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Jed A. Simon
The University of Montana

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Author's Signature Jed Simon

Date: 4/5/98
THE EFFECT OF A FOREST FIRE ON SUSPENDED SEDIMENT LOAD AND CHANNEL GEOMETRY IN A MOUNTAIN STREAM: A CASE STUDY OF SQUAW CREEK WATERSHED

by

Jed A. Simon

M.A. The University of Montana, 1995

presented in partial fulfillment of the requirements for the degree of Master of Arts

The University of Montana

1995

Approved by:

[Signatures]

Chairperson

Dean, Graduate School

[Signature]

April 5, 1995

Date
Severe wildfire can cause measurable increases in suspended sediment load, and changes in channel geometry in forest streams. Sediment increases are usually the result of overland flow moving across slopes denuded of vegetation by intense fire. Lack of infiltration, rain splash erosion, and increased peak flow move sediment into the channel, elevating suspended sediment levels. Increases in cobble embeddedness, fine sediments, and decreases in fish habitat quality may also occur. Debris torrents, particularly in first and second order tributaries, may contribute enough excess sediment to the channel to alter dynamic equilibrium and initiate changes in channel cross section.

To measure possible sediment increases, ISCO automated water samplers were installed at three locations in Squaw Creek, above, within, and below the perimeter of the 1988 Opus 7 Wildfire on the Powell Ranger District, Clearwater National Forest. Additionally, three channel cross section transects were established at the sampling locations. The lower station below the fire had prefire measurements for comparison, while the other two were setup to track future fire-induced changes in channel geometry. Sampling occurred for two years and included: velocity, bedload, and depth-integrated suspended sediment. Channel cross section measurements included Wolman Pebble Counts (n=200), and followed Rosgen methodology.

Sampling began immediately after the fire, and continued for two years. Suspended sediment samples were processed using the vacuum filtration method, and were stratified by calendar year, and flow component. After data transformation, paired t-tests were used to determine significance of difference between stations and years. No significant differences were noted. Comparison of cross sectional data also revealed no significant changes due to fire. A comparison of eight years of prefire suspended sediment data taken at the lower station, with data from immediately after the fire and one year later, showed sediment more than doubled in the spring following the fire, and returned to prefire levels one year later.
ACKNOWLEDGEMENTS

The Forest Service, specifically the Powell Ranger Station, provided funding, the study site, and equipment for this project. Their assistance is appreciated.

I would also like to thank Gayle Howard and Shanda Fallau for their unstinting support both technical and spiritual, their prodding, and their commiseration throughout the life of this project.

I am deeply indebted to Samuel Clemens for a lifetime of literary inspiration, but particularly for the following words which helped keep me barely sane down the arduous, and glacial-like path to the final completion of this work:

"...there is something fascinating about science. One gets such wholesale returns of conjecture out of such a trifling investment of fact..."

Mark Twain,

Life On The Mississippi
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CHAPTER I

INTRODUCTION

Severe wildfire can cause increased levels of suspended sediment that may adversely affect fish habitat quality. An inverse relationship between the amount of fine sediments in spawning or rearing areas versus fish survival and abundance has been found. When sediment yields increase beyond threshold levels, fish biomass decreases.\textsuperscript{1} Increases in sediment can also be of a magnitude that upset the dynamic equilibrium of a stream, causing changes in channel morphology. Changes in channel structure may also ultimately lead to a degradation of habitat quality. Because of the critical relationship between instream sediment and habitat quality, there has been considerable research devoted to the study of fire effects, erosional processes, sediment yield models, and measurement methodologies for water quality parameters.

\begin{flushright}
\end{flushright}
The effects of fire vary widely within natural ecosystems. The damage to vegetated slopes may ultimately be manifested as instream changes in water quality and quantity.

Fire's influence on the landscape is short and long term. Long term effects, although beyond the scope of this project, may be viewed as a) effects of fire on landform development, and b) effects of landform on fire behavior and pattern.2 The interrelationship of soil, vegetation, climate, and site-disturbance influences the productivity and vegetative composition of a site...which will determine local fire regime and the dynamics of fuel loading.

Within the context of a single fire, alterations in soil properties, vegetation, and hydrology may lead to changes in fluvial-geomorphic/hydrologic processes on hillslopes and in channels. The severity of a fire may change soil properties that control water movement into or over the soil surface. These changes can lead to increases in soil erosion and instream sediment.3

---


Complete or partial removal of vegetation by fire has numerous effects on hillslope hydrology. Vegetation functions as a protective cover over the soil, reducing its susceptibility to erosional processes. Gray\textsuperscript{4}, identified four mechanisms by which forest vegetation enhanced soil stability, namely:

1) Mechanical reinforcement from the root system.
2) Regulation of soil moisture content through transpiration, interception, and by affecting snow accumulation and rate of melting.
3) Buttressing or soil arching action between the trunks or stems.
4) Surcharging from the weight of trees.

Research by Gray and Megahan\textsuperscript{5} underscored the importance of vegetation in maintaining slope stability, especially in granitic soils.


The hydrologic responses and processes affected by fire are numerous and complex, and may be broken down into onsite and downstream effects. Research into such onsite effects as soil properties and erosion have been touched upon previously. Downstream effects include flow-related phenomena, water quality, and aquatic habitat responses.

Water quality, specifically increases in suspended sediment, cannot only affect a stream system by disturbing its dynamic equilibrium, but also by limiting its ability to support fish populations at a specific level of habitat quality. Instream sediment increases are the cumulative by-product of several related factors such as severity of burn, soil type, proximity to active stream channels, slope, etc. Beschta observed that it is sometimes difficult to isolate the effects of fire from associated inputs caused by suppression efforts, road building, and harvest. There is ample research to show that severe wildfire

__________________________


can cause increases in suspended sediment. Helvey\(^8\) studied wildfire in north central Washington and found that sediment production increased significantly during the first year after the fire. Sediment increases were a function of higher flow rates, reduced soil infiltration capacity, and mass movement. Cheng\(^9\) also noted elevated levels of stream sedimentation in his studies of the Eden Fire in British Columbia. Megahan\(^10\) has done extensive research on sediment yield changes as related to wildfire, logging, and road construction in Idaho batholith granitics. The Pine Creek Study, although limited to onsite effects, suggested that eroded material did move downslope out of the study area and ultimately to water. Megahan also cited an earlier study by Noble and Lundeen\(^11\) that concluded sediment production rates in burned batholith lands were seven times greater than those on similar,


unburned lands. Recent studies of the 1988 Yellowstone fires,\textsuperscript{12} suggested that the most "...adverse midterm delayed effects are likely to be due to increased sediment levels...."

However, wildfires do not always cause increases in stream sediment, and increases in sediment are not necessarily detrimental to fish habitat. Chapman\textsuperscript{13} noted that although a degradation of water quality can affect many aquatic organisms, it may not have undesirable effects on fish populations. Gerhardt and Green\textsuperscript{14} studied the 14,000-acre Footstool Fire on the Nez Perce National Forest in an attempt to quantify several effects including delivery of sediment to streams and impacts to fisheries habitats. Although they noted changes in particle size distribution, cobble embeddedness did not show a significant increase. Levels of fine sediment were higher in reaches close to direct sediment sources, but peak flows during the following spring were quite efficient at "flushing" the sediment through the system.


Although it can be generally stated that wildfire can cause accelerated erosion that leads to increases in suspended sediment, extrapolation between sites must be done cautiously. The variation in effects caused by minor differences in soil characteristics, topography, fuel moisture, aspect, weather, etc., can result in widely varying hydrologic responses. The use of models attempts to mitigate the variation so reasonable predictions of water and sediment yield changes can be made. However, if management considerations require site specific data to determine actual fire effects and to calibrate the sediment yield model, then field research in the specific watershed will be necessary.

The purpose of this research, undertaken at the request of the US Forest Service, is to determine to what extent a severe wildfire, the Opus 7 Fire, increased levels of suspended sediment, and caused shifts in channel geometry in the lower reaches of Squaw Creek.

Objectives:

This study is the first part of a project to monitor fire-related changes to the Squaw Creek stream system.

The specific objectives of the study are:
1) to determine if there are measurable differences in suspended sediment at three sampling sites, below, within, and above the fire perimeter; and

2) to determine if there are measurable changes in stream cross section at one transect below the fire.

Follow-up monitoring will continue to measure channel changes at three surveyed cross sections in the stream.

Problem Statement:

The null hypothesis states that there is no change in suspended sediment levels (below the fire vs. above the fire) as a result of the Opus 7 fire. The alternative hypothesis states that there is a significant change in sediment levels attributable to the fire.

\[ H_0 = \text{There is no change in levels of suspended sediment.} \]

\[ H_1 = \text{There is a significant change in suspended sediment levels.} \]
CHAPTER II

STUDY AREA: PHYSICAL SETTING

Location:

The Squaw Creek watershed is in the Powell Ranger District of the Clearwater National Forest, Idaho. Squaw Creek is a third order stream that flows into the Upper Lochsa River approximately 25 miles west of the Idaho/Montana border at Lolo Pass (figure 1). The approximate center of the basin is at 46° 34' 45" north latitude and 114° 52' 30" west longitude.

