WATERSHED EVALUATION AND HABITAT RESPONSE TO

RECENT STORMS

Annual Report for 1998

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INTRODUCTION

Large and powerful storm systems moved through the Pacific Northwest during the wet season of 1995-96, triggering widespread flooding, mass erosion, and, possibly altering salmon habitats in affected watersheds. This project study was initiated to assess whether watershed conditions are causing damage, triggered by storm events, to salmon habitat on public lands in the Snake River basin. This question is important because improvement in salmon habitat conditions is a goal of several plans for the recovery of salmon populations in the Columbia River Basin (e.g., CRITFC, 1995). The storms and flooding in 1995-96 provide a prime opportunity to examine whether habitat conditions are improving, because the effects of land management activities on streams and salmon habitat are often not fully expressed until triggered by storms and floods (Platts et al. 1989; Reid and Dunne, 1997).

To address these issues, we are studying the recent storm responses of watersheds and salmon habitat in systematically selected subbasins and watersheds within the Snake River system. Our study is designed to examine possible differences in the effects recent storms had in broadly comparable watersheds with differing magnitudes or types of disturbance. Watershed response is examined by comparing storm response mechanisms, such as rates of mass failure, among watersheds with similar attributes, but different levels of land management. The response of salmon habitat conditions is being examined by comparing habitat conditions before and after the storms in a stream and among streams in watersheds with similar attributes but different levels of land management. If appropriate to the results, the study will identify high-priority measures for reducing the severity of storm responses in watersheds within the Snake River Basin that are inhabited by at-risk salmon.

DESCRIPTION OF PROJECT AREAS

The primary study areas are eight watersheds and multiple segments of mainstem rivers within the upper portions of three subbasins tributary to the Snake River. These subbasins include the Tucannon in southeast Washington, the Wenaha in southeast Washington and northeast Oregon, and the Lochsa in north-central Idaho. Each of the three subbasins included in our study has a predominantly dendritic drainage pattern and runoff strongly influenced by snowmelt. Study areas within each subbasin contain habitat used by spring chinook salmon (Oncorhynchus tshawytscha), summer steelhead (O. mykiss), and bull trout (Salvelinus confluentus). At least one, and in many cases two or three of these species, are found within each of the study watersheds. All three can be found in the mainstem Tucannon, Wenaha, and Lochsa rivers. The Lochsa River also supports a strong population of westslope cutthroat trout (O. clarki lewisi). The general location of the these river subbasins and some of the watersheds selected for study are shown in Figure 1.

Tucannon and Wenaha Subbasins

Specific areas of study within the Wenaha and Tucannon River subbasins include mainstem segments of the Tucannon, S.Fk. Wenaha, and Wenaha Rivers, and the following watersheds within the Tucannon Subbasin: Panjab, Meadow, and Cummings Creeks and the Little Tucannon and Upper Tucannon Rivers. These watersheds are located in the Blue Mountains and most of the watershed areas are within the boundaries of the Umatilla National Forest (UNF). All six watersheds have volcanic (basalt) parent material. Table 1 outlines the general characteristics of the study watersheds.

Landforms in the study watersheds are typified by rounded ridgetops and canyons. Lower canyon slopes and north aspects are vegetated with mixed stands of grand fir, Douglas fir, Englemann spruce, lodgepole pine, or western larch. Vegetation is generally sparser on south-facing slopes, and often includes open stands of ponderosa pine. The first and second-order channels tend to be steep with strong lateral constraint. Higher order channels tend to have low to moderate gradients and variable constraint. Habitat use by spring chinook and summer steelhead is largely restricted to the higher order channels. One conspicuous feature of these channels is localized stream braiding, which is common in some stream settings.

Most of the Wenaha subbasin and the upper reaches of several streams in the Tucannon subbasin are within the Wenaha-Tucannon Wilderness Area. Natural disturbance regimes driven by wildfires, insects, and climatic extremes continue as a primary influence on ecological conditions within the wilderness. However, portions of the wilderness have been subjected to livestock grazing (primarily sheep), with the greatest grazing pressure generally occurring in the late 1800s and early 1900s. Outside the wilderness area, land use activities, combined with natural disturbances, have influenced watershed and salmon habitat conditions in the study areas.

Human uses of watersheds in the upper Tucannon subbasin have varied over time. These uses have included the subsistence activities of Native Americans, livestock (sheep and cattle) grazing, mining, road construction, and logging. The lower-most publicly owned segments of the mainstem Tucannon River was channelized after flooding in the mid-1960s (USFS, 1994). Grazing in upper portions of the subbasin has declined since the early 1900s and livestock are now excluded from some areas (D. Grote, USFS, pers comm.). Mining occurred in the Upper Tucannon and Cummings watersheds, with most operations abandoned in the 1920s (USFS, 1994). The first large timber sales on public lands in the subbasin occurred in the Cummings Creek watershed in the late 1950s. Since then an average of about 2-3 km^2 of per year have been logged using various timber harvest methods (USFS, 1994). Roads constructed in association with timber harvest activity have been correlated with higher quantities of fine sediment in streambeds, although cobble embeddedness values remain relatively low in most riffles monitored by the Forest Service (USFS 1994). The watersheds of Cummings Creek, Meadow Creek, and the Little Tucannon River have been significantly logged and roaded, while the watersheds of the Upper Tucannon River and Panjab Creek have been logged and roaded to a lesser degree.

