	32	11	101	182
		4%	17%	18%	6%	55%	

SUMMARY

FLOW DEF	FLOW DEF BANKSTAB	FLOW DEF SEDTRAP	POOL	NONE	
30	263	364	219	617	1493
2%	18%	24%	15%	41%	

APPENDIX D

ORIENTATION DIAGRAM



APPENDIX E PLOT FORM PG.1

STREAM NAME______________________ REACH #______ DATE ________________

LOCATION____

BANKFULL WIDTH________________ REACH LENGTH______________

ROSGEN STREAM TYPE_______________________

PFANKUCH RATING__________________

MONTGOMERY STREAM TYPE____________________

HABITAT TYPE/DOMINANCE TYPE_______________

LWD PIECE COUNT

SPECIES	DIAMETER	LENGTH IN	OUT	ORIENTATION	FUNCTION

STREAM WIDTH________ REACH LENGTH________

GRADIENT → RIFFLE ________ REACH ________

PROFILE

BANK BANK

PEBBLE COUNT

1		26		51		76	
2		27		52		77	
3		28		53		78	
4		29		54		79	
5		30		55		80	
6		31		56		81	
7		32		57		82	
8		33		58		83	
9		34		59		84	
10		35		60		85	
11		36		61		86	
12		37		62		87	
13		38		63		88	
14		39		64		89	
15		40		65		90	
16		41		66		91	
17		42		67		92	
18		43		68		93	
19		44		69		94	
20		45		70		95	
21		46		71		96	
22		47		72		97	
23		48		73		98	
24		49		74		99	
25		50		75		100	

APPENDIX F

CHANNEL RATING FORMS

Adapted from
Jones & Stokes Associates
(1992)

Draft - Version 5 6/19/93

Stream:________________ WRC#:________________ Reach#:________________ Reach Length:______________
Surveyor:______________ Date:____________ Cross Section Monumented? Yes No

I. CHANNEL CLASSIFICATION AND REACH CHARACTERIZATION FOR ALLUVIAL STREAMS

Average Channel Width ______________ Floodprone width ________
Average Valley Bottom Width __________ W/D Ratio _______
Drainage Area ________ Confinement _______

Sinuosity: Straight (1) Slightly sinuous (1.1-1.3) Sinuous (1.4-1.7) Meandering (>1.7)
Measured or Estimated_________

Average Channel Gradient_______________ Instrument used________

Rosgen Stream Type __________

Is the channel profile "stair-stepped"? Yes No
If yes, what forms steps? (Circle all that apply)
Bedrock Boulders Woody debris Other (explain in comments)

Do steps appear stable? Yes No

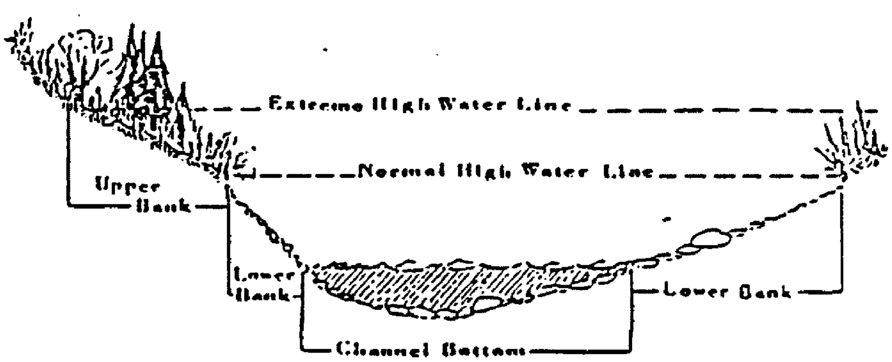
Well defined bedforms absent? Yes No

Is pool-riffle sequence present? Yes No

Montgomery Stream Type______________________

Position in drainage network: 1st order headwater/tributary 4th order mainstem
2nd or 3rd order tributary 5th order or larger river

II. BANK CONDITION



Evidence of overbank flow? Yes No Describe__________________________________
____
____

Evidence of downcutting or widening? Yes No Describe_______________________
____
____

Are overflow/side channels common? Yes No Describe_________________________
____
____

Percent of upper bank exposed? _______

Location of exposed/raw banks

a. nowhere in reach
b. in expected places such as outside of bends or constrictions
c. in unusual places such as straight stretches and/or inside of bends
d. other ____

Do the upper banks have the same slope on both sides? Yes No (If no estimate slopes separately).

