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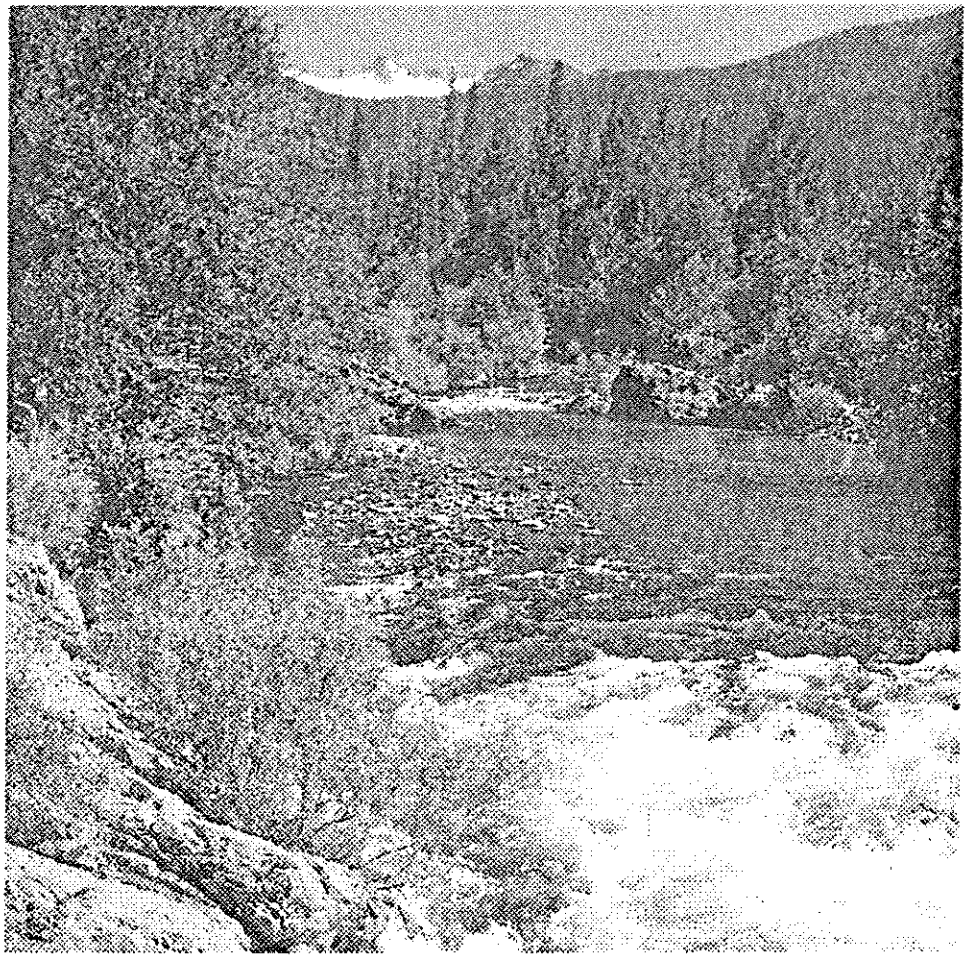
SALMON SUB-BASIN SEDIMENT ANALYSIS

by Juan de la Fuente and Polly A. Haessig

USDA - Forest Service, Klamath National Forest

1312 Fairlane Road, Yreka, California 96097



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Abstract

Hydraulic mining from about 1870-1950 delivered about 15.8 million yds^3 of sediment to the Salmon River system. By comparison, from 1904-1988, landslides delivered about 10.4 million yds^3 and surface erosion delivered about 1.5 million yds^3. Channel erosion was not quantified, but its contribution was probably greater than that for surface erosion, and less than that for landslides. Landslide occurrence was episodic, and controlled by climate. The most important landslide episodes occurred during a wet climatic cycle which lasted from about 1950-1975, and accounted for 84% of the total landslide volume produced from 1904-1988. Major floods in 1955, 1964, 1972, and 1974 severely modified the river channel and those of its larger tributaries. By far, the 1964 flood had the greatest effect on stream channels, and produced the most landslides. The influx of large volumes of landslide-derived sediment to flooding streams and rivers resulted in widespread disruption of channel beds and removal of riparian vegetation. Low gradient reaches were filled with sediment, and many of the steeper tributary channels were scoured by the passage of debris flows.

Large fires in excess of 50,000 acres occurred in 1917-1918, 1977, and 1987. None of these fires initiated significant landslide episodes. This may be due to the fact that all were followed by drought periods. Surface erosion was observed to increase markedly on burned granitic lands after the fires of 1987, but data are not available on earlier fires. There is a high risk of future catastrophic fire in the Salmon River watershed due to the accumulation of fuel over the past 50 years. This is important because fire can greatly increase landslide and surface erosion rates.

There was little correlation between historic sediment production and the current condition of fish habitat. That is, watersheds which produced large volumes of landslide-derived sediment did not necessarily exhibit poor quality habitat. This may be due to the fact that the last landslide producing storm occurred about 18 years prior to the time that the habitat surveys were conducted, allowing sufficient time for the channels to recover.

The large landslide producing storms of the 1960's and 1970's occurred when the Salmon River watershed had less than 3% of its area disturbed by roads, harvest, or recent fire. In 1989, about 18% of the watershed was disturbed, due in large part to the fires of 1977 and 1987. Roaded lands were found to produce landslides at a rate about 100 times greater than undisturbed land, and harvested lands produced landslides at a rate about 5 times greater than undisturbed land. Thus, it is estimated [by the landslide sediment model] that the Salmon River watershed would produce 2.68 million yds^3 of landslide sediment if a wet climatic sequence such as that of 1965-1975 [excluding the 1964 flood] were to occur today. This compares to an estimate of 1.33 million yds^3 if the watershed were completely undisturbed. The basin-wide air photo inventory measured a total of 1.79 million yds^3 of landslide-derived sediment for the time period 1965-1975.

Certain geomorphic terranes were found to produce the vast majority of the landslide volume. Similarly, certain soil types produced most of the surface erosion. Disturbance of these lands can further increase their landslide and erosion potential.

Executive Summary

INTRODUCTION

The Salmon River provides high quality habitat for a variety of anadromous fish, including spring and fall run chinook salmon [*Oncorhynchus tshawytscha*], summer, fall, and winter run steelhead [*O. mykiss*], and coho salmon [*O. kisutch*]. The watershed occupies 751 square miles within the Klamath Mountains physiographic province, and contains metamorphic, granitic, and ultramafic rock. Landsliding is one of the most important geomorphic processes in the watershed. Elevations range from 500-9,000 feet, and precipitation varies from 30-80 inches, with snow predominating above 4,000 feet in elevation. Forest cover occupies about 90% of the watershed, and includes mixed conifer, douglas-fir, true fir, and a variety of hardwoods. Fire is a very important element of the ecosystem. Only 1.3% of the land is privately owned, with the remainder within the Klamath National Forest. About half of the National Forest land is managed as wilderness.

Five basic issues were addressed by this study. They are as follows:

1. Sediment Production and Watershed Disturbances [Mining, Roads, Harvest, Fire]

2. Fish Habitat and How it is Affected by Sediment

3. Historic Floods and Their Effects on the Salmon River System

4. Identification and Prioritization of Watershed Rehabilitation Opportunities

5. Availability of Watershed and Fisheries Data in a Geographic Information System [GIS]

These five issues are discussed below.

HISTORY OF WATERSHED DISTURBANCES IN THE SALMON RIVER BASIN

Watershed disturbances [mining, roads, timber harvest, and fire] have influenced the present condition of streams and associated fish habitat in the Salmon River basin, and will continue to exert influence in the future.

Mining

Hydraulic mining of the main river valleys occurred from about 1880 to 1950, and disturbed at least 1200 acres of land. The removal of gold-bearing river gravels involved considerable disruption of the floodplains along the main river and major tributaries.

Roads

There are about 762 miles [3620 acres] of road in the watershed, two thirds of which were built after 1955 as part of the transportation system to manage forested public lands.

Timber Harvest

The earliest timber harvest occurred in conjunction with mining and homestead activity. Regeneration harvesting of timber on public land did not begin until the 1950's. By 1975, there were about 8,000 acres of harvested public land [plantations] in the watershed, and by 1990, there were about 30,000 acres. The 1990 figures include about 18,000 acres of harvested land burned by the fires of 1977 and 1987.

Fire

Large fires involving about 70,000 acres occurred early this century [1917 and 1918]. No data are available on the intensity of these fires. From 1919 to 1976 burned area was small, with only two fires larger than 5,000 acres. In 1977, 57,489 acres burned in the Hog Fire, and 102,369 acres burned in the wildfires of 1987. Area [acres] by intensity class for these fires was as follows:

	Fire	High	Moderate	Low
	Hog Fire [1977]	14,106	30,341	13,042
	1987 Fires	16,654	21,510	64,205

The fires of 1987 reburned 20,454 acres of the Hog Fire.

Total Area Disturbed

In 1975, the disturbed area in the watershed consisted of 7,962 acres of timber harvest, 2,893 acres of road, and 1,200 acres of hydraulic mine, totalling 12,055 acres of disturbed lands or, 2.5% of the watershed area. Following the fires of 1977 and 1987, the total disturbed area amounts to 89,682 acres [does not include low intensity fire areas], or 18.7% of the watershed. This includes 72,078 acres of fire [overlaps with some harvest], 12,784 acres of harvest, 3,620 acres of road, and 1,200 acres of hydraulic mined area. Substantial revegetation has occurred on the land harvested prior to 1975 [about 8,000 acres] since these plantations are now from 18-30 years old. Similarly, some of the hydraulic mines have revegetated.

SEDIMENT PRODUCTION IN THE SALMON RIVER WATERSHED

Methods

This study developed quantitative estimates of sediment derived from landslide and surface erosion sources, as well as from hydraulic mining. Past landslide production was measured by a combination of air photo and field inventories, and the universal soil loss equation [USLE] was used to estimate past surface erosion. The air photo inventory utilized photos dating from 1944-1988 and was used to estimate landslide production from 1904-1988. An air photo survey without direct field measurements was used to estimate mining related sediment. Estimates of future sediment production were derived from a landslide model and the USLE.

Mining-Related Sediment

Preliminary estimates of volume indicate that about 15.8 million yds³ of sediment were discharged into the river from 1870 to 1950 by hydraulic mining. The majority of this volume was delivered in the late 1800's and early 1900's. The mining involved the use of high pressure water nozzles, "giants", to wash gravel deposits, and caused major channel modifications in many areas, particularly along the upper South Fork of the Salmon River.

Sediment Production from Landslides and Soil Surface Erosion 1904-1988

During the period from 1904-1988, approximately 10.4 million yds³ of landslide-derived sediment entered the stream system. Of this, 58% was associated with the 1964 flood, and 17% with the storms of 1965-1975. Undisturbed land accounted for most of this volume [67%], while roads accounted for 30%, timber harvest 2%, and fire 1%. During this same period, surface erosion produced about 1.5 million yds³ of sediment. Channel erosion was not measured quantitatively, but it probably contributed a significant amount of additional sediment to the totals.

Landslide production for the main tributaries to the Salmon River from 1904-1988 was as follows:

Main Stem Salmon	4,392,458 yds³
North Fork Salmon	1,411,289 yds³
South Fork Salmon	2,610,519 yds³
Wooley Creek	1,997,811 yds³

Two large landslides created temporary dams on the main stem of the Salmon River, and accounted for about 20% of the total landslide volume measured by this study. These landslides greatly affect projections for future landslide production.

Sediment derived from soil surface erosion immediately after the 1987 fires was estimated at 106,190 yds³/year. Prior to the fire, it was estimated at 14,906 yds³/year. The impact of the fire was especially important in granitic watersheds. Cleanout records of a debris catchment basin in Olsen Creek, a severely burned watershed near Sawyers Bar, reveal that from 1987 to 1992, it yielded about 15,900 yds³ of sediment to the basin. This equates to 18 yds³ per acre of watershed, or about 3.7 yds³ per acre per year. Much of the sediment delivered to the river by burned granitic watersheds entered when flows were very low, and the sand resided in the river for a considerable length of time before flows capable of moving it occurred.

The results of this study indicate that landsliding is the primary natural sediment producing process in the Salmon River watershed. However, the potential contribution of channel erosion and surface erosion, particularly in burned granitic watersheds, was found to be important under certain conditions, such as in the Olsen Creek example described above.

Effects of Climate and Peak Flows on Past Sediment Production

Historic accounts reveal that the latter half of the 19th century was generally wet in the Pacific Northwest, and that large floods occurred in the winters of 1861-1862, and 1889-1890. From 1915 to 1950 precipitation was low in the Salmon River Watershed, and peak discharges in the river at

Somes Bar were also low. This dry period was followed by a wet period from 1950-1975 during whichfloods were frequent. The largest of these occurred in 1964, and this flood was probably larger than the 1890 event, but smaller than the 1861 event [Coghlan, 1984]. Since 1975, the climate has been primarily dry, with the exception of very wet winters in 1981-1982, and 1982-1983, and a wet spring in 1986. Landslides were found to coincide with the wet periods, and soil surface erosion is more closely linked to the occurrence of large scale reductions in vegetation [such as by fire or timber harvest], and by surface disturbances of the soil.

Effects of Roads, Harvest and Fire on Past Sediment Production

On average, roaded lands produced landslides at a rate 59-108 times greater than undisturbed lands. Harvested lands increased landsliding by 3 to 12 times. For example, during the 1965-1975 period, each acre of harvested land delivered 6.8 yds^3 of sediment to the channel system, while each undisturbed acre delivered 2.6 yds^3. Insufficient data were available to distinguish the change in landslide rate associated with fire from that of harvest. Landslide rates in yds^3 per acre for undisturbed, roaded, and harvested land are displayed below. Separate rates are given for the 1964 flood, and for the combined floods of 1965-1975.

Type of Flood Event	Disturbance	Landslide Rate [yds^3/acre]	Increase Over Undisturbed Rate
1964 Event	Roads Harvest Undisturbed	909.4 96.8 8.4	X 108.2 X 11.5 X 1.0
1965-75 Events	Roads Harvest Undisturbed	158.0 6.8 2.7	X 59.4 X 2.6 X 1.0

The values listed above represent area-weighted basin-wide averages. Detailed field studies and landslide measurements in the Little North Fork of the Salmon River revealed that the change in landslide rate associated with roads and harvest varies considerably in different geomorphic terranes. For example, during the period from 1965-1975, the granitic inner gorge terrane which had been clearcut produced landslide volume at a rate 20 times greater than that which was undisturbed. The rate was 254 times higher when these lands were roaded. Similarly, the steep granitic mountain slope terrane which was clearcut produced landslide volume at a rate 5 times greater than that which was undisturbed, and roaded areas produced landslides at a rate 156 time greater than undisturbed areas.

One large landslide which occurred in 1964 delivered about one million yds^3 of sediment to the river, and has a large effect on the computation of the road associated landslide rate displayed above. If this landslide is removed from consideration, the road rate decreases from 909 to 199 yds^3/acre, and the increase over natural goes from 108 to 24 times.

Soil surface erosion is greatly accelerated by road construction and by removal of vegetation by wildfire or timber harvest. Application of the Universal Soil Loss Equation [USLE] indicates that on average, roads in the Salmon River watershed produce sediment by surface erosion processes at

a rate 126 times greater than undisturbed areas. Intensely burned areas [1987 fires] increase the surface erosion rate by a factor of 43 over undisturbed areas. Intense summer showers were shown to be a serious problem in burned granitic watersheds. Olsen Creek delivered about 1,000 yds^3 to a debris catchment basin in response to a storm on September 25, 1990. This amounts to more than one cubic yard per acre of watershed.

Relationship of Landslides to Geomorphic Terranes and Elevation

Certain geomorphic terranes were found to produce most of the landslide volume. In addition, the portions of these terranes which were roaded or subjected to vegetation removal exhibited accelerated landslide rates. The inner gorge terrane occupies only 17% of landscape, yet accounted for 47% of the total landslide volume delivered to the river system from 1904-1988. Similarly, the slump-earthflow terrane occupies 7% of the landscape, but delivered 13% of the total landslide volume. During the 1964 flood, landslides were concentrated at an elevation of 5,000 feet while from 1965-1975, landsliding was concentrated at elevations of 2,500. These distributions were probably related to storm characteristics such as rain-on-snow.

Future Sediment Production in the Salmon River Watershed

Landslides

The major flood-and landslide-producing storms during this century occurred from 1964-1974 when only 2.5% of the watershed was disturbed by roads, harvest, or recent fire. Since that flood episode, disturbance levels have risen to 18.7% in the watershed. As a result, should storms such as those of the 1960's and 1970's occur under current disturbance levels, sediment production and damage to fish habitat can be reasonably expected to greatly exceed that which occurred in the past. The most highly disturbed watersheds are within the boundaries of the Hog Fire and fires of 1987. The landslide model predicts that under a 10 year climatic sequence such as that of 1965-1975, about 2.68 million yds^3 of landslide-derived sediment will be delivered to the Salmon River system. This compares to 1.79 million yds^3 which was actually measured by air photo inventories for the period 1965-1975. If the watershed were completely undisturbed, the model predicts that it would produce 1.33 million yds^3 of sediment. Thus, as a result of past disturbances, the model predicts that the watershed will produce more than double the landslide volume it would produce if undisturbed.

Soil Surface Erosion

The Universal Soil Loss Equation [USLE] predicts that 0.21 million yds^3 of sediment will be produced over the next 10 years. This compares to 0.08 million yds^3 if the watershed were undisturbed. The actual distribution and magnitude of future soil surface erosion will be controlled by the location of burned and roaded areas as well as by extreme climatic events such as severe summer showers.

Future Catastrophic Wildfire

The potential for large catastrophic fires in the future is very high due to the accumulation of fuel over the past 50 years. Large fires occurred in 1917, 1918, 1977, and 1987. This is significant because fires greatly increase the potential for landsliding and soil erosion in the ensuing years.

Climatic Trends

Though future climatic trends cannot be accurately forecast, the historic record shows a pronounced drought from 1915-1950, and the current dry period could persist for a similar length of time. Alternatively, we could enter a wet cycle similar to that of 1964-1975. During wet periods, landslide episodes dominate the production of sediment, while during droughts, the majority of sediment is produced by surface erosion.

Opportunities for Reducing Future Sediment Production

Future sediment production in the Salmon River can be reduced by:

a. Identifying and stabilizing existing landslides and controlling surface erosion sediment sources;

b. Identifying and repairing potential future sources of sediment on roads;

c. Avoiding new road construction [and similar ground disturbances] as well as vegetation removal on the most sensitive of the geomorphic terranes and soil types;

d. Avoiding high intensity site preparation burns on granitic lands;

e. Re-introducing fire into the ecosystem to reduce the long term risk of future large catastrophic fires.

RELATIONSHIPS BETWEEN FISH HABITAT AND SEDIMENT PRODUCTION

Historic sediment production was compared to various fish habitat attributes which were inventoried in 1990 and 1991. These attributes included embeddedness, substrate composition, number of pools, and percent shade. The correlation between past sediment production and current fish habitat conditions was poor. That is, watersheds which produced large volumes of sediment in the past 50 years did not necessarily exhibit poor fish habitat when recent surveys were completed in 1990 and 1991. Some of the likely reasons for this lack of correlation are described below.

Watershed Recovery

It has been 28 years since the major channel modifying event of 1964, and 18 years since the last large landslide producing storm in 1974. Aerial photographs document the severe channel modifications over a large percentage of the channels in the watershed during those floods. There have been no large sediment producing events since 1974, and channels which were filled with sediment and stripped of riparian vegetation have recovered to varying degrees. Studies of nearby watersheds [Lisle, 1981] similarly affected by the 1964 flood revealed that sediment-filled channels [confined by bedrock] lowered their beds to pre-flood levels within about 15 years after the flood. Observations of 1988 air photos revealed that a considerable amount of revegetation has occurred in flood-damaged riparian areas. Many channels are bounded by dense ribbons of alder stands which have grown since the large floods, and now parallel the streams.

Survey Protocol

Habitat surveys are very site specific and it is difficult to generalize this data for comparison to basin-wide sediment inventories. The habitat surveys were designed prior to this study, and were not meant to be directly correlated in this way.

Results of Other On-going Studies

Field work carried out in July of 1992 [Lisle and Hilton, research in progress] determined that many of the streams within the Salmon River basin had low volumes of sediment in the pools. Nordheimer Creek sub-watershed, which yielded some of the highest sediment volumes in 1964, has a $V^* = 0.03$. V^* is the fraction of pool volume filled with fine sediment, which is derived by dividing the fines volume in a pool by the sum of fines volume and residual pool volume. Little North Fork, which has been logged intensively and has had high erosion and landslide rates in the past, was also found to be relatively free of fine sediment in pools. The following watersheds were also studied by Lisle and Hilton: Crapo, Lower Knownothing, Plummer, Taylor and the South Fork of the Salmon River. Only Crapo had a fairly high value of V^*, [0.23], and Taylor had a moderate value, [0.11]; all the rest have low values [less than 0.10]. Lisle observed abundant volumes of fine sediment in the main stem reaches of North Fork and South Fork Salmon River [personal communication, 7-31-92].

EFFECTS OF HISTORIC FLOODS ON CHANNEL CONDITION AND RIPARIAN HABITAT

Air photo inventories revealed major channel alterations on the main river channel and most of the major tributaries during the 1964 flood. This included channel migration, aggradation, scour, and widespread loss of riparian vegetation. Most low gradient floodplains were stripped of riparian vegetation, and covered with fresh sediment. High gradient reaches experienced both scour and aggradation. Loss of fish habitat is clearly apparent on aerial photographs. The floods of 1965-1975 caused similar damage, but it was much less severe in most areas, and damage was more localized. These floods were accompanied by landslide episodes which delivered large sediment volumes to the streams. The flood of 1955 had a much smaller effect than the earlier floods. With the exception of one large landslide [Murderers Bar] which temporarily dammed the river, landsliding associated with the 1955 flood was relatively small [190,914 yds^3]. During the time interval from 1975-1992, no major floods occurred, allowing vegetation to recover to varying degrees along streams and rivers.

Hydraulic mining significantly altered the main river channels, changed the vegetation in the channel area [due in part to removal of soil down to bedrock]. This effect probably influenced the way in which the river responded to the floods of the 1960's and 1970's.

RESTORATION OPPORTUNITIES

Sub-watersheds which exhibit high disturbance levels [roads, mining, harvest, fire] and contain sensitive geomorphic terranes and soil types are most likely to produce large landslide volumes in future storms. These sub-watersheds have been identified by this study. Sub-watersheds which are most likely to produce landslides in the future at rates greatly in excess of undisturbed rates include: Big Creek, Olsen Creek, Kanaka Gulch, Crapo Creek, lower Little North Fork, lower Main Stem of the Salmon River, Steinacher Creek, Negro Creek, McNeil Creek, and the lower North Fork. This information as well as knowledge about past landsliding and channel disturbance is available for prioritizing watershed restoration activities.

ASSEMBLY OF DATA LAYERS INTO A GEOGRAPHIC INFORMATION SYSTEM [GIS]

This project assembled existing data layers and created new data layers which are now in a geographic information system [GIS]. These layers include geology, soil, vegetation, precipitation, fire, and digital terrain data. Landslide information is in a relational data base which allows asking questions about the relationship of landslides to other physical attributes, such as elevation, disturbance class, or whether it is natural or management-related.

FINAL RECOMMENDATIONS

A. Inventory and Repair of Existing Watershed Problems

Future management of the Salmon River basin should emphasize completion of a basin-wide road management plan, watershed improvement needs inventories and on repair of critical sediment producing sites. The information collected in this study will provide the initial screening for potential landslide stabilization projects, but field verification will be needed to develop stabilization plans.

1. Complete a basin-wide road management plan which will allow identification of sediment sources, and elimination of unneeded road segments.

2. Prioritize and repair identified road problems. Emphasis should be placed on the repair of fills, critical erosion sites, degraded riparian areas, and landslides. Landslide stabilization should be focused on sites where the potential damage to habitat is high, and there is a high likelihood that the landslide can be successfully stabilized.

3. Reduce the potential for large catastrophic fires. This can be best accomplished through a comprehensive fire management plan for the watershed which includes the re-introduction of fire into the ecosystem through prescribed burning.

4. Continue on-going Watershed Improvement Needs Inventories, and maintain and refine prioritized lists of critical sites for the entire watershed.

5. Prioritize watersheds for restoration activities across the entire Salmon River basin. This can be accomplished by integrating the results of this study with those of other inventories such as watershed improvement needs inventories [WIN]. This study identified watersheds which have produced large sediment volumes in the past, and those which are most likely to produce large volumes in the future due to high disturbance levels.

B. Prevention of Future Management-Associated Landslides and Erosion

This can best be accomplished through adoption of management standards and guidelines which protect the geomorphic terranes and sensitive soils which have been identified as landslide prone or erodible by this study. Included are road location, design, and construction standards. These would also apply to mining activity, and to timber harvest design and layout. Implement an active fuel management program involving prescribed burning, site preparation techniques which foster fire resistant plant successions, and other fuel reduction techniques. Lastly, standards of earth science investigation for significant ground and vegetation disturbing activities should be established and implemented.

1. Develop and implement standards and guidelines for managing the sensitive geomorphic terranes and soil types identified by this study. Certain terranes and soils account for a disproportionately large portion of the total sediment delivered to the river system. Roads, timber harvest, and other soil and vegetation disturbing activities should be minimized on these lands. State of the art geotechnical techniques should be applied whenever these lands are subjected to earth disturbance, particularly road construction. This includes practices such as controlled compaction and reinforcement of earthen fills, installation of subsurface drainage, design of stream crossings to account for debris torrents, and special attention to excavations within inner gorge, slump-earthflow, and granitic terrane.

2. Avoid high intensity site preparation fire on granitic lands in order to prevent greatly accelerated surface erosion.

3. Conduct appropriate geologic, soils and hydrologic investigations prior to conducting any significant soil or vegetation disturbing activities.

C. Enhancement of Our Understanding of the Relationship Between Sediment and Fish Habitat

Future research into sediment/fish habitat relationships should be focused on clearly stated questions and include the development of new, integrated fish habitat/watershed inventories.

1. In selected stream reaches, conduct integrated inventories of fish habitat and channel condition, including movement of sediment while considering historic landslide and soil erosion episodes.

2. Digitize active landslide and channel scour data collected by this study to allow quantitative assessment of the role of channel erosion in the sediment budget. This would allow queries to be run on active landslides, geomorphic terranes, and elevation zones.

3. Assemble relevant physical and biologic data for the remainder of the Klamath River in a format similar to that used in this study to allow basin-wide analysis on a GIS system.

4. Utilize this information should be used in prioritizing restoration projects within the watershed.

There are still many unanswered questions regarding the relationship between sediment production and fish habitat condition. This study provides the essential background data in GIS format for future focused studies which can address movement of sediment through the stream system, and the evolution of channel condition. It also provides background for monitoring the effects of future storms and management activities.

D. Monitoring

Monitoring should focus on key issues related to fish habitat-sediment relationships. This includes the movement of sediment through the stream system, and the recovery of a stream following a landslide episode.

1. Inventory landslide distribution, causes, and effects immediately after the next landslide producing storm.

2. Select and establish characteristic channel cross section data in key streams prior to the next flood events.

3. Re-occupy the cross sections at gauging stations on the North and South Forks of the Salmon River.

4. Continue residual pool volume monitoring.

5. Incorporate new technology, in monitoring changes in channel condition over time. Such technology includes use of global positioning system [GPS] along with an airbourne video camera to document existing channel condition.

E. GIS Data Layers

The GIS layers developed by this project will facilitate future studies and monitoring. There is a need to incorporate fish habitat data into the GIS and to develop new techniques for integrated inventories in the future which will involve fish and watershed information collected and placed in a GIS format.

1. Enter all the landslide and hydraulic mines identified by this study into the GIS.

2. Enter scoured channels and date of scour into the GIS.

3. Enter pre-1977 fires by intensity class.

4. Refine estimates of mining-related sediment.

5. Enter fish habitat survey data into the GIS so that it is spatially compatible with the remaining data.

6. Continually refine landslide volumes through on-going projects in the Salmon River.

Chapter 1 - Introduction

BACKGROUND

The Salmon River provides high quality habitat for a variety of anadromous fish, including spring and fall run chinook salmon, summer and winter run steelhead, and coho salmon. In 1986, Congress adopted Public Law 99-552, the "Klamath Act" in order to restore the fisheries resources in the Klamath River. Sedimentation related to certain land management practices was identified as one of the factors which has degraded fish habitat in the Klamath River. This study addresses sedimentation in the Salmon River. It was jointly funded by the U.S. Forest Service and the U.S. Fish and Wildlife Service.

GOALS AND OBJECTIVES

The goal of this project is to facilitate the restoration of the Klamath River Fishery as outlined by the Klamath Act of 1986. Accomplishment of this goal involved completing the following work elements.

1. **Improve our current understanding of sediment production rates in the Salmon River sub-basin and the relationship between those rates and fish habitat.**

This was accomplished by: [a] determining the volume of sediment which entered the stream system [1904-1989] from landslide, surface erosion, mining, and channel erosion sources; [b] comparing historic [1904-1989] sediment production to recent fish habitat condition surveys; [c] predicting future sediment production [landslide and surface erosion] under existing disturbance conditions, and also under undisturbed conditions. Sediment routing was not addressed.

2. **Determine the effects of historic floods on the river system, so that this information can be used in restoration activities.**

This was accomplished by mapping flood effects [scoured and aggraded channels] on a sequence of aerial photos taken from 1944-1988, and reviewing flow records and literature on historic floods. The information will be considered in scheduling restoration work.

3. **Collect all existing geologic, soil, wildfire, precipitation, and fish habitat data on the Salmon sub-basin, and organize it in a way to facilitate future analysis and planning. Make this data available to other agencies or interested parties.**

This has been accomplished, and data is available in electronic as well as paper and mylar format.

REPORT FORMAT

This report is contained in one volume, entitled **Salmon Sub-basin Sediment Analysis.** The volume contains a comprehensive summary of study design, important observations, results, conclusions, and recommendations. It also provides a brief description of the physical and biologic attributes of the Salmon River watershed which are relevant to the study. Appendices to the report provide more in-depth discussion of topics relating to physical and biological characteristics, disturbance history, analytical methods and findings of the study.

Chapter 2 - Physical and Biological Characteristics

TOPOGRAPHY AND LAND STATUS

The Salmon River is a tributary to the Klamath River, and drains an area of 480,626 acres [751 square miles] **[Figure 2-1]**. The Salmon Basin is subdivided into four major sub-watersheds, North Fork, South Fork, Wooley Creek and Main Stem **[Figure 2-2]**. These sub-watersheds have been further subdivided into 57 sub-basins **[Figure 2-3, Table 2-1]**. There are a total of 1,414 miles of stream in the watershed. The largest of the sub-watersheds, the South Fork has 509 miles of stream or 36% of the total. Elevations range from 500 to 9000 feet **[Figure 2-4]**. Along much of its course, the river flows through a rugged gorge in which rock outcrops and bluffs are common. Most of the land at elevations above 4,000 feet, particularly on north slopes, was sculpted by glacial erosion which resulted in broad glacial valleys and glacial lakes along the main mountain crests. The vast majority of the watershed is National Forest, with only 6,398 acres [1.3%] in private ownership **[Figure 2-5]**. Wilderness lands encompass 217,443 acres, or 45% of the watershed.

CLIMATE, STREAM DISCHARGE, AND FLOOD HISTORY

In the central Klamath Mountains, the coastal climatic influence is moderated by the mountains to the west. Summers are warm and dry, winters are cool and wet. Summer high temperatures are about 90 degrees Fahrenheit, low temperatures are about 55 degrees. Winter high temperatures are about 40 to 55 degrees while raining, cooler under clear skies. The annual precipitation during the period of record [1904 to present] at Orleans ranges from 26 to 84 inches. The average annual precipitation is about 50 inches. Approximately 90% of the precipitation occurs from October through May from north Pacific cyclonic storms. The remainder occurs during summer thunderstorms. Winter precipitation occurs mainly as snow above 4,000 feet elevation, and mainly as rain below that elevation. Fluctuation of the snow level occasionally results in rain falling on snow, causing rapid snow melt. Precipitation within the Salmon River Watershed varies from over 80 inches in upper Wooley Creek to less than 40 inches along the South Fork **[Figure 2-6]**. The amount of precipitation generally decreases in an easterly direction, and increases with elevation due to orographic effects. Intense, localized summer showers occur frequently, and have been associated with soil erosion and debris torrents.

The distribution of precipitation over time influences the behavior of erosion and landsliding processes, water quality and the structure of stream channels. The precipitation record has been analyzed to show climatic trends [Baldwin and de la Fuente 1986; Coghlan 1984]. During dry periods, annual precipitation is about 45 inches; during wet periods, the average precipitation increases to about 55 inches. The precipitation record at Orleans, along with longer records from Eureka and other stations in northwestern California, indicate that the period 1870 to 1910 was a wet time; 1911 to 1937 dry; 1938 to 1975 wet; and 1976 to present dry. These alternating periods of relatively wet and dry conditions last for a few decades.

Average annual discharge for the Salmon River is approximately 1.2 million acre feet. Salmon River discharge records [Young and Cruff, 1967; U. S. Geological Survey, 1966-1988, Water-Data Reports for California] reveal that exceptionally high flows occurred during the winters of 1952-1953, 1955-1956, 1964-1965, 1969-1970, 1971-1972, and 1973-1974. Additionally, historic accounts describe floods in 1861-1862, and 1889-1890 [McGlashan and Briggs, 1939]. Landsliding episodes are known to have accompanied many of these floods, particularly those of 1964 and 1972. The combination of landslide episodes and flood conditions resulted in major channel alterations throughout the watershed.

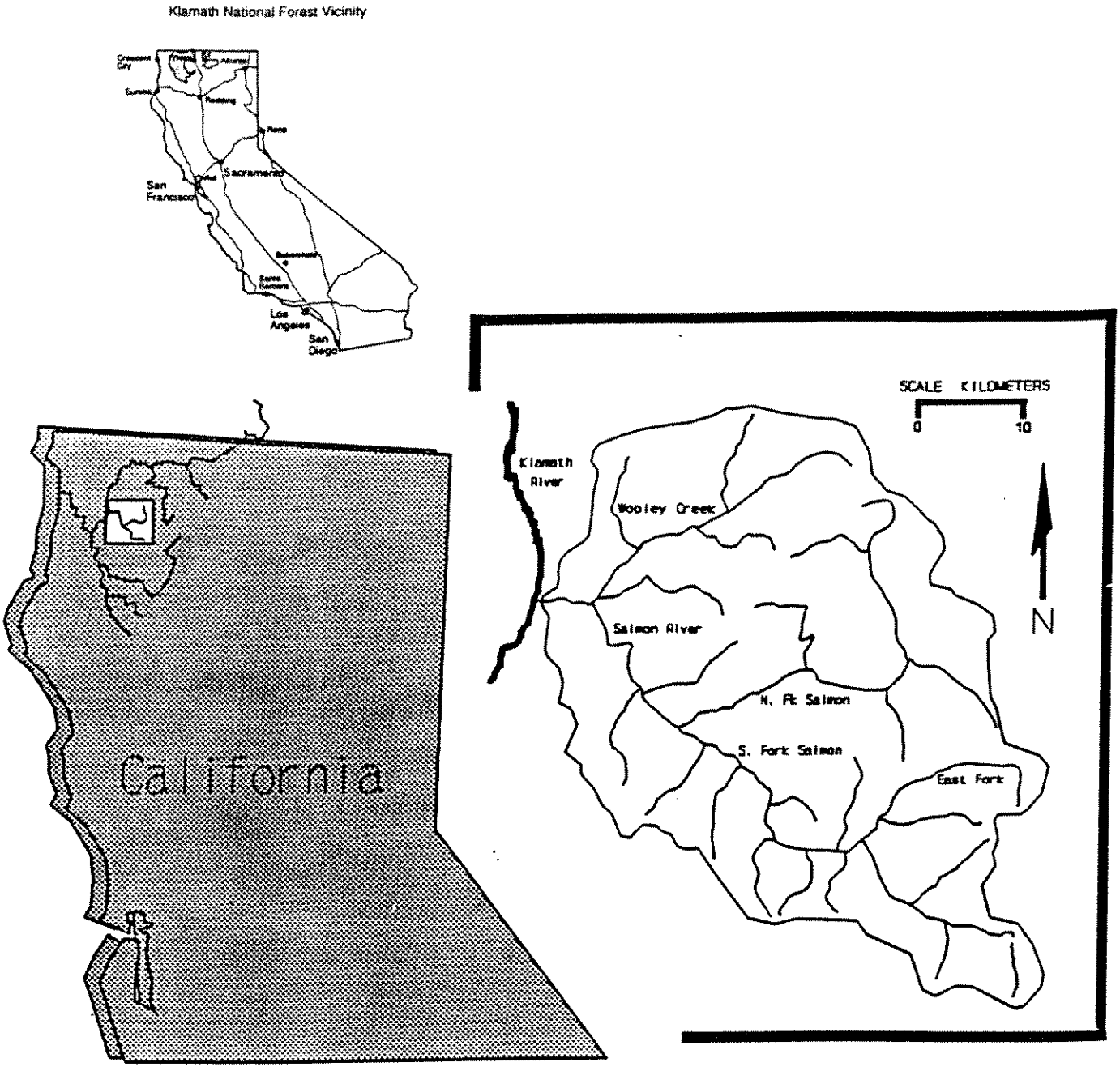


Figure 2-1. Location map of the Salmon River Basin within the Klamath River Basin, northern California.

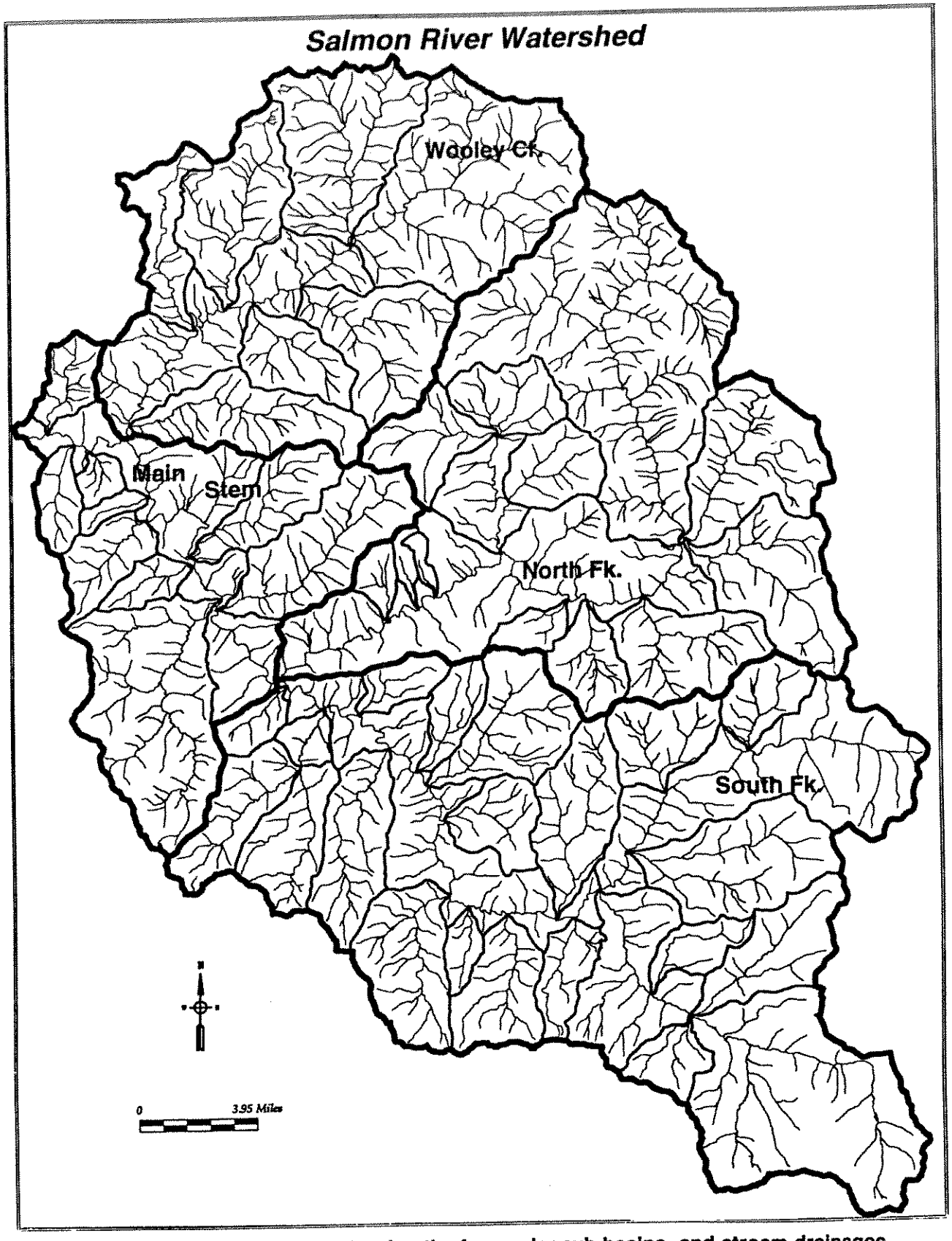


Figure 2-2. Salmon River watershed showing the four major sub-basins, and stream drainages.

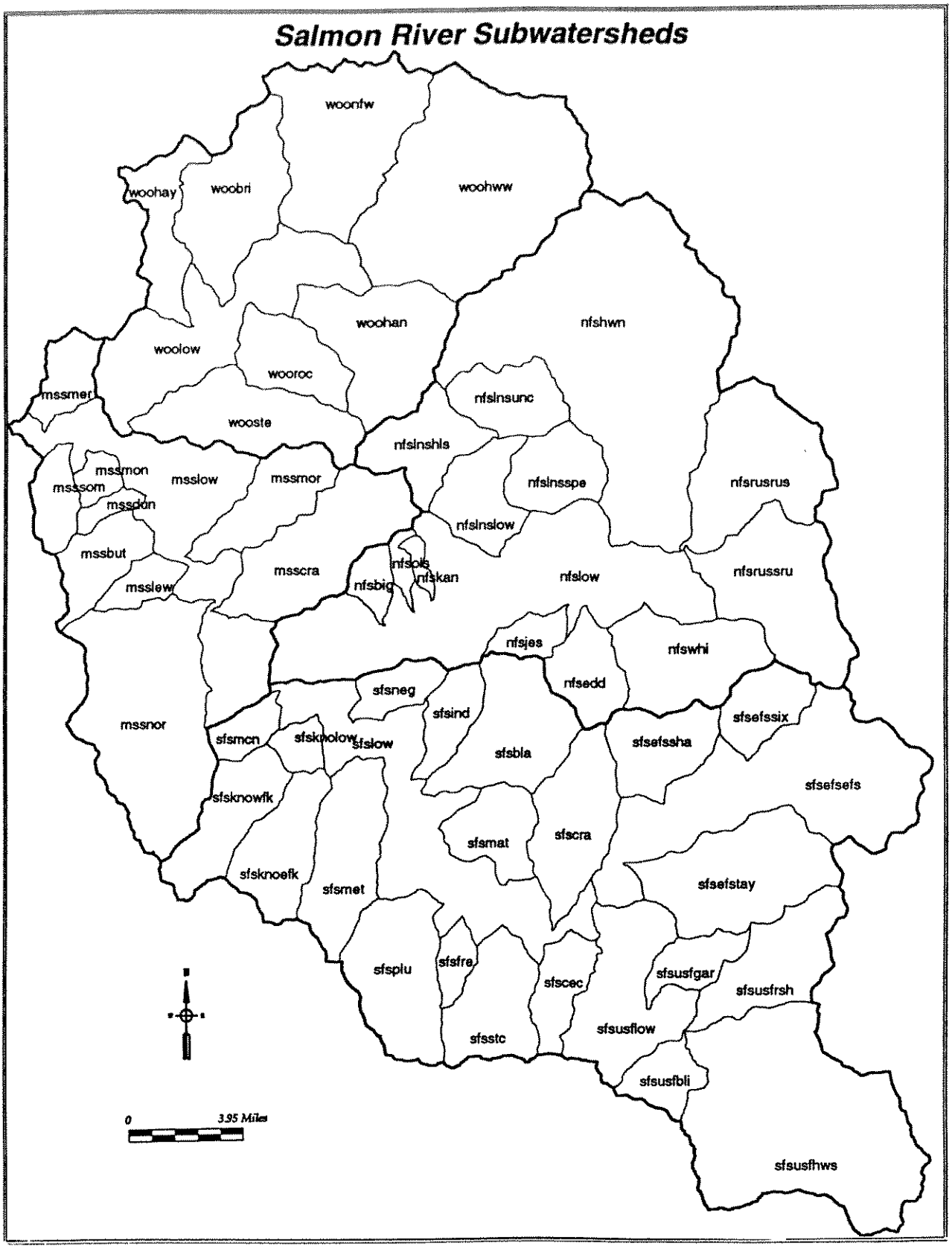


Figure 2-3. Salmon River watershed showing the 56 sub-basins.

Table 2-1. Listing of the named watersheds and sub-watersheds of the Salmon River watershed.

Main Stem [mss]	Wooley [woo]	North Fork [nfs]
Merrill [mer] Somes [som] Monte [mon Duncan [dun] Butler [but] Lewis [lew] Nordheimer [nor] Crapo [cra] Morehouse [mor] Lower Main Stem [low]	Steinacher [ste] Haypress [hay] Bridge [bri] Rock [roc] Hancock [han] North Fork Wooley [nfw] Headwater Wooley [hww] Lower Wooley [low]	Big [big Olsen [ols] Kanaka [kan] Little North Fork [lns] Specimen [lnsspe] Headwaters [lnshls] Uncles [lnsunc] Lower [lnslow] Jessups [jes] Whites [whi] Eddy [edd] Russian [rus] South Russian [russru] Main Russian [rusrus] Headwaters North Fork [hwn] Lower North Fork [low]

	South Fork [sfs]
	McNeal [mcn] Knownothing [kno] East Fork [knoefk] West Fork [knowfk] Lower Knownothing [knolow] Methodist [met] Negro [neg] Indian [ind] Black Bear [bla] Matthews [mat] Plummer [plum] French [fre] St. Claire [stc] Cecil [cec] Crawford [cra] East Fork [efs] Taylor [efstay] Shadow [efssha] Sixmile [efssix] Main East Fork [efsefs] Upper South Fork [usf] Garden [usfgar] Rush [usfrsh] Blindhorse [usfbli] Headwaters [usfhws] Main Upper S. Fk.[usflow] Lower South Fork [low]

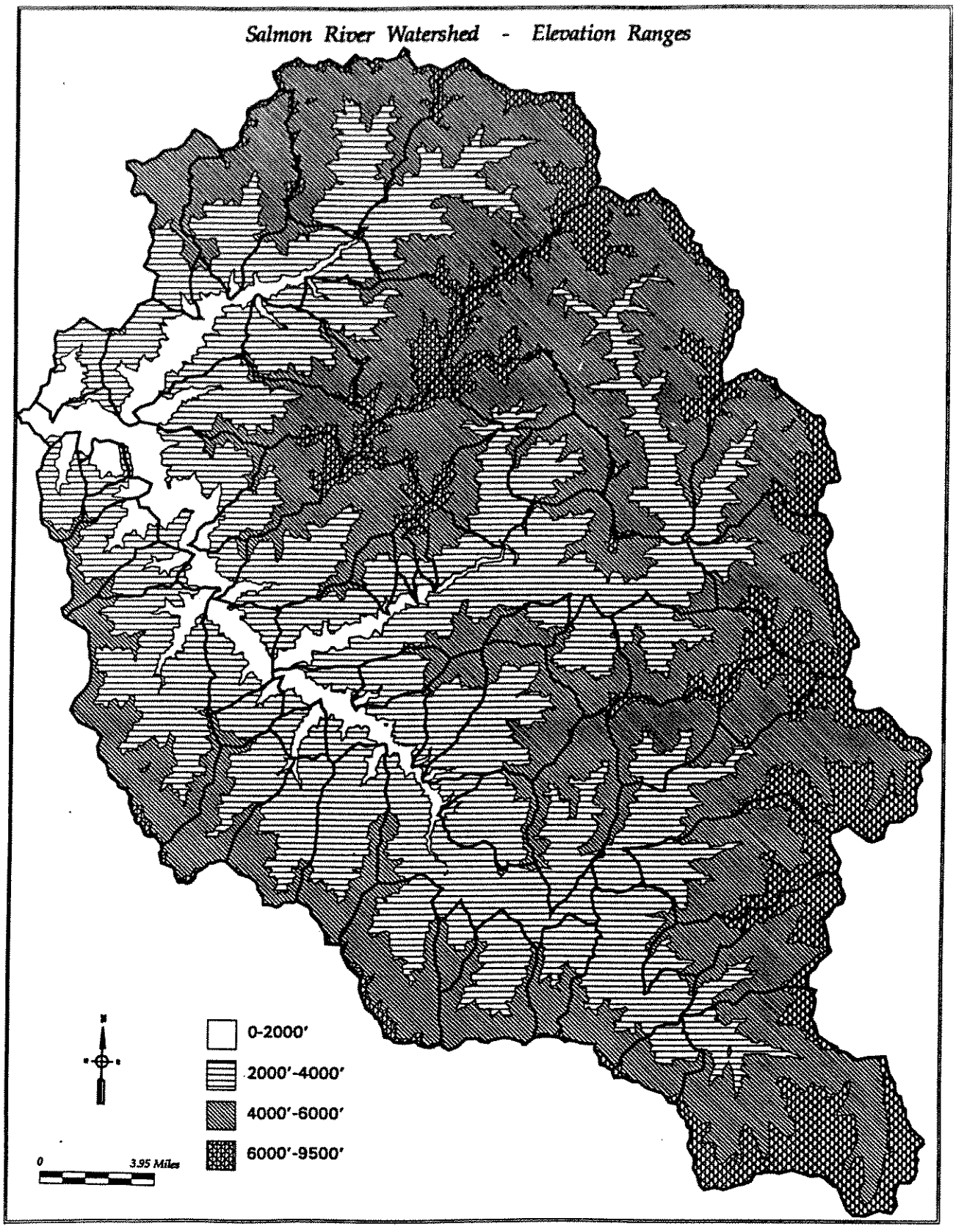


Figure 2-4. Elevation ranges of the Salmon River watershed.

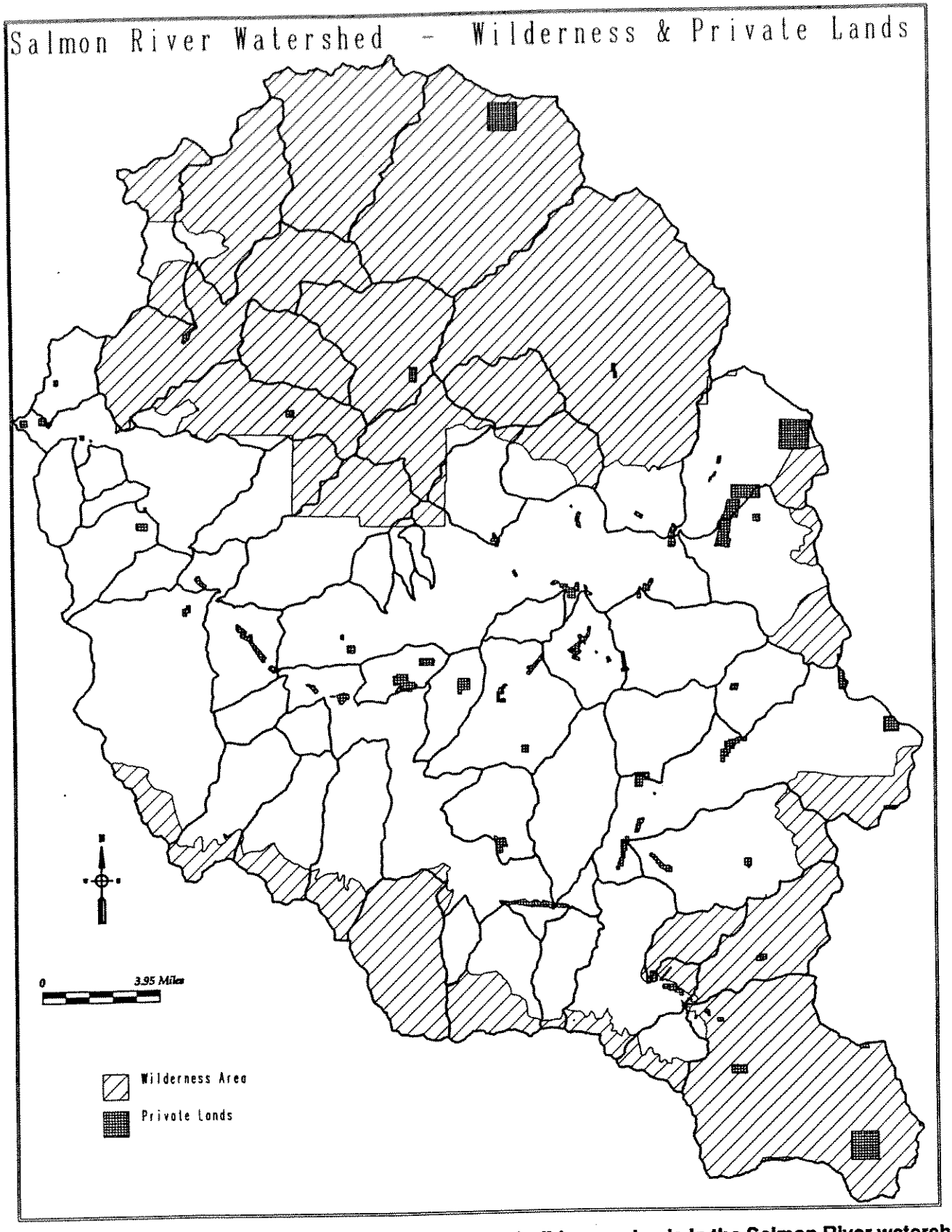


Figure 2-5. Land status and distribution of private and wilderness lands in the Salmon River watershed. Unpatterned areas are National Forest lands.

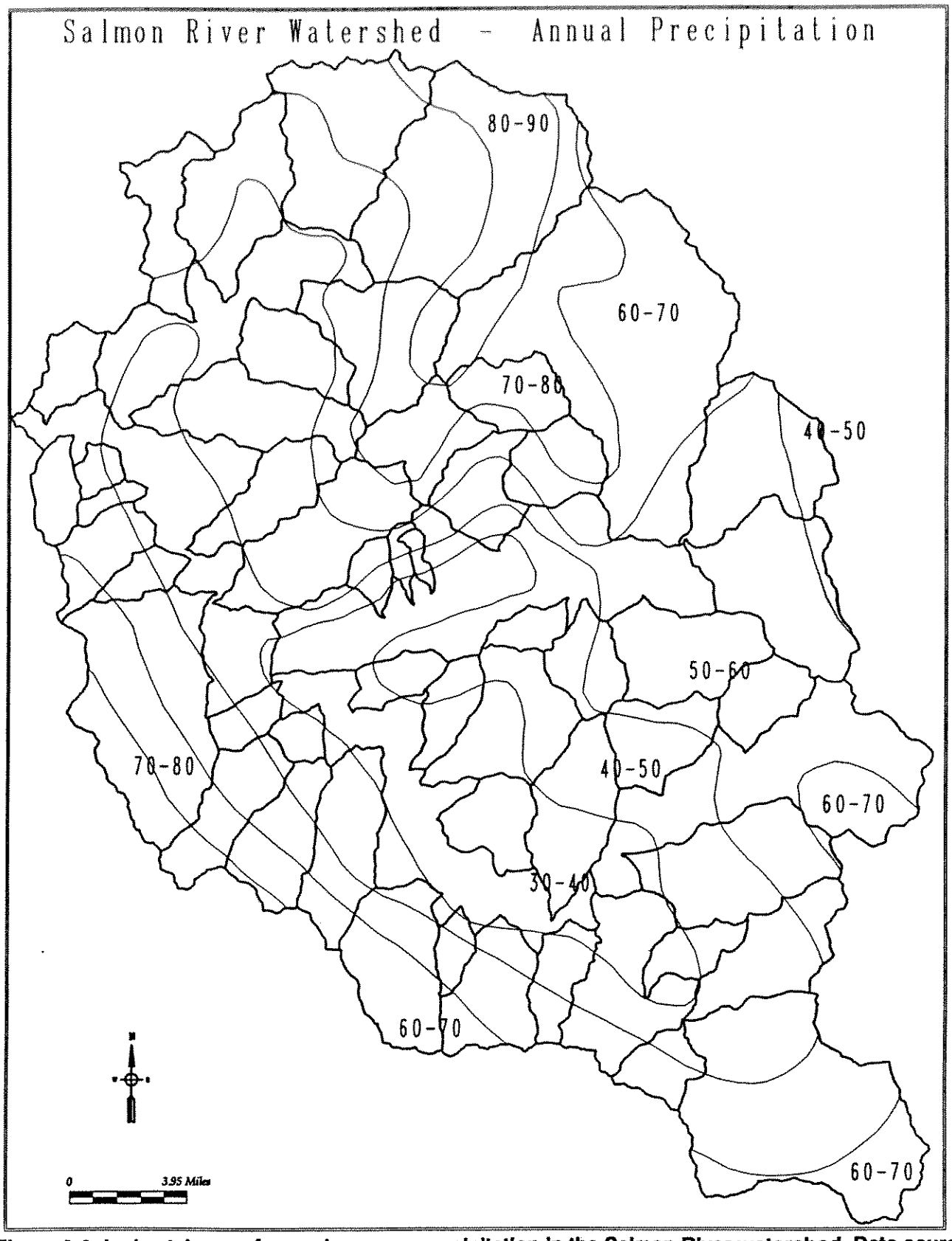


Figure 2-6. Isohyetal map of annual average precipitation in the Salmon River watershed. Data source is modified from Rantz [1968].

GEOLOGY AND GEOMORPHOLOGY

The Salmon River watershed is situated within the Klamath Mountains physiographic province, and includes three distinct rock belts. These are the Western Paleozoic and Triassic Belt, the Central Metamorphic Belt, and minor portions of the Eastern Klamath and Western Jurassic Belts [Irwin 1960]. The belts consist primarily of metasedimentary rock such as chert, argillite, and marble, metavolcanic rock, [primarily basaltic lavas], and ultramafic rock such as serpentinite and peridotite. Numerous granitic batholiths are also present, the largest of which are the Wooley Creek and the English Peak Batholiths **[Figure 2-7]**. Metamorphic rock occupies about 322,000 acres, granitic rock 143,000 acres, and ultramafic rock 15,000 acres. At various locations in the river basin, ancient terrace deposits as well as older erosional surfaces are preserved. The older river terraces occur up to several hundred feet above the present river channel and are identified by their deeply weathered, red, clayey soils. More recent terrace deposits occur near the active channel of the streams and consist of sand, gravel, and boulder deposits.

Landsliding is a dominant geomorphic process in the area. Large slump/earthflow deposits occupy much of the Western Paleozoic and Triassic Belt, particularly along Blue Ridge which forms the divide between the north and south forks of the Salmon River. Active slumps and earthflows up to 20 acres in size occur within these deposits. Debris landslides and avalanches are common in some areas, particularly in headwall areas and within the inner gorge. These landslides have devastating effects on channels and riparian vegetation. Several temporary landslide dams have formed along the Salmon River and its tributaries this century. Periods of high precipitation, seismic events, and activities which disturb the soil or the vegetation can initiate landslide activity.

SOILS

Soils in the project area exhibit physical properties which are directly related to underlying bedrock. Soils developed on metamorphic rock are typically shallow to deep, gravely loams which are deeper in areas where past landsliding has formed thick surficial deposits. Those developed on granitic rock are shallow to moderately deep, gravelly, coarse sandy loams, along with some deep gravelly loams. In areas where old erosional surfaces have been preserved, they consist of clay loams. Soils on ultramafic rock are shallow to moderately deep clay loams to gravelly loams, with local deep gravelly loams. Erosion rates under a forest cover are very low. However, when cover is removed, they rise sharply. In general, soils derived from granitic rock are the most erodible.

Soil erosion potential is closely related to detatchability. Soil detachability is the relative ease that soil is displaced by rain drop impact and splash. It is directly dependent upon soil aggregate stability. The more stable soil aggregates are, the more difficult it is for rain drops to break them apart. Soil derived from granitic parent material in the Salmon Basin have a detachability between 0.19 and 0.28, while non-granitic soils have values of 0.10 to 0.43 **[Figure 2-8]**. Coarse sandy loam soils are easily detached while those with a higher clay content have lower detachability.

VEGETATION

The Salmon River basin is primarily a forested landscape with about 90% in forest cover. The majority of the forested land [81%] is coniferous forest with 9% in hardwood forests **[Figure 2-9]**. The coniferous forests can be divided into the mixed conifer, Douglas-fir, and true fir types. There is also a small amount of knobcone pine forest type [> 1%]. The mixed conifer and Douglas-fir forest types tend to be below 6000 feet in elevation. The mixed conifer is more common. The Douglas-fir type occupies the western portion of the sub-basin while the mixed conifer occupies the eastern portion. The true fir and hemlock type is found at elevations above about 6000 feet. Other vegetation types in the sub-basin include brush lands [34,610 acres; 7%], meadow and grasslands [2,497 acres; > 1%], rocky and relatively barren areas [10,814 acres; 2%], developed areas such as town sites and agricultural fields [1,367 acres; > 1%], and lakes [357 acres].

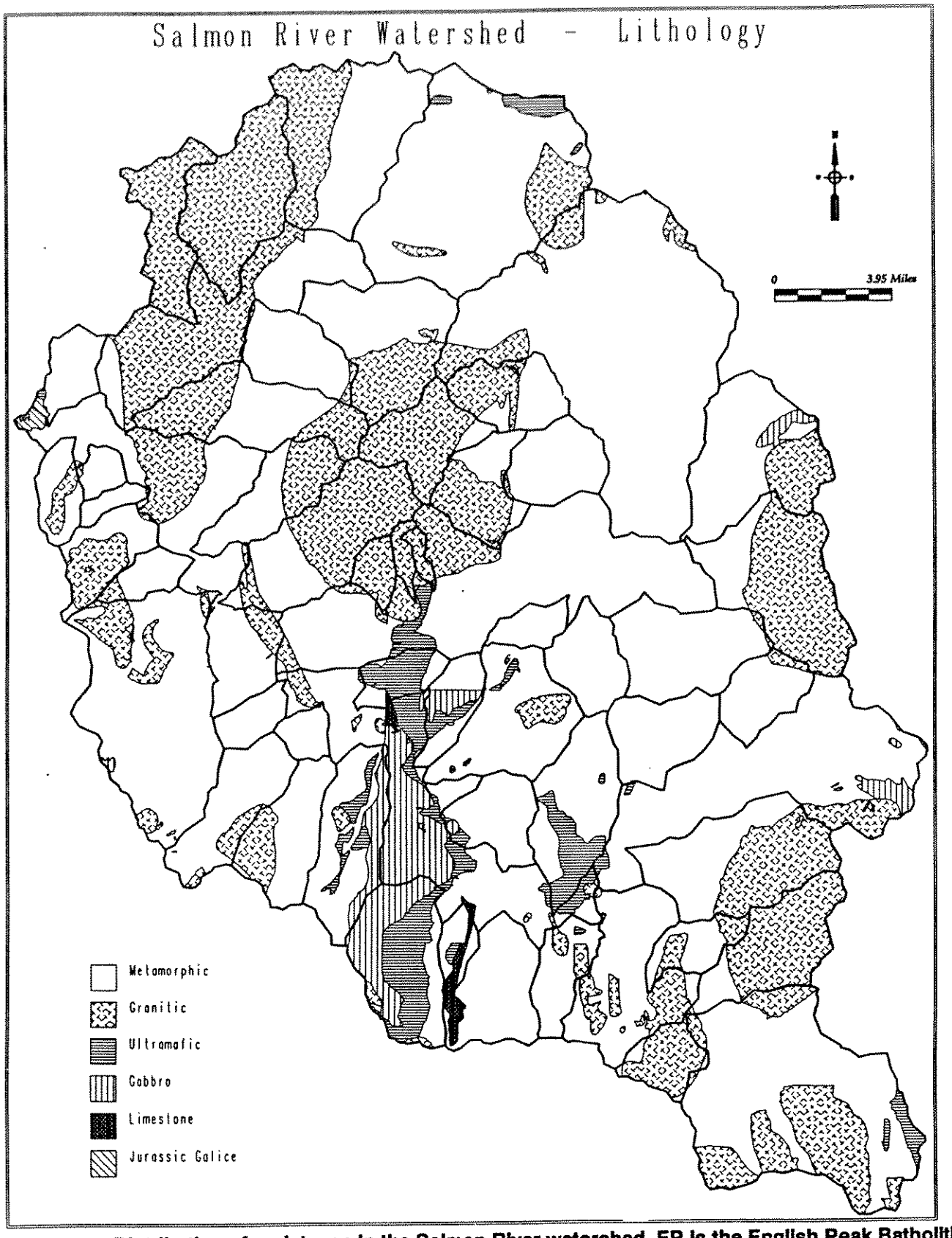


Figure 2-7. Distribution of rock types in the Salmon River watershed. EP is the English Peak Batholith, and WC is the Wooley Creek Batholith, the largest bodies of granitic rock in the watershed.

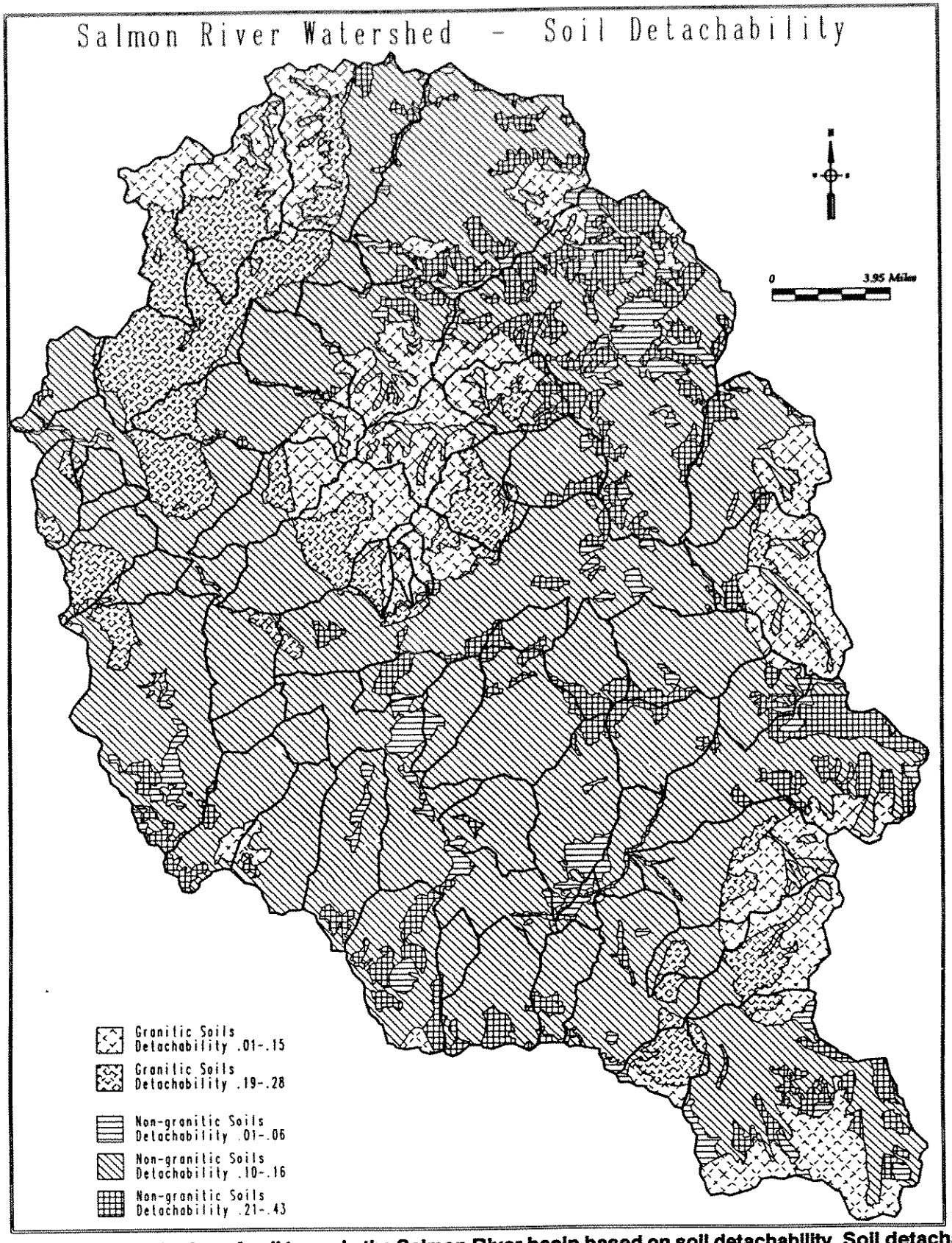


Figure 2-8. Distribution of soil types in the Salmon River basin based on soil detachability. Soil detachability is the relative ease that soil is displaced by rain drop impact and splash. Detachability is equivalent to the K-factor in the USLE. Sandy loam soils are more easily detached than soils with increasing clay content. The map shows that granitic soils with moderate detachability overlap with non-granitic soils of moderate to high detachability.

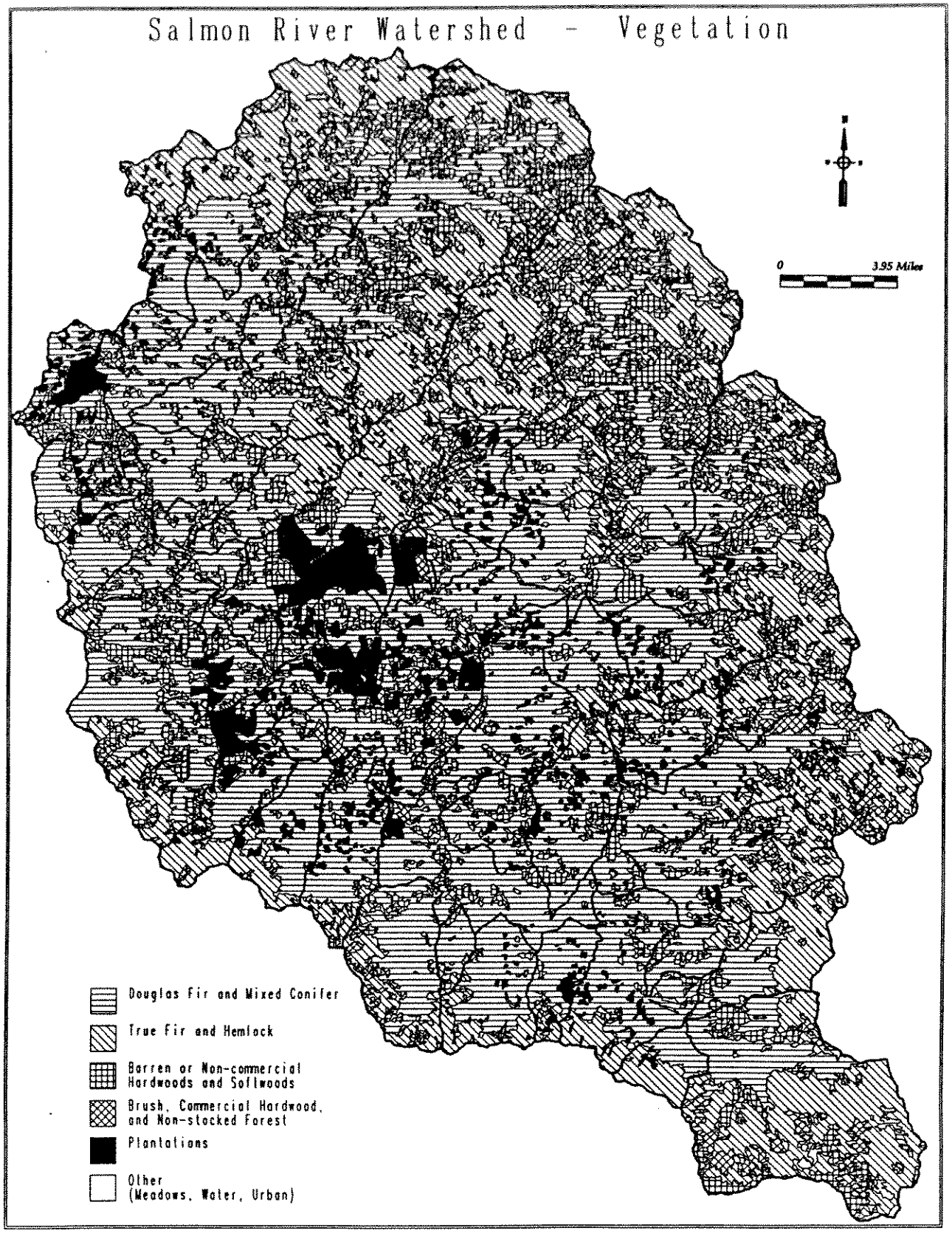


Figure 2-9. Distribution of vegetation types in the Salmon River basin.

The vegetation of the basin is dynamic over time. Based on paleobotanical studies in Northern California, the sub-basin was probably covered by a chaparral brush type, 8 to 10 thousand years ago during a warm era following the last glacial period. Since that time, the vegetation has changed to pine and oak woodland and then to more varied coniferous forests of today.

FIRE

Large fires in the watershed occurred early this century from 1911-1920, and in 1977, and 1987. Prior to establishment of the Klamath National Forest and effective fire control, there were frequent low intensity fires. Native Americans are known to have used fire as a tool to attain specific vegetative objectives in the Klamath Mountains. Low intensity fires probably occurred at 5 to 20 year intervals with an average of about 8 years. Stand replacement fires, prior to fire control, probably occurred on an average of every 150 to 200 years. That is, of the forested acres in the sub-basin, an average of 2,000 to 3,000 acres per year would burn hot enough to kill most of the trees and initiate a new stand. These fires, and the resultant stands, tended to be a few acres in size up to a few hundred acres. With the exclusion of fire, stocking and growth of conifers has increased. Stands today, on average, have more stocking than prior to fire control.

MINING

Hydraulic mining around the turn of the century disturbed approximately 1220 acres of land, primarily adjacent to the main channels of the North Fork, South Fork, and the main stem of the Salmon River below Forks of Salmon. These operations included the use of high pressure water cannons [giants] which were used to remove overburden and wash river gravels. After the gold was extracted, the mined material was discharged into the river, with the exception that large cobbles and boulders were placed in large piles, many of which persist to the present day. Some mines left residual vertical banks up to 60 feet in height. Field observations of vegetation which now covers many of the hydraulic mines indicates that the majority of the mining [in terms of area disturbed] occurred prior to 1920. However, some forms of hydraulic mining continued into the 1950's [Rock, 1992].

FISHERIES

The Salmon River basin has long been known for its exceptional fisheries resource. Anadromous salmonid habitat is extensive in the basin, distributed among tributaries of the Main Stem, Wooley Creek, North Fork and South Fork Salmon River **[Figure 2-10]**. The basin provides habitat for the largest wild run of spring chinook salmon in the entire Klamath River system; it is possibly the largest remaining wild spring chinook run left in California [West, 1991]. Endemic fish consist of both anadromous and resident species. The anadromous species include spring and fall run chinook salmon [*Oncorhynchus tshawytscha*], summer and winter run steelhead [*O. mykiss*], Coho salmon [*O. kisutch*], sea run Pacific lamprey [*Lampreta tridentata*], and sturgeon. Non-anadromous species include Klamath speckled dace [*Rhinichthys osculus Klamathensis*], Klamath small scale sucker [*Catostomus rimiculus*], and marbled sculpins [*Cottus klamathensis*]. Threespine sticklebacks [*Gasterosteus aculeatus*] may be present in the habitat, but their use of the habitat is unconfirmed. Introduced fish stocks include American shad, brown trout, and brook trout.