The drainage is well covered by maps and aerial photographs. The largest scale topographic maps available are the Cayuse Junction, Indian Postoffice, and Tom Beal Park quadrangles of the USGS 7.5' series at a scale of 1:24,000. The best aerial photographic coverage is in color at a scale of 1:12,000 flown by the USFS in 1990.
Squaw Creek Watershed
VICINITY MAP
Powell Ranger District
Clearwater National Forest

Scale in Miles

Legend:

Squaw Creek Watershed

Figure 1
Study Area: Squaw Creek Watershed

Legend

- Intermittent Stream
- Perennial Stream
- Opus 7 Fire
- Watershed Boundary
- Sub-watershed Boundary
- *Squaw #3* (Above Fire)
- *Squaw #2* (Within Fire)
- *Squaw #1* (Below Fire)

Figure 2
For purposes of watershed analysis the Squaw Creek drainage has been broken down into three subdrainages: West Fork Squaw, East Fork Squaw, and Lower Squaw (figure 2). Although this study is focused on the Lower Squaw area, many physical attributes are common to the watershed as a whole. Consequently, I will characterize the entire drainage, which will be referred to as "Squaw above Doe", and then focus on Lower Squaw. Quantitative morphometric characteristics may be found in Table 1.

**Squaw Above Doe:**

**Topography:**

Squaw Creek above Doe Creek is a 16.9 mi² (10,800 acre), pear shaped watershed. The elevation ranges from 3,192' at the confluence of Doe Creek and Squaw Creek, to 6,879' at the ridge-top. This gives the considerable relief of 3,687' (figure 4). Mainstem Squaw is deeply incised with slopes in excess of 80%. The West Fork, which also includes Spring Creek is moderately incised, with slopes ranging from 40-70%.
### Table 1

**Quantitative Morphometric Characteristics**

**of the study basin**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Lower Squaw</th>
<th>Squaw above Doe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elevation:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>max</td>
<td>5,393'</td>
<td>6,879'</td>
</tr>
<tr>
<td>min</td>
<td>3,192'</td>
<td>3,192'</td>
</tr>
<tr>
<td>Relief</td>
<td>2,198'</td>
<td>3,697'</td>
</tr>
<tr>
<td>Main Channel Length</td>
<td>3.08 miles</td>
<td>7.51 miles</td>
</tr>
<tr>
<td>Channel Slope</td>
<td>1.96%</td>
<td>3.90%</td>
</tr>
<tr>
<td>Basin Length</td>
<td>2.76 miles</td>
<td>7.04 miles</td>
</tr>
<tr>
<td>Basin Width</td>
<td>1.36 miles</td>
<td>2.40</td>
</tr>
<tr>
<td>Shape Factor</td>
<td>2.03</td>
<td>2.94</td>
</tr>
<tr>
<td>Stream Density</td>
<td>2.27 mi/mi²</td>
<td>2.01 mi/mi²</td>
</tr>
<tr>
<td>Orientation</td>
<td>180°</td>
<td>180°</td>
</tr>
<tr>
<td>Area</td>
<td>2,397 acres (3.75 mi²)</td>
<td>10,800 acres (16.87 mi²)</td>
</tr>
</tbody>
</table>
Landform Distribution: Squaw Creek Watershed

Legend

- Watershed Boundary
- Sub-watershed Boundary
- Rounded Mountain Slope Lands
- Stream Breaklands
- Low Relief Hills
- Glacially Derived

Figure 3
Several landforms\textsuperscript{15} are represented in the watershed. They are graphically depicted in figure 3, and include:

1. Dissected and nondissected stream breaklands make up approximately 38\% of the drainage. They are adjacent to stream channels, and are oversteepened as a result of streams downcutting faster than the adjoining slopes could retreat. Slope shapes are long and straight, to concave in shape. The nondissected slopes occur at higher elevations, on cool aspects, and have an average dissection spacing of 1300\'. Stream orders are predominantly first and second. Channel type is mainly A\textsuperscript{16}, entrenched, with bedrock control. Dissected slopes occur at lower elevations also on cooler aspects, but have a dissection spacing of 600\'. These channels are stable, step-pool systems with bedrock controlled nick points.

2. Thirty-six percent of the watershed is comprised of rounded mountain slopelands and uplands. They are found on warmer


\textsuperscript{16}An “A1” channel is a stream reach with a slope between 0.04 and 0.099 percent, and a bedrock substrate. It has a low width to depth ratio, and low sinuosity.
aspects, at both low and higher elevations. Slope shapes range from straight to slightly convex-concave, and are moderately dissected with V-shaped draws. Streams are mainly first and second order, stable, with a gravel-cobble substrate (A3-A4).

3. Nineteen percent of the landforms in Squaw above Doe are glacially derived, and include weakly scoured cirque basins and headwalls, glacial trough bottoms, and nondissected trough walls. They are all high elevation, cool aspect features with generally concave slopes. Stream orders range from first to fourth, with the higher orders being depositional, low gradient, and energy limited.

4. The final 6% of the watershed is made up of low relief hills, and moderate relief rolling uplands. These are gently rolling surfaces with well developed drainage patterns, concave, weakly developed V-shaped draws, and predominantly convex sideslopes. Stream order is mainly first and second. Channels are mainly B types with a gravel substrate, and are moderately entrenched.
Lochsa River near Lowell

Average Annual Discharge (cfs)

Annual Mean Discharge: 2,525 cfs

Figure 5 Lochsa River

Years

cfs
4000 3750 3500 3250 3000 2750 2500 2250 2000 1750 1500

Lochsa River

Figure 5
Parent Material & Soils:

Three parent material groups and their associated soil types characterize the Squaw Creek watershed. In general, the soils have a volcanic ash horizon over a weakly developed subsoil. They include:

1. Idaho batholith granites and gneisses underlay 31% of the drainage. Soils are generally well drained, and are 60 or more inches deep, with a coarse textured subsoil. They occur below 4800'. The volcanic ash layer is from 7-24 inches thick. Soil types are Vitrandepts and Dystrochrepts.

2. Twenty percent of the parent materials derive from glacial depositional material. They are both sorted and unsorted, and are weakly weathered coarse textured, cobbly material. These soils are generally deep (60''+) and well drained. Subsurface soil is coarse textured with 20-60% rock fragments. Large ice deposited boulders are common on the surface. Occurrence is usually above 4,000'. Soil types are Cryochrepts, Cryumbrepts, and Cryandepts.
3. Forty-nine percent of the parent materials are derived from undifferentiated material. They are moderately deep to deep, with a surface ash layer from 3-22 inches in depth. These soils are well-drained, and have a coarse textured sub soil. Soil types include Xerochrepts, Dystrochrepts, Cryandepts, Cryochrepts, and Cryumbrepts.

Climate:

The Squaw Creek watershed, and the Clearwater Forest in general, has a temperate, continental type climate moderated by Pacific Maritime air masses and prevailing westerly winds. Annual precipitation varies from 30 inches at the lower elevations to over 60 inches at the ridge tops. Approximately 75% of the precipitation falls during the autumn, winter, and spring months. Mean precipitation values at the Powell Ranger Station (10 miles east of Squaw Creek, elevation 3500'), are presented in table 2. Storms are predominantly long duration, low intensity events. Summer climatic conditions are usually influenced by stationary high pressure over the northwest coast.
### Table 2

**MEAN MONTHLY PRECIPITATION - INCHES**

<table>
<thead>
<tr>
<th>Site</th>
<th>Elev.</th>
<th>Annual</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>July</th>
<th>Aug</th>
<th>Sept</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Powell</td>
<td>3,500</td>
<td>37.9</td>
<td>3.8</td>
<td>2.5</td>
<td>3.0</td>
<td>2.5</td>
<td>3.2</td>
<td>1.5</td>
<td>3.6</td>
<td>2.6</td>
<td>1.5</td>
<td>2.3</td>
<td>4.1</td>
<td>7.3</td>
</tr>
</tbody>
</table>

**Hydrology & Sediment:**

There is relatively little historical streamflow data available for the Squaw Creek drainage. Continuous stream measurements began with the implementation of this study in Fall, 1988. Data prior to that time is based on either grab measurements, or interpolation from downstream gaging stations on the Lochsa River. Mean discharge for the Lochsa River is shown in figure 5. Average annual discharge for Squaw Creek above Doe Creek is depicted in figure 6. Typical hydrographs for 1989-1990 are presented in figures 7 & 8, and indicate a snowmelt dominated system.