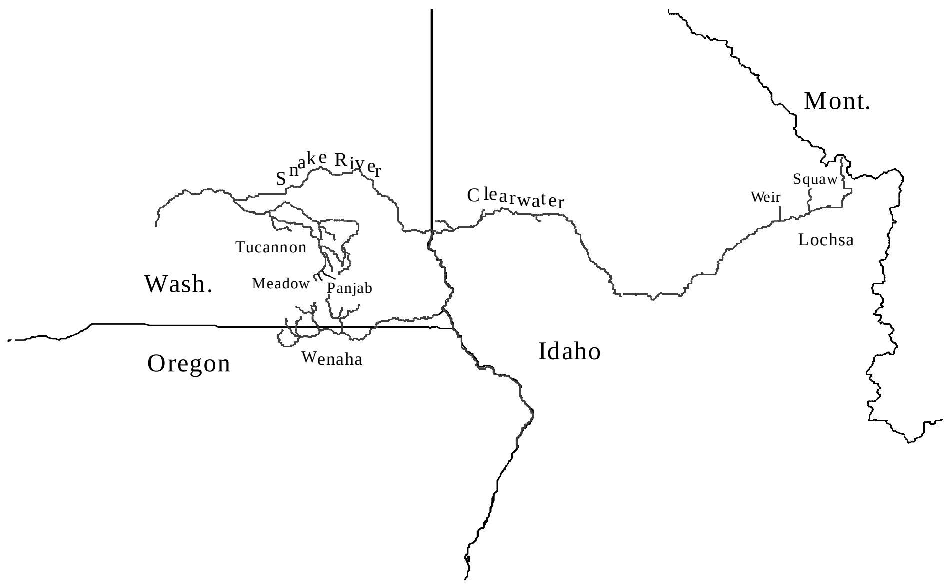

Figure 1. Generalized location map of the study areas within the Snake River basin.

Table 1. Selected characteristics of study watersheds nested within the upper portions of three subbasins of the Snake River Basin.

	Tucannon Subbasin				Wenaha Subbasin	Lochsa Subbasin	
Watershed(s)	Upper Tucannon	Panjab and Meadow	Little Tucannon	Cummings	S.Fk. Wenaha	Squaw	Weir
Drainage area (km^2)	101	66	21	51	140	44	34
Level of Development	wilderness to low	wilderness to mod. High	high	high	wilderness	high	unroaded
Primary parent material	basaltics	basaltics	basaltics	basaltics	basaltics	granite, gneiss, glacial deposits	granite, gneiss, glacial deposits
Landtypes	canyons, rounded ridgetops	canyons, rounded ridgetops	canyons, rounded ridgetops	canyons, rounded ridgetops	canyons, rounded ridgetops	breaklands, slopelands	breaklands, slopelands
Aspect	north-west	north	north-east	north-west	north-east	south	south
Elevation range (m)	908-1948	908-1948	869-1597	628-1695	853-1847	948-2048	856-2030
Stream order	fourth	fourth	third	third	fourth	fourth	fourth

Lochsa River Subbasin

Areas of study within the upper Lochsa subbasin include mainstem segments of the Lochsa River and Crooked Fork, and a pair of naturally similar watersheds with dissimilar land-use histories: Weir Creek and Squaw Creek (see Table 1). These two watersheds in the Lochsa subbasin have comparable landforms and parent materials, which include batholith granites, associated gneisses, and glacial deposits. The primary difference between these two watersheds, both of which are within the Clearwater National Forest (CNF), is that Weir Creek is essentially roadless, while the Squaw Creek watershed has been significantly roaded and logged.

Primary landforms in the Weir and Squaw Creek watersheds are stream breaklands (both dissected and non-dissected) and rounded mountain slopelands (Wilson et al. 1983). The breaklands occur near stream channels and are over-steepened with straight to concave slopes, while the rounded mountain slopelands are found at all elevations and have slopes ranging from straight to convex-concave (Wilson et al. 1983). First and second-order streams in the Weir and Squaw Creek watersheds are generally steep with strong lateral constraint. Third and fourth-order channels within these watersheds tend to have lower stream gradients and more variable constraint. Anadromous fish in the watersheds are dependent primarily on habitats in third and fourth-order channels, with very limited steelhead use of a few short segments of second order streams immediately upstream of confluences with larger order channels (C. Huntington, unpublished data).

Forest vegetation within the two study watersheds and elsewhere in the upper Lochsa subbasin includes western red cedar, subalpine fir, Englemann spruce, lodgepole pine, white pine, grand fir, Douglas fir, mountain hemlock, ponderosa pine, and western larch. Deciduous species common found in riparian areas include alder and red osier dogwood.

Natural disturbances in the upper Lochsa subbasin are similar to those in the Tucannon and Wenaha subbasins, and include wildfires, insects, and climatic extremes. Human activities within the Squaw Creek drainage have expanded considerably since road construction in the area began in the 1950s.

Logging and road construction intensified in the Squaw watershed from the 1950s through the 1970s, then diminished during the 1980s and 1990s (Espinosa et al., 1997). During the 1950s through 1970s, jammers and tractor skidding were the primary logging systems employed (CNF, 1998). These methods required the construction of an extensive system of low-standard roads on steep hillslopes. In the 1980s and 1990s, a shift to skyline and helicopter logging systems reduced the need for extensive construction of new harvest-related roads (Pipp et al. 1997). Currently, about 11% of the watershed area is estimated to be in a condition equivalent to a clearcut, according to the CNF's methods for estimating Equivalent Clearcut Area (CNF, 1998). The density of active roads in the watershed is estimated to be about 2.1 km/km^2, with another 2.0 km/km^2 of inactive roads that are not maintained (CNF, 1998). Prior to the 1995-96 events, in-channel habitat restoration work occurred in Squaw Creek, as part of efforts to mitigate previous damage to anadromous fish habitat in the watershed (Espinosa and Lee,1991; Espinosa et al. 1997)

METHODS AND MATERIALS

Selection of Study Watersheds

We identified initial pool of Snake River subbasins with watersheds containing spring chinook salmon habitat that could serve as candidates for project study, based on the following criteria: 1) they were affected by one or more of the 1995-96 major storms; 2) the subbasins have embedded watersheds with broadly comparable attributes, but differing levels of management disturbance, including largely undeveloped watersheds that could serve as controls in the study; 3) embedded watersheds have pre-storm or other data relevant to our study; 4) locations and other attributes of watersheds do not present major logistical obstacles; and, 5) ownership of candidate watersheds is primarily public, to facilitate access to sites and data. Based review of maps, existing publications, and interviews with resource specialists and scientists, five river subbasins were initially identified as potentially meeting the criteria, including the Lochsa (Idaho), South Fork Salmon (Idaho), Little Salmon (Idaho), Tucannon (Washington), and Wenaha (Oregon). Each of these basins include areas within the transient snow zone which were affected by the storms and all but the Wenaha include potential subsets of comparable watersheds with differing levels of land management disturbance.