Average slope of upper bank(s) _______% ________%

Does bank appear to be above the natural angle of repose (ie would they be unstable if the vegetation were removed)? Yes No

Degree of Bank Protection

1. Predominant bank vegetation class (circle more than one if applicable)

a.mature conifers	e.recent clearcut, trees < 10 feet tall
b.mature deciduous trees	f.shrubs
c.immature conifers 10-60 feet tall	g.grass/sedge
d.immature decidous trees	h.fern/forb

2. Vegetation density

a.upper banks are well protected by a deep dense root network; tree, shrub or grass sedge community dense, mature, well established (<10% open area)
b.upper banks well protected, some open areas (10-40% open area)
c.shallow root network with numerous openings (>40%)
d.little or no protection from roots

Bank Resistance

1. Upper bank rock content (gravel or larger) ________%

2. Dominant upper bank particle size (>50%)

a. resistant bedrock
b. erodible bedrock
c. boulder sized material
d. cemented matrix of fine material containing rock particles
e. cobble/rubble
f. gravel
g. noncohesive fine material (sand/silt)
h. cohesive fine material (silt/clay)

If bank is composed of a mixture of particle sizes, list:____________________________

Dominant lower bank particle size if different (list letter) ________

3. Bank undercutting

a. upper banks are not undercut anywhere along the reach
b. upper banks are undercut only along the outside of bends or where flow is deflected into banks
c. upper banks are undercut in a variety of locations along the reach

III. CONDITION OF CHANNEL BOTTOM

Deposition

1. Extent
   a. no deposits of fine material
   b. few deposits of fine (silt - gravel size) material (<20% of bankfull channel area)
   c. numerous deposits behind obstructions or small point bars (20-50% of the bankfull channel area)
   d. more than half the channel covered with depositional material; large mid-channel or point bars

2. Condition
   Vegetation present on bars or deposits? Yes No
   Describe ____

3. Storage
   a. most potential sediment storage areas behind logs, rocks, etc. have only small deposits
   b. most potential storage sites are nearly full
   c. nearly all potential storage sites are completely full

4. Source (may be more than one)
   a. evidence of mass movements or road failures directly into channel
   b. evidence of bank failure within channel
   c. material being transported from upstream reaches
   d. other. Describe ____
   ____

   Do tributaries appear scoured or "blown out"? Yes No None in reach

   Are extensive deposits of material present where tributaries enter the reach?
   Yes No None in reach

3. Size of deposited material (can be more than one)
   a. silt d. gravel
   b. sand e. mixed coarse
   c. fine organic material

Dominant substrate particle size in active channel
   a. bedrock/large boulder (>60 cm) d. small cobbles and gravel (1.5-6 cm)
   b. mix of large and small boulders (30-60 cm) e. sand/fine gravel
   c. mostly cobble (6-30 cm) f. silt/clay

Infilling
   If the dominant substrate particle size is a,b,c or d, are smaller particles (silt, sand, gravel):
   a. nearly absent in voids between larger particles
   b. present only in still or backwater areas
   c. present throughout the channel, but voids are not completely filled
   d. filling nearly all the void spaces so that larger particles are completely surrounded

Angularity

a. substrate consists mostly of flat or angular rocks resistant to rolling
b. substrate consists mostly of subangular rocks;some flat or rounded rocks present
c. substrate consists mostly of rounded rocks that have little resistance to rolling

Particle Packing (walk around!)

a. larger particles surrounded by smaller or overlapping ones, creating a tightly packed substrate
b. some overlap and particle packing; some surface rocks wiggle when you walk around
c. large particles surrounded by a loose matrix of smaller particles
d. substrate is very loose, most particles can be moved with your foot

Rock Brightness - Compare top and bottom of many rocks in different locations to evaluate "brightness!"

a. in all but channel thalweg, rocks are "dull";bed materials show extensive staining, algal growth or clinging vegetation
b. mix of "bright" and dull rocks throughout channel; staining, algae or clinging vegetation is evident in some places
c. substrate mostly "bright" rocks; staining, algae or clinging vegetation limited to sheltered areas
d. all substrate "bright"; no evidence of staining, algae or clinging vegetation
e. unknown Reason:_________________________ (geologic type, ephemeral stream, other)

IV. OTHER INDICATORS

Woody Debris

1.Location

a.frequent large debris jams completely block the channel
b.a few debris jams block channel
c.individual logs act as important roughness elements within channel area
d.woody debris may be numerous but few pieces appear to be stable
e.there are no logs in or adjacent to the channel

Do most pieces in channel or debris jams have cut ends? ________

Is there any evidence that in-channel woody debris has been removed in the past? Yes No

Evidence of past riparian harvest (stumps)? Yes No Approximate age________?