Squaw Creek is predominantly a type B channel\(^\text{17}\), with gradations in

---

\(^{17}\)Rosgen, Dave. *A Classification of Natural Rivers*. Wildland Hydrology Consultants. Pagosa Springs, CO. March 1993. A “B” channel is typically moderately entrenched with moderate sinuosity. Slope ranges from 0.02 to 0.039 percent.
Squaw above Doe: Hydrograph

Average Annual Discharge

Mean Q = 59.5 cfs

Figure 6
Squaw Creek Hydrograph

Above and Below Fire: 1989

Figure 7

Months

Jan  Feb  Mar  Apr  May  June  July  Aug  Sep  Oct  Nov  Dec
substrate particle size from bedrock through sand. The B3 and B4 types (cobble and gravel, respectively) are most representative. Squaw is a riffle-pool system, moderately entrenched, with low sinuosity\textsuperscript{18}. This stream system is considered to be supply-limited, which is reflected by it's relatively high geomorphic threshold\textsuperscript{19} of 207\%. Supply-limited systems generally have more stream energy available than there is sediment available in the channel to be moved. Geomorphic threshold tends to increase as a stream becomes more supply-limited.

Due to the intensive management of the drainage over the last forty years, there have been slight (6\%) increases in runoff, and a 7\% increase in the number of days that discharge (Q) exceeds 75\% of $Q_{\text{peak}}$.\textsuperscript{20} These data are not representative of a watershed that has been significantly altered; percentage change in the 10-20\% range are usually considered \textit{red flags}\textsuperscript{21}. Indices of sediment regime changes however, exhibit notable fluctuations (increases) in

\textsuperscript{18}Specific morphology parameters of three surveyed cross sections will be presented in Chapter 3.

\textsuperscript{19}Geomorphic threshold is a dynamic concept which represents the point at which the natural average energy of a stream (to move sediment) is exceeded by the production of sediment. It is manifested as changes in stream geometry such as lateral channel migration, bar formation, increased width to depth ratio, and changes in particle size distribution.


\textsuperscript{21}Ibid.
both instream stored sediment and sediment production. Natural watershed conditions, as estimated by WATBAL, show a sediment yield of 17 tons/mi²/yr. By the early 1970’s this value had increased by 460%. Sediment predictions for 1994 indicate loading at approximately 45% over natural. Modelled estimates of accumulated instream sediment were as high as 355 tons/mi²/yr. in the late 1980’s. Current figures indicate accumulated sediment at approximately 290 tons/mi²/yr. Model predictions are estimates, at best, and even the author of the WATBAL program\textsuperscript{22} feels that the accumulated sediment values must be interpreted cautiously.

Stream survey data collected over the last several years does corroborate the notion of relatively high sediment levels. A survey done in 1988\textsuperscript{23} shows moderately high levels of cobble embeddedness (CE) in Squaw Creek (table 3).


### TABLE 3

**MEAN COBBLE EMBEDDEDNESS PERCENTAGES FOR SQUAW CREEK***

**AUGUST 1988**

<table>
<thead>
<tr>
<th>Station</th>
<th>Pool</th>
<th>Riffle</th>
<th>Run</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>47</td>
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<tr>
<td>2</td>
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<tr>
<td>3</td>
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</tr>
<tr>
<td>5</td>
<td>41</td>
<td>44</td>
<td>41</td>
</tr>
</tbody>
</table>

**Mean** | 44 | 42 | 50 |

*Cobble Embeddedness is a value used to define fish habitat quality. It expresses the degree to which larger substrate particles (cobbles), are “embedded” in finer particles such as silt. A cobble that had only one half of its area visible would be considered a cobble embeddedness of 50%.

The sampling stations are in the lower three miles of Squaw Creek.

Station 1: Mouth of West Fork Squaw;

Station 2: Mouth of East Fork Squaw;

Station 3: Approximately 0.75 miles above (north) of fire perimeter;

Station 4: Within fire perimeter;

Station 5: Below confluence with Doe Creek.
Vegetation:

The Squaw Creek watershed supports several habitat types as defined by Cooper, et al. They include:

1. *Abies lasiocarpa* series. This series accounts for 42% by area, and is found at mid to higher elevations. Principal shrub components on the warm-wet sites include, *Clintonia uniflora*, and *Streptopus amplexifolius*. Colder and drier types found above 5,000' include *Xerophyllum tenax* and *Menziesia ferruginea*.

2. *Abies grandis* series. This series accounts for 40% of the area within the drainage, and dominates at the lower elevations. Principal shrub components include, *Asarum caudatum*, *Clintonia uniflora*, and *Xerophyllum tenax*.

3. *Thuja plicata* series. This series accounts for 11% of the area, and is found at lower to mid elevations along creek bottoms or on

---

adjacent moist aspects. Principal shrub components are *Asarum caudatum* and *Clintonia uniflora*.

4. **Pseudotsuga menziesii** series. This series comprises the remaining 7% of the land area. It is found exclusively on southern aspects with shallow, rocky soils. Principal shrub components are *Physocarpus malvaceus*, *Spirea betulifolia*, *Symphoricarpus albus*, and *Calamagrostis rubescens*.

Vegetative patterns within the watershed are strongly related to aspect, parent material and associated soils. Changes in soil/rock types are accompanied by abrupt changes in plant distribution and communities. Changes in aspect, however, tend to influence the micro-climate of a site. This may be manifested as changes in the frequency of suitable habitats, and favor species which are better adapted to a particular locale. Aspect changes will also influence the chemical and physical soil-forming processes, which also will dictate changes in floral composition and distribution.

**Land Use:**

The entire Squaw Creek watershed is under Federal ownership. Timber harvest activity began in the drainage in 1952, and consisted primarily
of harvest along creek bottoms and other easily accessible areas. The purpose of the early entries was to salvage Englemann Spruce mortality occurring from bark beetle attacks. Selection and modified shelterwood harvests were the predominant treatments. The mid 1960’s to mid 1970’s saw another period of intensive harvest activity in the watershed. It was partially spurred by an outbreak of Spruce Budworm killing many Douglas Fir in the West Fork Drainage. Clearcutting and Seed Tree cuts were the silvicultural methods utilized during that period. Ongoing timber sales are still occurring in the watershed; however, new road construction and major reconstruction have been virtually eliminated. The bulk of current harvest is on very steep, inaccessible ground, and yarding is being done by helicopter. In total, 33% of the watershed has been disturbed by logging and associated activity.

Equivalent Clearcut Acres (ECA) equal 13.6% of the drainage. The concept of ECA’s is a product of water yield calculations in the WATBAL model. It is a value related to the percent of crown cover before and after harvest activities. A unit that had 100% crown cover prior to harvest and that had 100% of that cover removed would have an ECA equal to the unit size. A 100 acre unit that had an initial crown cover of 50% with 50% of the crowns removed would have an ECA of 25 acres.

To date, 72 miles of road have been constructed throughout Squaw Creek. Road density is 4.3mi./mi², which is typical of the roaded portions of
the Clearwater Forest. Because much of the original transportation system was built in the valley bottoms, channel confinement by the road prism has been a source of some fill slope failures on the older roads. In several places unvegetated fill slopes contribute sediment directly into mainstem Squaw. Riparian encroachment from overzealous road maintenance also causes continuing sediment problems.

Fire History:

The Squaw Creek drainage has not experienced a great number of natural wildfires over the last century. Large, lightning-caused wildfire has been relatively absent. The only exception is the 1910 fire, which burned approximately 2,500 acres in the northwest portion of the drainage. Since 1950, there have been an average of seven lightning fires per year, all of which were between 1/4 and 10 acres in size.

Squaw Creek is fairly typical of intensively managed drainages in north Idaho. The predominantly granitic soils are erosive, and in association with early entries for timber harvest beginning in the 1950’s, have led to high levels of instream sediment and a concomitant decline in fish habitat quality. The relatively small number of lightning-caused wildfires in the drainage is

25Powell Ranger District Fire History Maps.
evidenced by large accumulations of forest fuels. Alpine glacial landforms tend to dominate the higher elevations, while steep stream breaklands and more rounded, frost-churned slopes are found in the lower elevations.

**LOWER SQUAW:**

**Topography:**

The Lower Squaw drainage is a 3.75 mi² (2,400 acre) watershed which begins just below the confluence of West Fork Squaw and mainstem Squaw, and flows in a southerly direction 2.7 miles downstream to the confluence with Doe Creek. The elevation ranges from 3,192' at the mouth to 5,393' at the ridge top, giving a relief of 2,198'. The basin is a simple, V-shaped valley. Side slopes are steep, ranging from 40-80%.

Principal aspects are due to the well defined valley and hence are NW & SE, the NW quadrant of the drainage faces due east, however.

Several landforms are represented in the watershed. These include:
1. Dissected and nondissected stream breaklands comprise 64% of the drainage. The characteristics of this landform type are similar to those previously described under “Squaw Above Doe.”

2. Rounded mountain slopelands and uplands make up 34% of Lower Squaw. These landforms are found on warmer aspects, at both low and higher elevations. Slope shapes range from straight to slightly convex-concave, and are moderately dissected with V-shaped draws. Streams are mainly first and second order, stable, with a gravel substrate.

3. The final 2% of Lower Squaw is represented by moderate relief rolling uplands. They are characterized by rounded convex ridgetops and straight to concave sideslopes. Channel bed and banks are usually poorly defined, and contain a high percentage of fine sediments.