The chinook population is composed of two distinct races. The spring race ascends the Salmon River in late spring, holds in deep pools through the summer months, then spawns in early fall. The fall chinook ascends the Salmon River from September through November and spawns till mid December. There are also two races of steelhead present in the Salmon river basin: the summer and winter race. The summer race is composed of two runs [spring and fall], both of which exhibit a 'half-pounder' phase in their life history. Half-pounders are immature, non-spawning male and female steelhead. Half-pounders are unique to Klamath, Eel, and Rogue River systems and are fish which return to the river after only one year at sea. The spring-run steelhead enters the Salmon River and Wooley Creek in early summer, holds over in the deep pools, and spawns in early January through late February. The fall run enters the stream system later; both

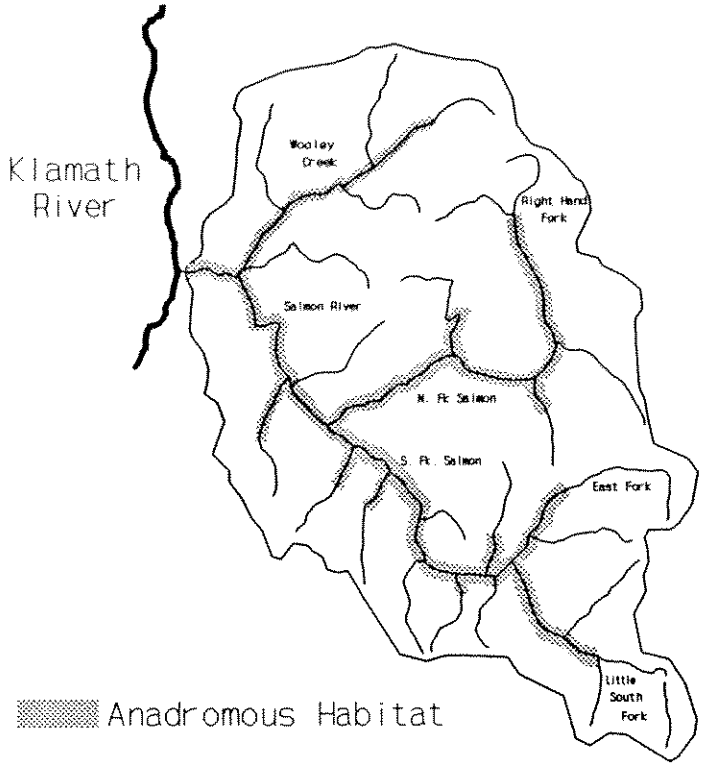


Figure 2-10. Anadromous salmonid habitat in the Salmon River watershed.

races spawn from late February through late May. Little is known about the distribution and abundance of coho salmon in the Salmon River and its tributaries.

Spring-run chinook habitat in the Salmon River is presently distributed between Wooley Creek, North Fork Salmon, South Fork Salmon, East Fork of the South Fork Salmon, and the Main Stem Salmon river. Approximately 177 km [106 miles] of habitat is typically accessible to spring-run chinook in this system. Compared to Wooley Creek, North Fork, East Fork of South Fork, and the main stem Salmon River, the South Fork consistently holds the majority of the basins' spring-run chinook spawning population. The high frequency of deep pools and relatively low level of human disturbance are in part responsible for this distribution. Wooley Creek, designated wilderness, provides habitat conditions largely unaffected by human influence. [West, 1991].

The basin has historically supported large runs of chinook salmon and steelhead trout. Although fluctuations in populations are a natural occurrence, a number of variables have contributed to a decline of spawning escapement runs to critical levels. The contributing variables include historic logging and mining practices, natural events [floods and fires], and possible over-harvest of adult fish by commercial and sport fishing [Faustini and Van de Water, 1991; West, 1991]. A dam near Sawyers Bar on the North Fork of the Salmon River prevented fish from migrating above the town until the 1950's. The chinook and steelhead are considered "Sensitive" by the U.S. Forest Service in Region 5 and have been identified as stocks at risk of extinction by the American Fisheries Society [Nehlsen, and others, 1991].

Chapter 3 - Methods, Materials and Assumptions

DATA SOURCES AND COMPILATION

This project utilized the results of previous studies as well as existing electronic data layers including: rock type; geomorphic type; soils; slope; vegetation; and 1987 fire intensity. Additional electronic data layers were developed for this study, including roads, streams, watershed boundaries, precipitation zones, elevation zones, soil detachability, and historic fire areas prior to 1987. These data layers were manipulated ultimately by the ARC/INFO geographic information system [GIS]. Active landslide databases were developed and manipulated in a relational data base. Precipitation, river discharge, and development (roads, timber harvest) and sedimentation history data were compiled and presented using spreadsheet and graphics software.

GIS DATA LAYERS

Watershed Layer

Watershed boundaries and streams were digitized from 7 1/2 minute topographic quadrangle maps. All streams shown as lines on the maps were digitized.

Digital Terrain Data

The USGS digital terrain data for 7 1/2 minute quadrangles covering the project area was used to generate an elevation zone map, and to determine the area occupied by each elevation zone. This data can be used in future landscape stratification.

Geomorphic Terrane Layer

The geomorphic terrane layer is a composite layer. That is, the attributes of rock type, slope gradient, geomorphic position [for example, mountain slope, inner gorge], and landform type [slump-earthflow deposit, debris basin], are grouped and classified into 11 geomorphic terrane types. Digital terrain data was not available when this layer was developed, and as a result, the slope information used in delineating geomorphic terranes was generated manually by use of a template on 7 1/2 minute topographic maps.

Soils Layer

Soils in the project area, mapped from an Order 3 soil resource inventory, were grouped into five classes based on parent material, detachability, and erosion hazard.

Road Layer

Roads were digitized from 1989 satellite imagery [SPOT Image Corporation, Reston, VA] at a scale of 1:24,000. The digitized lengths were multiplied by a correction factor of 1.05 in order to account for the difference between field measured length and digitized length. The area occupied by roads was obtained by assuming an average width of 40 feet to include cut, running surface, and fill. A correction factor was also applied to avoid double counting of the area where roads converge at junctions. As a result of this factor, area cannot be computed directly from length in most cases. There are about 4 acres of road per mile of length. In the GIS system, roads passing through other types of disturbance such fire or harvest, were subtracted out in order to avoid double counting of disturbed areas. Ages of roads were determined by reviewing sequential air photos, and noting the air photo on which they first appear. This process allows their age to be bracketed but not fixed to a specific year.

Vegetation Layer

The vegetation layer consists of the timber type map, and shows areas where timber has been harvested (plantations). This layer does not contain information on date of harvest, but rather, date of successful planting. The planting date is used as an indicator of harvest date, and as a result, the actual harvest date may be several years earlier than planting date. Revegetation on harvested land varies considerably from successful plantations over 20 feet in height to sparsely vegetated slopes.

Other Layers

The precipitation layer was digitized from a small scale map [1/2 inch = 1 mile] using isohyets developed for North-Coastal California [Rantz, 1968]. The extent and intensity of the Hog Fire of 1977 was mapped on color infrared aerial photos [1:10,000 scale] and the data was transferred to topographic base maps [1:15,840 scale], and then digitized. A similar process utilizing 1:15,840 color photos was used to map the fires of 1987.

SEDIMENT BUDGET DEVELOPMENT

Strategy

The strategy used in developing a sediment budget for the Salmon River involved the following three steps.

1. **Determination of Historic Sediment Production-** The volume of sediment which was delivered to the Salmon River by landslide, surface erosion, and mining during the period from 1904-1989 was determined. Quantitative estimates were developed for all sources except for channel erosion. The riparian area within channels damaged by debris torrents, and debris flows related to landsliding was evaluated. The period from 1904-1989 was selected since precipitation records begin in 1904, and the most recent air photos and satellite imagery which was readily available were from 1988 and 1989 respectively.

2. **Development of Coefficients for Predicting Future Landslide Rate-** The data acquired in determining historic sediment production described above was used to generate landslide production coefficients [cubic yards/acre] for each of the geomorphic terranes which occur in the watershed. Geomorphic terranes are defined as lands which share a common set of physical attributes and are likely to produce landslides at similar rates. Coefficients pertain to three disturbance classes; roaded, harvested or burned, and undisturbed conditions. They were designed to be representative of the effects of a climatic sequence such as that of 1965-1975, excluding the 1964 flood. These coefficients were used to predict future landslide outputs.

3. **Prediction of Future Sediment Production Rates-** Future landslide and surface erosion production was predicted for two disturbance conditions: those which existed in 1989; and undisturbed conditions. This was done in order to compare the volume of sediment which landslide and surface erosion processes are likely to produce under today's disturbance conditions to that which the watershed would produce if it were completely undisturbed. In this way, watersheds which are likely to experience accelerated landslide rates in the future due to high existing disturbance levels can be identified. Watershed restoration activities can be planned there if appropriate.

Historic Sediment Production

Historic sediment production was determined as follows: [a] landslide volume was measured by means of a basin wide air photo inventory; [b] supplemental data on landslide volume was obtained by field inventories in two sample watersheds; [c] surface erosion volume was estimated by means of the Universal

Soil Loss Equation [USLE]; and [d] channel erosion and sediment associated with mining were assessed by means of the basin wide air photo inventory.

Basin-wide Air Photo Inventory

A sequence of air photos covering the entire basin was examined, and all identifiable active landslides were mapped on 7 1/2 minute topographic quadrangles. Air photos included *1944* black & white, 1:20,000, *1955* black & white, 1:20,000, *1964* black & white, 1:15,840, *1965* black & white, 1:20,000, *1975* color, 1:15,840, and *1988* color infrared, 1:40,000 [partial]. **Table 3-1** lists all photos used in this study.

Table 3-1. Aerial photography used in the Salmon Basin Sediment Analysis Study.

Year	Agency	Type	Symbol/ID#	Scale
1944 a,b,c	U.S. Forest Service	B&W	DDD	1:20,000
1955 a,b,c	U.S. Forest Service & Calf. Div. of Highways	B&W	DDC	1:20,000
1964 a,b,c	U.S. Forest Service	B&W	ENU	1:15,840
1965 a,b,c	Soil Conservation Service	B&W	DDC	1:20,000
1971 a,b,c	U.S Forest Service	Color	EXW	1:15,840
1972 b	U.S. Forest Service	Color	K102	1:10,000
1975 a,b,c	U.S. Forest Service	Color	KL-05	1:15,840
1977 e	U.S. Forest Service	CIR		1:10,000
1980 a,b,c	U.S. Forest Service	Color	625050	1:12,000
1982 c	U.S. Forest Service Special flight Hog Fire	Color	615054	1:15,840
1983 d	USGS (Hap83)	CIR	412207	1:58,000
1986 a,b,c	U.S. Forest Service	Color	615050	1:15,840
1987 f	U.S. Forest Service	Color	755180	1:16,000
1988 a,b,c	U.S. Forest Service	CIR	715160	1:15,840
1988 a	U.S. Forest Service	CIR	725181	1:40,000

a photos used in basin-wide aerial photo inventory
b photos used in Little North Fork landslide inventory
c photos used in Negro Creek landslide inventory
d photos used in delineating geomorphic terranes
e photos used to map Hog fire fire intensity
f photos used to map 1987 fire intensity

Landslides smaller than 30 feet in either length or width were not mapped. At the scales of most of the photos, 30 feet is approximately equal to the width of a pencil line. The only slides of this size which are easily seen are those which occur in open areas or brush fields, and where the landslide has removed all vegetation. Landslides of that size under a timber canopy usually cannot be seen. Landslides were mapped on air photos and transferred directly to 1:24,000 topographic maps, with the assistance of orthophoto maps. Width measurements were made directly on photos in some cases [after determining photo scale at that elevation] and on maps after transfer in others. Lengths were measured by use of the topographic maps and orthophotos. Delivery ratios were photo interpreted for all landslides. Previous field experience in the watershed facilitated this interpretation. Errors in delivery ratio are expected to be largest for slumps and earthflows, and smallest for debris slides. A small sample of field measurements were compared to measurements from the photo inventory. The landslide data base can be easily refined as more field measurements are made in the future.

The vast majority of landslides mapped are debris slides. Debris slides typically remove all vegetation, making them easy to see on air photos. Slumps and earthflows identified as active by previous field studies were not included unless it was clearly evident on air photos that they were active. The photo inventory was most effective at identifying debris slides over an acre in size. The potential for missing landslides is greatest within forested slump and earthflow deposits where a continuous forest cover makes determination of activity level nearly impossible. Failure to identify active slumps which have not delivered sediment to the stream system would not adversely affect the results of the inventory since its focus is on delivered volume. Previous field observations indicate that most of the earthflows and slumps which contribute significant volumes of sediment to the stream system have debris slide components at the toe which are usually visible on air photos.

Landslides which were identified on air photos along pre-existing roads or timber harvest units were assumed to be associated with those disturbances. Positive cause/effect relationships were not established. Other features mapped included disturbed riparian areas along stream channels, areas burned in wildfires [prior to 1977], and hydraulic as well as open pit mines. Landslides were dated by noting the photo year in which they first appeared. This method allows assigning a time interval to a landslide rather than a specific year. Landslides associated with the 1964 flood are an exception, since photos taken in 1964 and 1964 allow identification of the exact year of occurrence. Enlargements of the landslides were noted on successive photographs.

Field Inventories

Field inventories were conducted in the Little North Fork of the Salmon River, and Negro Creek. The purpose of these inventories was to obtain a sample of detailed information in order to test the reliability of the basin-wide inventory. Landslide volumes in these tributaries were determined by a combination of air photo and field methods. At Little North Fork 373 landslides were measured [including an earlier inventory in 1976], with 48% measured in the field and 52% measured by air photo techniques. At Negro Creek, 119 landslides were inventoried, and all were measured in the field. Areas representative of the range of geomorphic characteristics in the watershed were chosen for these inventories. The Little North Fork consists of about half metamorphic and half granitic bedrock, and soils are shallow to moderately deep. Parts of the granitic land were landslide-prone, whereas most of the metamorphic land produced produced few landslides. Negro Creek consists almost entirely of slump and earthflow deposits, and contains metavolcanic, metasedimentary, and ultramafic rock.

Methods for interpretation and measurement of landslides on air photos were similar to those used in the basin-wide inventory. For each landslide inventoried in the field, length, width, and depth was measured, to determine landslide area, and the volume of material mobilized, delivered to the channel or stored on the slide site. Other data was collected on landslide attributes, such as slope steepness, aspect, disturbance class, [undisturbed, harvest, fire, and roads] bedrock type, type of failed material [including particle size

distribution], and geomorphic terrane type. The age of the landslide was estimated in the field and bracketed by year of first appearance on air photos.

Surface Erosion

Surface erosion was estimated by means of the Universal Soil Loss Equation [USLE] for undisturbed conditions and for disturbance levels in existence during the following years: 1986-1987, 1987-1988, and 1992-1993. These periods were selected in order to display erosion rates immediately before and after the fires of 1987, and to display the reduction which is likely to occur in the years following the fire. It utilized cover factors and a rainfall factor from Dissmeyer and Foster [1984], adjusted for local conditions . The USLE is an erosion model designed to predict the long term average soil loss from specific soils with specific site characteristics. This model computes soil loss for a given site as the product of six factors whose values for a specific site can be expressed numerically.

The soil loss equation is: A=RKLSCD. Variables in the equation are described below.

A is the computed soil loss per unit area. Tons/acre/year or cubic yards/acre/year are used as the per unit area. Tons/acre have been converted to yd^3/acre by using two factors, 0.71 for sandy loam textures and 0.81 for loam textures.

R is the rainfall and runoff factor, expressed as the number of the rainfall erosion index units.

K is the soil erodibility factor, expressed as the soil loss rate per erosion index unit for a specified soil.

L is the slope-length factor, expressed as the ratio of soil lost from a given field slope length to that from a length of 72.6 feet under identical conditions.

S is the slope-steepness factor, expressed as the ratio of soil lost from the field slope gradient to that from a 9 percent slope under otherwise identical conditions.

C is the cover factor, which is the ratio of soil lost from an area with specified cover and management to that from an identical area in tilled continuous fallow.

D is the delivery factor, which is the percentage of eroded surface soil that is delivered to a perennial or intermittent channel.

Calculated erosion values are compared to data from numerous erosion plots within the Salmon River watershed. These plots have been in place from 4 to 9 years. Erosion plot data within a USLE project area can be used as a check on the relative accuracy of the USLE values.

R Factor

A 2 year, 6 hour precipitation value of 1.34 inches from the Sawyers Bar Ranger Station within the project area was used [California Department of Water Resources, 1981] rather than more generalized isopluvial maps. This calculates an R value of 19.4. This R-value better represents the low intensity storms that dominate the precipitation events in this area of the Klamath Mountains.

In addition, two storm events were modeled to show potential sediment yields based on 1987-88 site conditions. Storms similar to what occurred in 1972 [25-year storm] and 1964 [100-year storm] were selected for modeling. The R-values used for these storms were calculated from 6 hour precipitation data from the Sawyers Bar Ranger Station data set [California Department of Water Resources, 1981]. The 25 year, 6 hour and 100 year 6 hour precipitation values were 2.46 inches and 2.97 inches respectively.

K Factor

The soil erodibility factor for each soil group was taken from the table of interpretations of the Order 3 Soil Survey of the Klamath National Forest [Foster and Lane, 1986]. K values were calculated from the Wischmeier Nomograph [Wischmeier and Smith, 1978]. The 64 soil map units within the project area were combined into 5 soil groups based upon their K-factor values. This was done to make the GIS data more manageable. K values for sandy loam soils [granitic parent material] were 0.18 and 0.24. K values for loam soils [metamorphic and ultrabasic parent materials] were 0.06, 0.11 and 0.24.

L and S Factors

The topographic factors, L [slope length] and S [slope length] affect the rate of soil erosion. These two factors are combined into a single topographic factor, LS. LS values were obtained from Table 3.2-4 of Curtis and others, [1977]. A slope length of 10 feet was uniformly used for the slope length factor over the Salmon River watershed project area. The comparison of local erosion plot data using a 10 foot slope length value for the USLE calculations indicates that a 10 foot slope length is reasonable. Slope groups used for calculating erosion were 0-35 percent, 36-65 percent and greater than 65 percent.

C Factor

The C factor, or the cover-management factor, is based upon Dissmeyer and Foster's [1984] cover factors for forested conditions. They identified the amount of bare soil, canopy, organic matter content, fine roots, residual binding effect, on-site storage, and steps as factors relating to surface erosion. These are applicable to conditions in the project area.

Six disturbance groups were used in this project. They are: undisturbed, 1987 wildfire, 1987 reburn of the Hog fire, plantations, Hog fire not reburned, and roads. These six groups were further subdivided into 225 unique vegetation, soil, slope, and landform classes.

D Factor

An index approach was used to provide a relative estimate of the sediment delivery ratios. This method evaluated 7 environmental factors and one site specific factor [Warrington, 1980]. This indexing method has not been validated by research [Warrington, 1980]. This methodology provides a relative estimate of the sediment delivery ratio for a given area. The eight factors used for estimating sediment delivery are: transporting agent, soil texture, percent ground cover, slope shape, slope gradient, delivery distance, surface roughness and a site specific factor [Warrington, 1980].

Sediment delivery ratios for each slope class [0-35%, 35-65%, >65%], geomorphic position [sideslope or inner gorge], parent material [granitic and non-granitic] and forest conditions [undisturbed, 1987 fires, roads, plantations, Hog fire and area of Hog fire that reburned in 1987].

Channel Erosion

Channel erosion involves the mobilization of soil, rock and organic debris from the channel bottom and wall which was delivered there previously by landslide, surface erosion, and other processes. Channel erosion was not investigated in the same detail as landslide and soil surface erosion. The basin-wide photo inventory allowed mapping of channels where vegetation was removed or damaged by flood or debris flows during various time periods. This can occur as a result of scour or aggradation, and often involves both processes. The majority of disturbed channels observed on the basin-wide air photo survey were associated with debris slides which originated on steep mountain slopes, in headwall areas, and on inner gorge slopes adjacent to streams. However, channel erosion was also observed in some streams lacking obvious debris slide initiation sites. This is particularly true along the Salmon river and some major tributaries. Where raw

slopes and areas of disturbed riparian vegetation were identified in the inner gorge, field observations revealed that the disturbance was usually the result of multiple processes, including landsliding, surface erosion, and channel erosion.

As part of the landslide inventory process, the length and width of disturbed channel areas below landslides was recorded and the percent scour was estimated based on photo observations and steepness of slope. Other disturbed stream channels without obvious landslide initiation sites, such as the main river segments, were mapped, and the year of disturbance was identified but quantitative measurements were not taken. The data collected by this study provides a means of comparing the area of channel disturbance between sub-watersheds, but does not provide quantitative information on sediment volumes.

Mining-Related Sediment

An estimate of the volume of sediment introduced into the river by mining during the hydraulic mining era [1870's-1950's] was obtained by mapping all of the hydraulic mines visible on air photos, determining their area, and estimating the average thickness of mined material. The mining activity consisted of extensive workings on elevated terraces using giants [high pressure water cannon] resulting in residual banks [nearly vertical] up to 60 feet in height, as well as smaller scale washing of more recent terrace material and alluvium near the present river channel. Mapping was done primarily on 1944 and 1955 air photos since they are the oldest photos and post-mining vegetation obscures less of the mined area. The depth estimate is based on field observations of mined areas in all of the main tributaries of the Salmon River [North Fork, South Fork, Main Stem], and on air photo observations of mines which are well-exposed. These observations indicated that most of the mine workings were at least 8 feet deep, and this figure was used as a basin average. This is considered to be conservative so that the actual volume may be much higher than reported here, but is is very unlikely to be lower. For example, the Catholic Church at Sawyers Bar, built in the 1850's, sits on a small knoll which was created when all the surrounding land was washed away by hydraulic mining [Rock, 1992]. The knob is about 30 feet higher than the surrounding ground. These estimates do not account for residual boulder piles which were left atop bedrock strath terraces along much of the river.

Development of Coefficients for Predicting Future Landslide Rates

Landslide coefficients were developed by stratifying the landscape into areas of similar landslide potential [geomorphic terranes], and then using the results of the basin-wide photo study to determine the rate at which these terranes produced landslides during intervals between photos taken in 1944, 1955, 1964, 1965, 1975, and 1988.

The landscape stratification process is described below. Landslide rates were computed for three disturbance classes for each terrane [undisturbed, harvested/fire, roaded]. A GIS was used to determine the number of acres in each disturbance class for each terrane during each air photo interval. Through this process, landslide production coefficients [yd^3/acre] were developed for each of the air photo intervals. The climatic episode of 1965-1975 [excluding the 1964 flood] was then selected as the reference period to model future landslide production. This specific climatic episode was selected for two primary reasons. First, the period 1965-1975 represents a moderately severe series of storm years, yet has a high likelihood of occurring during any 25 or 50 year time interval. The 1964 flood is a rare event,which has been characterized as having a probable return interval of slightly more than 100 years in the Salmon basin [U.S. Geological Survey, 1988, Water-Data Reports for California; Waananen and Crippen, 1977]. Second, a sufficient amount of timber harvest and road construction had occurred in all geomorphic terrane types by then, so that changes in landslide production associated with these disturbances could be evaluated. This was not the case for earlier photo intervals, since not much harvested land or roads existed then.

Landscape Stratification

A stratification scheme was developed which classifies lands according to landslide potential. Criteria for delineating these lands was influenced by the availability of data, and the ease of identification of features on air photos. These lands are referred to as geomorphic terranes. A geomorphic terrane is defined as a land type which shares a set of common physical attributes such as steepness of slope, soil type, bedrock type, and structure, as well as landform and geomorphic processes. Due to the presence of these commonly held attributes, slope hydrology and slope processes are relatively uniform within a geomorphic terrane type. Consequently, landslide production rates within a given type are likely to be very similar.

Five general geomorphic terranes were defined. These are: Mountain Slopes; Debris Basins [Headwalls]; Inner Gorges; Slump/Earthflow Deposits; and Glacial, Terrace and Fan Deposits. These general types are further subdivided into 11 specific geomorphic terrane types according to rock type, slope gradient, and geomorphic setting **[Table 3-2]**.

Table 3-2. Geomorphic terrane descriptions.

General Geomorphic Terranes	*Specific Geomorphic Terranes*	*Terrane No.*
MOUNTAIN SLOPES	Granitic Mt. Slopes > 65% Slope Granitic Mt. Slopes 0-65% Slope Non-Granitic Mt. Slopes > 65% Slope Non-Granitic Mt. Slopes 0-65% Slope	4 5 6 8
DEBRIS BASINS [HEADWALLS]	Debris Basins [Headwalls]	12
INNER GORGE	Inner Gorge Developed in Granitic Bedrock & Mountain Slopes Inner Gorge Developed in Non-granitic Bedrock & Mountain Slopes Inner Gorge Developed in Landslide, Glacial or Terrace Deposits	10 11 9
SLUMP/EARTHFLOW DEPOSITS	Slump/Earthflow Deposits Slump/Earthflow Toe Zones	3 2
GLACIAL, TERRACE & FAN DEPOSITS	Glacial, Terrace, & Fan Deposits	13

Some of the terranes consist of more than one geomorphic type [for example, Terrane #13, Table 3-2]. This grouping was done to limit the number of terrane types and thereby reduce the complexity of the model. These geomorphic units as well as active landslides were uniformly mapped throughout the Salmon River watershed on 1983 color infrared photography [1:58,000 scale]. Previously collected data on active landslides on the Klamath National Forest was incorporated into the geomorphic data layer.

Coefficient Development

The landslide coefficients developed in this study are an area-weighted average across the entire Salmon River watershed. The coefficient for a particular geomorphic terrane and disturbance class is calculated by dividing the total volume of sediment delivered by landslides by the total number of acres of the terrane in each disturbance class present during the time period of interest. Landslide coefficients for sub-watersheds vary widely from basin averages. For example, the granitic inner gorge in Little North Fork produced land-

slides at a rate of 14 yds³/acre under undisturbed conditions from 1965-1975. The coefficient developed from the basin-wide survey for granitic inner gorges is only 7 yds³/acre. This difference is due to the fact that some granitic inner gorges, such as those within Blindhorse Creek watershed, produced no observable landslides during that time. Thus, application of the area-weighted basin average to predict future response at Little North Fork results in a value smaller than the volume measured by the basin wide photo inventory. Application of the basin average to the Blindhorse Creek watershed yields a volume higher than the measured volume.

The landslide production coefficients developed from the basin-wide air photo survey for the photo interval 1965-1975 were used as the final values with minor adjustments on a few. The adjustments were made to account for higher landslide volumes measured in the sample watersheds by field inventories relative to those measured by the air photo inventory. These adjustments were very small [most were less than 1% with a maximum of 15%] such that the final values are nearly equal to the coefficients computed directly from the basin-wide air photo inventory.

Prediction of Future Landslide Sediment Production Rates

Landslide volumes for a future climatic sequence like that of 1965-1975 [excluding the 1964 flood] were determined by applying the final landslide coefficients to the geomorphic terranes and accounting for the area [acres] in each disturbance class. This was done by a GIS system which overlaid the appropriate layers. For example, the calculation of landslide production for terrane #3 [slump/earthflow deposits] predicted for 1989 disturbance conditions is illustrated below.

Geomorphic Terrane	Disturbance Class	Acres	Coefficient [yds³/acre]	1989 Predicted Landslide Volume Delivered [yds³]
#3 Slump/earthflow	1987 fire	5,644	3.22	18,173
	1977 fire	4,029	3.22	12,973
	Old Clearcuts	1,509	2.99	4,510
	New Clearcuts	1,525	3.22	4,912
	Roads	695	225	156,500
	Undisturbed	18,786	2.76	51,849
Total, 1989 Conditions		32,188		248,917

Notes: 1989 Predicted Landslide Volume is calculated by multplying Acres by the Coefficient for each Disturbance Class. Acres equal the the total area present in each disturbance class as of 1989. Coefficients used are those developed from the basin-wide air photo study for the 1965-1975 period.

Computations were made for two disturbance conditions, 1989 disturbance, and undisturbed conditions. Coefficients for land clearcut before 1975 [old clearcuts] were lowered in order to account for vegetative regrowth. It was assumed that the accelerated landslide risk on these lands had recovered halfway to pre-logging levels. In the example given above, the coefficient for new clearcuts is 3.22 yd³/acre compared to 2.76 yd³/acre for undisturbed land. The acceleration due to harvest is 0.46, [3.22 - 2.76]. This acceleration is assumed to have recovered by half 0.46 ÷ 2 = 0.23. Thus, the coefficient for old clearcuts is the undisturbed rate 2.76 plus the remaining harvest effect [0.23] which equals 2.99.

Roads were assumed to permanently alter landslide potential and not recover over time. Therefore, the landslide production for old roads was assumed to be the same as that for new roads.

Determination of Flood History of the Salmon River

Flood history and the effects of floods was assessed by reviewing flow records and historical accounts, and conducting a sequential air photo review of channel condition. Air photos taken in 1944, 1955, 1964, 1965, 1975, and 1988 were examined.

Determination of Sediment Production/Fish Habitat Relationships

Landslide production determined by the air photo and field inventories and surface erosion predicted by the USLE were compared to fish habitat inventory data in order to identify possible relationships. The elements of the habitat data that were compared include substrate composition [% fines, % gravel, % boulders, and % bedrock], number of primary pools, embeddedness, and % riparian shade. The purpose of this comparison was to discover possible links and correlations between sediment production from landslides and stream channel attributes measured in fish habitat surveys. The fish habitat inventories predate this study, and were developed independently, so that they were not designed specifically for comparison to sedimentation rates.

Fish Habitat Data Summary

Fish habitat data was compiled from 25 surveyed stream reach areas in the Salmon River watershed. The stream reach areas are within the 12 anadromous streams listed below:

Black Bear Creek	Negro Creek
Cecil Creek	North Fork Salmon
Indian Creek	Nordheimer Creek
Little North Fork	North Russian Creek
Main Stem Salmon River	South Fork Salmon River
Methodist Creek	Specimen Gulch

The habitat types within the surveyed streams were grouped into primary habitat groups of Pools, Riffles, and Runs. Within the three primary habitat groups, values of the habitat attributes measured by the stream surveys were averaged. For example, in Black Bear Creek, the average percent fines for 110 measured Pool habitat types was 30%.

Habitat attributes used as dependent variables in the analysis include: percent embeddedness, substrate composition [percent fines, gravel, cobbles, boulders, and bedrock], percent shade and number of primary pools. The average values were compared with sediment yield variables in the same watershed.

Landslide Data Summary

The landslide data used to compare with habitat attributes was from the basin-wide air photo inventory. The surface erosion data was from the final surface erosion model. Sediment-related attributes used as independent variables in the analysis included: landslide production all years [1944-1988]; landslide production 1975-1988; current annual surface erosion at 1988 conditions; total acres of landslide, and total acres of granitic lands. Sediment production values used for comparison are area-weighted, basin sediment production rates, reported in units of yd^3/acre, and total sediment yield, reported as yd^3.

Assumptions in the Landslide and Surface Erosion Models

Assumptions guiding the development and use of the landslide sediment model are detailed below.

1. Future storms will produce landslides at rates similar to past storms.

   As future storms occur, it is reasonable to expect that groundwater conditions will be affected in ways similar to those of past landslide-producing storms. At least two counteracting effects of successive storms are known: [a] a severe storm may trigger most of the potential debris slide sites in a particular area, such that storms of similar magnitude in the future trigger fewer new debris landslides; and [b] a series of storms may activate large earthflows during one year, making them prone to acceleration during subsequent years even if precipitation is lower than the triggering event.

2. Recovery of logged and burned land is essentially complete after 50 years.

   Timber harvest affects slope hydrology and mechanical characteristics of the soil [root support]. Studies indicate that root support drops to its lowest level about seven years after harvest, and recovers to pre-harvest levels by about 20 years after harvest [Ziemer, 1981]. However, effects on slope hydrology may be greatest the first year after harvest. The rate of return to pre-harvest hydrologic conditions depends on the rate of revegetation. It also depends on the characteristics of the vegetation which is harvested. For example, harvesting a dense stand of 300 year old conifers is likely to have a very different effect on the hydrology of the site than harvesting a sparse stand of conifers in a brush field. Some sites may revegetate rapidly, returning the site to pre-harvest hydrologic conditions in 20 to 30 years, whereas in others it may take more than 100 years. This study assumed that on average, the destabilizing effects [mechanical and hydrologic] of timber harvest are recovered by 50% 20 years after harvest. Recovery is 100% at 50 years after harvest.

3. Roads increase landslide potential in a way which recovers little over time.

   Roads are essentially permanent modifications of the landscape which change slope hydrology, and the distribution of mass [soil and rock] on the slope. Vegetation of cuts and fill over time has a stabilizing effect, but the modification of hydrology and mass distribution are permanent. Thus a recovery factor is not built into roads.

Assumptions guiding the surface erosion model are detailed below.

1. The Order 3 soil layer identifies soil groups which exhibit similar erosion rates.

   The Order 3 survey is designed for basin level assessment as is done here, and identifies the broad soil groups most prone to surface erosion.

2. The USLE can be adjusted to make reasonable predictions of surface erosion in mountainous terrain.

   USLE factors have been modified to reflect local conditions. For example, the choice of a rainfall factor [R-factor] reflects local conditions. Also, local erosion plot data was considered in developing erosion factors.

Chapter 4 - Watershed Disturbances: Results and Analysis

SUMMARY OF WATERSHED DISTURBANCES

In 1975, the disturbed area in the Salmon River watershed consisted of 7,962 acres of timber harvest, 2,893 acres of road, and 1,220 acres of hydraulic mine areas, totalling 12,055 acres. This amounts to 2.5% of the watershed area. Following the fires of 1977 and 1987, the total disturbed area increased to 89,721 acres, or 18.7% of the watershed. Areas of low intensity fire are not included. This includes 72,078 acres of fire, 12,784 acres of harvest outside of burned areas, 3,639 acres of road, and 1,220 acres of hydraulic mined area. Included in the acres of fire are 18,000 acres of land that was salvaged logged and replanted to conifers. Substantial revegetation has occurred on the land harvested prior to 1975, [about 7,500 acres], since these plantations are now from 18-30 years old. Similarly, some of the hydraulic mines have revegated, especially where exposed slopes were not excessively steep or rocky.

MINING

Hydraulic mining of the main river valleys occurred from about 1870 to 1950, and involved approximately 1220 acres of land. Preliminary estimates of volume indicate that approximately 15.8 million cubic yards of sediment were discharged into the river during this time, and major channel modification occurred in many areas, particularly along the upper South Fork of the Salmon River.

ROADS

Road construction began in the early 1900's and by 1944, about 188 miles of road were present. By 1989, the miles of road had increased to 762 miles or 3,639 acres **[Figures 4-1, 4-2]**.

TIMBER HARVEST

The earliest timber harvest occurred in conjunction with mining and homestead activity. Clearcutting of mature timber stands on public land did not begin until the 1950's. By 1974, there were about 7,500 acres of harvested public land in the watershed, and by 1989, there were about 30,000 acres **[Figures 4-3, 4-4]**. The 1989 figures include about 18,000 acres of harvested land burned by the fires of 1977 and 1987.

FIRE

Large fires involving about 70,000 acres of land occurred early this century [1917 and 1918], **[Figure 4-5]**. No data are available on the intensity of these fires. From 1919 to 1976 the area burned was small, with only two fires larger than 5,000 acres, **[Figure 4-5]**. One of these fires fires occurred in the East Fork of the Salmon River (near Six Mile Creek) in 1955, involving about 5200 acres. A considerable amount of the fire burned at high and moderate intensity, but mapping by intensity class was not available. The other fire was the Off Fire (1973) which burned about 9,000 acres near the mouth of the Salmon River watershed, including parts of Wooley Creek and Merrill Creek. A large proportion of this fire also burned at high and moderate intensity. Intensity mapping was not available for this study. In 1977, the Hog Fire burned 57,489 acres, **[Figure 4-6]**, and the fires of 1987 burned 102,369 acres **[Figure 4-7]**. A histogram plot of the area burned per year over the 1911-1989 period is shown in **Figure 4-8**; a plot of cumulative area burned appears in **Figure 4-9**.

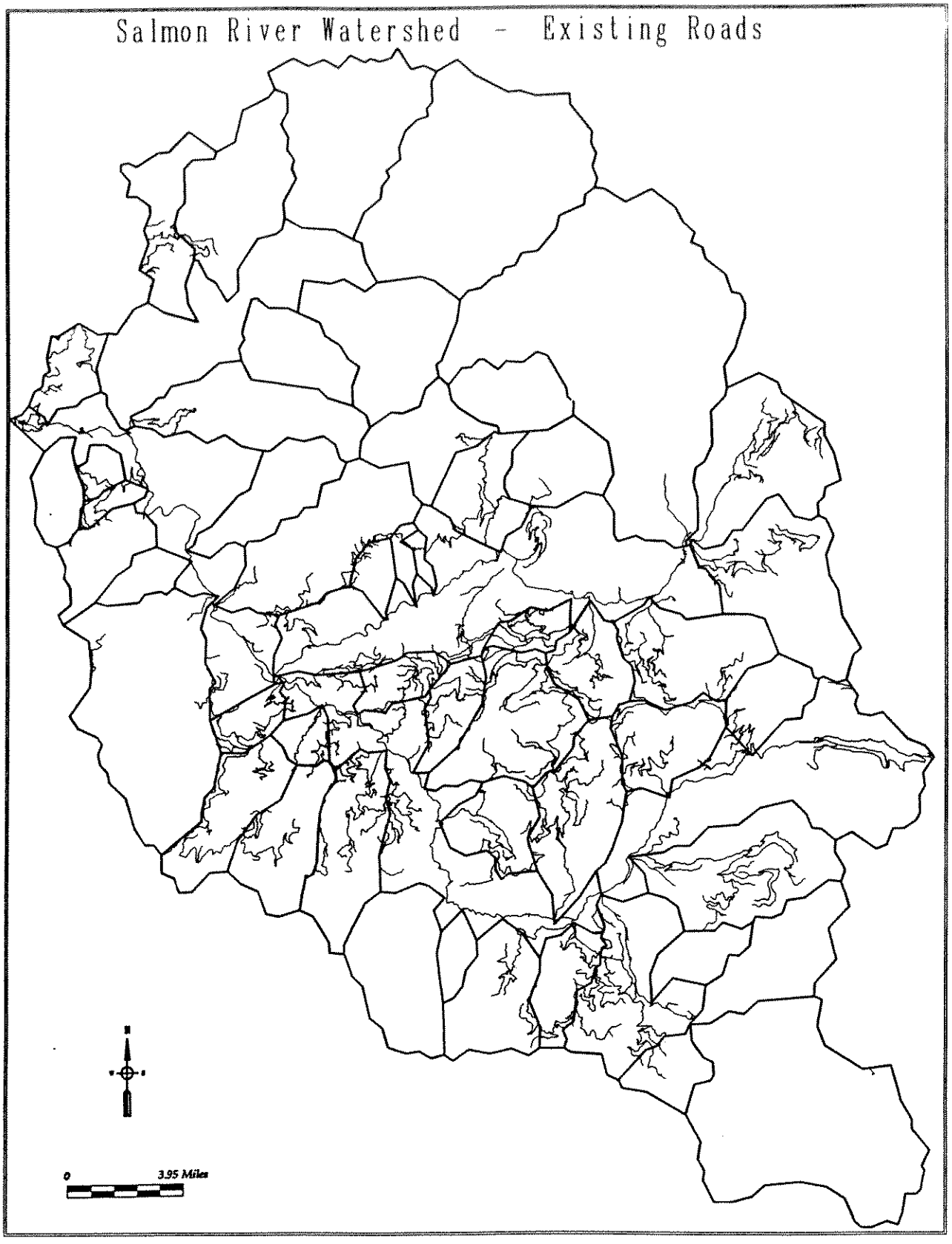


Figure 4-1. Existing roads as of 1989, in the Salmon River watershed.

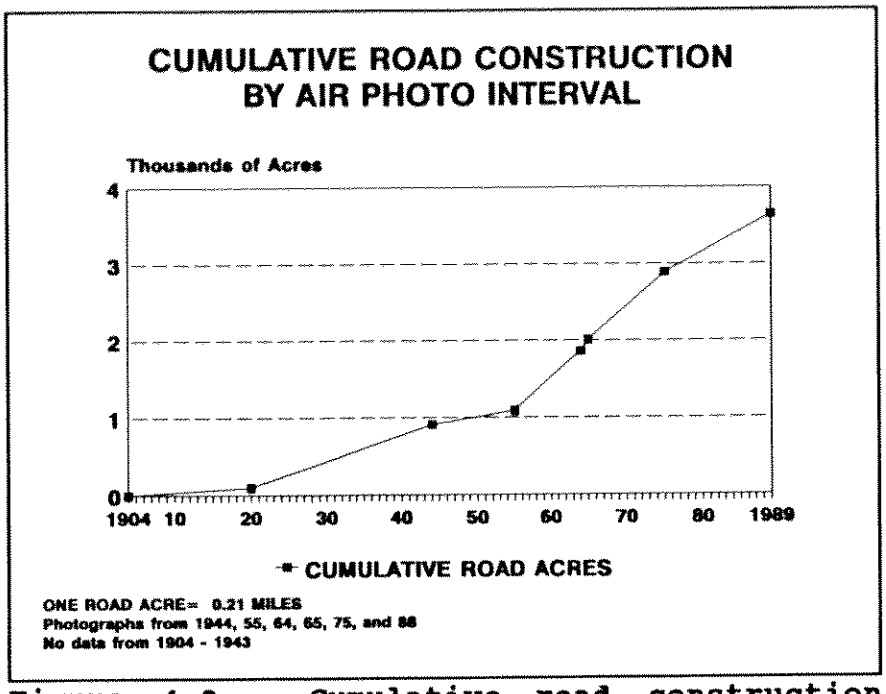


Figure 4-2. Cumulative road construction acres by air photo interval, 1904-1989.

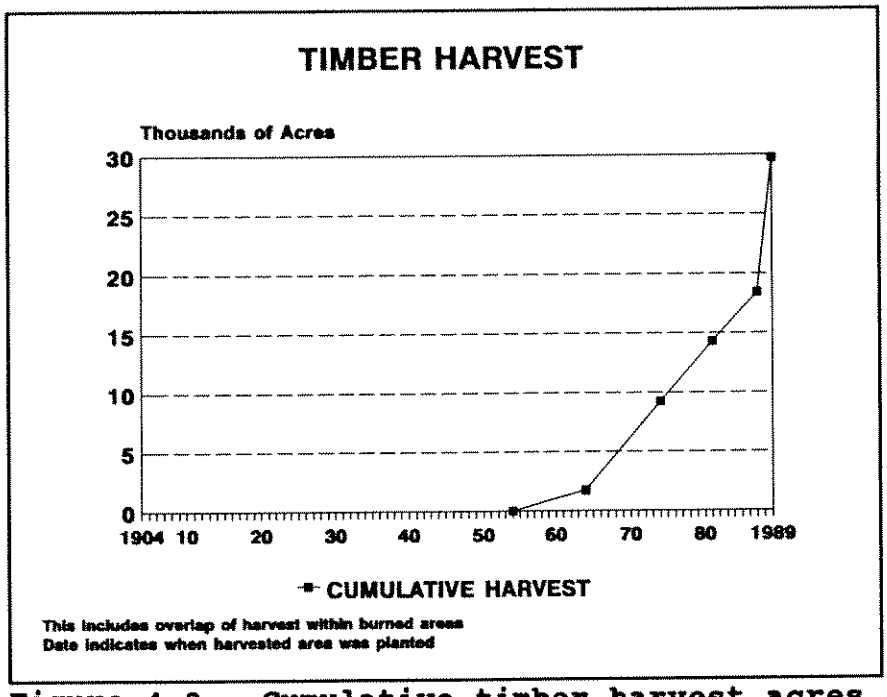


Figure 4-3. Cumulative timber harvest acres, 1904-1989.

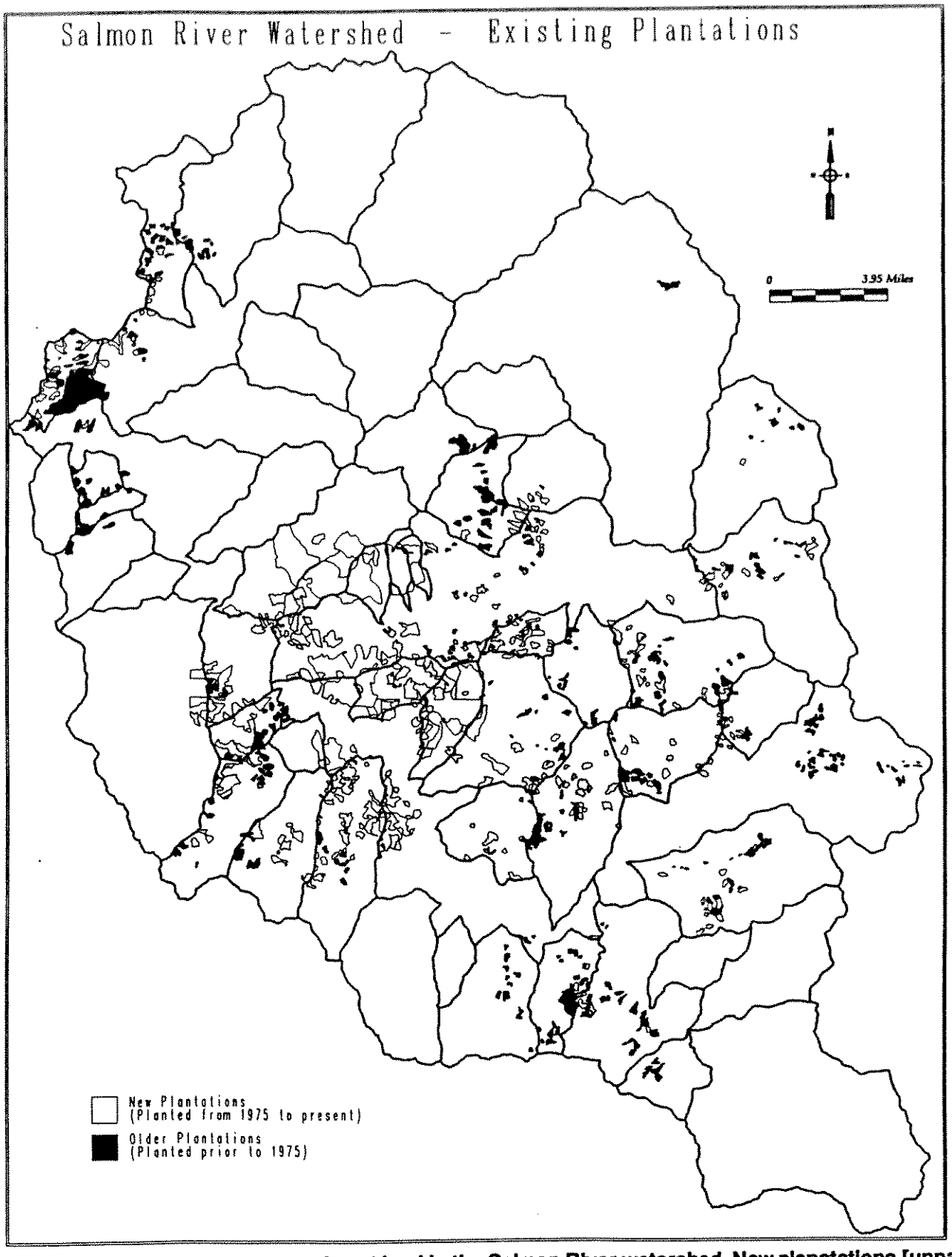


Figure 4-4. Existing plantations on forest land in the Salmon River watershed. New planatations [unpatterned] are those planted from 1975 to 1990. Old plantations, [solid pattern] are those planted prior to 1975.

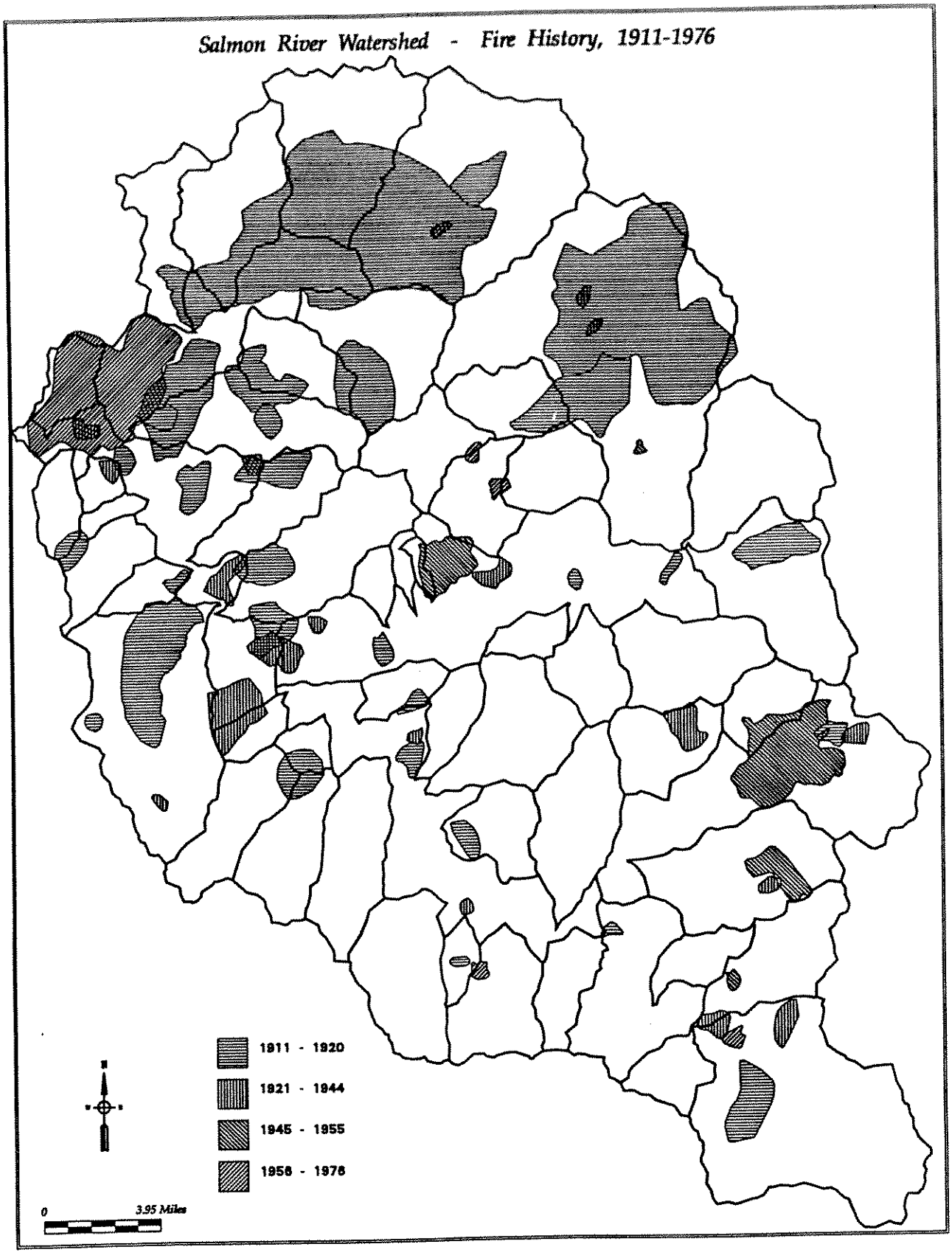


Figure 4-5. Salmon River basin fire history, 1911 to 1976.

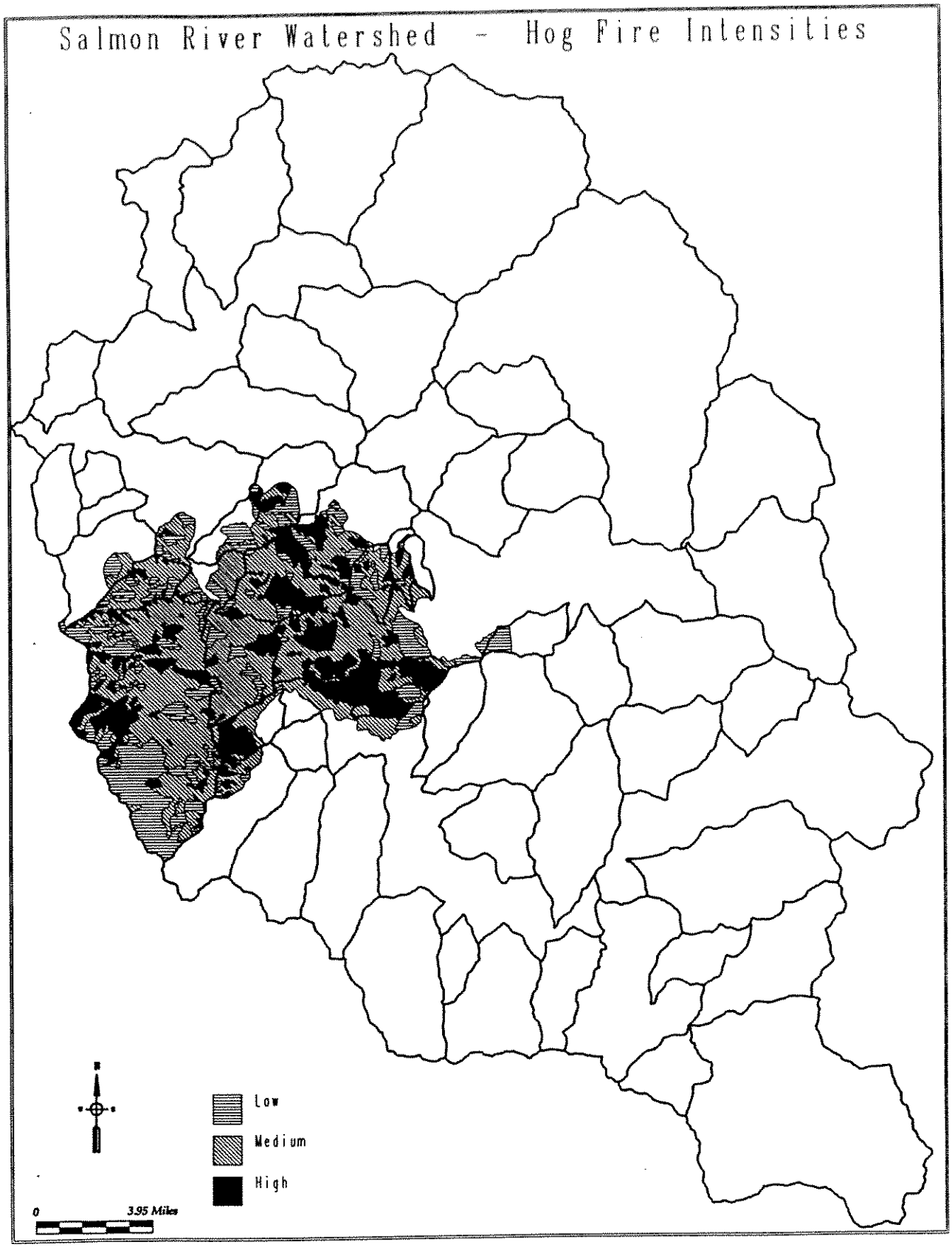


Figure 4-6. Area of Hog Fire, 1977, displaying fire intensity ranges.

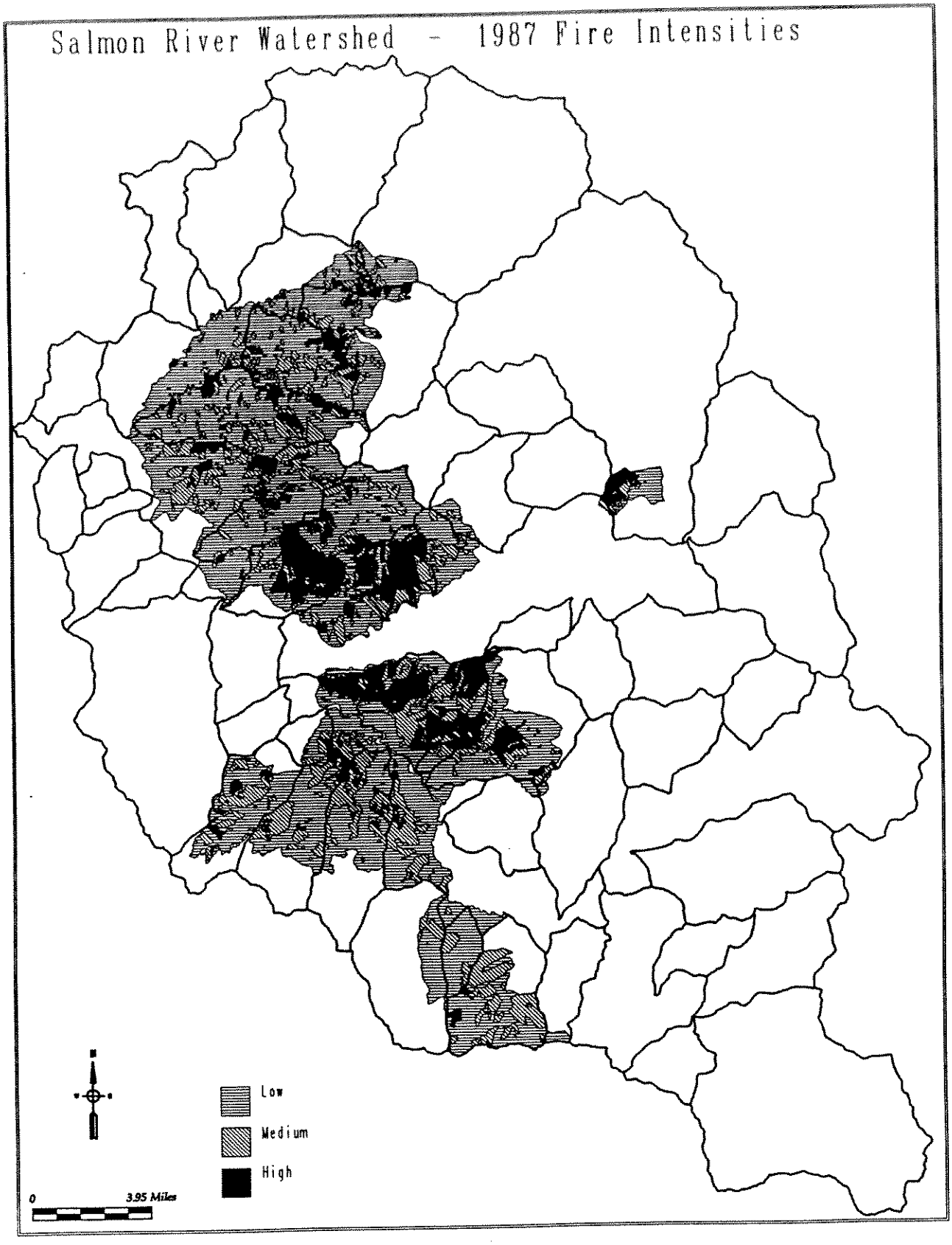


Figure 4-7. Fire Intensity map for the 1987 fires.

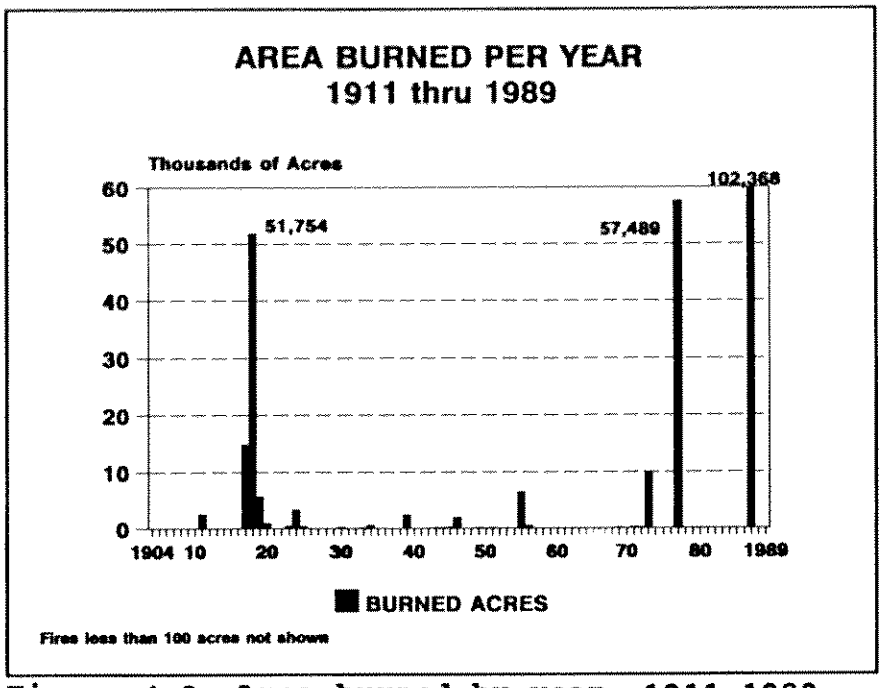


Figure 4-8. Area burned by year, 1911-1989.

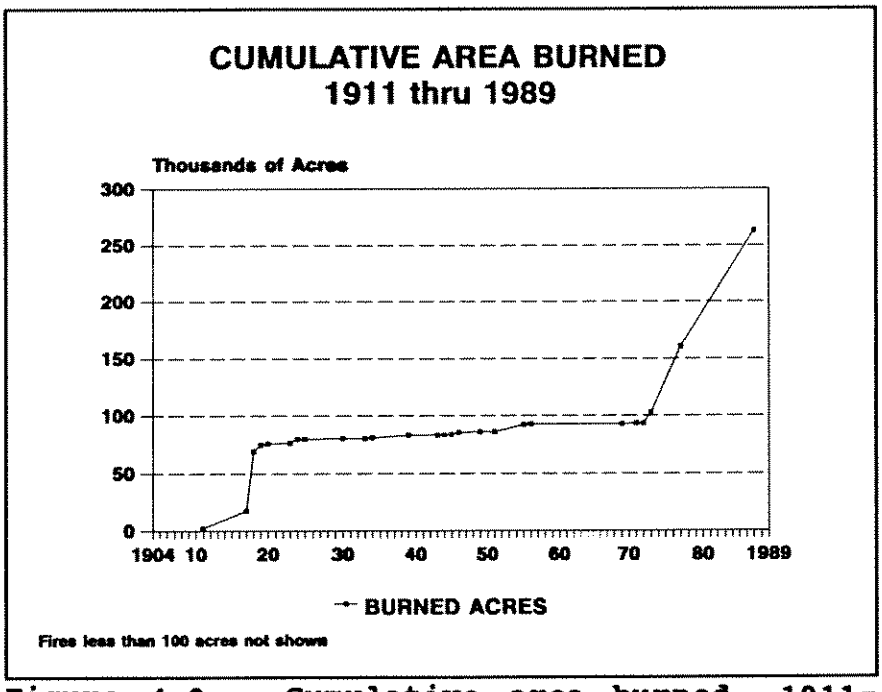


Figure 4-9. Cumulative area burned, 1911-1989.

Chapter 5 - Sediment Production: Results and Analysis

INTRODUCTION

This chapter presents project results. Findings on historic sediment production [1904-1988] are presented first, followed by the results of the landslide coefficient development process, and lastly, predictions of future sediment production in the Salmon River watershed. Measured landslide volumes are compared to those predicted by applying landslide production coefficients developed in an adjacent watershed, Grider Creek. An evaluation of the accuracy of landslide identification and measurement is presented. This evaluation compares the volume and number of landslides identified by two independent inventory processes, the basin-wide air photo inventory, and the field inventory in sample watersheds.

SEDIMENT PRODUCTION FROM LANDSLIDES, 1904 - 1988

During the period from 1904-1988, the basin-wide photo inventory revealed that about 10.4 million yds^3 of landslide-derived sediment entered the stream system **[Table 5-1]**. A total of 1711 landslides are measured by this inventory. The average sediment production is 21.4 yds^3/acre. Over an 84 year period, [1904-1988], the average annual sediment production for the Salmon River Watershed is 0.26 yds^3/acre/year. Of this, 58% of the volume is associated with the 1964 flood, and 17% with the storms of 1965-1975. Landslide production from 1965-1975 [excluding the 1964 flood] is about 1.8 million cubic yards, or 0.37 yds^3/acre/year. Undisturbed land accounted for most of this volume [67%], while roaded lands accounted for 30%, harvested lands 2%, and burned lands 1%. **Figure 5-1** displays historic sediment production, [1944-1988] from landslides [yds^3/acre] measured by the air photo inventory for the 56 sub-watersheds.The highest sediment delivery rates are from sub-watersheds in the Main Stem and South Fork Salmon River.

Table 5-1. Total volume of material delivered by landslides from sub-watersheds of the Salmon River, tabulated by photo period. Data source is the basin-wide photo inventory.

	Pre-44	44-55	55-64	64-65	65-75	75-88	Total
Salmon River	1,377,090	190,914	941,671	6,048,485	1,793,811	60,106	10,412,077
Main Stem [MSS]	292,391	56,928	682,127	2,967,130	360,876	33,006	4,392,458
North Fork [NFS]	272,906	38,764	46,785	658,190	381,196	13,448	1,411,289
South Fork [SFS]	541,839	67,785	81,515	1,305,585	606,090	7,704	2,610,519
Wooley Creek [WOO]	269,953	27,437	131,245	1,117,580	445,648	5,948	1,997,811

Though the air photo record spans the years from 1944-1988, the period of record used in this analysis is 1904-1988. The assumption that the 1944 photos provide a reasonable estimate of landsliding back to 1904 is supported by the observation that most of the debris slides which occurred during the 1964 flood are still clearly visible on 1988 air photos. It is likely that some of the landslides which occurred from 1904 to 1944, were missed by this survey due to revegetation of landslide scars during intervening years. Counteracting this effect is the likelihood that some of the slides mapped on 1944 photos occurred prior to 1904, and are possibly associated with the flood of 1891.

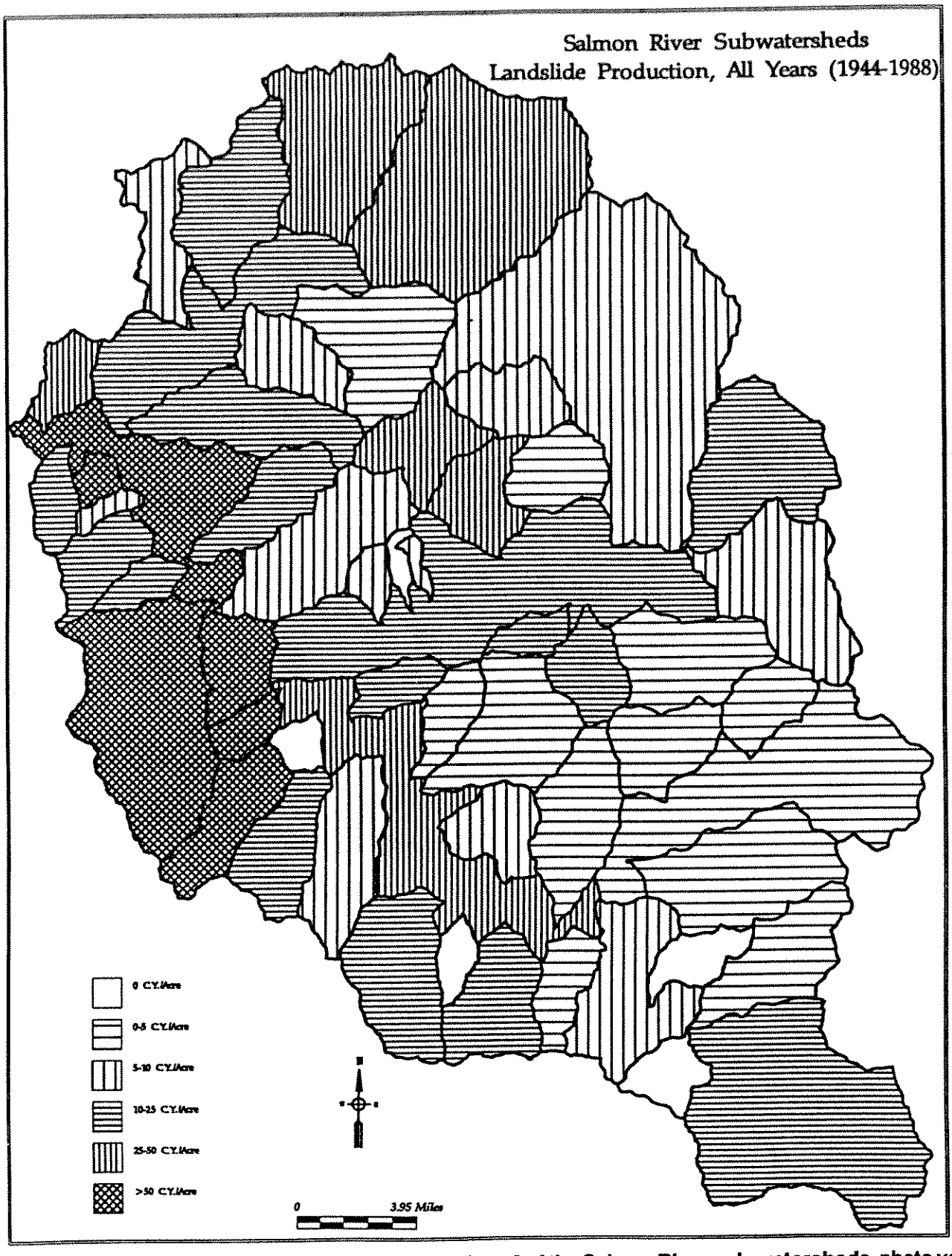


Figure 5-1. Landslide sediment production [yds³/acre] of the Salmon River sub-watersheds, photo years 1944-1988.

Review of **Table 5-1** and **Figure 5-1** reveals that sediment production varied considerably among sub-watersheds. This variation is due to the presence of different combinations of geomorphic terrane types in each watershed, and differences in disturbance history reflected by roads, timber harvest and fire.

Two very large landslides play an important role in the analysis of landslide volume, accounting for about 20% of the total **[Figure 5-2]**. One is the Bloomer landslide, a large, structurally-controlled debris slide involving metamorphic bedrock, which delivered about 1.43 million yds^3 of material to the lower main stem of the Salmon River in 1964, temporarily blocking it. The other is the Murderers Bar Landslide, a large translational landslide developed in older landslide deposits, with a debris slide at the toe. The landslide delivered about 0.59 million yds^3 to the lower main stem of the Salmon River some time between 1955 and 1964 [probably during the flood of 1955]. This landslide also temporarily dammed the river. Other landslide dams were documented on the North Fork of Russian Creek [North Russian Landslide] and on Big Elk Fork of Wooley Creek [Big Elk Landslide].

LANDSLIDE PRODUCTION BY GEOMORPHIC TERRANE

The geomorphic terranes into which the Salmon River watershed was stratified are displayed in **Table 5-2, Figure 5-3,** and **Figure 5-4**. Mountain slopes comprise 67% of the watershed; of this, 28% is composed of granitic mountain slopes. Inner gorges, which are most prone to landslides, comprise 17% of the watershed **[Figure 5-3]**. Slump-earthflow deposits comprise 7% of the watershed.

Table 5-2. Geomorphic terrane types and acreage in the Salmon River watershed.

Geomorphic Terrane	Terrane No.	Acres	% of Watershed
Granitic Mountain Slopes >65%	4	38,548	8
Granitic Mountain Slopes <65%	5	50,446	10
Non-Granitic Mountain Slopes >65%	6	136,753	28
Non-Granitic Mountain Slopes <65%	8	97,143	20
Debris Basins [Headwalls]	12	12,032	2
Inner Gorge, Granitic Bedrock & Mt. Slope	10	16,842	3
Inner Gorge, Non-Granitic Bedrock & Mt. Slope	11	52,534	11
Inner Gorge in Landslide, Terrace or Glacial Deposits	9	10,646	2
Slump/Earthflow Deposits	3	32,455	7
Slump/Earthflow Toe Zones	2	998	<1
Glacial, Terrace & Fan Deposits	13	32,145	7
	TOTAL	480,542	

Percent of watershed does not total 100% due to rounding. The total acre figure of 480,542 does not equal the total acres of watershed [540,626] due to differences in the digitized Forest boundary on different GIS layers.

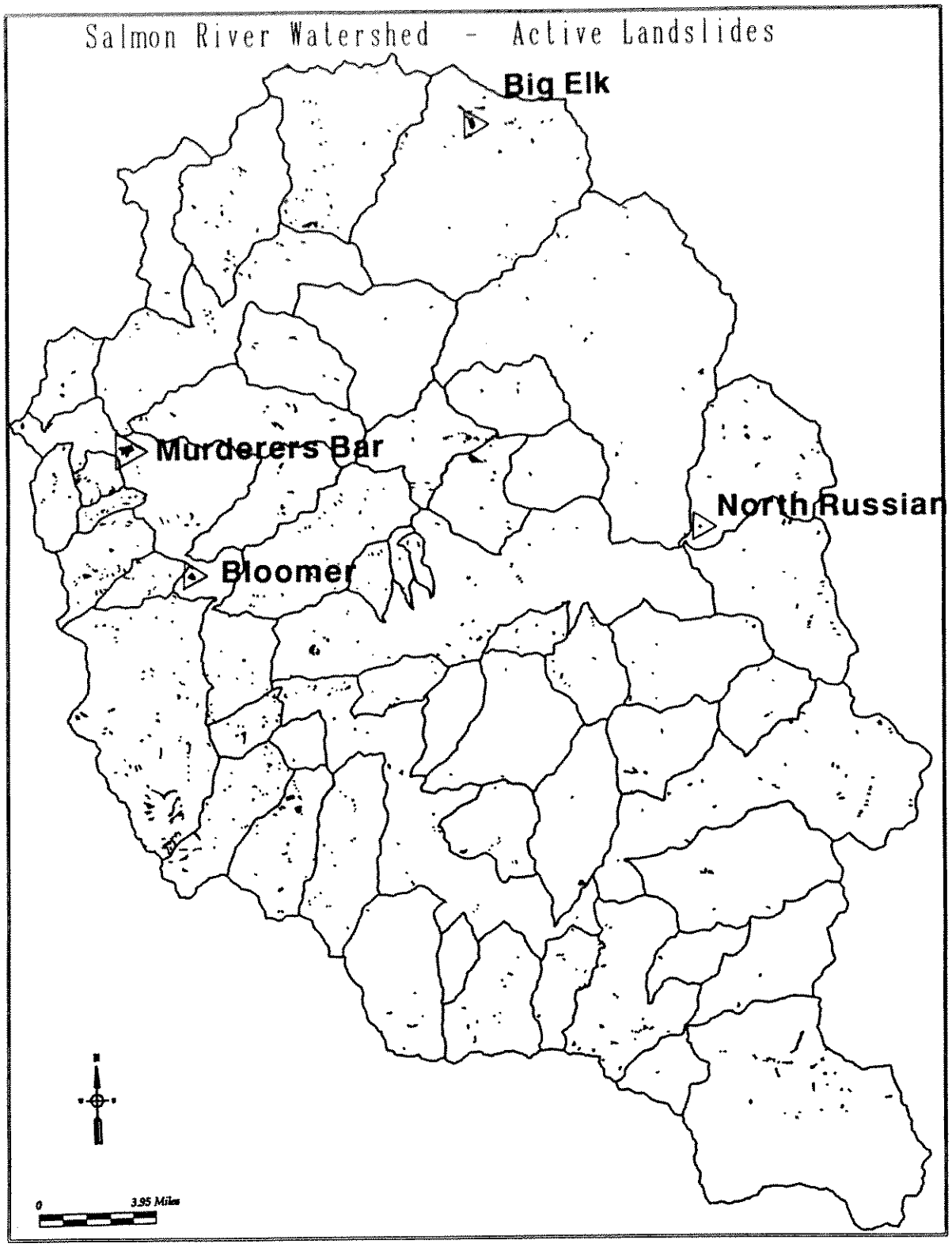


Figure 5-2. Major landslides and landslide dams in the Salmon River watershed. Shaded areas are 880 active landslides recorded in the Forest database developed in 1988. The area of active landslides totals 2,072 acres. The database has not been updated to record new landslides discovered from the basin-wide photo inventory. Note that 1,711 active landslides, encompassing 1,251 acres were inventoried in the basin-wide photo study conducted in 1992.