Watersheds within each of these five river subbasins were examined for how well they met study criteria, based on available information. On the basis of this initial assessment, a list of watersheds within the subbasins that potentially met the study criteria was developed for more detailed examination. Table A in Appendix 1 contains a list of the candidate watersheds, and their attributes related to the study criteria, that were examined as potential study sites. Candidate watersheds with the Little Salmon River and the Tucannon River subbasins were evaluated on the ground to examine physical watershed attributes and stream characteristics. In June, all of the candidate watersheds shown in Table A in Appendix 1, except those in Lochsa River subbasin, were examined by air for land use patterns, comparability of physical attributes, and stream characteristics. Based on the aerial and ground reconnaissance and review of available information summarized in Table A, the study team made the final selection of the watersheds within river subbasins for study under the project.

The watersheds nested within the Tucannon, Wenaha, and Lochsa River subbasins were selected for project monitoring. The Tucannon subbasin was selected because the embedded watersheds have different levels of logged areas and roads, allowing comparison of storm response across a gradient of land disturbance, in broadly comparable watersheds. Due to the availability of pre-storm data on the Tucannon River mainstem above Marengo, sections of this river were also selected for in-channel habitat monitoring. The South Fork of the Wenaha River is entirely within wilderness and was selected as a comparison point for the Tucannon mainstem. All of the Tucannon and Wenaha watersheds have been subjected to grazing. Due to the almost widespread nature of grazing in the Columbia River basin, completely ungrazed watersheds are relatively rare (Rhodes et al., 1994). Based on evidence from the aerial survey of the candidate watersheds, it was not possible to key into ungrazed watersheds for use as an untreated control in basaltic river systems in the Snake River basin.

In the Lochsa, the Squaw Creek and Weir Creek were selected for study because the watersheds have comparable natural attributes, but highly dissimilar levels of land management. Additionally, of all of the candidate watersheds, Squaw Creek had some of the most comprehensive pre-existing data relevant to the study.

The South Fork Salmon River subbasin was rejected because the location would have exponentially increased project logistics and it did not contain watersheds that met the study criteria and included significant amounts of salmon habitat. In the Little Salmon River subbasin, habitat conditions in Boulder Creek (roaded) and Rapid River (unroaded) were intensively monitored prior to the storm events (Overton et al., 1993). However, these watershed candidates were rejected because aerial and ground evaluation indicated that Boulder Creek and Rapid River have dissimilar watershed and stream attributes.

<u>Aquatic Habitat Conditions in Tucannon and Wenaha River Subbasins</u>

After selecting watersheds for study, we identified gaps in post-storm data on conditions in salmon habitat that were needed to make comparisons of stream conditions before and after the storms. To increase accuracy and precision in the comparisons of conditions, we used the same methods to monitor post-storm habitat conditions as were used to gather pre-storm data on habitat conditions. Because the methods of collecting pre-storm data on habitat conditions varied among the streams in our study, the methods for monitoring post-storm habitat conditions are not constant across all of the subbasins, watersheds, and streams included in our study.

Most pre-storm data on streams in the upper Tucannon and Wenaha subbasins were collected by the UNF, using habitat survey methods based on modifications of Hankin and Reeves (1988). Pre-storm data on the mainstem Tucannon River were also available from: 1) compilations of historic Bureau of Commercial Fisheries habitat surveys and subsequent re-surveys (McIntosh et al. 1993); 2) varied studies conducted or commissioned by the Soil Conservation Service (e.g., Hecht et al. 1982; D.W. Kelly & Associates,1982); and, 3) other unpublished sources and aerial photos. Pre-storm data on these streams provide a baseline for making multiple pre- versus post-storm comparisons within individual streams and across watersheds (Table 2). These data have been acquired from appropriate sources or are still being pursued. Post-storm data needed to evaluate changes in streams was either collected by us during 1998, as needed to fill identified data gaps using sampling protocols identical to those used to collect pre-storm data, or are in the process of being accessed.

Data on anadromous fish habitat in study areas within the upper Tucannon and Wenaha subbasins will be analyzed to identify pre- versus post-storm changes in pool frequency and distribution, residual pool depths, abundance and distribution of coarse woody debris, substrate conditions, bank stability, and channel form. Once defined, the storm responses of individual stream reaches will be related to conditions in surrounding watersheds and compared across watersheds with differing types or patterns of land-use. Data on pre- and post-storm habitat conditions will be summarized in the forthcoming final report.

<u>Aquatic Habitat Conditions in the Lochsa River Subbasin</u>

Pre-storm data on study streams in the upper portions of this subbasin included aerial photos and a variety of aquatic inventory and monitoring data, most of which were collected by Clearwater BioStudies, Inc. (CBS) over the past decade under contract to the CNF. The majority of these inventory and monitoring data were collected using transect-based methods described by CBS (1996a), CBS (1996b), Espinosa (1988), or Platts et al. (1983). These data provide a baseline for assessing pre- versus post-storm changes in stream conditions (Table 3). CBS has conducted some monitoring of stream conditions in selected areas of the Squaw watershed and in the mainstem Lochsa River since the 1995-96 event, also under contract to the U.S. Forest Service. These data were made available to our study in exchange for post-storm data we collected in 1998 at additional locations within the Weir and Squaw watersheds, as well as in lower mainstem Crooked Fork.