**Parent Material & Soils:**

Two groups of parent materials and their associated soil types comprise the Lower Squaw watershed.
1. Idaho batholith granites and gneisses make up over 70% of the parent material in the drainage. As previously described, they are generally well-drained, 60 or more inches deep, with a coarse textured subsoil. The volcanic ash layer is from 7-24 inches thick. Soil types are Vitrandspts and Dystrochrepts.

2. The remaining 30% is represented by undifferentiated parent materials. They are moderately deep, with an ash layer from 3-22 inches in depth. This type is well-drained, with a coarse textured subsoil. Soil types include Xerochrepts, Dystrochrepts, Cryandepts, Cryochrepts, and Cryumbrepts.

Climate:

Climate was described in the section "Squaw Above Doe."

Hydrology:

The hydrologic and sediment regimes discussed in the section "Squaw Above Doe", are germane to Lower Squaw as well. This section of the stream contains the majority of the B channel types, with B3 and B4 being most
representative. At least seven A2a-A4, first order tributaries enter mainstem Squaw in this reach.

**Vegetation:**

The Lower Squaw Creek watershed supports several habitat types, including:

1. *Abies grandis* series. This series makes up 49% of the area in the drainage. Principal shrub components on the warm-wet sites include, *Clintonia uniflora* and *Streptopus amplexifolius*. Colder and drier types include *Xerophyllum tenax* and *Menziesia ferruginea*.

2. *Thuja plicata* series. The western Red Cedar habitat type accounts for 42% of the area in Lower Squaw. It is found predominantly on riparian sites, or adjacent moist aspects. The principal shrub components are *Asarum caudatum* and *Clintonia uniflora*.

3. *Pseudotsuga menziesii* series. This series comprises the final 9% of the area. It is found on warm aspects in association with
Physocarpus malvaceus, Symphoricarpus albus, and Calamagrostis rubescens.

Land Use:

The previous discussion on land use in the “Squaw Above Doe” section is applicable to the lower part of the watershed as well. Harvest activity however was more intensive in the early years, undoubtedly a function of the relatively easier access. Other than an ongoing Cedar salvage sale (remnants of the Opus 7 fire), there is no planned future activity in Lower Squaw. The total disturbed area is equal to 69% of the watershed, and ECA’s are 25%.

There have been 28.8 miles of road constructed in the watershed, and road density is 7.68 mi/mi².

Fire History:

The Opus 7 Fire, is the only large man-caused fire to occur in the Squaw Creek watershed. It ignited in logging slash in Badger Creek (adjacent drainage to the east) at 0930 on 8/26/88. Hot, windy weather inhibited suppression efforts, and the fire ultimately grew to over one thousand acres
(figure 2). It burned with high intensity and relatively long duration in several locations immediately adjacent to Squaw Creek for 0.5 miles, and in very heavy fuels on the road cut of the Squaw Creek Road that parallels the creek for 1.5 miles. At several sites along the creek, accumulations of cedar logs developed as a result of suppression efforts. Much of it was oriented in a fashion that would be beneficial to stream stability and fish habitat, although some would cause severe erosion of the encroaching roadbed and banks, or would trap sediment to the degree that fish habitat would be degraded. The risk of sediment delivery to Squaw Creek was considered high, and the following measures were used to mitigate potential effects to the stream.26

1. Hand and aerial seed (annual rye, white Dutch clover, hard fescue, Canada bluegrass, smooth brome, and orchard grass) and fertilize entire burned area.

2. Remove heavy buildups of tops and limbs where they occur in the stream.

3. Remove new logs from stream where accumulations are more than one deep or less than 30 feet apart.

4. Install waterbars on all handline and dozer line.

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All of the spatial characteristics of the watershed as a whole also apply to Lower Squaw, except on a much smaller scale. Because it is so small in terms of acreage, road densities are very high, and problems associated with excessive road construction (sedimentation) are exacerbated.
CHAPTER III

METHODOLOGY

SITE SELECTION

Criteria:

Three suspended sediment sampling sites were chosen to isolate the effect of the fire on the Squaw Creek stream system (figure 2). Basic site criteria required selecting areas of uniform flow, free of influences from braided or split channels.

1) **Below the fire: "Squaw #1."** This site is immediately above the confluence with Doe Creek, and includes all the fire area. This has been a water quality monitoring site since 1981, and will provide baseline data.
2) **Within the fire: “Squaw #2.”** This site is just downstream of a tributary on the west side of Squaw where the fire crossed the creek and burned in the riparian zone. It was chosen to isolate sediment input from this source.

3. **Above the fire: “Squaw #3.”** This is the control, and is located upstream of the fire perimeter. The location was the closest to the upper perimeter of the fire where the channel was not split.

**Instrumentation:**

ISCO Corporation, model 1850 Automatic Water Samplers were installed at all three sites to collect suspended sediment. The samplers are programmed to take four, 125ml samples per day at 0600, 1200, 1800, and 2400 hours. Each day’s sample is collected in one bottle. The instrument cycles for 28 days before requiring a change of bottles and batteries. The intake tubes for the ISCO’S were suspended in the water column to get as representative a sample as possible. Every attempt was made to avoid picking up sand from the substrate. Each site also had a staff gage installed. Squaw #1 was equipped with a Stevens Recorder Model F to establish stage/flow relationships.
Other measurements taken at each site included velocity (Price AA current meter), bedload (Helley-Smith sampler), depth integrated grab suspended sediment sample (DH-48 sampler), conductivity, and air and water temperature. Standard methods\textsuperscript{27} were used for taking velocity, depth integrated suspended sediment, and bedload samples.

Channel cross sections were surveyed using a Topcon GT-66 level, surveyor’s rod, and 200’ tape. The following methodology was followed to establish monumented cross sections:\textsuperscript{28}

1. Establish temporary elevation benchmark by setting a 10 inch stove bolt in a “Sacrete” filled hole in ground.

2. Establish temporary benchmarks similarly to mark both ends of transect. These pins were set well above the high watermark.

3. The profile of the stream cross-section was measured by recording the distance and elevation reading of rod intercept

\textsuperscript{27}National Handbook of Recommended Methods for Water Data Acquisition. Office of Water Data Coordination. USDI, USGS. Reston, Virginia. 1977.

\textsuperscript{28}Rosgen, David L., Classification of Natural Rivers (draft), Wildland Hydrology, Pagosa Springs, CO. March 1993.
with the tightly stretched tape across the stream. Measurement intervals varied from one to two feet, depending on channel morphology.

4. The following major features were measured:
   a. left benchmark
   b. left bankfull
   c. left wetted edge
   d. differences in bed configuration across the channel
   e. thalweg
   f. right wetted edge
   g. right bankfull
   h. right benchmark

Accurate location of bankfull is particularly important, because the cross sectional area of the channel at bankfull is used to detect channel changes such as scour or aggradation. Commonly used indicators of bankfull flow include:

- perennial vegetation or 'grassline limits';
- slope break between active channel and flood plain;
- top of point bars;
- small benches or flats;
- soil material or grain size variation;
- lichen on rocks;
- armoring or frequent inundation water lines.
5. Additional measurements for purposes of Rosgen\textsuperscript{29} Channel typing include:

   a. water surface gradient
   b. bankfull width
   c. bankfull depth at thalweg
   d. floodprone width
   e. entrenchment ratio

Particle size distribution analysis along the transects utilized the Wolman Pebble Count technique\textsuperscript{30}. The sample is usually obtained on a riffle. Wolman used a sample of one hundred particles, however, other related, more recent techniques\textsuperscript{31} suggest a sample size of two hundred to provide a reproducible estimate of the distribution. Sampling points are determined by walking heel to toe across the bankfull channel, and measuring the first particle at the end of your foot. Samples are tallied by Udden-Wentworth size classes. Large particles are counted as often as your foot intersects it. The cumulative percent for each size class is calculated, and

\textsuperscript{29}Ibid.


the median ($D_{50}$) particle size is determined. The $D_{16}$ and $D_{84}$ particle size are also determined, since they are both one standard deviation from the median.

**Sampling Frequency:**

Measurements began in mid April 1989, and continued for two years. Sampling occurred weekly during peakflow, and twice per month during low flows. The channel cross section transect (at Squaw #1) was originally surveyed on 8/19/87, and was resurveyed on 1/24/94. Transects were surveyed at Squaw #2 and Squaw #3 on 5/24/94.

**Problems Encountered:**

Spring start-up of ISCO water samplers has always been fraught with problems, and this study was not spared those frustrations. On numerous occasions either one of the ISCO’s, or the Stevens Recorder, was malfunctioning, and had to be recalibrated or replaced. Additionally, peakflows made the taking of instream measurements too dangerous at times. These gaps in the data record will be discussed in more detail in Chapter IV.
This chapter is presented in four sections. The first will describe the laboratory methods used to process the raw ISCO data; the second will address the analysis of the cross sectional data; the third will discuss the statistical analyses of the suspended sediment data; and the final section will present results of the analyses.