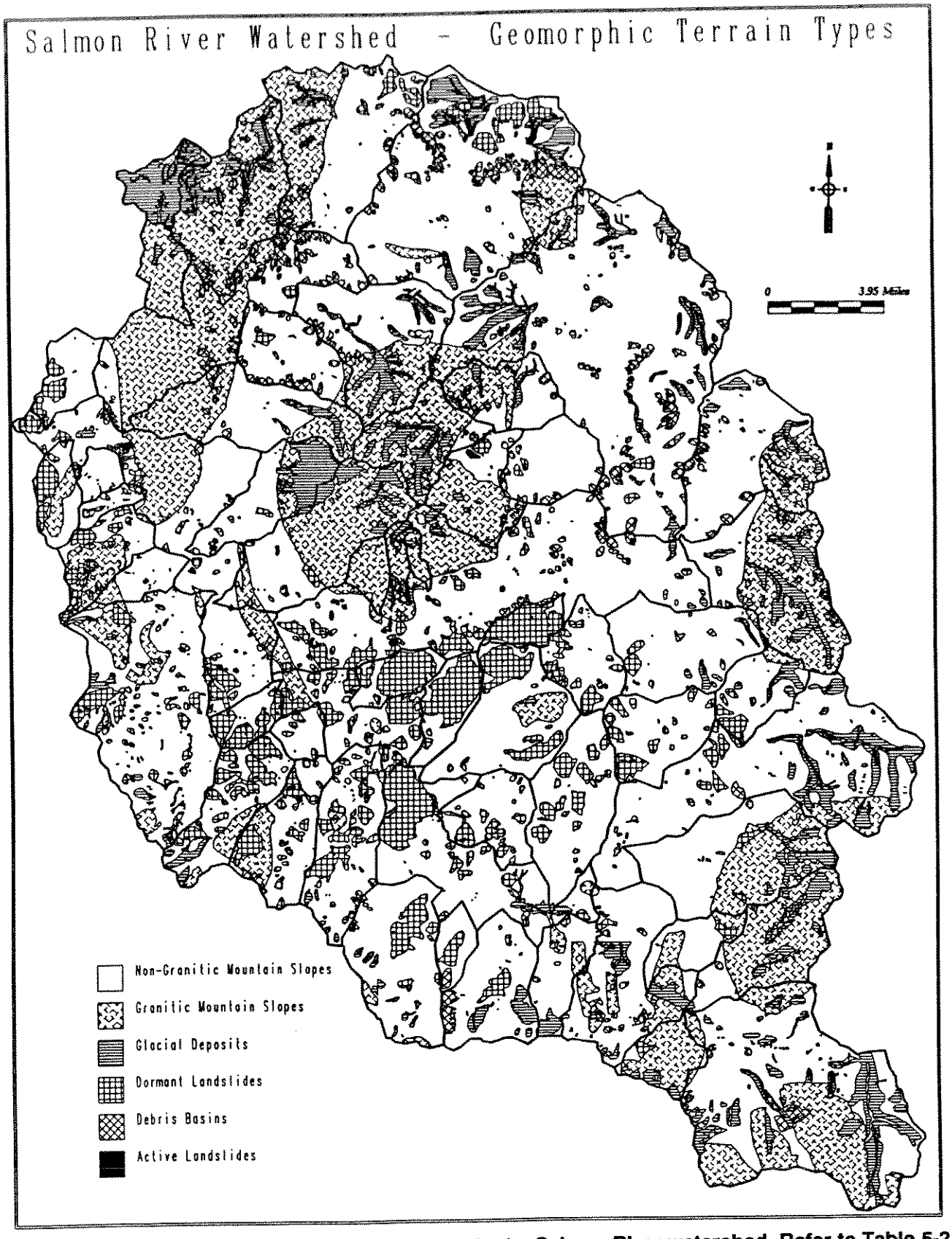


Figure 5-3. Distribution of geomorphic terranes in the Salmon River watershed. Refer to Table 5-2 for acre data.

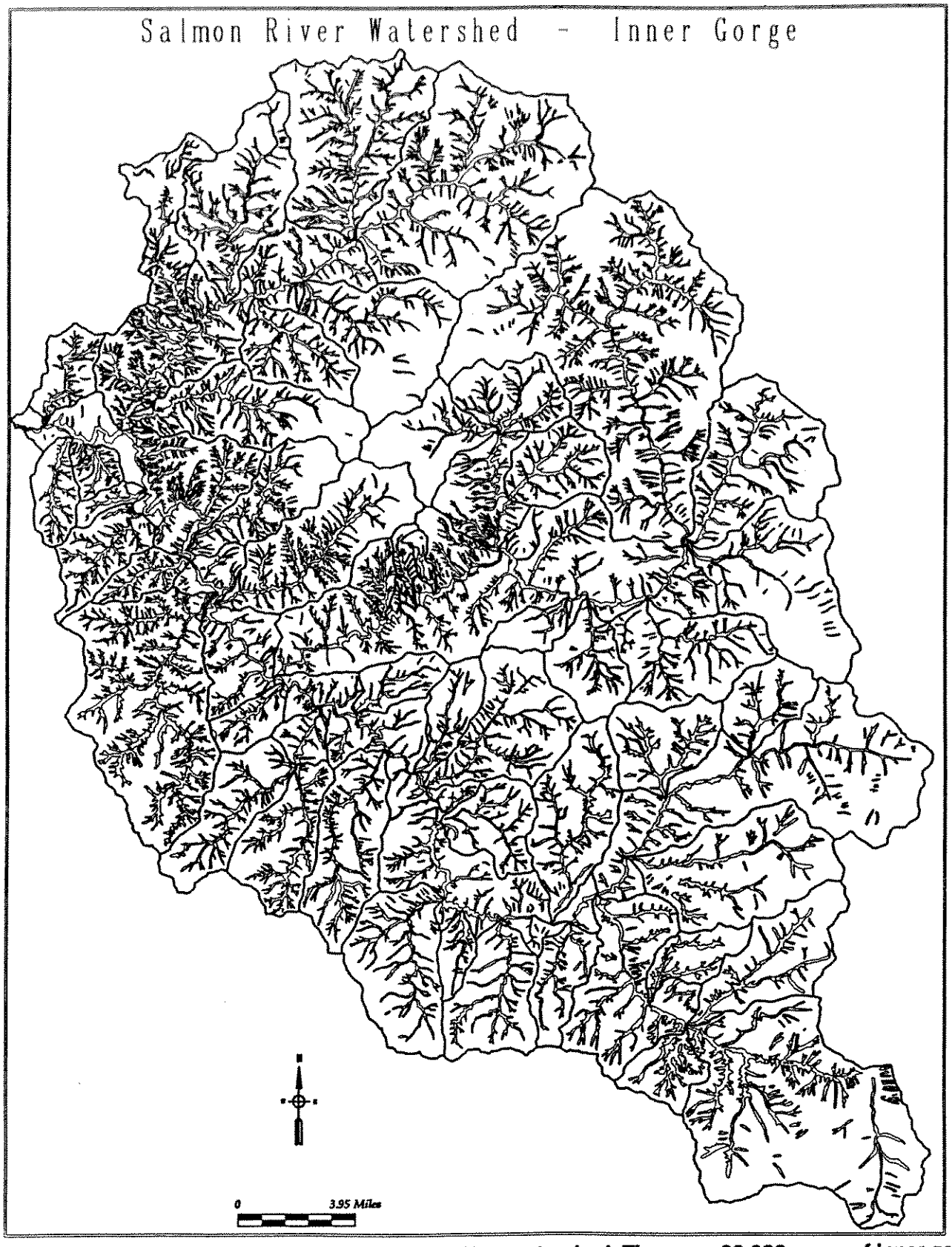


Figure 5-4. Inner gorge terranes in the Salmon River watershed. There are 80,022 acres of inner gorge in the watershed.

Landslide production by geomorphic terrane is tabulated in **Table 5-3**. This table shows landslide rate [yds³/acre] for each terrane for all photo years [1944-1988], and also for 1965-1975, the climatic sequence selected for predicting future landslide production. The values include all landslides, whether on undisturbed, harvested, or roaded land. Notice the high degree of variation in landslide production rate [yd³/acre] between terranes for the period 1944-1988. The inner gorge developed in unconsolidated deposits [#9] occupies 2% of the land area, yet produced 23% of the landslide volume, whereas moderate to gently sloping non-granitic mountain slopes [#8] occupy 20% of the land area and produced only 3% of the landslide volume.

Table 5-3. Volume of material delivered by landslides in the Salmon River watershed, tabulated by geomorphic terrane type, landslide rate, and time period. Data source is the basin-wide photo inventory.

Terrane No.	Terrane Type	Acres in Watershed	1944-88 Landslide Volume Yds³	1944-88 Landslide Rate Yds³/Ac	1965-75 Landslide Volume	1965-75 Landslide Rate Yds³/Ac.
2	Toe Zones of Slump Earthflow Deposits	998	0	0	0	0
3	Slump-Earthflow Deposits	32,455	1,399,621	43.1	222,643	6.9
4	Granitic Mt. Slope Steep [> 65%]	38,548	291,065	7.6	125,147	3.2
5	Granitic Mt. Slope Mod. Steep [0-65%]	50,446	185,115	3.7	48,939	1.0
6	Non-granitic Mt. Slope Steep [>65%]	136,753	2,658,735	19.4	271,287	2.0
8	Non-granitic Mt. Slope Mod. Steep [0-65%]	97,143	332,965	3.4	49,579	0.5
9	Inner Gorge, Unconsol. Material	10,646	2,375,693	223.2	290,705	27.3
10	Inner Gorge, Gran. Mt. Slope	16,842	676,391	40.2	206,101	12.2
11	Inner Gorge, Non-Granitic Mt. Slope	52,534	1,817,696	34.6	459,004	8.7
12	Debris Basins	12,032	105,122	8.7	16,860	1.4
13	Glacial, Terrace & Fan Deposits	32,145	569,674	17.7	103,546	3.2
Total		480,542	10,412,077	21.7	1,793,811	3.7

Notes: Geomorphic terrane type #2, toe zones of slump earthflow deposits, was found to be inconsistently mapped in the data layer and therefore is not useful. Landslides are associated with this terrane, and had it been mapped accurately, the volume would have been higher.

RESULTS OF FIELD INVENTORIES

Field inventories of Little North Fork and Negro Creek watersheds were conducted to evaluate the reliability and accuracy of the basin-wide photo inventory and to collect detailed landslide information on watersheds with geomorphic types representative of the Salmon River watershed. The following sections summarize the findings of the field inventories.

Little North Fork

Over the period of record, 1944-1988, 373 landslides scarred 103.5 acres of land, mobilized 2.9 million yds³, and delivered 483,170 yds³ of sediment to stream channels **[Table 5-4]**. The field inventory found that 81% of the total Volume delivered was from landslides on undisturbed slopes, 9% was from landslides in harvest units, and 10% was from landslides originating in the road prism. The volume of material delivered by landsliding resulting from the flood of 1964 comprises 69% of the total volume. Landslide volume during the 1965-1975 period comprises 27% of the entire volume. During this period, the distribution of landslide volume by disturbance class was 28% from undisturbed land, 34% from harvest units, and 37% from roads.

Table 5-4. Number of landslides, landslide area, and delivered sediment volume by time period and disturbance class for Little North Fork watershed.

1944 Undisturbed			1964-1965 Undisturbed		
Number	Area Acres	Volume Yds³	Number	Area Acres	Volume Yds³
11	2.1	19,673	133	69.9	332,590

1965-1975				1944-1988			
Class	Number	Area Acres	Volume Yds³	Class	Number	Area Acres	Volume Yds³
Undisturbed	47	5.2	37,285	Undisturbed	191	77.3	389,548
Harvest	114	14.5	45,078	Harvest	114	14.5	45,078
Roads	68	11.9	48,544	Roads	68	11.9	48,544
TOTAL	229	31.6	130,907	**TOTAL**	373	103.7	483,170

Table 5-5 shows the landslide production coefficients for the 1964-1965 and 1965-1975 periods at Little North Fork, and the increase of road- and harvest-related landslide rates over undisturbed. Road-related landslides show an increase in sediment production 313 times the undisturbed rate; harvest-related landslides show an increase of 30 times the undisturbed rate.

Table 5-5. Landslide rates associated with roaded, harvested and undisturbed lands in Little North Fork. The factor of increase over the undisturbed rate is also given. Landslide rates are area-weighted basin averages.

Flood Event	Type of Disturbance	Landslide Rate [yds³/acre]	Increase over Undisturbed Rate
1964 Event	Undisturbed	15.9	
1965-75 Events	Roads Harvest Undisturbed	595.6 56.8 1.9	X 313 X 30 X 1

Negro Creek

Over the record 1944-1988, 119 landslides scarred 21.1 acres, mobilized 689,566 yds³, and delivered 78,145 yds³ of sediment to stream channels **[Table 5-6]**. The volume of material delivered to streams from landslides resulting from the flood of 1964 comprises 52% of the total volume. The volume delivered during the 1965-1975 period comprises 4% of the total, and the volume for 1975-1988 makes up 38% of the total. The distribution of volume by disturbance class is 61% from undisturbed lands, 4% from roads, and 35% from lands burned in the Hog and 1987 wildfires.

Table 5-6. Number of landslides, landslide area, and delivered sediment volume by time period and disturbance class for Negro Creek watershed.

1944 Undisturbed			1944-1955 Roads		
Number	Area Acres	Volume Yds³	Number	Area Acres	Volume Yds³
6	1.4	4,365	1	0.2	72

1964-1965				1965-1975			
Class	Number	Area Acres	Volume Yds³	Class	Number	Area Acres	Volume Yds³
Undisturbed	10	4.7	40,448	Undisturbed	6	0.9	3,101
Roads	2	0.1	187	Roads	4	0.3	268
TOTAL	12	4.8	40,635	TOTAL	10	1.2	3,369

Table 5-6 continued.

1975-1988				1944-1988			
Class	**Number**	**Area Acres**	**Volume Yds³**	**Class**	**Number**	**Area Acres**	**Volume Yds³**
Undisturbed				Undisturbed	22	7.0	47,914
Roads	8	1.2	2575	Roads	15	1.8	3,102
Fire	82	12.3	27,129	Fire	82	12.3	27,129
TOTAL	90	13.5	29,704	**TOTAL**	119	21.1	78,145

COMPARISON OF AIR PHOTO INVENTORY DATA TO FIELD-BASED DATA

In order to get a measure of the thoroughness of the basin-wide photo inventory, the results of the air photo inventory were compared to those obtained by detailed field inventories in Little North Fork, and Negro Creek.

The field inventory at Little North Fork identified a total of 483,170 yds³ of landslide-derived sediment from 1944-1988. Of this, 130,906 yds³ occurred from 1965-1975. This compares to 402,036 [1944-1988] and 140,510 yds³ [1965-1975] respectively, measured in the basin-wide photo inventory. The photo inventory identified a total of 184 landslides, compared to 373 by the field inventory for 1944-1988.

The field inventory at Negro Creek identified a total of 78,145 yds³ of landslide sediment from 1944-1988, with 3,369 yds³ occurring in 1965-1975. The basin-wide photo study identified 43,102 and 5,824 yds³ respectively. The photo inventory identified 12 landslides from 1944-1988 compared to 119 for the field inventory.

A comparison of 12 field-measured to air photo-measured landslide volumes at Little North Fork revealed that differences between the methods varied from 1 to 53%.

Field Estimate		Air Photo Estimate	
Inventory Number	Delivered Volume	Delivered Volume	Inventory Number
88003	22,500	22,272	88260
88004	49,600	43,320	88259
88005	16,445	15,000	88258
88020	8,258	2,886	88257
88026	3,145	7,656	88250
88027	5,404	8,064	88251
88024	26,289	12,444	88248
88025	7,860	8,160	88249
88091	303	1,404	88269
88087	2,429	768	88268
80029	32,950	35,840	80029
71022	7,500	11,300	71022

Though not designed for statistical validity, this comparison allows a general impression of the level of accuracy of the basin-wide air photo inventory.

In summary, the basin-wide photo inventory underestimated landslide volumes over the period 1944-1988 in Little North Fork by about 17%, and by about 45% in Negro Creek. One factor influencing better correlation at Little North Fork than at Negro Creek is that most of the landslides at Little North Fork are debris slides in light-colored slope colluvium, making them easy to detect on air photos.

The basin-wide photo inventory underestimated the total number of landslides by 51% at Little North Fork, and 90% at Negro Creek. The reason that total volumes agree more closely than the number of landslides is that most of landslides missed by the photo inventory were small. Landslides less than 500 yds^3 in delivered volume account for 55% of the total number identified by the field inventory at Little North Fork, and 83% of the total at Negro Creek. The photo inventory identified most of the larger landslides, particularly the debris slides. The majority of the landslides which were undetected were small debris slides within the inner gorge and active slumps or earthflows. Debris slides in the inner gorge are obscured by timber canopy and active slump-earthflows which are difficult to detect on air photos unless they have debris slide components at the toe. Another factor influencing the number of landslides which were not detected by the photo study was that larger scale photos were used in association with the field studies [for example, 1:10,000 at Little North Fork], and smaller scale photos were used for part of the basin-wide study [the sacle of the 1988 photos is 1:40,000]. Previous field studies undertaken by the USFS during the winter of 1982-1983 in areas with slump and earthflow terrane [Horn Creek, Fong Wah Gulch, Lunch Creek, and Crapo Creek] revealed numerous active slumps and earthflows in areas which had burned in the Hog fire of 1977. Some of these active landslides were not detected by the basin-wide photo inventory. Thus, the basin photo inventory may have underestimated the landslide volume produced by slump-earthflow terrane [burned by the Hog Fire] from 1975-1988 by a considerable amount. Additional landslides are being measured as part of on-going projects, and this information will be used to refine the basin-wide totals in the future.

THE GRIDER CREEK SEDIMENT ANALYSIS

The Grider Creek watershed is a 27,730 acre tributary basin to the Klamath River. The watershed is about 10 miles to the north and is geomorphically and climatically similar to the lower Salmon River basin. Previous studies in this watershed utilized both air photo and field measurement techniques to estimate volumes of material mobilized and delivered to streams by landslides. Measured landslide production from 1965-1975 was used to develop sediment yield coefficients for 12 geomorphic terrane types [de la Fuente, 1991; U.S. Forest Service, 1989]. As with the Salmon sub-basin sediment analysis, the coefficients reflect landslide production in response to a climatic sequence similar to that of the 1965-1975 period. The Grider Creek landslide coefficients and total sediment yield derived from the coefficients are compared to those developed by this study for the Salmon Basin in the following sections.

COMPARISON OF LANDSLIDE COEFFICIENTS: GRIDER CREEK AND LITTLE NORTH FORK

Landslide production coefficients developed at Grider Creek were compared to those developed at Little North Fork from a detailed field and photo inventory, **[Table 5-7]**, and also to those developed by an independent air photo inventory, the Salmon River basin-wide photo inventory **[Appendix A, Table A-1]**. The coefficients developed by the basin-wide inventory, and displayed in the "LNS Photo Study" column utilized only data from Little North Fork. Note the variability in the values, particularly for harvested and roaded conditions. The sample size [acres] of some terrane and disturbance class combinations is very small, thus increasing the likelihood of high variability. Another important factor affecting the differences in coefficients is that while Grider Creek has a considerable amount of granitic terrane, little of it was roaded or harvested when the landslide-producing storms of the 1960's and 1970's occurred. Thus, there was little data available on the effect of roads and harvest on landslide rates from which to develop coefficients for granitic terrane.

Table 5-7. Comparison of landslide coefficients [yds³/acre] from the Grider Study, the Little North Fork [LNS] Photo Study, and the Little North Fork [LNS] Field Study. Coefficients given are for landslides documented in the 1965-1975 period. Acres of each type of disturbance are indicated for each geomorphic terrane.

	Undisturbed			Harvest/Fire			Roads		
Geo Terrane	Grider Study	LNS Photo Study	LNS Field Study	Grider Study	LNS Photo Study	LNS Field Study	Grider Study	LNS Photo Study	LNS Field Study
#2	6.00 990	0 7 Ac	0 7 Ac	30.00 0 Ac	- 0 Ac	- 0 Ac	120.00 0 Ac	- 0 Ac	- 0 Ac
#3	1.40 322Ac	17.92 322 Ac	0 322 Ac	7.00 32 Ac	15.24 32 Ac	17.90 32 Ac.	28.00 4 Ac	204.00 4 Ac	36.80 4 Ac
#4	4.00 2880Ac	0.57 2880 Ac	2.90 2880 Ac	20.00 46 Ac	38.70 46 Ac	14.90 46 Ac	80.00 14 Ac	1056.92 14 Ac	450.60 14 Ac
#5	1.50 4374Ac	0 4374 Ac	0.03 4374 Ac	7.50 249 Ac	33.99 249 Ac	0 249 Ac	30.00 26 Ac	143.08 26 Ac	54.40 26 Ac
#6	0.70 4965Ac	0 4965 Ac	0.06 4965 Ac	3.50 85 Ac	42.94 85 Ac	0 85 Ac	14.00 7 Ac	1640.76 7 Ac	355.10 7 Ac
#8	0.10 2003Ac	0 2003 Ac	0 2003 Ac	0.50 95 Ac	0 95 Ac	0.60 95 Ac	2.00 6 Ac	0 6 Ac	31.80 6 Ac
#9	35.00 311Ac	2.06 311 Ac	27.0 311 Ac	175.00 5 Ac	0 5 Ac	0 5 Ac	700.00 0 Ac	- 0 Ac	- 0 Ac
#10	8.00 1008Ac	8.37 1008 Ac	13.7 1008 Ac	40.00 134 Ac	136.32 134 Ac	278.3 134 Ac	160.00 10 Ac	2118.00 10 Ac	3482.20 10 Ac
#11	3.30 1751Ac	16.56 1751 Ac	3.8 1751 Ac	16.50 51 Ac	99.29 51 Ac	16.90 51 Ac	66.00 2 Ac	630.00 2 Ac	421.90 2 Ac
#12	3.50 793Ac	0 793 Ac	0 793 Ac	17.50 0 Ac	- 0 Ac	- 0 Ac	70.00 0 Ac	- 0 Ac	- 0 Ac
#13	0.40 1600Ac	0 1600 Ac	0 1600 Ac	2.00 20 Ac	0 20 Ac	0 20 Ac	8.00 1 Ac	0 1 Ac	0 1 Ac

Landslide production coefficients for the entire Salmon River watershed that were derived from the basin-wide photo inventory, are displayed in **Appendix A, Table A-1**. These coefficients provide a better representation of the increase in landslide production associated with roads and harvest than those in **Table 5-7** since the sample size for combinations of geomorphic terranes and disturbance class was much larger. The landslide production rate for each of the geomorphic terranes is expected to vary by elevation and precipitation zone, and also by other physical variables which were not part of the stratification criteria. The information developed here will allow further refinement of geomorphic terrane delineation.

TOTAL LANDSLIDE PRODUCTION: COMPARING THE RESULTS OF DIFFERENT METHODS

Landslide production from 1965-1975 for the Salmon River basin was estimated by two methods. The first was by means of a basin-wide photo inventory, described previously, which involved mapping of all visible landslides and estimating delivered sediment volume. The second was by applying landslide production coefficients developed in the Grider Creek basin to the Salmon River watershed, and assuming disturbance levels [road, harvest, fire] which existed during the period 1965-1975. **Table 5-8** shows that application of the Grider coefficients predicts a volume which is about a third smaller than that measured by the basin-wide photo inventory.

In Little North Fork and Negro Creek watersheds, a third method was used in addition to the two described above. The third method consisted of a comprehensive field and air photo inventory, where a large proportion of the landslides were measured in the field.

Table 5-8. Total landslide sediment production values determined from field inventory, air photo inventory, and sediment model methods, assuming 1965-1975 disturbance conditions. Watersheds used for analysis and comparison are: Little North Fork, Negro Creek, and the Salmon River.

	WATERSHED		
Data Source	**Salmon River**	**Little North Fork**	**Negro Creek**
Field Inventory		130,907 yds³	3,369 yds³
Basin Air Photo	1,793,811 yd³	136,439 yd³	5,824 yd³
Grider Coefficients	1,280,662 yds³	66,983 yd³	16,168 yd³

In the Little North Fork, the air photo inventory measured a landslide volume which is 4% greater than that measured by the field inventory **[Table 5-8]**. Over the entire period of record [1904-1988], the air photo inventory identified a landslide volume which was 17% lower than that measured by the field inventory.

At Negro Creek, the photo inventory volume is 73% greater than the field inventory volume **[Table 5-8]**. The field inventory measured ten landslides while the air photo inventory evaluated four landslides. The field inventory estimated that the ten landslides delivered 3,369 cubic yards of sediment to the channel system, while the photo inventory estimated 5,824 cubic yards. The differences in results are likely due to better recognition of small landslides by the field inventory and over-estimation of delivered volume by the air photo inventory.

Application of Grider Creek landslide coefficients to the Little North Fork resulted in a landslide volume which is half that actually measured by the field inventory. At Negro Creek, the Grider coefficients predicted a value almost 5 times larger than that measured by the field inventory. Application of the Grider coefficients to the entire Salmon basin resulted in a volume which is 71% of the volume measured by the basin-wide photo inventory. Likely reasons for the variation in estimates of landslide volume are described above under the section "Comparison of landslide Coefficients: Grider Creek and Little North Fork".

In summary, Grider Creek landslide coefficients underestimate total sediment production by landslides in the Salmon basin for the 1965-1975 period by about 29%. The basin-wide photo inventory measured 1.79 million yds³ of sediment for the Salmon River from 1965-1975. The coefficients from Grider Creek predict about 1.28 million yds³.

FINAL LANDSLIDE COEFFICIENTS: SALMON RIVER WATERSHED

Landslide production coefficients were developed for all geomorphic terranes in order to predict future landslide rates in the Salmon River basin **[Table 5-9]**. These coefficients are referred to as the "Final Landslide Coefficients", and were derived primarily from the basin-wide air photo inventory, with minor modifications to reflect findings of the field inventories. In order to maintain consistency with the format used in Interim Report #1, [de la Fuente, 1991],active landslides [geomorphic terrane type #1] identified in the 1988 geologic layer are kept separate from the other terranes, and a separate coefficient applied to them.

Table 5-9. Final landslide coefficients for 12 geomorphic terrane types of the Salmon River Basin. Coefficients are in yds³/acre and are derived primarily from the basin-wide photo inventory. The values reflect sediment production in reponse to a climatic episode similar to that observed during 1965-1975 in the watershed.

Terrane No.	Terrane Type	Undisturbed	Harvest 1950-1974	Harvest 1975-1987, Hog & 1987 Fire	Roads All Ages
1	Active Landslides	25.00	75.00	125.00	1,000.00
2	Toe Zones of Slump Earthflow Deposits	2.76	2.98	3.20	225.00
3	Slump-Earthflow Deposits	2.76	2.99	3.22	225.05
4	Granitic Mt. Slope Steep [>65%]	1.25	6.53	11.81	1005.48
5	Granitic Mt. Slope Mod. Steep [0-65%]	0.60	5.93	11.26	36.33
6	Non-Granitic Mt. Slope, Steep, [>65%]	1.69	2.48	3.26	81.84
8	Non-granitic Mt. Slope Mod. Steep [0-65%]; also Alluvium [Qal] & Lake Deposits	0.30	1.21	2.12	18.72
9	Inner Gorge, Unconsolidated Material	26.48	38.98	51.48	375.58
10	Inner Gorge, Granitic Mt. Slope/Bedrock	7.32	76.85	146.38	1,201.31
11	Inner Gorge, Non-granitic Mt. Slope	7.22	9.21	11.20	285.28
12	Debris Basins	1.26	3.78	50.41	25.20
13	Glacial, Terrace & Fan Deposits	3.23	4.85	6.46	7.45

FUTURE LANDSLIDE PRODUCTION: SEDIMENT MODEL COMPUTATIONS

Future sediment production by landslides can be estimated for present-day disturbance levels by using the final Salmon River basin coefficients. The computation requires information on the area [acres] occupied by each of the geomorphic terranes, distinguishing between the undisturbed, harvested prior to 1974, harvested or burned after 1974, and roaded portions. The area in each geomorphic terrane and disturbance class combination is then multiplied by the appropriate coefficient **[Table 5-9]**. **Table 5-10** displays volumes predicted using the final Salmon Basin coefficients. The predicted values are the quantities of sediment expected to be delivered by landslides if storm events similar to those in 1965-1975 occurred in the watershed with disturbance levels present in 1989. **Figure 5-5** displays predicted landslide outputs by sub-watershed for the Salmon basin. These predicted outputs can be compared to the actual volume which was measured for each of the sub-watersheds **[Figure 5-1]** by the basin-wide air photo over the entire time period from 1904-1988.

Table 5-10. Predicted sediment production [yds³] from landslides. The predicted values shown are those obtained using the final Salmon River watershed coefficents, at disturbance levels present in 1989. Disturbance types include: 1987 fires, Hog Fire 1977, old harvest units 1950-1974, recent harvest units 1974-1989, roads, and undisturbed lands. Refer to Table 5-9 for coefficients used.

	PREDICTED DELIVERED SEDIMENT VOLUME USING FINAL SALMON COEFFICIENTS, 1989 CONDITIONS
Salmon River	2,684,238
Main Stem [MSS]	680,049
North Fork [NFS]	699,881
South Fork [SFS]	924,622
Wooley Creek [WOO]	379,776

SEDIMENT PRODUCTION FROM SURFACE EROSION

It is estimated that surface erosion produced 1.5 million yd³ of sediment from 1904-1988, or 0.04 yds³/acre/year. This figure was derived by utilizing erosion rates which were developed for undisturbed conditions and for disturbance levels present during 1986-87, 1987-88 and 1991-92. It accounts for the large fires of 1918 and 1919 by assuming that the old fires accelerated soil erosion at the same rate as the fires of 1987, in direct proportion to their area. Despite the fact that this figure is very imprecise, it allows a general means of comparing long-term cumulative sediment derived from surface erosion to other primary sediment sources.

Total sediment production delivered to channels by surface erosion in the Salmon River watershed in the year following the 1987 wildfire is estimated by the USLE at 105.1 thousand yds³ **[Figure 5-6]**. Effects of the 1987 wildfire are responsible for most of the erosion during this time period. The 1987 wildfires, which occurred in 21% of the watershed, account for 87% of the total delivered sediment by surface erosion sources in the watershed. Surface erosion from roaded and undisturbed lands make up 7 and 5% of the total, respectively. The greatest sediment production rates [delivered sediment to channels] were in watersheds that burned with high intensity and have sandy loam soils derived from granitic parent materials, specifically Olsen Creek Big Creek and Kanaka Creek watersheds **[Figure 5-6]**.

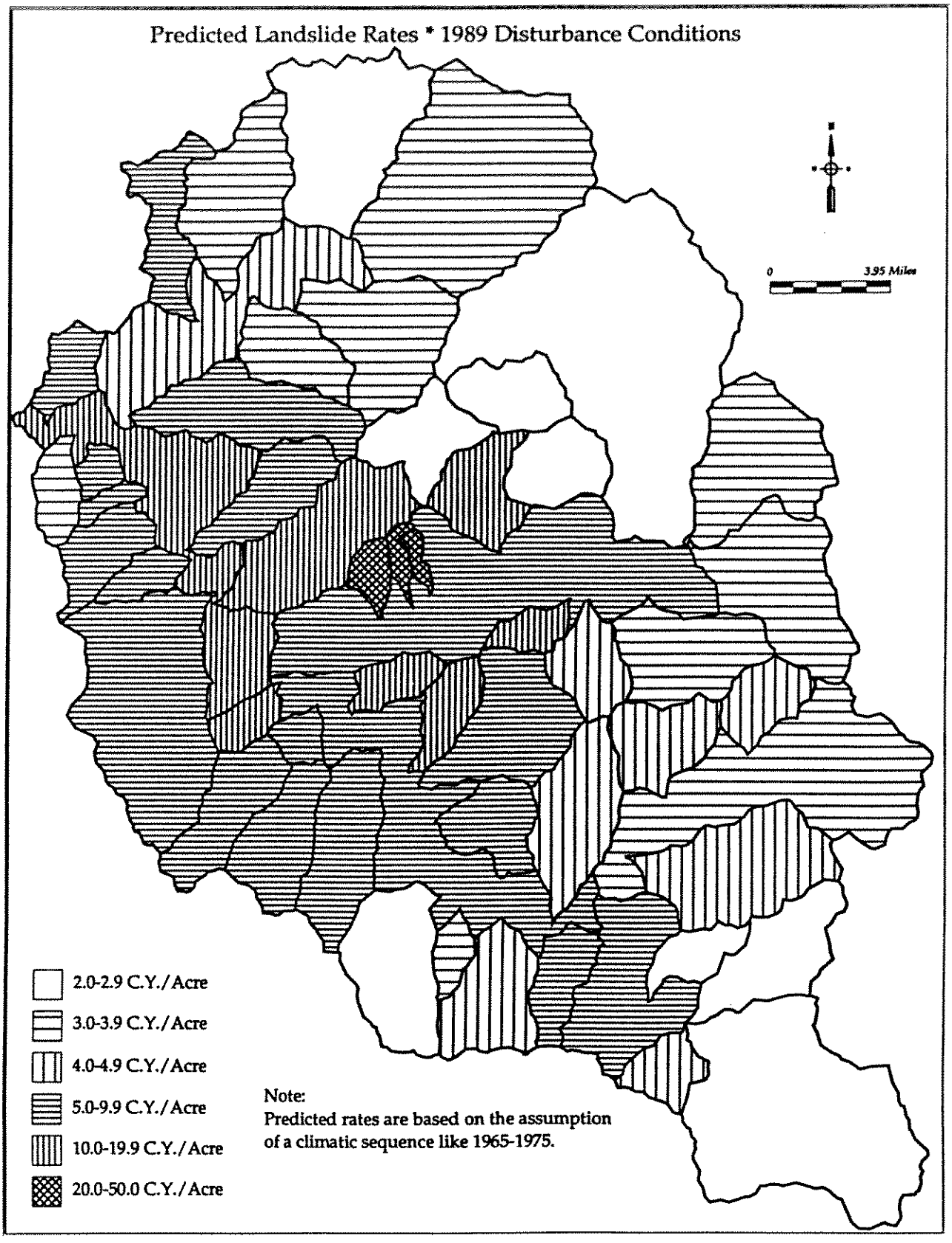


Figure 5-5. Predicted landslide sediment yield [yds³/acre] in the Salmon River watershed at disturbance levels present in 1989.

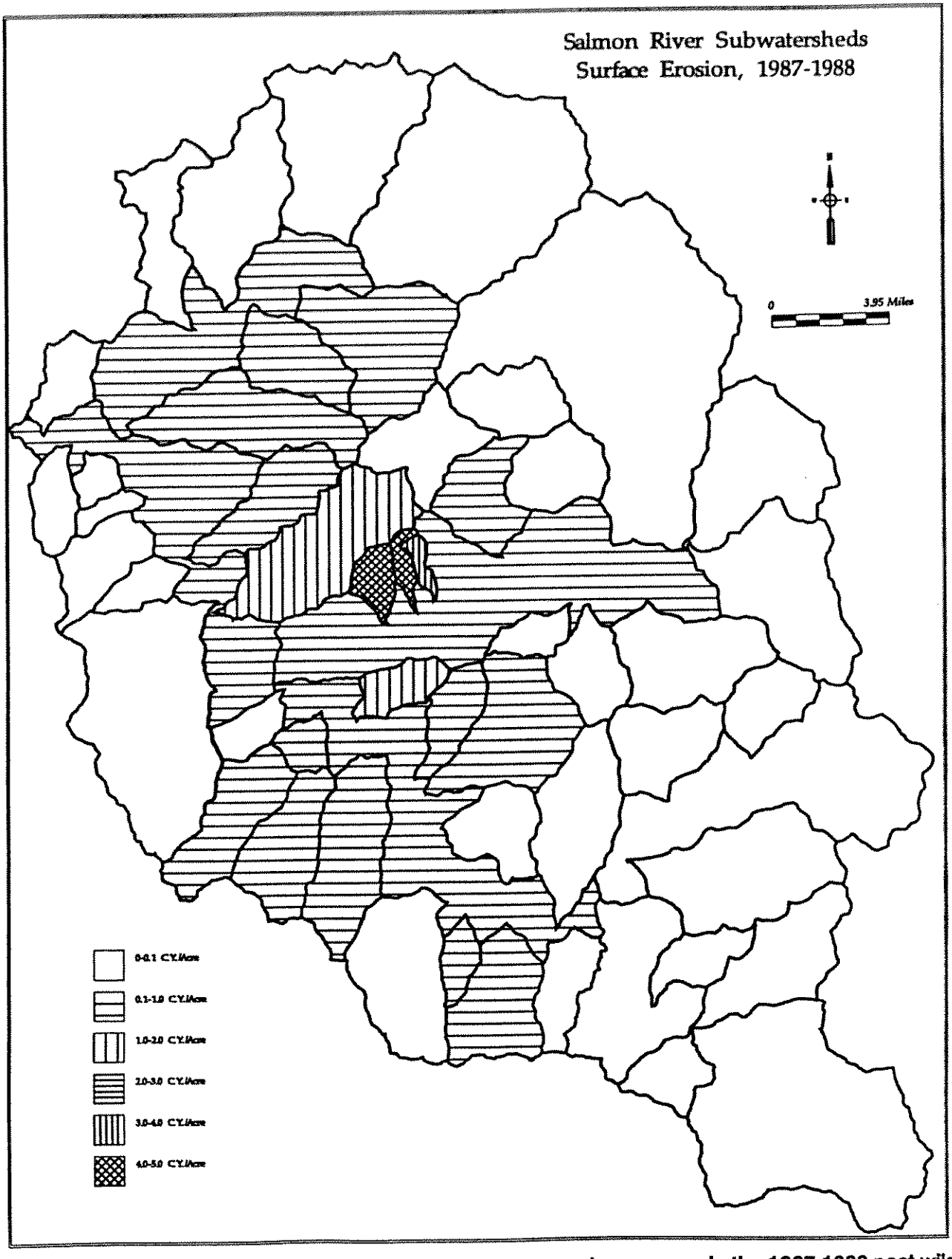


Figure 5-6. Delivered sediment [yds³/acre] from surface erosion sources in the 1987-1988 post wildfire period for Salmon River watershed.

Table 5-11 displays the predicted variation in soil erosion rates over time which is expected to occur in response to vegetative recovery. Volumes are in thousands of yds³/year delivered to the channel system. The rapid drop in predicted erosion rate following the 1987 fire is a result of revegetation and the breakdown of water repellent soil conditions.

Table 5-11. Variation in surface erosion rates over time in the Salmon River watershed. Sediment production is in units of thousands of yds³/year.

	Undisturbed Conditions	1986-87 Conditions	1987-88 Conditions	1991-92 Conditions	2007-08 Conditions
Total Salmon River	7.6	15.8	105.1	24.0	15.5
Main Stem Salmon	1.1	1.6	33.5	3.9	1.8
North Fork Salmon	2.1	4.0	22.5	5.3	4.1
South Fork Salmon	3.0	8.1	30.0	11.4	7.7
Wooley Creek	1.5	2.1	19.2	3.7	2.1

Notes: 1987-88 is immediately after the fires of 1987. Acres of harvested and roaded land for 1991-92 and 2007-08 are assumed to be unchanged from post-1987 wildfire levels.

The periods displayed in **Table 5-11** were chosen to show the relationship between surface erosion and recovery of vegetation in the post-fire periods. Assumptions in this recovery are detailed below. Vegetative cover [soil cover] remained constant for undisturbed and roaded conditions. In disturbed conditions, vegetative recovery was assumed to increase in a non-linear manner with the greatest amount of recovery occurring after the first five years. Hydrophobicity was assumed to deteriorate significantly by five years after the fire [Dyrness, 1976].

CHANNEL EROSION

Channel erosion was not measured quantitatively, but a large proportion was observed to be directly related to landsliding. It probably contributed a considerable amount of additional volume but insufficient data is available at this time to obtain meaningful estimates.

The basin-wide photo inventory revealed that about 891 acres or 1,143,090 linear feet [216.5 miles] of channel was damaged in direct association with landslides from 1944-1988. This consisted of 221 acres in Wooley Creek, 222 acres in the Main Stem of the Salmon River, 240 acres in the North Fork Salmon River, and 208 acres in South Fork of the Salmon River. During the interval 1965 to 1975, the acres of channel damaged amounted to 221,410 feet [42 miles] and 127 acres. **Figures 5-7**, through **5-12** display the distribution of all disturbed channels by air photo interval including that which is not directly related to landslides.

In Grouse Creek, a tributary to the Trinity River, streambank erosion constitutes about 7% of the total sediment budget [Raines and Kelsey, 1991]. Their buget period extended from 1960-1989. In the Ashland Batholith, channel erosion was estimated at 68% of the total budget [Wilson and Hicks, 1975]. Another study, conducted in the Salmon, Scott, and Shasta watersheds [USDA-Soil Conservation Service, 1972], estimated channel erosion at 61% of the total sediment budget; landslides and surface erosion contributed 25% and 14% respectively. In the Middle Klamath basin, which is similar to lower Salmon River, this same study reported that streambanks contributed 36%, landslides contributed 49%, and surface erosion contributed 15% to the total sediment volume. This study looked at the period from 1940 to 1965.

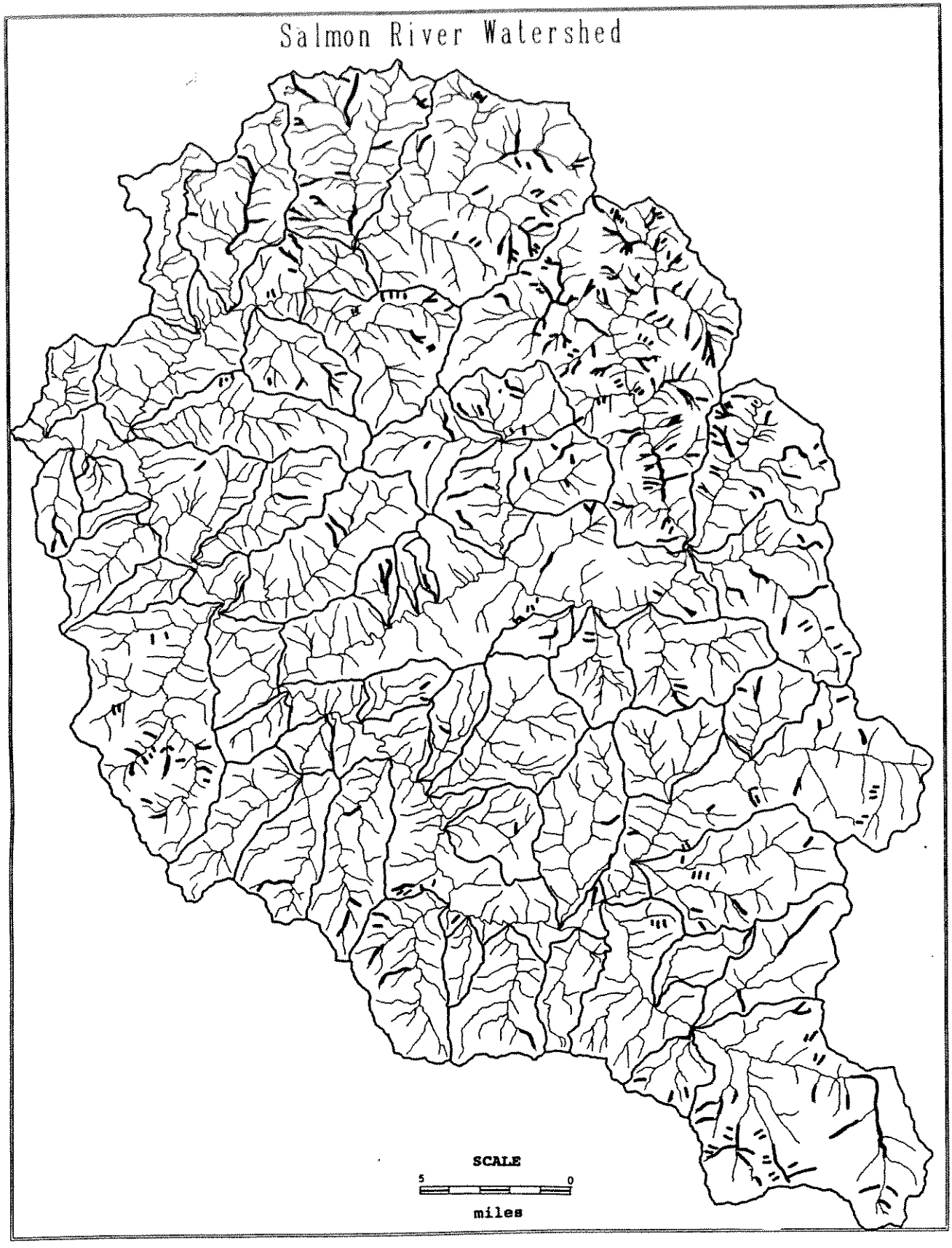


Figure 5-7. Scoured channels in the Salmon River watershed, visible on the 1944 air photos.

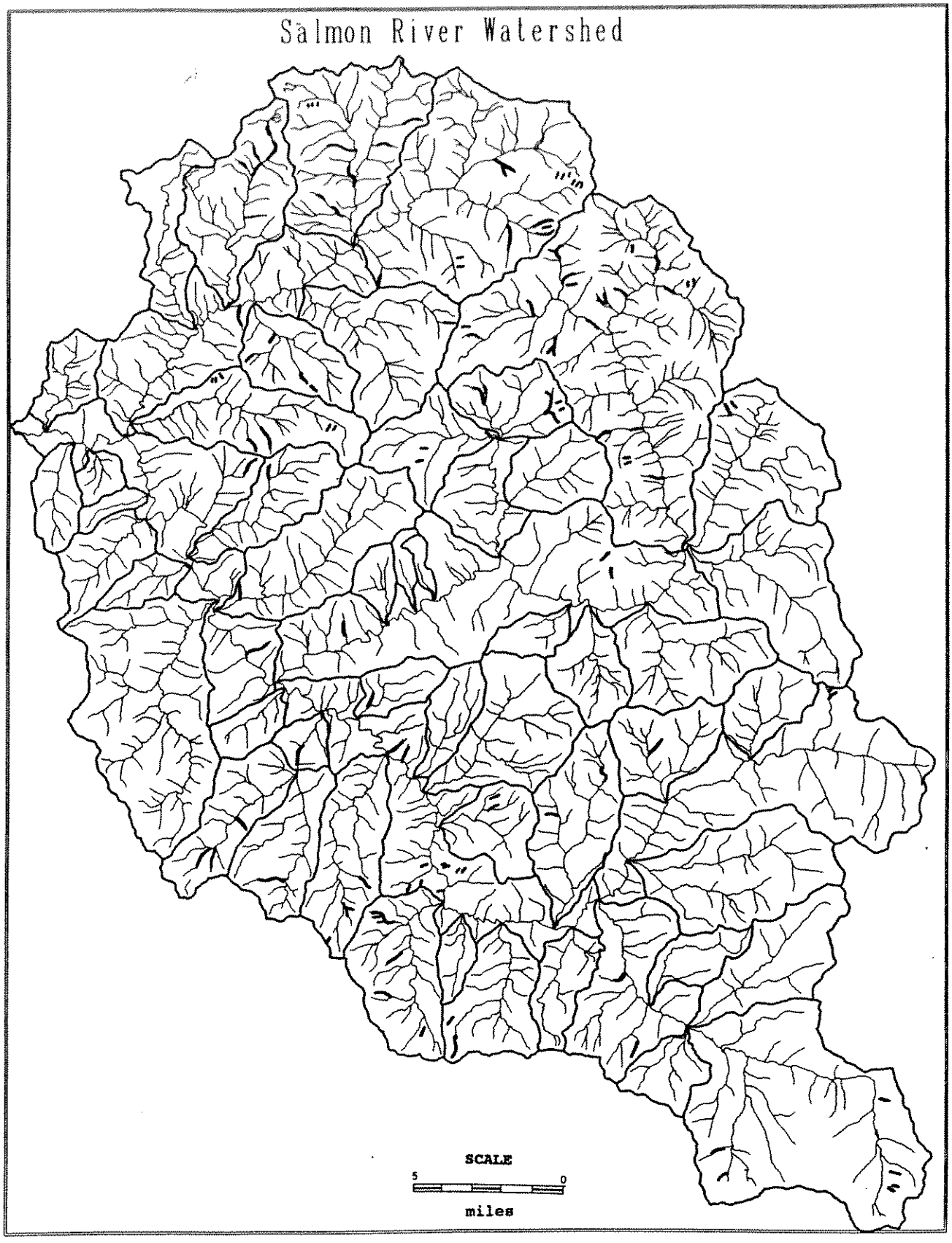


Figure 5-8. Scoured channels in the Salmon River watershed, visible on the 1955 air photos.

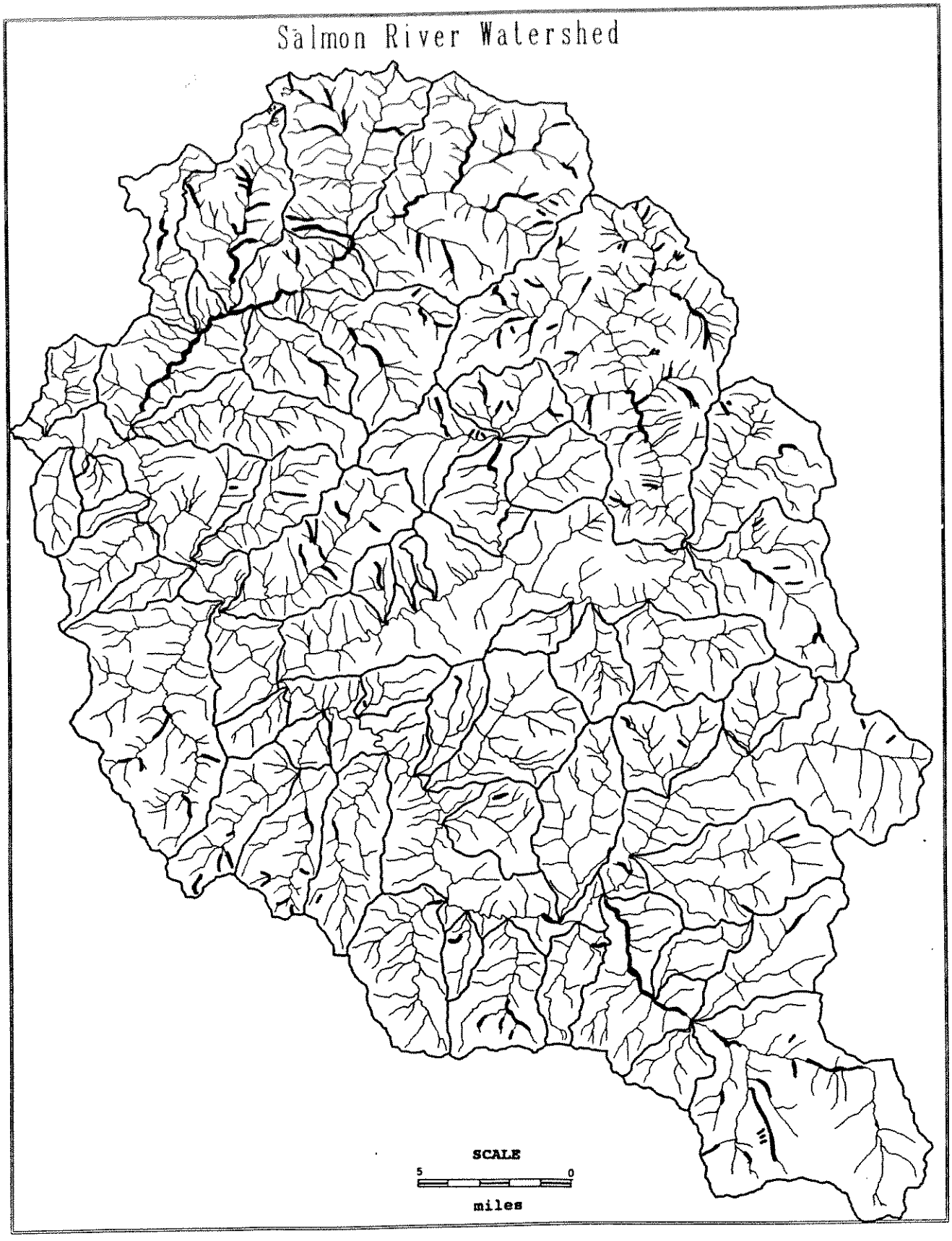


Figure 5-9. Scoured channels in the Salmon River watershed, visible on the 1964 air photos.

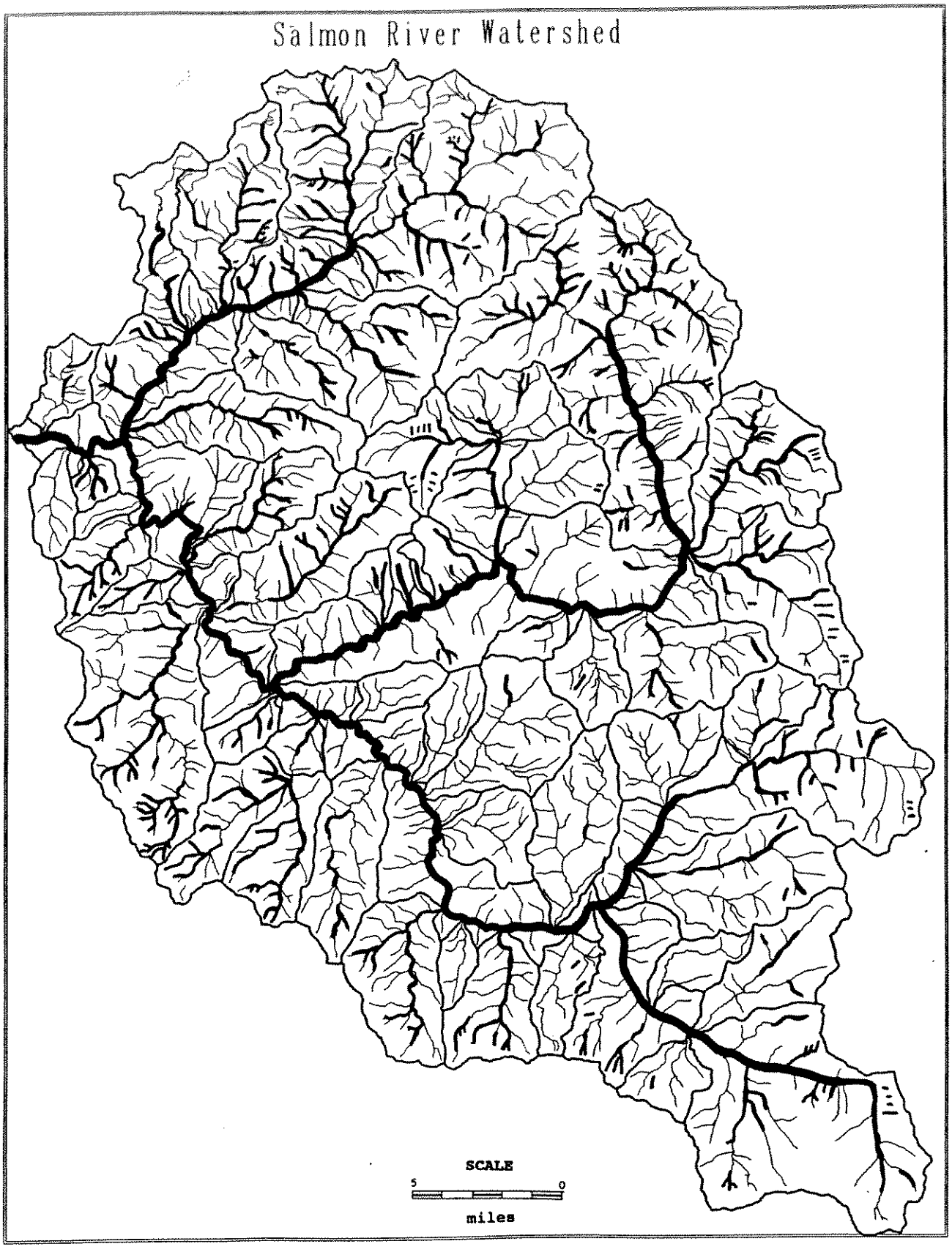


Figure 5-10. Scoured channels in the Salmon River watershed, visible on the 1965 air photos.

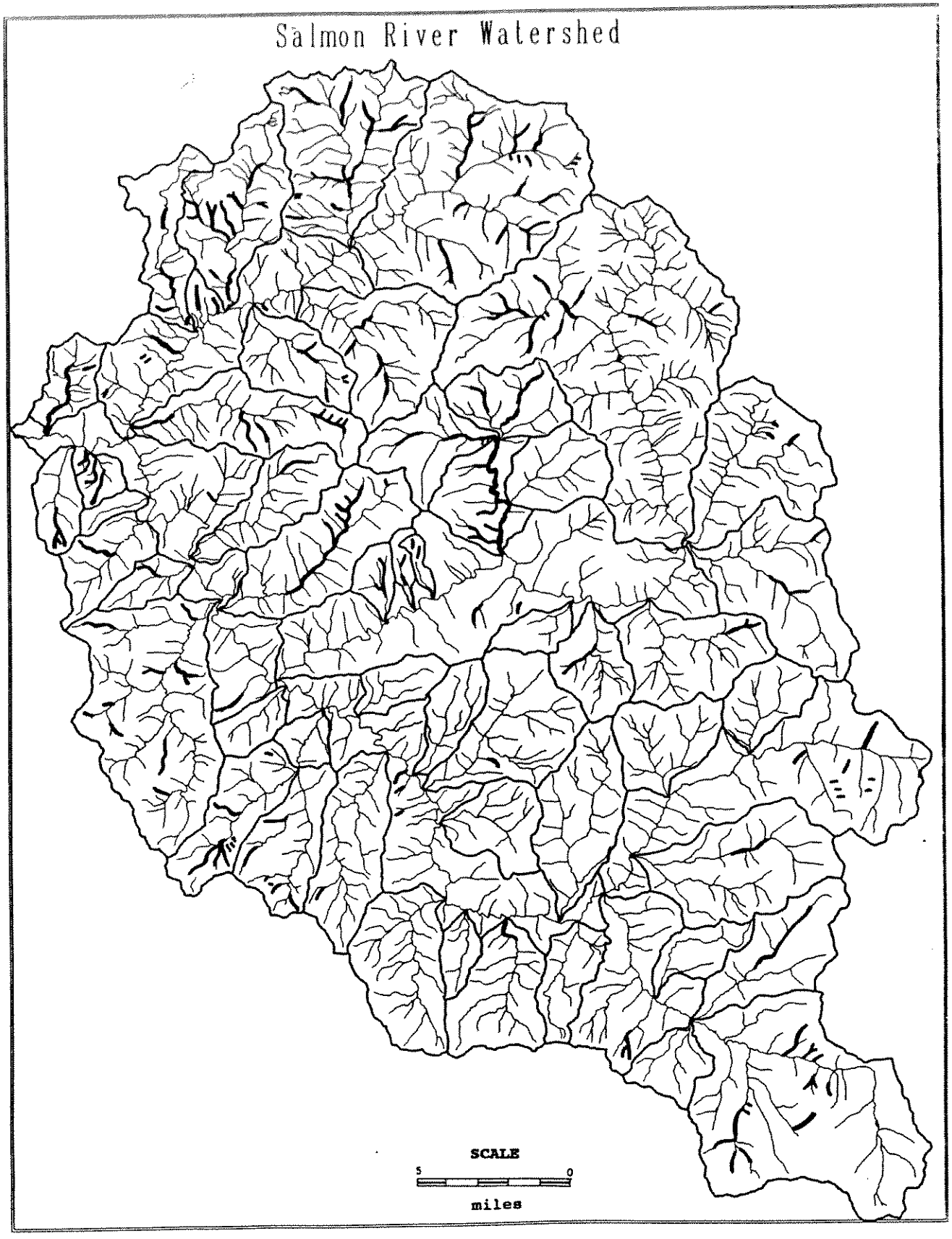


Figure 5-11. Scoured channels in the Salmon River watershed, visible on the 1975 air photos.

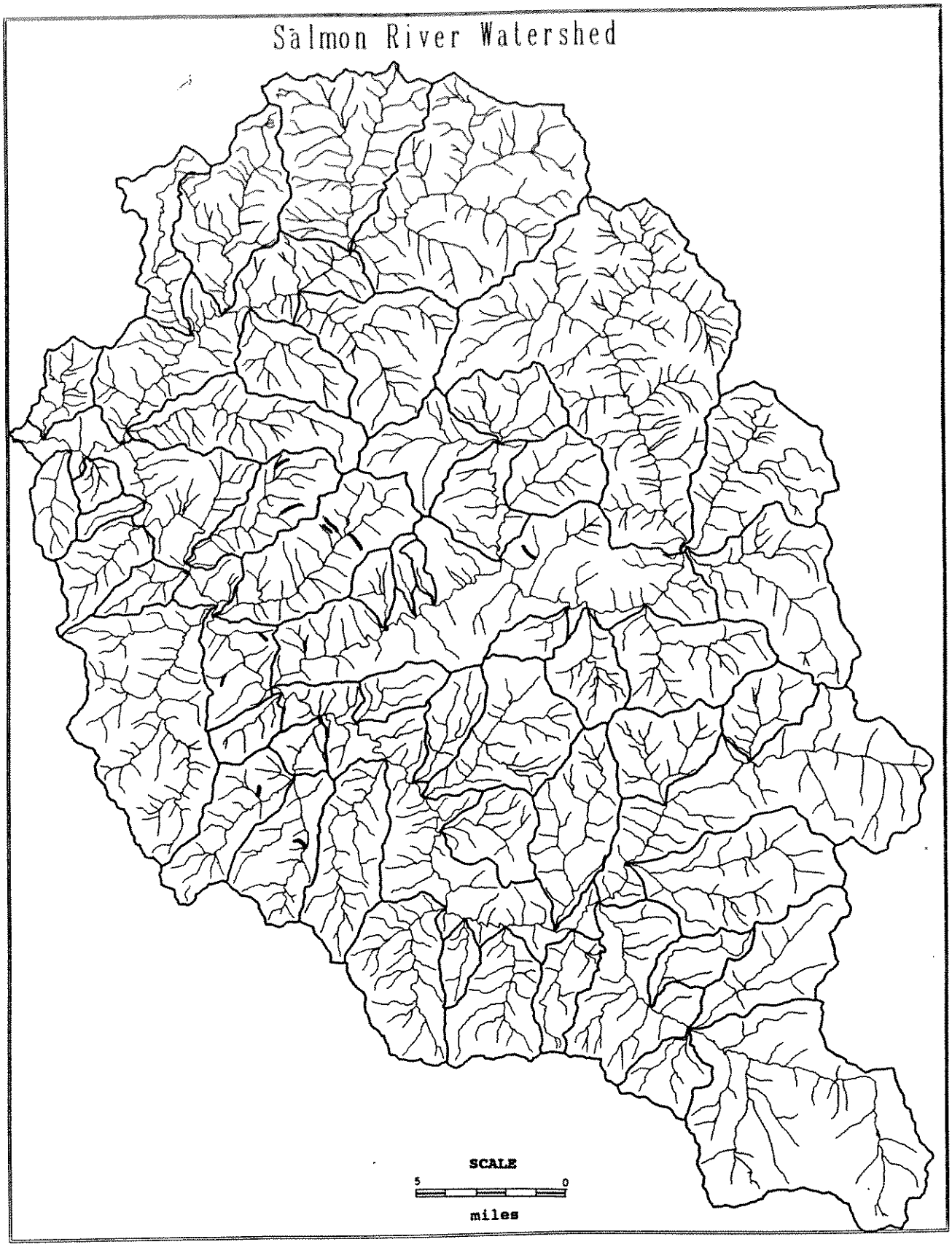


Figure 5-12. Scoured channels in the Salmon River watershed, visible on the 1988 air photos.

SEDIMENT PRODUCTION FROM MINES

Mining of river alluvium and older terrace deposits disrupted approximately 1,224 acres in the Salmon River Watershed. The volume of sediment generated was about 15.8 million cubic yards. This is a preliminary estimate which may be too low. Additional work is underway to refine the estimate. Mining activities in the South Fork contributed 50% of the total, the North Fork 30%, the Main Stem 20%, and Wooley Creek none. This activity resulted in major changes in channel configuration, particularly along the South Fork of the Salmon River, upstream from its junction with the East Fork.

SUMMARY

In the following sections, results of the sediment analysis of the Salmon River watershed are summarized covering the following topics: [a] total sediment production, and sediment sources; [b] distribution of landslides by geomorphic terrane; [c] distribution of landslides by elevation, [d] and predicted future landslide rates.

Sediment Production and Sediment Sources, 1904-1988

Over the period 1904-1988, a total of 27.7 million yds^3 sediment entered the stream system of the Salmon River watershed **[Figure 5-13]**. Mining activities and landslides are the primary sediment sources during this period, with mining contributing 15.8 million yds^3, and landslides contributing 10.4 million yds^3. The results indicate an average annual landslide volume over the 84 year period of approximately 1.24 thousand yds^3 per year; calculated on an area basis, the average rate is 0.26 yds^3/acre/year in the watershed. Landslides caused by the 1964 flood delivered 6.05 million yds^3 to channels, or 58% of the total landslide volume over the whole period **[Figure 5-14]**.

Landslide production rates during the period 1904-1988 for the 57 sub-basins of the Salmon River watershed are shown in **Figure 5-1**. Rates were highest in portions of the Main Stem and South Fork of the Salmon River [McNeil Creek, West Fork of Knownothing, Nordheimer Creek, Monte Creek, and Lower Main Stem].

Surface erosion sources are estimated to have delivered approximately 1.5 million yds^3 of sediment from 1904-1989; the average annual sediment yield is 0.04 yds^3/acre/year. Surface erosion was accelerated after major fires **[Figure 5-15]**. In the year immediately following the 1987 wildfires, 105,100 yds^3 of sediment was delivered to channels by surface erosion processes in the Salmon basin.

Mining and landslides are the major sediment sources contributing 57% and 38% of the total sediment volume from 1904-1989 **[Figure 5-16]**. Surface erosion contributes 5%; channel erosion was not quantified in this study. Among landslides, those occurring in undisturbed land comprise 67% of the total volume; landslides related to roads are the second major volume source, accounting for 30% of the volume. Landslides related to harvest and fire disturbance comprise 2% and 1% respectively. A total of 3368 acres of land were damaged as a result of landslides, mining activities, and channel erosion **[Figure 5-16]**.

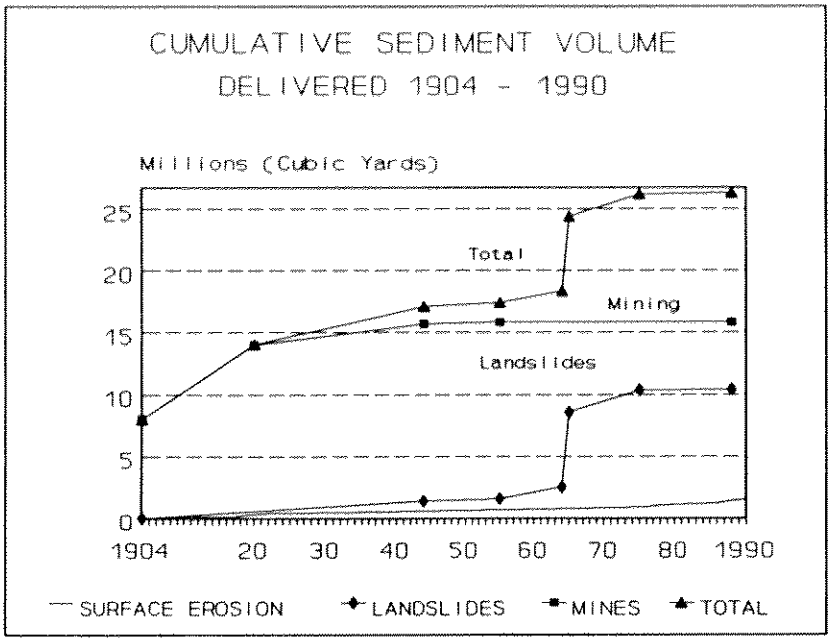


Figure 5-13. Cumulative sediment volume delivered to channels, Salmon River watershed, 1905-1990.

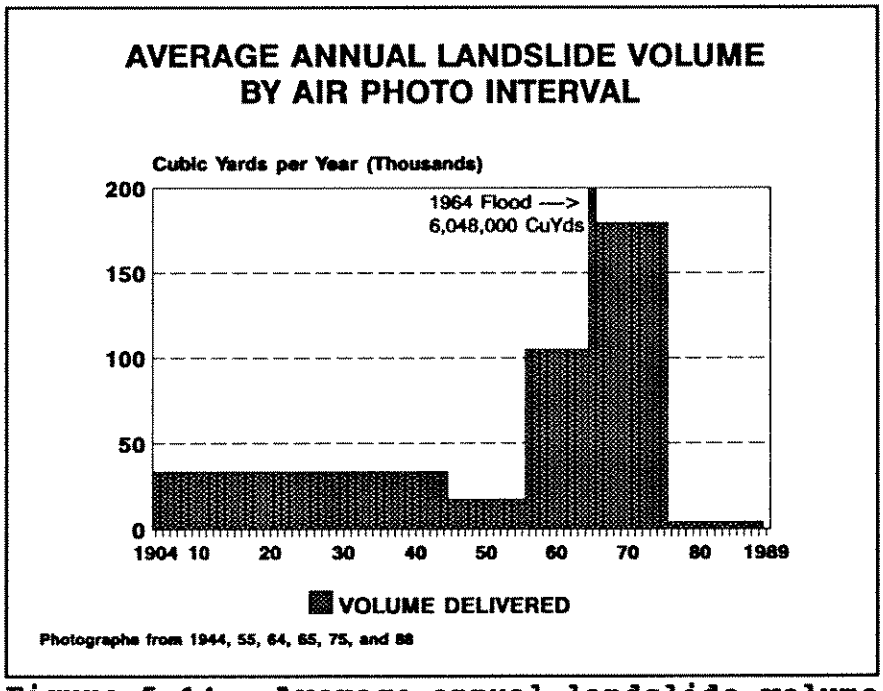


Figure 5-14. Average annual landslide volume by air photo year.

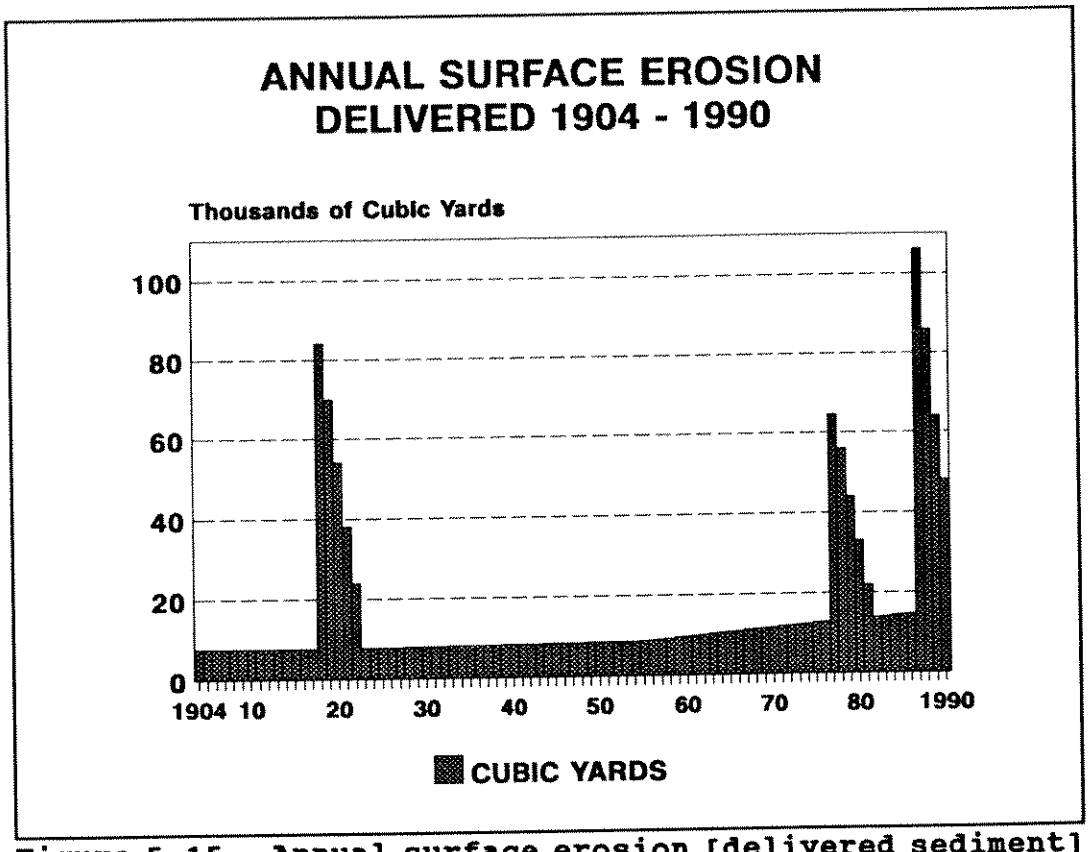
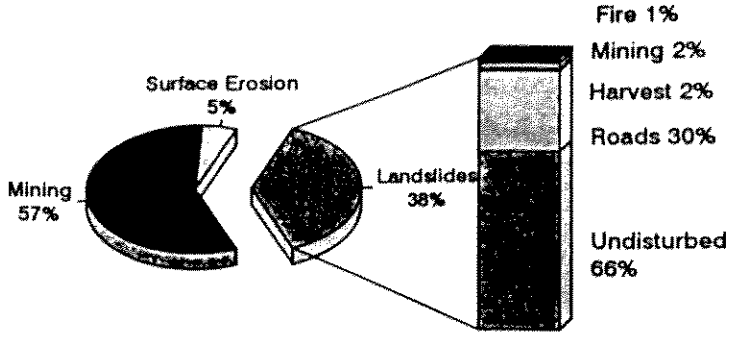


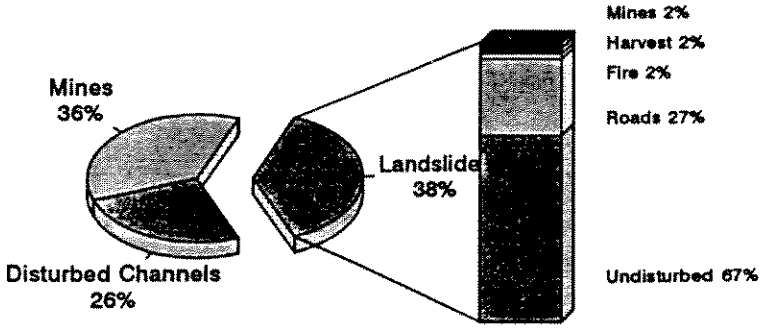
Figure 5-15. Annual surface erosion [delivered sediment] for Salmon River watershed, delivered 1904-1990.

Sediment Production, 1904-1989



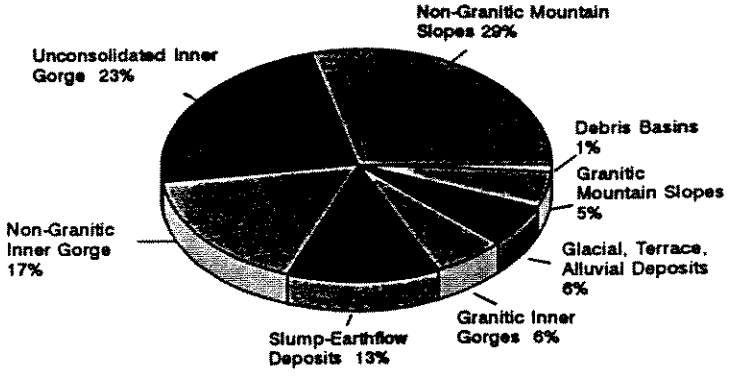
Total Volume = 27.7 m. cu.yds.
Mining = 15.8 m. cu.yds. Landslides= 10.4 m. cu.yds.
Surface Erosion = 1.5 m. cu.yds.

Disturbed Areas [Acres]: Landlsides, Channels, Mining, 1904-1989



Total Acres = 3368
Landslide = 1253 acres; Mining = 1224 acres
Disturbed Channels = 891 acres

Distribution of Landslides by Geomorphic Terrane, 1904-1989



Total Volume = 10,400,000 cubic yards

Figure 5-16. Charts of sediment production, area of disturbed land, and distribution of landslides by geomorphic terrane, 1904-1989.