Data on anadromous fish habitat in specific stream reaches within the Weir and Squaw watersheds will be analyzed to identify pre- versus post-storm differences in pool abundance and distribution, residual pool depths, abundance and distribution of coarse woody debris, substrate conditions, bank stability, and channel form. The storm responses observed in individual reaches will be related to conditions in surrounding watersheds and compared across watersheds. Analyses of storm responses in the mainstem Lochsa River and Crooked Fork will include assessments of pre- versus post-storm differences in residual pool depths and channel form in both streams and in riffle substrates in the Lochsa River. Patterns of change in mainstem conditions, if any, will be compared to patterns of development throughout the upper Lochsa subbasin. The results will be reported in the forthcoming final report.

Table 2. Available pre-storm data on selected streams within the upper Tucannon and Wenaha subbasins and data needed for analyses of post-storm differences in these streams.

	Stream(s)	Location(s)	Available pre-storm data on aquatic habitat	Post-storm data needs
Tucannon Subbasin				
mainstem Tucannon R.	Tucannon R.	km 71.9-80.7	1935 BOF surveys[1]	1997 USFS surveys[3]
			1992 USFS surveys[2]	1997 USFS surveys[3]
		km 80.7-89.9	1935 BOF surveys[1]	1997 USFS surveys[3]
			1992 USFS surveys[2]	1997 USFS surveys[3]
		Multiple reaches	extent of channel braiding[4]	new (1998) surveys
			1937/1978 SCS river maps[5]	post-storm air photos
Upper Tucannon watershed	Tucannon R.	km 89.9-97.3	1992 USFS surveys[2]	1997 USFS surveys[3]
		km 97.3-103.3	1992 USFS surveys[2]	1997 USFS surveys[3]
Meadow & Panjab watersheds	Panjab Cr.	km 0.0-3.1	1935 BOF surveys[1]	new (1998) surveys
			1992 USFS surveys[2]	new (1998) surveys
		km 3.1-4.8	1935 BOF surveys[1]	new (1998) surveys
			1992 USFS surveys[2]	new (1998) surveys
	Meadow Cr.	km 0.0-2.1	1992 USFS surveys[2]	new (1998) surveys
Little Tucannon watershed	Little Tucannon R.	km 0.0-1.9	1992 USFS surveys[2]	1996 USFS surveys[3]
Cummings watershed	Cummings Cr.	km 0.0-5.6	1935 BOF surveys[1]	new (1998) surveys
			1992 USFS surveys[2]	1998 USFS surveys[3]
		km 5.6-10.0	1935 BOF surveys[1]	new (1998) surveys
			1992 USFS surveys[2]	new (1998) surveys
multiple watersheds	multiple streams	Multiple sites	multi-year substrate data[5]	new (1998) data
			pre-storm air photos	post-storm air photos
Wenaha Subbasin				
mainstem Wenaha R.	Wenaha R.	km 23.0-34.6	1994 USFS surveys[2]	1998 USFS surveys
S.Fk. Wenaha watershed	S.Fk. Wenaha R.	km 4.0-7.1	1994 USFS surveys[2]	new (1998) surveys

[1] McIntosh et al. (1993).

[2] Hankin and Reeves (1988) surveys, as modified by USFS, Region 6 protocols. Minor changes in these protocols over the years made it necessary to collect supplemental data for comparisons of data on some stream characteristics collected during pre- and post-storm years.

[3] Hankin and Reeves (1988) surveys as modified by USFS, Region 6 protocols. Changes in Region 6 protocols for coarse woody debris and substrate conditions required partial re-survey to allow valid comparisons of pre- and post-storm data.

[4] D.W. Kelly & Associates (1982).

[5] Hecht et al. (1982).

Table 3. Available pre-storm data on selected streams within the upper Lochsa Subbasin and data needed for analyses of post-storm differences in these streams.

	Stream(s)	Location(s)	Available pre-storm data on aquatic habitat	Post-storm data needs
mainstem Lochsa River	Lochsa R.	55 specific pools	residual depths in 1994[a]	Depths in 1998[b]
		5 sets of riffles	pebble counts in 1994[a]	1996 and 1998 counts[b]
mainstem Crooked Fork.	Crooked Fork	10 specific pools	residual depths in 1994[a]	Depths in 1998[b]
Squaw watershed	Squaw Cr.	km 0.00-0.83	1995 transect surveys[a]	1996, 1998 surveys[b]
		km 0.83-1.23	1995 transect surveys[a]	1996, 1997, 1998 surveys[b]
		km 4.53-5.10	1995 transect surveys[a]	1998 surveys[b]
		km 5.52-6.00	1995 transect surveys[a]	1996, 1998 surveys[b]
		km 6.00-6.81	1994 transect surveys[a]	1998 surveys[b]
		km 6.81-7.83	1995 transect surveys[a]	1996, 1997, 1998 surveys[b]
		4 monitoring sta.	1988-92 sediment data[a]	1996 and 1998 data[b]
		multiple sites	1995 pebble count data	USFS multi-year counts
	W.Fk. Squaw Cr.	km 0.00-0.76	1991 transect surveys[a]	1996, 1997, 1998 surveys[b]
		1 monitoring sta.	1988-92 sediment data[a]	1996 and 1998 data[b]
		monitoring site	1995 pebble count data	USFS multi-year counts
Weir watershed	Weir Cr.	km 0.64-1.33	1991 transect surveys[a]	1998 surveys[b]
		km 1.33-3.09	1991 transect surveys[a]	1998 surveys[b]
		km 3.09-5.13	1991 transect surveys[a]	1998 surveys[b]
		5 monitoring sta.	1988-92 sediment data[a]	1996 and 1998 data[b]
	W.Fk. Weir Cr.	km 0.00-2.42	1991 transect surveys[a]	1998 surveys[b]
Multiple watersheds	multiple streams	multiple sites	pre-storm air photos	Post-storm air photos

[a] Data collected by CBS under contract to the Forest Service.