Laboratory Methods:

All suspended sediment samples were processed using the vacuum filtration method standard on the Clearwater National Forest. Suspended sediment was measured as the difference of washed filter weight (weighed to the nearest 0.0001 grams on a Torbal Analytical Balance), subtracted from the sediment sample and filter disk weight. This gave the weight of the
suspended sediment. Suspended load was then calculated using the formulae:

\[
\text{Suspended Load (mg/l)} = \frac{\text{Suspended Sediment wt. (mg)}}{\text{Volume of Sample (ml)}} \times 1000
\]

\[
\text{Suspended Load (tons/day)} = \text{Q (cfs)} \times \text{mg/l} \times 0.0027
\]

\[
\text{Suspended Load (lbs/day)} = \text{Q (cfs)} \times \text{concentration (mg/l)} \times 5.3939
\]

**Hydraulic Geometry:**

The channel cross sections and Wolman Pebble Count transects measure changes in hydraulic geometry in two ways:

1. Changes in cross sectional area, calculated at bankfull, are indices of channel change, and possibly disequilibrium in the stream system. Scour and aggradation are readily apparent by calculating stream area at bankfull. Changes in channel type, both form and substrate composition, can also be tracked by a series of measurements at a well-monumented transect.

2. Shifts in particle size distribution over time are also indicative of cross-sectional changes. Trends toward finer particles usually imply aggradation, while trends toward larger particles imply
scour. Shifts in equilibrium between streamflow and sediment will produce changes in bedload transport, and overall stream competence. When the transport capacity of a stream is exceeded, there is a decrease in bed material size, and a concomitant aggradation of the channel. Changes in the $D_{50}$ indicate changes in channel geometry.

Statistical Analysis:

Data Adjustments:

During the field phase of the study, it was discovered that the intake tube for the ISCO at Squaw #2 was lying directly on the sandy stream bottom. After examining the data, it was determined that #2 showed considerably higher sediment loading than the other two stations. For the period 4/29/89 - 5/28/89, suspended sediment at the three sampling sites was:

- Station #1: 9,426.7 lbs/day
- Station #2: 10,152.1 lbs/day
- Station #3: 7,301.7 lbs/day

Possible explanations for this are:

1. Sediment was settling out at #2.
2. The intake for #2 was not located in a site comparable to #1 & #3.

Because the stream was at a peak flow stage, it was unlikely that sediment was settling out. Observation of the flow regime at station #2 corroborated this belief. It was concluded that the higher sediment values were a result of intake placement, and a decision was made to throw out the suspect data and use only the upper and lower stations for analysis.

Bedload measurements were also excluded from this analysis. Although bedload constitutes 60 to 70 percent of total load\textsuperscript{33} in a stream with predominantly granitic parent material, sampling of bedload was considered too spotty to allow reliable comparisons. During peak flows, velocity measurements at Squaw #1 were taken by bridgeboard, and the equipment to sample bedload from the bridge was not available at the time of this study.

Partitioning of Data:

After removing data which were considered unreliable, several other steps were carried out prior to analysis.

1. The raw ISCO data were stratified by flow components, i.e., the three limbs of the hydrograph, so comparisons between stations would be more meaningful. Based on stream flow data from Squaw Creek and other adjacent drainages, the data were partitioned as follows:

- Rising Limb: 3/15 - 5/15
- Falling Limb: 5/16 - 7/15
- Low Flow: 7/16 - 3/14

Each data set was further broken down by calendar year, so for each year, the following six sets of data were analyzed:

- **1989:** Squaw #1; Rising, Falling, and Low flow.
  Squaw #3; Rising, Falling, and Low flow.

- **1990:** Squaw #1; Rising, Falling, and Low flow.
  Squaw #3; Rising, Falling, and Low flow

2. For purposes of clarity, the data were arranged for analysis and presentation according to the calendar year rather than water year (10/1 - 9/30), which is the normal reporting convention.
3. Only days for which data were available from both the upper and lower station were used for analysis. Because of equipment problems, the data record is not complete at both sites; consequently, only data that is matched day for day was analyzed.

4. The statistical analysis of the suspended sediment data will be compared as a concentration: milligrams per liter (mg/l). When presented in this fashion, the results are "flow neutral", i.e., they are not influenced by the higher discharges expected at downstream stations. Graphic representation of the data will be depicted both as a concentration, and as a rate, and will be discussed in chapter V.

**Assumption Testing:**

Because the objective was to determine relative sediment increases below the fire compared to above the fire, Paired t-tests were chosen for the analysis. Paired samples assume the "...observations are collected in pairs, i.e.  

34Ibid.
when a sample is collected at Station A, one is collected at Station B. Additional assumptions which must be satisfied are a) the data must be normally distributed, b) observations must be a random sample from the population, and c) the samples must not be autocorrelated. Autocorrelation is a measure of how data points are related in time.

It was determined that the tests should be two tailed. The null hypothesis states that: there is no change in suspended sediment levels (below the fire vs. above the fire) as a result of the Opus 7 fire. Because I did not know in which direction (higher or lower) sediment levels might change, the test was designed two-tailed.

Normality

Two procedures were used to test normality of the data.

---


1. Histograms for each data set were created and analyzed for their approximation of a normal distribution (Appendix A).

2. Normal Probability Plots (NPP) were graphed for the difference between the means of the upper and lower station plotted against the Nscores of that difference. If the NPP is approximately a straight line, it is reasonable to assume that the sample came from a population that is approximately normal\textsuperscript{39} (Appendix A).

Analysis of these two tests indicated that the distributions were not normal, especially at both tails. Because a log 10 transformation will usually normalize a water quality data set\textsuperscript{40}, it was chosen for this analysis.

After transforming the data, histograms and Normal Probability Plots were redone. Analysis of the plots indicated that the data were much closer to a normal distribution (Appendix B).


Randomness:

A runs test is a nonparametric procedure that tests the randomness of the data selected. A run is a series of consecutive observations that fall above the sample mean, or consecutive observations that fall on or below the sample mean. The difference of the log transformed means were tested at alpha = 0.05, with the hypotheses:

\[ H_0 = \text{The sampling process is random.} \]
\[ H_1 = \text{The sampling process is not random.} \]

The runs test (table 4) indicates that four of the six data sets were selected randomly. The two tests that were not random i.e., the null hypothesis was rejected, were both low flow components of the hydrograph.

There was a pattern throughout the analysis of low flow segments, and flow components with a small sample size, to show different test results than the other data sets. This phenomenon will be discussed in the “Results” section of this chapter.

---

### Table 4

**Runs Test of Randomness**

#### 1989

<table>
<thead>
<tr>
<th>Hydrograph Component</th>
<th>P-Value</th>
<th>Result: $\alpha = 0.05$</th>
<th>Random?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rising</td>
<td>0.5054</td>
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<tr>
<td>Falling</td>
<td>0.1932</td>
<td>fail to reject $H_0$</td>
<td>Yes</td>
</tr>
<tr>
<td>Low</td>
<td>0.0026</td>
<td>reject $H_0$</td>
<td>No</td>
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</table>

#### 1990

<table>
<thead>
<tr>
<th>Hydrograph Component</th>
<th>P-Value</th>
<th>Result: $\alpha = 0.05$</th>
<th>Random?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rising</td>
<td>0.1142</td>
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<td>Yes</td>
</tr>
<tr>
<td>Falling</td>
<td>0.3065</td>
<td>fail to reject $H_0$</td>
<td>Yes</td>
</tr>
<tr>
<td>Low</td>
<td>0.0025</td>
<td>reject $H_0$</td>
<td>No</td>
</tr>
</tbody>
</table>

**Autocorrelation:**

Auto (or Serial) correlation, and partial autocorrelation, is the degree of relationship between observations $k$ time periods (or lags) apart.\(^{42}\)

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\(^{42}\)Ibid.
Values of the autocorrelation function range from negative one to positive one. A value of one or negative one indicates a perfect correlation (complete dependence). A value of zero indicates no correlation (independence). Partial autocorrelation plots were used to evaluate these data, and no correlation of any significance was noted. This indicates very little time dependence between samples.

Because all assumptions were substantially met, paired, two tailed t-tests at a significance level of alpha = 0.05 were done on the transformed data. The tests were performed on the means of the difference between upstream and downstream stations for paired days. The non transformed data were also tested to determine what effect, if any, the transformation had on the outcome of the tests. Test results are in table 5, and will be presented in the next section.