Distribution of Landslides by Geomorphic Terrane

This study revealed that landslide sediment production is greatest within inner gorges [geomorphic terrane types 9, 10, and 11] and in non-granitic mountain slopes [geomorphic terrain types 6 and 8]. Note that inner gorges [all three types] comprise approximately 17% of the land area in the watershed. Non-granitic mountain slopes make up about 49% of the watershed. Inner gorges account for 46% of the total volume and non-granitic mountain slopes account for 29% of the total volume **[Figure 5-16]**. Slump-earthflow deposits comprise 13% of the total volume. The landslide rate in yds^3/acre related to geomorphic terranes is greatest within inner gorges in unconsolidated materials [geomorphic terrane type 9] which yield more than 220 yds^3/acre [see **Table 5-3**]. Slump-earthflow deposits, granitic inner gorges, and non-granitic inner gorges yield from 34 to 43 yds^3/acre [see **Table 5-3**].

Landslide Occurrence and Elevation

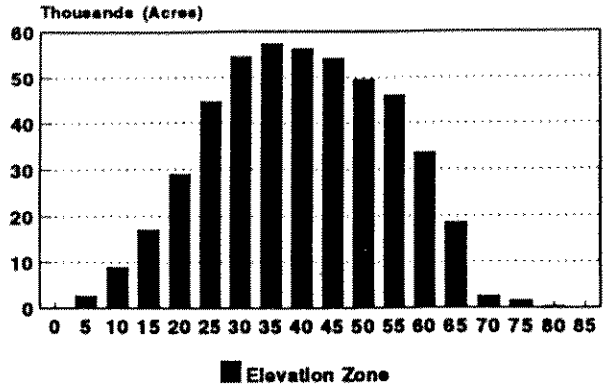
There is a pronounced concentration of landslides in specific elevation zones for different periods of the air photo record **[Figure 5-17]**. The 1964 flood produced landslides concentrated in the 4500-5500 elevation range. From 1965-1975, landslides were concentrated at elevations from 2000-3500 feet, and prior to 1944, they were concentrated from 3500-4500 feet. These patterns suggest that rain-on snow processes may play an important role in landslide distribution, and that elevation zones may provide useful means of refining the delineation of geomorphic terranes.

Future Sediment Production

The landslide model predicts that if a climatic sequence like that of 1965-75 were to begin in 1992 under existing disturbance levels [1989], the Salmon River watershed would produce 2,684,238 yds^3 of landslide-derived sediment, or about 5.6 yds^3/acre. This equates to 0.56 yds^3/acre/year. Sediment delivered to channels from surface erosion is estimated at a total of 210,000 yds^3, 0.44 yds^3/acre, or 0.04 yd^3/acre/year. Both these estimates assume no new disturbances in the watershed. In comparing these two values, it should be noted that the landslide volume is based on the assumption of a relatively wet period [like that of 1965-1975] whereas the surface erosion is based on annual averages. The predicted landslide sediment rate within the 56 sub-watersheds of the Salmon River is shown in **Figure 5-5**. The highest rate would occur in sub-watersheds of the South Fork, North Fork [Big Creek and Olsen Creek], and Main Stem Salmon sub-basins. These areas have been extensively disturbed by the Hog fire and the wildfires of 1987.

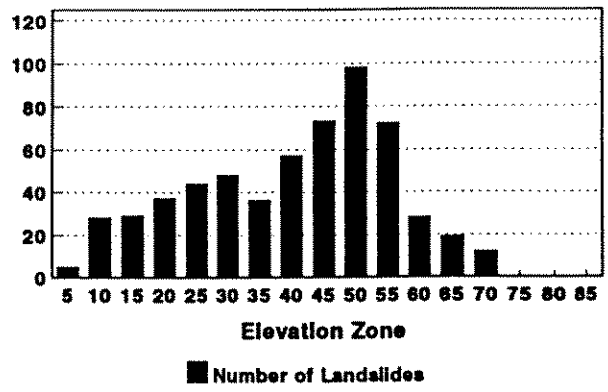
The landslide model predicts that in an undisturbed condition, the Salmon River basin would produce 1,332,481 yds^3 of landslide material, about 2.8 yds^3/acre , or 0.28 yd^3/acre/year **[Figure 5-18]**. The highest sediment rates occur in watersheds that have large areas of slump-earthflow deposits, and inner gorges. Surface erosion for undisturbed conditions is predicted to be 7,690 yd^3, or 0.016 yds^3/acre/year.

Salmon River
Area (Acres) By Elevation Zone



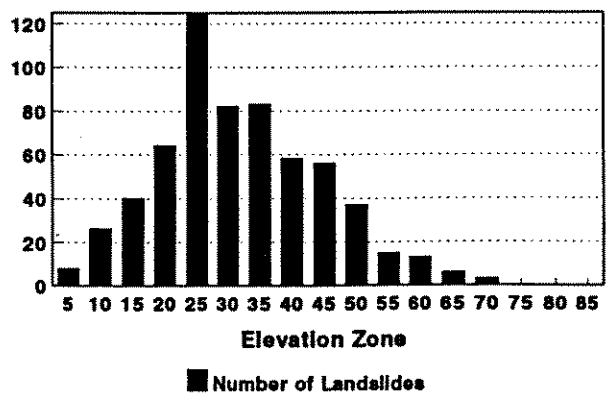
Note: 10= 1000 - 1499 Foot Elev.

1965
Landslides vs Elevation



Note: 10= 1000 - 1499 Foot Elev.

1975
Landslides vs Elevation



Note: 10= 1000 - 1499 Foot Elev.

Figure 5-17. Distribution of landslides by elevation zones in the Salmon River watershed.

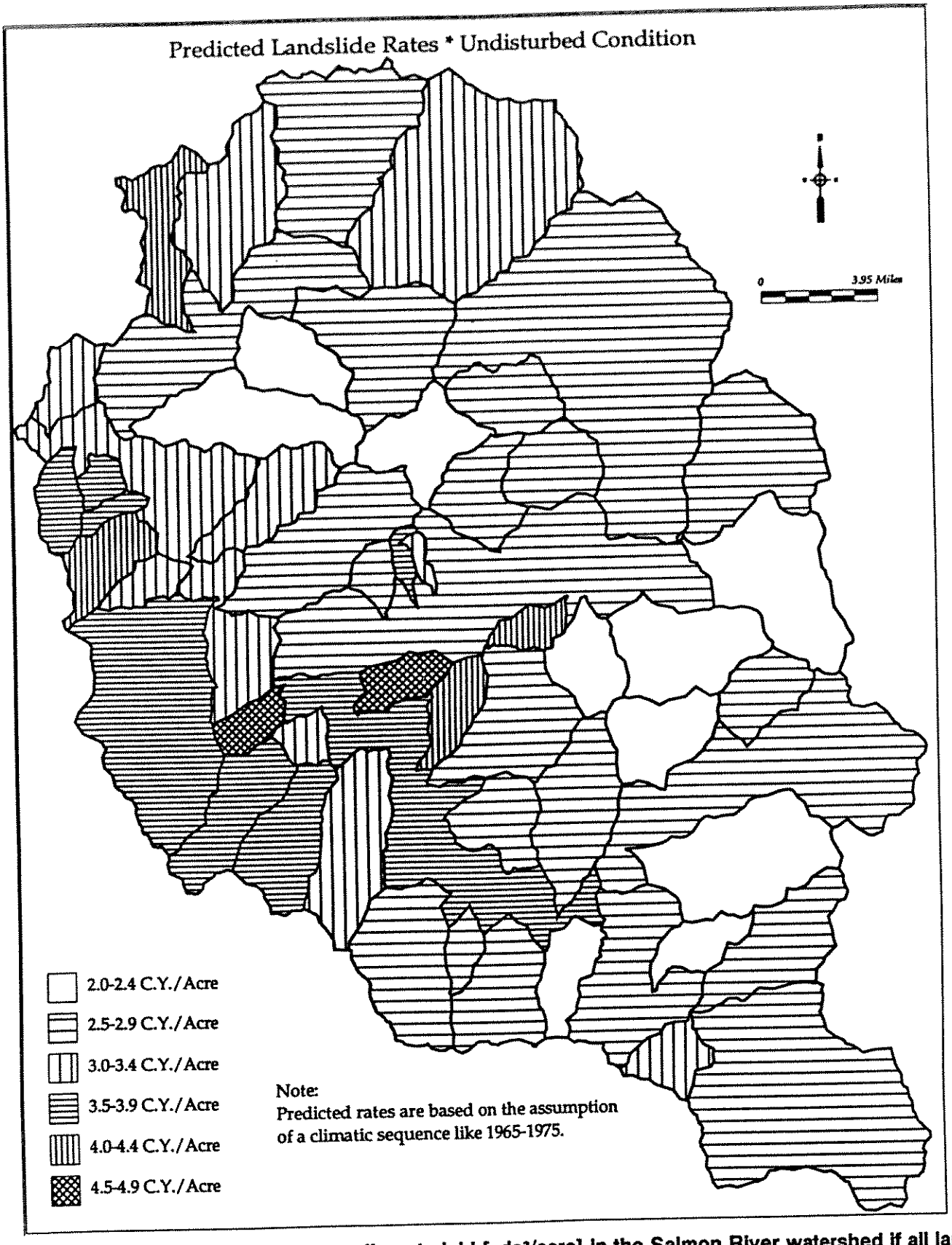


Figure 5-18. Predicted landslide sediment yield [yds³/acre] in the Salmon River watershed if all lands were undisturbed.

Chapter 6 - Flood History of the Salmon River: Results and Analysis

Historical records and flow data reveal that large floods occurred in the Klamath River system in the winters of 1861-62, 1889-90, and 1964-65. Based on limited information for the older floods, it is estimated that the 1861 flood was the largest, followed by 1964, and 1890 [Coghlan, 1984].

CLIMATE, FLOODS, AND LANDSLIDE EPISODES

The distribution of precipitation over time influences landslide and surface erosion processes, which in turn affect water quality and the condition and structure of stream channels. Channel condition and structure is affected primarily by landsliding. Precipitation records from Orleans, California, on the Klamath River approximately 10 miles from Somes Bar, date back to 1904. Data on annual precipitation and cumulative departure from average annual precipitation show that during dry periods, the annual precipitation is about 45 inches; for wet periods, the average is 55 inches [Baldwin and de la Fuente, 1986], **[Figure 6-1]**. The Orleans record, along with other records from Northern California [Coghlan, 1984], indicate that the period from 1870 to 1910 was a wet time; the period 1911 - 1937 dry; the period 1938-1975 wet; and 1976 to the present dry.

Flow records for the Somes Bar gaging station [USGS Station #11522500, near the mouth of the Salmon River] are available back to 1912. Peak flows [1 day maximum] in excess of 40,000 cfs occurred in the winters of 1952-53, 1955-56 [1955 flood], 1964-65 [1964 flood], 1969-70, 1970-71, 1971-72, and 1973-74 **[Figure 6-2]**. The highest flows occurred during the 1964 flood [100,000 cfs] and the 1955 flood [63,700 cfs].

EFFECTS OF FLOODS AND STORM EVENTS ON STREAM CHANNELS

Widespread channel modification occurred in association with floods and storm flows in the 1960's and 1970's. A survey of air photos taken in 1944, 1955, 1964, 1965, 1975, and 1988 [partial coverage] provided an assessment of the effects of the floods of 1955, 1964, and storm events occurring between 1965 to 1975. A brief summary of observations follows. Refer to Chapter 8, under the heading Effects of Landslides, Floods, and Peak Flows: Findings of the Air Photo Survey, for a more detailed description.

Air photos from 1944 revealed that most channels were well vegetated with a mixture of hardwoods and conifers. Disturbed channels were rare, and occurred primarily in the headwaters of the North Fork. The highest recorded flow prior to 1944 occurred in 1927 [approximately 37,000 cfs]. There may have been a larger peak flow in 1904 [since total precipitation was higher that year], but no flow information exists for that year.

The flood of 1955 is manifest by disruption of riparian vegetation on several tributary streams and by localized aggradation and scour visible on 1964 photos [the first photos available after the flood]. It is possible that some of these effects were caused by high flows some time between 1955 and 1964. However, this is unlikely, since the maximum peak flow recorded from 1955 to 1964 was only about 25,000 cfs. Landsliding associated with the 1955 flood [excluding the Murderers Bar Landslide] was relatively small [342,630 yds^3]. The Murderers Bar Landslide produced another 599,041 yds^3, and temporarily dammed the river. The most concentrated channel disturbance was seen in lower Wooley Creek and the South Fork, above its confluence with the East Fork **[Figure 5-6]**.

The 1964 flood caused major channel alterations along the main stem of the Salmon River and most of the major tributaries **[Figure 5-7]**. This included channel migration, aggradation, scour, and widespread loss of riparian vegetation. Most low-gradient floodplains were stripped of riparian vegetation, and covered with fresh sediment. High gradient reaches experienced both scour and aggradation. Loss of fish habitat due to deposition of sediment and destruction of riparian vegetation is clearly apparent on aerial photographs.

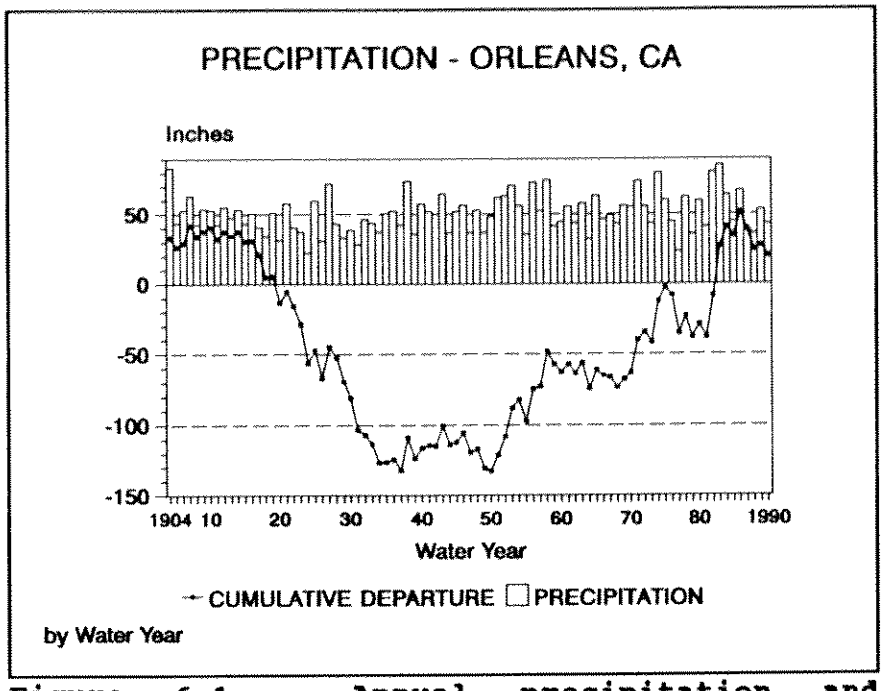


Figure 6-1. Annual precipitation and cumulative departure from average annual precipitation at Orleans, 1904-1990.

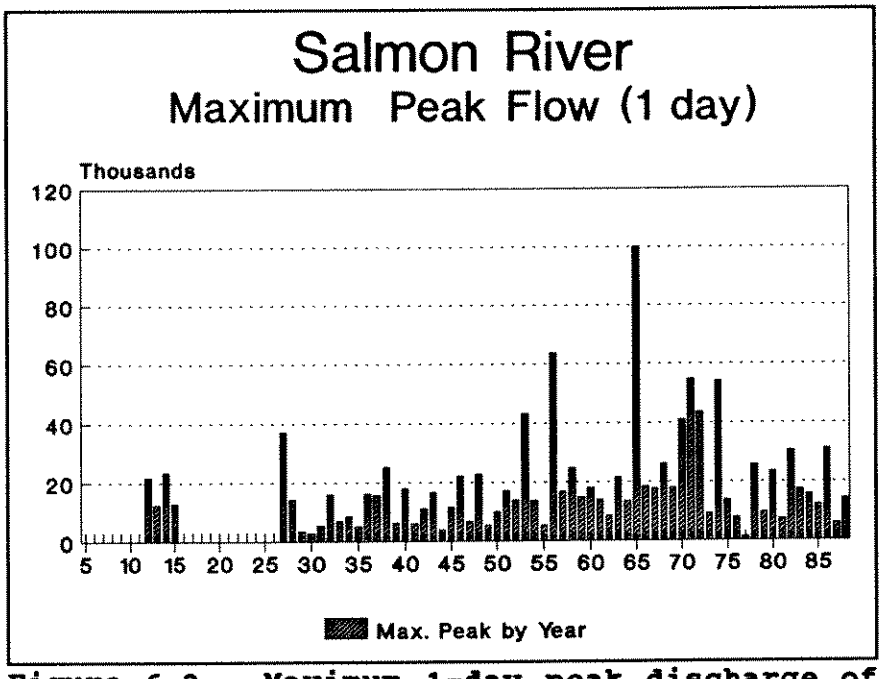


Figure 6-2. Maximum 1-day peak discharge of the Salmon river at Somes Bar station, 1904-1988.

Storm events known from 1965-1975 caused damage which was similar to that of 1964, but it was much less severe in most areas, and more localized. Concentrations were observed at Crapo Creek, Little North Fork, Bridge Creek, Haypress Creek, and the South Fork of the Salmon above Rush Creek where a large debris slide entered the river from a tributary on the north side of the River **[Figure 5-8]**.

During the time interval from 1975-1992, no major floods occurred, allowing vegetation to recover to varying degrees along streams and rivers.

FLOOD EVENTS AND MINING

Hydraulic mining significantly altered the main river channels, changed the vegetation in the channel area [due in part to removal of soil down to bedrock], and delivered more than 15 million yds^3 yards of sediment to the river. One of the most disturbed areas was the upper South Fork of the Salmon River, above its junction with the East Fork. These channel modifications likely influenced the response of the channels to later floods.

Chapter 7 - Relationship between Fish Habitat and Sediment Production: Results and Analysis

REGRESSION ANALYSIS

Regression analyses of fish habitat variables and sediment volumes showed little association between sediment yields and the following attributes: % embeddedness, substrate composition [% fines, % gravel, % cobble, % boulder, % bedrock], number of primary pools, and % riparian shade. Values for the fish habitat attributes were grouped within primary habitat types of Pool, Run and Riffle. Sediment production from landslides and surface erosion was compared to the habitat attributes described above for 12 sub-watersheds. Landslide volumes used in the analysis were those measured in the air photo inventory from 1944-1988 and 1975-1988. Soil volumes used for comparison were derived from the USLE model based on 1988 disturbance levels. Habitat attribute values were also analyzed against the area [acres] of landslides and granitic terrane. Shade values were compared to sediment yields [$yds^{3©}$/acre] and the area of granitic terrane to determine if a measurement of riparian vegetation conditions could be correlated with sediment yields or amount of granitic terrane within a basin.

In most cases less than 25% of the variance in habitat attributes could be associated with sediment yields from landslides and surface erosion. The lack of associations observed may be because the stream systems within the basin have stabilized since the major channel altering events of 1955, 1964, and 1972. Studies in the area suggest that channels may stabilize 5 to 30 years after a major episode [Lisle, 1981; Lisle, 1992, personal communication]. The habitat-condition evaluations were conducted between 1988-1991, at least 24 years since the 1964 flood. Unfortunately, pre-episode data, comparable with that collected between 1988-1991, is not available.

Another reason strong associations were not found initially between habitat attributes and the amount of sediment produced within the sample drainages was that habitat variables were not specifically designed to be related to sediment inputs. Of the habitat attributes, embeddedness is considered as being linked most closely to sediment supply, but this attribute is difficult to sample and measure. The spatial distribution of landslides relative to reaches where habitat data was collected was also not accounted for. It is impossible to differentiate the effects of nearby landslides on channels from the effects of distant landslides. The small sample size [only 12 comparisons] is another factor limiting the usefulness of the analysis.

GRAPHICAL ANALYSES

In addition to the statistical analyses, graphical analyses were also performed: scatter-plot diagrams produced for sediment yield levels and habitat attributes did not show strong relationships. The sediment yield rates [yds^3/acre] from surface erosion [annual rate for 1988], were graphed against the percent presence of substrate components and percent embeddedness. In addition, scatter plots were made graphing the the total sediment yield/acre from landslides over the periods 1944-1988 and 1975-1988 against percent embeddedness and substrate components.

The graphical analyses were done for each major habitat type: Run, Riffle, and Pool. The scatter-plots showed considerable scatter, [as verified by the results of the regression analysis], but some trends could be established. Overall, the results were consistent for each major habitat type. The scatter-plot diagrams and lines of best fit [trend lines] showed that high values of sediment yield/acre from landslides and surface erosion were associated with high percentages of embeddedness, fines, and gravel substrates. In addition, high values of sediment yield/acre were associated with low percentages of cobble and boulder substrates. In Riffle habitat types, high bedrock values were associated with high sediment values, but in Pool and especially in Run habitat types, no association was shown.

SUMMARY

Despite the fact that landslide episodes in the 1960's and 1970's are known to have caused severe habitat damage [air photo observations, this study, and historical accounts], habitat condition data from surveys conducted from 1988 to 1991 did not reveal strong correlations between high sediment production and habitat condition. This observation suggests that the habitat, at least in the sampled watersheds, has recovered from the effects of the landslide episodes. Low sediment production rates since 1975, associated with a dry period, probably influenced this recovery. Another factor which probably influenced these findings was that the habitat surveys were not designed specifically to address the effects of sediment on fish habitat. The opportunity exists to design future inventories to address this question.

Chapter 8 - Effects of Roads, Harvest and Fire on Sediment Production; Watershed Response to Floods and Landslides: Results and Analysis

LANDSLIDE RATES AND DISTURBANCES: ROADS, HARVEST, AND WILDFIRE

Roaded lands in the Salmon River Watershed produced landslides at a rate 108 times greater than undisturbed land during the 1964 flood, and 59 times greater than undisturbed during the storms from 1965-1975. Harvested lands exhibited landslide rates 3-12 times higher than undisturbed land during the floods of the 1960's and 1970. For example, from 1965-1975, each acre of harvested land delivered 7 yds^3 of sediment to the channel system, while each undisturbed acre delivered 3 yds^3. Due to the fact that there were no landslide-producing storms after the fires of 1977 and 1987, there is insufficient data to reasonably characterize fire-associated increases in landslide production. **Table 8-1** displays landslide rates in yds^3 acre for undisturbed, roaded, and harvested land. Separate rates are given for the 1964 flood, and for the combined storm events that occurred during 1965-1975.

Table 8-1. Landslide rates associated with roaded, harvested and undisturbed lands in the Salmon River watershed. The factor of increase over the undisturbed rate is also given. Landslide rates are area-weighted basin averages.

Flood Event	Type of Disturbance	Landslide Rate [yds^3/acre]	Increase over Undisturbed Rate
1964 Event	Roads Harvest Undisturbed	909.4 96.8 8.4	X 108.2 X 11.5 X 1.0
1965-75 Events	Roads Harvest Undisturbed	158.0 6.8 2.7	X 59.4 X 2.6 X 1.0

Detailed field studies and landslide measurements in the Little North Fork of the Salmon River revealed that landslide rates associated with roads and harvest vary considerably among different geomorphic terranes. For example, during the period from 1965-1975, clearcut lands within the granitic inner gorge terrane [# 10], produced sediment from landslides at a rate 20 times greater than landslides in undisturbed lands. The rate was 254 times greater than the undisturbed rate when these lands were roaded. Similarly, clearcut lands within the steep granitic mountain slope terrane [#4] produced sediment from landslides at a rate 5 times greater than the undisturbed rate, and roaded areas produced landslides at a rate 156 times greater than undisturbed areas.

The Bloomer landslide, a large landslide which occurred in 1964 in the Lower Main Stem sub-watershed, delivered about 1.4 million cubic yards of sediment to the Salmon River. Since the Salmon River road pre-dates the landslide, it is therefore assumed to be associated with it. The large volume of sediment delivered by this landslide greatly influences the road-associated landslide rate which was computed for the entire Salmon River watershed. If this landslide is removed from consideration, the landslide rate for roaded land decreases from 909 to 199 yds^3/acre, and the increase over the undisturbed rate decreases 108 to 24 times.

SURFACE EROSION RATES AND DISTURBANCES: ROADS, HARVEST, AND WILDFIRE

Annual surface erosion yields were computed for sub-watersheds of the Salmon River at various time periods including: 1986-1987, 1987-1988, and 1991-1992. This was done to evaluate the fluctuations in surface erosion in response to initial disturbances and vegetative recovery of disturbed areas. Disturbances for which recovery factors have been applied include the Hog Fire of 1977, the wildfires of 1987, and timber harvest. Recovery factors were not applied to roads.

Surface erosion rates for 1986-1987 pre-wildfire conditions range from a low of 0.017 yds^3/acre in undisturbed lands of the Salmon River watershed to a high of 0.49 yds^3/acre on roads **[Table 8-2]**. Roads, which occupy 1 percent of the area, contribute from 48 to 53 percent of the delivered sediment from surface erosion in three of the four sub-basins of the Salmon River watershed which are roaded **[Table 8-3]**. Undisturbed lands are the second largest producer of sediment, the majority of which comes from lands within the inner gorge.

Increases in the amount of delivered sediment from surface erosion sources over undisturbed conditions vary dramatically by the level of watershed disturbance. The Salmon River watershed was 94% over undisturbed surface erosion levels in 1986-1987 **[Table 8-3]**.

Table 8-2. Delivered sediment [yds^3/acre] from surface erosion sources for each disturbance group for 1986-87 pre-wildfire conditions.

Watersheds	Undisturbed	Roads	Plantations	Hog Fire	All Lands
SALMON	0.017	0.49	0.02	0.006	0.03
Main Stem	0.020	0.49	0.005	0.007	0.03
North Fork	0.015	0.48	0.04	0.006	0.03
South Fork	0.016	0.50	0.02	0.12	0.04
Wooley	0.019	0.38	0.01		0.02

Table 8-3. Distribution by percent, of surface erosion sources for 1986-1987 pre-wildfire conditions.

Watershed	Undisturbed	Roads	Plantations	Hog Fire	Increase Over Undisturbed Rate, [%]
SALMON	46	49	2	3	+94
Main Stem	34	48	1	17	+45
North Fork	43	52	4	1	+90
South fork	35	53	1	11	+174
Wooley	87.5	12	0.5	-	+36

Annual delivered sediment in 1987-1988, following the 1987 wildfires, indicates that burned areas contribute the largest proportion of sediment. Areas burned by the 1987 fires comprise 23% of the total watershed area, and are responsible for 87% of the total delivered sediment in the Salmon River watershed **[Table 8-4]**.

Table 8-4. Distribution of delivered sediment [by percent] from surface erosion sources for each disturbance group for 1987-88 post-wildfire conditions.

Watersheds	Undisturbed	Roads	Plantations	Hog Fire not burned in 1987	Hog Fire reburned in 1987	1987 Fires
SALMON	5	7	0.3	0.2	34	53
Main Stem	1	2	0.03	1	53	44
North Fork	7	9	0.1	0.1	61	22
South Fork	7	14	0.3	1	17	60
Wooley	7	1	0.05			92

Notes: Assumes no harvesting and site preparation in fire areas.

The soil model predicts that for the time period 1991-1992, there is a reduction of the total sediment delievered in the Salmon River watershed due to vegetative recovery of areas damaged by wildfire. Erosion in burned areas is still responsible for 44% of the total erosion in the watershed, which is a 77% reduction from the 1987-1988 conditions **[Table 8-5]**.

Table 8-5. Delivered sediment [yds³] from surface erosion sources for each disturbance group for 1991-92 post-wildfire conditions. The percent reduction from 1986-1987 erosion levels is also given.

Water-sheds	Undisturbed	Roads	Plantation	Fire	1991-1992 Total	1987-1988 Total	% Reduct-tion from 1987 - 1988 Levels
SALMON	5386	7392	277	10899	23,954	106,190	77
Main Stem	299	778	11	2767	3,855	33,519	77
North Fork	1615	2049	155	1473	5,292	22,463	76
South Fork	2146	4318	101	4801	971	29,959	62
Wooley	1356	247	10	2093	3,706	19,153	81

Notes: Fire includes: Hog Fire, not burned in 1987; Hog Fire reburned in 1987; and 1987 wildfires. Vegetative recovery factors were applied to areas burned by fire and plantations. The totals assume no harvesting and site preparation in fire areas.

The 1987 wildfires, produced 87% of the total surface erosion-related sediment in 1987-1988. This is 12 times greater than the sediment produced by road-related surface erosion. The soil model predicts that the annual sediment production rate [surface erosion] immediately after the 1987 fires is about 14 times greater than the undisturbed rate. In the period 1991-1992, it predicts that the sediment production rate is about 3 times greater than the undisturbed rate. It will take 20 years without wildfire or other disturbances for sediment yields from surface erosion to be reduced to the pre-wildfire levels of the period 1986-1987.

The major management-related sediment source is from roads. Roads comprise 1% of the watershed and produce 49% of the total sediment where wildfires are not a factor, such as in 1986-1987.

EFFECTS OF LANDSLIDES AND FLOODS: FINDINGS OF THE AIR PHOTO SURVEY

A survey of air photos taken in 1944, 1955, 1964, 1965, 1975, and 1988 [partial coverage] provided an assessment of the effects of the 1964 flood and also those which occurred between 1965 and 1975. Refer to **Figures 5-7 to 5-12** which identify disturbed channels by photo year.

In 1944, virtually all tributaries to the Salmon River supported dense vegetation adjacent to the streams, including conifers. Active landslides were rare, and roads were limited to the main river routes and the mining areas of Black Bear, King Solomon, and Eddy Gulch. Approximately 910 acres of road are present. The only logging evident is associated with private land and mining. Small recent fires were identified in scattered areas. Large hydraulic mines were evident along main tributaries, and the upper South Fork near Petersburg is the most affected area. Active and recent landslides, primarily debris slides occupied about 212 acres.

In 1955, an additional 38 acres of active landslide were identified, raising the total to 250 acres. Riparian areas remain little changed from 1944. Approximately 1000 acres of road were present, and logging of irregular patches first appear in the South Fork of the Salmon. A limited amount of new, small scattered burned areas are evident. The largest of these is in Boulder Creek along the North Fork of the Salmon River. A few channels appear to be recently scoured by high flows and debris torrents, but main tributaries are little changed from 1944 appearances. A moderate sized fire occurred this year, but does not appear on the air photos because they were taken a short time before the fire. This fire is discussed below under the 1964 photo observations.

In 1964, new landslide area amounts to 115 acres, raising the total to 365 acres. About 1858 acres of road and 1470 acres of timber harvest are present. A large [60 acres] landslide at Murderers Bar on the main stem of the Salmon River is visible. This landslide temporarily dammed the river, and a remnant pool is evident upstream from the landslide. In addition to more small, scattered fires, a 5,290 acre fire is evident on the East Fork of the Salmon, including part of Six Mile Creek. Lower Wooley Creek and the South Fork of the Salmon above its confluence with the East Fork exhibit new disturbances to the channels and riparian vegetation, probably associated with the flood of 1955. Several smaller tributaries also exhibit disturbed riparian vegetation, but the effect was localized, and the majority of the channels were not noticeably disturbed.

In 1965, large scale modification of riparian areas and channels is evident. Entire stream reaches up to several miles in length in creeks such as Steinacher, Big Elk, Little North Fork, Morehouse, Crapo, Nordheimer, McNeal, Knownothing and Taylor [North Fork] are stripped of riparian vegetation. Fresh new sediment deposits are visible in the low gradient reaches of these streams. A small landslide-formed lake in upper Nordheimer Creek was filled with sediment. New landslides occupy 615 acres, raising the total to 980 acres and scoured channels directly related to these landslides encompass an additional 650 acres. A large landslide near the Bloomer Mine [Bloomer Landslide] temporarily dammed the main stem of the Salmon River, greatly modifying the channel. The 1965 air photos reveal restricted flow. Another but smaller temporary landslide dam occurred on North Russian Creek. A considerable amount of landsliding and scoured channels are evident in the recently burned area on the East Fork [near Six Mile Creek]. Harvested area is similar to 1964, and 2008 acres of road are present.

In 1975 timber harvest increases to 7962 acres and roads increase to 2893 acres. The largest new fire is the Off Fire near the mouth of the Salmon River which burned about 9000 acres, a large proportion of which was at high and moderate intensity. New landslides occupy 261 acres, bringing the total to 1241 acres. Damaged riparian areas associated with these slides comprise an additional 127 acres. Landsliding is concentrated in certain watersheds, such as the Little North Fork where many landslides are associated with harvest units and roads. In 1965, about 67% of the landslide sediment delivered to the Salmon River was from undisturbed lands while in 1975, 72% was from undisturbed lands. The landslide dam which originally formed in the 1964 flood on North Russian is enlarged. A few large new debris slides originating in headwall areas are evident. The most prominent of these is in the headwaters of the South Fork Salmon River near Rush Creek. Several large landslides which were activated in by the 1964 storms have enlarged. The Big Elk

landslide, in the Wooley Creek Watershed [Big Elk Creek], grew considerably and appears on the air photos to have formed a temporary dam.

In 1988 major vegetative changes associated with the Hog Fire and the wildfires of 1987 are evident. Some of the harvested area was burned in the fires. New landsliding comprises 10 acres, raising the total to 1251 acres. New landslides are very limited in extent and size when compared to 1965 and 1975 photos. Areas scoured in 1964 have thick alder borders but barren floodplains created by deposition of sediment produced during the storms of the 1960's and 1970's are locally preserved. Due to the small photo scale used for this period [1:40,000], it is likely that some landslides were missed. Harvested lands comprise 30,000 acres which includes a considerable amount of overlap with burned areas. Roads occupy 3638 acres.

EFFECTS OF DEBRIS SLIDES ON CHANNELS

Shallow, rapidly moving debris landslides can affect streams or roads for long distances from the initiation site due to terrain steepness. They often mobilize water-charged debris which travels long distances down stream courses, removing riparian vegetation and road crossings. Channel disturbance can occur as a result of either scour of channel bed material or deposition of debris. The basin-wide air photo survey revealed that for each acre of debris slide in headwall areas [geomorphic terrane # 3], there were about of 1.4 acres of disturbed riparian land in the channel downslope. In contrast, for each acre of debris slide within the inner gorge only 0.14 acres of riparian area was disturbed downstream.

Landslides in undisturbed areas account for most of the damage to channels and riparian vegetation, resulting from the flood of 1964 **[Table 8-6]**. As disturbance to the watershed increased during 1965-1975, there is only a small increase in riparian acres damaged from landslides associated with roads or harvested land.

Table 8-6. Disturbance conditions related to damage of riparian areas by landslides in the Salmon River watershed. Areas damaged by landslides were measured from air photos.

Time Period	Disturbance	Riparian Acres Damaged
1964-1965	Roads	21.1
	Harvest	8.1
	Fire	33.9
	Undisturbed	587.2
1965-1975	Roads	28.1
	Harvest	10.2
	Mining	0.46
	Undisturbed	88.4

The basin-wide air photo inventory indicates that over the period from 1944-1988, 45% of the total acres of damaged riparian areas was from landslides in mountain slope terranes, which occupy 66% of the watershed, and 32% was from landslides in inner gorge terranes **[Table 8-3]**, which occupy 17% of the watershed. Landslides in debris basins produced 8% of the riparian damage, while occupying 2% of the watershed.

Table 8-7. Geomorphic terrane types and acres of riparian area damaged by landslides, 1944-1988.

Geomorphic Terrane	Riparian Acres Damaged
Granitic Mt. Slopes > 65% Slope	95.6
Granitic Mt. Slopes 0-65% Slope	58.2
Non-Granitic Mt. Slopes > 65% Slope	184.1
Non-Granitic Mt. Slopes 0-65% Slope	68.7
Debris Basins [Headwalls]	68.6
Inner Gorge Developed in Granitic Slopes	78.3
Inner Gorge Developed in Non-granitic Slopes	110.8
Inner Gorge Developed in Landslide, Glacial or Terrace Deposits	96.6
Slump-Earthflow Deposits	66.9
Slump-Earthflow Toe Zones	-----
Glacial, Terrace, & Fan Deposits	63.2

Field and air photo inventory in Little North Fork watershed revealed that landslides damaged a total of 68.4 acres of riparian vegetation along channels, or 100,800 linear feet of channel. Landslides associated with damaged riparian areas number 158 and encompass a total of 27.2 acres in the watershed. For every acre of landslide associated with an inner gorge or channel, 2.5 acres of riparian area was damaged. This ratio is much higher than the average for the Salmon River basin, and is probably due to the fact that much of the sliding occurred in high gradient channels in granitic colluvium, a material which typically fails by debris slide/flow processes, involving considerable channel disturbance downslope. Road and harvest-associated landslides in granitic inner gorges [geomorphic terrane # 10] damaged more than 13 acres of riparian area as a consequence of the 1972 storm events.

OLSEN CREEK DEBRIS BASIN: EFFECTS OF WILDFIRE ON SURFACE EROSION IN GRANITIC LANDS

The 1987 wildfires caused severe erosion and sedimentation in several granitic watersheds. Cleanout records of a debris catchment basin in Olsen Creek, a severely burned watershed near Sawyers Bar, reveal that from 1987 to 1992, it yielded about 15,900 yds^{3}of sediment **[Figure 8-1]**. This equates to 18 yds^3/acre of watershed, or about 3.7 yds^3/acre/year. This compares to 4.4 yd^3/acre/year predicted by the USLE for the first year following the fire. Some of this sediment was delivered during relatively low flows in the Salmon River, allowing it to remain in storage for several months before it was re-mobilized by higher flows [Orion Dix, personal communication, 1992].

Localized summer showers are a serious problem in burned granitic watersheds. Olsen Creek delivered about 1,000 yds^3 to the debris catchment basin in response to a storm on September 25, 1990 **[Figure 8-1]**. This amounts to a rate of more than one yds^3/acre for the watershed. Another 800 yds^3 was delivered to debris basin during the months following the storm.

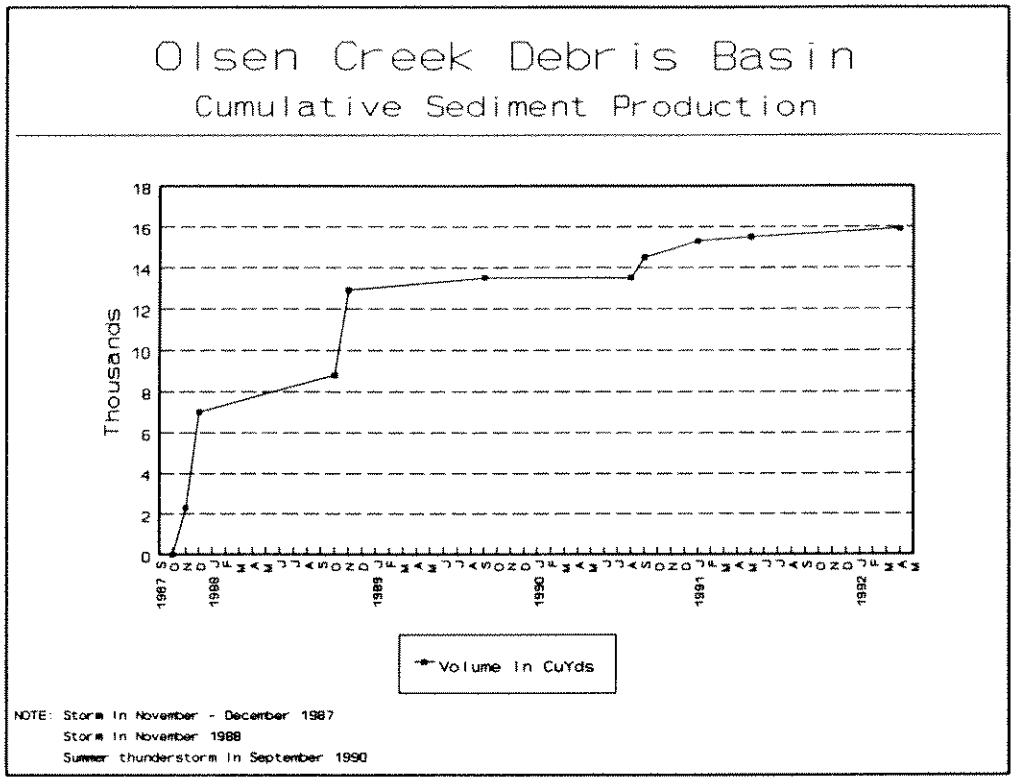


Figure 8-1. Cumulative sediment production, 1987-1992, Olsen Creek debris basin.

LARGE LANDSLIDES AND LANDSLIDE DAMS

The two largest landslides recorded by the air photo inventory are the Bloomer Landslide and the Murderers Bar Landslide **[Table 8-8, Figure 5-2]**. The Bloomer Landslide is a large debris slide in metamorphic bedrock. It is located in the Lower Main Stem sub-watershed and delivered approximately 1.4 million yds^3 of sediment to the Salmon River. The slide was initiated during the 1964 flood and temporarly blocked the Main Stem Salmon River. The landslide is assumed to be road-related, since the road across lower portion predates the failure. However, cause-effect relationships were not verified with field investigations. The Murderers Bar Landslide is also located in the Lower Main Stem sub-watershed of the Salmon River. This landslide occurred sometime between 1955 and 1964. Most likely it was initiated during or after the 1955 flood event. The landslide is a translational slide developed in older landslide deposits, and it delivered about 0.59 million yds^3 of sediment to the Salmon River. The landslide temporarily dammed the Salmon River, and similar to the Bloomer Landslide, appears to have been road-related. **Figure 8-2** is profile of the landslide, shown to display its size, complexity and depth. The slip surface daylights above level of the river, a condition typical of many of the large landslides along the Salmon and Klamath Rivers in this region.

Two other landslides are known to have temporarly blocked streams **[Table 8-8]**. They are the North Russian Landslide located in the Main Russian Subwatershed [NFSRUSRUS] tributary to the North Fork Salmon River, and the Big Elk Landslide, located in the Headwaters sub-watershed of the Wooley Creek [WOOHWW].

Table 8-8. Major landslides and landslide dams in the Salmon River watershed.

Name	Sub-Sub-Basin	Water-Shed	Photo Year	Dist. Class	Map Terrane Type	Deliv-ered Area [ac.]	Volume [yds^3]
Bloomer	MSS	LOW	1965	R	6	155.1	1,469,000
Murderers Bar	MSS	LOW	1964	R	3	60.1	599,042
North Russian*	NFS	RUSRUS	1975	N	11	1.6	32,400
Big Elk*	WOO	HWN	1965	N	3	39.3	211,200

* These landslides produced sediment in multiple years; the table displays only the most significant episode.

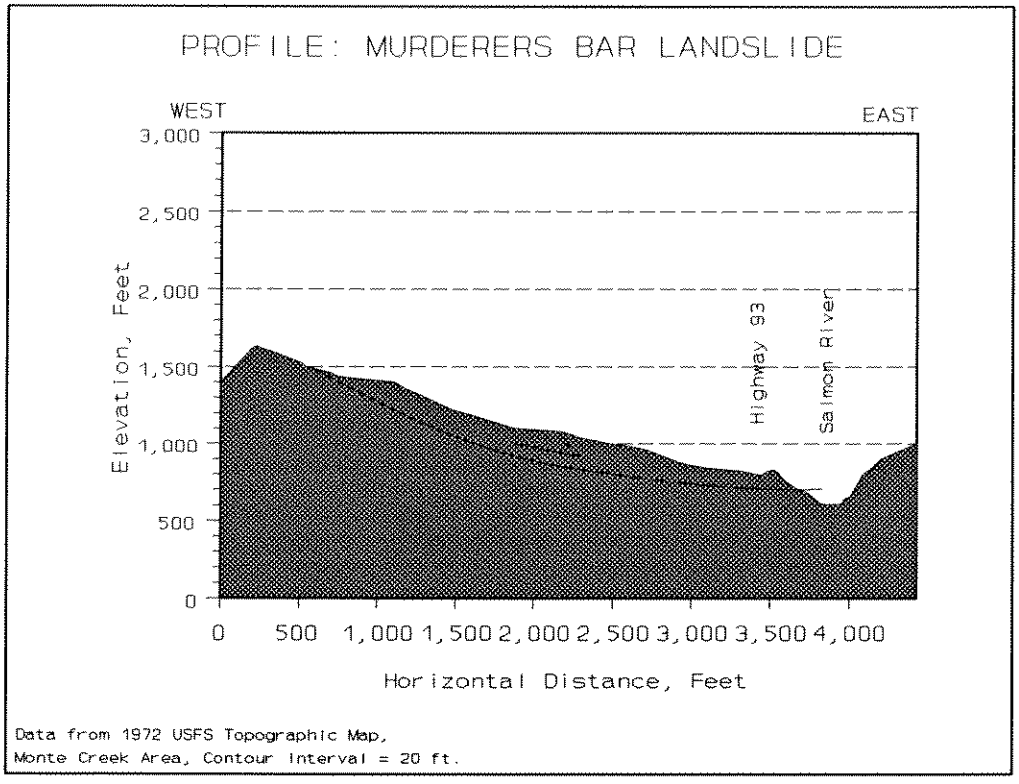


Figure 8-2. Profile of the Murderers Bar Landslide, Lower Main Stem Salmon River.

MAJOR LANDSLIDE-PRODUCING WATERSHEDS

The following discussions are intended to provide information on landslide rates in specific sub-watersheds during particular time intervals or related to flood events in the Salmon River basin. Intervals of time examined include the period of record, 1904-1988 which corresponds to an air photo interval of 1944-1988, the 1964 flood event [which corresponds to a photo interval of 1964-1965] and the climatic period of 1965-1975.

Much of the previous discussions of landslide rates have centered on geomorphic processes and how landslide rates are tied to specific geomorphic terranes. This presentation looks broadly at landslide rates of sub-watersheds and their relationship to key floods and storms, as well as disturbance levels.

The following sections tabulate data on sediment production from landslides among the 56 sub-watersheds of the Salmon basin at various time periods. The source of data is from the basin-wide air photo inventory. Data presented includes landslide-derived sediment production in yds^3/acre by disturbance class, the total sediment volume delivered to streams, and the total number of landslides.

Sub-watersheds having relatively high landslide rates after meeting certain specific criteria are presented in the tables. The causes for the high landslide rates are many and varied. Geomorphic terranes and geomorphic processes are key factors. As disturbance levels increased in 1970's, landslide rates also increased over the undisturbed rates. Factors influencing landslide rates such as harvest, site preparation, and road construction practices may also influence the landslide rates. The relationships of these factors to landslide rates are questions for further study.

Landslide Production, 1904-1988

The results of the basin-wide air photo inventory indicate that sub-watersheds of the Main Stem and South Fork Salmon River have had the highest overall landslide production rates over the period 1904-1988 [photo interval 1944-1988],[see **Figure 5-1**]. Note that all disturbance classes are considered. **Table 8-9** lists sub-watersheds that have met specific criteria described in the table. The sub-watersheds listed may be considered as having historically high landslide rates.

Table 8-9. List of sub-watersheds having high landslide-production rates over the air photo interval, 1944-1988. See also Figure 5-1, Chapter 5 for map representation. Watersheds on this list have met the following criteria: [a] have a landslide sediment delivery rate of 20 yds³/acre or more, [b] have delivered 100,000 yds³ or more of sediment over the air photo interval, or [c] have 100 or more recorded landslides. Landslides occurring in all disturbance types are considered together. Acres used in calculating sediment production rates are total watershed acres.

1944-1988, All Disturbance Classes

WS	Sub-watershed	Sediment Production yds³/ acre	Total Volume Produced	Number of Landslides
SFS	McNeal	209	454,495	34
MSS	Lower Main Stem Salmon	137	2,429,476	107
MSS	Monte	77	106,512	24
MSS	Nordheimer	70	1,396,190	129
SFS	West Fork Knownothing	51	327,734	56
WOO	Headwaters, Wooley	35	901,129	112
NFS	Lower Little North Fork	33	169,563	129
NFS	Headwaters, Little North Fork	33	184,900	34
MSS	Merrill	28	494,835	43
SFS	Lower South Fork	28	494,835	43
WOO	North Fork, Wooley	27	386,797	89
MSS	Somes	24	69,830	11
MSS	Butler	23	98,196	19
SFS	Plummer	22	203,784	20
SFS	Headwaters, Upper South Fork	22	589,902	71
WOO	Bridge	19	184,829	70
SFS	St. Claire	18	123,549	24
WOO	Steinacher	18	165,149	41
WOO	Lower Wooley	16	236,690	90
NFS	Lower North Fork	15	316,022	54
NFS	South Russian	15	174,282	48
NFS	Headwaters, North Fork	8	330,660	121
SFS	Negro Creek●	30	78,145	119

Notes: ● Negro Creek was added to the list because the field-based landslide inventory recorded more than 100 landslides.

A total of 23 sub-watersheds are listed out of the 56 sub-watersheds in the basin. No landslides were recorded in five of the 56 sub-watersheds. The range in landslide sediment production varies from 8 to 209 yds³/acre, total volume delivered from about 70,000 yds³ to 2.4 million yds³, and the number of landslides from 11 to 129.

Landslide Production Related to the 1964 Flood

The flood of 1964 had a large effect on stream channels in the Salmon basin and produced the majority of the landslide-related sediment production in the watershed. Disturbance levels related to harvest and road construction were relatively low. Harvest acres in the watershed totalled about 1500 acres, roads about 2000 acres, and undisturbed lands about 477,000 acres.

Landslides in Undisturbed Lands, 1964-1965

Criteria for listing of sub-watersheds are described in **Table 8-10**. The nine watersheds listed below may be considered as having the highest undisturbed landslide rates attributed to the 1964 flood.

Table 8-10. 1964 flood-related landslide production in undisturbed lands. Sub-watersheds listed meet the following criteria: [a] the sediment delivered by landslides was at a rate of 20 yds³/acre or more, or [b] the landslides in the watershed delivered 100,000 yds³ or more of sediment. Acres used in calculating sediment production rates are the total undisturbed acres at that time period in the sub-watershed.

1964-1965, Undisturbed

WS	Sub-watershed	Sediment Production yds³/ acre	Total Volume Produced	Number of Landslides
SFS	McNeal	140	263,805	10
MSS	Nordheimer	58	1,143,072	50
SFS	West Fork Knownothing	39	244,055	20
NFS	Headwaters, Little North Fork	30	166,996	23
WOO	Headwaters, Wooley	23	598,129	49
SFS	Plummer	17	154,837	9
WOO	North Fork,Wooley	16	226,359	30
WOO	Lower Wooley	9	127,964	29
NFS	Headwaters, North Fork	4	145,408	55

All sub-watersheds contained undisturbed land. Of the 56 sub-watersheds, 45 had landslides [in undisturbed land] during the 1964-1965 time interval. Among the nine listed above, the landslide sediment production varies from 4 to 140 yds³/acre, total volume delivered from nearly 128,000 to 1.1 million yds³, and number of landslides from 9 to 55. The most severe damage in undsisturbed land was in McNeal and Nordheimer sub-watersheds.

Harvest-Related Landslides, 1964-1965

By the end of 1965, harvesting had occurred in 17 of 56 watersheds. Harvested lands encompassed about 1500 acres in the Salmon basin. Five sub-watersheds produced harvest-related landslides during the 1964-1965 period. Of these five, those listed below in **Table 8-11** delivered sediment at a rate greater than 10 yds³/acre.

Table 8-11. Harvest-related landslides, 1964-1965 period. The sub-watersheds listed delivered sediment from landslides at a rate of 10 yds³/acre or greater. Acres used in calculating sediment production rates are harvested acres present in 1965.

1964-1965, Harvest

WS	Sub-watershed	Sediment Production yds³/ acre	Total Volume Produced	Number of Landslides
SFS	McNeal	488	115,787	5
SFS	West Fork Knownothing	33	4,776	4
MSS	Merrill	ND●	19,554	2

Notes: ● Acre data to calculate the sediment production rate is absent. The plantation acres were not accurately indicated in the GIS vegetation data layer. It is likely that the sediment production rate exceeded the minimum value.

McNeal Creek sub-watershed was greatly affected by the 1964 flood and had significant numbers of landslides in undisturbed and harvested lands. Merrill Creek had landslides in harvest units; it did not have any in undisturbed lands.

Road-Related Landslides, 1964-1965

By 1965 33 of 56 watersheds had roads in them, totalling about 2000 acres. Only sub-watersheds with a sediment production rate of 100 yds³/acre or more are included in **Table 8-12**. A total of 16 sub-watersheds had road-related landslides during the photo interval; of these, six are considered to have high road-related landslide rates. The others have rates that range from 4 to 99 yds³, and delivered no more than 3,500 yds³.

Table 8-12. Road-related landslides, 1964-1965 air photo period. Sub-watersheds listed have a landslide sediment production rate of 100 yds³ or greater. Acres used in calculating the rate are the acres of road present in the sub-watershed in 1965.

1964-1965, Roads

WS	Sub-watershed	Sediment Production yds³/ acre	Total Volume Produced	Number of Landslides
MSS	Lower Main Stem Salmon	10,929	1,495,114	9
SFS	St. Claire	3,527	9700	1
MSS	Monte	1,614	23,242	5
SFS	Lower South Fork	1,211	209,821	8
SFS	McNeal	554	31,483	6
NFS	Lower North Fork	182	39,971	4

Of the sub-watersheds listed, the Lower Main Stem Salmon River had the most landslides and delivered the most volume of sediment to the stream system. The large landslide volume associated with the Lower Main Stem is due in large part to the Bloomer landslide which delivered about 1 million yds³.

Landslide Production, 1965-1975 Period

By 1975, disturbance levels in the Salmon River watershed had increased over previous levels seen in 1965. Undisturbed lands comprised 470,000 acres, harvested lands 8,000 acres, and roads about 3,000 acres. The storm events during this time period were much less severe than the 1964 flood.

Landslides in Undisturbed Lands, 1965-1975

A total of 40 sub-watersheds recorded landslides in undisturbed lands during the 1965-1975 time period. Of these, 22 delivered sediment from landslides at a rate of 5 yds³/acre or more, or delivered 20,000 or more yds³ of sediment to streams. Note that the rate of 5 yds³/acre is 25% of the rate used to list sub-watersheds in **Table 8-10** 1964 flood -related landslides in undisturbed lands.

Table 8-13. Undisturbed landslide rates for selected sub-watersheds during the 1965-1975 period. Sub-watersheds listed have either a sediment production rate of 5 yds³/ acre or more, or delivered 20,000 yds³ to streams. Acres used in calculating the sediment production rates are the total of undisturbed acres present in 1975 in the sub-watershed.

1965-1975, Undisturbed

WS	Sub-watershed	Sediment Production yds³/ acre	Total Volume Produced	Number of Landslides
MSS	Monte	15	17,488	4
MSS	Merrill	14	28,036	10
WOO	Bridge	11	109,250	31
SFS	West Fork Knownothing	9	53,888	20
SFS	Headwaters, Upper South Fork	9	227,896	15
MSS	Nordheimer	7	138,288	44
NFS	Kanaka	7	4,421	3
MSS	Somes	7	19,170	6
NFS	Lower Little North Fork	6	28,681	14
MSS	Lewis	6	11,813	5
SFS	NcNeal	5	9,784	4
SFS	East Fork Knownothing	5	30,941	11
WOO	Headwaters, Wooley	5	120,521	29
SFS	St. Claire	5	29,680	11
WOO	North Fork Wooley	4	58,550	20
WOO	Lower Wooley	4	59,428	38
NFS	Main Russian	4	45,134	8
SFS	Plummer	3	30,696	6
SFS	Methodist	3	23,983	10
WOO	Steinacher	3	23,861	10
SFS	Lower South Fork	2	36,432	6
NFS	Headwaters, North Fork	1	44,372	22

Within the group of sub-watersheds listed above, the sediment production rate from landslides ranges from 1 to 15 yds³/acre, the total volume delivered from about 4,400 to 227,900 yds³, and the number of landslides from 3 to 44. These sub-watersheds had the highest landslide rates on undisturbed land during the 1965-1975 time period.

Harvest-Related Landslides, 1965-1975

A total of 10 sub-watersheds produced landslides associated with harvest units in the time period, 1965-1975. Of these, 9 delivered sediment from landslides at a rate of 5 yds³/acre or more.

Table 8-14. Selected sub-watersheds with high harvest-related landslide rates over the 1965-1975 period. Sub-watersheds listed have landslide sediment production rates greater than 5 yds³/acre. Acres used in calculating sediment production rates are the total acres of harvested land present in 1975.

1965-1975, Harvest

WS	Sub-watershed	Sediment Production yds³/ acre	Total Volume Produced	Number of Landslides
NFS	Lower Little North Fork	65	36,268	65
NFS	Jessups	47	1,433	1
SFS	West Fork Knownothing	13	3,733	1
WOO	Bridge	12	2,076	2
WOO	Lower Wooley	10	2,204	2
NFS	Headwaters, Little North Fork	9	1,440	3
SFS	Lower, Upper South Fork	7	2,667	1
MSS	Lower Main Stem	7	2,160	2
SFS	East Fork, Shadow Creek	7	1,692	1

Of the 9 sub-watersheds listed above, Lower Little North Fork had the the greatest volume and number of landslides related to harvest units in this time period.

Road-Related Landslides, 1965-1975

During the 1965-1975 period, 28 sub-watersheds in the Salmon basin had road-related landslides. Of these, 14 have a landslide sediment production rate of 100 yds³/acre or more, or delivered 10,000 or more yds³ or sediment to stream channels. The sub-watersheds listed below in **Table 8-???** were the most severely affected by road-related landslides in this time period.

Table 8-15. Selected sub-watersheds with high road-related landslide rates during the 1965-1975 time period. Sub-watersheds listed have a sediment production rate of 100 yds³/acre or delivered more than 10,000 yds³ of sediment to streams. Acres used in calculating sediment production rates are the total acres of road present in the watershed in 1975.

1965-1975, Road-Related Landslides

WS	Sub-watershed	Sediment Production yds³/ acre	Total Volume Produced	Number of Landslides
WOO	Lower Wooley	5,534	16,063	6
MSS	Monte	2,139	51,347	11
WOO	Steinacher	967	27,090	8
NFS	Lower Little North Fork	838	50,270	30
NFS	Eddy	434	39,460	2
SFS	McNeal	386	21,922	3
SFS	Matthews	380	24,765	4
MSS	Lower Main Stem Salmon	357	54,997	13
NFS	Headwaters, Little North Fork	299	2,988	3
NFS	Lower North Fork	232	66,736	5
SFS	St. Claire	219	9,616	2
SFS	Lower South Fork	168	39,743	4
SFS	West Fork, Knownothing	102	10,426	6
SFS	Lower Upper South Fork	95	14,532	14

Among the 14 sub-watersheds listed, the range in sediment production rate ranges from 95 to 5,534 yds³/acre, the total volume delivered from nearly 3,000 to about 66,700 yds³, and the number of landslides ranges from 2 to 30. Note that though the sediment production rates are lower than the rates for the 1964 flood, there are more sub-watershed with road-related landslide rates exceeding 100 yds³/acre.

Summary

The preceeding tables listing major sediment-producing watersheds show how landslide rates have varied over the Salmon watershed with flood intensity and disturbance levels. The lists are important in that they can provide a starting oint for prioritization of watersheds for inventory of improvement needs and restoration.

PRIORITIZATION OF WATERSHED RESTORATION WORK

The preceding section identified sub-watersheds which have produced the greatest number, volume, and rate [yd^3/acre] of landslides during the key storms of 1964-1965 and 1965-1975. It also distinguished between natural landslides [those on undisturbed ground], road-related landslides, and harvest-related landslides. This information is useful for the initial prioritization of watershed restoration work in the Salmon River. The tables of road-related landslides are of most use since they address the type of landslide which can most often be effectively stabilized.

Prioritization of future watershed restoration work also needs to take into account the potential for future landslides. The landslide model provides information on the rate at which sub-watersheds are expected to produce landslide sediment in the future. These predictions take into account the effects of existing disturbances [road, harvest, fire]. The model also estimates the landslide volume which would be produced if the sub-watersheds were undisturbed. **Table 8-16** displays the expected increase in landslide production for all sub-watersheds which is associated with disturbances [roads-harvest-fire]. The increase is expressed in terms of the percent over the undisturbed rate. For example, if the landslide model predicts that a given watershed would produce 1,000 cubic yards of sediment under undisturbed condition and 1,500 cubic yards under todays' disturbance levels, it is described as being 50% over undisturbed [1,500 - 1,000 = 500; 500 ÷ 1,000 x 100 = 50%].

Table 8-16. Predicted landslide production rate [from the landslide model] for all sub-watersheds in yds^3/acre. Also displayed is the percent increase over undisturbed rates. The percent increase = 1989 rate minus undisturbed rate, divided by undisturbed rate, times 100.

Sub-watershed	Landslide Rate Undisturbed [yd^3/Acre]	Landslide Rate 1989 Disturbance [yd^3/Acre]	Percent over Undisturbed
NFSBIG	2.6	42.0	1515
NFSOLS	3.6	39.1	986
NFSKAN	3.3	32.6	888
MSSCRA	2.6	16.2	523
NFSLNSLOW	2.9	11.0	279
MSSLOW	3.1	10.7	245
WOOSTE	2.4	7.9	229
SFSNEG	4.8	14.0	192
SFSMCN	4.6	13.2	187
NFSLOW	2.7	7.2	167
NFSJES	4.2	11.1	164
SFSCEC	2.1	5.5	162
MSSNOR	3.7	9.4	154
SFSIND	4.3	10.4	142
MSSLEW	3.1	7.4	139
MSSMON	3.5	7.8	123
SFSLOW	3.5	7.7	120
SFSKNOEFK	3.6	7.7	114
NFSEDD	2.3	4.9	113
SFSUSFLOW	2.7	5.7	111
SFSKNOWFK	3.7	7.6	105
SFSEFSTAY	2.3	4.7	104
SFSKNOLOW	3.0	6.1	103
MSSMOR	3.1	6.3	103
SFSEFSSHA	2.4	4.8	100
SFSMAT	2.6	5.1	96
SFSBLA	2.8	5.4	93
SFSCRA	2.6	4.6	77

Sub-watershed	Landslide Rate Undisturbed [yd³/Acre]	Landslide Rate 1989 Disturbance [yd³/Acre]	Percent over Undisturbed
NFSRUSSRU	2.2	3.9	77
MSSMER	3.3	5.8	76
WOOHAY	4.1	7.0	71
MSSDUN	3.7	6.2	68
SFSMET	3.4	5.6	65
WOOLOW	2.7	4.4	63
NFSWHI	2.3	3.7	61
SFSSTC	2.8	4.4	57
SFSEFSSIX	2.7	4.2	56
MSSBUT	4.1	6.3	54
WOOROC	2.4	3.6	50
NFSRUSRUS	2.5	3.7	48
SFSUSFBLI	3.1	4.5	45
SFSEFSEFS	2.8	3.2	28
WOOHAN	2.5	3.0	20
WOOBRI	3.2	3.6	13
SFSFRE	2.9	3.3	14
NFSLNSSPE	2.6	2.8	8
NFSHWN	2.7	2.8	4
SFSUSFRUS	2.8	2.8	0
MSSSOM	3.6	3.6	0
SFSPLU	2.7	2.7	0
WOOHWW	3.0	3.0	0
WOONFW	2.8	2.8	0
NFSLNSUNC	2.8	2.8	0
SFSUSFGAR	2.2	2.2	0
SFSUSFHWS	2.7	2.7	0

Table 8-16 ranks all sub-watersheds according to the expected increase in landslide production over the undisturbed rate. As such, it provides useful information to be used in conjunction with the data on past landslide production [previous section] and fish habitat condition to prioritize watershed restoration activities.

RELATIVE IMPORTANCE OF SEDIMENT SOURCES: COMPARISON TO OTHER STUDIES

Three different sediment studies in the Klamath River Basin have addressed landslide-related sediment production and can be compared to the results of the Salmon River sediment analysis. The studies are: *Scott River Watershed Granitic Sediment Study*, [Sommarstrom and others, 1990]; *Sediment Budget for the Grouse Creek Basin, Humboldt County, California*, [Raines and Kelsey, 1991] and, *Water, Land and Related Resources, North Coastal Area of California, and Portions of Southern Oregon, Appendix No. 2, Sediment Yield and Land Treatment, Klamath [and other] Basins*, [USDA, Soil Conservatio Service, 1972].

The various studies have different data collection and reporting methods, and periods of record. They are also different in focus and emphasis relating to the common types of sediment sources such as: roads, hillslope erosion, landslides, and channel bank erosion. The following comparisons are presented to give a broader persepctive on the source contributions of sediment in the watersheds studied.

The results of the Salmon River watershed study, using data derived from the air photo inventory, and the surface erosion model over the period 1904-1989 , indicate that the distribution of delivered sediment by sources is: landslides 38%; surface erosion 5%; and mining-related, 57%

The Scott River Watershed study [Somarstrom and others, 1990] found that roads comprised the major component of total annual surface erosion, and that landslides were a minor source of sediment. The distribution of total annual surface erosion by sources is: Road and Skid Trails, 75%; Streambanks, 23%,

Sheet and Rill Erosion, 1% and Landslides, <1%. The estimated delivery factor for the total annual erosion rate is 0.21 or 21%.

The Grouse Creek Basin study [Raines and Kelsey, 1991] found that over the period of record, 1960-1989, the distribution of delivered sediment by source type was: Landslides, 86%, Streambank Erosion, 7%, Hillslope Erosion 5%, and Road-related Erosion, 2%.

LANDSLIDE RATES IN THE PACIFIC NORTHWEST

The sediment production values developed in this study are compared below to those reported by numerous researchers in the Pacific Northwest [**Table 8-17**].

Table 8-17. Sediment production rates measured in the Pacific Northwest [modified after Amaranthus, 1985].

REGION	RECORD LENGTH YEARS	AVERAGE SLIDE VOLUME CU. YDS.	FREQUENCY NO./THOUS. AC./YR	VOLUME CU. YD. AC./YR.	SOURCE
NATURAL					
Coast Range	15	71	.33	.15	Swanson et.al. [1977]
Coast Range	15	33	.27	.06	Ketcheson [1978]
Cascades	25	1,908	.02	.19	Swanson & Dryness [1975]
Cascades	15	2,601	.014	.24	Morrison [1975]
Olympic Penin.	84	6,091	.009	.38	Fiksdal [1974]
British Colum.	32	3,973	.0023	.06	O'Loughlin [1972]
Klamath Mts.	20	3,231	.04	.13	Amaranthus et.al. [1985]
Klamath Mts.	43	2,851	.07	.21	USFS Grider EIS [1989]
Klamath Mts.	84	5,192	.03	.18	Salmon River Basin [1993]
HARVEST					
Coast Range	10	144	.63	.59	Swanson et.al. [1977]
Coast Range	15	44	.91	.69	Ketcheson [1978]
Cascades	25	1,751	.058	.70	Swanson & Dryness [1975]
Cascades	15	575	.16	.62	Morrison [1975]
Olympic Penin.	6	-	.00	-	Fiksdal [1974]
British Colum.	32	1,503	.013	.13	O'Loughlin [1972]
Klamath Mts.	20	1,085	.76	.89	Amaranthus et.al. [1985]
Klamath Mts.	43	1,530	.40	.61	USFS Grider EIS [1989]
Klamath Mts.	33	2,137	.22	.46	Salmon River Basin [1993]
ROADS					
Coast Range	15	555	4.97	18.52	Swanson et.al. [1977]
Cascades	25	1,804	.83	9.36	Swanson & Dryness [1975]
Cascades	15	2,444	5.03	82.53	Morrison [1975]
Olympic Penin.	6	732	11.94	62.43	Fiksdal [1974]
British Colum.	32	4,614	.53	1.49	O'Loughlin [1972]
Klamath Mts.	20	2,305	5.51	14.51	Amaranthus et.al. [1985]
Klamath Mts.	43	1,362	4.88	6.65	USFS Grider EIS [1989]
Klamath Mts.	44	12,542	1.51	18.92	Salmon River Basin [1993]

It is noteworthy that the values in **Table 8-17** are sensitive to the period of record over which they are calculated. For example, the values listed for natural conditions in the Salmon River Basin [1993] are for a very long period relative to many of the other studies. If this study had examined only the 12 year high precipitation period from 1964-1975, the annual rates would have been much higher. Another factor which significantly affects the results of such a table is the timing of roads and harvest relative to landslide producing storms. If a large proportion of the road construction or harvest occurs after the last landslide producing storm

of the period being examined, then the landslide production rate will be smaller than it would have been if the harvest had occurred before the last storm.

Chapter 9 - Conclusions and Recommendations

CONCLUSIONS

Historic Sediment Production in the Salmon River Watershed

1. Hydraulic mining from about 1870-1950 delivered more sediment [about 15.8 million yds^3] to the Salmon River than landsliding and surface erosion combined. In addition, the mining caused considerable modification of the river channel in some areas, and removed soil and vegetation from the floodplain adjacent to the river and its major tributaries.

2. Landsliding is the dominant natural process which delivered sediment to the Salmon River from 1904-1988. Landslides delivered about 10.4 million yds^3 from 1904-1988, about 13 times more than surface erosion during the same time period. Channel erosion also contributed a considerable amount of sediment to the total, but it was not quantified. It is believed that the volume it contributed was less than landsliding, but more than surface erosion.

3. Landslide occurrence since 1904 has been controlled by climate, with the wet period from about 1950-1975 accounting for 84% of the total landslide derived sediment. Landslide production has been episodic, and major landslide events have coincided with exceptionally high peak flows in the Salmon River [40,000 cubic feet per second or greater]. The introduction of large volumes of landslide debris into flood swollen channels resulted in numerous debris torrents which removed riparian vegetation and deposited coarse sediment in low gradient reaches. Most of the landslide derived sediment was generated by landslides on undisturbed land [67%]. However, the proportion of the watershed which was roaded, harvested, or recently burned was very small [about 2.5%] during the landslide episodes of 1964-1975. Roads were found to increase landslide production by a factor of about 100, and harvest by about 5 times undisturbed rates.

4. From 1904-1988, soil surface erosion delivered about 1.5 million yds^3 of sediment to the stream system. The rate of delivery has been controlled by the occurrence of large watershed disturbances such as large fires, and cumulative road construction and timber harvest. Once a landscape is disturbed, surface erosion occurs in response to average precipitation events. Thus, surface erosion is a chronic sediment source, and involves the delivery of fine sediment which can damage spawning gravels, and degrade water quality, even during years of average precipitation. When slopes are vegetated, surface erosion rates are very low, and as long as this cover is maintained, little sediment is delivered to streams. However, when lands are roaded, clearcut, or burned at high or moderate intensity, surface erosion accelerates greatly over undisturbed rates. In steep, burned granitic watersheds, surface erosion may produce sediment volumes which are similar in magnitude to those produced by landsliding.

5. From 1904-1988, certain parts of the landscape [geomorphic terranes] accounted for most of the landslide derived sediment which entered the Salmon River system. The inner gorge terrane occupies about 17% of the landscape, but produced 47% of the landslide sediment. Similarly, slump-earthflow terrane occupies 7% of the landscape but produced 13% of the landslide volume. Certain soil types were responsible for the majority of the sediment delivered by surface erosion processes. Wherever these terranes and soil types were disturbed, sediment production was increased significantly.

6. Two large landslides account for about 20% of the total landslide derived sediment, and temporarily dammed the main stem of the Salmon River. These dams blocked fish passage, and affected the river channel both upstream and downstream.

7. The large wildfires of 1918-1919 do not appear to have initiated widespread landsliding. However, this lack of landsliding may be due to the fact that a long dry period came on the heels of the wildfires. Though

data are not available, it is assumed that these wildfires resulted in short term [10 years] acceleration of surface erosion. Similarly, the wildfires of 1977 [Hog Fire] and 1987 did not initiate large scale landsliding, but they too were followed by drought conditions which lasted from 1975-1988. The 5,290 acre wildfire which occurred in the East Fork of the Salmon River in 1955 experienced a considerable amount of debris sliding during the 1964 flood. Similarly, portions of the Hog fire experienced slumps and earthflows during the winter of 1982-83, but it was minor relative to that of the storms in the 1960's and 1970's. Soil erosion is known to have been greatly accelerated in granitic areas burned in 1987.

Future Sediment Production in the Salmon River Watershed

1. Future sediment production will be controlled by the climatic trends of the next few decades. A wet trend would be conducive to landslide episodes and flood flows, whereas a dry trend would mean that most of the sediment entering the system would be from surface erosion. In addition, climatic conditions which favor the occurrence of intense summer showers would greatly increase soil surface and channel erosion but not landsliding.

2. Should a wet decade like that of 1965-1975 [excluding the 1964 flood] occur now, approximately 2.68 million yds^3 of landslide sediment would enter the streams. This compares to 1.79 million yds^3 which was measured by an air photo inventory for the 1965-1975 period. By comparison, if the watershed were completely undisturbed, the model predicts 1.33 million yds^3. The reason that the predicted landslide volume for today's conditions is so high is a result of disturbances which have occurred since 1975. At present 18.7% of the watershed is disturbed [fire-harvest-roads] whereas in 1975, only 2.5% was disturbed. Soil surface erosion over the next 10 years would produce about 0.21 million yds^3 of sediment. This compares to 0.08 if the watershed were completely undisturbed.

3. Lastly, climatic conditions which favor the widespread ignition of wildfire which exceeds the U.S. Forest Service suppression capabilities would indirectly accelerate surface erosion in succeeding years, and possibly landsliding, if followed by a wet trend. Due to the gradual accumulation of fuel during this century, it is generally agreed that the potential for large catastrophic wildfire is much greater now than it was 50 years ago.

Relationships Between Fish Habitat and Sediment Production

There was little correlation between historic sediment production and recent fish habitat condition. Watersheds which produced large volumes of sediment from 1904-1988 did not exhibit a corresponding degradation of fish habitat. This lack of correlation was likely due to the length of time since the last landslide producing storm [about 18 years], allowing time for the habitat to recover from the influx of sediment and loss of riparian vegetation. Another factor influencing the lack of correlation was the fact that the fish habitat inventory was developed prior to, and independent of this study, and was not designed specifically for direct comparison to sediment production.

Effects of Historic Floods on Channel Condition and Riparian Habitat

The flood of 1955 disturbed the main channels and some tributaries of lower Wooley Creek and the South Fork of the Salmon River [above its junction with the East Fork]. Additionally, scattered segments of tributaries in other parts of the Salmon River watershed were disturbed. Effects of the flood of 1964 were unprecedented this century, and dwarfed those of the 1955 flood. Virtually all the main river channels were stripped of riparian vegetation, and experienced either sediment deposition or mobilization of channel deposits. The major tributaries were similarly affected, with thick layers of sediment deposited in low gradient reaches. The area least affected by the 1964 flood included the watersheds which lie between the North and South Forks of the Salmon River, from Forks of Salmon to Sixmile Creek. The storm flows of the 1970's were much less severe than the 1964 flood, and had the greatest effects in Wooley Creek, tributaries to the lowermost main stem of the Salmon River, Little North Fork, Crapo Creek, and parts of the Upper South Fork.

In summary, the series of floods from 1955-1974 caused widespread channel modification and removal of riparian vegetation. The floods coincided with the introduction of large volumes of landslide debris into the stream system. Hydraulic mining probably influenced the way in which the floods affected some portions of the river. Since 1974, peak flows have been relatively low, allowing streams to recover to varying degrees from the flood effects.

Watershed Restoration

The flood and landslide history of a watershed is essential to the development of an effective and efficient restoration effort. This information allows restoration to be focused on the key problem watersheds, and identifies the types of land and disturbances which have produced the most sediment in the past. It also allows estimates to be made of future landslide production. Among the most effective methods of restoring the watershed are those which reduce sediment such as: repair of road-related landslides; reducing the risk of catastrophic wildfires; and preventing the disturbance of the most sensitive geomorphic terranes and soil types.

Assembly of Data Layers into a Geographic Information System [GIS]

Assembly of pertinent data layers [geology, soils, vegetation, precipitation, fire, digital terrain data etc.] into a GIS system fosters efficient use of the information. Data manipulation in a GIS allows spatial relationships to be investigated and quantified, such as the distribution of harvest units relative to geomorphic terranes. Once more information is entered into the GIS, such as fish habitat data, additional questions can be answered. Future monitoring will also be facilitated by GIS since new data can be entered, such as new information on landslides, and compared to the old.