2.Size

a.most woody debris >50cm in diameter
b.most woody debris 10-50 cm in diameter and greater than .5 channel widths in length
c.most woody debris <10 cm in diameter and greater than .5 channel widths in length
d.numerous pieces of woody debris < .5 channel widths in length

Culverts and Bridges

Describe culverts or bridges within or near the study reach (size, condition, location of rust line on culvert, capability for handling flood flows and debris passage)

____

____

Anthropomorphic channel controls

Describe riprap or levees that have been constructed along the channel (which bank, length, height, effectiveness)

____

____

Other observations (grazing, mining, diversions, fish habitat structures, beaver activity, etc.)

____

____

____

____

____

Sketch valley bottom and channel cross section.

V. SUMMARY OF CHANNEL CONDITION

	Existing	Potential
Channel Banks		
More than 30% of the bank exposed or cutting evident in unusual locations	_______	
Mass wasting along banks contributing significant amounts of sediment	_______	
Upper bank above the natural angle of repose		_______
Banks not boulder or bedrock and vegetation young trees or shrubs, or fern/forb or shallow rooted grass community		_______
Upper bank rock content <50% or dominant particle size class e, f,g, h, or i		_______
Channel Bottom		
More than 20% of the channel bottom covered by deposits of fine material	_______	
Sediment storage class c	_______	
Infilling class d	_______	
Rock brightness class c or d	_______	
Sediment storage class b		_______
Infilling class c		_______
Particle packing class c or d		_______
Tributaries appear to be scouring or dumping sediment into channel	_______	_______
Other indicators		
Evidence of frequent overbank flows causing extensive sediment deposition or scour	_______	
Evidence that woody debris has been removed from channel		_______
Culverts or bridges appear inadequate		_______
Location of woody debris class d or e		_______

APPENDIX G

MODIFIED PFANKUCH EVALUATION FORM

REVISED VERSION 5/1/

STREAM CHANNEL AND RIPARIAN ZONE FIELD EVALUATION FORM *

Item Rated	Stability Indicators by Classes							
RIPARIAN ZONE UPPER BANKS	EXCELLENT	A	GOOD	B	FAIR	C	POOR	D
Mass wasting (existing or potential)	No evidence of past or potential for future mass wasting into channels	6	Infrequent and/or very small. Mostly healed over. Low future potential	12	Moderate frequency & size, with some raw spots eroded by water during high flows	18	Frequent or large, causing sediment nearly year long OR imminent danger of same	24
Bank Protection from Vegetation	90% + plant density. Vigor & variety suggests a deep, dense root mass	2	70-90% density. Fewer plant species or lower vigor suggests a less dense or deep root mass	4	50-70% density. Lower vigor & still fewer species form a somewhat shallow & discontinuous root mass	6	<50% density plus fewer species & less vigor indicate poor, discontinuous, & shallow root mass	8
Stream surface shading	>75% stream surface shading	1	50-75% stream surface shading	2	25-50% stream surface shading	3	Little or no stream surface shading	4
Soil disturbance and/or sediment delivery	no raw soils, or evidence of sediment delivery to the stream	2	Some raw soils, slight sediment delivery to stream	4	Moderate raw soils and sediment delivery to the stream	6	Raw soils abundant, obvious sediment delivery to the stream	8
LOWER BANKS								
Bank Rock Content	65% + with large, angular boulders 12" + numerous	2	40-65%, mostly small boulders to cobble 6-12".	4	20-40%, with most in the 3-6" diameter class	6	<20% rock fragments of gravel sizes, 1-3" or less	8
Large organic debris, logs longer than one half the channel width are functioning as flow deflectors & sediment traps	Large quantities present. Stable in all flows	2	Moderate quantities present. Moveable by flood flows	4	Some LOD present. Moveable at high flows	6	Little or no LOD present. If present, unstable in moderate flows	8
Cutting	Little or none evident. Infrequent raw banks less than 6" high generally.	4	Some, intermittently at outcurves & constrictions. Raw banks may be up to 12".	8	Significant. Cuts 12-24" high. Root mat overhangs & sloughing evident.	12	Almost continuous cuts, some over 24" high. Failure of overhangs frequent.	16
BOTTOM								
Consolidation or particle packing	Assorted sizes tightly packed and/or overlapping	2	Moderately packed with some overlapping	4	Mostly a loose assortment with no apparent overlap	6	No packing evident. Loose assortment, easily moved	8
Scouring and deposition	Less than 5% of the bottom affected by scouring & deposition.	6	5-30% affected. Scour at constrictions & where grades steepen. Some deposition in pools.	12	30-50% affected. Deposits & scour at obstructions, constrictions & bends. Some filling of pools.	18	More than 50% of the bottom in a state of flux or change nearly yearlong.	24
COLUMN TOTALS								