---


### Table 5

**Comparison of Results of Paired T-Tests:**

**Log 10 Transformed Data vs. Non Transformed Data**

#### 1989

<table>
<thead>
<tr>
<th>Hydrograph Component</th>
<th>Sample Size (pairs)</th>
<th>P-Value</th>
<th>Result: alpha = 0.05</th>
<th>Changed due to Log 10 Transformation?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rising</td>
<td></td>
<td>0.58</td>
<td>fail to reject H₀</td>
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<tr>
<td>Rising (Log 10)</td>
<td>29</td>
<td>0.38</td>
<td>fail to reject H₀</td>
<td>No</td>
</tr>
<tr>
<td>Falling</td>
<td></td>
<td>0.074</td>
<td>fail to reject H₀</td>
<td></td>
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<tr>
<td>Falling (Log 10)</td>
<td>49</td>
<td>0.18</td>
<td>fail to reject H₀</td>
<td>No</td>
</tr>
<tr>
<td>Low</td>
<td></td>
<td>0.091</td>
<td>fail to reject H₀</td>
<td></td>
</tr>
<tr>
<td>Low (Log 10)</td>
<td>60</td>
<td>0.0072</td>
<td>reject H₀</td>
<td>Yes</td>
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</table>

#### 1990

<table>
<thead>
<tr>
<th>Hydrograph Component</th>
<th>Sample Size (pairs)</th>
<th>P-Value</th>
<th>Result: alpha = 0.05</th>
<th>Changed due to Log 10 Transformation?</th>
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</thead>
<tbody>
<tr>
<td>Rising</td>
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<td>0.046</td>
<td>reject H₀</td>
<td></td>
</tr>
<tr>
<td>Rising (Log 10)</td>
<td>7</td>
<td>0.020</td>
<td>reject H₀</td>
<td>No</td>
</tr>
<tr>
<td>Falling</td>
<td></td>
<td>0.092</td>
<td>fail to reject H₀</td>
<td></td>
</tr>
<tr>
<td>Falling (Log 10)</td>
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<td>0.0001</td>
<td>reject H₀</td>
<td>Yes</td>
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<tr>
<td>Low</td>
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<td>0.098</td>
<td>fail to reject H₀</td>
<td></td>
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<td>Low (Log 10)</td>
<td>62</td>
<td>0.060</td>
<td>fail to reject H₀</td>
<td>No</td>
</tr>
</tbody>
</table>
In addition to paired t-tests, two nonparametric procedures were used to test the data.45

Some statisticians maintain that if parametric and nonparametric procedures yield the same results, then the assumptions underlying the parametric procedures are reasonable. This provides a quick method for "checking" the validity of assumptions in parametric analyses.46

The Sign test, and the 1-sample Wilcoxon, are used to test the central tendency (median) of a population that is not necessarily normal. If the median of one data set is significantly different from another at the significance level tested, an estimate of the median is given. In accordance with the other procedures used, these tests are two tailed, and were performed on the means of the difference of the log transformed data at a significance level of alpha=0.05. Both tests used the hypotheses:

\[ \text{H}_0 = \text{The median is equal to zero} \]
\[ \text{H}_1 = \text{The median is not equal to zero} \]

Results of the Sign test and the Wilcoxon test are in tables 6 & 7, respectively, and will be discussed in the next section of this chapter.

45 The Runs Test discussed previously is also a nonparametric procedure, but was included in the earlier discussion because it was used to test basic assumptions.

### TABLE 6

**SIGN TEST OF MEDIAN**

#### 1989

<table>
<thead>
<tr>
<th>Hydrograph Component</th>
<th>P-Value</th>
<th>Median</th>
<th>Result: $\alpha = 0.05$</th>
<th>Change from Paired t-test?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rising</td>
<td>0.05716</td>
<td>0.02803</td>
<td>fail to reject $H_0$</td>
<td>No</td>
</tr>
<tr>
<td>Falling</td>
<td>0.2976</td>
<td>0.1011</td>
<td>fail to reject $H_0$</td>
<td>No</td>
</tr>
<tr>
<td>Low</td>
<td>0.0145</td>
<td>0.1383</td>
<td>reject $H_0$</td>
<td>No</td>
</tr>
</tbody>
</table>

#### 1990

<table>
<thead>
<tr>
<th>Hydrograph Component</th>
<th>P-Value</th>
<th>Median</th>
<th>Result: $\alpha = 0.05$</th>
<th>Change from Paired t-test?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rising</td>
<td>0.2187</td>
<td>0.05386</td>
<td>fail to reject $H_0$</td>
<td><strong>Yes</strong></td>
</tr>
<tr>
<td>Falling</td>
<td>0.0001</td>
<td>0.3358</td>
<td>reject $H_0$</td>
<td>No</td>
</tr>
<tr>
<td>Low</td>
<td>0.6985</td>
<td>0.09691</td>
<td>fail to reject $H_0$</td>
<td>No</td>
</tr>
</tbody>
</table>
### Table 7

**Wilcoxon Test**

#### 1989

<table>
<thead>
<tr>
<th>Hydrograph Component</th>
<th>P-Value</th>
<th>Estimated Median</th>
<th>Result: ( \alpha = 0.05 )</th>
<th>Change from Paired t-test?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rising</td>
<td>0.759</td>
<td>-0.02539</td>
<td>fail to reject ( H_0 )</td>
<td>No</td>
</tr>
<tr>
<td>Falling</td>
<td>0.226</td>
<td>0.07990</td>
<td>fail to reject ( H_0 )</td>
<td>No</td>
</tr>
<tr>
<td>Low</td>
<td>0.013</td>
<td>0.1305</td>
<td>reject ( H_0 )</td>
<td>No</td>
</tr>
</tbody>
</table>

#### 1990

<table>
<thead>
<tr>
<th>Hydrograph Component</th>
<th>P-Value</th>
<th>Estimated Median</th>
<th>Result: ( \alpha = 0.05 )</th>
<th>Change from Paired t-test?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rising</td>
<td>0.059</td>
<td>0.5386</td>
<td>fail to reject ( H_0 )</td>
<td>Yes</td>
</tr>
<tr>
<td>Falling</td>
<td>0.000</td>
<td>0.3375</td>
<td>reject ( H_0 )</td>
<td>No</td>
</tr>
<tr>
<td>Low</td>
<td>0.082</td>
<td>0.09966</td>
<td>fail to reject ( H_0 )</td>
<td>No</td>
</tr>
</tbody>
</table>
RESULTS & DISCUSSION

Hydraulic Geometry:

Channel Cross-sectional profiles and Wolman Pebble Count transects were established using the methodology described in Chapter III, pages 42-44. Only one site, Squaw #1 Below the Fire, had pre-fire measurements to use as a basis for comparison. The original transect was done on 8/19/87 (figure 9), and was monumented well enough to allow a duplication of the measurements. Using the USFS Hydraulics software R4 Cross47, cross sectional area at bankfull was calculated for the 1987, and 1994 transects below the fire (table 8).

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>CROSS SECTIONAL AREA AT BANKFULL</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>SQUAW ABOVE DOE</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1987 (Pre-Fire)</td>
<td>37.93 ft.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1994 (Post-Fire)</td>
<td>37.81 ft.2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

There is only a very slight decrease in cross-sectional area indicated between 1987 and 1994, which is most likely a result of measurement error. If

47United States Forest Service Cross-Sectional Hydraulics Software R4 Cross.
the decrease could be attributed to aggradation as a result of the fire, it is extremely minor.

Figure 10 represents the particle size distribution associated with the 1987 work. Unfortunately, the size classes were only estimated visually, so comparisons cannot be drawn between the pre-fire and post-fire D$_{50}$'s.

On 1/24/94 and 5/24/94, cross-section and Pebble Count transects were established at the suspended sediment sampling sites below, within, and above the fire, and are depicted in figures 11 & 12, 13 & 14, and 15 & 16, respectively. The transects at Squaw #2 & Squaw #3, are intended to allow further monitoring of conditions in Squaw Creek. Because no pre-fire information existed at those sites, no inferences can be drawn from them.

Table 9 presents the channel geometry information measured at all three sites for reach classification using the Rosgen methodology. Measurements for Rosgen Channel typing were not taken with the 1987, pre-fire transect, but may be assumed to be approximately the same as values measured in 1994.
**TABLE 9**

**ROSSEN CHANNEL CHARACTERISTICS**

**BELOW, WITHIN, & ABOVE THE FIRE**

<table>
<thead>
<tr>
<th>Site #</th>
<th>Slope %</th>
<th>Bankfull Thalweg (feet)</th>
<th>Floodprone width (feet)</th>
<th>Bankfull Width (feet)</th>
<th>*Entrenchment Ratio</th>
<th>D$_{50}$ (mm)</th>
<th>Channel Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.80</td>
<td>2.51</td>
<td>33.9</td>
<td>27.5</td>
<td>1.23</td>
<td>85</td>
<td>B3</td>
</tr>
<tr>
<td>2</td>
<td>0.84</td>
<td>1.56</td>
<td>83.4</td>
<td>30.35</td>
<td>2.75</td>
<td>28</td>
<td>C4</td>
</tr>
<tr>
<td>3</td>
<td>1.60</td>
<td>1.85</td>
<td>133.6</td>
<td>32.45</td>
<td>4.12</td>
<td>40</td>
<td>C4</td>
</tr>
</tbody>
</table>

*Entrenchment Ratio* is equal to the floodprone width/bankfull width.