RECOMMENDATIONS

A. Inventory and Repair of Existing Watershed Problems

Future management of the Salmon River basin should emphasize completion of a basin wide road management plan, watershed improvement needs inventories and repair of critical sediment producing sites. The information collected in this study will provide the initial screening for potential landslide stabilization projects, but field verification will be needed to develop stabilization plans.

1. Complete a basin-wide road management plan which will allow identification of sediment sources, and elimination of unneeded road segments.

2. Prioritize and repair identified road problems. Emphasis should be placed on the repair of fills, critical erosion sites, degraded riparian areas, and landslides. Landslide stabilization should be focused on sites where the potential damage to habitat is high, and there is a high likelihood that the landslide can be successfully stabilized.

3. Reduce the potential for large catastrophic fires. This can be best accomplished through a comprehensive fire management plan for the watershed which includes the re-introduction of fire into the ecosystem through prescribed burning.

4. Continue on-going Watershed Improvement Needs Inventories, and maintain and refine prioritized lists of critical sites for the entire Salmon River watershed.

5. Prioritize watersheds for restoration activities across the entire Salmon River basin. This can be accomplished by integrating the results of this study with those of other inventories such as watershed improvement needs inventories [WINI]. This study identified watersheds which have produced large

sediment volumes in the past, and those which are most likely to produce large volumes in the future due to high disturbance levels.

B. Prevention of Future Management-Associated Landslides and Erosion

This can best be accomplished through adoption of management standards and guidelines which protect the geomorphic terranes and sensitive soils which have been identified as landslide prone or erodible by this study. Included are road location, design, and construction standards. These would also apply to mining activity, and to timber harvest design and layout. Implement an active fuel management program involving prescribed burning and site preparation techniques which foster fire resistant plant successions, and other fuel reduction techniques. Lastly, standards of earth science investigation can be established and implemented.

1. Develop and implement standards and guidelines for managing the sensitive geomorphic terranes and soil types identified by this study. Certain terranes and soils account for a disproportionately large portion of the total sediment delivered to the river system. Roads, timber harvest, and other soil and vegetation disturbing activities should be minimized on these lands. State of the art geotechnical techniques should be applied whenever these lands are subjected to earth disturbance, particularly road construction. This includes practices such as controlled compaction and reinforcement of earthen fills, installation of subsurface drainage, design of stream crossings to account for debris torrents, and special attention to excavations within inner gorge, slump/earthflow, and granitic terrane.

2. Avoid high intensity site preparation fire on granitic lands in order to prevent greatly accelerated surface erosion.

3. Conduct appropriate geologic, soils and hydrologic investigations prior to conducting any significant soil or vegetation disturbing activities.

C. Enhancement of Our Understanding of the Relationship Between Sediment and Fish Habitat

Future research into sediment/fish habitat relationships should be focused on clearly stated questions and include the development of new, integrated fish habitat/watershed inventories.

1. In selected stream reaches, conduct integrated inventories of fish habitat and channel condition, including movement of sediment while considering historic landslide and soil surface erosion episodes.

2. Digitize active landslide and channel scour data collected by this study to allow quantitative assessment of the role of channel erosion in the sediment budget. This would allow queries to be run on active landslides, geomorphic terranes, and elevation zones.

3. Assemble relevant physical and biologic data for the remainder of the Klamath River basin in a format similar to that used in this study to allow basin-wide analysis on a GIS system.

4. Utilize the information described in item 3 above in developing a watershed restoration plan, and in prioritizing activities.

There are still many unanswered questions regarding the relationship between sediment production and fish habitat condition. This study provides the essential background data in GIS format for future focused studies which can address movement of sediment through the stream system, and the evolution of channel condition. It also provides background for monitoring the effects of future storms and management activities.

Approaches to Further Study of Fish Habitat and Sediment Relationships

Two types of approaches to data analysis are needed: one that takes a more generalized look at habitat data and one that takes a more detailed look at specific landslides or erosion sites. To take the former approach, streams might be categorized as "Good", "Fair", and "Poor" based on habitat conditions, and compared with sediment yields. One area that would lend itself to this approach is the West and East Fork sub-watersheds of Knownothing Creek. These are similar drainages but have different sediment yields over the periods 1944-1988, 1964-1965, and 1965-1975. The analysis can be designed to determine whether significant differences in habitat quality correlate with sediment yields in the two sub-watersheds. An overlay of mapped landslides with general habitat conditions ratings would highlight areas of concern. This is an application for GIS.

The more detailed approach would involve the study of landslides as point sources influencing habitat quality. Habitat conditions would be compared upstream, adjacent to, and downstream of a landslide. One would expect the quality of the habitat to improve as distance from the slide increased. Three large landslides may be appropriate for this type of analysis: Bloomer Landslide, Murderer's Bar Landslide, and North Russian Landslide. The effects of landslides on habitat conditions have been noticed, but not studied in detail or quantified. One observation has been that when landslides temporarily block a stream, an accumulation of gravels occurs upstream of the landslide. The gravels deposited upstream of the landslide dams are commonly associated with a high quality spawning grounds [West, 1992 personal communication]. Analysis of stream channel morphology, such as areas of deposition and bank stability should be included in a detailed study. Logical sections to examine are those that have low stream power relative to adjacent reaches, and therefore transport sediment at a low rate. These are generally low gradient stream reach areas characterized by sediment aggradation, and unconfined channels, as in "C" channels, [Rosgen, 1991]. The "C" channels might show the impacts of major episodes longer than other portions of the creek, recovering more rapidly.

Another approach is to study relationships between sediment transport, storage and routing and habitat conditions in areas near the mouths of streams and in the lower portions of watersheds. In the analyses conducted as part of this sediment budget, sediment yields were compared to habitat conditions generalized over an entire stream. It would be more revealing to take a look at habitat conditions within the lower section of a stream system where the sediment would accumulate. Additionally, fish passage problems at the mouths of streams may correlate with stream systems having high sediment yields.

Future research should emphasize spatial compatibility between data collected on habitat and sediment sources and yields. That is, the data collected should focus on habitat conditions within specific sections of the creeks at confluences of tributaries with high sediment producing basins. Selection of sites for future study should be made by a team of biologists and earth scientists.

A critical factor in determining the relationship between sediment production and habitat quality is understanding processes of sediment transport, routing and storage. If the rate of the sediment movement through a stream system could be determined, then a measure of recovery and disturbance could then be predicted and assessment data could be collected accordingly.

Biological Attributes

To date, only data from physical attributes have been used to compare to the sediment budget. Information is available on fish species utilization of habitats, especially spawning data, for comparisons. It may also be useful to investigate the effects of sediment on benthic invertebrates and amphibians.

D. Monitoring

Monitoring should focus on key issues related to fish habitat-sediment relationships. This includes the movement of sediment through the stream system, and the recovery of a stream following a landslide episode.

1. Inventory landslide distribution, causes, and effects immediately after the next landslide producing storm.

2. Select and establish characteristic channel cross section data in key streams prior to the next flood events.

3. Re-occupy the cross sections at gauging stations on the North and South Forks of the Salmon River.

4. Continue residual pool volume monitoring.

5. Incorporate new technology in monitoring changes in channel condition over time. Such technology includes things like the global positioning system [GPS] used in conjunction with an airbourne video camera system.

E. GIS Data Layers

The GIS layers developed by this project will facilitate future studies and monitoring. There is a need to incorporate fish habitat data into the GIS and to develop new techniques for integrated inventories in the future which will involve fish and watershed information collected and placed in a GIS format.

1. Enter all the landslide and hydraulic mines identified by this study into the GIS.

2. Enter scoured channels along with date and widths from maps.

3. Enter pre-1977 fires by intensity class.

4. Refine estimates of mining-related sediment by conducting sample field measurements.

5. Enter fish habitat survey data into the GIS so that spatial relationships between this data and other layers of information can be assessed.

6. Continually refine landslide volumes through on-going projects in the Salmon River watershed.

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APPENDIX A

Data Tables

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Table A-1. Salmon River watershed landslide coefficients [yds³/acre] for 1965-1975. Coefficients are presented from: [1] Grider Study, [2] Little North Fork, [LNS] Photo Inventory, [3] Little North Fork, [LNS] Field Inventory, [4] Basin-wide Photo Inventory, and [5] Final Salmon Model. Acres of each disturbance and terrane type are also included.

	Undisturbed					Harvest					Roads				
Geo Ter-rane	Grid-er Study	LNS Photo Study	LNS Field Study	Basin-wide Photo Study	FINAL	Grid-er Study	LNS Photo Study	LNS Field Study	Basin-wide Photo Study	FINAL	Grid-er Study	LNS Photo Study	LNS Field Study	Basin-wide Photo Study	FINAL
#2	6.00 7 Ac	0 7 Ac	0 7 Ac	0 990 Ac	2.76 990Ac	30.00 0 Ac	- 0 Ac	- 0 Ac	0 3 Ac	3.20 3 Ac	120.00 0 Ac	- 0 Ac	- 0 Ac	- 7 Ac	225.00 7 Ac
#3	1.40 322Ac	17.92 322Ac	0 322Ac	2.76 30078Ac	2.76 30078Ac	7.00 32Ac	15.24 32 Ac	17.90 32 Ac	3.17 1781Ac	3.22 1781Ac	28.00 4 Ac	204.00 4 Ac	36.80 4 Ac	224.93 596Ac	225.05 596 Ac
#4	4.00 2880 Ac	0.57 2880 Ac	2.90 2880 Ac	1.07 38311 Ac	1.25 38311 Ac	20.00 46Ac	38.70 46Ac	14.90 46Ac	11.81 152Ac	11.81 152Ac	80.00 14Ac	1056.92 14Ac	450.60 14 Ac	1005.48 82 Ac	1005.48 82 Ac
#5	1.50 4374 Ac	0 4374 Ac	0.03 4374 Ac	0.60 49218 Ac	0.60 49218 Ac	7.50 249Ac	33.99 249 Ac	0 249 Ac	11.26 1000 Ac	11.26 1000 Ac	30.00 26Ac	143.08 26 Ac	54.40 26 Ac	36.33 226Ac	36.33 226 Ac
#6	0.70 4965 Ac	0 4965 Ac	0.06 4965 Ac	1.69 134,703 Ac	1.69 134,703 Ac	3.50 85 Ac	42.94 85 Ac	0 85 Ac	3.26 1570 Ac	3.26 1570 Ac	14.00 7 Ac	1640.76 7 Ac	355.10 7 Ac	81.84 477 Ac	81.84 477 Ac
#8	0.10 2003 Ac	0 2003 Ac	0 2003 Ac	0.29 93985 Ac	0.30 93985 Ac	0.50 95 AC	0 95 Ac	0.60 95 Ac	2.09 2211 Ac	2.12 2211 Ac	2.00 6 Ac	0 6 Ac	31.80 6 Ac	18.33 941 Ac	18.72 941 Ac
#9	35.00 311 AC	2.06 311 Ac	27.0 311 Ac	25.74 10487 Ac	26.48 10487 Ac	175.00 5 Ac	0 5 Ac	0 5 Ac	0 101 Ac	51.48 101 Ac	700.00 0 Ac	- 0 Ac	- 0 Ac	375.31 55 Ac	375.58 55 Ac

Geo Ter-rane	Grid-er Study	LNS Photo Study	LNS Field Study	Basin-wide Photo Study	FINAL	Grid-er Study	LNS Photo Study	LNS Field Study	Basin-wide Photo Study	FINAL	Grid-er Study	LNS Photo Study	LNS Field Study	Basin-wide Photo Study	FINAL
#10	8.00 1008 Ac	8.37 1008 Ac	13.7 1008 Ac	6.99 16512 Ac	7.32 16512 Ac	40.00 134 Ac	136.32 134 Ac	278.3 134 Ac	71.77 255 Ac	146.38 255 Ac	160.00 10 Ac	2118.00 10 Ac	3482.20 10 Ac	1011.86 72 Ac	1201.31 72 Ac
#11	3.30 1751 Ac	16.56 1751 Ac	3.8 1751 Ac	7.19 51702 Ac	7.22 51702 Ac	16.50 51 Ac	99.29 51 Ac	16.90 51 Ac	11.20 543 Ac	11.20 543 Ac	66.00 2 Ac	630.00 2 Ac	421.90 2 Ac	285.28 285 Ac	285.28 285 Ac
#12	3.50 793 Ac	0 793 Ac	0 793 Ac	1.26 12004 Ac	1.26 12004 Ac	17.50 0 Ac	- 0 Ac	- 0 Ac	50.41 22 Ac	50.41 22 Ac	70.00 0 Ac	- 0 Ac	- 0 Ac	0 3 Ac	25.20 3 Ac
#13	0.40 1600 Ac	0 1600 Ac	- 1600 Ac	3.23 31665 Ac	3.23 31665 Ac	2.00 20 Ac	0 20 Ac	0 20 Ac	0 324 Ac	6.46 324 Ac	8.00 1 Ac	0 1 Ac	0 1 Ac	7.45 150 Ac	7.45 150 Ac

- Indicates no landslides in this type.

Table A-2. Landslide coefficients for the Salmon River watershed and its four subbasins, 1965-1975. Coefficients expressed in yds³/acre. Data is from the basin-wide air photo inventory.

	Undisturbed					Harvest					Roads				
Geo-mor-phic Ter-rane	SAL	MSS	NFS	SFS	WOO	SAL	MSS	NFS	SFS	WOO	SAL	MSS	NFS	SFS	WOO
2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	2.76	6.31	1.11	1.40	12.18	3.17	-	5.91	3.23	-	224.93	910.08	284.56	112.99	-
4	1.07	0.08	0.15	0.78	2.91	11.81	-	27.87	-	-	1005.48	3924.83	493.23	272.72	857.99
5	0.60	0.70	0.64	0.03	1.11	11.26	-	26.92	-	7.45	36.33	-	57.63	33.63	22.00
6	1.69	0.85	0.17	3.62	1.74	3.26	-	12.02	-	15.70	81.84	236.02	64.68	32.46	-
8	0.29	0.43	0.34	0.22	0.45	2.09	-	-	3.73	-	18.33	15.75	10.35	21.25	-
9	25.74	62.53	4.49	25.28	24.29	-	-	-	-	-	375.31	-	-	472.55	-
10	6.99	2.54	6.57	2.12	13.18	71.77	-	134.52	-	-	1011.86	-	1482.71	1161.90	1497.93
11	7.19	11.06	7.59	5.04	7.33	11.20	4.38	38.26	-	-	285.28	134.12	671.78	63.72	-
12	1.26	-	-	-	2.88	50.41	552.00	-	-	-	-	-	258.82	-	-
13	3.23	-	0.67	2.22	8.22	-	-	-	-	-	7.45	-	-	10.19	-

\- Indicates no landslides in this type.

Table A-3. Data Summary: Salmon River Basin Air Photo Landslide Inventory

Water-shed	Sub-Water-shed 1	Sub-Water-shed 2	Photo Year	Disturbance Class	Geomorphic Terrane Type	Slide Acres (Map Area)	Delivered Volume Cu.Yds.	Total Number of Slides	Riparian Area Damaged (Map Acres)
mss	but		44	N	9	2.80	46400	2	0.00
mss	but		44	N	10	0.76	5867	1	0.00
mss	but		64	N	9	0.21	1280	1	0.14
mss	but		65	N	3	1.23	11536	2	4.68
mss	but		65	N	4	2.28	18788	4	8.20
mss	but		65	N	6	0.92	5600	2	4.87
mss	but		65	N	9	2.53	4400	1	0.00
mss	but		65	N	11	0.21	720	1	0.00
mss	but		75	N	3	0.21	1293	2	0.46
mss	but		75	N	11	0.18	1232	2	0.00
mss	but		75	R	8	0.31	1080	1	1.61
mss	cra		44	N	4	0.79	7846	3	0.28
mss	cra		44	N	6	0.11	610	1	0.32
mss	cra		44	N	8	0.15	1056	1	0.14
mss	cra		44	N	11	1.89	15864	2	0.00
mss	cra		64	N	4	0.33	1760	1	1.52
mss	cra		65	N	4	1.83	8990	5	13.98
mss	cra		65	N	9	0.42	2971	2	0.00
mss	cra		65	N	10	2.03	16299	8	0.51
mss	cra		75	N	4	0.11	610	1	0.00
mss	cra		75	N	5	0.50	3509	2	1.65
mss	cra		75	N	9	0.61	4120	3	0.00
mss	cra		75	N	10	0.42	2151	2	0.00
mss	cra		88	F	5	0.78	6720	2	1.70
mss	cra		88	F	9	0.76	7920	1	0.00
mss	cra		88	R	3	0.07	512	1	0.00
mss	dun		64	N	6	0.52	5490	1	0.00
mss	dun		65	N	11	0.56	1944	1	0.00
mss	dun		75	R	3	0.13	293	1	0.00
mss	dun		75	R	6	0.27	953	2	0.17
mss	dun		75	R	8	0.09	213	1	0.10
mss	lew		44	N	6	0.39	4104	1	0.00
mss	lew		65	N	4	0.35	2475	1	4.30
mss	lew		65	N	6	0.35	3520	1	0.21
mss	lew		65	N	11	0.62	8640	1	2.64
mss	lew		75	N	6	0.52	6720	2	2.36
mss	lew		75	N	11	0.63	5093	3	0.46
mss	low		44	N	6	1.03	4456	5	1.66
mss	low		44	N	8	1.28	12197	4	0.41
mss	low		44	N	10	0.08	402	1	0.00
mss	low		44	N	11	2.38	25216	2	0.00
mss	low		44	R	6	1.63	14719	3	0.08
mss	low		44	R	10	0.87	4632	2	0.00
mss	low		44	R	11	6.35	70866	9	0.15
mss	low		55	N	6	0.31	1720	2	0.21
mss	low		55	N	11	0.15	1056	1	0.00
mss	low		55	R	8	0.46	711	1	0.00
mss	low		55	R	11	0.52	2288	3	0.17
mss	low		64	N	3	0.33	0	1	0.00
mss	low		64	N	4	0.10	352	1	0.24
mss	low		64	N	6	0.31	1080	1	0.00
mss	low		64	N	9	0.64	7464	2	0.00
mss	low		64	N	11	1.34	12780	2	0.00
mss	low		64	R	3	60.13	599041	2	0.00
mss	low		64	R	9	0.23	1608	1	0.00
mss	low		64	R	10	1.99	11337	6	0.18
mss	low		64	R	11	1.20	8804	3	0.00
mss	low		65	N	3	3.48	36128	2	0.00
mss	low		65	N	4	0.95	5204	5	0.67
mss	low		65	N	5	0.27	928	3	1.65
mss	low		65	N	6	0.22	1152	1	0.28
mss	low		65	N	8	0.19	224	1	0.23
mss	low		65	N	9	1.14	15840	1	0.00
mss	low		65	N	10	0.23	800	2	0.51

Table A-3. Data Summary: Salmon River Basin Air Photo Landslide Inventory

Water-shed	Sub-Water-shed 1	Sub-Water-shed 2	Photo Year	Distur-bance Class	Geomor-phic Terrane Type	Slide Acres (Map Area)	Delivered Volume Cu.Yds.	Total Number of Slides	Riparian Area Damaged (Map Acres)
mss	low		65	N	11	1.01	9061	2	0.00
mss	low		65	R	4	0.56	4326	2	0.14
mss	low		65	R	6	155.08	1469600	3	0.00
mss	low		65	R	8	0.18	868	1	0.00
mss	low		65	R	9	0.14	960	1	0.07
mss	low		65	R	11	2.78	19360	2	0.00
mss	low		75	H	11	0.15	1056	1	0.00
mss	low		75	H	12	0.23	1104	1	0.14
mss	low		75	N	3	0.69	8533	1	0.92
mss	low		75	N	6	0.35	1540	2	0.55
mss	low		75	N	10	0.65	4310	4	0.00
mss	low		75	N	11	0.78	3211	2	0.00
mss	low		75	R	3	7.20	46758	8	1.33
mss	low		75	R	4	0.18	502	1	0.00
mss	low		75	R	6	0.71	4041	2	0.14
mss	low		75	R	11	0.53	3696	2	0.00
mss	low		88	F	3	0.39	2784	1	0.07
mss	low		88	F	11	0.18	1264	1	0.46
mss	low		88	H	11	0.23	2440	1	0.14
mss	low		88	R	3	2.87	2417	1	0.00
mss	low		88	R	5	0.09	640	1	0.24
mss	mer		44	N	6	0.78	4754	3	0.00
mss	mer		44	N	9	0.50	6144	1	0.00
mss	mer		55	N	3	0.34	2440	1	0.00
mss	mer		55	N	9	0.41	4392	1	0.00
mss	mer		55	N	11	0.41	2368	3	0.00
mss	mer		64	N	3	6.89	2667	1	0.00
mss	mer		64	N	9	0.30	3168	1	0.00
mss	mer		65	H	6	0.17	576	1	0.28
mss	mer		65	H	9	2.01	18978	1	0.00
mss	mer		65	N	3	6.89	6667	1	0.00
mss	mer		65	N	6	0.21	2160	1	0.00
mss	mer		65	N	9	0.17	1200	1	0.00
mss	mer		65	R	6	0.27	1908	1	3.44
mss	mer		65	R	11	0.22	1560	1	0.41
mss	mer		75	N	3	7.35	8444	2	0.00
mss	mer		75	N	6	0.37	2603	1	0.00
mss	mer		75	N	9	5.58	11973	4	0.00
mss	mer		75	N	11	0.84	5016	3	0.00
mss	mon		65	N	4	0.51	3520	1	2.41
mss	mon		65	N	11	1.39	10916	3	3.40
mss	mon		65	R	6	2.47	15322	4	7.35
mss	mon		65	R	11	0.76	7920	1	1.53
mss	mon		75	N	11	1.70	17488	4	1.15
mss	mon		75	R	4	4.93	36784	4	1.61
mss	mon		75	R	6	3.31	13699	6	1.01
mss	mon		75	R	11	0.12	864	1	0.05
mss	mor		44	N	6	0.27	2385	1	0.28
mss	mor		55	N	11	2.07	3945	1	0.00
mss	mor		64	N	11	0.12	416	1	0.00
mss	mor		65	N	10	2.52	16963	4	4.78
mss	mor		65	N	11	1.10	11136	1	10.61
mss	mor		65	N	13	1.93	42600	2	28.51
mss	mor		75	N	6	0.13	880	1	0.24
mss	mor		75	N	11	0.52	3648	2	0.00
mss	mor		88	N	10	0.41	2880	1	0.51
mss	nor		44	N	3	0.11	384	1	0.37
mss	nor		44	N	4	0.33	1152	1	0.00
mss	nor		44	N	6	2.42	17322	9	7.35
mss	nor		44	N	8	0.43	2756	2	0.05
mss	nor		44	N	9	15.06	20892	3	0.00
mss	nor		44	N	10	0.25	1728	1	0.00
mss	nor		44	N	11	3.49	10919	6	0.34
mss	nor		55	N	9	0.41	3667	1	0.00

Table A-3. Data Summary: Salmon River Basin Air Photo Landslide Inventory

Water-shed	Sub-Water-shed 1	Sub-Water-shed 2	Photo Year	Distur-bance Class	Geomor-phic Terrane Type	Slide Acres (Map Area)	Delivered Volume Cu.Yds.	Total Number of Slides	Riparian Area Damaged (Map Acres)
mss	nor		55	N	10	0.53	2805	2	0.00
mss	nor		55	N	11	2.23	31536	2	0.00
mss	nor		64	N	10	0.28	1936	1	0.00
mss	nor		64	N	11	2.24	14304	2	0.00
mss	nor		65	N	3	2.44	38211	4	15.01
mss	nor		65	N	4	0.36	2370	2	0.46
mss	nor		65	N	5	5.51	10667	1	5.10
mss	nor		65	N	6	14.13	325971	18	30.35
mss	nor		65	N	8	1.26	12400	4	1.06
mss	nor		65	N	9	19.86	382035	5	10.34
mss	nor		65	N	11	5.04	54828	9	6.42
mss	nor		65	N	13	22.90	316591	7	11.57
mss	nor		75	N	3	1.20	10293	3	0.37
mss	nor		75	N	6	1.30	8133	5	0.41
mss	nor		75	N	8	0.48	3360	2	0.23
mss	nor		75	N	9	6.24	51883	13	1.40
mss	nor		75	N	10	0.43	2992	2	0.00
mss	nor		75	N	11	8.32	61627	19	2.34
mss	nor		88	F	6	0.22	1536	2	0.25
mss	nor		88	F	11	0.55	3893	2	0.01
mss	som		44	N	9	0.93	9720	2	0.00
mss	som		64	N	9	0.83	8640	1	0.00
mss	som		65	N	9	3.17	32300	2	0.00
mss	som		75	N	9	2.85	14730	4	0.00
mss	som		75	N	11	0.40	4440	2	0.55
nfs	big		44	N	10	0.19	1344	1	1.29
nfs	big		65	N	4	0.24	2100	1	2.62
nfs	big		65	N	10	1.08	8528	3	4.04
nfs	big		75	N	10	0.26	1824	1	6.31
nfs	edd		44	N	3	0.29	672	1	0.00
nfs	edd		44	N	6	0.80	11200	1	0.00
nfs	edd		65	H	3	0.18	821	1	0.92
nfs	edd		65	N	6	0.09	480	1	0.41
nfs	edd		65	N	11	0.34	1800	1	0.41
nfs	edd		75	N	8	0.98	7819	2	0.00
nfs	edd		75	R	3	2.25	39200	1	3.28
nfs	edd		75	R	6	0.45	260	1	0.00
nfs	hwn		44	N	6	3.07	24081	12	4.37
nfs	hwn		44	N	8	0.41	4320	1	0.41
nfs	hwn		44	N	9	0.67	4640	2	0.46
nfs	hwn		44	N	10	0.13	1100	1	0.00
nfs	hwn		44	N	11	7.12	64627	20	3.40
nfs	hwn		55	N	11	2.33	22560	3	0.00
nfs	hwn		64	N	6	0.10	360	1	0.18
nfs	hwn		64	N	9	0.92	9600	1	0.00
nfs	hwn		64	N	11	1.18	9592	3	0.18
nfs	hwn		65	N	4	0.69	2240	2	0.73
nfs	hwn		65	N	5	0.41	1440	1	0.00
nfs	hwn		65	N	6	4.63	28975	24	17.27
nfs	hwn		65	N	8	9.71	73878	6	10.56
nfs	hwn		65	N	9	0.71	6384	2	0.00
nfs	hwn		65	N	11	4.09	20178	15	9.96
nfs	hwn		65	N	12	1.41	9289	4	3.86
nfs	hwn		65	N	13	0.43	3024	1	1.01
nfs	hwn		75	N	6	0.81	6516	4	0.69
nfs	hwn		75	N	9	0.55	3840	2	0.00
nfs	hwn		75	N	11	4.09	31136	15	1.70
nfs	hwn		75	N	13	0.41	2880	1	0.00
nfs	jes		44	N	9	0.69	11000	1	0.78
nfs	jes		64	R	3	0.14	533	1	0.05
nfs	jes		65	N	9	0.58	6048	1	1.15
nfs	jes		65	R	9	0.05	284	1	0.09
nfs	jes		75	H	3	0.93	1433	1	0.00
nfs	jes		75	N	9	0.42	2960	2	0.00

Table A-3. Data Summary: Salmon River Basin Air Photo Landslide Inventory

Water-shed	Sub-Water-shed 1	Sub-Water-shed 2	Photo Year	Distur-bance Class	Geomor-phic Terrane Type	Slide Acres (Map Area)	Delivered Volume Cu.Yds.	Total Number of Slides	Riparian Area Damaged (Map Acres)
nfs	jes		75	R	3	0.08	256	1	0.00
nfs	kan		55	N	10	0.15	1024	1	0.00
nfs	kan		75	N	5	0.37	3141	2	0.83
nfs	kan		75	N	10	0.18	1280	1	0.00
nfs	lln		44	N	3	0.81	7347	2	0.10
nfs	lln		44	N	6	1.06	10944	4	0.55
nfs	lln		44	N	8	0.30	1216	2	0.00
nfs	lln		44	N	9	1.01	14080	1	0.00
nfs	lln		44	N	10	0.24	747	1	0.00
nfs	lln		44	N	11	3.23	37187	5	0.12
nfs	lln		44	R	11	0.65	4776	2	0.00
nfs	lln		55	N	10	0.22	1536	1	0.55
nfs	lln		55	N	12	0.28	960	1	7.81
nfs	lln		55	R	11	0.21	1113	1	0.09
nfs	lln		64	N	9	0.66	6974	1	0.37
nfs	lln		64	N	11	0.46	1884	2	0.00
nfs	lln		64	R	11	1.27	8124	3	0.00
nfs	lln		65	N	3	2.55	19640	4	4.06
nfs	lln		65	N	5	0.21	1280	1	0.83
nfs	lln		65	N	9	5.59	68080	3	24.79
nfs	lln		65	N	10	0.09	640	1	0.00
nfs	lln		65	R	6	0.19	117	2	0.37
nfs	lln		65	R	11	2.98	39853	2	0.00
nfs	lln		75	N	10	0.49	3128	4	0.83
nfs	lln		75	N	11	0.72	6192	2	0.00
nfs	lln		75	R	3	0.29	2000	1	0.00
nfs	lln		75	R	10	0.89	6176	2	0.00
nfs	lln		75	R	11	4.82	58560	2	0.00
nfs	lln		88	F	3	0.11	341	1	0.00
nfs	lln		88	F	9	0.92	8440	2	0.00
nfs	lln		88	R	6	0.57	4667	1	2.57
nfs	lns	hls	44	N	12	0.27	1428	2	0.69
nfs	lns	hls	64	N	9	0.29	1512	1	0.00
nfs	lns	hls	65	N	3	1.93	20604	2	0.00
nfs	lns	hls	65	N	4	0.58	3048	4	4.06
nfs	lns	hls	65	N	5	3.57	19970	2	8.63
nfs	lns	hls	65	N	8	0.21	1440	1	0.46
nfs	lns	hls	65	N	9	1.01	16448	2	0.46
nfs	lns	hls	65	N	10	3.85	81996	4	1.15
nfs	lns	hls	65	N	11	1.90	21136	3	0.00
nfs	lns	hls	65	N	12	0.76	2354	5	7.67
nfs	lns	hls	75	H	11	0.21	1440	3	0.00
nfs	lns	hls	75	N	10	0.41	2880	1	0.00
nfs	lns	hls	75	N	11	0.73	7656	1	0.00
nfs	lns	hls	75	R	6	0.37	1728	2	0.60
nfs	lns	hls	75	R	11	0.14	1260	1	0.41
nfs	lns	lln	44	N	5	0.44	3744	2	0.30
nfs	lns	lln	44	N	6	0.06	448	1	0.37
nfs	lns	lln	55	N	9	0.11	600	1	0.00
nfs	lns	lln	64	N	6	0.08	616	1	0.00
nfs	lns	lln	64	N	10	0.18	1056	2	0.18
nfs	lns	lln	65	N	3	0.10	240	1	0.00
nfs	lns	lln	65	N	4	0.07	378	1	1.52
nfs	lns	lln	65	N	6	0.40	1513	2	0.60
nfs	lns	lln	65	N	10	0.49	4848	2	0.00
nfs	lns	lln	65	N	11	3.83	40900	7	0.73
nfs	lns	lln	75	H	3	0.07	480	1	0.00
nfs	lns	lln	75	H	4	0.26	1792	4	0.84
nfs	lns	lln	75	H	5	1.21	8467	15	2.67
nfs	lns	lln	75	H	6	0.66	3637	3	0.96
nfs	lns	lln	75	H	10	2.63	18308	38	3.90
nfs	lns	lln	75	H	11	0.51	3584	4	0.41
nfs	lns	lln	75	N	3	0.55	5760	1	0.00
nfs	lns	lln	75	N	4	0.30	1636	2	0.00

Table A-3. Data Summary: Salmon River Basin Air Photo Landslide Inventory

Water-shed	Sub-Water-shed 1	Sub-Water-shed 2	Photo Year	Disturbance Class	Geomorphic Terrane Type	Slide Acres (Map Area)	Delivered Volume Cu.Yds.	Total Number of Slides	Riparian Area Damaged (Map Acres)
nfs	lns	lln	75	N	10	0.40	2816	3	0.48
nfs	lns	lln	75	N	11	2.11	18469	8	0.21
nfs	lns	lln	75	R	3	0.35	816	1	0.00
nfs	lns	lln	75	R	4	1.84	14797	8	1.68
nfs	lns	lln	75	R	5	0.53	3720	7	1.70
nfs	lns	lln	75	R	6	1.66	9757	4	1.61
nfs	lns	lln	75	R	10	2.03	21180	10	3.03
nfs	lns	spe	44	N	11	0.55	2960	2	0.18
nfs	lns	spe	55	N	6	0.19	672	1	0.07
nfs	lns	spe	55	N	11	0.32	1120	2	0.32
nfs	lns	spe	64	N	10	0.18	1153	1	0.32
nfs	lns	unc	44	N	4	0.07	228	1	0.78
nfs	lns	unc	44	N	10	0.06	171	1	0.00
nfs	lns	unc	55	N	8	0.34	800	1	0.32
nfs	lns	unc	55	N	9	0.34	3600	1	0.00
nfs	lns	unc	65	N	4	2.15	23751	4	4.17
nfs	lns	unc	65	N	6	0.11	400	1	0.11
nfs	lns	unc	65	N	9	0.38	2392	2	0.69
nfs	lns	unc	75	N	9	0.09	640	1	0.00
nfs	lns	unc	75	N	10	0.39	2736	2	3.40
nfs	lns	unc	75	N	11	0.41	2880	1	0.00
nfs	rus	rus	44	N	9	0.56	2940	1	0.46
nfs	rus	rus	44	N	10	1.16	9360	3	0.00
nfs	rus	rus	44	N	11	2.03	9288	5	1.84
nfs	rus	rus	44	N	13	1.70	21280	3	0.00
nfs	rus	rus	44	R	11	1.82	4928	2	0.00
nfs	rus	rus	55	N	11	0.55	3840	1	0.00
nfs	rus	rus	64	N	11	0.30	2080	1	0.00
nfs	rus	rus	65	N	4	1.53	9540	6	2.98
nfs	rus	rus	65	N	5	0.18	796	1	0.69
nfs	rus	rus	65	N	6	0.92	8533	1	0.00
nfs	rus	rus	65	N	8	1.56	14507	1	4.13
nfs	rus	rus	65	N	9	1.71	11920	2	0.00
nfs	rus	rus	65	N	10	1.62	4136	4	0.00
nfs	rus	rus	65	N	11	1.93	20400	5	4.02
nfs	rus	rus	65	N	12	0.21	960	1	0.46
nfs	rus	rus	65	R	8	0.07	200	1	0.14
nfs	rus	rus	65	R	11	0.18	1920	1	1.01
nfs	rus	rus	75	N	5	0.49	3058	2	0.14
nfs	rus	rus	75	N	11	2.47	39700	5	0.23
nfs	rus	rus	75	N	13	0.37	2376	1	0.00
nfs	rus	rus	75	R	11	0.35	2520	1	0.00
nfs	rus	sru	44	N	4	0.83	3516	3	0.60
nfs	rus	sru	44	N	10	1.38	6720	1	0.69
nfs	rus	sru	44	N	11	0.31	2176	1	0.69
nfs	rus	sru	55	N	10	0.20	939	1	0.00
nfs	rus	sru	64	N	4	0.10	720	1	1.06
nfs	rus	sru	64	N	12	0.14	480	1	1.01
nfs	rus	sru	64	R	9	0.41	2100	1	0.00
nfs	rus	sru	65	N	4	2.37	21277	5	15.52
nfs	rus	sru	65	N	5	0.35	1340	2	1.97
nfs	rus	sru	65	N	6	0.45	3136	2	6.15
nfs	rus	sru	65	N	8	0.08	560	1	0.07
nfs	rus	sru	65	N	10	0.52	3600	1	0.32
nfs	rus	sru	65	N	11	0.25	1744	2	0.09
nfs	rus	sru	65	N	12	1.97	11602	7	16.16
nfs	rus	sru	65	R	9	0.42	1712	2	0.00
nfs	rus	sru	75	N	5	0.24	1680	1	0.28
nfs	rus	sru	75	N	9	0.25	1728	1	0.00
nfs	rus	sru	75	N	10	0.58	4032	1	0.00
nfs	rus	sru	75	N	11	0.34	2368	2	0.00
nfs	rus	sru	75	R	8	0.05	178	1	0.14
nfs	rus	sru	75	R	11	0.67	4704	3	0.05
nfs	whi		44	N	6	0.16	840	1	0.28

Table A-3. Data Summary: Salmon River Basin Air Photo Landslide Inventory

Water-shed	Sub-Water-shed 1	Sub-Water-shed 2	Photo Year	Distur-bance Class	Geomor-phic Terrane Type	Slide Acres (Map Area)	Delivered Volume Cu.Yds.	Total Number of Slides	Riparian Area Damaged (Map Acres)
nfs	whi		44	N	11	0.69	3600	1	0.00
nfs	whi		65	N	6	0.49	3208	2	1.74
nfs	whi		65	N	11	0.11	600	1	0.00
nfs	whi		75	N	6	0.17	1152	1	1.03
nfs	whi		75	R	8	0.29	2000	1	0.00
nfs	whi		75	R	12	0.19	660	1	0.00
sfs	bla		44	N	3	0.25	38	1	0.14
sfs	bla		55	N	3	0.43	3000	1	0.18
sfs	bla		65	N	9	1.61	24889	1	0.92
sfs	bla		75	R	6	0.39	2688	1	0.00
sfs	cec		65	R	5	0.21	2180	1	0.60
sfs	crf		44	N	9	1.26	489	1	0.00
sfs	efs	efs	44	N	6	0.37	2592	1	0.37
sfs	efs	efs	44	N	8	0.14	427	1	0.32
sfs	efs	efs	64	N	6	0.21	600	1	0.60
sfs	efs	efs	64	R	8	2.20	3840	1	0.00
sfs	efs	efs	64	R	9	0.34	600	1	0.00
sfs	efs	efs	65	N	6	1.17	4120	4	1.84
sfs	efs	efs	65	N	8	2.30	15064	7	19.61
sfs	efs	efs	65	N	9	0.62	6528	1	0.00
sfs	efs	efs	65	N	11	0.68	3280	4	11.00
sfs	efs	efs	75	N	6	0.25	1141	2	0.96
sfs	efs	efs	75	N	8	1.62	10885	4	2.11
sfs	efs	sha	44	N	8	0.15	683	1	0.23
sfs	efs	sha	65	N	3	0.12	768	1	0.14
sfs	efs	sha	65	N	6	0.12	288	1	0.18
sfs	efs	sha	65	N	8	18.45	192	2	0.37
sfs	efs	sha	65	N	11	0.18	1280	1	0.00
sfs	efs	sha	75	H	8	1.09	1692	1	0.00
sfs	efs	sha	75	R	3	1.47	2276	1	0.00
sfs	efs	six	44	N	11	0.41	1440	1	0.46
sfs	efs	six	64	N	9	0.28	1920	1	0.00
sfs	efs	six	65	N	8	0.24	1260	1	0.51
sfs	efs	tay	55	N	6	0.09	640	1	0.18
sfs	efs	tay	64	N	5	0.25	1296	1	0.83
sfs	efs	tay	65	N	6	0.62	3240	1	1.47
sfs	efs	tay	65	N	11	0.45	2352	1	0.51
sfs	efs	tay	75	R	6	0.09	427	1	0.00
sfs	ind		44	N	11	0.47	4872	1	0.32
sfs	kno	efk	44	N	4	0.59	5040	2	0.00
sfs	kno	efk	44	N	9	2.16	11419	3	0.00
sfs	kno	efk	44	N	10	0.45	3120	2	0.23
sfs	kno	efk	44	N	11	0.76	5616	3	0.00
sfs	kno	efk	64	N	9	2.18	25207	2	0.00
sfs	kno	efk	64	N	11	0.10	720	1	0.00
sfs	kno	efk	65	N	6	0.28	1440	1	0.55
sfs	kno	efk	65	N	9	1.86	7644	4	1.84
sfs	kno	efk	65	N	11	0.40	2660	2	0.69
sfs	kno	efk	65	N	12	0.41	2880	1	0.60
sfs	kno	efk	75	N	3	1.30	11200	3	0.09
sfs	kno	efk	75	N	4	0.39	2736	1	0.92
sfs	kno	efk	75	N	5	0.07	512	1	0.18
sfs	kno	efk	75	N	9	2.20	15485	5	0.00
sfs	kno	efk	75	N	11	0.14	1008	1	0.00
sfs	kno	efk	75	R	5	0.14	560	1	0.23
sfs	kno	efk	88	R	3	0.13	1472	1	16.07
sfs	kno	wfk	55	N	6	0.25	1760	1	0.14
sfs	kno	wfk	64	N	3	0.26	1368	1	0.14
sfs	kno	wfk	64	N	9	0.37	3888	1	0.00
sfs	kno	wfk	64	R	9	0.34	2400	1	0.55
sfs	kno	wfk	65	H	3	1.55	3336	3	3.31
sfs	kno	wfk	65	H	11	0.21	1440	1	0.00
sfs	kno	wfk	65	N	3	0.17	900	1	0.14
sfs	kno	wfk	65	N	8	0.62	6480	1	0.55

Table A-3. Data Summary: Salmon River Basin Air Photo Landslide Inventory

Water-shed	Sub-Water-shed 1	Sub-Water-shed 2	Photo Year	Disturbance Class	Geomorphic Terrane Type	Slide Acres (Map Area)	Delivered Volume Cu.Yds.	Total Number of Slides	Riparian Area Damaged (Map Acres)
sfs	kno	wfk	65	N	9	9.21	208774	8	5.46
sfs	kno	wfk	65	N	10	0.47	3307	2	0.96
sfs	kno	wfk	65	N	11	2.65	16315	4	1.01
sfs	kno	wfk	65	N	13	0.98	8280	4	2.34
sfs	kno	wfk	65	R	6	0.21	1440	1	0.14
sfs	kno	wfk	75	H	3	0.64	3733	1	0.18
sfs	kno	wfk	75	N	3	1.08	9360	3	2.48
sfs	kno	wfk	75	N	8	0.08	249	1	0.00
sfs	kno	wfk	75	N	9	2.78	21744	6	0.00
sfs	kno	wfk	75	N	10	0.22	1520	2	0.96
sfs	kno	wfk	75	N	11	2.87	20215	7	1.84
sfs	kno	wfk	75	N	13	0.11	800	1	0.09
sfs	kno	wfk	75	R	3	0.29	1711	1	0.32
sfs	kno	wfk	75	R	4	0.58	3648	2	0.46
sfs	kno	wfk	75	R	5	0.23	1067	1	0.14
sfs	kno	wfk	75	R	9	0.41	2880	1	0.00
sfs	kno	wfk	75	R	13	0.16	1120	1	0.18
sfs	lsf		44	N	3	2.33	22637	4	0.09
sfs	lsf		44	N	6	1.07	11636	1	0.00
sfs	lsf		44	N	8	0.51	5360	1	0.00
sfs	lsf		44	N	9	5.17	94000	2	0.00
sfs	lsf		44	N	11	0.55	4800	1	0.00
sfs	lsf		44	R	9	2.33	26511	2	0.00
sfs	lsf		44	R	11	2.63	24940	4	0.00
sfs	lsf		55	N	3	6.89	0	1	0.00
sfs	lsf		55	N	9	0.25	49	1	0.00
sfs	lsf		55	N	11	0.22	1152	1	0.00
sfs	lsf		55	R	10	0.78	8280	1	0.00
sfs	lsf		55	R	13	0.11	683	1	0.00
sfs	lsf		64	N	11	0.21	1440	1	0.00
sfs	lsf		65	N	9	0.81	6776	3	0.05
sfs	lsf		65	N	10	0.11	576	1	0.05
sfs	lsf		65	R	8	0.46	1067	1	0.00
sfs	lsf		65	R	9	8.72	193200	2	0.00
sfs	lsf		65	R	10	0.31	3240	1	0.00
sfs	lsf		65	R	11	2.72	12315	4	0.00
sfs	lsf		75	N	3	0.51	5280	1	0.32
sfs	lsf		75	N	9	3.80	29296	4	0.00
sfs	lsf		75	N	11	0.26	1856	1	0.23
sfs	lsf		75	R	3	0.11	1067	1	0.28
sfs	lsf		75	R	8	0.33	3456	1	0.46
sfs	lsf		75	R	9	1.38	9600	1	0.00
sfs	lsf		75	R	10	1.45	25620	1	0.00
sfs	mat		64	N	11	0.22	1536	1	0.00
sfs	mat		65	H	6	0.18	1369	1	0.23
sfs	mat		75	R	3	1.24	21600	1	0.34
sfs	mat		75	R	6	0.38	2507	2	0.46
sfs	mat		75	R	8	0.57	659	1	0.00
sfs	mcn		44	N	3	0.52	5707	2	0.00
sfs	mcn		44	N	9	0.20	1252	1	0.00
sfs	mcn		64	R	6	0.33	1540	2	0.32
sfs	mcn		65	H	3	0.21	2160	1	0.51
sfs	mcn		65	H	9	4.32	104267	3	2.89
sfs	mcn		65	H	11	0.66	9360	1	0.00
sfs	mcn		65	N	3	0.62	19200	1	0.00
sfs	mcn		65	N	9	7.46	219968	4	17.68
sfs	mcn		65	N	11	2.00	24637	5	0.00
sfs	mcn		65	R	3	0.63	2507	2	1.29
sfs	mcn		65	R	6	2.80	12176	3	1.15
sfs	mcn		65	R	9	1.61	16800	1	0.00
sfs	mcn		75	N	9	0.56	3872	2	0.00
sfs	mcn		75	N	11	0.84	5912	2	0.09
sfs	mcn		75	R	3	1.62	13815	2	0.69
sfs	mcn		75	R	9	0.87	8107	1	0.00

Table A-3. Data Summary: Salmon River Basin Air Photo Landslide Inventory

Water-shed	Sub-Water-shed 1	Sub-Water-shed 2	Photo Year	Disturbance Class	Geomorphic Terrane Type	Slide Acres (Map Area)	Delivered Volume Cu.Yds.	Total Number of Slides	Riparian Area Damaged (Map Acres)
sfs	mcn		88	F	3	0.45	3216	1	0.14
sfs	met		44	N	3	0.06	256	1	0.14
sfs	met		44	N	6	0.11	452	1	0.46
sfs	met		44	N	9	1.74	19752	2	0.00
sfs	met		55	N	11	1.39	9787	3	0.00
sfs	met		64	N	9	1.50	10480	2	0.00
sfs	met		64	N	11	0.13	880	1	0.32
sfs	met		65	N	11	0.21	1440	1	0.00
sfs	met		65	R	6	0.08	420	1	0.11
sfs	met		75	H	8	0.17	256	1	0.00
sfs	met		75	N	9	3.04	10811	5	0.73
sfs	met		75	N	10	0.70	4880	3	0.00
sfs	met		75	N	11	1.18	8292	2	0.00
sfs	met		75	R	3	0.10	480	1	0.07
sfs	met		75	R	6	0.27	952	2	0.00
sfs	met		75	R	9	0.18	205	1	0.00
sfs	met		88	N	3	0.11	1152	1	0.37
sfs	neg		44	N	11	0.41	3667	1	0.00
sfs	neg		65	N	9	5.18	29817	3	0.00
sfs	neg		65	N	11	0.18	651	1	0.00
sfs	neg		65	R	3	0.18	1280	1	0.00
sfs	neg		75	N	9	0.30	2080	1	0.00
sfs	neg		75	R	3	0.54	3744	3	0.37
sfs	neg		88	F	3	1.12	1864	2	0.00
sfs	plu		44	N	8	0.09	480	1	0.80
sfs	plu		44	N	9	2.00	16011	3	0.00
sfs	plu		64	N	9	0.25	1760	1	0.00
sfs	plu		65	N	3	1.10	17600	1	2.75
sfs	plu		65	N	6	2.69	31296	2	10.33
sfs	plu		65	N	8	3.54	82133	1	16.41
sfs	plu		65	N	11	1.63	21504	4	1.93
sfs	plu		65	N	13	0.33	2304	1	1.38
sfs	plu		75	N	9	0.61	5544	2	0.14
sfs	plu		75	N	11	2.00	20880	2	0.00
sfs	plu		75	N	13	0.61	4272	2	0.09
sfs	stc		44	N	13	0.48	5040	1	0.00
sfs	stc		65	N	6	0.43	2325	2	0.46
sfs	stc		65	N	9	1.31	13680	3	0.00
sfs	stc		65	N	11	2.48	31668	3	1.95
sfs	stc		65	N	13	2.09	21840	1	12.86
sfs	stc		65	R	9	2.02	9700	1	2.30
sfs	stc		75	N	9	2.94	20480	9	0.00
sfs	stc		75	N	11	0.46	3200	1	0.00
sfs	stc		75	N	13	0.57	6000	1	0.00
sfs	stc		75	R	11	1.38	9616	2	0.00
sfs	usf	hws	44	N	4	2.40	9323	6	2.34
sfs	usf	hws	44	N	6	1.21	8400	1	0.00
sfs	usf	hws	44	N	8	0.86	9000	1	0.00
sfs	usf	hws	44	N	9	7.47	74416	3	1.19
sfs	usf	hws	44	N	10	1.19	7747	4	0.96
sfs	usf	hws	44	N	11	18.23	147152	12	0.28
sfs	usf	hws	44	N	13	1.38	2400	1	0.60
sfs	usf	hws	55	N	6	0.40	2816	1	0.00
sfs	usf	hws	55	N	9	6.57	11059	1	0.00
sfs	usf	hws	55	N	11	0.28	1920	1	0.00
sfs	usf	hws	64	N	4	0.18	640	1	0.69
sfs	usf	hws	64	N	10	0.27	1904	1	0.00
sfs	usf	hws	64	N	11	1.23	5536	3	0.00
sfs	usf	hws	64	N	13	1.78	13960	2	0.00
sfs	usf	hws	65	N	4	0.51	320	2	1.15
sfs	usf	hws	65	N	6	0.89	3346	4	4.17
sfs	usf	hws	65	N	8	1.39	8928	2	1.24
sfs	usf	hws	65	N	9	0.19	288	1	0.14
sfs	usf	hws	65	N	11	9.83	51312	8	6.49

Table A-3. Data Summary: Salmon River Basin Air Photo Landslide Inventory

Water-shed	Sub-Water-shed 1	Sub-Water-shed 2	Photo Year	Distur-bance Class	Geomor-phic Terrane Type	Slide Acres (Map Area)	Delivered Volume Cu.Yds.	Total Number of Slides	Riparian Area Damaged (Map Acres)
sfs	usf	hws	65	N	13	0.88	1540	1	0.00
sfs	usf	hws	75	N	4	0.59	4096	1	0.00
sfs	usf	hws	75	N	6	5.21	157973	2	9.13
sfs	usf	hws	75	N	9	7.71	19059	4	4.82
sfs	usf	hws	75	N	11	7.63	38368	6	3.11
sfs	usf	hws	75	N	13	2.75	8400	2	0.00
sfs	usf	low	44	N	11	0.74	5168	1	0.00
sfs	usf	low	55	N	11	2.55	26640	1	0.00
sfs	usf	low	65	N	11	0.99	6912	2	1.93
sfs	usf	low	65	N	12	0.25	1728	1	0.32
sfs	usf	low	65	R	9	0.14	960	1	0.00
sfs	usf	low	75	H	8	0.46	2667	1	0.09
sfs	usf	low	75	N	10	0.29	2000	1	0.00
sfs	usf	low	75	N	13	0.86	6000	1	0.23
sfs	usf	low	75	R	4	0.49	2720	4	0.05
sfs	usf	low	75	R	5	0.20	1692	2	0.37
sfs	usf	low	75	R	6	0.19	448	1	0.00
sfs	usf	low	75	R	8	1.65	9672	7	0.55
sfs	usf	rsh	65	N	10	0.41	2640	1	0.00
woo	bri		44	N	4	0.22	519	1	0.00
woo	bri		44	N	5	0.17	1024	2	0.37
woo	bri		44	N	9	0.29	3072	1	0.00
woo	bri		44	N	10	2.01	17828	5	1.38
woo	bri		55	N	4	0.20	1035	1	0.37
woo	bri		55	N	9	0.47	2790	2	0.18
woo	bri		55	N	13	0.09	640	1	0.00
woo	bri		64	N	4	0.36	2318	2	0.48
woo	bri		64	N	9	0.31	2160	1	0.00
woo	bri		64	N	10	0.23	1627	1	0.00
woo	bri		65	N	4	1.27	8880	2	2.34
woo	bri		65	N	5	0.62	3740	3	5.76
woo	bri		65	N	10	3.83	22540	9	6.05
woo	bri		65	N	12	0.23	800	1	0.00
woo	bri		65	N	13	0.37	2560	1	0.56
woo	bri		75	H	5	0.33	2076	2	0.69
woo	bri		75	N	4	1.25	4480	3	2.30
woo	bri		75	N	5	1.41	9880	5	1.56
woo	bri		75	N	9	0.79	2784	2	2.25
woo	bri		75	N	10	5.59	31626	18	2.20
woo	bri		75	N	13	1.42	60480	3	0.55
woo	bri		75	R	4	0.46	1422	1	0.00
woo	bri		75	R	5	0.35	548	3	0.00
woo	han		44	N	5	0.16	840	1	0.32
woo	han		44	N	6	0.15	792	1	0.32
woo	han		44	N	8	0.28	1920	1	0.00
woo	han		55	N	8	0.20	1020	1	0.41
woo	han		55	N	12	0.09	651	1	0.37
woo	han		55	N	13	1.91	13320	1	0.00
woo	han		64	N	6	0.39	1813	1	0.00
woo	han		65	N	9	0.95	6624	2	1.24
woo	han		65	N	11	0.73	6115	2	0.00
woo	han		65	N	13	0.34	1800	1	0.00
woo	han		75	N	6	0.14	1008	1	0.46
woo	han		75	N	11	0.16	1139	1	0.00
woo	han		75	N	13	1.45	6093	2	0.00
woo	hay		44	N	10	2.41	28871	1	0.00
woo	hay		64	N	10	0.16	541	1	0.00
woo	hay		65	N	10	0.19	1344	1	1.84
woo	hay		65	R	5	0.15	939	1	0.17
woo	hay		65	R	10	0.22	1984	1	0.83
woo	hay		75	N	4	0.19	1368	1	0.55
woo	hay		75	N	5	0.12	864	1	0.14
woo	hay		75	N	10	1.04	8557	4	0.00
woo	hay		75	R	4	0.12	480	1	0.28

Table A-3. Data Summary: Salmon River Basin Air Photo Landslide Inventory

Water-shed	Sub-Water-shed 1	Sub-Water-shed 2	Photo Year	Distur-bance Class	Geomor-phic Terrane Type	Slide Acres (Map Area)	Delivered Volume Cu.Yds.	Total Number of Slides	Riparian Area Damaged (Map Acres)
woo	hay		75	R	5	0.14	619	1	0.10
woo	hww		44	N	3	41.56	18379	4	0.14
woo	hww		44	N	6	0.52	5400	1	0.46
woo	hww		44	N	9	5.06	43232	3	3.44
woo	hww		44	N	10	1.14	7883	3	0.37
woo	hww		44	N	11	4.25	29364	10	0.37
woo	hww		55	N	8	0.35	2432	1	0.55
woo	hww		55	N	11	0.14	480	1	0.00
woo	hww		64	N	3	5.05	41849	2	0.00
woo	hww		64	N	5	2.07	7200	1	4.13
woo	hww		64	N	6	0.08	320	1	0.00
woo	hww		64	N	9	1.93	17472	2	0.00
woo	hww		64	N	11	0.96	6272	3	0.00
woo	hww		64	N	12	0.56	2196	2	0.32
woo	hww		65	N	3	53.55	274409	9	4.20
woo	hww		65	N	6	13.44	215076	19	25.16
woo	hww		65	N	9	14.94	55132	5	3.90
woo	hww		65	N	11	5.95	48928	10	1.56
woo	hww		65	N	12	0.84	4584	6	4.91
woo	hww		75	N	3	19.09	22818	3	0.37
woo	hww		75	N	6	1.01	6432	5	1.52
woo	hww		75	N	9	8.99	45320	10	2.78
woo	hww		75	N	10	0.13	880	1	0.55
woo	hww		75	N	11	6.81	29991	8	0.00
woo	hww		75	N	12	1.24	11880	1	0.28
woo	hww		75	N	13	0.46	3200	1	0.60
woo	lwo		44	N	5	0.17	864	1	0.32
woo	lwo		44	N	10	0.29	2080	1	0.00
woo	lwo		44	N	12	0.71	8059	4	3.57
woo	lwo		55	N	6	0.13	587	1	0.14
woo	lwo		64	N	4	0.18	1232	1	0.00
woo	lwo		64	N	10	1.20	12668	2	0.00
woo	lwo		64	N	11	0.37	1952	2	0.00
woo	lwo		64	N	12	0.11	813	1	0.14
woo	lwo		65	N	4	0.15	795	1	0.28
woo	lwo		65	N	5	10.11	69992	5	12.14
woo	lwo		65	N	8	0.38	2400	2	2.20
woo	lwo		65	N	10	2.12	17457	11	12.29
woo	lwo		65	N	11	1.97	19285	5	1.42
woo	lwo		65	N	12	2.22	18035	5	16.80
woo	lwo		75	H	5	0.10	720	1	0.00
woo	lwo		75	H	6	0.21	1484	1	0.28
woo	lwo		75	N	4	1.05	6668	7	1.29
woo	lwo		75	N	5	1.06	6826	7	1.47
woo	lwo		75	N	6	0.06	448	1	0.00
woo	lwo		75	N	10	4.13	30071	16	3.49
woo	lwo		75	N	11	1.55	13159	4	0.00
woo	lwo		75	N	12	0.32	2256	3	0.55
woo	lwo		75	R	4	1.10	7696	3	0.28
woo	lwo		75	R	6	0.23	1584	1	0.28
woo	lwo		75	R	10	0.66	6783	2	0.37
woo	lwo		88	H	10	0.31	2200	1	0.23
woo	lwo		88	R	5	0.08	576	1	0.23
woo	nfw		44	N	4	1.39	4249	2	0.45
woo	nfw		44	N	6	3.12	30741	3	1.77
woo	nfw		44	N	9	0.32	996	1	0.98
woo	nfw		44	N	10	0.72	6144	3	1.03
woo	nfw		44	N	11	3.26	27680	11	0.46
woo	nfw		44	N	12	2.85	11520	2	0.32
woo	nfw		55	N	11	0.07	107	1	0.14
woo	nfw		55	N	13	0.06	109	1	0.28
woo	nfw		64	N	4	0.07	256	1	0.46
woo	nfw		64	N	6	0.24	840	1	0.00
woo	nfw		64	N	9	0.20	2816	1	0.92

Table A-3. Data Summary: Salmon River Basin Air Photo Landslide Inventory

Water-shed	Sub-Water-shed 1	Sub-Water-shed 2	Photo Year	Distur-bance Class	Geomor-phic Terrane Type	Slide Acres (Map Area)	Delivered Volume Cu.Yds.	Total Number of Slides	Riparian Area Damaged (Map Acres)
woo	nfw		64	N	10	0.85	5422	4	0.00
woo	nfw		64	N	11	0.67	5720	2	2.48
woo	nfw		64	N	12	0.57	2116	5	0.62
woo	nfw		65	N	4	1.01	4287	5	3.35
woo	nfw		65	N	8	1.59	10336	4	1.10
woo	nfw		65	N	9	1.88	47460	1	1.01
woo	nfw		65	N	10	6.86	105891	2	11.13
woo	nfw		65	N	11	7.99	50914	15	6.50
woo	nfw		65	N	12	1.99	7472	3	1.47
woo	nfw		75	N	4	0.32	3360	1	0.64
woo	nfw		75	N	6	3.13	26304	6	2.57
woo	nfw		75	N	8	0.41	2581	2	0.09
woo	nfw		75	N	9	0.55	1564	1	0.00
woo	nfw		75	N	10	0.91	7660	3	0.00
woo	nfw		75	N	11	2.31	16120	6	0.60
woo	nfw		75	N	12	0.14	960	1	0.09
woo	nfw		88	N	11	0.30	3172	1	0.00
woo	roc		44	N	3	0.19	896	1	0.00
woo	roc		44	N	4	0.14	732	1	0.32
woo	roc		44	N	6	0.35	2444	2	0.28
woo	roc		44	N	12	0.06	336	1	0.46
woo	roc		55	N	11	0.51	3520	1	0.55
woo	roc		65	N	6	2.33	21552	4	7.02
woo	roc		65	N	11	0.15	528	1	1.38
woo	roc		75	N	6	0.24	1696	1	0.55
woo	roc		75	N	8	0.40	2812	2	0.46
woo	ste		44	N	6	1.26	8800	4	1.74
woo	ste		44	N	8	0.39	2720	3	0.37
woo	ste		44	N	11	0.37	2568	2	0.55
woo	ste		55	N	4	0.24	747	1	0.23
woo	ste		64	N	6	0.35	2677	1	0.14
woo	ste		64	N	8	0.07	512	1	0.18
woo	ste		64	N	10	1.34	10452	2	0.00
woo	ste		65	N	4	0.28	1965	2	1.08
woo	ste		65	N	6	2.30	20333	1	6.43
woo	ste		65	N	11	5.25	55266	4	4.87
woo	ste		65	N	13	0.77	8158	2	2.07
woo	ste		75	N	4	3.54	15953	7	2.07
woo	ste		75	N	6	0.43	4575	1	0.00
woo	ste		75	N	11	0.20	1408	1	0.92
woo	ste		75	N	13	0.35	1925	1	0.28
woo	ste		75	R	4	2.05	14400	2	2.92
woo	ste		75	R	10	1.97	12690	6	0.41

Table A-4 Notes

Watershed Names

Main Stem (mss)

Merrill (mer)
Somes (som)
Monte (mon
Duncan (dun)
Butler (but)
Lewis (lew)
Nordheimer (nor)
Crapo (cra)
Morehouse (mor)
Lower Main Stem (low)

Wooley (woo)

Steinacher (ste)
Haypress (hay)
Bridge (bri)
Rock (roc)
Hancock (han)
North Fork Wooley (nfw)
Headwater Wooley (hww)
Lower Wooley (lwo)

North Fork (nfs)

Big (big
Olsen (ols)
Kanaka (kan)
Little North Fork (lns)
    Specimen (lnsspe)
    Headwaters (lnshls)
    Uncles (lnsunc)
    Lower (lnslln)
Jessups (jes)
Whites (whi)
Eddy (edd)
Russian (rus)
    South Russian (russru)
    Main Russian (rusrus)
Headwaters North Fork (hwn)
Lower North Fork (lln)

South Fork (sfs)

McNeal (mcn)
Knownothing (kno)
    East Fork (knoefk)
    West Fork (knowfk)
    Lower Knownothing (knolow)
Methodist (met)
Negro (neg)
Indian (ind)
Black Bear (bla)
Matthews (mat)
Plummer (plum)
French (fre)
St. Claire (stc)
Cecil (cec)
Crawford (crf)

South Fork (sfs)

East Fork (efs)
    Taylor (efstay)
    Shadow (efssha)
    Sixmile (efssix)
    Main East Fork (efsefs)
Upper South Fork (usf)
    Garden (usfgar)
    Rush (usfrsh)
    Blindhorse (usfbli)
    Headwaters (usfhws)
    Main Upper S. Fk (usflow)
Lower South Fork (lsf)

Geomorphic Terrane Types

Geomorphic Terrane	Terrane No.
Slump/Earthflow Toe Zones	2
Slump/Earthflow Deposits	3
Granitic Mountain Slopes >65%	4
Granitic Mountain Slopes <65%	5
Non-Granitic Mountain Slopes >65%	6
Non-Granitic Mountain Slopes <65%	8
Inner Gorge Developed in Landslide, Terrace or Glacial Deposits	9
Inner Gorge, Granitic Bedrock & Mt. Slope	10
Inner Gorge, Non-Granitic Bedrock & Mt. Slope	11
Debris Basins [Headwalls]	12
Glacial, Terrace & Fan Deposits	13

Table A-4. Delivered sediment yds³ from surface erosion sources for each disturbance group for 1987-88 post-wildfire conditions by subwatershed.

Watersheds	Undisturbed	Roads	Plantations	Hog Fire not burned in 1987	Hog Fire reburned 1987	1987 Fires	Total	
				yd³			yd³/acre	
SALMON	5386	7392	277	480	36422	55107	105,094	0.22
Main Stem	299	778	11	205	17607	14619	33,519	0.48
North Fork	1615	2049	155	30	13711	4903	22,463	0.17
South Fork	2146	4318	101	245	5104	18045	29,959	0.16
Wooley	1356	247	10	-	-	17540	19,153	0.20
Butler	92	23	0	-	-	-	121	0.03
Crapo	0	137	-	6	14927	1608	16,678	1.39
Duncan	17	50	1	-	-	-	67	0.06
Lewis	0	2	-	17	-	-	19	0.01
Lower Main Stem	75	349	1	37	211	6475	7,072	0.40
Merrill	29	98	9	-	-	-	136	0.04
Monte	27	53	1	-	-	-	81	0.06
Morehouse	0	-	-	-	2095	1971	4,066	0.69
Nordheimer	0	62	-	139	0	-	201	0.01
Somes	58	6	0	-	-	-	64	0.02

Table A-4 continued.

Watersheds	Undisturbed	Roads	Plantations	Hog Fire not burned in 1987	Hog Fire reburned 1987	1987 Fires	Total	
	yd^3						yd^3/acre	
Big	-	52	-	-	7271	37	7,360	4.39
Eddy	47	197	0	-	-	-	244	0.05
Headw. N. Fork	610	31	1	-	-	1690	2,333	0.06
Jessups	17	125	2	0	0	-	144	0.07
Kanaka	0	19	-	-	59	1494	1,572	3.39
Little N. Fork	337	201	78	-	-	205	821	0.04
Lower N. Fork	267	686	30	30	2664	2254	5,931	0.22
Olsen	0	10	-	0	3551	180	3,741	4.40
Russian	245	475	34	-	-	-	754	0.03
Whites	92	252	9	-	-	-	353	0.04
Black	29	339	2	0	1	3378	3,749	0.40
Cecil	43	155	2	-	-	16	216	0.06
Crawford	107	315	16	-	-	19	457	0.05
East Fork	562	1042	66	-	-	-	1,670	0.04
French	0	-	-	-	-	414	414	0.24
Indian	0	143	-	0	4	2622	2,769	0.84
Knownothing	64	447	2	0	391	4013	4,917	0.34
Lower S. Fork	126	612	2	2	1457	2774	4,974	0.28
Matthews	58	170	1	-	-	14	243	0.05
McNeal	7	138	0	8	0	-	154	0.07
Methodist	61	267	1	-	-	1946	2,275	0.28
Negro	0	159	0	0	3252	0	3,412	1.30
Plummer	119	-	-	-	-	351	470	0.05
St. Claire	29	109	1	-	-	2466	2,604	0.38
Upper S. Fork	911	421	8	-	-	0	1,341	0.03

Table A-4 continued.

Watersheds	Undisturbed	Roads	Plantations	Hog Fire not burned in 1987	Hog Fire reburned 1987	1987 Fires	Total	
	yd^3						yd^3/acre	
Bridge	241	53	1	-	-	-	295	0.03
Hancock	44	-	-	-	-	2811	2,855	0.27
Haypress	140	111	6	-	-	1	257	0.05
Headw. Wooley	329	-	-	-	-	369	698	0.03
Lower Wooley	331	8	4	-	-	4771	5,114	0.35
N. Fork Wooley	271	-	-	-	-	-	271	0.02
Rock	0	-	-	-	-	3019	3,019	0.55
Steinacher	1	75	-	-	-	6569	6,645	0.72
Headw. LNF	41	29	1	-	-	6	77	0.01
Lower LNF	110	155	57	-	-	430	752	0.15
Specimen	81	18	21	-	-	2	121	0.02
L+R Hand Forks	105	-	-	-	-	-	105	0.02
Main Russian	149	253	1	-	-	-	403	0.03
South Russian	97	222	33	-	-	-	352	0.03

Table A-4 continued.

Watersheds	Undisturbed	Roads	Plantations	Hog Fire not burned in 1987	Hog Fire reburned 1987	1987 Fires	Total	
	yd^3						yd^3/acre	
Main E. Fork	272	374	4	-	-	-	650	0.03
Shadow	79	206	19	-	-	-	304	0.05
Six Mile	56	70	1	-	-	-	127	0.03
Taylor	155	392	41	-	-	-	588	0.05
E. Fork Knownothing	35	147	1	-	-	1795	1,978	0.31
Lower Knownothing	10	71	0	-	-	492	573	0.35
W. Fork Knownothing	19	228	1	0	-	1758	2,006	0.31
Blindhorse	128	34	1	-	-	-	163	0.05
Garden	64	1	0	-	-	-	65	0.02
Headw. South Fork	403	5	-	-	-	-	408	0.02
Main Upper S. Fork	187	381	7	-	-	0	233	0.02
Rush	130	-	-	-	-	-	130	0.02

Table A-5. Little North Fork Data Summary.

LITTLE NORTH FORK (LNS) 0-1944 PERIOD

GEO-TYPE NO.	GEO-TYPE AC	Total: GEO-TYPE AC	all disturbance classes # OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL: C.Y./AC	undisturbed/unfailed lands UNDIS. UNFLD' AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL: C.Y./AC	landslides in harvested land HAR. AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL: C.Y./AC	landslides assoc. w/ roads ROAD AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD: C.Y./AC
TZ_DS 2	6	6					6														
DLS.. 3	356	356					356														
MS_SG 4	2939	2939	2	0.091	748	0.3	2939	2	0.091	748	0.3										
MS_MG 5	4649	4649	1	0.072	0	0.0	4649	1	0.072	0	0.0										
MS_SN 6	5058	5058					5058														
MS_LS 8	2104	2104					2104														
IG_LD 9	317	317	3	1.138	11855	37.4	317	3	1.138	11855	37.4										
IG_GS 10	1152	1152					1152														
IG_NG 11	1805	1805	1	0.056	233	0.1	1805	1	0.056	233	0.1										
DB... 12	793	793	4	0.767	6837	8.6	793	4	0.767	6837	8.6										
GT_FD 13	1622	1622					1622														
TOTAL	20801	20801	11	2.124	19673		20801	11	2.1243	19673											

LITTLE NORTH FORK 1964-1965 PERIOD

GEO-TYPE NO.	GEO-TYPE AC	Total: GEO-TYPE AC	all disturbance classes # OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL: C.Y./AC	undisturbed/unfailed lands UNDIS. UNFLD' AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL: C.Y./AC	landslides in harvested land HAR. AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL: C.Y./AC	landslides assoc. w/ roads ROAD AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD: C.Y./AC
TZ_DS 2	6	6					6														
DLS.. 3	356	356	0.5	35.000	0	0.0	356	0.5	35	0	0.0										
MS_SG 4	2939	2939	6	0.649	3439	1.2	2939	6	0.649	3439	1.2										
MS_MG 5	4649	4649	2	0.081	435	0.1	4649	2	0.081	435	0.1										
MS_SN 6	5058	5058	2	0.139	1014	0.2	5058	2	0.139	1014	0.2										
MS_LS 8	2104	2104	1	0.055	256	0.1	2104	1	0.055	256	0.1										
IG_LD 9	317	317	41.5	13.442	96344	303.9	317	41.5	13.442	96344	303.9						2 TRAIL SLIDES				
IG_GS 10	1152	1152	52	12.723	188673	163.8	1152	52	12.723	188673	163.8						USED UNDISTURBED ACRE FIGURE				
IG_NG 11	1805	1805	23	4.230	34278	18.2	1805	21	4.072	32688	18.1						1805	2	0.158	1590	0.9
DB... 12	793	793	3	0.171	1422	1.8	793	3	0.171	1422	1.8										
GT_FD 13	1622	1622	2	3.454	6729	4.1	1622	2	3.454	6729	4.1										
TOTAL	20801	20801	133	69.945	332590		20801	131	69.787	331000							1805	2	0.1579	1590	

LITTLE NORTH FORK 1965-1975

GEO-TYPE NO.	GEO-TYPE AC	Total: GEO-TYPE AC	all disturbance classes # OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL: C.Y./AC	undisturbed/unfailed lands UNDIS. UNFLD' AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL: C.Y./AC	landslides in harvested land HAR. AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL: C.Y./AC	landslides assoc. w/ roads ROAD AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD: C.Y./AC
TZ_DS 2	6	6					6														
DLS.. 3	356	356	2	0.084	739	2.1	320					31	1	0.056	555	17.9	5	1	0.028	184	36.8
MS_SG 4	2939	2939	20	2.403	15823	5.4	2837	1	0.482	8200	2.9	88	3	0.188	1314	14.9	14	16	1.733	6309	450.6
MS_MG 5	4649	4649	9	0.526	1567	0.3	4362	2	0.061	152	0.0	261					26	7	0.465	1415	54.4
MS_SN 6	5058	5058	13	6.084	4535	0.9	4955	1	0.052	273	0.1	91	2	3.054	0	0.0	12	10	2.978	4262	355.1
MS_LS 8	2104	2104	2	0.094	343	0.2	1999					96	1	0.018	57	0.6	9	1	0.076	286	31.8
IG_LD 9	317	317	10	1.345	8402	26.5	311.5	10	1.345	8402	27.0	5					0.5				
IG_GS 10	1152	1152	155	16.694	90660	78.7	990	23	2.189	13532	13.7	152	102	8.179	42306	278.3	10	30	6.326	34822	3482.2
IG_NG 11	1805	1805	18	4.344	8838	4.9	1752	10	1.091	6726	3.8	50	5	3.001	846	16.9	3	3	0.252	1266	421.9
DB... 12	793	793					792										1				
GT_FD 13	1622	1622					1601					20					1				
TOTAL	20801	20801	229	31.574	130907		19925	47	5.221	37285		794	114	14.496	45079		81.5	68	11.856	48543	

LITTLE NORTH FORK 0-1988 PERIOD OF RECORD

TOTAL	20801		373	103.643	483170			189	77.132	387957			114	14.496	45079		82	70	12	50133	

Table A-5. Little North Fork Data Summary.

HEADWATERS, LITTLE NORTH FORK (HLS) 0-1944 PERIOD

GEO-TYPE NO.	GEO-TYPE AC	all disturbance classes: GEO-TYPE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	undisturbed/unfailed lands: UNDIS. UNFLD' AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides in harvested land: HAR. AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides assoc. w/ roads: ROAD AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC
TZ_DS 2																					
DLS.. 3	14	14					14														
MS_SG 4	997	997	1	0.043	370	0.4	997	1	0.043	370	0.4										
MS_MG 5	2424	2424					2424														
MS_SN 6	55	55					55														
MS_LS 8	281	281					281														
IG_LD 9	94	94	2	0.770	9722	103.4	94	2	0.770	9722	103.4										
IG_GS 10	230	230					230														
IG_NG 11	136	136					136														
DB... 12	202	202	3	0.198	2570	12.7	202	3	0.198	2570	12.7										
GT_FD 13	1210	1210					1210														
TOTAL	5643	5643	6	1.011	12662		5643	6	1.011	12662											

HEADWATERS, LITTLE NORTH FORK (HLS) 1964-1965 PERIOD

GEO-TYPE NO.	GEO-TYPE AC	all disturbance classes: GEO-TYPE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	undisturbed/unfailed lands: UNDIS. UNFLD' AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides in harvested land: HAR. AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides assoc. w/ roads: ROAD AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC
TZ_DS 2																					
DLS.. 3	14	14					14														
MS_SG 4	997	997	4	0.602	2941	2.9	997	4	0.602	2941	2.9										
MS_MG 5	2424	2424	1	0.056	294	0.1	2424	1	0.056	294	0.1										
MS_SN 6	55	55					55														
MS_LS 8	281	281	1	0.055	256	0.9	281	1	0.055	256	0.9										
IG_LD 9	94	94	38	9.156	74193	789.3	94	38	9.156	74193	789.3										
IG_GS 10	230	230	24	8.959	153955	669.4	230	24	8.959	153955	669.4										
IG_NG 11	136	136	9	2.218	16876	124.1	136	9	2.218	16876	124.1										
DB... 12	202	202	3	0.171	1422	7.0	202	3	0.171	1422	7.0										
GT_FD 13	1210	1210	1	3.330	5989	4.9	1210	1	3.330	5989	4.9										
TOTAL	5643	5643	81	24.547	255926		5643	81	24.547	255926											

HEADWATERS, LITTLE NORTH FORK (HLS) 1965-1975 PERIOD

GEO-TYPE NO.	GEO-TYPE AC	all disturbance classes: GEO-TYPE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	undisturbed/unfailed lands: UNDIS. UNFLD' AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides in harvested land: HAR. AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides assoc. w/ roads: ROAD AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC
TZ_DS 2																					
DLS.. 3	14	14					9					4					1				
MS_SG 4	997	997					997														
MS_MG 5	2424	2424					2388					33					3				
MS_SN 6	55	55	3	1.653	552	10.0	42					12					1	3	1.653	552	552.0
MS_LS 8	281	281	2	0.094	343	1.2	196					82	1	0.018	57	0.7	3	1	0.076	286	95.3
IG_LD 9	94	94	2	0.104	390	4.1	94	2	0.104	390	4.1										
IG_GS 10	230	230	7	0.662	2034	8.8	229	7	0.662	2034	8.9	1									
IG_NG 11	136	136	9	3.611	6119	45.0	118	3	0.535	4507	38.2	17	5	3.001	846	49.8	1	1	0.076	766	766.0
DB... 12	202	202					202														
GT_FD 13	1210	1210					1202					7					1				
TOTAL	5643	5643	23	6.125	9438		5477	12	1.301	6931		156	6	3.019	903		10	5	1.805	1604	

HEADWATERS, LITTLE NORTH FORK 0-1988 PERIOD OF RECORD

TOTAL	5643		110	31.6830	278026			99	26.859	275519			6	3.019	903			5	2	1604	

Table A-5. Little North Fork Data Summary.