[b] Data collected by CBS under contract to the Forest Service (all 1996 and 1997 data, plus a sizable portion of the 1998 data) or to the Columbia River Intertribal Fish Commission (the remainder of the 1998 data).

Mass Failure Surveys and Mapping

In two days in July 1998, the watersheds of the Wenaha and Tucannon River were surveyed by helicopter to identify mass failures and their locations for subsequent field investigation. While information indicated that aerial surveys had also been conducted by the Umatilla National Forest (UNF) in the watersheds of the Tucannon River (UNF, 1997; Fitzgerald and Clifton, 1997), we were unable to determine if the surveys included global positioning system (gps) locations for all failures so that they could be subsequently surveyed on the ground. The Tucannon surveys also only enumerated failures with volumes estimated to be greater than about 76 m^3 (UNF, 1997; Fitzgerald and Clifton, 1997). Aerial survey was unnecessary in the watersheds of Weir and Squaw Creeks, because such surveys had already been completed. The CNF provided us with mass failure data, including the latitude and longitude for all inventoried sites in the Squaw and Weir Creek watersheds, as well as additional information on failure attributes.

Each flight was done in a commercially rented helicopter and used two observers. In the Wenaha River, the entire watershed area above the confluence of the mainstem with Butte Creek was surveyed. In the Tucannon, the watershed area above Marengo was surveyed. In each survey, each major tributary was flown to the headwaters. Tributary watersheds flown in the Wenaha River watershed include: Butte, Rock, Slick Ear, Beaver, Shooly, Milk, Cougar, and Jaussaud Creeks, and the South and North Forks of the Wenaha River. Tributary watersheds flown in the Tucannon River watershed include: Tumulum, Cummings, Meadow, and Panjab Creeks, and the Little Tucannon River. The generalized flight paths of both flight surveys will be mapped and presented in the forthcoming final report. When a mass failure was spotted, the helicopter was maneuvered directly over the initiation point and the latitude and longitude from the gps was recorded along with: general estimates of failure size, whether the failure directly entered the channel network, associated land use at the initiation point (e.g., natural, grazed, roads, recent logging), and failure type (e.g., scoured headwall, slump, etc.)

The gps locations and notes from the aerial surveys were used to direct the ground survey efforts in the Tucannon watershed. During the ground surveys, mass failures identified from the air were located and site characteristics were measured. For purposes of consistency, the site characteristics measured were based on the those previously measured in the CNF survey of failures in the Lochsa River subbasin (Pipp et al., 1997). These site characteristics include: associated land use (roads, natural, etc.), slope shape, lineal distance from watershed divide, slope gradient above and below the failure, failure dimensions, and other site attributes (Pipp et al., 1997).

Site characteristics of mass failures in the Wenaha subbasin will be derived from location information from the aerial overflight in conjunction with analysis of topographic maps. Logistical obstacles, in combination with project budget constraints, precluded ground investigation of all mass failures in the Wenaha.

The results of the ground and aerial surveys will be cross-checked with maps to refine the latitude and longitude locations, which will be provided in the forthcoming final report. Failure dimensions and field notes will be used to estimate mass failure volumes in the Wenaha and Tucannon. Efforts to access the UNF's failure survey in the Tucannon are continuing. Once accessed, the results of the UNF survey will be used to cross-check and augment the project survey of mass failures. The CNF's mass failure data will be used for the Squaw and Weir watersheds in the Lochsa. The final report will include summary data for all inventoried mass failures in all surveyed watersheds, including location, associated land use, slope gradients, slope aspect, slope shape, estimated failure volumes, and whether or not the failures directly entered the channel networks. Failures will be grouped by primary type of land use (e.g., roads, natural, etc) associated with the initiation point. These groupings will be analyzed to determine if there appears to be significant differences in attributes, such as slope gradient or aspect, at the initiation points of failures associated with different land use categories (e.g., logged areas, roads, natural, etc.). The number and mean and total volume of failures will be reported by watershed and primary type of land use at the initiation point.

Headwater Channel Conditions

In the Tucannon and Wenaha subbasins, we monitored conditions in smaller tributary channels in 18 roaded and 18 unroaded subwatersheds to investigate potential differences in headwater channel response to the storms within the two strata. Initial reconnaissance indicated that increased channel erosion might have been one of the major storm response mechanisms in the basaltic watersheds of the Tucannon and Wenaha, while available data indicated that mass failures were the dominant watershed storm response in the study watersheds in the Lochsa River subbasin. Initial landscape analysis indicated that it was not possible to stratify roaded and unroaded subwatersheds on the basis of similar aspect and area without creating significant logistical obstacles with respect to access. Therefore, subwatersheds in both strata were selected based on access considerations and land use criteria (roaded, unroaded), across a range of drainage area and aspects. The size of the subwatersheds monitored ranged from about 0.9 to 3.6 km^2. The channels were monitored for bank stability, height and number of nick points, channel width, thalweg depth, and channel gradient. Bank stability was determined via the methods of Bauer and Burton (1993) with minor modifications.

The final report will include spreadsheets summarizing data from headwater channel monitoring, including location of the monitoring, upstream subwatershed area, bank stability (%), height and number of nick points, channel width, thalweg depth, and channel gradient. The data for width, depth, and bank stability will be analyzed with subwatershed area treated as an independent variable.

Survey of Channel Network Extension by Road Networks

A subsample of roads in the study watersheds in both the Lochsa and Tucannon River subbasins were surveyed to estimate the degree of hydrologic integration of the road network with the stream network. Roads can contribute to elevated peakflows by causing overland flow, intercepting subsurface flow, and accelerating delivery of runoff by extending of the channel network in managed basins (Wemple et al., 1996). The road survey used an approach patterned after a simplification of the methods of Wemple et al. (1996).