Add values in each column for a total reach score (A)__+ (B)__+ (C)__+ (D)__=__

Reach score of: <53= excellent, 54-81= good/fair, 82+= poor
GREEN YELLOW RED

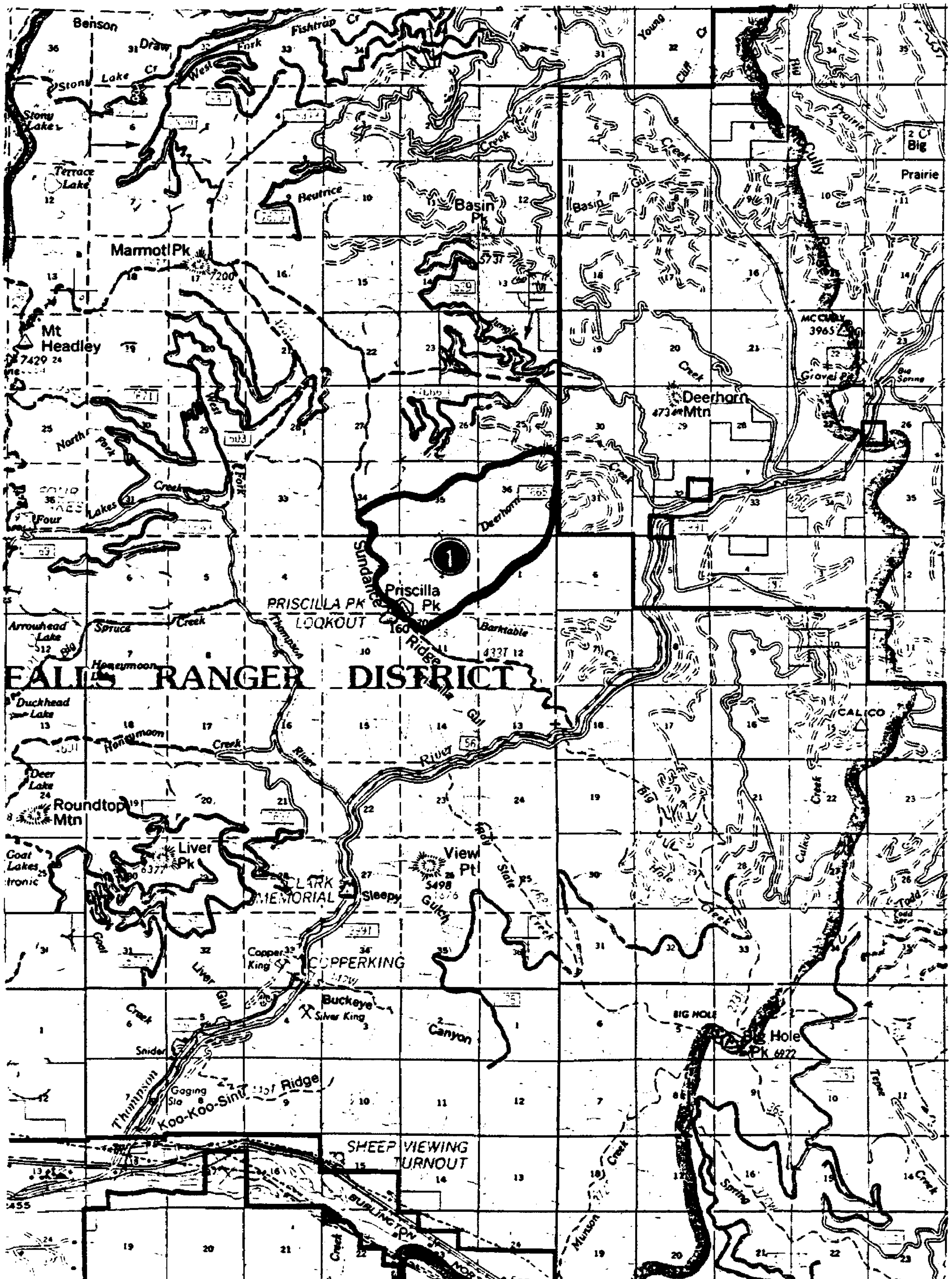
Green - proceed with project Yellow/Red - conduct watershed analysis