LOWER, LITTLE NORTH FORK, (LOW) 0-1944 PERIOD

GEO-TYPE NO.	GEO-TYPE	GEO-TYPE AC	all disturbance classes # OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	undisturbed/unfailed lands UNDIS. UNFLD' AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides in harvested land HAR. AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides assoc. w/ roads ROAD AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC
TZ_DS 2		1	1																		
DLS.. 3		217	217																		
MS_SG 4		1096	1096																		
MS_MG 5		1203	1203	1	0.072	0	0.0	1203	1	0.072	0	0.0									
MS_SN 6		984	984																		
MS_LS 8		226	226																		
IG_LD 9		33	33																		
IG_GS 10		703	703																		
IG_NG 11		376	376																		
DB... 12		158	158																		
GT_FD 13		123	123																		
TOTAL		5120	5120	1	0.072	0		1	0.072	0											

LOWER, LITTLE NORTH FORK, (LOW) 1964-1965 PERIOD

GEO-TYPE NO.	GEO-TYPE	GEO-TYPE AC	all disturbance classes # OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	undisturbed/unfailed lands UNDIS. UNFLD' AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides in harvested land HAR. AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides assoc. w/ roads ROAD AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC
TZ_DS 2		1	1				1														
DLS.. 3		217	217				217	0.5	35	0	0.0										
MS_SG 4		1096	1096				1096														
MS_MG 5		1203	1203				1203														
MS_SN 6		984	984	2	0.139	1014	1.0	984	2	0.139	1014	1.0									
MS_LS 8		226	226					226													
IG_LD 9		33	33	2	39.093	20863	632.2	33	1.5	4.093	20863	632.2									
IG_GS 10		703	703	21	2.962	24010	34.2	703	21	2.962	24010	34.2					TRAIL; USED NATURAL ACRES				
IG_NG 11		376	376	13	1.884	16602	44.2	376	11	1.7255	15012	39.9					376	2	0.158	1590	4.2
DB... 12		158	158					158													
GT_FD 13		123	123					123													
TOTAL		5120	5120	38	44.078	62489			36	43.919	60899						376	2	0.158	1590	4.2

LOWER, LITTLE NORTH FORK, (LOW) 1965-1975 PERIOD

GEO-TYPE NO.	GEO-TYPE	GEO-TYPE AC	all disturbance classes # OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	undisturbed/unfailed lands UNDIS. UNFLD' AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides in harvested land HAR. AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides assoc. w/ roads ROAD AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD C.Y./AC
TZ_DS 2		1	1				1														
DLS.. 3		217	217	2	0.084	739	3.4	187					27	1	0.056	555	20.6	3	1	0.028	184	61.3
MS_SG 4		1096	1096	20	2.403	15823	14.4	994	1	0.482	8200	8.2	88	3	0.188	1314	14.9	14	16	1.733	6309	450.6
MS_MG 5		1203	1203	9	0.526	1567	1.3	952	2	0.061	152	0.2	228					23	7	0.465	1415	61.5
MS_SN 6		984	984	10	4.431	3983	4.0	899	1	0.052	273	0.3	79	2	3.054	0	0.0	6	7	1.325	3710	618.3
MS_LS 8		226	226					209					14					3				
IG_LD 9		33	33	5	0.640	4885	148.0	27.5	5	0.640	4885	177.6	5					0.5				
IG_GS 10		703	703	147	15.904	88366	125.7	543	15	1.399	11238	20.7	150	102	8.179	42306	282.0	10	30	6.326	34822	3482.2
IG_NG 11		376	376	5	0.458	1607	4.3	342	2	0.230	875	2.6	33					1	3	0.227	732	732.5
DB... 12		158	158					158														
GT_FD 13		123	123					109.5					13					0.5				
TOTAL		5120	5120	198	24.4449	116970		4422	26	2.864	25623		637	108	11.477	44175		61	64	10.103	47172	

LOWER LITTLE NORTH FORK, 0-1988 PERIOD OF RECORD

TOTAL		5120		237	68.5945	179459		4422	63	46.855	86521.		637	108	11.477	44175			66	10.261	48761.

Table A-5. Little North Fork Data Summary.

SPECIMEN CREEK, LITTLE NORTH FORK (SPE) 0-1944 PERIOD

GEO-TYPE NO.	GEO-TYPE AC	all disturbance classes: GEO-TYPE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL: C.Y./AC	undisturbed/unfailed lands: UNDIS. UNFLD' AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL: C.Y./AC	landslides in harvested land: HAR. AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL: C.Y./AC	landslides assoc. w/ roads: ROAD AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD: C.Y./AC
TZ_DS 2	3	3					3														
DLS.. 3	125	125					125														
MS_SG 4	48	48					48														
MS_MG 5	23	23					23														
MS_SN 6	3093	3093					3093														
MS_LS 8	608	608					608														
IG_LD 9	16	16					16														
IG_GS 10	14	14					14														
IG_NG 11	844	844					844														
DB... 12	241	241					241														
GT_FD 13																					
TOTAL	5015	5015																			

SPECIMEN CREEK, LITTLE NORTH FORK (SPE) 1964-1965 PERIOD

GEO-TYPE NO.	GEO-TYPE AC	all disturbance classes: GEO-TYPE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL: C.Y./AC	undisturbed/unfailed lands: UNDIS. UNFLD' AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL: C.Y./AC	landslides in harvested land: HAR. AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL: C.Y./AC	landslides assoc. w/ roads: ROAD AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD: C.Y./AC
TZ_DS 2	3	3					3														
DLS.. 3	125	125					125														
MS_SG 4	48	48					48														
MS_MG 5	23	23					23														
MS_SN 6	3093	3093					3093														
MS_LS 8	608	608					608														
IG_LD 9	16	16					16														
IG_GS 10	14	14	2	0.178	2724	194.6	14	2	0.178	2724	194.6										
IG_NG 11	844	844					844														
DB... 12	241	241					241														
GT_FD 13																					
TOTAL	5015	5015	2	0.178	2724		5015	2	0.178	2724											

SPECIMEN CREEK, LITTLE NORTH FORK (SPE) 1965-1975 PERIOD

GEO-TYPE NO.	GEO-TYPE AC	all disturbance classes: GEO-TYPE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL: C.Y./AC	undisturbed/unfailed lands: UNDIS. UNFLD' AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL: C.Y./AC	landslides in harvested land: HAR. AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL: C.Y./AC	landslides assoc. w/ roads: ROAD AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD: C.Y./AC
TZ_DS 2	3	3					3														
DLS.. 3	125	125					125														
MS_SG 4	48	48					48														
MS_MG 5	23	23					23														
MS_SN 6	3093	3093					3089										4				
MS_LS 8	608	608					605										3				
IG_LD 9	16	16					16														
IG_GS 10	14	14					12.5					1					0.5				
IG_NG 11	844	844	1	0.028	12	0.0	843.5	1	0.028	12	0.0						0.5				
DB... 12	241	241					240										1				
GT_FD 13																					
TOTAL	5015	5015	1	0.028	12		5005	1	0.028	12		1	0	0	0		9	0	0	0	

SPECIMEN CREEK 0-1988 PERIOD OF RECORD

TOTAL	5015		3	0.206	2736			3	0.206	2736			0	0	0			0	0	0	

Table A-5. Little North Fork Data Summary.

UNCLES CREEK, LITTLE NORTH FORK (UNC) 0-1944 PERIOD

GEO-TYPE NO.	GEO-TYPE AC	all disturbance classes: GEO-TYPE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	undisturbed/unfailed lands: UNDIS. UNFLD' AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides in harvested land: HAR. AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides assoc. w/ roads: ROAD AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD C.Y./AC
TZ_DS 2	2	2					2														
DLS.. 3																					
MS_SG 4	798	798	1	0.048	378	0.5	798	1	0.048	378	0.5										
MS_MG 5	999	999					999														
MS_SN 6	925	925					925														
MS_LS 8	989	989					989														
IG_LD 9	173	173	1	0.367	2133	12.3	173	1	0.367	2133	12.3										
IG_GS 10	206	206					206														
IG_NG 11	449	449	1	0.056	233	0.5	449	1	0.056	233	0.5										
DB... 12	192	192	1	0.569	4267	22.2	192	1	0.569	4267	22.2										
GT_FD 13	288	288					288														
TOTAL	5021	5021	4	1.041	7011		5021	4	1.0412	7011											

UNCLES CREEK, LITTLE NORTH FORK (UNC) 1964-1965 PERIOD

GEO-TYPE NO.	GEO-TYPE AC	all disturbance classes: GEO-TYPE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	undisturbed/unfailed lands: UNDIS. UNFLD' AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides in harvested land: HAR. AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides assoc. w/ roads: ROAD AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD C.Y./AC
TZ_DS 2	2	2					2														
DLS.. 3																					
MS_SG 4	798	798	2	0.047	498	0.6	798	2	0.047	498	0.6										
MS_MG 5	999	999	1	0.025	141	0.1	999	1	0.025	141	0.1										
MS_SN 6	925	925					925														
MS_LS 8	989	989					989														
IG_LD 9	173	173	2	0.193	1288	7.4	173	2	0.193	1288	7.4										
IG_GS 10	206	206	5	0.625	7984	38.8	206	5	0.625	7984	38.8										
IG_NG 11	449	449	1	0.129	800	1.8	449	1	0.129	800	1.8										
DB... 12	192	191					192														
GT_FD 13	288	288	1	0.124	740	2.6	288	1	0.124	740	2.6										
TOTAL	5021	5021	12	1.142	11451		5021	12	1.142	11451											

UNCLES CREEK, LITTLE NORTH FORK (UNC) 1965-1975 PERIOD

GEO-TYPE NO.	GEO-TYPE AC	all disturbance classes: GEO-TYPE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	undisturbed/unfailed lands: UNDIS. UNFLD' AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides in harvested land: HAR. AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides assoc. w/ roads: ROAD AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD C.Y./AC
TZ_DS 2	2	2					2														
DLS.. 3																					
MS_SG 4	798	798					798														
MS_MG 5	999	999					999														
MS_SN 6	925	925					925														
MS_LS 8	989	989					989														
IG_LD 9	173	173	3	0.601	3127	18.1	173	3	0.601	3127	18.1										
IG_GS 10	206	205	1	0.129	260	1.3	206	1	0.129	260	1.3										
IG_NG 11	449	449	3	0.246	1099	2.4	449	3	0.246	1099	2.8										
DB... 12	192	192					192														
GT_FD 13	288	288					288														
TOTAL	5021	5021	7	0.976	4486		5021	7	0.976	4486											
UNCLES CREEK WATERSHED TOTALS	5021	5021	23	3.160	22948			23	3.1595	22948											

Table A-6. Negro Creek Data Summary.

NEGRO CREEK (SFSNEG) 0-1944 PERIOD

GEO-TYPE NO.	GEO-TYPE AC	all disturbance classes: GEO-TYPE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD. C.Y./AC	undisturbed/unfailed lands: UNDIS. UNFLD' AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD. C.Y./AC	landslides harvest units: HAR. AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD. C.Y./AC	landslides assoc. w/ roads: ROAD AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD. C.Y./AC	landslides assoc. w/ fire: FIRE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD C.Y./AC
TZ_DS 2																										
DLS.. 3	1408	1408	1	0.843	0	0.0	1408	1	0.843	0	0.0															
MS_SG 4																										
MS_MG 5																										
MS_SN 6	276	276					276																			
MS_LS 8	547	547					547																			
IG_LD 9	255	255	1	0.232	2400	9.4	255	1	0.232	2400	9.4															
IG_GS 10																										
IG_NG 11	130	130	4	0.308	1965	15.1	130	4	0.308	1965	15.1															
DB... 12																										
GT_FD 13																										
TOTAL	2616	2616	6	1.383	4365		2616	6	1.383	4365																

NEGRO CREEK (SFSNEG) 1955-1964 PERIOD

GEO-TYPE NO.	GEO-TYPE AC	all disturbance classes: GEO-TYPE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD. C.Y./AC	undisturbed/unfailed lands: UNDIS. UNFLD' AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD. C.Y./AC	landslides harvest units: HAR. AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD. C.Y./AC	landslides assoc. w/ roads: ROAD AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD. C.Y./AC	landslides assoc. w/ fire: FIRE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD C.Y./AC
TZ_DS 2																										
DLS.. 3	1408	1408					1376.2										31.8									
MS_SG 4																										
MS_MG 5																										
MS_SN 6	276	276					274.8										1.2									
MS_LS 8	547	547	1	0.220	72	0.1	535.6										11.4	1	0.220	72	6.3					
IG_LD 9	255	255					250.8										4.2									
IG_GS 10																										
IG_NG 11	130	130					130																			
DB... 12																										
GT_FD 13																										
TOTAL	2616	2616	1	0.22	72		2567.4										48.6	1	0.22	72						

NEGRO CREEK (SFSNEG) 1964-1965 PERIOD

GEO-TYPE NO.	GEO-TYPE AC	all disturbance classes: GEO-TYPE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD. C.Y./AC	undisturbed/unfailed lands: UNDIS. UNFLD' AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD. C.Y./AC	landslides harvest units: HAR. AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD. C.Y./AC	landslides assoc. w/ roads: ROAD AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD. C.Y./AC	landslides assoc. w/ fire: FIRE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD C.Y./AC
TZ_DS 2																										
DLS.. 3	1408	1408					1376.2										31.8									
MS_SG 4																										
MS_MG 5																										
MS_SN 6	276	276	0.5	1.751	0	0.0	274.8	0.5	1.751	0	0.0						1.2									
MS_LS 8	547	547	2	0.077	187	0.3	535.6										11.4	2	0.077	187	16.4					
IG_LD 9	255	255	1	0.646	5800	22.7	250.8	1	0.646	5800	23.1						4.2									
IG_GS 10																										
IG_NG 11	130	130	8.5	2.304	34648	266.5	130.0	8.5	2.304	34648	266.5															
DB... 12																										
GT_FD 13																										
TOTAL	2616	2616	12	4.778	40635		2567.4	10	4.701	40448							48.6	2	0.077	187						

Table A-6. Negro Creek Data Summary.

NEGRO CREEK (SFSNEG) 1965-1975 PERIOD

GEO-TYPE NO.	GEO-TYPE AC	all disturbance classes: GEO-TYPE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD. C.Y./AC	undisturbed/unfailed lands: UNDIS. UNFLD' AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD. C.Y./AC	landslides harvest units: HAR. AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD. C.Y./AC	landslides assoc. w/ roads: ROAD AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD. C.Y./AC	landslides assoc. w/ fire: FIRE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD C.Y./AC
TZ_DS 2																										
DLS.. 3	1408	1408	1	0.092	72	0.1	1368.2										39.75	1	0.092	72	1.8					
MS_SG 4																										
MS_MG 5																										
MS_SN 6	276	276					274.5										1.5									
MS_LS 8	547	547	2	0.436	1116	2.0	532.75	1	0.278	935	1.8						14.25	1	0.158	181	12.7					
IG_LD 9	255	255	4	0.390	705	2.8	249.75	2	0.351	690	2.8						5.25	2	0.039	15	2.9					
IG_GS 10																										
IG_NG 11	130	130	3	0.285	1476	11.4	130	3	0.285	1476	11.4															
DB... 12																										
GT_FD 13																										
TOTAL	2616	2616	10	1.203	3369		2555.2	6	0.914	3101							60.75	4	0.289	268						

NEGRO CREEK (SFSNEG) 1975-1988 PERIOD

GEO-TYPE NO.	GEO-TYPE AC	all disturbance classes: GEO-TYPE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD. C.Y./AC	undisturbed/unfailed lands: UNDIS. UNFLD' AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD. C.Y./AC	landslides harvest units: HAR. AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD. C.Y./AC	landslides assoc. w/ roads: ROAD AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD. C.Y./AC	landslides assoc. w/ fire: FIRE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD C.Y./AC
TZ_DS 2																										
DLS.. 3	1408	1408	8	2.899	2766	2.0	0										53	3	0.6	1523	28.7	1355	5	2.299	1243	0.9
MS_SG 4																										
MS_MG 5																										
MS_SN 6	276	276	1.25	2.817	0	0.0	4										2				0.0	270	1.25	2.817	0	0.0
MS_LS 8	547	547	4	0.560	747	1.4	0										19	2	0.429	417	21.9	528	2	0.131	330	0.6
IG_LD 9	255	255	54	4.367	14968	58.7	0										7	2	0.139	275	39.3	248	52	4.228	14693	59.2
IG_GS 10																										
IG_NG 11	130	130	22.75	2.872	11223	86.3	0										1	1	0.074	360	360.0	129	21.75	2.798	10863	84.2
DB... 12																										
GT_FD 13																										
TOTAL	2616	2616	90	13.515	29704		4										82	8	1.242	2575		2530	82	12.273	27129	

NEGRO CREEK ALL PERIODS

SUM TOTAL	2616	2616	119	21.099	78145			22	6.998	47914		0						15	1.828	3102			82	12.273	27129	

Tables A-5 and A-6: Notes

Geomorphic Terrane Types

Geomorphic Terrane	Code	Terrane No.
Slump/Earthflow Toe Zones	TZ_DS	2
Slump/Earthflow Deposits	DLS..	3
Granitic Mountain Slopes >65%	MS_SG	4
Granitic Mountain Slopes <65%	MS_MG	5
Non-Granitic Mountain Slopes >65%	MS_SN	6
Non-Granitic Mountain Slopes <65%	MS_LN	8
Inner Gorge Developed in Landslide, Terrace or Glacial Deposits	IG_LD	9
Inner Gorge, Granitic Bedrock & Mt. Slope	IG_GS	10
Inner Gorge, Non-Granitic Bedrock & Mt. Slope	IG_NG	11
Debris Basins [Headwalls]	DB..	12
Glacial, Terrace & Fan Deposits	GT_FD	13

APPENDIX B

Physical and Biological Characteristics of the Salmon River Watershed

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INTRODUCTION

In-depth discussions of the climate, geology, vegetation, and fire history are presented in this appendix. Shorter summaries of these topics are found in Chapter 2 of the main body of the report. The purpose of this appendix is to provide more complete coverage of these subjects.

CLIMATE

In the central Klamath Mountains, the coastal climatic influence is moderated by the mountains to the west. Summers are warm and dry, winters are cool and wet. Summer high temperatures are about 90 degrees Fahrenheit, low temperatures are about 55 degrees. Winter high temperatures are about 40 to 55 degrees while raining, cooler under clear skies. The annual precipitation during the period of record [1904 to present] at Orleans ranges from 26 to 84 inches. The average annual precipitation is about 50 inches. Approximately 90% of the precipitation occurs from October through May from north Pacific cyclonic storms. The remainder occurs during summer thunderstorms. Winter precipitation occurs mainly as snow above 4,000 feet elevation, and mainly as rain below that elevation. Fluctuation of the snow level occasionally results in rain falling on snow, causing rapid snow melt. Precipitation within the Salmon River Watershed varies from over 80 inches in upper Wooley Creek to less than 40 inches along the South Fork **[Figure B-1]**. The amount of precipitation generally decreases in an easterly direction, and increases with elevation due to orographic effects. Intense, localized summer showers occur frequently, and have been associated with soil erosion and debris torrents.

The distribution of precipitation over time influences the behavior of erosion and landsliding processes, water quality and the structure of stream channels. The precipitation record has been analyzed to show climatic trends [Baldwin and de la Fuente 1986; Coghlan 1984]. Annual precipitation and cumulative departure data **[Figure B-2]**, show the actual annual precipitation by year and a running sum of the difference between actual annual and average annual precipitation [or cumulative departure]. The cumulative departure diagram indicates periods of accumulating precipitation deficit and surplus. The drier periods are of approximately 45 inches average annual precipitation, the wetter are of approximately 55 inches. The Orleans record, along with longer records from Eureka and other stations in northwestern California, indicate that the period 1870 to 1910 was a wet time; 1911 to 1937 dry; 1938 to 1975 wet; and 1976 to present dry **[Table B-1]**. These alternating periods of relatively wet and dry conditions last for a few decades.

The short duration of the record with respect to the duration of these trends and irregular nature of climatic change preclude forecasting. Significant exceptions to the pattern include precipitation of the 1982 and 1983 seasons associated with the relatively strong El Nino/Southern Oscillation [ENSO] event and volcanic eruptions of that time. Although there is an approximate seven year return interval of the ENSO event, patterns of the influence of these events on local climate have not been established. Comparing these precipitation trends with the snow depth record from Crater Lake, it is apparent that fluctuations in temperature on a scale of decades influence the proportion of precipitation falling as snow.

Similar fluctuations in climate have been described by Coghlan [1984] for northwestern California floods, Meko and Stockton [1984] from stream flow records in the western United States, and LaMarche [1974] from interpretation of tree rings in the White Mountains of California. Fritts and Gordon [1980] examined high quality precipitation records in California and interpreted tree rings to extend the precipitation record. In their synthesized 360 year record, the time since 1890 has been of precipitation surplus with respect to the long term average. The most interesting feature of their record is a dry period from 1760 to 1820.

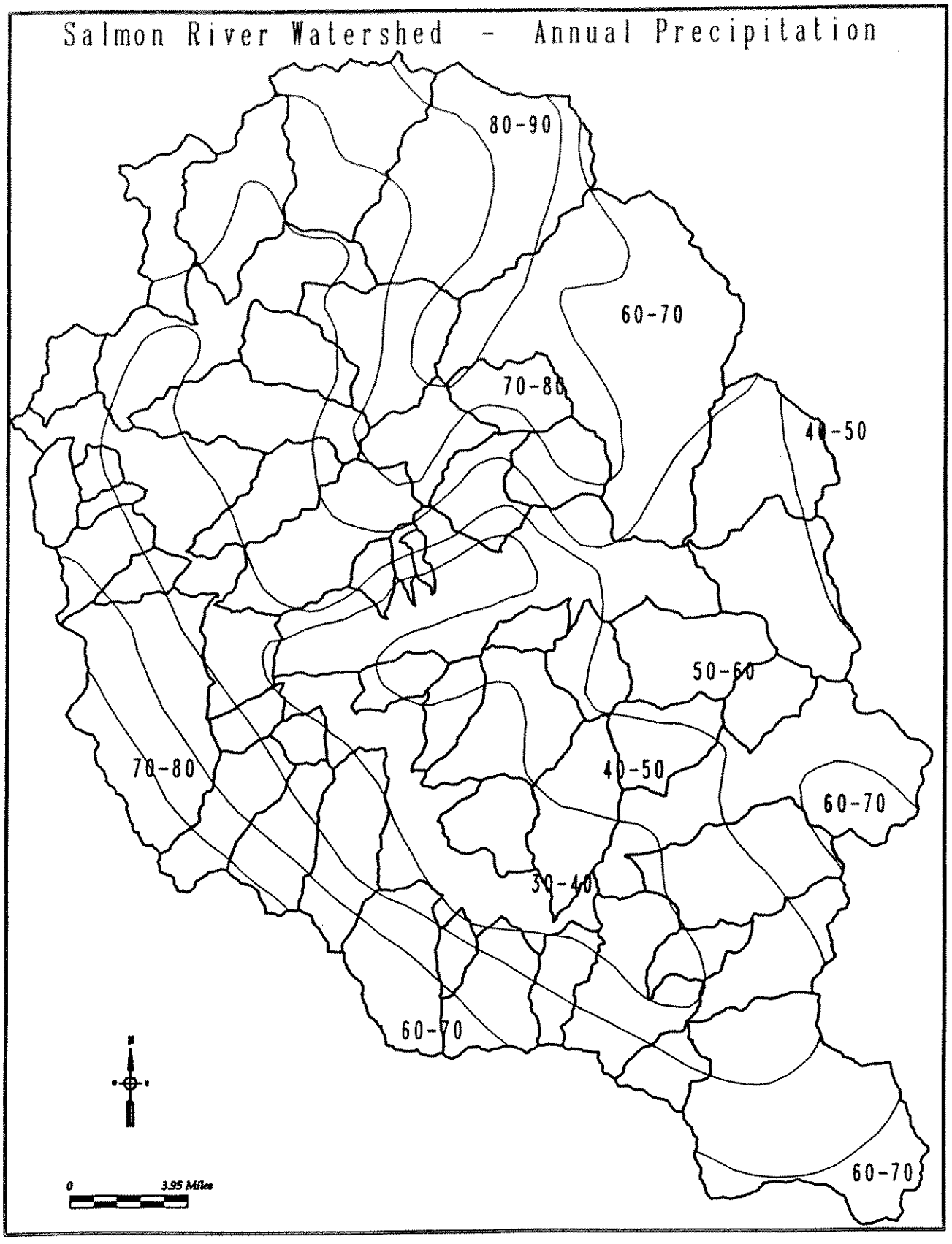

Figure B-1. Isohyetal map of annual average precipitation in the Salmon River watershed. Data source is modified from Rantz [1968].

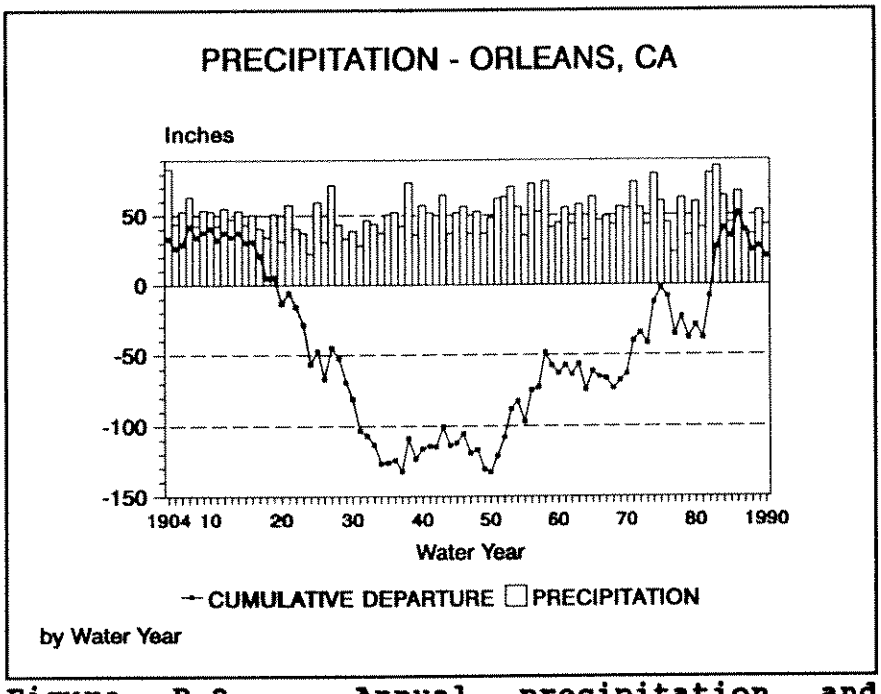

Figure B-2. Annual precipitation and cumulative departure from average annual precipitation at Orleans, 1904-1990.

Table B-1. Number of Years within annual precipitation ranges showing climatic trends, 1904-1991, Orleans, California.

INCHES	1904-91	1904-14	1915-37	1938-75	1976-91
20-30	3	0	1	1	1
30-40	18	4	5	5	4
40-50	23	2	13	4	4
50-60	25	1	3	18	3
60-70	14	2	1	9	2
70-80	3	1	0	1	1
80-90	2	1	0	0	1
AVE. ANNUAL PRECIPITATION	**50.3**	**53.0**	**43.5**	**53.9**	**49.8**

Notes: Annual precipitation range among observations: 26.2 - 84.2 inches

Fluctuations of climate that occur at scales of tens-of-thousands to a hundred thousand years have been attributed to multiple cyclic changes in the Earth's geometric relationship with the Sun [100,000, 43,000, 24,000 and 19,500 year Milankovich cycles]. The solar energy budget on Earth is also influenced by fluctuations of solar energy flux [11 year sunspot cycle] and changes in the trace-gas chemistry of the Earth's atmosphere. Weiner [1986] has summarizes the body of science of the Earth's climate that has accumulated in the last few decades.

The progression of climate at a scale of thousands of years is relevant to this assessment because landscape features that originated in response to past climatic conditions continue to influence present landscape behavior. Lacking local interpretation of paleoclimate, the work of others in nearby comparable regions is used. Reneau and others [1986] noted a clustering of minimum ages of radiocarbon dated colluvial deposits of coastal northern California around 12,000 years ago, thus suggesting a time of higher rate of landsliding. Adam and West [1983] and Adam [1988] have described the transition from the last glacial advance that occurred 10,000 to 15,000 years ago. Their interpretation of pollen stratigraphy at Clear Lake [Lake County, California] suggests that climatic warming and substantial drying occurred during the transition. Glacial landforms described in the Marble and Siskiyou Mountains by Long [1983, 1985] support the view that the glacial influence in the Salmon River watershed has been strong in the past. Cool, wet periods of the transition and more recent wetter periods are believed to have contributed to the activity of presently dormant, large earthflow-slump landslides found in the Salmon River watershed [Baldwin and de la Fuente, 1987].

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GEOLOGY

The Salmon River drainage lies entirely within the Klamath Mountains geologic province. This geologic province represents an imbricate succession of lithotectonic units [terranes] that record the systematic westward growth of the North American plate from early Cambrian to late Jurassic time. The arcuate N-S trending terranes are generally younger and structurally lower from east to west, and are juxtaposed along east-dipping regional thrust faults. All Klamath lithologic units contain similar rock types as all were originally deposited in marine settings. Therefore subdivisions of the Klamath Mountains into terranes have been made on the basis of structural, metamorphic, and temporal discontinuities between geologic units.

Most bedrock units mapped within the Salmon River watershed belong to the Western Paleozoic and Triassic lithotectonic belt. However, in the southeastern corner of the watershed, rocks of the Devonian Central Metamorphic belt are found, and Silurian[?]-Ordovician Yreka terrane rocks of the Eastern Klamath belt form a small structural outlier northwest of Cecilville. These amalgamated oceanic crustal rocks are intruded by Middle Jurassic to Early Cretaceous plutons.

At least five tectonic events of mountain building occurred in the Klamath Mountains. During these tectonic episodes, succeeding terranes were regionally metamorphosed, deformed and stitched together by eastward thrust faults beneath older Klamath terranes. The Late Jurassic Nevadan orogenic episode was the last of these regional tectonic events.

In general, metamorphic grade increases northward through the study area. This pattern can be attributed to differential post-Nevadan uplift that has exposed deeper crustal levels to the north.

Cecilville Outlier

The oldest and structurally highest unit found within the Salmon River drainage consists of rocks of the Cecilville outlier that have been tentatively correlated by Wagner and Saucedo [1987] with the Duzel Formation of the Yreka terrane of the Eastern Klamath belt. This unit occurs near Cecilville, in the Matthews and Crawford Creek watersheds. The Duzel Formation is a loose grouping of Lower Paleozoic rock units whose age and structural relationship with each other is poorly understood. Representative rock types include phyllite, graywacke, chert, siltstone, quartzite, silty limestone, greenstone, and amphibolite. The rocks have undergone low-grade greenschist facies metamorphism. Radiometric ages from Duzel Formation rocks northeast of the study area yield Ordovician and younger Devonian ages. The Ordovician dates [467-440 Ma] likely represent Callahan event metamorphism [Cotkin and others 1987] while the younger dates reflect Devonian metamorphism during the Coffee Creek event occurring at about 370 Ma [Cashman, 1980; Wagner and Saucedo, 1987]. The outlier is bound on the northwest by the post-Nevadan high-angle Grouse Point fault, and elsewhere by the Devonian Bully Choop [or Trinity] thrust [Davis and others, 1979].

Central Metamorphic Terrane

Two units make up the Central Metamorphic terrane [belt]: the Salmon Hornblende Schist and the structurally overlying Abrams Mica Schist [or Grouse Point Formation]. This unit occurs in the Crawford Creek watershed, in the South Fork of the Salmon River near its junction with the East Fork, and also in the headwaters of Cecil and St. Claire Creeks. The Salmon Hornblende Schist was originally a basaltic volcanic rock that underwent metamorphism at conditions of high temperature and moderate pressure. This unit occupies much of the South Fork of the Salmon River, from the headwaters down to its junction with the East Fork. The lithology of the Salmon Hornblende Schist consists of foliated or schistose hornblende-bearing amphibolite. The Abrams Mica Schist is composed of schistose metamorphosed sedimentary rocks, including micaceous quartzite, impure marble and phyllite, with lesser amphibolite and other metavolcanic rocks. Metamorphic recrystallization has destroyed nearly all primary igneous and sedimentary features. The rock units were deformed during the Late Devonian [~370 Ma] Coffee Creek event, when Central Metamorphic Terrane rocks were thrust beneath Eastern Klamath rocks along the Bully Choop [or Trinity] thrust.

Stuart Fork Terrane

The Stuart Fork terrane consists predominantly of interlayered siliceous metasedimentary and mafic metavolcanic rocks [Davis and others, 1965]. It occurs primarily in the East Fork of the Salmon River. This unit is unique in that it contains rocks with mineral assembalges indicating metamorphism under high pressure and low temperature blueschist facies conditions [Goodge, 1987]. The deformation features of the rocks, together with blueschist metamorphism, indicate that Stuart Fork rocks were deformed deep within a subduction zone. Stuart Fork rocks were overprinted by a later greenschist-facies metamorphism during the regional Siskiyou event and/or during Jurassic to Cretaceous pluton emplacement. The siliceous metasediments were originally composed of interbedded chert and argillite, that occurs now as thinly layered phyllitic quartzite. Other metasedimentary rocks include lesser amounts of phyllite, mica schist and argillite; carbonate rocks are rare or absent [Goodge, 1989]. Near Fort Jones, radiometric dating of these rocks yield Late Triassic dates of 219 Ma and 227 Ma [Hotz and others 1977] which probably represent the time of metamorphic mineral formation or cooling age.

The Stuart Fork terrane lies structurally beneath the Central Metamorphic terrane along the Siskiyou thrust, whose age is unconstrained. The Late Triassic age cited above, together with a 234 + 30 Ma reset age [Lanphere and others 1968; recalculated and reported in Wagner and Saucedeo, 1987], in the overlying Central Metamorphic terrane near the Siskiyou thrust, suggest Late Triassic motion on the Siskiyou thrust.

Western Paleozoic and Triassic Belt

The Western Paleozoic and Triassic belt [WPT] is composed of several individual terranes, known as the Rattlesnake Creek, Marble Mountains, Western Hayfork, Eastern Hayfork, North Fork, and Salmon River terranes. The Hayfork terrane occupies the western 2/3 of the Salmon River basin (excluding plutons). The Rattlesnake Creek terrane forms the westernmost, basal part and consists of a Triassic to Early Jurassic block-on-block melange [mixture] overlain by metasedimentary and metavolcaniclastic rocks [Gray, 1985; US Forest Service, 1992]. Typical lithologies in the melange include serpentinite, metabasalt, metachert [quartzite], quartz-rich argillitic rocks, and marble. The Marble Mountain terrane, exposed along the northern margin of the basin, is thought to be equivalent to the Rattlesnake Creek terrane but metamorphosed to a higher grade [Donato, 1987].

The Rattlesnake Creek terrane is structurally overlain by the Middle Jurassic [~177-168 Ma] Western Hayfork terrane. This unit occupies only a small area on the western margin of the Salmon River basin (Merrill Creek). It is comprised of two units: a distinctive porphyritic volcanic breccia and crystal-lithic tuff volcaniclastic lower unit, and a chert/argillite metasedimentary upper unit [Wright and Fahan, 1988]. The fault separating the Rattlesnake Creek and Western Hayfork terranes was named the Salt Creek thrust by Wright and Fahan [1988] in an area in the southern Klamath Mountains.

Structurally overlying the Western Hayfork terrane along the Wilson Point thrust [Wright and Fahan, 1988] is the Eastern Hayfork-North Fork terrane [EH-NF]. The EH-NF terrane consists of basal block-in-matrix melange, composed of numerous lensoidal blocks of chert and lesser metavolcanic and marble blocks within an anastomosing scaly argillitic matrix [Elder and S. Cashman, 1992; Elder and S. Cashman, in press; P. Cashman, 1979]. This melange is best exposed within the watershed west of English Peak pluton and around the southern tip of the Wooley Creek batholith and southward. Some authors [Elder and S. Cashman, 1992; Elder and S. Cashman, in press] have concluded that the Eastern Hayfork and North Fork terranes of Blake and others [1982] and Mortimer [1984], represent a single Klamath terrane. Ernst [1990] suggests that the recognized Salmon River terrane could also be a part of the WPT "composite" terrane. At Quartz Hill, east of the study area, chert blocks contain Carnian age, or Late Triassic radiolarian assemblages. Overlying the melange is a metavolcanic unit consisting of dark green, fine-grained vesicular basaltic greenstone, in varied deposits of coarse-grained breccias to tuffs with interbedded pillows and flows. At Quartz Hill this metavolcanic unit depositionally overlies the melange, but along the South Fork of the Salmon River, they are separated by metavolcanic and ultramafic rocks of the Twin Sisters/North Fork fault zone. Depositionally

overlying the greestone unit are coherently bedded chert, argillite, marble, and volcaniclastic metasedimentary rocks. This upper unit contains radiolarian assemblages of Late Triassic [Norian] age.

A fourth unit recognized within the basin either comprises the Salmon River terrane or is part of the EH-NF composite terrane [see above; Elder and S. Cashman, 1992; Elder and S. Cashman, in press; Ernst, 1990]. The basal section of this unit consists of interlayered turbiditic metasedimentary and altered basaltic rocks [Ernst, 1987]. Overlying this section is an aerally extensive metavolcanic unit, consisting of light green, porphyritic greenstone, in monontonous flows and shallow intrusive bodies [Elder and S. Cashman, 1992; Elder and S. Cashman, in press; Ernst, 1987]. Regional metamorphic grade within this terrane in the Salmon River drainage varies from greenschist facies to zeolite facies.

The Soap Creek Ridge fault [SCRF] is an east-dipping regional structure that places the low-grade weakly metamorphosed and deformed greenschist facies, structurally highest terranes of the WPT beneath high-pressure/low-temperature blueschist and eclogite facies tectonites of the Stuart Fork terrane. This fault is economically very important, as lode gold mines in the central Klamath Mountains are clustered along this major transcrustal structure and occur only in the lower plate or fault zone of this thrust [Elder and S. Cashman, 1992]. The lode gold mines of the Liberty Mining District occur along the Soap Creek Ridge fault. This mining district is about 5 miles southeast of Sawyers Bar in the headwaters of Eddy Gulch. The contrast in metamorphic grade of rocks on opposing sides of the SCRF requires a vertical "throw" along the fault of nearly 30 km, implying that the thrust is major transcrustal structure. A 300-2000 foot wide fault zone developed along the fault.

Plutons

Intrusive rocks exposed within the study area belong to three general Klamath plutonic belts, as defined primarily on the basis of age and locality by Irwin [1985]. The three belts are [1] the Ironside Mountain belt [pre-Siskiyou event, ~174-169 Ma], [2] the Wooley Creek belt [post-Siskiyou, ~164-159 Ma], and [3] the Shasta Bally belt [post-Nevadan, ~144-130 Ma]. Ages of intrusive bodies reported below are U-Pb zircon dates from Wright and Fahan [1988].

Representative of the Ironside Mountain belt is the elongate, ~174 Ma dioritic and monzodioritic Forks of Salmon pluton. Plutons of the Wooley Creek belt areally and numerically dominate. The English Peak batholith, [~164 Ma], the Wooley Creek batholith [~161 Ma] and the Russian Peak pluton [~ 159 Ma] represent three of the largest intrusive bodies exposed in the province. The English Peak batholith and Russian Peak pluton exhibit concentric compositional zoning, grading from mafic gabbroic outer rims, inward to zones comprised of hornblende and biotite diorite and tonalite, to areally dominant centers of biotite-hornblende granodiorite. The Wooley Creek batholith grades upward [from northeast to southwest] from two-pyroxene diorite and gabbro to biotite-hornblende granodiorite and granite [Barnes and others, 1986]. These intrusive bodies are "normal" calc-alkaline plutons and represent typical mantle melts that have assimilated metasedimentary crustal rocks. In contrast, "abnormal" post-Nevadan plutons are typically tonalitic to trondhjemitic [Hotz, 1971] and are commonly calcic. Located in the southeastern corner of the drainage, plutons of this group include Deadman Peak [~144 Ma], Canyon Creek [~144 Ma], and Caribou Mountain [~141 Ma] With the exception of the tonalite to granodiorite [with minor hornblende diorite-to-gabbro] Deadman Peak pluton, all of these plutons are predomonantly biotite-hornblende tonalite with late-stage trondhjemite [Barnes and others 1992]. Isotopic studies suggest that these plutons originated by partial melting of young ophiolitic [oceanic rocks of the upper mantle and crust] crustal rocks underthrust during the Nevadan event [Barnes and others 1992].

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GEOMORPHOLOGY OF THE SALMON RIVER BASIN

Introduction

The Salmon River basin is situated in the center of the Klamath Mountains Physiographic Province. This province has been the subject of a considerable amount of geologic investigation in the past 20 years, but the focus of this study has been on its pre-Cenozoic development, with little emphasis on the Cenozoic history. Few studies have addressed late Cenozoic tectonic, climatic, and geomorphic factors which are responsible for the landscape which we see today. Work conducted early this century [Diller, 1902; Hershey, 1903] still provides useful information on this topic, despite the subsequent evolution of geologic and geomorphic concepts.

Overview

Recent studies of the late Cenozoic tectonic evolution of the California Coast Ranges have shed some light on the development of the Klamath Mountains during the same time period. The following is brief summary taken from one such work [Aalto, 1992]. It describes some of the current, though evolving, ideas on the late Cenozoic development of the Klamath Mountains.

> During the Paleocene epoch, the Klamath Mountains were sufficiently high to shed sediment to adjacent basins, and to block transport of sediment from the interior of the continent to the Pacific Coast. By the middle of the Eocene Epoch, topography had been reduced by erosional processes to a relatively subdued landscape. This condition allowed rivers to cut across the province from the east, and transport sediment to the Pacific basins of Oregon and California. Some of this sediment is believed to have originated in the Idaho Batholith. During the Oligocene Epoch, rapid uplift occurred. This uplift is believed to be associated with movement on the La Grange detachment fault. During the Neogene Period, much of the topographic relief was again reduced by erosion, creating a gentle landscape. From the middle of the Miocene to early Pleistocene Epochs, topographic relief in the Klamath Mountains was low. Rapid uplift began in the early to middle Pleistocene, and has continued through the Holocene, elevating the Klamath Mountains to their present elevation.

Uplift History

The belief that much of the uplift of the Klamath Mountains has occurred since the middle of the Pleistocene Epoch was first expressed by Hershey [1903] who felt that the Salmon River watershed had been uplifted 2,000-3,000 feet since that time. There are still many unknowns and different ideas regarding the age and the processes involved in the uplift of the Klamath Mountains. Work in the Condrey Mountain area [north of the Salmon River, including parts of California and Oregon] indicates that domal uplift of about 7 kilometers occurred there during the Neogene period [Mortimer and Coleman, 1985]. The influence of this dome is believed to have reached well into the Wooley Creek Batholith, in the Salmon River basin. Uplift on the east flank of the dome is described as middle Miocene to earliest Pliocene in age. This period of uplift would have occurred during the time when other investigators believe that the Klamath Mountains exhibited low relief [Aalto, 1992].

Ancestral Valleys of the Klamath and Salmon River

Most of the literature supports the concept that the Klamath River once flowed across a landscape of low relief with broad valley floors and a meandering river system. However, there is little conclusive evidence on how long ago, or how many times this condition existed. Regardless of the timing of uplift, the climate which coincided with the gentle landscape was probably humid. It is generally accepted that humid conditions existed during much of the Pleistocene Epoch. In addition, fossil evidence from the Western Cascades reveals that humid, and at times semi-tropical, conditions existed from the Eocene through the Miocene Epochs immediately east of the Klamath Mountains Province. Redwood trees persisted in the Cascades area into the

late Miocene Epoch, suggesting that the Klamath Mountains were not high enough to prevent Pacific storms from delivering adequate precipitation. The humid climate resulted in deep weathering of bedrock underlying valley floors, and in the formation of saprolite along with thick residual soils.

Development of River Terraces and Erosional Surfaces

When the gentle landscape of the ancestral valleys of the Klamath and Salmon Rivers were rapidly uplifted, the rivers cut deeply into the valley floors. As downcutting progressed, terraces were left stranded on valley walls. Such terraces and associated river gravels have been described at elevations of 2800 feet above the present river level near Weitchpec [Diller, 1902], and 900 feet at Swillup Creek, south of Happy Camp [U. S. Forest Service, 1976]. Several levels of river terraces are exposed along the flanks of the South Fork of the Salmon River, beginning near the present river level, and extending upward for several hundred feet in elevation [Hershey, 1903]. Some segments of the Salmon River may have taken different courses in the past. One example is where the South Fork joins the East Fork. The river may have originally flowed through a low saddle between Cecil Creek and the South Fork.

Early studies of the Klamath Mountains have suggested that a succession of erosional surfaces exist above the highest river gravels, with the oldest of these surfaces occupying the modern mountain crests [Diller, 1902]. This surface has been referred to as the "Klamath Peneplain". More recently, these surfaces have been linked to the formation of slump and earthflow deposits [Baldwin and de la Fuente, 1989]. Digital terrain modeling has been identified as a useful tool in identifying erosional surfaces over broad areas of the Klamath Mountains [Baldwin and Ricks, 1993].

Glaciation

Pleistocene glaciers greatly modified the landscape across the Klamath Mountains during the Pleistocene Epoch as they carved out U-shaped valleys and delivered large volumes of sediment to rivers. A remarkable example of stream capture occurs in the headwaters of the South Fork of the Salmon River. Here, the river makes an abrupt bend to the west. This segment of the river originally flowed northward, and formed the headwaters of Coffee Creek [a tributary to Trinity River] before it was captured by the South Fork of the Salmon River during the late Pleistocene Epoch [Hershey, 1903; Sharp, 1960].

Geomorphic Terranes

The preceeding outline of the Cenozoic geomorphic history of the Klamath Mountains, though sketchy, provides a framework for understanding the existing landforms and slope processes of the Salmon River watershed. The distribution and characteristics of the geomorphic terranes used in this study are intimately linked to the geomorphic history.

Inner Gorge Terrane

As the gentle landscape of the ancestral Klamath and Salmon Rivers was uplifted, a dense stream network was incised through the weathered rock underlying the old valley floors. This process is evident in the distribution and density of the inner gorge geomorphic terrane. A dense network of inner gorges is apparent at elevations between 2,000 and 4,000 feet in the Salmon River basin. This dense network is particularly noticeable along the margins of the English Peak and Wooley Creek Batholiths. Above 4,000 feet, inner gorge density is very low. Similarly, inner gorge density is very low in slump and earthflow deposits, and in areas underlain by sheared serpentinite and ultramafics, regardless of elevation.

Slump-Earthflow Terrane

The presence of thick, residual soils and saprolite on a rapidly uplifted landscape resulted in the formation of large slump-earthflow deposits. Factors facilitating this included steepening of the landscape due

to river incision, seismic activity, removal of lower slope support by river undercutting, humid climate, and in some cases, structural weaknesses in the underlying bedrock. Slump-earthflow deposits are most common in areas underlain by rock of the Hayfork terrane south of the English Peak Batholith. Moderate concentrations occur in the Stuart Fork Formation southeast of Eddy Gulch, and in the Eastern Klamath terrane near Matthews Creek. Slump and earthflow deposits are virtually absent in areas underlain by granitic plutons, since these rocks typically weather to sandy, clay-poor soils which are not conducive to slump and earthflow processes. Landslide activity in this terrane continues to this day in the form of localized slumps and earthflows, usually less than 10 acres in size. Debris sliding is common where the deposits have been undercut by streams. Some of the largest of these landslides [Murderer's Bar Landslide] exhibit basal slip surfaces which have been exposed by river downcutting, and now daylight several hundred feet above river level. A large proportion of the modern sediment production originates in slump-earthflow terrane.

Glacial Deposit Terrane

This geomorphic terrane includes both glacial deposits and river terraces. The glacial deposits were formed by glacial erosion, and are generally confined to elevations above 4,000 feet in elevation. The river terraces are usually situated from 100-500 feet in elevation above streams and rivers, and many are weathered to a deep red color, particularly when exposed in hydraulic mine cuts. Both glacial moraines and stream terraces are unconsolidated, and are prone to landsliding when they occur on steep slopes, such as on valley walls.

Mountain Slope Terrane

Rapid uplift created steep mountain side slopes with thin soils except near ridge crests where older residual soils have escaped erosion. Debris sliding of shallow colluvial deposits is the most common landslide process, with landslides usually less than an acre in size. Some of the largest recent landslides have occurred in this terrane [Bloomer Landslide]. Such landslides involve bedrock as well as colluvium, and are usually associated with structural weaknesses in the rock. On mountain slope terrane developed on granitic bedrock, deep weathering is common below 4,000 feet in elevation. Debris slides are common in such weathered areas, particularly where slopes are steep [>65%], and where the vegetation or soil has been disturbed. The deep weathering zone along the south margin of the English Peak Batholith is likely associated with an ancient valley floor [de la Fuente and Haessig, 1993].

Debris Basin Terrane

This terrane consists of the steep amphitheater or fan-shaped basins which occupy the headwaters of many tributary streams. They are described as fan-shaped, because many small drainages which begin near the ridge crest converge at a common point near the bottom of the basin, similar to the folds in a fan. These basins were formed by debris slide processes as the mountains were being uplifted. They are concentrated in the steepest parts of watershed, where soils are very shallow, and are usually less than 200 acres in size. Due to the steepness of this terrane, debris slides which occur there can disturb streams for a considerable distance downslope.

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VEGETATION

The Salmon River watershed is primarily a forested landscape **[Figure B-3]**. Approximately 90% of the watershed is currently covered by forest. The majority of the forested land [81%] is coniferous forest with 9% in hardwood forests. The coniferous forests can be divided into the mixed conifer, Douglas-fir, and true fir types. There is also a small amount of knobcone forest type, <2%. The mixed conifer and Douglas-fir forest types tend to be below about 6000 feet elevation. The mixed conifer is more common. The Douglas-fir type is in the western portion of the watershed with the mixed conifer to the east. The true fir and hemlock type is found at elevations above about 6000 feet. Other vegetation types in the watershed include brush lands 7%, meadow and grasslands <2 %, rocky and relatively barren areas, 2%, developed areas such as town sites and agricultural fields <2%, and lakes <1%.

Prior to establishment of the Klamath National Forest and effective fire control, there were frequent low intensity fires. Low intensity fires probably occurred at 5 to 20 year intervals with an average of about 8 years. The effect of these fires was to produce forests of open stands of conifers, probably a larger component of hardwoods, less brush, and more grass and forbs than is found today. With the exclusion of fire, stocking and growth of conifers has increased. Stands today, on average, have more stocking than prior to fire control.

At the landscape scale, the frequent low intensity fires, and less frequent stand replacement fires, produced a mosaic of relatively even-aged stands of various densities and age classes. This pattern is still visible on the landscape, but the structure of stands has changed as trees seeded in and grew beneath the open forests.

Stand replacement fires, prior to fire control, probably occurred on an average of every 150 to 200 years. That is, of the forested acres in the watershed, an average of 2,000 to 3,000 acres per year would burn hot enough to kill most of the trees and initiate a new stand. These fires, and the resultant stands, tended to be a few acres in size up to a few hundred acres.

The vegetation of streamside areas is probably less frequently affected by fire than the general forest. However, the vegetation of these areas is also dynamic. Additional forces, such as floods and debris movement, affect these areas. The 1964 flood is an example. The high water and moving debris scoured many of these areas removing all or most of the vegetation. Since that time, most of these areas have revegetated with a cover of willow, alder, maple some conifers and other vegetation.

Harvest of timber in the watershed began on a regulated, sustained basis in the 1960's. There were incidental harvests prior to this time for local use, but there were few or no regeneration harvests and the volumes cut were small. Since the 1960's, harvested volume has been primarily from regeneration cuts [clearcuts and shelterwood cuts] or salvage following wildfire. Currently, there are 26,472 acres of conifer plantations in the watershed [6.2% of the forested area or 5.5% of the total]. These areas were reforested following timber harvest or wildfire and range in age from 1 to 30 years.

New stands created by harvest have averaged 15 to 20 acres in size. New stands created following wildfire have tended to be much larger with a resultant overall change in landscape patterns in the large burn areas.

Over the longer term, the vegetation of the watershed has been dynamic. Based on paleobotanical studies in Northern California, the watershed was probably covered by a chaparral brush type, about 8 to 10 thousand years ago during a warm era following the last glacial period. Since that time the vegetation has changed to pine and oak woodland and then to more varied coniferous forests.

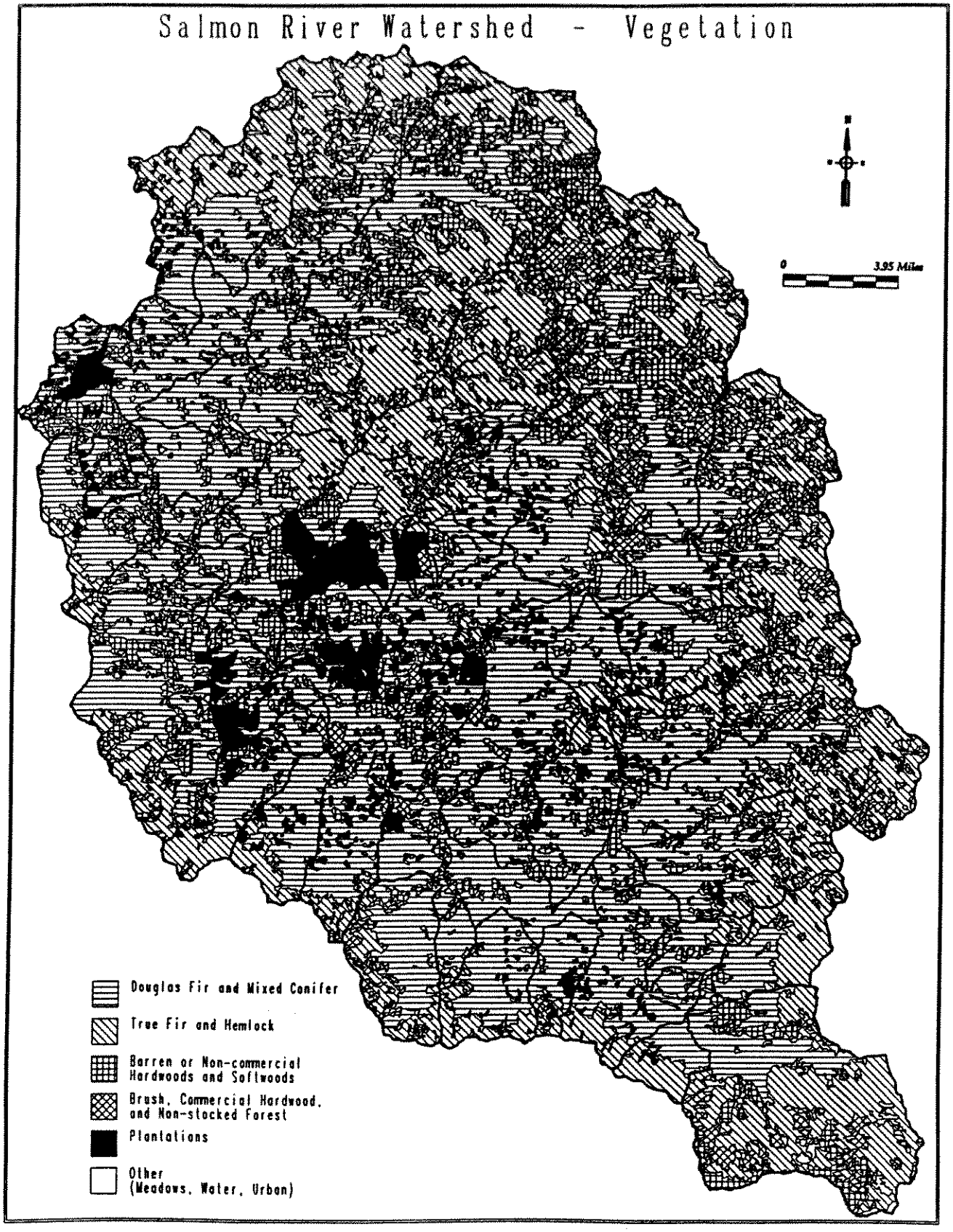

Figure B-3. Distribution of vegetation types in the Salmon River basin.

As the climate changed and species migrated into the area, the forests of the past developed. Each species migrated into the watershed from outside at its own rate based on a number of factors. During the 20th century, climates have tended to warm again. The current forests are a product of many forces operating at various scales of time and geography. Change is the only constant.

FIRE

Fire History

The Salmon River Watershed averages 20-25 [21.5] small fires per year with the average size being less than 0.5 acres each. Small fires appear to be wide-spread throughout the watershed with the single highest fire occurrence in the Ray's Peak area. Total acreage burned by small fires is dramatically lower than that burnt by large fires.

Large fires involving about 70,000 acres occurred early this century [1917 and 1918] **[Figure B-4]**. No data is available on the intensity of these fires. From 1919 to 1976, the total burned area was small, with only two fires larger than 5,000 acres. In 1977, 57,489 acres burned in the Hog Fire, and 102,369 acres burned in the wildfires of 1987. The fires of 1987 reburned 20,454 acres of the Hog Fire **[see Chapter 4, Figures 4-6 and 4-7]**. Area [acres] by intensity class for these fires was as follows.

Fire	High	Moderate	Low
Hog Fire [1977]	14,106	30,341	13,042
Fires of 1987	16,654	21,510	64,205

Fuel Loading

It is the general opinion of USFS fire management personnel at the Salmon River Ranger District that fuel loading has increased in the last 50 years. The two major contributors to this are fire suppression and management activity [such as timber harvest without slash abatement] that generate both dead and down fuels as well as live fuels. It is estimated that forest residue builds approximately 60% faster than it decompose in this area. Periodic fire was formally the mechanism to strike a balance between the accretion and decomposition of forest residue. Periodic fire also reduced the stocking levels within the stands, and the ladder fuels which are the main contributors to crown fires, and live fuel loading. Many past management activities have changed the type as well as the composition of today's fuel loading. Increases in dead fuel loading have occurred from over-stocked stands that die and fall down and or activities that generate an unnatural increase in the large diameter fuel loading. The type of fire that is associated with this type of fuel loading is high intensity fires that burn for long periods of time consuming virtually all organic material. Within the natural stands [areas with no management activity, excluding fire suppression] the forest floor litter layer has continued to build as a result of continued fire suppression. This fuels component when burned, usually smoulders for days to weeks maintaining high subsurface ground temperatures [100+ degrees]. This type of fire will usually kill trees as a result of the high soil temperatures around the tree roots. Old growth trees are severely affected by this because the heaviest accumulation of this fuel is usually at the base of these trees. The risk of large catastrophic wildfire is much higher today than it was 50 years ago.

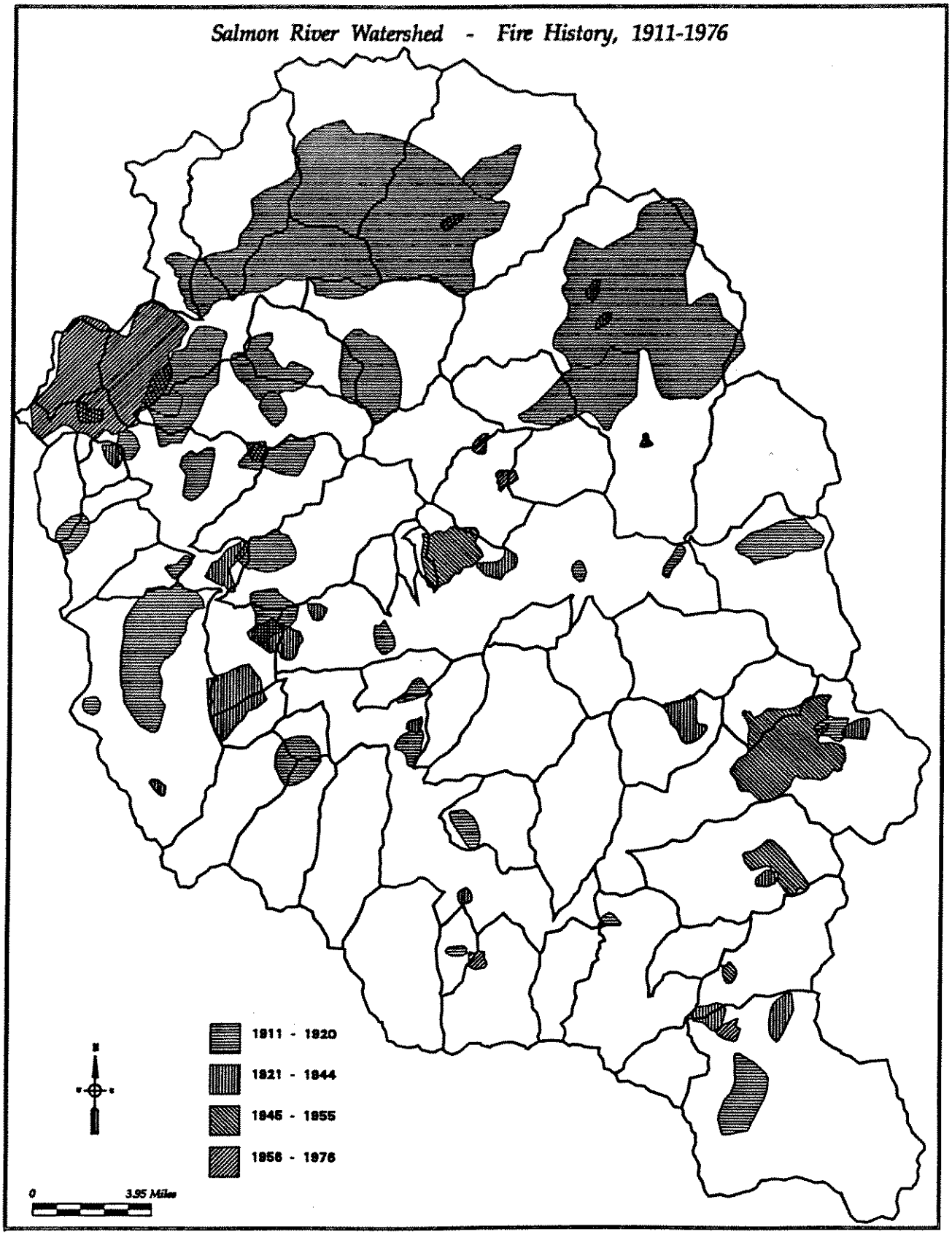

Figure B-4. Distribution and age of fires in the Salmon River basin, 1911-1976.

Fuel Loads and Fire Intensity in the 1987 Wildfires

Fuel loading and type of fuels were a major factor in the intensities of the 87 fires. The fire intensity maps seem to indicate that there were four major factors affecting fire intensity. These factors are: high fuel loading in recent activity areas; areas of past management activity; aspect and elevation; and the timing and season of the fire. High burn intensity was found where activity fuels were created and not cleaned up. In areas of past management activity or where fires had previously occurred, the site conversion was associated with high burn intensity. The intensity maps show areas of high intensity burn at high elevations on south aspects. This is most likely due to the fact that these areas naturally support this type of burn and it is a part of the natural cycle. One other factor that could play a roll in this is that a major portion of these high intensity burns appear to be on the upper slopes [above 4500 feet in elevation]. The typical inversion band for the Salmon River basin is 3500' to 4500' and could have influenced these burn patterns. At this time this has not been verified but could be another factor in the natural burn patterns for this area.

Burn season played a role in the 1987 fires as with most large fires. Since the fires occurred in late summer, fuels were tinder dry, and the fall rains did not come until November. Dry lightning [lightning without rain] during a drought period could also be considered as a critical factor. One of the biggest factors in 1987 was that other fires were already burning in the west. Multiple fire starts on the Klamath and adjacent forests quickly depleted available fire-fighting resources.

The fire intensity maps also show that much of the high intensity burning occurred during the first few days of the fire, before the atmospheric inversion set in. When the atmospheric inversion occurred, it created cooler temperatures at lower elevations due the shading effect of the smoke. However, not all burning during the first few days of the fire was at high intensity. Those which did burn with high intensities were in areas similar to those described above which had high fuel concentrations. Fires like the one in St. Claire Creek started in old growth mixed timber stands and burned for a period of days to weeks at low to moderate intensities before abruptly changing in character and burning at high intensity.

APPENDIX C

The Landslide Model and Landscape Stratification Into Geomorphic Terranes

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INTRODUCTION

This appendix contains discussions of the following topics: (a) landslide processes in the Salmon River watershed; (b) the landslide model used in the Salmon sub-basin sediment analysis; (c) the method of landscape stratification used in the development of the landslide model; and (d) the development and limitations of the geologic database used to stratify the landscape. Shorter summaries of these topics are found in Chapters 2 and 5 of this report.

LANDSLIDE PROCESSES IN THE SALMON RIVER WATERSHED

Based on the findings of this study, landsliding is considered to be one of the most important erosional and landscape-forming processes in the Salmon River watershed. Consequently, this process is described more fully below.

The term "landsliding" is used in this document to encompass all of the processes involving the movement of rock and soil masses in a downslope direction under the influence of gravitational forces. Landsliding is a natural process which has played a dominant role in the evolution of the local landforms, streams, and rivers. Natural landslides are usually initiated by rare climatic events or earthquakes. They transport large volumes of soil and rock from steep mountains down into the major streams and rivers. Through this process, they sculpt the mountains and influence stream and river channels by delivering sediment which affects the distribution of pools and riffles, the makeup of channel bottom and bank material, and riparian vegetation. With the exception of glaciated areas, virtually all of the gravels and boulders in stream beds of the Salmon River are delivered there by landslide processes.

Landslides have a high probability of occurrence in the Salmon River Watershed. In addition, landslide hazards are directly influenced by routine forest management activities such as road construction and timber harvest. The main effect of roads and harvest is: to cause landslides to occur in response to smaller storms than they would naturally; to increase the severity of the response; and to create landslides which would not have occurred naturally [road fill failures]. Numerous systems have been developed for classifying landslides. One of the best of these is that of Varnes [1978] which subdivides them according to slope failure process and type of failing material. For purposes of this study, a more simplified approach was used, classifying landslides into two basic types, those which are shallow and rapidly-moving, and those which are generally deep and slow-moving. The shallow, rapidly-moving type includes debris slides, debris flows, and debris avalanches. The deep, slow-moving type includes slumps, slides, and earthflows.

Shallow, rapidly moving landslides can affect streams or roads for long distances from the initiation site due to their occurrence on steep terrain. They often mobilize water-charged debris which travels long distances down stream courses, removing riparian vegetation and road crossings. Since these landslides often occur within the rooting zone, tree roots play an important stabilizing role, binding the slope material together and anchoring it to underlying bedrock.

Slow-moving landslides are generally larger than the shallow landslides. Adverse effects are usually confined to the area near the slide site, but exceptions are common. The failure plane on such landslides is usually below the rooting depth. As a result, the anchoring effect of vegetation is small. Vegetation helps reduce the risk of such landsliding by removing water through evapotranspiration.

Virtually all documented historic landslides in the Salmon River watershed have occurred in response to the addition of water to natural or disturbed slopes during intense winter storms, rapid snowmelt, or extended periods of high precipitation. One possible exception is a landslide which occurred near Tripp Point on March 11, 1990. This landslide may have been influenced by an earthquake which occurred on January 18, 1990. The epicenter was in the Hoopa area [USFS Memo 3-13-90].

THE LANDSLIDE MODEL

The landslide model is a relatively simple tool for predicting future landslide production in the Salmon River watershed. Its basic elements are: [1] landscape stratification, [2] coefficient development, and [3] computation of landslide volume. The elements of the landslide model are displayed below. The following discussions provide information on the landscape stratification scheme used in the landslide model.

Landslide model process used in the Salmon sub-basin sediment analysis.

Stratification of Landscape: 11 Geomorphic Terrane Types	Determination of Disturbance Status of Each Terrane | | | | | | V	Development of Landslide Coeff-icients by Terrane in Cubic Yards Per Acre for 1965-1975 Climatic Episode | | V	Computation of Predicted Landslide Volume | | | | | V
	Acres by Geo-morphic Type Undisturbed	x Coefficient	= Volume Sediment Cubic yards
	Acres by Geo-morphic Type Old Harvest Unit	x Coefficient	= Volume Sediment Cubic yards
	Acres by Geo-morphic Type New Harvest & Fire	x Coefficient	= Volume Sediment Cubic yards
	Acres by Geo-morphic Type Roaded	x Coefficient	= Volume Sediment Cubic yards
			Total Sediment

LANDSCAPE STRATIFICATION

Observations by geologists on the Klamath National Forest as well as studies in many areas of the Pacific Northwest reveal that landsliding is not evenly distributed across the landscape, but rather is concentrated in certain types of land. With this concept in mind, a stratification scheme was developed which classifies lands according to landslide potential. Criteria for delineating these lands was influenced by the availability of data, and the ease of identification of features on air photos. These lands are referred to as geomorphic terranes.

Geomorphic Terranes

A "geomorphic terrane" is defined as a type of land which shares a set of common physical attributes such as steepness of slope, soil type, bedrock type and structure, geomorphic history, and degree of channel development or dissection. Due to the presence of these commonly held attributes, slope hydrology and slope processes are relatively uniform within a geomorphic terrane type. Consequently, landslide production rates within a given type are likely to be similar.

Five basic geomorphic terranes were defined. These are: Mountain Slopes; Debris Basins [Headwalls]; Inner Gorges; Slump/Earthflow Deposits; and Glacial, Terrace and Fan Deposits. These basic types were then further subdivided according to rock type and slope gradient and geomorphic setting into 11 specific geomorphic terrane types as follows:

Basic Geomorphic Terranes	***Specific Geomorphic Terranes***	***Terrane No.***
MOUNTAIN SLOPES	Granitic Mt. Slopes > 65% Slope Granitic Mt. Slopes 0-65% Slope Non-Granitic Mt. Slopes > 65% Slope Non-Granitic Mt. Slopes 0-65% Slope	4 5 6 8
DEBRIS BASINS [HEADWALLS]	Debris Basins [Headwalls]	12
INNER GORGE	Inner Gorge Developed in Granitic Bedrock Inner Gorge Developed in Non-granitic Bedrock Inner Gorge Developed in Landslide, Glacial or Terrace Deposits	10 11 9
SLUMP/EARTHFLOW DEPOSITS	Slump/Earthflow Deposits Slump/Earthflow Toe Zones	3 2
GLACIAL, TERRACE & FAN DEPOSITS	Glacial, Terrace, & Fan Deposits	13

Some of the terranes consist of more than one geomorphic type, for example geomorphic terrane type #13, Glacial, Terrace, and Fan Deposits. This grouping was necessary to limit the number of terrane types and thereby reduce the complexity of the model. These geomorphic units were uniformly mapped throughout the Salmon River watershed.

The geomorphic terranes which were found to be most prone to landsliding include inner gorges, slump and earthflow deposits, debris basins, and parts of the granitic mountain slope terranes. The terranes are described below.

Slump and Earthflow Terrane

This includes geomorphic terrane types 2 and 3. Slump and earthflow terrane occupies 7% of the Salmon River watershed, and accounts for a large proportion of the natural and management-associated landslides. Slump and earthflow deposits are irregular to hummocky. Topography is usually more gentle than on the surrounding unfailed mountain slopes. This geomorphic terrane was formed by landsliding which occurred in thick residual soils tens to hundreds of thousands of years ago [or perhaps even earlier]. It

consists primarily of unconsolidated deposits of soil and rock debris, often with a high clay content. The toe zones or margins of these deposits [terrane #2] are particularly sensitive and often coincide with inner gorge slopes. In nested slump and earthflow terrane, toe zones may also occur in midslope positions which are a considerable distance from the inner gorge. The toe zones are usually steep, 60-80 percent, and often the site of springs. Debris slides occur regularly in the toe zone due to steepness of slope, weakness of the soil and rock materials, and groundwater conditions. Soil, rock, and organic debris mobilized by these landslides often travels long distance through ephemeral channels and enters perennial streams. Though this terrane [#2] is extremely sensitive, it was not mapped consistently during development of the geology layer and as a result, was not useful in this project. It should be refined and used in future work.

Inner Gorge Terrane

This includes geomorphic terrane types 9, 10, and 11. Inner gorge terrane occupies 16.6% of the Salmon River watershed, and consists of steep [greater than 65% slope] canyon walls which occur along rivers and streams in rugged, mountainous areas. The upslope boundary is usually marked by a prominent slope break separating the inner gorge from gentler slopes above. This geomorphic terrane is formed by the rapid downcutting of streams and rivers in response to relative uplift during the Holocene [10,000 years]. The incision process occurs rapidly, in geologic terms, and usually involves the periodic passage of debris flows which scour the banks and tend to produce nearly vertical walls. These debris flows originate upslope in headwall areas, toe zones of slump-earthflow complexes, and from the inner gorge itself further up the channel. The vertical walls created by the passage of debris flows and flood flow gradually fail back to a more stable gradient [usually in the 65-100% range] by processes such as debris falls, topples, and slides, and gradually revegetate. Exceptions are: (a) where sound bedrock is involved, and a near-vertical configuration can be maintained; and (b) in very weak material such as slump deposits, which may be incapable of standing at steep slopes, and inner gorges do not develop. Due to its position on a slope, the inner gorge typically experiences high groundwater levels and seepage rates during the wet season.

Inner gorges range from a few tens of feet wide to over 1,000 feet wide on major streams and rivers. The nature of the foundation material and the local landform is critical in determining the sensitivity of an inner gorge slope to disturbance. Those cut into slump/earthflow deposits, thick colluvium, glacial debris, and deeply weathered granitic rock are much more sensitive than those cut into sound bedrock. The presence of steep swales on these slopes usually dndicates debris landsliding. In timbered areas, bedrock inner gorges cannot be distinguished from other types by air photo techniques, rather, field verification is needed. Most of the inner gorges were identified on 1:58,000 color infrared air photos, allowing for consistent mapping. A recent inventory has revealed that the inner gorge mapping in a small tributary of the South Fork of the Salmon River delineates a zone which is too wide. The new inventory revealed that actual inner gorge width was 25% of the mapped width in the data layer.

The inner gorge is a critical zone in the management of watershed values. Some of the reasons for this are listed:

1. It is immediately adjacent to flowing streams or channels which typically flow water during landslide-producing storms.

2. It is shaped by landslide processes, debris flows from further up the channel, and debris sliding on the inner gorge itself.