The roads were surveyed using a random stratified sampling scheme. Roads on the UNF within the Tucannon subbasin and on the CNF in the Squaw watershed in the Lochsa were assigned to one of three strata based on hillslope position: 1) valley bottoms, which included the bottom third of slopes extending from the mainstem rivers (>3rd order) to drainage divide; 2) ridgetops, which included the upper third of the slopes extending from the mainstem rivers to drainage divide; and, 3) midslopes, which included the remainder of the slope area. These strata were delineated on USFS administrative maps. Total road lengths within the delineated strata areas were estimated from the maps, using scaled measurements of individual road segments. Road segments 1609 m in length were randomly selected so that the total length of surveyed segments was approximately 10% of the estimated total length of roads within the strata.

Each surveyed road in each stratum was monitored for 1609 m, as measured with a hip chain on foot. Based on field evidence, the surveyed road segments were divided into sections with drainage that terminated homogeneously in one of four categories: 1) to channel tributaries or tributary extensions with clear signs of active, contiguous flow to channels; 2) to slopes without any of evidence of downslope gullying or concentrated runoff; 3) to slopes with downslope gullying <10 m in length; and 4) to slopes with downslope gullying >10 m in length. In each of the sections, the length, width, average longitudinal road slope, and length of cut and fill slopes were measured. The road drainage in each section was also characterized by whether it exited the road via a ditch, a culvert, a waterbar, or via diffuse outsloped drainage. The average height of the contiguous cut and fill sections within road segments was also estimated. The length, width, and depth of gullies <10 m long were measured. The length of gullies that were > 10m long was not measured for logistical reasons; these length will be estimated from maps under the assumption that they terminate at the nearest downslope stream tributary.

The length of road sections within the drainage categories were summed for each road in each stratum, in each watershed sampling unit. These lengths were used to determine the average fraction of the road network within the slope categories that act as extensions of the channel network. A summary of the road survey data for each road and slope position stratum in each watershed will be included in the final report

Based on our field evaluations in the Tucannon and those of Pipp et al. (1996) in the Lochsa, road lengths derived from available administrative maps significantly underestimate the total length of roads in watersheds, because the maps omit some roads that are low standard, closed, or abandoned. To provide a correction factor for road lengths estimated from the maps, road lengths will be estimated from recent aerial photos in subsections of the watersheds and compared to road lengths estimated from the administrative maps over the same watershed area. This will be used to provide a more accurate estimate of the fraction of the actual road network sampled during the surveys and to estimate the amount of road in each stratum that act as channel extensions which can increase storm runoff.

Soil Loss on Non-forested Lands

Soil loss in historically and currently grazed non-forested lands was investigated in the Tucannon watersheds by measuring soil pedestals (also termed "erosion mounds") beneath plants and lichen bands on exposed rocks. Soil pedestals are widespread on non-forested areas in the Tucannon River watersheds. The soil pedestals and rock bands can provide an indication of the amount of soil eroded from the area during the life of the plant on the pedestal (Reid and Dunne, 1996). Topsoil loss can influence storm runoff by reducing infiltration rates and soil moisture storage in the soil profile.

Five sites were randomly selected for monitoring of soil loss indicators from a pool of 10 non-forested and accessible sites on the UNF that were identified from a 1:150,000 scale topographic map. In each site, two plots with an area of 9 m^2, were randomly placed on each site. Within each plot, the following were determined and recorded: estimated plant cover, slope, aspect, plant type on pedestal, and the number of exposed rocks and soil pedestals within the plot. The height of subset of the pedestals and bands were measured and the basic soil texture of the pedestals was determined. A truncated pebble count based on the method of Wolman (1954) was used to provide a quantitative indication of the soil particles sizes at the soil surface outside of the pedestals. The soil pedestal data will be provided in the final report to provide an indication of the amount of soil eroded from these sites during the life of the plants on the pedestals.

Flood Recurrence Intervals

Where possible, recurrence intervals for the flood events triggered by 1995-1996 storm events will be estimated from hydrologic records from the U.S. Geological Survey stream gaging stations within the study river basins that have an adequate period of record (>20 years). The data will be analyzed via standard hydrologic analysis to estimate recurrence interval (e.g., Dunne and Leopold, 1978) for the 1995-1996 flood events.

Peakflow records from the USGS station #13337000 on the Lochsa River near Lowell, Idaho will be used for standard hydrologic analysis for recurrence intervals for the events in Squaw and Weir Creek. Other gaging stations within the Lochsa River system will also be evaluated for potential use in the analysis of recurrence intervals. The results of alternative methods for estimating the recurrence intervals of the storms and flood flows in the watersheds of the Tucannon subbasin (Fitzgerald and Clifton, 1997) and Squaw Creek (Pipp et al., 1997) will be compared to recurrence intervals estimated from stream gage records.

RESULTS AND DISCUSSION

Aquatic Habitat Conditions

Data we have collected or otherwise acquired include most of the pre- and post-storm information outlined in Tables 2 and 3. Aquatic habitat data we collected in the Tucannon and Wenaha subbasins have been analyzed to the degree feasible without acquiring additional data from agency sources. These additional data are available to us, but most have been difficult to acquire in digital or other formats suitable for the analyses to be performed. Therefore, we have no detailed results to report to date.

Preliminary analyses of stream data collected within the Weir and Squaw watersheds have been completed, but post-storm patterns of change remain to be examined in detail or correlated to specific watershed conditions. Analysis cannot be completed until the data collected by CBS in 1998, under contract to the CNF, in the Weir and Squaw watersheds and the mainstem Lochsa River are released by the CNF. It is expected that these data will be available in mid-March

Mass Failure Surveys and Analysis

The data from the ground and aerial surveys in the Wenaha and Tucannon River watersheds are being cross-verified with topographic maps. Analysis will ensue once cross-verification is complete. Based on our ground surveys in the Tucannon system, it is clear that there were some mass failures and road failures at culverts that could not be properly inventoried on the ground or identified from the air due to post-storm reconstruction of roads prisms, culverts, and cut and fill slopes. Fitzgerald and Clifton (1997) reported that 95% of surveyed culverts in the Tucannon River watershed failed. Our fieldwork indicated that most of these culvert failures had been reconstructed by the beginning of our surveys in July 1998. Therefore, the UNF's mass failure survey data will be used to augment our data and analyses of mass failure characteristics.