* - natural riparian area, not less than 75' for class I streams

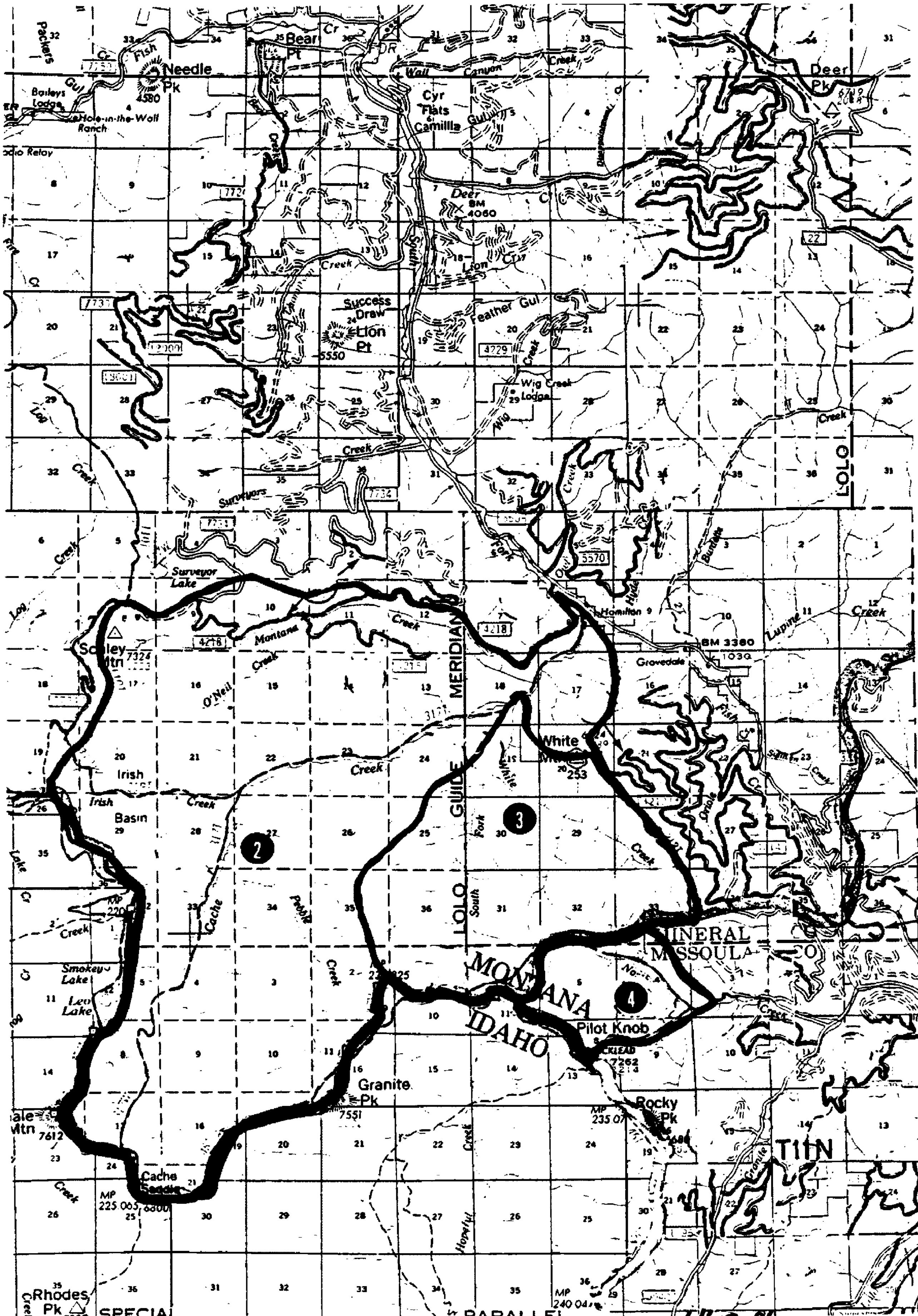
APPENDIX H

1/2 "/ MILE STUDY AREA MAPS

DEERHORN CREEK