3. Due to its slope position [below a slope break] and steepness, it is difficult to log without disturbing the soil mantle and residual vegetation.

4. Granitic inner gorges, and some metamorphic inner gorges deliver large volumes of sediment to the channel by dry flow processes when vegetative material is removed by fire or logging.

Local studies in the Rock Creek watershed, Ukonom Ranger District, Klamath National Forest, have shown that 62% of the active landslides identified in the watershed are situated within the inner gorge, while the inner gorge constitutes only 12% of the total area [Wolfe 1982]. In the Grider Creek watershed, Oak Knoll Ranger District, it was found that 65% of the total landslide sediment volume delivered to the channel system since 1944 originated from landslides within the inner gorge [Grider EIS, 1989]. In Grider Creek the inner gorge constitutes about 11% of the total watershed area. Those inner gorges developed on the toe zones of slump/earthflow complexes accounted for 49% of the total delivered sediment while comprising only 2% of the land base. Landslide investigations in the Penney Ridge area of the Shasta Trinity National Forest [Haskins, 1989] have revealed that 70% of all active landslides were within the inner gorge while the inner gorge constituted 4.6% of the landbase. The Penney Ridge area is in the Coast Ranges, and includes rock of the Franciscan Complex, South Fork Mountain Schist, and other types. Since most of the area is undeveloped [75%], these figures attest to the natural instability of the inner gorge in this area.

Granitic Mountain Slope Terrane

This geomorphic terrane includes types 4 and 5. This terrane occupies about 18.5% of the Salmon River watershed. In areas of high elevation it generally supports a thin soil cover and glacially-exposed rock outcrops are common. Topography at elevations from 1000 to 4000 feet is severely dissected, and exhibits a dense network of incised topographic draws with a spacing of 150-200 feet. The incised draws typically originate in steep [60-90%], spoon-shaped swales which are revegetated debris slide scars. Below the swales, the draws typically exhibit inner gorges.

At low to mid-elevation [800-4000 feet] most of it exhibits a dense drainage pattern and bedrock is weathered to depths of 10-30 feet. It is likely that the deep weathering in this elevation zone occurred in association with broad valley floors which existed during the Pleistocene. These valley floors were removed by subsequent erosion, leaving only remnants on present valley walls. Soils in these weathered areas are rich in sand, poor in coarse gravels, cobbles, silt, and clay and lack cohesive strength. Removal of vegetative cover can increase debris slide risk by removing root support and altering slope hydrology. Additionally, due to the steepness of slope and limited amount of clay, removal of vegetation allows dry flow processes to transport sand into small, intermittent channels which then convey it to larger channels during winter storm flow. Road and landing fills are difficult to stabilize due to limited cohesive strength, steepness of slope, and subsurface hydrology which operates in granitic terrane.

The dissected granitic terrain is prone to shallow debris slides and torrents which generally scour small tributary drainages and deposit debris in larger [2nd or 3rd order] streams. Due to the large proportion of sand in such debris, it can severely damage spawning gravels by filling void space. In addition, debris torrents can radically change channel morphology.

Debris Basins

This corresponds to geomorphic terrane 12. Debris basins, or headwalls, occupy about 2.5% of the Salmon River Watershed, and are prone to shallow debris slides. Debris basins are amphitheater-shaped steep basins usually situated at the heads of first order tributary channels. These basins typically have a thin soil cover, outcrops are common, and slope gradients are typically much steeper than 65%. Channels within the basin frequently exhibit a fan-shaped pattern with the channels coalescing near the bottom of the basin. Due to steepness of slope and location high in a watershed, debris slides which occur in these basins can be very damaging to watershed values for considerable distances downstream.

Non-Granitic Mountain Slopes

This corresponds to terrane numbers 6 and 8, which together occupy nearly as much area as all the other terranes combined, or 49% of the Salmon River watershed. This terrane typically produces shallow debris slides, small to moderate in size, on steep slopes. In a few areas, it produced large, structurally

controlled landslides, such as the Bloomer Landslide in 1964. Since this terrane includes a broad variety of bedrock and associated structural features, as well as geomorphic settings, landslide potential is likely to be much more variable than in the other terranes. It was found that slope steepness alone provides a useful characterization of landslide potential. Slopes steeper than 65% produce landslides at a rate 4 to 5 times higher than more gentle slopes of 0 to 65% [**Table 5-3, this volume**]. This terrane should be refined and subdivided further.

Glacial, Terrace, and Fan Deposits

This terrane [#13], occupies about 7% of the basin and consists of unconsolidated Quaternary deposits including a wide variety of soil and earth materials. The alluvial deposits are typically cobbly and sandy, whereas some of the older glacial deposits and terraces may be rich in clay. This variation in particle size results in a variety of potential slope failure mechanisms. Glacial deposits comprise the majority of this terrane, but valley alluvium, fan deposits and stream terraces are also present. An important source of landslides in this terrane was identified where these deposits occur perched up on steep valley walls created by glacial erosion or stream downcutting. Slope would have been a useful stratification tool in further subdividing these deposits.

GEOLOGIC DATABASE

The geologic database is commonly referred to as the "geology layer" because of its use as a layer in the geographic information system, [GIS]. The geologic data layer was the primary tool used in developing the landslide portion of the sediment budget. This data base was produced by Klamath Forest geologists, and utilized the information contained in reports on file and also recent work which has yet to be documented and filed. This layer was developed as follows: In 1988, geologists mapped the entire west side of the forest including geomorphic type, rock type, degree of dissection, slope gradient, geomorphic setting, and hazard class. Active landslides were also mapped and combined with information from previous studies on the forest. Consistency in mapping of geomorphic types was attained by having one geologist review air photos and edit all maps prior to drafting. This process minimized the variability in mapping styles between different geologists, particularly in mapping features like inner gorge. Features mapped within the six categories were as listed and described below.

1. Geomorphic Type

a. Active Landslide
b. Inner Gorge
c. Dormant Landslide Deposits
d. Mixed Dormant Landslide Deposits and Glacial Moraines
e. Glacial Moraines
f. Valley Alluvium and Alluvial Fans
g. Terrace Deposits
h. Lake Deposits
i. Debris Basins [Headwall Areas]
j. Mountain Slopes

2. Rock Type

Rock type information was obtained from published mapping, some of which was generalized, and some more detailed. The minimum level of information was from California State Geologic mapping series, The Weed Sheet [Wagner and Saucedo, 1987].

a. Granitic Rock
b. Gabbro
c. Metamorphic Rock [Undifferentiated]
d. Ultramafic Rock
e. Marble
f. Galice Formation

3. Degree of Dissection

Dissection was determined by examining topographic maps and determining the spacing between topographic draws for each polygon in the database.

This attribute was assigned manually by workers coding polygons. It is based solely on an evaluation of the USGS 7 1/2 minute topographic quadrangles, and reflects the spacing of topographic draws evident on the contours.

a. High; draw spacing < 500 feet
b. Moderate; draw spacing 500-1,000 feet
c. Low; draw spacing > 1,000 feet

4. Slope Gradient

Slope gradient was derived from a hand-generated slope map which was made by using templates and drawing polygons directly on the topographic map. The USGS digital terrain data was not used in constructing the slope map because it was not yet available when the layer was developed.

a. High; > 65%
b. Medium; 35-65%
c. Low; < 35%

5. Geomorphic Setting

This attribute describes the environment of each polygon in light of the geomorphic features around it. For example, the geomorphic setting of an active landslide may be at the toe of a dormant landslide within an inner gorge.

6. Hazard Class

Hazard classes were assigned according to a combination of criteria, including geomorphic type and setting, slope gradient, rock type, and degree of dissection. Hazard class was defined as follows:

HAZARD CLASS	GEOMORPHIC CHARACTERISTICS
EXTREME	Active debris slides Active slumps Inner gorges Toe zone slump, or slump/glacial deposit. Granitic terrain which is highly dissected, with slopes >65%
HIGH	Dormant slumps and slump/glacial deposits, [young]; steep [> 65%] portions of older ones Granitic terrain; highly dissected, slopes 35-65% moderately dissected, slopes > 65% Steep [> 65%] debris slide prone mountain slopes Steep [> 65%], moraines and terrace deposits
MODERATE	Dormant slumps and slump/glacial deposits, [old, undifferentiated and questionable] from 0-65% Moraines, Terraces 35- 65% Slope Granitic terrain; moderately dissected, with slopes 35-65% Low dissection, with slopes > 65% Undifferentiated mountain slopes, [unfailed] > 65%.
LOW	Glacial deposits, terraces, etc. [unfailed] < 35% slope Undifferentiated mountain slopes [unfailed] < 65% Granitic terrain with low dissection and slopes < 35%.

Delineation of Polygon Attributes

The process described above resulted in a polygon map with each polygon having 6 attributes. The map was then drafted and electronically scanned. Polygon size ranges from less than one acre for active landslides to more than 200 acres, with most polygons in the 5-40 acre size class. Each polygon was coded with 6 attributes, allowing a variety of different map products to be generated from the base geologic layer.

Limitations of the Geology Layer

1. Visibility of landslides in roads and harvest units versus under a forest cover.

2. Measurements and mapping of small landslides.

3. Width of inner gorge.

4. Accuracy of geologic mapping.

The accuracy of the geologic layer has not been systematically reviewed at this point in time. It is estimated that on the order of 80% of the active debris slides over an acre in size are correctly identified, and approximately 50% of active slumps and earthflows are correctly identified. It is likely that many additional

slumps and earthflows are yet unidentified. Approximately 85% of inner gorges, and 80% of dormant landslide are correctly identified. A recent project indicates that inner gorge widths in the upper South Fork of the Salmon River are mapped wider than they should be. It was found that the geologic layer correctly identified almost all of the inner gorges, but exaggerated the width by a factor of 4. The area where the inner gorges were exaggerated was in Blindhorse Creek, a highly dissected granitic watershed. The inner gorges there typically begin at their heads with one or several steep swales, or debris slide scars. The mapping included the swale area in the inner gorge. Another reason for less than accurate inner gorge widths is that the inner gorge is typically a long narrow feature, and there was a tendency to slightly exaggerate the width during initial mapping, and during drafting work. This is also true of small narrow debris slides. More accurate estimates will be developed by a mapping and monitoring program.

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APPENDIX D

Surface Erosion Model for the Salmon River Watershed

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GENERAL SOILS OF PROJECT AREA

Soils in the Salmon River Watershed have formed from metamorphic [metasedimentary, metavolcanic and inclusions of limestone], granitic and ultramafic [peridotite and serpentinite] rocks. Soils formed on each different lithology have properties unique to that individual lithology **[Chapter 2, Figure 2-8, this volume]**.

Soils that have developed from metamorphic rocks occupy 322,497 acres of the project area. Soils on mountain sideslopes with southwest to southeast aspects are generally shallow [less than 20 inches deep] very gravelly loam soils represented by Deadwood, Vititzum and Woodseye series. Soils formed on mountain sideslopes with northwest to northeast aspects are generally moderate deep [20 to 40 inches deep] very gravelly loam soils represented by Neuns, Marpa and Fiddletown series with deep [40 to 60 inches deep] very gravelly loam and gravelly loam soils represented by Kindig, Deadtown [proposed], Casabonne and Happycamp [proposed] series. Soils on dormant landslide features are usually very deep [greater than 60 inches deep] gravelly loam to gravelly clay loam soils. These soils are represented by Pishpishee [proposed], Fong [proposed] and Coosewayp [proposed] series.

Soils that have developed from granitic rocks occupy 142,783 acres of the project area. Soils on mountain sideslopes with southwest to southeast aspects are generally shallow [less than 20 inches deep] very gravelly sandy loam soils represented by the Chawanakee series. Soils on mountain sideslopes with northweast to northeast aspects are predominately moderate deep [20 to 40 inches deep] very gravelly loam soils represented by Chaix and Bowerman [proposed] series with deep [40 to 60 inches deep] very gravelly loam and gravelly loam soils represented by Dome, Rogue, Gerle, Goodwin and Pilliken series. Soils that have developed on old geomorphic surfaces are usually very deep [greater than 60 inches deep] loam to clay loam soils. These soils are represented by Holland and Hiker series.

Soils that have developed from ultramafic rocks occupy 15,304 acres of the project area. Soils on mountain sideslopes with southwest to southeast aspects are generally shallow [less than 20 inches deep] very gravelly clay loam and gravelly loam soils represented by Johnsoncreek [proposed] and Hotelling [proposed] series. Soils on mountain sideslopes with northwest to northeast aspects are predominately moderate deep [20 to 40 inches deep] gravelly loam and gravelly sandy loam soils represented by Blueridge [proposed] and Blackcreek [proposed] series with deep [40 to 60 inches deep] loam and gravelly loam soils represented by the Yoakumville [proposed] series on the benchy areas.

SOIL EROSION PROCESSES

Soil erosion, specifically sheet erosion in mountainous terrane, can be difficult to see. As an example, loss of surface soil equal to the thickness of a single sheet of paper is equivalent to 0.5 tons/acre of erosion. Average soil formation from bedrock as reported by Alexander [1988] is about 0.75 tons/acre/year. Sheet erosion equal to 2 sheets of paper in thickness exceeds this reported soil formation rate, yet this is for the most part unobservable. Most people expect to see dramatic visual evidence such as rills, gullies or thick deposits of sediment to confirm that erosion has occurred.

Erosion processes as observed in the Klamath Mountains consists of sheet, rill and gully erosion caused by water, dry ravel caused by gravity and wind erosion.

Sheet Erosion

Sheet erosion consists of raindrop splash displacement of soil particles and downslope deposition of this disloged material. Rainsplash is the result of water drop impact forces where a raindrop falling on a wetted soil surface produces a splash-crown, which is made up of one or two soil particles encased in a film of water. The detached soil particles move laterally about four times their height. Splash in a downslope direction travels further than in the upslope direction, about three times as far on a 10 percent slope [Thornes 1980].

Additional soil particles are displaced by the impact of detached particles arriving from upslope. The main sources of energy for this process are the kinetic energy of falling rain and gravitational energy. Splash erosion requires a saturated surface soil and is greatest when a thin film of water is present on the soil surface [Thornes 1980]. The splash erosion process creates micro-step geomorphic surface features that resembles microterraces. Figures S-2 and S-3 are examples of these microterraces. It is on the terrace flats where the film of water is retained and soil is detached during the raindrop/splash detachment process.

Figures D-1 and **D-2** show 2 cross-sections of the soil surface orientated perpendicular to the contour. These microterraces are not readily apparent to the naked eye when viewed from above. They become readily apparent when seen in cross section. The front edge of the terraces are held inplace by gravel pedestals. These terraces disintgrate and reform over time. The terraces in **Figure D-1** formed in a loamy soil [metamorphic parent material] while the terraces in **Figure D-2** formed in a sandy loam soil [granitic parent material]. The less cohesive soil [sandy loam] has a wider terrace surface and higher leading edges. These cross sections are direct evidence of the raindrop splash erosion process.

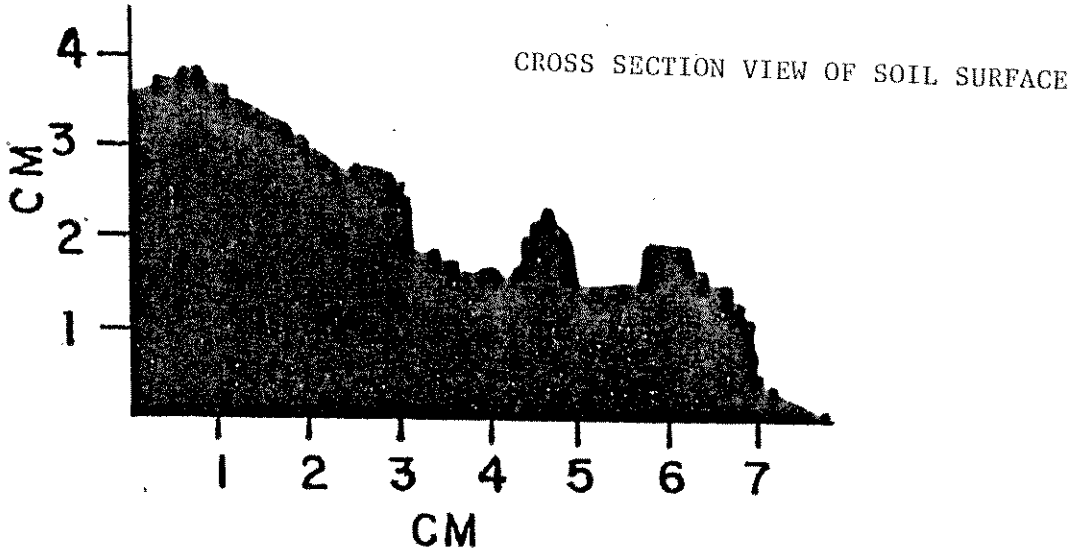
During a rainstorm, the thin film of water on the terrace benches is constantly flowing downslope. Fine organic particles have been observed [Laurent 1989] moving on and around these terraces. In this way, soil particles [silt and clay] are transported further downslope after being disloged by raindrop splash. This is the sheet erosion process that has been observed on soils within the project area by typical low intensity precipitation events.

Infiltration/Crust Formation

Many people believe that soil erosion is not a significant event since surface erosion is not readily evident. Forest soils generally are considered to have high infiltration rates which are higher then rainfall rates. Infiltration of loam soils range from 0.6 to 2.0 inches/hour. The 2 year, 6 hour precipitation rate from the California Division of Water Resources data [1981] for the Sawyers Bar ranger station [Salmon River Watershed] is 1.34 inches/6 hour. This value, when converted to an average hourly rate, is 0.22 inches/hour which is significantly below the 0.6 to 2.0 in/hour infiltration rate of the soil. McNabb [1988] indicated that increased erosion in burned areas is most likely to result from either raindrop splash on exposed soil or by large storm events that saturate the soil profile causing reduced infiltration and consequently overland flow. McNabb further indicated that loss of the forest floor and not changes in infiltration capacity is most likely to increase erosion during storms.

The approach by McNabb in describing the erosion process ignores the role that raindrop induced soil crust formation plays in the erosion process. Onofiok and Singer [1984] describe crust formation as occurring in 4 steps. The first step is the breakdown of soil aggregates by raindrop impact and detachment of soil particles; [2] then these detached soil particles, dominated by clay and silt sized material, move into pores, reducing the pore size; [3] deposition of suspended soil particles on the surface of the soil and; [4] the compaction of the immediate soil surface due to rearrangement of soil particles upon deposition. They showed that this process occurs between 1.5 and 11 minutes after exposure to precipitation. Thin surface crusts, 2 to 5 mm thick on exposed soils have been observed for sandy loam and loam textures within the project area [Laurent 1989]. McNabb [1988] studied bulk density of exposed soil and found that after 3 years, the bulk density of fine soil in burned plots was 0.50 g/cm^3 compared to 0.28 g/cm^3 in unburned plots with the forest cover intact. This may be the result of raindrop induced surface crusts and compaction. Parks and Cundy [1988] felt that splash erosion causes surface sealing that further increases surface runoff and hence erosion.

Figure D-1. Microtopography of soil surfaces.



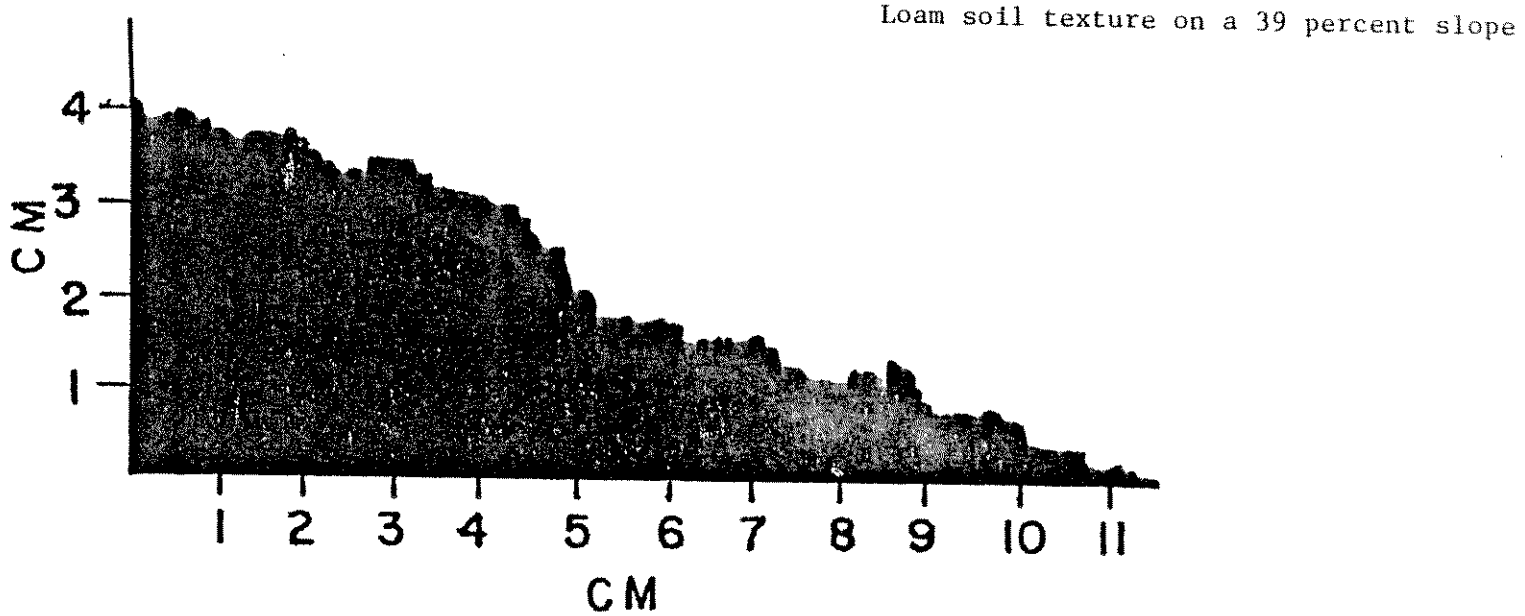
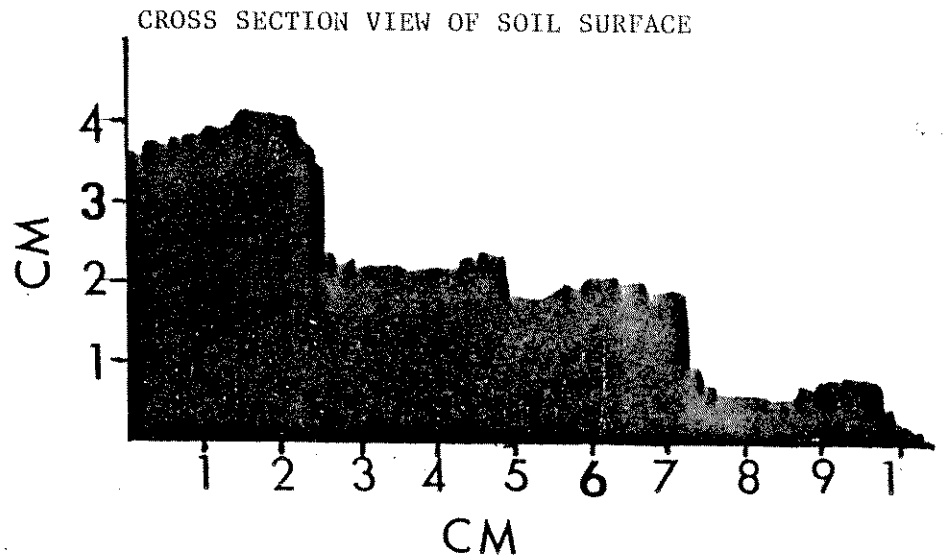


Figure D-2. Microtopography of soil surfaces.



Sandy loam soil texture on a 53 percent slope

Rill Erosion

Rill erosion is not a common part of the erosion process in this part of the Klamath Mountains as is sheet erosion. Rill erosion usually occurs when the soil cover and surface drainage patterns have been altered by management activities and fire or naturally induced hydrophobic soil conditions occur. Average precipitation events do not seem to produce rills except on road cut and fill slopes and other areas where the overland flow is concentrated like skid trail waterbar outlets. Rill formation usually requires more intense precipitation events such as intense winter storms or summer thunderstorms. These intense localized storms have the potential to produce rills on exposed soil such as clearcut and burned or tractor piled areas. Rills that have been observed within the project area are usually 2 to 6 inches wide and 1 to 4 inches deep. Frozen ground in distrubed areas is another condition that can increase overland flow and cause rills.

Estimated rill erosion from field observations on loamy sand soils [granitic terrane] after the 1987 wildfires on undisturbed slopes was approximately 2.8 to 4.3 yd^3/acre resulting from increased overland flow on fire induced water repellent soils [Laurent 1989]. Two skyline harvest units [logged in 1988] in the same area experienced approximately 3.6 to 80 yd^3/acre rill erosion as observed and measured in the field [Laurent 1989]. The higher rill erosion value was the result of a increased overland flow from an upslope contributing area resulting from fire induced water repellency. This overland flow entered the harvest unit and was concentrated by yarding corridors and logging slash orientated parallel to the slope. In an adjacent area within the same harvest unit where trees were felled on the contour and not yarded did not experience the same level of rill erosion due to the logs acting as sediment traps and flow diffusion.

Rill erosion on a loam soil that was tractor piled [brush, grass and forbs] parallel to slope was approximately 7.3 yd^3/acre for the first year [Laurent 1989]. This was the result of surface drainage being orientated parallel to the slope by the tractor track lines. This rilling is not a common occurrance in tractor logged or piled harvest units on the Klamath National Forest as observed over the past 10 years [Laurent 1989]. This may be due to the type of precipitation this part of the Klamath Mountains receives.

Gully Erosion

Gully erosion is more of a localized longterm feature that is caused by concentrated runoff and drainage over time. A gully is an erosional feature that varies in depth from 20 inches to 100 feet [SSSA 1987]. Gullies have been found to occur below road culverts, swales and on abandoned skid trails or roads. Rills can develop into gullies especially when concentrated runoff continues to enlarge existing rills. The difference between rills and gullies is one of size that is not precisely defined. Rice and Datzman [1981] found that 80 percent of gully erosion was associated with roads and skid trails. There is no gully erosion data within the project area to compare with the work of Rice and Datzman mainly because no gullies were observed during post-wildfire field observations [Laurent 1989].

Dry Surface Ravel

When soil is exposed by wildfire, prescribed fire, mechanical soil disturbance or roads, the first erosion process that occurs is dry soil ravel. Soil ravel occurs when organic material [such as logs, branches, twigs and litter] have been acting as small sediment traps are removed by fire and the unconsolidated soil material that has been trapped by these materials moves downslope due to gravity. Dry ravel quickly drops to a much lower annual rate due to a reduction in potential ravel material and increasing vegetative cover with time. Dry soil ravel rates reported by Bennett [1982], collected within 24 hours after burning, were 147 m^3/ha [63 yd^3/acre] on slopes greater than 60 percent and 10 m^3/ha [4.3 yd^3/acre] on slopes less than 60 percent for clearcut and broadcast burned harvest units in the Coast Range mountains of Western Oregon. These values on slopes greater than 60 percent were 65 percent of the first years total erosion and 35 percent for slopes

less than 60 percent. Soil textures ranged from clay loams to gravelly loams. In Bennett's study [1982], composition of this dry ravel on slopes greater than 60 percent was 8 percent organic materials, 58 percent coarse soil material [>2mm in diameter] and 34 percent fine soil material [<2mm diameter]. On slopes less than 60 percent, 38 percent was organic materials, 21 percent was coarse soil material and 41 percent was fine soil material. Megahan [1978] reported dry ravel rates of 2.6 tonnes/km^2/day [1.2 yd^3/acre/year] in granitic terrane on bare soils with 70 percent slopes. Overall, dry ravel accounted for an average of 15 percent of the total erosion in Megahan's study.

Soils most susceptable to this process within the project area are sandy loams and loamy sands that have formed from granitic rock types [granite to diorite]. Most dry ravel occurs on steep slopes [>50 percent] in noncohensive [low clay content] soil material. Dry ravel deposits [colluvial fans] were very visible in narrow inner gorges in the toe slope position [Laurent 1989]. In many instances, the toes of these fanse were within the high flow mark of streams. In some cases, such as intermittent streams, the toes of colluvial fans from opposite sides of the inner gorge actually met in the middle of the draw.

Dry ravel data within the project area on a 60 percent slope in granitic terrane recorded 2.1 yd^3/acre over a period of 2 months after a wildfire removed the brush vegetation [Laurent 1989]. Approximately 66 percent of the ravel occurred within 15 days after the wildfire and 97 percent of the ravel had occurred at the end of 50 days. Thirty-eight percent of the first years erosion was dry ravel. This erosion process was not readily observable on mountain sideslopes except in shallow depressional areas and at the toe slope position in perennial and intermittent channels. Halvey et al. [1985] concluded that dry ravel along stream channels is an important part of the erosion process, especially after wildfires. They indicated that dry ravel also occurs during the dry summer months.

Surface Freeze/Thaw Process

Freeze and thaw of the upper few milimeters of soil can contribute to the erosion process. This soil is lifted above the soil surface by ice crystals and is vertically sorted with upper layers coarser than lower layers [Megahan 1978]. This detached soil material is easily moved downslope by rainfall or as dry ravel when the sun melts the ice and dries this material. There is no data from within the project area for this process but it has been observed in the field [Laurent 1989].

Animal Disturbance

Larger animals, such as deer, horses, sheep, cattle or humans can cause dry ravel when soils are dry, noncohesive and have loose surfaces. Clayton (1981] reported that 4 percent (0.20 yd^3/acre] of measured erosion in his study area was due to animal distrubance. This is very evident on sandy loam soils which are generally loose and noncohesive. In areas devoid of vegetation, this ravel can travel great distances before deposition occurs. This type of erosion was very evident when traversing the post 1987 wildfire areas in Crapo Creek, Olsen Creek and Big Creek [all in granitic terrane]. Each step would disloge soil material [sand and gravel sized material] that raveled downslope until deposited behind an obstacle such as logs or stumps, deposited in depressions or in drainage channels [Laurent 1989].

In the higher elevations of the Klamath Mountains, pocket gophers loosen soil and deposit this material on the soil surface. Taskey et al. [1988] reported that 33 percent of total erosion was gopher related dry ravel. The gophers contribute to erosion by piling soil loosely on the surface, from which it was easily moved by sheet or rill erosion and by casting soil material downslope during excavation. Clayton [1981] reported that on undisturbed plots, 0.2 yd^3 of erosion was due to gopher activity. This loosened material can move by fluvial processes or by gravitational processes. Swanson et al. [1982] reported vole related erosion as 0.01 yd^3/acre in grassland habitat. They felt that vole burrowing is locally important. Measurements of tunnels and debris piles yielded volumetric rates of 0.004 to 0.024 yd^3/acre/year.

Water Repellency in Soils

Hydrophobic soil conditions occur when soil particles become coated with organic compounds that repell water. Water repellency in soils commonly forms in the following two ways. The first is caused by fire, where organic compounds are released into the soil by consumption of surface organic materials. These organic compounds move downward into the soil, condense and coat soil particles and/or fill in pore spaces. Sand to sandy loam soils tend to become more severely water-repellent than do finer textured clay soils because of the larger pore sixe in the coarser textured soils [DeBano et al. 1970]. In the project area, water repellent related erosion predominately occurred on coarse textured soils [sandy loam or loamy sands] within the granitic terrane.

A natural repellency has been observed in high elevation soils within the true fir zone. This is caused by the products of decomposition of plant litter and soil fungi.

Dyrness [1976] reported that the first fall rains after the dry summer period, results in a highly variable pattern of soil wetting [mosiac pattern of wet and dry areas]. He surmized that this mosiac pattern was due to scattered points where the lower wet zones were wetted via old root channels or where the repellency was not as severe. Personal observations [Laurent 1989] made after the 1987 wildfires showed that the loamy sand soils were only wet for the upper one-half inch of soil after approximately 2 inches of precipitation. Later field observations showed that wetting was occurring below the repellent zone in a similar pattern as reported by Dyrness. It was speculated that the mosiac wet areas could also be caused by deer tracks breaking the repellent layer and causing an entry way for infiltration.

Once the soil has become wetted, the runoff potential decreases. The effect of repellency decreases throughout the winter because the soil stays moist and the wetting front has crossed the repellent zone. During the spring, when the soil begins drying out between storms, water repellency returns as the soil surface dries. This wetting/drying cycle can be repeated many times during the spring.

These wet/dry cycles resulted in 27 tons/acre of soil erosion in an erosion plot located on the headwall of a dormant debris slide landform. Numerous rills were observed in the plot. Rills were observed in a fan shaped pattern coalessing at the bottom of the headwall zone. The same wet/dry cycles in an adjacent plot on the lateral side wall of the same dormant debris slide feature resulted in only 2.3 tons/acre of erosion. No rills were observed within the plot. The geomorphic landform was principally responsible for the difference in erosion values between plots rather than differences in repellency.

Snowmelt Erosion

Erosion due to snowmelt was assumed to be insignificant when compared to raindrop splash erosion processes. Hart and Loomis [1982] reported soil erosion loss from clear-weather snowmelt ranging from 3 to 26 pounds/acre. They showed that soil erosion depends more upon the rate of snowmelt than upon the volume of snowmelt runoff. They also showed that greater soil loss occurs when snowmelt is concentrated in short periods of warm weather. These low erosion rates were due to most of the snowmelt water infiltrating into the soil rather than occurring as overland flow.

Wind Erosion

This type of erosion is considered insignificant in the Klamath Mountains, although it has been observed in granitic terrane where large acreage was denuded by wildfire in 1987. Some dust clouds were observed by district personnel [Laurent 1989] in this large burned area in the early summer following the fire. No estimates of erosion volumes were made during these observations.

SOIL EROSION MODEL

The surface erosion model used for this project is the USLE using cover factors and a rainfall factor adjusted for localized conditions from Dissmeyer and Foster [1984]. The USLE is an erosion model designed to predict the long term average soil loss from specific soils with specific site characteristics. This model computes soil loss for a given site as the product of 6 factors whose values for a specific site can be expressed numerically. Erosion variables reflected by these factors vary about their means from storm to storm, but these fluctuations tend to average out over an extended period of time [Wischmeier and Smith 1978]. Calculated soil loss values are substantially less accurate when predicting specific events than predicting long term averages [Wischmeier and Smith 1978].

The soil loss equation is: A=RKLSCD, where

A- is the computed soil loss per unit area. Tons/acre/year or cubic yards/acre/year are used as the per unit area. Tons/acre have been converted to yd^3/acre by using two factors, 0.71 for sandy loam textures and 0.81 for loam textures.

R- the rainfall and runoff factor, is the number of the rainfall erosion index units.

K- the soil erodibility factor, is the soil loss rate per erosion index unit for a specified soil.

L- the slope-length factor, is the ratio of soil loss from field slope length to that from a 72.6 feet length under identical conditions.

S- the slope-steepness factor, is the ratio of soil loss for the field slope gradient to that from a 9 percent slope under otherwise identical conditions.

C- the cover factor, is the ratio of soil loss from an area with specified cover and management to that from an identical area in tilled continuous fallow.

D- the delivery factor, is the percentage of eroded surface soil that is delivered to a perennial or intermittent channel.

The USLE is by far the most widely used method for predicting sheet and rill erosion [Foster and Lane 1987] and one of the most useful guidelines available [Browning 1983] until the Water Erosion Prediction Project [WEPP] model is available for use. The USLE is an empirical and lumped equation while WEPP is process based and computes erosion by storm events. WEPP also determines depostion in furrows, on concave slopes, at edges of a land use change and in concentrated flow channels and concentrated flow erosion.

USLE data are most accurate on slopes between 3 and 18 percent with slope lengths less than 400 feet. Wischmeier and Smith [1978] reported that about 53 percent of the differences between their calculated and plot data were less than 1 ton/acre and 84 percent were less that 2 tons/acre. They showed that the accuracy of predicted soil loss depends on how accurately the physical soil and site conditions are described by the parameter values used to select data from the factor-evaluation tables and charts. Wischmeier and Smith [1978] indicated that large-scale averaging of parameter values on large drainages will reduce USLE accuracy.

The soil erosion model cannot hope to predict with a high degree of certainty actual erosion losses that would be experienced by the selected precipitation events used in this study. The data is expected to be reasonable and representative of actual erosion events and processes. Calculated erosion values are compared to

erosion plot data from numerous erosion plots within the Salmon River watershed. These plots have been inplace from 4 to 9 years. Erosion plot data within a USLE project area can be used as a check on the relative accuracy of the USLE values. Recent studies adjacent to the Salmon River Watershed project area [Raines and Kelsey 1991; Sommarstrom et al. 1990] used the USLE without the benefit of local erosion plot data.

R Factor

Wischmeier [1962] showed that a rainfall factor used to estimate average annual soil erosion must include the cummulative effects of many moderate-sized storms, as well as the effects from the occasional severe storms. The numerical value for R must quantify the raindrop impact effect as well as provide relative information on the amount and rate of runoff likely to be associated with the rain. Specific-storm or specific-year soil losses and short-term averages may differ substantially from the longtime average predicted by the USLE for the specified physical soil and site conditions.

Rain showers of less than one-half inch and separated from other rain periods by more than 6 hours were omitted from the erosion index computations, unless as much as 0.25 inches of rain fell in 15 minutes [Wischmeier and Smith 1978]. Statistical analysis showed that the total storm energy values for such rains are usually too small and collectively, they have little effect on monthly percentage of the annual storm energy [Wischmeier and Smith 1978]. This may be valid for the mid-western part of the U.S. but this does not represent precipitation patterns or intensities in the Klamath Mountains. Maximum precipitation data from within the project area shows that the 2 year 15 minute precipitation intensity is 0.20 inches [California Division of Water Resources 1981]. This maximum precipitation value is below the minimum rate used in the standard USLE equation. This would indicate that the normal way to calculate the R value is not representative of the Klamath Mountains since these low intensity storms are not considered by definition.

Standard R-values for the Western States have been estimated from R values determined in the Western Plains and northern Central States. These ratios are expressed as:

$$R=10.20P^{2.17}\text{[Type 1A]}$$
$$R=16.55P^{2.17}\text{[Type 1]}$$
$$R=27.38P^{2.17}\text{[Type 2]}$$

where P is the 2 year 6 hour rainfall amount in inches.

The Type 1A storm distribution is characteristic of the west side of the Cascade and Sierra Nevada Mountians to the coast in Northern California, Oregon and Washington. Type 1 storm distribution represents the west side of the Sierra Nevada Mountians to the coast in southern California. The Type 2 storm distribution represents the rest of the United States [Brooks et al. 1975; Mitchell and Bubenzer 1980].

The above relationships used isopluvial maps to approximate erosion index values from the Western States [Wischmeier and Smith 1978]. The 2 year 6 hour rainfall values for the Salmon River watershed using an isopluvial map from the NOAA Atlas 2 [Miller et al. 1973] range from 1.8 to 2.2 inches. Using an average value of 2.0 inches gives an R value of 46.9 using the Type 1A equation above. This R value when used to calculate soil erosion rates, produced values 2.4 times greater than plot data within the Salmon River watershed.

A recent study adjacent to the Salmon River Watershed project area [Raines and Kelsey 1991] used the Type 2 R-value equation. Their R-value was 182. If the Type 2 R-value equation was used for the Salmon River Watershed project, the R-value would be 123 which would calculate USLE values 6.5 times higher than plot data within the project area.

In order to best represent the precipitation for the project area, a 2 year 6 hour precipitation value of 1.34 inches from the Sawyers Bar Ranger Station within the project area was used [California Division of Water Resources 1981] rather than more generalized isopluvial maps. This calculates an R value of 19.4. This R-value better represents the low intensity storms that dominate the precipitation events in this area of the Klamath Mountains. About 36 percent of the differences between USLE and plot data, using the above equation, were less than 1 ton/acre and 62 percent were less than 2 tons/acre for soils formed from granitic rocks. Approximately 79 percent of the difference were less that 1 ton/acre and 93 percent were less than 2 ton/acre for soils formed from metamorphic rocks. These differences are comparable to what Wischmeier and Smith [1978] reported for their data. It is apparent that more variability is involved in calculating erosion for sandy loam soils formed from granitic rocks compared to that for loam soils formed from metamorphic rocks.

Rain on snow precipitation events occur in the Klamath Mountains in the fall and winter. Usually these events are not significant, but occasionally they are destructive as occurred in 1964 where widespread landsliding and channel scouring resulted. The scope and size of this project did not warrant creating a separate rainfall factor to include snowmelt.

As part of this project, two storm events were modeled to show potential sediment yields based on 1987-88 site conditions. Storms similar to what occurred in 1972 [25-year storm] and 1964 [100-year storm] were selected for modeling. The R-values used for these storms were calculated from 6 hour precipitation data from the Sawyers Bar Ranger Station data set [California Division of Water Resources 1981]. The 25 year 6 hour and 100 year 6 hour precipitation values were 2.46 inches and 2.97 inches respectively.

Individual thunderstorms are not part of the R-value that was used for this project because they are unpredictable and localized other than measurable thunderstorm data from Swayers Bar that is part of the data set used to calculate the 2 year 6 hour values. Also, we have no data to indicate where they occurred in the 1987-88 time period. Erosion plot data was used to determine a better R-value that would represent these intense and localized storms for future modeling. The standard Type 1A R-value equation, $R=10.2P^{2.17}$ using a 10 year 6 hour precipitation value of 2.1 inches to represent thunderstorm events was tried. The average USLE values, using a R-value of 51.0, was 4.7 tons/acre [3.3 yd^3/acre]. Comparing this value to the plot data average of 11.3 tons/acre [8.0 yd^3/acre] for sandy loam soils [granitic parent material] from within the project area showed very little correlation.

When the Type 2 R-value equation, $R=27.38^{2.17}$ was used to calculate thunderstorm erosion in conjunction with the 2 year 6 hour precipitation value of 1.34 inches, a much better correlation occurred. The average USLE value was 11.4 tons/acre [8.1 yd^3/acre]. This compares very nicely to average plot data of 11.3 tons/acre [8.0 yd^3acre]. This close fit between USLE and plot values using the Type 2 R-value equation may be because these thunderstorms are more representative of precipitation used to determine the Type 2 equation.

K Factor

The soil erodibility factor for each soil group was taken from the table of interpretations of the Order 3 Soil Survey of the Klamath National Forest [Foster and Lang 1986]. These values were calculated from the Wischmeier Nomograph [Wischmeier and Smith 1978] The 64 soil map units within the project area were combined into 5 soil groups based upon their K-factor values. This was done to make the GIS data more manageable. K values for sandy loam soils [granitic parent material] were 0.18 and 0.24. K values for loam soils [metamorphic and ultrabasic parent materials] were 0.06, 0.11 and 0.24.

L and S Factors

The topographic factors, L [slope length] and S [slope length] affect the rate of soil erosion. These two factors are combined into a single topographic factor, LS.

LS values were taken from Table 3.2-4 [Curtis et al. 1977].

Recent users of the USLE model for the Klamath Mountain Province have used 25 feet as their slope length or have reported average soil particle movement of 18 to 25 feet on slopes over 60 percent [Striffer and Mogren 1971; Bennett 1982; Miles et al. 1988; and Sommarstrom et al. 1990].

Helvey and Fowler [1979] reported that the maximum soil particle movement in a skid trail was 7.9 feet on a 30 percent slope. Bennett [1982] used glass beads [2.6 gm/cc density] to determine the distance soil material moved downslope. The beads moved an average of 17.7 feet [3.3 to 50.0 feet range] on slopes greater than 60 percent and 3.6 feet [1.0 to 7.9 feet range] on slopes less than 60 percent.

Miles et al. [1988] used a slope length of 25 feet for their USLE calculations. Slope lengths measured by Raines and Kelsey [1991] in the field were 1.6 to 75.5 feet. Sommarstrom et al. [1990] used a 25 feet slope length uniformily over their study area.

Striffler and Mogren [1971] reported maximum soil movement of 25 feet on a 62 percent slope. Soil particle movement by raindrop splash as measured around dye spots on level ground averaged 5 feet.

A slope length of 10 feet was uniformly used for the slope length factor over the Salmon River watershed project area. It was felt that rain drop dislodged soil particles do not travel great distances before they are deposited on the slope. Striffler and Mogren [1971] reported an average soil particle movement by raindrop splash of 5 feet on flat ground. The comparison of local erosion plot data using a 10 foot slope length value for the USLE calculations indicates that a 10 foot slope length is reasonable. Slope groups used for calculating erosion were 0-35 percent, 36-65 percent and greater than 65 percent.

C Factor

The C factor, the cover-management factor is based upon Dissmeyer and Foster's [1984] cover factors for forested conditions. They identified amount of bare soil, canopy, organic matter content, fine roots, residual binding effect, onsite storage and steps as subfactors that are applicable to conditions in the project area. Tables 3, 5, 7 and Figure 19 from Dissmeyer and Foster [1984] were used in calculating the cover factors.

Six disturbance groups were used in this project. They are: undisturbed, 1987 wildfire, 1987 reburn of the Hog fire, plantations, Hog fire not reburned and roads. These six groups were further subdivided into 225 unique vetetation, soil, slope and landform classes.

Undisturbed condition represents wilderness and nonwilderness areas that have not been impacted by management activities or fire. The 1987 wildfire condition was stratified into three burn intensities classes [high, moderate and low] which reflect differences in soil cover and vegetative mortality. These areas were generally forested areas prior to the fires. The 1987 wildfire burn intensities were 11 percent high, 22 percent moderate and 67 percent low. The 1987 reburn of the Hog fire was also stratified into the same three burn intensities. These areas were dominated by brush and with or without untreated logging slash. The burn intensities in these areas were 39 percent high, 46 percent moderate and 15 percent low. Plantations were stratified into three age classes which were 0-5 years old, 5-10 years old and 10-20+ years old.

D Factor

Sediment delivery from a source area to a stream channel is dependent on the following factors: sediment source, quantity of sediment, proximity of sediment source to channel, transporting agent, soil texture, soil cover, surface morphology, slope and watershed topography [Foster and Meyer 1977; Megahan 1974; and Renfro 1975].

An index approach was used to provide a relative estimate of the sediment delivery ratios. This method evaluated 7 environmental factors and one site specific factor [Warrington 1980]. This indexing method has not been validated by research [Warrington 1980]. This methodology provides a relative estimate of sediment delivery ratio for a given area. The eight factors used for estimating sediment delivery are: transporting agent, soil texture, percent ground cover, slope shape, slope gradient, delivery distance, surface roughness and a site specific factor [Warrington 1980].

Stiff diagrams **[Figure D-3]** were used to calculate the sediment delivery ratios for each slope class [0-35%, 35-65%, >65%], geomorphic position [sideslope or inner gorge], parent material [granitic and metamorphic] and forest conditions [undisturbed, 1987 fires, roads, plantations, Hog fire and area of Hog fire that reburned in 1987].

The calculated sediment delivery rates for surface erosion are listed in **Table D-1**. Sediment delivery rates for inner gorge areas are substantially higher compared to mountain sideslopes of similar slope [65%+]. This is due to a shorter delivery distance and slope shape.

All of the USLE surface erosion values pertaining to this project are delivered sediment volumes in yd^3/acre. This was done to be compatible with mass wasting volumes.

Repellency

One erosion plot within the project area [Crapo Creek] was able to measure erosion as a direct result of water repellent soil. The other erosion plots within the project area, may have experienced repellency but it was not apparent because the erosion rates were within the normal range for these soils. The one plot that measured excessive erosion due to repellency was also influenced by landform shape. The geomorphic landform was the steep [73% slope] headwall area [scarp] of a dormant debris slide. Numerous rills were observed in these fan-like landforms with rills merging at the bottom of the headwall area. Erosion plot data was 26.8 tons/acre [19.0 yd^3/acre]. The portion that was estimated to be the result of repellency caused erosion was that part exceeding the USLE value. This is:

26.8 tons/acre - 16.4 tons/acre = 10.4 tons/acre [7.4 yd^3/acre]

The acres of dormant debris slide features where repellency was a major factor were calculated from a geomorphic landform map that was completed for the Hog fire in 1984. The average value calculated from Olsen Creek and Kanaka Gulch was one acre of debris slide headwall per 21.81 watershed acres [1 acre/21.81 acres]. These repellency erosion values were added to the USLE data for each watershed subbasin. This repellency erosion factor was only used in the granitic terrane.

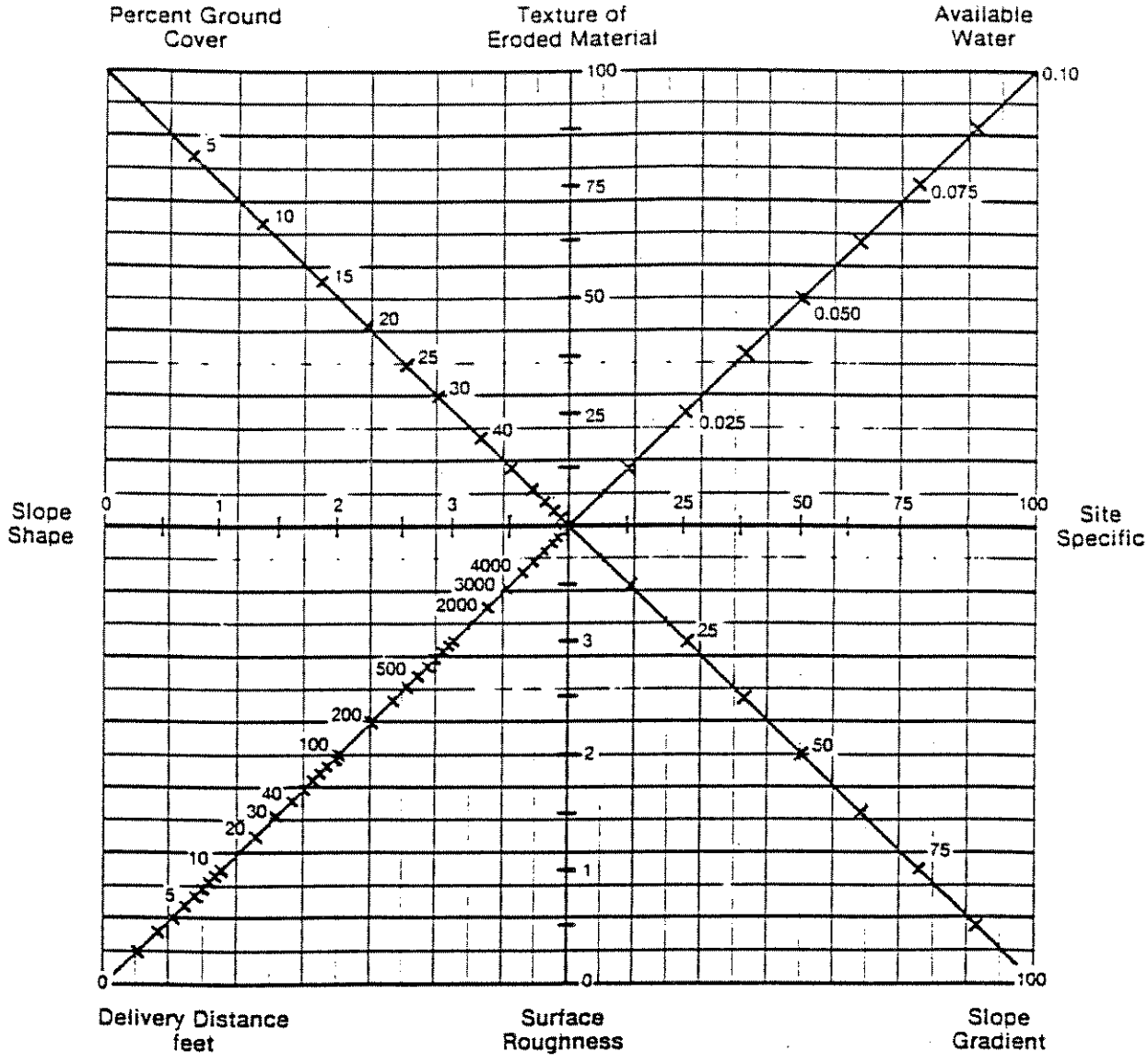


Figure IV.22—Stiff diagram for estimating sediment delivery.
(Warrington, 1980)

Figure D-3. Stiff diagram used to estimate sediment delivery.

Table D-1. Sediment delivery rates (factors) for surface erosion for each disturbance group by soil group and slope.

Soil Group	Slope Class %	Undis. Cond.	Hog Fire Not Burned in 1987	1987 Fire Burn Intensity			Reburn Hog Fire Burn Intensity			Plantations Age Class [yrs]			Roads
				High	Mod	Low	High	Mod	Low	0-5	5-10	10-20	
								yd³/acre					
G1	0-35	0.02	0.04	0.22	0.22	0.12	0.22	0.22	0.12	0.07	0.04	0.04	0.29
G2	0-35	0.02	0.04	0.22	0.22	0.12	0.22	0.22	0.12	0.07	0.04	0.04	0.29
NG1	0-35	0.02	0.04	0.14	0.14	0.09	0.14	0.14	0.09	0.07	0.04	0.04	0.29
NG2	0-35	0.02	0.04	0.14	0.14	0.09	0.14	0.14	0.09	0.07	0.04	0.04	0.29
NG3	0-35	0.02	0.04	0.14	0.14	0.09	0.14	0.14	0.09	0.07	0.04	0.04	0.29
G1	35-65	0.02	0.05	0.37	0.37	0.20	0.37	0.37	0.20	0.09	0.06	0.05	0.29
G2	35-65	0.02	0.05	0.37	0.37	0.20	0.37	0.37	0.20	0.09	0.06	0.05	0.29
NG1	35-65	0.02	0.05	0.22	0.22	0.15	0.22	0.22	0.15	0.09	0.06	0.05	0.29
NG2	35-65	0.02	0.05	0.22	0.22	0.15	0.22	0.22	0.15	0.09	0.06	0.05	0.29
NG3	35-65	0.02	0.05	0.22	0.22	0.15	0.22	0.22	0.15	0.09	0.06	0.05	0.29
G1	65+	0.02	0.07	0.45	0.45	0.28	0.45	0.45	0.28	0.12	0.07	0.07	0.29
G2	65+	0.02	0.07	0.45	0.45	0.28	0.45	0.45	0.28	0.12	0.07	0.07	0.29
NG1	65+	0.02	0.07	0.30	0.30	0.23	0.30	0.30	0.23	0.12	0.07	0.07	0.29
NG2	65+	0.02	0.07	0.30	0.30	0.23	0.30	0.30	0.23	0.12	0.07	0.07	0.29
NG3	65+	0.02	0.07	0.30	0.30	0.23	0.30	0.30	0.23	0.12	0.07	0.07	0.29
								Inner Gorge					
G1	65+	0.25	0.40	0.90	0.90	0.80	0.90	0.90	0.80	0.60	0.40	0.40	0.29
G2	65+	0.25	0.40	0.90	0.90	0.80	0.90	0.90	0.80	0.60	0.40	0.40	0.29
NG1	65+	0.25	0.40	0.90	0.90	0.80	0.90	0.90	0.80	0.60	0.40	0.40	0.29
NG2	65+	0.25	0.40	0.90	0.90	0.80	0.90	0.90	0.80	0.60	0.40	0.40	0.29
NG3	65+	0.25	0.40	0.90	0.90	0.80	0.90	0.90	0.80	0.60	0.40	0.25	0.29

EROSION RATES

Literature Review

Granitic Terrane

Soil erosion rates in granitic terrane have been reported by nunmerous researchers. Ryan [1984] reported values from 15.3 to 27.8 tons/acre [10.9 to 19.7 yd^3/acre] after broadcast burning chaparrel brush on the Angeles National Forest. Slopes varied from 58 to 80 percent and cover varied from 15 to 40 percent. Clayton [1981] reported values of 6 tons/acre [4.3 yd^3/acre] for logged and burned areas of which 60 percent or 3.6 tons/acre [2.6 yd^3/acre] was due to fire, animals, sheet erosion and misc. factors. Logging was responsible for 40 percent of the erosion or 2.4 tons/acre [1.7 yd^3/acre]. Megahan [1978] reported an average erosion rate of 3.4 tonnes/km^2/day [3.9 yd^3/acre/year] for a bare 70 percent road fill. Anderson [1969] reported erosion rates in disturbed lands at 0.12 to 0.27 inches/year [13.5 to 31 yd^3/acre].

Metamorphic Terrane

Soil erosion rates in metamorphic terranes have been reported by numerous researchers. Datzman [1978] reported an average erosion rate from 17 harvest units of 2.8 yd^3/acre on the Six Rivers National Forest. Rice and Datzman [1981] reported average surface erosion rates of 26.8 m^3/ha [14.2 yd^3/acre]. Rice et al. [1979] reported average erosion rates [soil erosion] of 42.9 yd^3/acre for tractor and cable clear cut and partial cuts in the Coast Mountains of Northern California. Bennett [1982] reported average first year surface erosion rates of 17 m^3/ha [9 yd^3/acre] in burned clearcut harvest units. She also reported a rate of 133 m^3ha [70.5 yd^3/acre] in a compacted skyline yarding corridor. Average erosion rates in clearcut and burned harvest units was 29 m^3/ha [15.4 yd^3/acre] on slopes less than 60 percent and 224 m^3/ha [118.7 yd^3/acre] on slopes greater than 60 percent. Anderson [1969] reported average erosion rates in loam soils of 0.3 in/yr [39 yd^3/acre in distrubed [logged] areas. Striffler and Mogren [1971] reported average soil loss of 0.25 inches [16 yd^3/acre] for a very gravelly sandy loam soil.

Road Related Erosion

Reid and Dunne [1984] reported sediment production for various roads. They reported that heavy used roads produced an average of 500 tonnes/km/year [69.3 yd^3/acre/year] while moderately used roads produced an average of 42 tonnes/km/year [5.8 yd^3/acre/year] and lightly used roads produced an average of 3.8 tonnes/km/year [0.5 yd^3/acre/year]. Raines and Kelsey [1991] used Reid and Dunnes values but adjusted them for localized conditions and reported erosion rates of 7.6 m^3/km/year [1.5 yd^3/acre/year].

Simons et al. [1982] reported a mean sediment yield of approximately 7.6 yd^3/acre of road prism. Rice et al [1979] reported rates of 1304.02 yd^3/mi^2 during construction phase [2.0 yd^3/acre]. McCashion and Rice [1983] reported average road erosion rate of 47 yd^3/acre from rills, gullys and surface sloughing in Northern California. This road erosion was 17 times the average erosion reported from harvest units in the same area. Forty percent of the total erosion in their study came from roads. Bilby [1985] reported erosion rate of 20.4 tonnes/3250 m^2 of road prism [22.7yd^3/acre]. Megahan et al. [1986] reported an average road erosion rate of 31 m^3/ha [16.4 yd^3/acre] during the construction phase in the Idaho Batholith.

Delivery Rates

Amaranthus [1988] used delivery rates from 0.20 to 0.75 for fire burned areas and proposed harvest units and 0.70 to 0.86 for roads. Sommarstrom et al. [1990] used 0.21 as their delivery ratio. The Grass Valley study in Trinity County [SCS 1986] used 0.55 as a sediment delivery ratio. The Grider EIS Watershed Erosion model delivery rates varied from 0.16 to 0.24 for various reaches of the watershed [Klamath National Forest 1989].

USLE Data

Raines and Kelsey [1991] reported USLE derived erosion from cable yarded harvest units ranging from 2.0 to 8.4 yd^3/acre two years post harvest, 1.3 to 2.6 yd^3/acre five years after harvest and 0.02 to 0.03 yd^3/acre 25+ years after harvest. They also reported calculated erosion rates in tractor yarded units ranging from 8.7 to 10.7 yd^3/acre two years after harvest, 2.2 to 8.7 yd^3/acre five years after harvest and 0.2 yd^3/acre 25+ years after harvest. They used an R value of 182. The Siskiyou National Forest used surface erosion rates of 2.9 to 14.8 tons/acre/decade [0.29 to 1.48 tons/acre/year] for skyline yarded units and 8.7 to 44.4 tons/acre/decade [0.62 to 3.2 yd^3/acre/year] for tractor yarded units [Siskiyou National Forest 1988]. Amaranthus [1988] used basic erosion rates of 1.3 to 30.0 tons/acre [0.9 to 21.3 yd^3/acre] for wildfire burned areas and 10.5 tons/acre [7.5 yd^3/acre] for first-year surface erosion rates for roads.

Salmon River Watershed Results

Granitic Terrane

Soil erosion plots within the project area varied from 0.4 to 19.0 yd^3/acre for first year data. Slopes for all plots ranged from 45 to 70 percent. Soil cover ranged from 0 to 22 percent in these plots. Average erosion value was 3.8 yd^3/acre. Thunderstorm caused erosion varied from 8.7 to 16.4 tons/acre [6.2 to 11.6 yd^3/acre]. Repellency caused erosion was at least 10.4 tons/acre [7.4 yd^3/acre] from one plot.

Erosion in a downhill yarded clearcut in granitic terrane within the project area estimated from field observations was 3.6 to 80 yd^3/acre [Laurent 1989]. Sheet and rill erosion was studied in the Little North Fork area of the project area by a Forest Service Task Force [Abraham 1973] after two 25-year winter storm events a few months [Jan., 1972 had 9.24 inches/3 days; March, 1972 had 6.51 inches/3 days; data recorded at Sawyers Bar Ranger Station] apart caused significant erosion and environmental damage. Soil erosion values were estimated from field observations and do not include soil loss from debris slides. Soil loss values from sheet and rill erosion were estimated at 40,768 yd^3over 350 acres [117 yd^3/acre that were clearcut and broadcast burned. Soil erosion from individual harvest units varied from 54 to 168 yd^3/acre.

Sediment deposited in a sediment storage basin near the mouth of Olsen Creek trapped an estimated 7000 yd^3 within 2 months after the 1987 wildfire and an additional 6500 yd^3over the next 22 months [de la Fuente 1990]. This totals 13,500 yd^3. By the end of 1992, the volume had increased to 15,900 yd^3. USLE calculated erosion from this watershed is approximately 6210 $yd^3$for the same time period. Personal observations in 1987-88 [Laurent 1989] showed that channel scour had occurred as well as deposition and rescouring. There is no way of knowing what percent of trapped sediment is due to surface erosion or channel scour of pre-existing sediment.

Metamorphic Terrane

Erosion plots within the project area varied from 2.8 to 7.2 yd^3/acre for the first years data. Slopes for all plots ranged from 37 to 65 percent. Soil cover ranged from 0 to 45 percent in these plots. Average erosion value was 3.5 yd^3/acre.

Rill erosion on a loam soil that was tractor piled [brush, grass and forbs] parallel to slope was approximately 7.3 yd^3/acre for the first year [Laurent 1988]. This was the result of surface drainage being orientated parallel to the slope by the tractor track lines. This rilling is not a common occurrance in tractor logged or piled harvest units on the Klamath National Forest as observed over the past 10 years [Laurent 1988]. This may be due to the type of precipitation storms this part of the Klamath Mountains receives.

Roads

Roads in the project area varied from insloped and outslopes, surfaced with native materials, crushed rock or paved. These differences were not stratified by the current data base used. No erosion plots have been established to record road related erosion within the project area or on the Forest. The USLE data is an estimated average value for all of these conditions.

USLE Sediment Yields for the Project Area

Introduction

USLE surface erosion rates for six disturbance groups [undisturbed, roads, plantations, Hog Fire not reburned, Hog Fire reburned in 1987 and 1987 wildfires], stratified by soil group and percent slope are displayed in **Table D-2**. These are the basic erosion rates [yd^3/acre] used for determining sediment yields from surface erosion sources for this project.

Management activities have been stratified into six disturbance groups. These groups represent soil disturbance conditions with varying amounts of soil cover. Undisturbed condition assumes no management activities and no wildfires. Plantations represent three age classes [0 to 5 years old, 6 to 10 years old and greater then 10 years old]. Hog Fire not reburned represents that portion of the 1977 Hog Fire that did not reburn during the 1987 wildfires. Hog Fire reburned in 1987 represents that portion of the Hog Fire that reburned during the 1987 wildfires. The 1987 wildfires represent those areas that burned in the wildfires that are outside of the Hog Fire.

Comparing USLE surface erosion rates used in this study **[Table D-2]** to erosion rates reported in the literature indicates that USLE values used in this study are on the lower end of reported values from other studies. Surface erosion studies in the literature reported values ranging from 4 to 31 yd^3/acre for granitic terrane and 3 to 119 yd^3/acre in metamorphic terrane. USLE values in this study for bare soil range from 0.6 to 11.8 yd^3/acre in granitic terrane and 0.4 to 12.4 yd^3/acre in metamorphic terrane. Road prism erosion reported in the literature varied from 1.5 to 22.7 yd^3/acre with some higher rates associated with heavy use areas. USLE road prism erosion values used in this study were 6.7 and 9.1 yd^3/acre for metamorphic and granitic terranes, respedtively. This shows that our values are within rates reported by other researchers. The differences between the above values are probably the result of our using substantially lower R-factor and shorter slope lengths compared to these other reported studies.

The following discussion addresses the fluctuations in surface erosion with time which is the result of revegetation in disturbed areas. The rate of revegetation is dependent upon the level of disturbance or fire intensity. Revegetation is usually rapid except in areas where the upper soil containing the seed source has been removed or severely distrubed.

Undisturbed Conditions

Surface erosion rates for undisturbed conditions were computed in order to compare them with existing levels of disturbance. Undisturbed conditions assume no disturbance from naturally occurring wildfires or man's activities.

Table D-3 displays delivered sediment [USLE] from surface erosion sources for undisturbed conditions in the Salmon River watershed and its four main project subdivisions. The average delivered sediment yield is 0.016 yd^3/acre/year for the entire watershed. **Table D-4** shows that inner gorge, which occupies 16.6 percent of the land, produces 96 percent of the delivered sediment for undisturbed conditions. This result is based on the assumption that inner gorges have much higher sediment delivery rates due

Table D-2. Surface erosion rates [yd³/acre] for each disturbance group by soil group and slope.

Soil Group	K Factor	Slope Class %	Undis. Cond.	Hog Fire Not Burned in 1987	1987 Fire Burn Intensity			Reburn Hog Fire Burn Intensity			Plantations Age Class [yrs]			Roads Rock Type	
					High	Mod	Low	High	Mod	Low	0-5	5-10	10-20	Gran	Met
								yd³/acre							
G1	0.18	0-35	0.001	0.005	0.6	0.3	0.06	1.3	0.6	0.1	0.4	0.09	0.009	9.1	
G2	0.24	0-35	0.004	0.01	1.4	0.8	0.01	1.7	0.8	0.01	0.5	0.1	0.01	9.1	
NG1	0.06	0-35	0.001	0.004	0.4	0.2	0.04	0.4	0.2	0.04	0.2	0.04	0.004		6.7
NG2	0.11	0-35	0.002	0.007	0.7	0.4	0.08	0.8	0.4	0.08	0.3	0.07	0.007		6.7
NG3	0.24	0-35	0.004	0.01	1.6	0.9	0.20	1.8	0.9	0.20	0.6	0.10	0.01		6.7
G1	0.18	35-65	0.007	0.03	2.9	1.7	0.3	6.4	3.0	0.6	2.0	0.5	0.05	9.1	
G2	0.24	35-65	0.017	0.06	6.9	4.0	0.7	8.5	4.0	0.7	2.5	0.7	0.06	9.1	
NG1	0.06	35-65	0.005	0.02	2.0	1.2	0.2	2.2	1.2	0.2	0.7	0.2	0.02		6.7
NG2	0.11	35-65	0.009	0.03	3.7	2.1	0.4	4.1	2.1	0.4	1.3	0.4	0.03		6.7
NG3	0.24	35-65	0.020	0.07	8.0	4.6	0.8	8.9	4.6	0.8	2.9	0.8	0.07		6.7
G1	0.18	65+	0.010	0.04	4.0	2.3	0.4	8.9	4.2	0.8	2.8	0.7	0.07	9.1	
G2	0.24	65+	0.024	0.09	9.7	5.6	1.0	11.8	5.6	1.0	3.5	1.0	0.09	9.1	
NG1	0.06	65+	0.007	0.03	2.8	1.6	0.3	3.1	1.6	0.3	1.0	0.3	0.03		6.7
NG2	0.11	65+	0.012	0.05	5.1	2.9	0.5	5.7	2.9	0.5	1.8	0.5	0.05		6.7
NG3	0.24	65+	0.028	0.10	11.2	6.4	1.2	12.4	6.4	1.2	4.0	1.1	0.10		6.7
							Inner Gorge								
G1	0.18	65+	0.261	0.04	4.0	2.3	0.4	8.9	4.2	0.8	2.8	0.7	0.70		
G2	0.24	65+	0.626	0.09	9.7	5.6	1.0	11.8	5.6	1.0	3.5	1.0	0.09		
NG1	0.06	65+	0.181	0.03	2.8	1.6	0.3	3.1	1.6	0.3	1.0	0.3	0.03		
NG2	0.11	65+	0.331	0.05	5.1	2.9	0.5	5.7	2.9	0.5	1.8	0.5	0.05		
NG3	0.24	65+	0.723	0.10	11.2	6.4	1.2	12.4	6.4	1.2	4.0	1.1	0.10		

Notes:
1. G1 and G2 soil groups are on granitic parent material.
2. NG1, NG2 and NG3 soil groups are on metamorphic and ultrabasic parent materials.

Table D-3. Delivered sediment from surface erosion sources for undisturbed conditions.

Watershed	Undisturbed yd^3	Area acres
SALMON	7690	480,649
Main Stem	1109	69,334
North Fork	2088	130,514
South Fork	2970	185,608
Wooley	1523	95,193

Table D-4. Acres, mobilized erosion and delivered sediment for innergorge [IG] areas for 1987-88 post-wildfire conditions for the Salmon River watershed.

	Undisturbed	Roads	Plantations	Hog Fire not burned in 1987	Hog Fire reburned in 1987	1987 Fire
Total Acres	327653	3639	11118	36737	20209	81294
IG Acres	51389	-	1073	7438	4038	14880
Percent IG	16	-	10	20	20	18
Total yd^3	23698	25490	2050	1727	69660	113885
IG yd^3	20576	-	232	415	17065	20581
Percent	87	-	11	24	24	18
Deliv. yd^3.	5386	7392	277	245	33300	46569
IG Deliv. yd^3	5144	-	122	158	15246	17816
Percent	96	-	44	65	46	41

to shorter delivery distance and slope distance compared to other geomorphic land types [see **Table D-1**].

1986-87 Pre-Wildfire Conditions

This time period represents undisturbed, roads, plantations and Hog Fire disturbance conditions.

Table D-5 displays USLE delivered sediment from surface erosion sources for the 1986-87 pre-wildfire conditions for the Salmon River watershed and its four main subdivisions. Erosion is stratified into four disturbance groups: undisturbed, roads, plantations and the 1977 Hog Fire. Acres of each disturbance group are also displayed in **Table D-5**.

Table D-6 displays the percent areal distribution of acres and delivered sediment for each disturbance group. Roads, which occupy 1 percent of the area, are responsible for 47 to 53 percent of the erosion in the three watershed subdivisions that have substantial road acres [main stem, north fork and south fork]. The undisturbed areas are the second largest producer of delivered sediment of which the majority derives from the inner gorge.

1987-88 Post-Wildfire Conditions

This time period represents undisturbed, roads, plantations, Hog Fire not reburned in 1987, Hog Fire reburned in 1987 and 1987 wildfire areas.

Table D-7 displays surface erosion sediment yields in the major watersheds by disturbance groups for 1987-88 post-wildfire conditions. It is apparent that the 1987 wildfire is responsible for most of the erosion for this time period. The 1987 wildfires, occurring on 21 percent [4% + 17%] of the acres, are responsible for 87 percent [35% + 52%] of the total delivered sediment for the Salmon River watershed **[Table D-8]**. The majority [average of 56.5%] of this delivered wildfire derived sediment comes from the inner gorge areas as indicated in **Table D-4**.

Roads and undisturbed conditions represent 7 and 5 percent of the total, respectively.

1991-1992 Post-Wildfire Conditions

This time period represents undisturbed, roads, plantations, Hog Fire not reburned in 1987, Hog Fire reburned in 1987 and 1987 wildfire area conditions as they occur four years after the wildfires. Plantations and roads represent all plantations and roads as existing in 1988. Post-wildfire harvesting and road building are not part of this data base.

Table D-9 show delivered sediment for 1991-92 post-fire conditions for the Salmon River watershed and its four main project subdivisions. The wildfires are still responsible for 44 percent of the total erosion for the Salmon River watershed which is a 77 percent reducton from 1987-88 conditions.

Table D-10 compares the undisturbed, 1986-87, 1987-88, 1991-92 and 2007-08 time periods. Delivered sediment increases ranged from 268 to 1990 percent above pre-fire conditions [1986-87] for the first year following the wildfires for the various major watersheds. These increases were reduced to values ranging from 33 to 140 percent above pre-fire condtions for the various major watersheds by 1991-92. This is approximately a 10-fold decrease in delivered sediment values in 4 years. By 2007-08, the effects of the wildfire [excluding new roads and new harvesting] on surface erosion will have approximately returned to 1986-87 conditions [pre-wildfire]. **Figure D-4** visually represents these same events from 1986 to 2008 for the Salmon River watershed. These decreased in delivered sediment are due mostly to vegetative recovery in the wildfire burned areas. Erosion from undisturbed areas, roads, plantations and that portion of the Hog fire that

Table D-5. Delivered sediment from surface erosion sources for each disturbance group for 1986-87 pre-wildfire conditions.

Watersheds	Undisturbed	Roads	Plantations	Hog Fire	Total
			acres		
SALMON	409254	3639	11118	56638	480,649
Main Stem	27659	383	2151	39141	69,334
North Fork	116052	989	3462	10011	130,514
South Fork	171539	2173	4410	7486	185,608
Wooley	94004	94	1095		95,193
			yd^3		
SALMON	6880	7392	277	1230	15,779
main stem	544	778	11	271	1,604
north fork	1704	2049	155	61	3,969
south fork	2825	4318	101	898	8,142
Wooley	1807	247	10		2,064
			yd^3/acre		
SALMON	0.017	0.49	0.02	0.02	0.03
main stem	0.020	0.49	0.005	0.007	0.03
north fork	0.015	0.48	0.04	0.006	0.03
south fork	0.016	0.50	0.02	0.12	0.04
Wooley	0.019	0.38	0.01		0.02

Table D-6. Disturbance classes: Areal distribution and sediment delivery from surface erosion sources by disturbance group for 1986-87 pre-wildfire conditions.

Watershed	Undisturbed	Roads	Plantations	Hog Fire
	% of land area			
SALMON	83	1	2	14
main stem	40	1	3	56
north fork	89	1	3	7
south fork	92	1	3	4
Wooley	98.9	0.1	1	-
	% of total volume			
SALMON	44	47	2	8
main stem	34	48	1	17
north fork	43	52	4	1
south fork	35	53	1	11
Wooley	87.5	12	0.5	-

Table D-7. Acres and delivered sediment for each disturbance group from surface erosion sources for 1987-88 post-wildfire conditions.

Watersheds	Undisturbed	Roads	Plantations	Hog Fire not burned in 1987	Hog Fire reburned 1987	1987 Fires	Total
				acres			
SALMON	327653	3639	11118	36737	20208	81294	480,649
main stem	14023	383	2151	29601	9540	13636	69,334
north fork	110828	989	3462	5094	5224	4917	130,514
south fork	133841	2173	4410	2042	5444	37698	185,608
Wooley	68961	94	1095			25043	95,193
				yd^3s			
SALMON	5416	7392	277	480	36422	55107	105,094
main stem	299	778	11	205	17607	14619	33,519
north fork	1615	2049	155	30	13711	4903	22,463
south fork	2146	4318	101	245	5104	18045	29,959
Wooley	1356	247	10			17540	19,153

Notes: Assumes no harvesting and site prep in fire areas because data not in data base at this time. Undisturbed conditions assumes no management activities and no wildfire.
Hog fire not burned refers to that portion of the 1977 Hog Fire that did not reburn in 1987. The 1987 fires refers to the wildfires that burned in 1987 excluding that portion of the Hog Fire that reburned in 1987.