Analysis of mass failure data from the CNF for Squaw and Weir Creeks is ongoing and all results are preliminary. Table 4 summarizes some of the preliminary results of the analysis of mass failures triggered by the 1995-96 storms, as inventoried by the CNF in Squaw and Weir Creeks. In Squaw Creek, there were a total of 35 mass failures inventoried. As previously reported by the CNF (Pipp et al., 1997; CNF, 1998), nineteen of the failures were associated with roads, 15 were associated with timber harvest, and one initiated in a natural setting. By land use category, failures associated with roads accounted for the greatest percentage of the number of failures (54%). Our preliminary analysis indicates that mass failures associated with roads also had the highest mean volume (1,091 m^3) of failures by land use category (Table 4). In the unroaded and unlogged watershed of Weir Creek, there were no mass failures triggered by the 1995-96 storm events. Other analyses of failure frequency and volume associated with site characteristics are ongoing.

Table 4. Number and volume of mass failures triggered by the 1995-1996 storm events in Squaw and Weir Creek watersheds by associated land use at the initiation point. The density of mass failures is expressed in the number mass failures per unit watershed area (n/km^2). Mass failure volume is expressed in terms of the volume eroded by the mass failure. A dash (-) indicates that the category is not applicable.

	Total--All settings				Roads				Harvested Areas				Natural Settings			
Watershed	n	(n/km^2)	Vol. (1000 m^3)		n	(n/km^2)	Vol. (1000 m^3)		n	(n/km^2)	Vol. (1000 m^3)		n	(n/km^2)	Vol. (1000 m^3)	
			Total	Mean			Total	Mean			Total	Mean			Total	Mean
Squaw Cr.	35	0.8	31.9	0.91	19	0.43	20.7	1.09	15	0.34	11.0	0.73	1	0.02	0.15	-
Weir Cr.	0	0	0	0	-	-	-	-	-	-	-	-	0	0	0	0

Headwater Channel Conditions

The results of monitoring of headwater channel conditions are undergoing analysis. Currently, there are no preliminary results to report from this monitoring effort.

Survey of Channel Network Extension by Road Networks

The preliminary results of the road drainage survey are summarized in Table 5. Based on these results, a significant amount of the surveyed road network in all slope position strata, in both watersheds, acts as extensions of the channel network, with road drainage routed to tributary channels or gullies >10 m in length. In both watersheds surveyed, the mean percentage of the road length contributing to streams or tributary channels increased in a downslope direction by slope position stratum, with valley bottom roads having the highest percent length draining into streams or tributary channels. A significant amount of the road network also contributes to the formation of gullies >10 m in length, as indicated in Table 5. In both watersheds, roads in the valley bottom stratum had the lowest mean percent length contributing to gullies >10 m. This may be due to the relatively close proximity of the roads to streams or the generally less steep slopes in the valley bottom stratum. Wemple et al. (1996) found that gullies from road drainage generally occurred on steeper slopes.

Table 5. Summary of preliminary results of channel network extension by roads in the watersheds of the Tucannon River subbasin and in the Squaw Creek watershed. The categories of mean percent road length routed to streams and gullies >10 m length are not exclusive; some road lengths with drainage routed directly to tributary channels via gullies >10 m in length are included in both categories.

Watershed	Road segments surveyed (n)	Slope position category of roads	Mean percent road length with drainage routed to streams or tributary channels	Mean percent road length routed to gullies >10 m in length
Tucannon	13	Ridgetop	18	6.2
Tucannon	2	Midslope	28	24
Tucannon	3	Valley bottom	52	7.1
Squaw	4	Ridgetop	7.5	6.3
Squaw	4	Midslope	18	3.6
Squaw	1	Valley bottom	59	0

Soil Loss on Non-forested Lands

The results of monitoring of soil pedestals have been entered into spreadsheets and are undergoing analysis. Currently, there are no preliminary results to report.

Flood Recurrence Intervals

The analysis of flood recurrence intervals from data at the USGS stream gaging site on the Lochsa River near Lowell, Idaho is ongoing. The gaging site clearly meets study criteria because it includes more than 80 years of peakflow data. Other gaging station records are being evaluated for use in estimating the recurrence intervals of the flood. Currently, there are no other interim results to report.

SUMMARY AND CONCLUSIONS

Analysis of the data is still in progress. Therefore, it is too early to summarize the project conclusions. Conclusions will be summarized in the forthcoming final report.

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SUMMARY OF PROJECT EXPENDITURES

There were no major purchases of property under the project during the year. Table 6 summarizes project expenditures for the year.

Table 6. Summary of project expenditures in 1998 by major category of expenditure.

Category	Total Expenditures from 1/1/98 to 12/31/98
Salaries and Fringe	$16,910.20
Travel	$3,790.84
Supplies	$12.00
Oper. & Maint.	$2,600.00
Subcontracts	$51290.80
Indirect	$8,434.52
Total	$82,038.89

Appendix A: Table 1. Preliminary assessment of general attributes (related to study criteria) of candidate watersheds considered for study