The values measured are fairly typical of streams on the north side of the Lochsa River on the Powell Ranger District. Channel confinement by stream-side roads tends to skew measurements of floodprone width and entrenchment ratio; however, B type channels with gravel to small cobble substrate are quite common in this region.
Squaw Above Doe Cross Section
Station #1, 8/19/87 (Below Fire)

Baseline Transect  Pre-Fire
Gradient 2.8%

Bank Full
Waters Edge

Figure 9
Horizontal Feet
Channel Type: B3
Squaw #1 (Below the Fire)

Pebble Count: Ocular

Figure 10

Particle Size (Millimeters)

D50 = 128mm (Small Cobble)

% Distribution 8/19/87

Pre-Fire

% Distribution

% Cumulative
Squaw Above Doe Cross Section

Station #1, 1/24/94, Measurements Matched to Pre-Fire Transect

Gradient: 2.8% Vertical Feet

Figure 11

Horizontal Feet

Channel Type: B3
Squaw #1 (Below the Fire)

Wolman Pebble Count (N=227)

% Distribution 1/24/94 Post-Fire

D50 = 85mm (Small Cobble)

Figure 12 Particle Size (Millimeters)
Squaw Creek Cross Section

Station #2  5/24/94 (Within the Fire)

Figure 13

Vertical Feet

Post-Fire

Gradient: 0.84%

Horizontal Feet

Channel Type: C4

Bank Full

Waters Edge

Thalweg
Squaw #2 (Within the Fire)

Wolman Pebble Count (n=220)

Figure 14 Particle Size (Millimeters)
Squaw Creek Cross Section

Station #3  5/24/94  (Above the Fire)

Gradient: 1.6%

Figure 15

Channel Type: C4
Squaw #3 (Above the Fire)

Wolman Pebble Count (n=240)

% Distribution 5/24/94 Post-Fire

D50=40mm (Very Coarse Gravel)

Figure 16 Particle Size (Millimeters)
**Statistical Analysis:**

Nonparametric Tests:

The Sign Test (table 6) yielded the same results as the paired t-test of transformed data for both sampling years, with one notable exception: the Rising limb, 1990.

The Wilcoxon Test (table 7) also supported results of the t-test except for the Rising Limb, 1990. It is probable that the test differences are a function of the small sample size (n=7). With such a small sample, variation within the population is large, as reflected in the test results. Assuming a 95% confidence interval that the differences in means were ± 0.50 mg/l, then using the following formula,\(^48\) sample size would need to be at least thirty.

\[
n = \left[ \frac{1.96 \sigma}{e} \right]^2
\]

(Where "n" equals sample size; "\(\sigma\)" equals the population standard deviation; and "e" equals a specified sampling error allowance).

---

As previously mentioned, the results of the nonparametric procedures support the notion that the assumptions underlying the parametric tests were reasonable.

Paired t-tests:

The results of the paired t-tests partially support the null hypothesis that there was no increase in suspended sediment as a result of the Opus 7 Fire (table 5). The tests of the non transformed data supported the null hypothesis, except for the rising limb component for 1990, in which the $H_0$ was rejected. The tests of the log transformed data on three of the six data sets supported the $H_0$ (fail to reject), that there is no significant evidence of difference between the means of Station one vs. Station three. This is true for both years of the study.

The three cases in which the null hypothesis was not upheld were: Low flow 1989, Rising limb 1990, & Falling limb 1990. This suggests that there was a significant difference in suspended sediment between the two stations for those three periods, although other factors may be responsible for the
differences. Actual concentration means were:

Low Flow 1989;  \( n=81 \)
- Station #1  4.04 mg/l
- Station #3  3.38 mg/l

Falling Limb, 1990; \( n=49 \)
- Station #1  3.41 mg/l
- Station #3  2.38 mg/l

Rising Limb 1990: \( n=7 \)
- Station #1  2.37 mg/l
- Station #3  1.05 mg/l

Sample size provides a reasonable explanation for the "Rising Limb 1990" data, and may also have influenced the results for the other two hydrograph components. Optimal sample size given the range of means would be 105, and 63, for "Low Flow 1989", and "Falling Limb 1990", respectively. Additionally, stream competence decreases at the lower flows. Material that would move through the system at higher discharges is now being stored, which alters sediment relationships between stations.
CHAPTER V

SUMMARY & CONCLUSIONS

Hydraulic Geometry:

Based on a comparison of the 1987, pre-fire transect at Squaw #1 with the 1994 post-fire transect at Squaw #1, there is no evidence to conclude that there were any changes in channel cross section as a result of the Opus 7 fire. Channel cross-sectional areas at bankfull were virtually identical (table 8). These findings are similar to those of Minshall, et. al.\textsuperscript{49}, in studies of the 1988 wildfires in Yellowstone National Park. He found that most high gradient (A & A\textsubscript{b} type channels) burned streams displayed major changes in channel cross-section morphology, while lower gradient burned streams remained relatively constant. Additionally, due to the methodology used for the 1987 pebble count, there is no way to assess changes in particle size distribution and the D\textsubscript{50}.

**Suspended Sediment:**

As previously discussed, the units of analysis for this study were milligrams per liter; however, several other data formats can provide insight into processes at work in a watershed. Suspended sediment is traditionally expressed as mass/unit area/unit time. Figures 17 & 18 show comparisons expressed in lbs/mi$^2$ and tons/mi$^2$, respectively. They are further broken down by flow components for consistency. Although the difference in contributing areas is relatively small, *within year* differences are a function of increased contributing area, and higher discharges.

The substantial differences in output *between years* is attributable to higher annual discharge in 1989. Average annual discharge (at Squaw Above Doe) was 27% higher in 1989 than 1990 (figure 6, Chapter II).

Figure 19 presents sediment data as a function of miles of channel within the contributing area. Anderson and Potts\(^5^0\) found that most sediment in an undisturbed forested watershed is a result of erosion along the perimeter of the channel. They stated that sediment is not derived from large areas in a drainage as might be presumed when overland processes are most

Squaw Creek: Above Fire & Below Fire

Suspended Sediment: Pounds per Square Mile

Lbs./Square/Mile/Year

1989

1990

Above Fire: 14.4 sq. miles

Below Fire: 16.9 sq. miles

Figure 17
Squaw Creek: Above Fire & Below Fire

Suspended Sediment: Tons per Square Mile

Tons/Square Mile/Year

Above Fire: 14.4 sq. miles
Below Fire: 16.9 sq. miles

Figure 18
prevalent, and conclude that sediment production is more closely related to channel length than basin area. The slightly greater number of stream miles (below fire) produced more sediment, as would be expected. It should also be noted, however, that the “below fire” area has a greater percentage of alluvial channels that contain finer, more easily entrained materials than the lower order channels higher up in the drainage. Another point of consideration is the role of overland flow immediately following the fire. This fire burned extremely hot, and in many areas adjacent to Squaw Creek the soils were hydrophobic as a result. There was a period between the beginning of fall rain, and snowfall, that overland flow did play an important role in moving soil downslope, and ultimately into Squaw Creek.

Based on the data provided by the two ISCO stations, one could conclude that the evidence to support the hypothesis that the fire did not increase sediment was, at best, tenuous. Of the six paired t-tests performed on the data, three supported the hypothesis, and three did not. The nonparametric procedures corroborated the validity of the original assumptions, and generally did add credibility to the test results.
Squaw Creek: Above Fire & Below Fire

Suspended Sediment: Tons per Mile of Channel

Tons/Mile of channel

- Above Fire: 29.81 Stream miles
- Below Fire: 33.97 Stream miles

Figure 19
A comparison of historical suspended sediment data compared against the two years of ISCO data, however, suggests considerably different conclusions. Figure 20 depicts suspended sediment samples taken for eight years at Squaw Creek above Doe Creek, and compares them to the ISCO data at the same location for 1989 and 1990. The 1980-1988 samples were collected with a DH-48 suspended sediment sampler, using the depth-integrated method. Samples were processed by the same techniques described previously. The graph indicates suspended sediment virtually doubled immediately following the fire, and by 1990, had returned to near (or below) pre-fire levels. Table 10 shows the same data in a numerical format. There was no other concurrent activity in the watershed that could explain such a dramatic increase in suspended sediment.

---

Squaw above Doe (Suspended Sediment)

Historical Data vs. Two Year Study

Milligrams per Liter 1980-1988 (Depth Integrated Grab Samples)

<table>
<thead>
<tr>
<th>Year</th>
<th>Rising Limb</th>
<th>Falling Limb</th>
<th>Low Flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980-1988</td>
<td>4</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>1989</td>
<td>8</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>1990</td>
<td>6</td>
<td>6</td>
<td>4</td>
</tr>
</tbody>
</table>

Figure 20

Years

1980-1988

1989

1990
The Opus 7 Fire was essentially extinguished by intense rainfall.

Precipitation records from the RAWS station at Powell indicate that 2.58 inches of rain fell from 9/27/88 to 10/22/88 (table 11).
During that time, rain-splash erosion and overland flow moved soil material downslope and into the stream system. Debris avalanches also deposited substantial amounts of material either directly into Squaw Creek, or into the side ditches of the forest road adjacent to the stream. After spring snow melt in the spring of 1989, accumulated sediment moved through the ditch system and into Squaw Creek. Soil movement from adjacent slopes continued to input sediment into the system, especially in areas where aerial seeding was not effective. By spring of 1990, the burned area was essentially stabilized: a thick layer of grasses and forbs covered the ground, and bank erosion resulting from suppression operations in the riparian zone had also healed over. This served to inhibit overland flow and soil movement, hence the rapid drop off of stream sediment in 1990. Minshall, et. al.\textsuperscript{52}, reported a similar phenomenon in Yellowstone Park streams. They measured fine sediments as a function of cobble embeddedness, and found mean embeddedness doubled in the year following the fire, then decreased to pre-fire values in 1990 through 1992 in 3rd order streams.