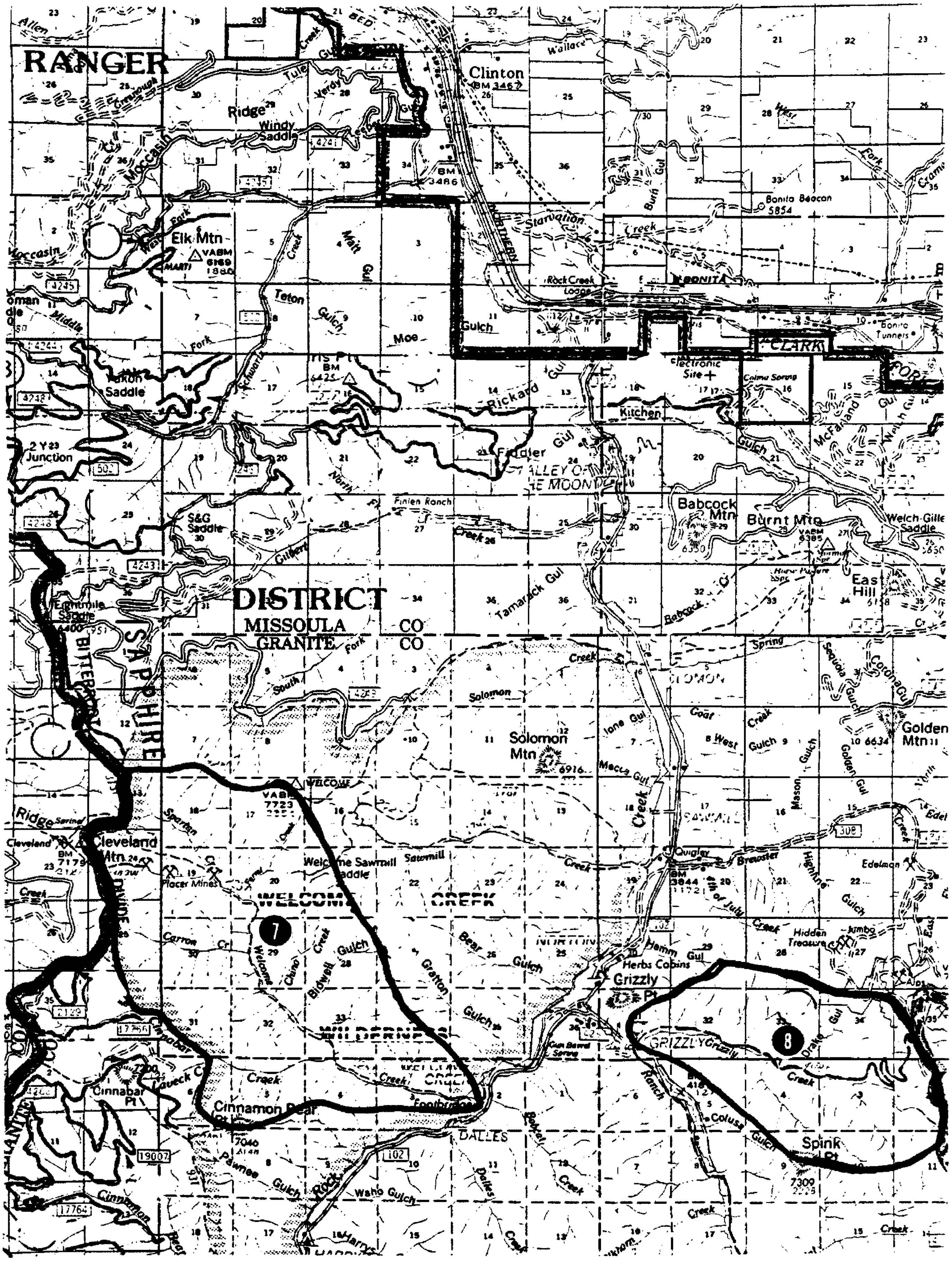


CACHE, WHITE, N.F. GRANITE CREEKS



CLOUDBURST, S.F. LOLO CREEKS

WELCOME, GRIZZLY CREEKS



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