Subbasins	Lochsa	Lochsa	Lochsa	Lochsa	Lochsa	S.Fk. Salmon	S.Fk. Salmon	S.Fk. Salmon	S.Fk. Salmon
Nested watersheds	**Papoose**	**Squaw**	**Beaver**	**Weir**	**Mainstem**	**Blackmare**	**Buckhorn**	**Fitsum**	**Mainstem**
Ownership	pred. public	public	mixed	public	pred. public	public	public	public	public
Level of development	heavy	heavy	intermed.	none	light	none	developed	light	intermed.
Natural disturbances	***	fires	***	fires	fires	fires	fires	fires	fires
Potential control(s)	Weir	Weir	Weir	control	none	control	Blackmare	Blackmare	none
Extent of salmon habitat	several km	several km	several km	a few km	181 km	2-3 km	2-3 km	2-3 km	extensive
Primary geology/parent material	granitic	granitic	granitic	granitic	granitic	granitic	granitic	granitic	granitic
Landtypes	breaklands/ slopelands	breaklands/ slopelands	breaklands/ slopelands	breaklands/ slopelands	breaklands	breaklands/ slopelands	breaklands/ slopelands	breaklands/ slopelands	breaklands/ slopelands
Aspect	south	south	west	south	west	east	east	east	north
Elevation (m above MSL)	1006-2115	948-2048	1091-2112	856-2030	466-2688	1276-2658	1183-2761	1139-2761	640-2740
Runoff pattern	snowmelt	snowmelt	snowmelt	snowmelt	snowmelt	snowmelt	snowmelt	snowmelt	snowmelt
Drainage pattern	dendritic	dendritic	dendritic	dendritic	dendritic	dendritic	dendritic	dendritic	dendritic
Drainage area (sq km)	54	44	28	34	3045	47	65	80	3290
Channel types	B, A	B, A	B, A	B, A	B,A	B,A	B,A	B,A	C,B
Stream order	4	4	4	4	7	3	4	4	5
Streamflow gage(s)	no	yes	no	no	yes	no	no	no	yes
Watershed analyses	yes	yes	no	no	no	no	no	no	partial
Specialized GIS layers	yes	yes	yes	yes	yes	yes	yes	yes	yes
Landslide inventories	yes	yes	yes	yes	yes	no	no	no	no
Pre-storm air photos	yes	yes	yes	yes	yes	yes	yes	yes	yes*
Post-storm air photos	yes	yes	yes	yes	yes	no	no	no	yes
Historic channel surveys	no	no	no	no	yes	no	no	no	no
Pre-storm habitat surveys	yes	yes	yes	yes	yes	no	yes	no	no
Post-storm habitat surveys	yes	yes	yes	yes	no	no	no	no	no
Pre-storm sediment data	yes	yes	no	no	yes	yes	yes	yes	yes
Post-storm sediment data	yes	yes	no	yes	yes	yes	yes	yes	yes
Pre-storm channel data	yes	yes	no	no	no	no	no	no	yes*
Post-storm channel data	yes	yes	no	no	no	no	no	no	yes*

* high resolution videography

*** Unknown/uncertain

Appendix A: Table 1 (continued). Preliminary assessment of general attributes (related to study criteria) of candidate watersheds considered for study

Subbasins	L. Salmon	L. Salmon	L. Salmon	L. Salmon	Tucannon	Tucannon	Tucannon	Tucannon	Tucannon	Tucannon	S.F. Wenaha
Nested watersheds	**Boulder**	**Rapid**	**Mainstem**	**Whitebird**	**U. Tucannon**	**Panjab/ Meadow**	**Bear**	**L. Tucannon**	**Cummings**	**Mainstem**	**S.F. Wenaha**
Ownership	95% public	public	mixed	pred. public	public	public	public	public	pred. public	mixed	public
Level of development	developed	none-light	developed	mod	light-mod	light/mod	light	high	high	heavy	wilderness
Natural disturbances	***	fires	***	***	***	***	***	***	***	***	fires
Potential control(s)	Rapid	control	none	Rapid	S.F. Wenaha	control/ treatment	control?	Panjab?	upper Tucannon?	S.F. Wenaha	control
Extent of salmon habitat	Several km	several km	extensive	several km	extensive	limited	limited	limited	limited	extensive	extensive
Primary geology/parent material	border/ volcanic	volcanic/ border	mixed	volcanic/ granitic	basaltic	basaltic	basaltic	basaltic	basaltic	basaltic	basaltic
Landtypes	Slopelands/ breaklands	breaklands	variable	breaklands	canyons/ ridgetops	canyons/ ridgetops	canyons/ ridgetops	canyons/ ridgetops	canyons/ ridgetops	bottomland	canyons/ ridgetops
Aspect	north-east	north-east	north	west	north	north	north	north-east	north-west	north	northeast
Elevation (m above MSL)	920-2012	597-2438	539-2862	475-1783	908-1948	908-1948	1247-1945	869-1597	628-1695	497-1948	853-1847
Runoff pattern	snowmelt	snowmelt	snowmelt	snowmelt	snowmelt	snowmelt	snowmelt	snowmelt	snowmelt	snowmelt	snowmelt
Drainage pattern	dendritic	dendritic	dendritic	dendritic	dendritic	dendritic	dendritic	dendritic	dendritic	dendritic	dendritic
Drainage area (sq km)	101	142	1491	277	101	66	18	21	51	419	140
Channel types	B,A	B,A	C,B	B,A	B,A	B,A	A,B	A,B	A,B	B,C	B
Stream order	4	5	7	4	4	4	3	3	3	4	4
Streamflow gage(s)	no	no	no	no	no	no	no	no	no	yes	no
Watershed analyses	yes	yes	yes	no	yes	yes	yes	yes	yes	yes	no
Specialized GIS layers	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Landslide inventories	no	no	no	no	yes	yes	yes	yes	yes	yes	no
Pre-storm air photos	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Post-storm air photos	no	no	no	yes	yes	yes	yes	yes	yes	yes	yes
Historic channel surveys	no	yes	no	no	no	yes	no	no	yes	yes	yes
Pre-storm habitat surveys	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Post-storm habitat surveys	no	no	no	no	yes	no	no	no	no	yes	yes
Pre-storm sediment data	yes	yes	no	yes	yes	yes	yes	yes	yes	yes	yes
Post-storm sediment data	no	no	no	no	yes	yes	no	no	no	yes	no
Pre-storm channel data	no	no	no	yes	no	no	no	no	no	yes	no
Post-storm channel data	no	no	no	no	yes	yes	no	no	no	yes	no

*** Unknown/uncertain