The apparent contradiction with the ISCO data seems to lie in the original test hypothesis. As stated previously, I chose a two-tailed test because

\begin{flushright}
\end{flushright}
I did not know if there would be a change in sediment regime, and I also did not know in which direction (higher or lower), a change might occur. Under those circumstances, a two-tailed test was appropriate. Had I run the tests as one-tailed, the probabilities would have been one half of the values reported. This would have made all the results less than alpha = 0.05; consequently, the null hypothesis would have been rejected in all cases.

It is evident that this particular fire caused a sharp increase in suspended sediment levels in the Squaw Creek system. It is equally obvious that the sediment moved through the system quite quickly. Any long term effects can only be determined by further study. I suspect that the fluvial/geomorphological responses exhibited here can be generalized for other watersheds, but site specific conditions will certainly make each situation unique. It is interesting to note, that photographs taken in 1934 of the Lochsa River on the Powell District following the catastrophic fires of 1929 shows bar formations in the river that are no longer there today. Those fires burned 45,094 acres, and were certainly more intense than the comparatively small Opus 7 Fire.


Recommendations For Further Study:

As discussed in the section on hydraulic geometry, permanent cross section sites have been established in Squaw Creek to allow continuing monitoring of channel changes. Cross sections and particle size measurements offer the best available resources for tracking changes in dynamic equilibrium. Regrettably, analyses that rely solely on ISCO's are prone to gaps in the data record due to equipment failure, overturned samplers, vandalism, etc.. When this study was initiated, it was the technology in use on this Forest. Surveyed cross sections and Wolman Pebble Counts were not standard procedure on the Clearwater Forest at that time. Perhaps the greatest shortcoming is the inability to adequately measure bedload. This is particularly important in granitic watersheds, where it comprises such a large percentage of the total load.

Obviously, transects cannot be set up in every drainage to anticipate possible changes as a result of future fires. Pre-fire data for any given stream would be ideal, although impractical. There are, however, large numbers of stream transects being established for other purposes: forest plan monitoring, effectiveness monitoring, fish habitat surveys, etc.. It would be quite simple to create a database that would catalog and identify channel characteristics, so when a fire did occur where changes in channel equilibrium were expected, a
similar drainage could be chosen from the database and used for a "pre-disturbance" comparison.
RAW DATA
NORMAL PROBABILITY PLOT
RISING LIMB, SQUAW ABOVE DOE, 1989

NORMAL PROBABILITY PLOT
RISING LIMB, SQUAW ABOVE DOE, 1989

NSCORES: DIFFERENCE BETWEEN MEANS
APPENDIX A

RAW DATA

HISTOGRAM

RISING LIMB, SQUAW ABOVE DOE, 1989

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<th>Midpoint</th>
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N = 29

MG/L: 1-3
RAW DATA

NORMAL PROBABILITY PLOT

RISING LIMB, SQUAW ABOVE DOE, 1990

NSCORES: DIFFERENCE BETWEEN MEANS
APPENDIX A

RAW DATA

HISTOGRAM

RISING LIMB, SQUAW ABOVE DOE, 1990

MG/L; 1-3   N = 7

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0.00  0.70  1.40  2.10  2.80
APPENDIX A

RAW DATA

NORMAL PROBABILITY PLOT

FALLING LIMB, SQUAW ABOVE DOE, 1989

\[
\begin{align*}
N* &= 1 \\
N S C O R E S : D I F F E R E N C E B E T W E E N M E A N S
\end{align*}
\]
APPENDIX A

RAW DATA

HISTOGRAM

FALLING LIMB, SQUAW ABOVE DOE, 1989

MG/L: 1-3  N =  60

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<tr>
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</table>
APPENDIX A

RAW DATA

NORMAL PROBABILITY PLOT

FALLING LIMB, SQUAW ABOVE DOE, 1990

NORMAL PROBABILITY PLOT
FALLING LIMB, SQUAW ABOVE DOE, 1990

N* = 5
NSCORES: DIFFERENCE BETWEEN MEANS
APPENDIX A

RAW DATA

HISTOGRAM

FALLING LIMB, SQUAW ABOVE DOE, 1990

MG/L; 1-3  N =  49  N* =  5

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0.0  6.0  12.0  18.0  24.0
APPENDIX A

NORMAL PROBABILITY PLOT
LOW FLOW, SQUAW ABOVE DOE, 1989

NORMAL PROBABILITY PLOT
LOW FLOW, SQUAW ABOVE DOE, 1989

N* = 10

NSCORES: DIFFERENCE BETWEEN MEANS
APPENDIX A

RAW DATA

HISTOGRAM

LOW FLOW, SQUAW ABOVE DOE, 1989

MG/L: 1-3  N = 81  N* = 9

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APPENDIX A

RAW DATA

NORMAL PROBABILITY PLOT
LOW FLOW, SQUAW ABOVE DOE, 1990

NORMAL PROBABILITY PLOT
LOW FLOW, SQUAW ABOVE DOE, 1990

N* = 10
NSCORES: DIFFERENCE BETWEEN MEANS
RAW DATA
HISTOGRAM
LOW FLOW, SQUAW ABOVE DOE, 1990

Midpoint | Count
---------|------
-14      | 1    
-12      | 0    
-10      | 0    
-8       | 0    
-6       | 0    
-4       | 0    
-2       | 10   
0        | 22   
2        | 17   
4        | 7    
6        | 2    
8        | 1    

MG/L;1-3  N =  62  N* =  10
LOG 10 TRANSFORMED DATA
NORMAL PROBABILITY PLOT
RISING LIMB, SQUAW ABOVE DOE, 1989

NORMAL PROBABILITY PLOT
LOG 10 TRANSFORMED DATA
RISING LIMB, SQUAW ABOVE DOE, 1989

NSCORES: DIFFERENCE BETWEEN MEANS
LOG 10 TRANSFORMED DATA

HISTOGRAM

RISING LIMB, SQUAW ABOVE DOE, 1989

LOG 1-3      N = 29

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<tr>
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LOG 10 TRANSFORMED DATA

NORMAL PROBABILITY PLOT

RISING LIMB, SQUAW ABOVE DOE, 1990

N* = 1

NSCORES: DIFFERENCE BETWEEN MEANS
APPENDIX B

LOG 10 TRANSFORMED DATA

HISTOGRAM

RISING LIMB, SQUAW ABOVE DOE, 1990

LOG 1-3 \( N = 6 \quad N^* = 1 \)

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0.00 0.70 1.40 2.10 2.80
LOG 10 TRANSFORMED DATA
NORMAL PROBABILITY PLOT
FALLING LIMB, SQUAW ABOVE DOE, 1989

NORMAL PROBABILITY PLOT
LOG 10 TRANSFORMED DATA
FALLING LIMB, SQUAW ABOVE DOE, 1989

NSCORES: DIFFERENCE BETWEEN MEANS
Log 10 Transformed Data

Histogram

Falling Limb, Squaw Above Doe, 1989

Log 1-3

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<tbody>
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<tr>
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N = 60
LOG 10 TRANSFORMED DATA
NORMAL PROBABILITY PLOT
FALLING LIMB, SQUAW ABOVE DOE, 1990

NORMAL PROBABILITY PLOT
LOG 10 TRANSFORMED DATA
FALLING LIMB, SQUAW ABOVE DOE, 1990

NSCORES: DIFFERENCE BETWEEN MEANS

N* = 9
APPENDIX B

LOG 10 TRANSFORMED DATA

HISTOGRAM

FALLING LIMB, SQUAW ABOVE DOE, 1990

LOG.1-3  N = 45  N* = 9

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LOG 10 TRANSFORMED DATA
NORMAL PROBABILITY PLOT
LOW FLOW, SQUAW ABOVE DOE, 1989

N* = 9
NSCORES: DIFFERENCE BETWEEN MEANS
LOG 10 TRANSFORMED DATA

HISTOGRAM

LOW FLOW, SQUAW ABOVE DOE, 1989

LOG.1-3  N = 81  N* = 9

Midpoint   Count
-1.0       1
-0.8       0
-0.6       4
-0.4       10
-0.2       10
0.0        13
0.2        15
0.4        10
0.6        10
0.8        3
1.0        2
1.2        2
1.4        0
1.6        1
LOG 10 TRANSFORMED DATA
NORMAL PROBABILITY PLOT
LOW FLOW, SQUAW ABOVE DOE, 1990

NORMAL PROBABILITY PLOT
LOG 10 TRANSFORMED DATA
LOW FLOW, SQUAW ABOVE DOE, 1990

N* = 11
NSCORES: DIFFERENCE BETWEEN MEANS
LOG 10 TRANSFORMED DATA

HISTOGRAM

LOW FLOW, SQUAW ABOVE DOE, 1990

<table>
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LOG 1-3  N = 61  N* = 11
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