Table D-8. Percent distribution of acres and delivered sediment from erosion sources for each disturbance group for 1987-88 post-wildfire conditions

Watersheds	Undisturbed	Roads	Plantations	Hog Fire not burned in 1987	Hog Fire reburned 1987	1987 Fires
			% by acres			
SALMON	68	1	2	8	4	17
main stem	20	1	3	42	14	20
north fork	84	1	3	4	4	4
south fork	72	1	2	1	3	21
Wooley	73	0.1	1			26
			% by yd^3			
SALMON	5	7	0.3	0.5	35	52
main stem	1	2	0.03	1	53	44
north fork	7	9	0.1	0.1	61	22
south fork	7	14	0.3	1	17	60
Wooley	7	1	0.05			92

Notes: 1. Assumes no harvesting and site prep in fire areas because data not in data base at this time

Table D-9. Delivered sediment from surface erosion sources for each disturbance group for 1991-92 post-wildfire conditions

Watersheds	Undisturbed	Roads	Plantations	Hog Fire not burned in 1987	Hog Fire reburned 1987	1987 Fires	1991-92 Total	1987-88 Totals	% Reduction
					yd^3				%
SALMON	5416	7392	277	480	3381	7273	24,219	105,094	77
main stem	299	778	11	205	1485	1077	3,855	33,519	88
north fork	1615	2049	155	30	925	518	5,292	22,463	76
south fork	2146	4318	101	245	971	3585	11,366	29,959	62
wooley	1356	247	10	---	---	2093	3,706	19,153	81

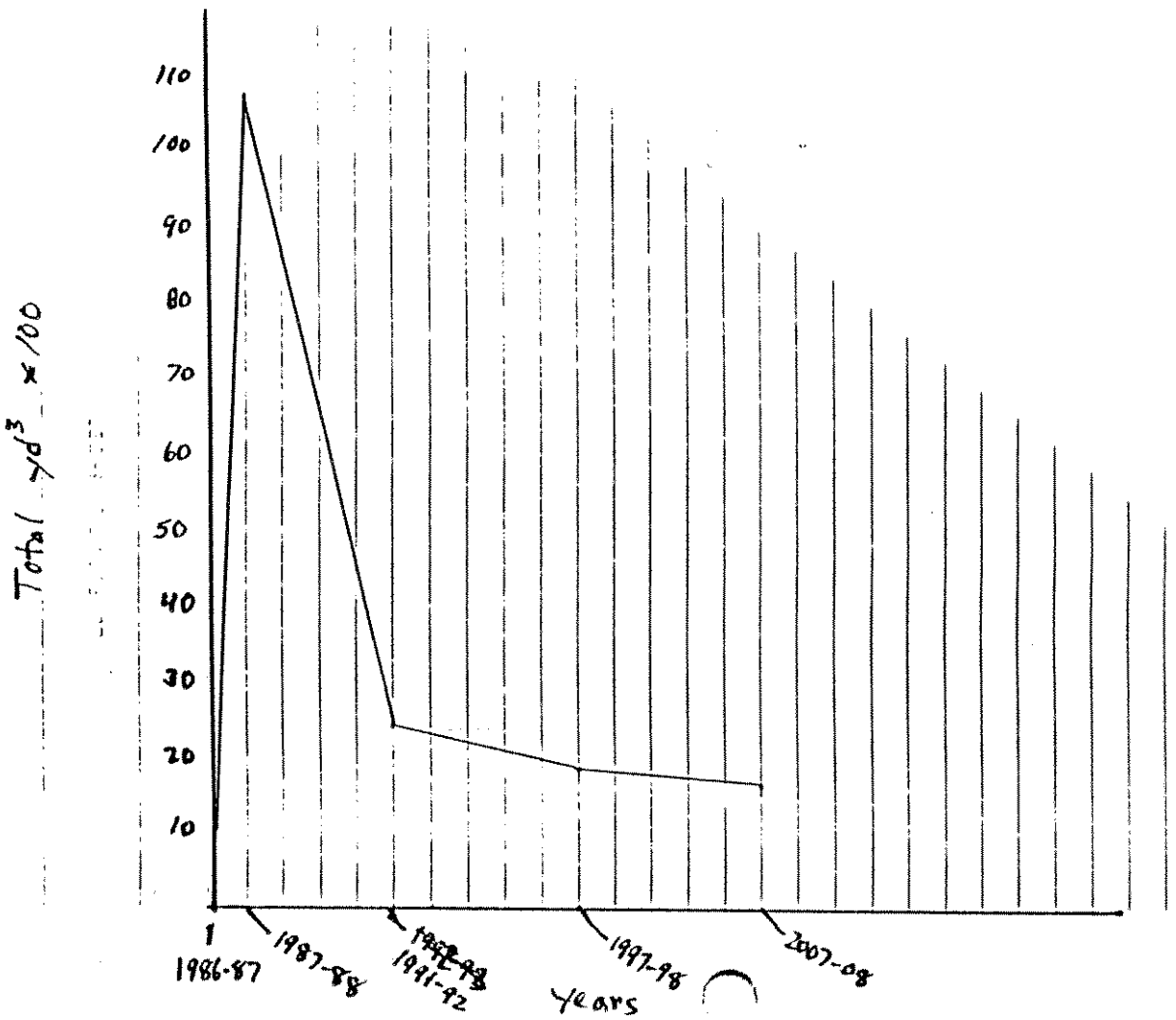
Notes:
1. Assumes no harvesting and site prep in fire areas because data not in data base at this time.
2. Uses natural vegetation recovery rates.

Table D-10. Comparative percent change in delivered sediment from surface erosion between Undisturbed, 1986-87, 1987-88, 1991-92 and 2007-08 conditions for an average precipitation year (Q2).

Watersheds	Undisturbed Conditions	1986-87 Conditions	1987-88 Conditions	1991-92 Conditions	2007-08 Conditions
			yd^3		
SALMON	7690	15779	105094	24219	15665
main stem	1109	1604	33519	3855	1767
north fork	2088	3969	22463	5292	4080
south fork	2970	8142	29959	11366	7688
Wooley	1523	2064	19153	3706	2130
			% change from Undisturbed conditions		
SALMON		+105	+1267	+215	+104
main stem		+45	+2922	+157	+59
north fork		+90	+976	+153	+95
south fork		+174	+909	+283	+159
Wooley		+36	+1158	+143	+40
			% change from 1986-87 conditions		
SALMON			+566	+53	-1
main stem			+1990	+140	+10
north fork			+466	+33	+3
south fork			+268	+40	-6
Wooley			+828	+80	+3
			% change from 1987-88 conditions		
SALMON				-77	-85
main stem				-88	-95
north fork				-76	-82
south fork				-62	-74
Wooley				-81	-89
			% change from 1991-92 conditions		
SALMON					-35
main stem					-54
north fork					-23
south fork					-32
Wooley					-43

Note: Assume no changes in plantation and road acres from 1986-87 levels.

Figure D-4. Delivered sediment from surface erosion versus average annual precipitation for the Salmon River Watershed.



was not reburned in 1987, remained the same or slightly decreased over this 22 year time period.

Particle-size data from soil surface samples from within the project area were used to determine the percent suspended and deposited components of the delivered sediment. Existing in-channel sediment and the possibility of debris flow and torrents are not considered in this determination. Suspended material generally consists of clay, silt and very fine sand [<0.002-0.10mm] sized particles and deposited material generally consists of fine and coarser sand [0.10mm-2.00mm] sized particles or greater

Table D-11 shows the estimated distribution between suspended and deposited sediment. Approximately 45 percent of the delivered sediment will be deposited in the stream system for average [Q2] storms. Percent deposited sediment is estimated to be 58 percent for sandy loam textures [granitic terrane] and 38 percent for loam textures [metamorphic and ultrabasic terranes]. These values will probably vary from actual eroded material because they were not calculated from eroded sediment samples. It is reasonable to assume that the percent suspended would actually be higher because this size material would be preferentially eroded from mountain sideslopes.

Sediment Modeling Of Selected Storm Events

Sediment modeling can be used to predict soil erosion under differing storm intensities. **Table D-12** shows three storm types: 1] average; 2] a 25-year return event; and 3] a 100-year return event. No additional management activities that have ocurred since 1988, such as roads and harvest units have been included in this comparison. The average precipitation year represents average conditions. The 25-year event represents a storm of the type which occurred in the Salmon River in 1972 and the 100-year event represents a storm of the type which occurred in December of 1964. R-values used for these three storm events were 19.4, 25.4 and 47.9 respectively. No other changes in the USLE model were made for this comparison.

Table D-12 displays the effects of such storms, had they occurred in 1987-88, 1992-93, 1997-98 and 2007-08 years on soil erosion. Comparing the delivered sediment for average years for 1986-87 and 2007-08 [20 years post-wildfire] shows that after 20 years of vegetative recovery, the erosion rates are only 4 percent above the pre-fire conditions.

Salmon River Model - LMP Model Comparison

The USLE proceedure used for this project was compared to the USLE proceedure used for the Land Management Plan [LMP] on the Klamath National Forest. Numerous differences in the proceedures are apparent which are due to: different personnel, different project scales and objectives, differences in the watershed boundary, road acres, sediment delivery factors, gully erosion factors, R-factors, cover factors and K values. **Table D-13** represents the comparison of the outputs for 1987-88 conditions and **Table D-14** displays the differences in the two proceedures.

Differences in predicted sediment yields appear to result primarily from the differences in delivery coefficients used in the two models. **Table D-13** also shows the Salmon River watershed surface erosion sediment yield using the same delivery coefficient as used in the LMP model. The Salmon River data is 49 percent lower than the LMP data when using the 0.05 delivery coefficient. This clearly shows that the delivery coefficients are responsible for the output differences between both USLE proceedures.

When using the same delivery coefficient for both USLE proceedures, the other differences become apparent such as differences in R-values, slope length factor [LS], cover factors, erosion rates and gully erosion factor. This then becomes more of an interpretation difference betweeen USLE users.

Table D-11. Distribution of delivered suspended and deposited sediment for 1987-88 post-wildfire conditions.

Watershed	Total Sediment	Suspended Sediment	Deposited Sediment	Percent Deposited
	yd^3			%
SALMON	105094	57904	47190	45
main stem	33519	18771	14748	44
north fork	22463	12804	9659	44
south fork	29959	16178	13781	46
Wooley	19153	10151	9002	47

Table D-12. Delivered sediment from surface erosion sources for an Average Precipitation Year, 25-Year Precipitation Year and a 100-Year Precipitation Year for site conditions as existing in 1987-88 [post-fire], 1992-93, 1997-98 and 2007-08.

	Average Precipitation		25-Year Precipitation		100-Year Precipitation	
Watershed	Total	Per Acre	Total	Per Acre	Total	Per Acre
	yd^3					
1987-88						
SALMON	105094	0.22	137673	0.29	259583	0.55
main stem	33519	0.48	43910	0.63	82792	1.19
north fork	22463	0.17	29427	0.23	55484	0.43
south fork	329959	0.16	39246	0.21	73999	0.40
Wooley	19153	0.20	25090	0.26	47308	0.50
1991-92						
SALMON	24219	0.05	31727	0.07	59821	0.12
main stem	3855	0.06	5050	0.08	9522	0.08
north fork	5292	0.04	6933	0.05	13071	0.10
south fork	11366	0.06	14889	0.08	28074	0.15
Wooley	3706	0.04	4855	0.05	9154	0.10
1997-98						
SALMON	18470	0.04	24196	0.05	45620	0.09
main stem	2454	0.04	3215	0.05	6061	0.09
north fork	4467	0.03	5852	0.04	11033	0.08
south fork	8895	0.05	11652	0.06	21971	0.12
Wooley	2654	0.03	3477	0.04	6555	0.07
2007-08						
SALMON	15665	0.03	20521	0.04	38692	0.08
main stem	1767	0.03	2315	0.03	4364	0.06
north fork	4080	0.03	5345	0.04	10078	0.08
south fork	7688	0.04	10071	0.05	18989	0.10
Wooley	2130	0.02	2790	0.03	5261	0.05

Table D-13. Comparison of Salmon River watershed model to the Forest Land Management Plan (LMP) model for 1990 conditions.

Watersheds	Undisturbed	Roads	Plantations	Hog Fire	Total Sal. R. Model	Total LMP Model	Diff. from LMP
	Varied Delivery Factors yd³						%
SALMON	6880	7392	277	1230	15779	4502	+250
Main Stem	544	778	11	271	1604	1013	+58
North Fork	1704	2049	155	61	3969	1400	+184
South Fork	2825	4318	101	898	8142	1621	+402
Wooley	1807	247	10		2064	468	+341
	0.05 Delivery Factor yd³						%
SALMON	376	1275	277	379	2307	4502	-49

Notes: The 1987 fire impacts are not used because this data was not included in the LMP database at this time. The 1987 fire acres were therefore assumed to be undisturbed or part of the Hog fire.

Table D-14. Comparison of USLE methodology used for Salmon River Watershed Project and the Forest Land Management Plan [LMP].

Factors	Salmon River Model	Forest LMP Model
Sediment Delivery Rates	0.02-0.90	0.05
R values	19	20-50
K values	0.06-0.24	0.10-0.49
LS values	10 feet	20 feet
Cover Factor [bare soil]	0.396	1.0
Roads-Granitic	9.1 tons/acre	29-91 tons/acre
Roads-Metamorphic	6.7 tons/acre	6-111 tons/acre
Surface Erosion-Granitic 0-35% slope > 35% slopes	 0.6-1.7 tons/acre 4.0-11.8 tons/acre	 4.5-17.7 tons/acre 5.0-21.5 tons/acre
Surface Erosion-Metamorphics 0-35% slopes > 35% slopes	 0.4-1.8 tons/acre 2.8-11.2 tons/acre	 4.5-17.9 tons/acre 3.7-27.3 tons/acre
Gully erosion factor	No	Yes
Inner gorge factors	Yes	No
Road acres	Actual	Estimated
Watershed acres	480,649	476,160

Note: Surface erosion values are for bare soil.

CONCLUSION

Delivered Sediment

Increases in delivered sediment from surface erosion sources above undisturbed conditions [background erosion] varied dramatically by level of watershed disturbance. **Table D-10** showed that the Salmon River watershed was 105 percent above background surface erosion sediment levels in 1986-87, 1267 percent above background in 1987-88 [post-wildfire], 215 percent above background in 1991-92 and 104 percent above background in 2007-08. It will take 20 post-wildfire years for sediment levels derived from surface erosion to lower to pre-wildfire rates.

The primary management related sediment source was shown to be roads. They occupy 1 percent of the watershed and produce 49 percent of the sediment where wildfires are not a factor, such as in 1986-87.

The primary natural sediment source is wildfires. The 1987 wildfires, which occupy 23 percent of the watershed, produced 87 percent of the sediment in 1987-88. This is a 1157 percent increase above existing road related erosion values.

Inner Gorge

The inner gorge was shown to be a major source of mobilized and delivered sediment for undisturbed conditions [96%], plantations [44%] and wildfire [43%]. This is due to short delivery distances and shorter slope lengths.

Wildfire

Wildfires were shown to be the single most important contributor of surface erosion derived sediment in forest watersheds. Quick revegetation in the first 2 years is critical to reduce sediment production from this soil erosion source.

Further Study

Delivery coefficients need field verification inorder to increase the accuracy of USLE or the future WEPP sediment predictions. Road related surface erosion estimates are also lacking field data inorder to verify the accuracy of USLE road erosion predictions.

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APPENDIX D-1

Surface Erosion Data Summary

Table D1-1. Delivered sediment from surface erosion sources for each disturbance group for 1987-88 post-wildfire conditions by subwatershed.

Watersheds	Undisturbed	Roads	Plantations	Hog Fire not burned in 1987	Hog Fire reburned 1987	1987 Fires	Total	
	yd^3	yd^3	yd^3	yd^3	yd^3	yd^3	yd^3	yd^3/acre
SALMON	5386	7392	277	480	36422	55107	105,094	0.22
Main Stem	299	778	11	205	17607	14619	33,519	0.48
North Fork	1615	2049	155	30	13711	4903	22,463	0.17
South Fork	2146	4318	101	245	5104	18045	29,959	0.16
Wooley	1356	247	10	-	-	17540	19,153	0.20
Butler	92	23	0	-	-	-	121	0.03
Crapo	0	137	-	6	14927	1608	16,678	1.39
Duncan	17	50	1	-	-	-	67	0.06
Lewis	0	2	-	17	-	-	19	0.01
Lower Main Stem	75	349	1	37	211	6475	7,072	0.40
Merrill	29	98	9	-	-	-	136	0.04
Monte	27	53	1	-	-	-	81	0.06
Morehouse	0	-	-	-	2095	1971	4,066	0.69
Nordheimer	0	62	-	139	0	-	201	0.01
Somes	58	6	0	-	-	-	64	0.02

Table D1-1. Delivered sediment from surface erosion sources for each disturbance group for 1987-88 post-wildfire conditions by subwatershed

Watersheds	Undisturbed	Roads	Plantations	Hog Fire not burned in 1987	Hog Fire reburned 1987	1987 Fires	Total	
	yd^3	yd^3	yd^3	yd^3	yd^3	yd^3	yd^3	yd^3/acre
Big	-	52	-	-	7271	37	7,360	4.39
Eddy	47	197	0	-	-	-	244	0.05
Headw. N. Fork	610	31	1	-	-	1690	2,333	0.06
Jessups	17	125	2	0	0	-	144	0.07
Kanaka	0	19	-	-	59	1494	1,572	3.39
Little N. Fork	337	201	78	-	-	205	821	0.04
Lower N. Fork	267	686	30	30	2664	2254	5,931	0.22
Olsen	0	10	-	0	3551	180	3,741	4.40
Russian	245	475	34	-	-	-	754	0.03
Whites	92	252	9	-	-	-	353	0.04
Black	29	339	2	0	1	3378	3,749	0.40
Cecil	43	155	2	-	-	16	216	0.06
Crawford	107	315	16	-	-	19	457	0.05
East Fork	562	1042	66	-	-	-	1,670	0.04
French	0	-	-	-	-	414	414	0.24
Indian	0	143	-	0	4	2622	2,769	0.84
Knownothing	64	447	2	0	391	4013	4,917	0.34
Lower S. Fork	126	612	2	2	1457	2774	4,974	0.28
Matthews	58	170	1	-	-	14	243	0.05
McNeal	7	138	0	8	0	-	154	0.07
Methodist	61	267	1	-	-	1946	2,275	0.28
Negro	0	159	0	0	3252	0	3,412	1.30
Plummer	119	-	-	-	-	351	470	0.05
St. Claire	29	109	1	-	-	2466	2,604	0.38
Upper S. Fork	911	421	8	-	-	0	1,341	0.03

Table D1-1. Delivered sediment from surface erosion sources for each disturbance group for 1987-88 post-wildfire conditions by subwatershed

Watersheds	Undisturbed	Roads	Plantations	Hog Fire not burned in 1987	Hog Fire reburned 1987	1987 Fires	Total	
	yd^3	yd^3	yd^3	yd^3	yd^3	yd^3	yd^3	yd^3/acre
Bridge	241	53	1	-	-	-	295	0.03
Hancock	44	-	-	-	-	2811	2,855	0.27
Haypress	140	111	6	-	-	1	257	0.05
Headw. Wooley	329	-	-	-	-	369	698	0.03
Lower Wooley	331	8	4	-	-	4771	5,114	0.35
N. Fork Wooley	271	-	-	-	-	-	271	0.02
Rock	0	-	-	-	-	3019	3,019	0.55
Steinacher	1	75	-	-	-	6569	6,645	0.72
Headw. LNF	41	29	1	-	-	6	77	0.01
Lower LNF	110	155	57	-	-	430	752	0.15
Specimen	81	18	21	-	-	2	121	0.02
L+R Hand Forks	105	-	-	-	-	-	105	0.02
Main Russian	149	253	1	-	-	-	403	0.03
South Russian	97	222	33	-	-	-	352	0.03

Table D1-1. Delivered sediment from surface erosion sources for each disturbance group for 1987-88 post-wildfire conditions by subwatershed

Watersheds	Undisturbed	Roads	Plantations	Hog Fire not burned in 1987	Hog Fire reburned 1987	1987 Fires	Total	
	yd^3	yd^3	yd^3	yd^3	yd^3	yd^3	yd^3	yd^3/acre
Main E. Fork	272	374	4	-	-	-	650	0.03
Shadow	79	206	19	-	-	-	304	0.05
Six Mile	56	70	1	-	-	-	127	0.03
Taylor	155	392	41	-	-	-	588	0.05
E. Fork Knownothing	35	147	1	-	-	1795	1,978	0.31
Lower Knownothing	10	71	0	-	-	492	573	0.35
W. Fork Knownothing	19	228	1	0	-	1758	2,006	0.31
Blindhorse	128	34	1	-	-	-	163	0.05
Garden	64	1	0	-	-	-	65	0.02
Headw. South Fork	403	5	-	-	-	-	408	0.02
Main Upper S. Fork	187	381	7	-	-	0	233	0.02
Rush	130	-	-	-	-	-	130	0.02

APPENDIX E

Landslide Inventory and Sediment Production

for

Little North Fork and Negro Creek Watersheds

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ACKNOWLEDGEMENTS

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INTRODUCTION

Detailed field-based landslide inventories were undertaken in the Little North Fork and Negro Creek watersheds during the summer of 1991. The objectives of the two inventories were to provide accurate empirical data on landslide type, size, morphology, age, and distribution among geomorphic terrane types. Field inventory along with air photo survey of these watersheds was conducted to provide measured sediment production and delivery rates, to determine the occurrence of active landslides caused by natural flood events, and to evaluate rates of landsliding due to disturbances such as fire, roads, and timber harvest. The landslide production rates evaluated for different geomorphic terrane types, disturbance classes, and major flood events were used to develop landslide coefficients for the Salmon Basin Sediment Model.

STUDY AREAS AND LAND STATUS

Little North Fork and Negro Creek watersheds were selected for field inventory because they contain a representative sample of geologic, geomorphic, natural, as well as management-related characteristics that are shared by the other watersheds in the Salmon River Basin. Numerous studies of landslides in the Little North Fork Watershed during the 1970's have provided a wealth of information [Pillsbury 1976; Hicks, 1973 Kojan and others 1972; and Hicks and others 1973].

Little North Fork

Little North Fork is a 20,801 acre tributary to the North Fork Salmon River **[Figure E-1]**. Little North Fork is divided into four sub-basins: [a] Headwaters [5644 acres], [b] Left and Right Hand Fork of Uncles Creek [5021 acres], [c] Specimen Creek [5015 acres], and [d] Lower Little North Fork [5121 acres]. Current land status is detailed as follows **[Table E-1]**. Sixty-six percent of the land area is included in the Marble Mountains Wilderness Area, and 32.5 acres of land [less than 1% of the total land area] is privately owned. The remaining land is managed national forest land. Currently, the watershed contains 17 miles of road, [less than 1 % of the total land area or 82 acres of disturbed land from the top of cut to the toe of the fill], and 1070 acres of plantations [5.1% of the total land area]. The watershed contains 57.02 miles of stream.

Negro Creek

Negro Creek is a 2617 acre watershed that drains into the South Fork Salmon River **[Figure E-1]**. Current land status is summarized below **[Table E-1]**. The watershed contains 260 acres of private land [10% of the land area]. The remainder is national forest land. The watershed currently has 17 miles of road, comprising 3.1% of the total land area [82 acres of disturbed land from the top of cut to the toe of the fill]. Based on air photo reconnaissance, the watershed contained approximately 316 acres [12% of the watershed] of plantations in 1975. Approximately 59 acres that were burned in the Hog fire of 1977 were stocked with trees from 1978 to 1979. Following the 1987 fires, 827 acres were planted from 1988 to 1991. Non-stocked areas, which include private and unsuitable land, comprise 254 acres. The watershed contains 6.89 miles of stream.

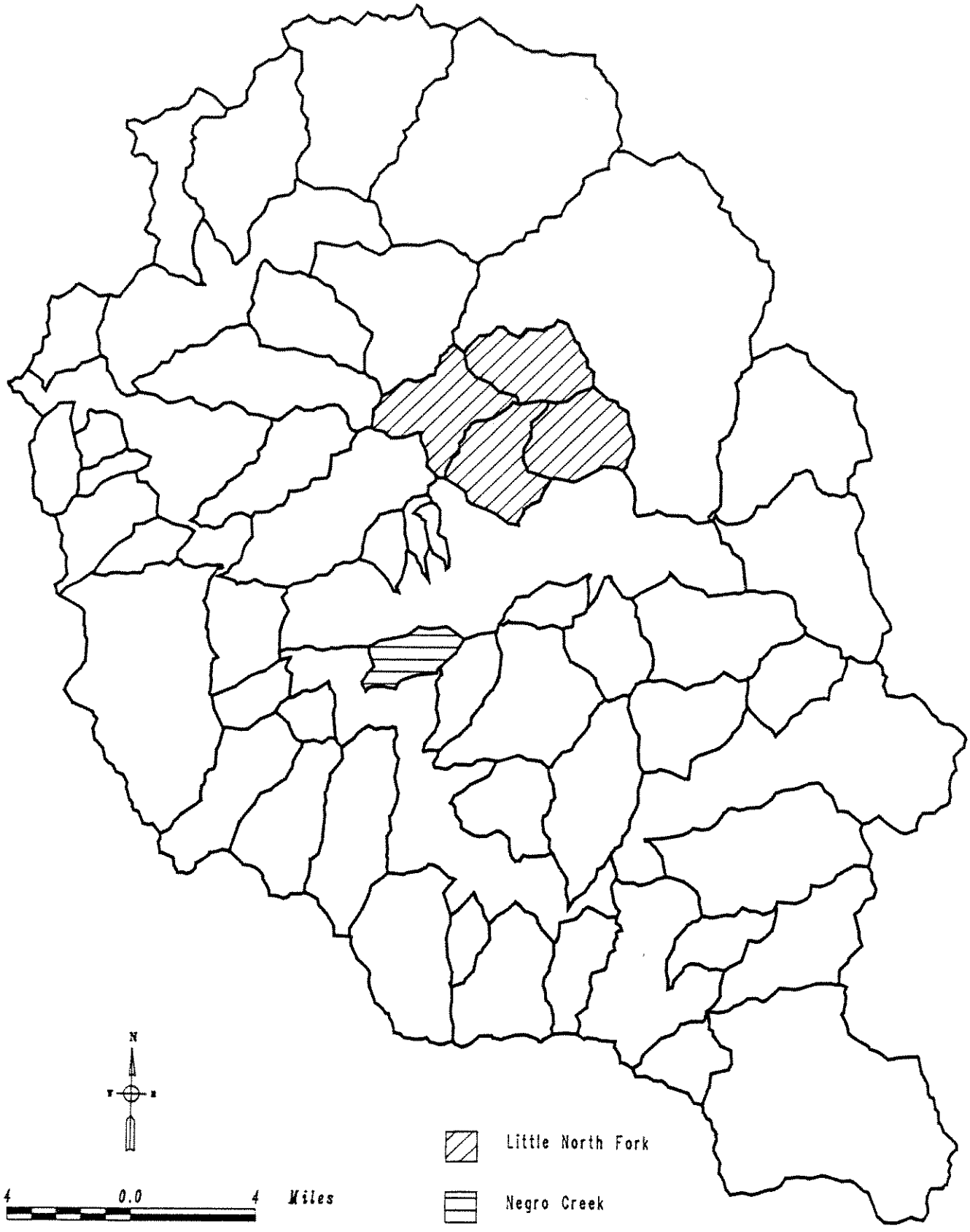


Figure E-1. Location map for Little North Fork and Negro Creek Watersheds.

Table E-1. Areas classified by land status as of 1991.

Little North Fork, [20,801 acres]

Land Status	Acres	% of Total Area
Wilderness	13635	65.6
Forested Lands ●	7133.5	34.3
Private Land	32.5	0.2
Road Prism ●●	82	0.4
Plantations Pre-1975 1975 and younger	1070 794 276	5.1 3.8 1.3
Streams ●●●	207	1.0

Negro Creek, [2617 acres]

Land Status	Acres	% of Total Area
Private Land	260	9.9
Forested Lands ●	2357	90.0
Road Prism ●●	82	3.1
Plantations 1975 - 1981 1988 and younger Non-Stocked Areas	1140 59 827 254	43.6 2.3 31.6 9.7
Streams ●●●	12.5	0.48

● Non-wilderness, national forest land.

●● Road prism is calculated as follows: [Road Length X 1.05] X Basin Average Road Width]]/43560 sq. feet/acre. Digitized miles of road were increased by a factor of 5% to compensate for the difference between field-measured road miles and digitized road lengths. Basin average road width used was 40 feet. An additional correction factor was used at road intersections.

●●● Total length of perennial and intermittent blue-line streams digitized off of USGS 7.5 minute quadrangle topographic maps.

Little North Fork: Stream length equals 57 miles or 301,077 feet. Assumed an average stream width of 30 feet.

Negro Creek: Stream length equals 6.89 miles or 36,399 feet. Assumed an average stream width of 15 feet.

METHODS

Summary

The landslide inventory for Little North Fork and Negro Creek watersheds covers the period 1944-1988. Both field inventory and air photo interpretative methods were used to document landslide occurrence and evaluate qualitative and quantitative aspects of landslides. Field inventory was conducted between June and September 1991. Air photos used in this study are listed below in **Table E-2**. The landslide data sheet used to collect information on landslides measured in the field is illustrated in **Figure E-2**.

A total of 373 landslides were inventoried in Little North Fork. Of these, 158 [42%] were measured in the field, 113 [30%] were interpreted from air photos, and the remaining 102 landslides [27%] were photo interpreted in a previous study [Pillsbury 1976; Rice and Pillsbury, 1982]. A total of 119 landslides were inventoried from Negro Creek. All were measured and evaluated in the field.

Table E-2. Aerial photography used in the landslide inventories of Little North Fork and Negro Creek watersheds.

Year	Agency	Type	Symbol/ID#	Scale
1944 a,b	U.S. Forest Service	B&W	DDD	1:20,000
1955 a,b	U.S. Forest Service & Calf. Div. of Highways	B&W	DDC	1:20,000
1964 a,b	U.S. Forest Service	B&W	ENU	1:15,840
1965 a,b	Soil Conservation Service	B&W	DDC	1:20,000
1971 a,b	U.S Forest Service	Color	EXW	1:15,840
1972 a	U.S. Forest Service	Color	K102	1:10,000
1975 a,b	U.S. Forest Service	Color	KL-05	1:15,840
1980 a,b	U.S. Forest Service	Color	625050	1:12,000
1982 b	U.S. Forest Service Special flight Hog Fire	Color	615054	1:15,840
1986 a,b	U.S. Forest Service	Color	615050	1:15,840
1988 a,b	U.S. Forest Service	CIR	715160	1:15,840

a photos used in Little North Fork landslide inventory
b photos used in Negro Creek landslide inventory

Figure E-2. Landslide data sheet used in the field inventory of Little North Fork and Negro Creek watersheds.

LANDSLIDE DATA SHEET--KLAMATH NATIONAL FOREST [Rev. 7-15-91]

1. **Date**_____ 2. **Quad No.**_____ 3. **Slide#**_____ 4. **Recorder**_____
5. **Watershed**_____ **Subwatershed**_____
6. **Slide Name**_____
7. **Type of Landslide-** Slump, Earth Flow, Block Glide, Debris Slide, Debris Flow, Debris Avalanche, Debris Torrent, Channel Bank Debris Slide
_____
8. **Average Dimensions [feet]:** L_____ W_____ D_____
*8b.Sketch Plan Map and Profile View on back of form w/volume calculations
9. **Area Mobilized [sq.ft.]:** **Slope Area**_____ **Map Area**_____
10. **No. of Subareas Measured**_____. See field map for details: **YES**____ **NO**___
11. **Volume of Material Mobilized** [cu. yds.] _____
12. **Volume Delivered to Channel** [cu. yds.] _____ %_____
13. **Volume Remaining in Slide Site** [cu. yds.] _____ %_____
14. **Volume Stored on Slope Outside of Slide Site** [cu.yds.] _____ %_____
15. **Elevation-** Maximum_____ Minimum_____.
16. **Aspect** -North; South; East; West; and Azimuth_____ degrees **T** or **M**.
17. **Slope Gradient** [%]-Slide_____ Above Slide_____ Below Slide_____
18. **Bedrock Type-** Granitic; Metasedimentary (chert, argillite, marble); Metavolcanic; Ultramafic [serpentinite, peridotite]_____
19a **Failing Material-** Bedrock; Slope Colluvium; Landslide Deposits; Glacial Deposits; Stream Terrace; Alluvium; Other_____
19b **Size Class**; % clay_____ % silt_____ % sand_____ % gravel_____
% cobbles_____ and boulders_____ 19c **Color**_____ 19d. **USCS:**_____
20. **Cause**: *NATURAL*; *HARVEST* [within tractor unit; related to tractor road] [within skyline unit; related to yarding corridor]; *ROAD* [cut failure, fill failure, both]; *LANDING* [cut failure, fill failure, both]; *MINING* [cut failure, fill failure, both]; ***FIRE*** ; ***STREAM UNDERCUTTING***; ***COMBINATION:***
_____
21. **Field Estimate of Age [date]:**_____
22. **Slope Hydrology:** ***SPRINGS:*** Present [flow_____GPM]; Absent. ***WATER ASSOCIATED PLANTS*** [horsetail, alder, willow] Present_____ Absent_____
23. **Geomorphic Setting-** Toe of dormant landslide, Inner Gorge, etc._____
_____
24. **Influence of Bedrock Structure-**_____
25. **Adverse Effects on Watershed or Structures-** VH___ HI__ MED_____ LO_____
26. **Adverse Effects on** - VH___ HI__ MED_____ LO_____
27. **Downstream Channel Effects-** ***AREA OF RIPARIAN VEGETATION DAMAGED BY SLIDE***
CHANNEL SCOUR [ft] L_____ W_____ D_____ Area [a]_____ Vol._____
CHANNEL DEPOSITION [ft] L_____ W_____ D_____ Area [b]_____ Vol._____
CHANNEL SCOUR/DEPOSITION [ft] L_____ W_____ Area [c]_____
Total area damaged: a+b+c=_____
28. **Stabilization Potential** [costs and effectiveness]: **LOW, MEDIUM, HIGH**
_____
29. **Detailed Information Available-**_____
30. **Comments:**_____
_____
31. **Date of Activation-** _____ Photo Year First Appears_____
32. **Topographic Map with Location Plotted....**Attach with record or daily notes
33. **Aerial Photo Overlay Sheets**_____
34. **Field Photo: Roll #**_____ **Exp.**_____ **View**_____
Sources of data above: [O]cular, [I]nstruments, [R]emote, [M]ap, [L]iterature.
Clay=[<0.075mm]; Silt=[-No.200, 0.075mm]; Sand=[#4-#200, 4.75-0.075mm]; Gravel [+No.4-3 in., 4.75mm-75mm];Cobbles & Boulders [>75mm, > 3 in.]

PREVIOUS WORK

Little North Fork

Three reports have been written by U. S. Forest Service personnel, assessing the environmental damage from the 1972 storm events in the Little North Fork Watershed. The reports are listed below:

Kojan, G., Leger, P., Charter, W. and Dougharty, R. July, 1972. Region 5, Pacific Southwest Region, U.S. Forest Service, Task Force on The Little North Fork Drainage, Storm Damage and Environmental Problems.

Hicks, B.G. February, 1973. Region 5, Pacific Southwest Region, U.S. Forest Service, Engineering Geologic Report, Stability of the Little North Fork, Salmon River Study Area, Klamath National Forest.

Hicks, B.G., Bush, G., Faust, B., Lanse, R., Gale, B., Ryce, M., Falkner, T. and Barrington, J. May, 1973. Little North Fork Study Area Report, Salmon River Ranger District, Klamath National Forest.

An evaluation of debris flows in harvest units in Little North Fork, triggered by the two storm events in 1972, was conducted by Norman Pillsbury as part of his Ph.D. dissertation [Pillsbury, 1976]. Pillsbury studied debris flows in six clear-cut units in extremely dissected and weathered granitic terrane. Twenty-one landslides were measured in the field and area-volume relationships derived from these debris flows were used to determine the sediment delivery from 102 landslides in the study area. Major findings of Pillsbury used in this report are summarized below.

> The two storm events in the winter of 1972 triggered 102 debris avalanches in six clear-cut units encompassing a total area of 301.5 acres [122 ha]. The debris avalanches scarred 8.2 acres [3.31 ha] of land and delivered 42,306 yds^3 [32,344 cubic meters] of sediment to stream channels [Pillsbury, 1976; Rice and Pillsbury, 1982:304].

The forest geologic data base as of 1991, identified a total of 37 active landslides in Little North Fork encompassing 112 acres. The landslides include slumps as well as debris flows. This study inventoried 373 landslides [102 are from Pillsbury, 1976], encompassing a total of 103.6 acres.

Negro Creek

The forest geologic data base as of 1991 identified nine active landslides in Negro Creek watershed encompassing 11.4 acres. Field investigations had previously been conducted on two of these landslides, the Zane Landslide [#7008] and Negro Creek Landslide [#81050].

This study inventoried 119 landslides encompassing 21.1 acres.

TOPOGRAPHY

Little North Fork

Little North Fork Watershed has a topographic relief of 5323 feet. The lowest elevation is 2000 feet at Ahlgren Ranch; the highest elevation is 7322 feet at English Peak Lookout. An elevation range summary is presented in **Table E-3.** Ridge crests bounding the watershed to the North and East are part of the Marble Mountains; Yellow Jacket Ridge forms the western boundary of the watershed. Topography is moderately steep to very steep with the majority of slopes in excess of 65% **[Table E-4]**. Maximum slope steepness approaches 140%. All directions of aspect are represented.

Negro Creek

Negro Creek Watershed has a topographic relief of 4053 feet with elevations ranging from 1360 feet at the mouth of Negro Creek, to 5413 on the south flank of Blue Ridge. An elevation range summary is presented in **Table E-3**. The northern ridge boundary of the watershed is named Blue Ridge; the southern ridge boundary is unnamed. Topography varies from steep to gentle with the majority of slopes in the range or 35 to 65% **[Table E-4]**. Though all aspects are represented in the watershed, north-facing slopes are the least common.

Table E-3. Elevation range summaries for Little North Fork and Negro Creek watersheds. Data is from the forest database. Data source is USGS digital terrain data.

Little North Fork

Elevation Range	Acres	Percent Area
1500-2000	9	< 1
2000-2500	585	3
2500-3000	1123	5
3000-3500	1715	8
3500-4000	2441	12
4000-4500	2963	14
4500-5000	3072	15
5000-5500	3034	15
5500-6000	3150	15
6000-6500	2032	10
6500-7000	603	3
7000-7500	75	< 1
Total	20802	100

Negro Creek

Elevation Range	Acres	Percent Area
1000-1500	6	<1
1500-2000	138	5
2000-2500	322	12
2500-3000	446	17
3000-3500	625	24
3500-4000	485	19
4000-4500	418	16
4500-5000	147	6
5000-5500	29	1
Total	2616	100

Table E-4. Slope per cent summary for Little North Fork and Negro Creek watersheds. Data is compiled from the Klamath National Forest slope map, manually generated.

Little North Fork

Slope	Percent Range	Acres	Percent Area
High	65% and greater	12153	58
Medium	35% - 65%	6874	33
Low	0 - 35%	1773	9
Total		20800	100

Negro Creek

Slope	Percent Range	Acres	Percent Area
High	65% and greater	683	26
Medium	35% - 65%	1301	50
Low	0% - 35%	632	24
Total		2616	100

GEOLOGY AND GEOMORPHOLOGY

Little North Fork

The Little North Fork Watershed is underlain by metamorphic and plutonic rocks of the Western Paleozoic and Triassic Belt of the Klamath Mountains Geologic Province [Irwin, 1966]. The belt is one of four eastward-dipping imbricate thrust sheets that comprise the Klamath Mountains Province. The four belts are named: the Eastern Klamath, Central Metamorphic, Western Paleozoic and Triassic, and the Western Jurassic **[Figure E-3]**. The belts are arcuate, trend generally north-south, and become progressively younger in age from east to west. All Western Paleozoic and Triassic Belt terranes were deformed and overprinted by metamorphism during their accretion. The mid-Jurassic and younger plutons were intruded before, during, and after terrane amalgamation and accretion to North America. The Western Paleozic and Triassic Belt has been subdivided into three geologic terranes: the North Fork, Hayfork, and Rattlesnake Creek terranes. The metamorphic rocks in the Little North Fork watershed have been considered by various workers as similar to the Hayfork terrane, [Donato and others; 1982; 1983] and the North Fork Terrane [Ernst, 1990; Ando, 1983]. The rock units of the uppermost Hayfork and North Fork terranes are believed to constitute the fragments of a single, evolving oceanic volcanic arc complex [Ernst 1990].

The metamorphic rocks in the Little North Fork Watershed consist of greenschist-facies metasedimentary, metavolcaniclastic, and metavolcanic rocks **[Figure E-4]**. The metasedimentary rocks include metachert, metaclastic rocks, and minor marble. Protolith rocks include argillite, micrograywakes, calcareous quartzo-feldspathic sandstone, limestone, and chert [Donato, 1982; Seyfert 1965; Ernst, 1990]. The metamorphic rocks display a high degree of structural coherency and lateral continuity, a strong schistocity, and locally preserve evidence of primary bedding features. Metavolcanic rocks include metabasalts and metadiabases informally named the Yellow Dog Greenstone [Ernst,1990]. The metavolcanic rocks include massive flows and rare pillow basalts. Original interstratification and tight folding are evident from interdigitating outcrop patterns of the metasediments

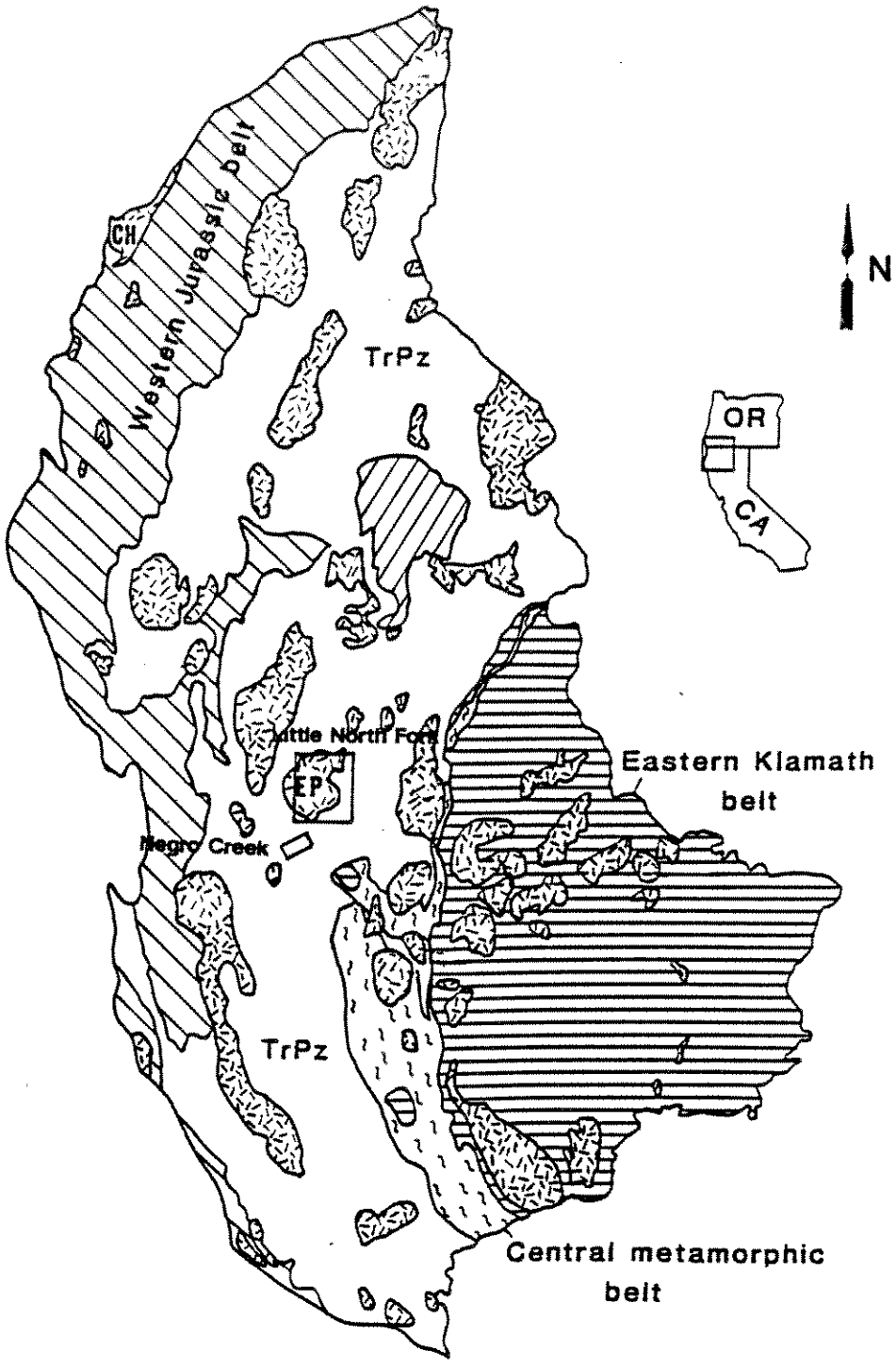


Figure E-3. Simplified geologic map of the Klamath Mountain province in California and Oregon showing the four lithotectonic belts, and granitoid plutons. TrPz is the Western Paleozoic and Triassic belt; for simplicity, subterranes of this belt are not shown. EP is the English Peak batholith.Generalized study areas of Little North Fork and Negro Creek are outlined. Figure modified after Irwin, 1985.

Little North Fork

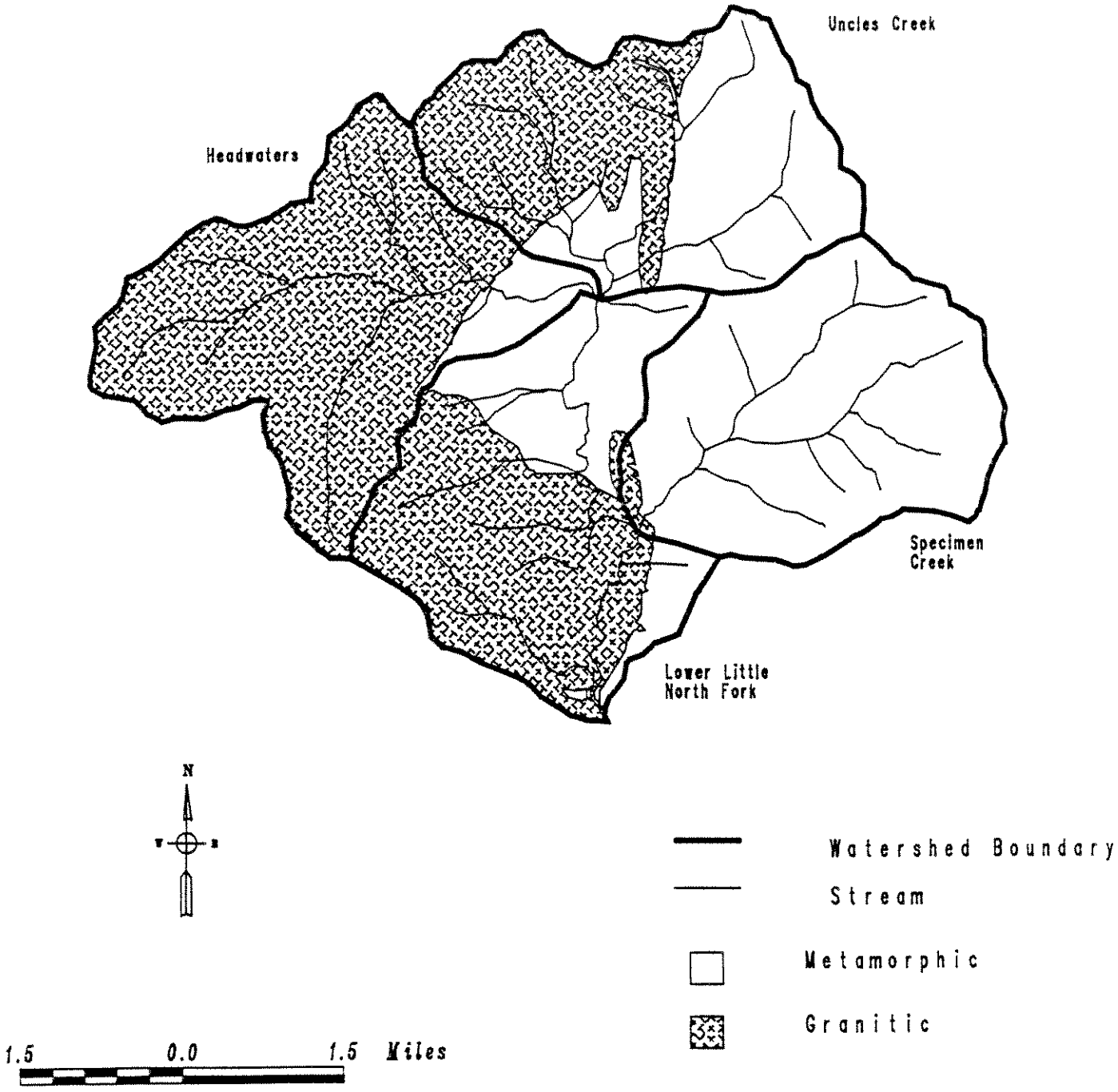


Figure E-4. Generalized geologic map of the Little North Fork Watershed. "Granitic rocks" include the rocks of the English Peak batholith which range in composition from gabbro to granite. Metamorphic rocks include rocks of the North Fork terrane of Ando (1983) or Sawyers Bar terrane of Ernst (1990). Metamorphic rocks include metasedimentary and metavolcanic lithologies. Data is from the forest geologic data base, source: Wagner and Saucedo: 1987.

and metavolcanic units. The tectonic setting of deposition of the sediments comprising the metasedimentary units are thought to be part of a distal turbidite-fan complex. The sediments were interlayered with massive to pillowed flows and intrusions of oceanic basalt. Previous workers have included the metasedimentary and metavolcanic rocks of the Little North Fork area in the Hayfork terrane [Donato, 1987; Mortimer, 1985, among others]. Recent mapping of the Sawyers Bar area by Ernst in 1979-1988, indicates that despite debatable tectonic correlations, the Yellow Dog greenstones and associated metasediments are equivalent to the North Fork Terrane to the south, as described by Ando and others [1983]. Based on his work, Ernst informally refers to the rock of the Sawyers Bar area as the Sawyers Bar terrane.

Plutonic rocks exposed in the watershed are part of the English Peak pluton studied and described by Seyfert [1965]. The English Peak pluton intruded the metamorphic country rock in the Jurassic Period, approximately 157 million years ago [Lanphere and others, 1968]. The batholith has an internal intrusive contact that separates an early mafic intrusive phase in the southeast part of the watershed from the rest of the pluton. The mafic phase ranges from gabbro to granodiorite in composition; the silicic portion of the rest of the pluton ranges from diorite to granite. **Table E-5** shows a summary of acres of major bedrock units in the Little North Fork watershed.

Glacial erosion and deposition is evident at upper elevations of the Little North Fork watershed, particularly on north-facing slopes. Prominent U-shaped valleys are present in the headwaters of Devil's Canyon, Dollar Creek, and the main stem of the Little North Fork. Glacio-fluvial deposits occur all along the east-flowing portion of the Little North Fork to Snowslide Gulch. These deposits are composed of rounded granitic cobbles, boulders, and gravels. The 1964 flood event created many exposures of these deposits resulting from debris slides and channel scour.

Negro Creek

The Negro Creek Watershed is underlain by metamorphic rocks of the Western Paleozoic and Triassic Belt [Irwin, 1966] **[Figure E-3]**. The metamorphic rocks have been considered as belonging to the North Fork Terrane [Ando, 1979; Ando and others, 1983]. The North Fork terrane represents a tectonically disrupted ophiolitic sequence and associated volcanic and sedimentary rocks of oceanic affinity.

Metamorphic rock types in the Negro Creek Watershed include metamorphosed rocks of an ophiolite sequence and associated metamorphosed volcanic and sedimentary rocks **[Figure E-5]**. An ophiolite is geologic term used to describe a complete sequence of rock types form the oceanic lithosphere. The typical structural sequence, in succession from bottom to top is peridotite, gabbro, diabase, and basalt. Often, only fragments of an ophiolite are preserved. In Negro Creek watershed, ophiolitic rock types include peridotite [hartzburgite], gabbro, diabase, pillow basalts, and serpentinite. Contacts between these rock types are typically marked by bodies of sheared serpentinite. Other volcanic and sedimentary rocks include metamorphosed basalt [greenstone], mafic volcaniclastic rocks, bedded chert, argillite, and limestone. **Table E-5** shows a summary of acres of the various rock types found in Negro Creek watershed.

Much of the watershed is comprised of large, complex, multi-lobed landslide deposits. The headwall of the massive slump-earthflow deposits is Blue Ridge. The term "head wall" as used here, refers to the main scarp of the landslide caused by the movement of the slide material away from the undisturbed ground. The terrain displays bench-slope and hummocky topography typical of earthflows. Several ponds are located on bench slopes of the old landslide deposits, and indicate high groundwater levels, or zones of perched water tables. Springs and seeps are common as well. The age of the oldest dormant landslide deposits is not known; the deposits may be hundreds to several thousands of years old. Earthflow activity continues to shape the landscape today.

Table E-5. Bedrock Summary for Little North Fork and Negro Creek watersheds. Data is from the forest geologic data base, source: Wagner and Saucedo: 1987.

Little North Fork

Watershed	Bedrock Type	Acres	Percent Area
LNS	Granite Metamorphic Gabbro	10748 10036 17	52 48 < 1
LNSHLS	Granitic Metamorphic	5136 509	91 9
LNSLOW	Gabbro Granitic Metamorphic	17 3203 1901	< 1 63 37
LNSSPE	Granitic Metamorphic	85 4930	2 98
LNSUNC	Granitic Metamorphic	2324 2697	46 54

Negro Creek

Watershed	Bedrock Type	Acres	Percent Area
SFSNEG	Ultramafic Metamorphic Gabbro Limestone	1681 891 10 36	64 34 <1 1

* Bedrock type values are from Klamath National Forest Land Management Planning Data Base, data source Wagner and Saucedo, 1987.

Watershed Designations:
LNS - Little North Fork
HLS - Headwaters Sub-basin
LOW - Lower Sub-basin
SPE - Specimen Creek Sub-basin
UNC - Uncles Creek Sub-basin

SFSNEG - Negro Creek

Negro Creek

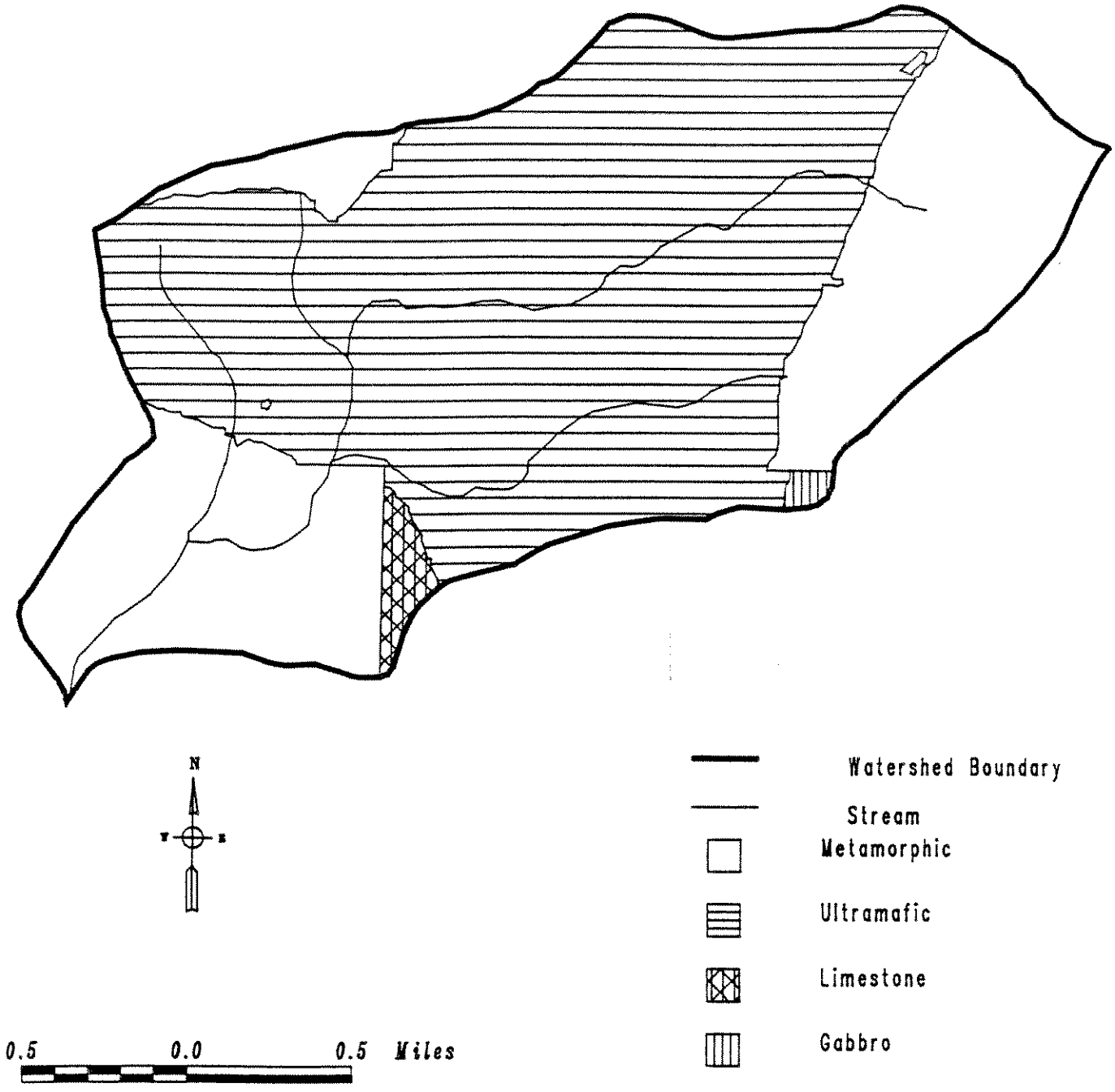


Figure E-5. Generalized geologic map of Negro Creek Watershed. Metamorphic rocks include: undifferentiated metamorphosed basalt, diabase and volcaniclastics, bedded chert, and argillite. Undifferentiated ultramafic rocks include peridotite and serpentinite. Data is from the forest geologic data base, source: Wagner and Saucedo: 1987.

MINING HISTORY

Little North Fork

There are numerous unpatented placer mineral claims located along various streams in the watershed. The primary mineral occurrence is gold. Specimen Gulch is an area of recent mining activity. Some of these mining activities in Specimen Gulch are associated with considerable removal of overburden and alluvium which is evident on the 1986 air photos.

Negro Creek

There are numerous placer and lode gold mineral claims located along Negro Creek and its tributaries. Mining activity areas are mainly in the vicinity of Godfrey Ranch. Placer mining appears to have been most active at the mouth of Negro Creek and in Sections 17 and 19, T39N, R12W, MDBM. Tailings deposits composed of cobbles and boulder are piled up and evidence of ditch lines are still present.

SOILS

Little North Fork

Soils within the Little North Fork drainage formed primarily from granitic and metamorphic rocks. Soils formed from granitic rocks on mountain sideslopes are predominately deep to very deep [40 to 60+ inches] sandy loams [Dome series] and loams [Holland series]. Shallow [less than 20 inches] gravelly sandy loam soils associated with rock outcrop occur on ridges and some south aspects. In the higher elevations, very bouldery sandy loam soils occur on glacial moraines. Soils formed from granitic rocks usually have high to very high erosion hazard ratings and are moderately productive.

Soils formed from metamorphic rocks on mountain sideslopes are predominately moderately deep to deep [20-40 inches] very gravelly loams [Neuns and Kindig series]. Soils formed in landslide deposits are very deep [60+ inches] gravelly loams [Pishpishee [T] series]. Shallow extremely gravelly loam soils [Deadwood series] associated with rock outcrops occur on south aspects and ridges. In the higher elevations, very bouldery/cobbly sandy loam soils [Isinglass [T] series] occur on glacial moraines. Soils formed from metamorphic rocks usually have high erosion hazard ratings and are moderately to highly productive.

Negro Creek

Soils that have developed from metamorphic rocks with southwest to southeast aspects are generally shallow [less than 20 inches], very gravelly loam soils represented by the Deadwood series. Soils formed on mountain sideslopes with northwest to northeast aspects are generally moderately deep [20-40 inches] very gravelly loam soils represented by Neun and Marpa series and may include some deep, [40 to 60 inches] very gravelly loam soils represented by Kindig, Deadtown [T] and Casabonne series. Soils on dormant landslide features are usually very deep [greater than 60 inches] gravelly loam to gravelly clay loam soils represented by Pishpishee [T] and Forks [T] series. Soils that have developed from serpentinitic rocks on mountain sideslopes include: shallow gravelly loam soils represented by the Johnsoncreek [T] series; moderately deep gravelly loam soils represented by the Blackcreek [T] and Blueridge [T] series; and deep loam soils represented by Yoakumville [T] series.

VEGETATION

Little North Fork

Dominant timber types in the watershed are mixed conifers, softwoods and hardwoods **[Table E-6]**. Conifers represented include ponderosa pine, sugar pine, douglas fir, and incense cedar. Above roughly 4800 feet in elevation, stands are composed largely of true-fir. Understory vegetation other than young conifers, consists of tan oak, chinquapin, black oak, deebrush, yew, madrone,and live oak.

South- and west-facing slopes are generally composed of scattered clumps of mixed conifer stands, noncommercial timber [hardwoods and softwoods], rock outcrop and talus slopes. The largest volume of commercial timber stands are located on granitic lands. Timber stands are more scattered on metamorphic lands, with the highest volumes on north-, northwest-, and east-facing slopes. Hardwood vegetation can be extremely dense on north- and east-facing slopes, under an open canopy of conifers.

Table E-6. Little North Fork vegatation summary. Data is from the forest data base, vegetation layer.

Vegetation Type	Area, acres	% of Area
Douglas-Fir, Mixed Conifer	7091	34
True-fir, Hemlock	9202	44
Barren, Non-commercial		
Hardwoods, softwoods	939	5
Brush, Commercial Hardwoods, Nonstocked	2474	12
Meadows	24	<1
Plantations	1070	5

Negro Creek

Timber types present in the watershed prior to the 1977 Hog fire included mixed conifer and douglas fir stands, a small amount of softwood species [knob-coned pine], and hardwoods. Hardwoods, typically tan oak, black oak, chinquapin and live oak were dominant on southerly aspects. Mixed conifers were dominant on north-, and west-facing exposures.

Today, much of the watershed exists as plantations [34%], restocked with trees following the fires of 1987 **[Table E-7]**. The remainder of the watershed is comprised of the following timber types: douglas fir and mixed conifer stands, softwoods, hardwoods, and brush. Significant amounts of land are barren.

Table E-7. Vegetation summary of Negro Creek watershed, post 1987 fire condition. Data is from the forest data base, vegetation layer.

Vegetation Type	Area, acres	% of Area
Douglas-Fir, Mixed Conifer	953	36
True-fir, Hemlock	15	<1
Barren, Non-commercial		
Hardwoods, softwoods	409	16
Brush, Commercial Hardwoods, Nonstocked	324	12
Meadows	30	1
Plantations	885	34

HYDROLOGY, AND DRAINAGE BASIN MORPHOLOGY

Drainage basin parameters were compiled from a 7.5' quadrangle map base. Data on stream length, drainage basin area, and basin perimeter was obtained from the watershed and stream layer of the forest GIS database. Drainage basin characteristics of the Little North Fork watershed were previously compiled in Hicks and others [1973], and Pillsbury [1976], using a 15' quadrangle map base.

Little North Fork

The Little North Fork drainage basin is 32.5 mi.^{2} in area, has a stream length of 57.02 miles and a drainage density of 1.75 mi./mi^2 **[Table E-8]**. Drainage density is an indicator of the efficiency of a stream. The greater the drainage density, the more efficient the watershed is in concentrating rainfall in the catchment area, thereby generating higher flood peaks and greater damage to channels. Values of the basin's compactness coefficient and ruggedness are 1.29 and 1.74, respectively. The compactness coefficient is the ratio of the perimeter of the watershed to the circumference of a circle having the same area. The ruggedness factor is the product of the total relief and drainage density. The two factors are dimensionless. The values of compactness, drainage density, and ruggedness indicate that the basin is efficient in delivering water to the stream channels and has the potential for generating high flood peaks.

The bedrock lithology of Specimen Gulch, a sub-basin of the Little North Fork, is composed predominantly of metamorphic rock types (98%). Few landslides were inventoried in the watershed (a total of 3) and air photo review indicates that minor amounts of channel scour by flood flows has occurred during the period of record. The sub-basin is the most stable of the four sub-basins comprising Little North Fork.

Specimen Gulch has a drainage basin area of 7.84 mi.^{2}, a stream length of 6.89 mi. and drainage density of 0.879 mi/mi.^{2} **[Table E-8]**. Its low values of drainage density, compactness (1.11), and ruggedness (0.695), compared to Little North Fork, indicate that it too, is efficient in delivering water, but is more subdued in relief, and more stable, overall. The drainage density of Specimen Gulch is controlled by more-resistant metamorphic rocks.

The movement of storm fronts through the Klamath Mountains and drainage basin patterns may be important factors influencing the distribution of channel-bank landslides and occurrence of riparian damage in watersheds of the Salmon Basin. Storm front systems during the wet months of November through March generally track from the west and south across the Klamath Mountains. The majority of the stream segments of the Little North Fork watershed flow east and south in three of the four sub-basins, Headwaters, Uncles Creek and Lower Little North Fork. During an east-moving storm system, peak flows from these three sub-basins would reach the Lower Little North Fork sooner than peak flows from Specimen Gulch. This storm and and stream discharge pattern could explain the some of the impacts to the watershed from the 1964 and 1972 events where extreme riparian damage occurred in the three sub-basins.

Negro Creek

Negro Creek watershed has a drainage basin area of 4.09 mi.^{2}, a stream length of 6.89 mi. and a drainage density of 1.68 mi./mi.^{2} **[Table E-9]**. It is a second-order stream as it enters into the South Fork Salmon River, and the basin has a west aspect. The compactness coefficient is 1.27 and the ruggedness coefficient is 1.28. The basin is elongated and its low relief and ruggedness indicate a subdued topograhy and increased stability.

Table E-8. Little North Fork watershed and Specimen Gulch sub-basin: summary of drainage basin characteristics.

	Little North Fork	Specimen Gulch
Drainage Area	32.5 mi.^{2}	7.84 mi.^{2}
Miles of Stream	57.02 mi.	6.89 mi.
Minimum Elevation	1990 ft.	2314 ft.
Maximum Elevation	7233 ft.	6487 ft.
Total Relief	5243 ft.	4177 ft.
Mean Elevation by Area	4696 ft.	4183 ft.
Aspect	S	SW
Main Channel Slope Index	6%	15%
Drainage Density	1.75 mi./mi.^{2}	0.879 mi./mi.^{2}
Bifurcation Ratio	3.3	3.3
Compactness Coefficient	1.29	1.11
Ruggedness	1.74	0.695
Perimeter	26.06 mi.	11.02 mi.
Stream Order	4	3
1st Order Tributaries	37	9
2nd Order Tributaries	10	2
3rd Order Tributaries	3	1
4th Order Tributaries	1	0

Table E-9. Negro Creek watershed: summary of drainage basin characteristics.

	Negro Creek
Drainage Area	4.09 mi.^{2}
Miles of Stream	6.89 mi.
Minimum Elevation	1380 ft.
Maximum Elevation	4033 ft.
Total Relief	4033 ft.
Mean Elevation by Area	3317 ft.
Aspect	W
Main Channel Slope Index	16%
Drainage Density	1.68 mi./mi.^{2}
Bifurcation Ratio	4.0
Compactness Coefficient	1.27
Ruggedness	1.28
Perimeter	9.13 mi.
Stream Order	2
1st Order Tributaries	4
2nd Order Tributaries	1

CLIMATE

Most of the anuual precipitation in the Klamath Mountains occurs during a five-month period, from November to March. Snow occurs in moderate amounts at altitudes above 2000 feet. In normal water-years, a significant amount of the runoff is supplied by snowmelt untill mid-summer [Rantz, 1967].

The isohyetal map of North-Coastal California, [Rantz, 1968], indicates that the average annual precipitation along the North Fork Salmon River in the vicinity of Sawyers Bar is roughly 40 inches per year. Within the Little North watershed, annual precipitation ranges from 40 inches near the mouth to almost 80 inches at the English Peak divide. Average annual precipitation in Negro Creek watershed ranges from more than 30 to 40 inches [Rantz, 1968]. Temperatures range in both watersheds from an occaisional 100°F in the river canyon and unshaded stream areas during the summer months, to below zero at the highest elevation in the winter months. Heavy warm rains are not uncommon during the winter, at all elevations.

Records of annual precipitation from Sawyers Bar Ranger Station extend from 1934 -1980 [California Department of Water Resources, 1981]. The water year of 1958 records the highest annual precipitation on record and is 166% of average **[Figure E-6]**. The water year of 1974 records the second highest annual precipitation, or 152% of average.

The precipitation record for the Forks of Salmon Station extends from 1959 to 1972 and records an average annual precipitation of 42.47 inches [California Department of Water Resources, 1981].

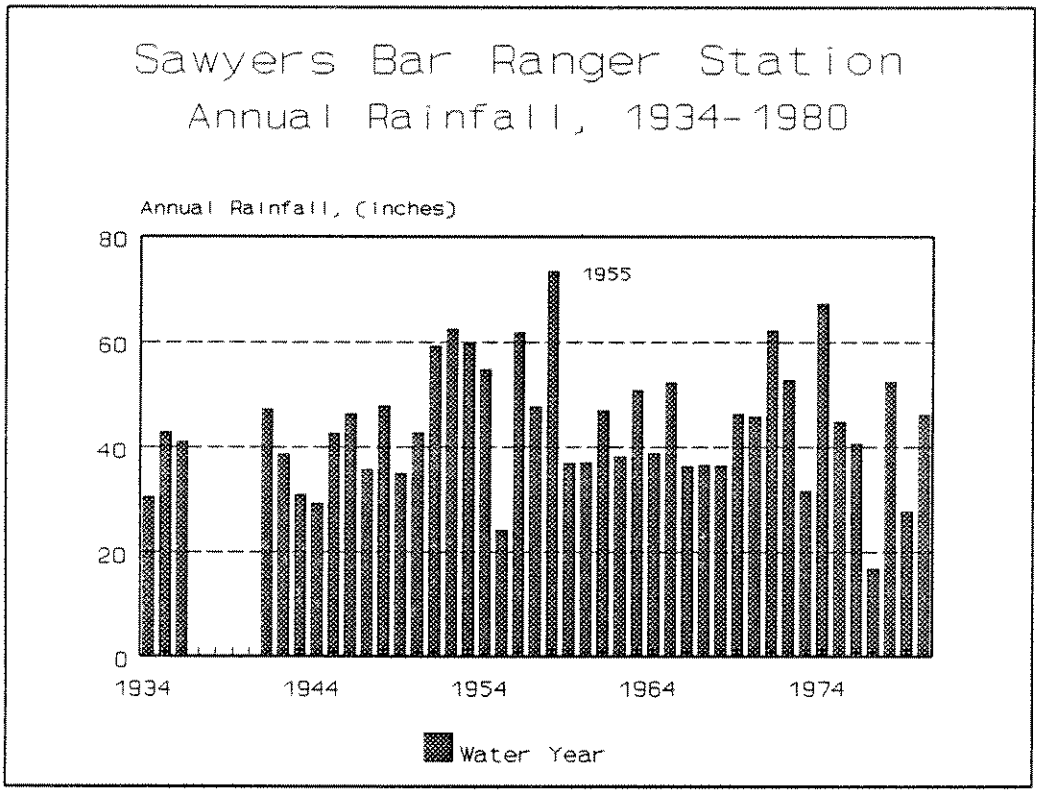


Figure E-6. Annual rainfall measured at Sawyers Bar Ranger Station, 1934-1980.

ROAD CONSTRUCTION, LOGGING AND FIRE HISTORY

Data Sources and Methods

Data sources and methods used to evaluate the timing and occurrence of road building, timber harvest, and fire during the period of record, 1944-1988, for both watersheds are summarized here. Data sources include the forest land management planning data base and review of air photographs. Sequential air photos reveal changes in the watershed over time.

The existing roads in the watersheds were digitized from 1989 SPOT [SPOT Image Corporation, Reston, VA] satellite images, 1:24,000 scale. All USFS system roads were digitized. Those roads which are not considered part of the USFS system were not digitized. Non-system roads that were not digitized in Little North Fork are estimated to total roughly 8 acres [1.5 miles]; in Negro Creek these roads total roughly 5 acres [1 mile]. District engineering personnel used primary base series maps, forest transportation maps, and their knowledge of road locations as additional information sources. Miles of road were converted to acres of road by the following formula.

[Road length [feet] x 1.05 x Basin Average Road Width [feet]] / [43560 square feet/acre] = Road Acres

Digitized miles of road were increased by 5% to compensate for the difference between field-measured road miles and digitized road lengths. An additional correction factor was applied to eliminate double counting of area at road junctions and intersections. To simplify the analysis, 40 feet was given as a basin average road width. Road construction history was evaluated by sequential aerial photography. To obtain the miles of the road in a given photo bracket, a visual estimate was made of the fraction [percent] of the total miles or acres of roads existing at that photo year. Photo years evaluated in this way are: 1944, 1955, 1964, 1965, 1975, and 1988.

Acres of stocked plantations and the timing of timber harvest were derived from the forest land management planning data base and review of air photographs. Outlines of timber harvest units, primarily clear-cuts and shelterwoods, were digitized from 1989 SPOT satellite images. District silviculture personnel used records to date the year each harvest unit was planted, or stocked with trees. All discernable harvest units cut before September 1989 were recorded. District records of areas stocked in the period of 1988 to 1990, following the 1987 fire, were used to update the database. These units are referred to as post-fire plantations. Aerial photo review was used to bracket the actual time period of harvest, since stocking a plantation may occur some years after harvest. In some cases, the actual year of harvest was known from district records.

The extent and intensity range of the Hog Fire in 1977 and 1987 wildfires were evaluated for this study. The extent and intensity of the Hog Fire was mapped on color infrared air photos at 1:15,840 scale and the data was transferred to topographic base maps at 1:15,840 scale, and then digitized. A similar process was used to map the extent and intensity of the 1987 fires. Air photos used were taken in 1988, in color, at a scale of 1:15,840.

ROAD CONSTRUCTION HISTORY

Little North Fork

Road construction began in 1966 with building of the Little North Fork road system, which includes approximately 17 miles of road [82 acres] **[Figure E-7]**. The road system was constructed over the period 1966-1971. The system includes the 41N33, 41N33A5, 40N51, 40N51A, 40N51B, and 40N45 roads. The Specimen Gulch section of the 40N42 Road in the Kelly Gulch road system is included. This section of road was constructed between 1975 and 1980.

Negro Creek

The first road construction in the watershed occurred during the period 1955-1964. The present road system was completed by 1988 **[Figure E-8]** The total miles of road existing in the watershed is 17 [82 acres]. Based on air photo examination, approximately 10.2 miles of road existed by photo year 1965 [60%]; an additional 2.5 miles was constructed by 1975 [15%]; an additional 4.3 miles was constructed by 1988 [25%]. The road system includes the 39N28, 10N01, 39N72, 29N67, 39N30, 39N29, 39N27, and associated road extensions.

TIMBER HARVEST AND PLANTING

Little North Fork

Timber harvest activities in the watershed began in 1967 **[Table E-10]**. During the period 1967 to 1971, 18 harvest units were clear cut, totalling approximately 794 acres. During the period 1975 to 1988, 6 units were clear cut, totalling 276 acres **[Figure E-7]**.

Table E-10. Areas [acres] of harvested land, roads and Forest land burned by fire by time period in Little North Fork watershed. Data is from the Forest database, and air photo interpretations.

Watershed	Class	0-1965	1965-1975	1975-1988	Total
LNS	Harvest	0	794	276	1070
	Roads	0	82		82
	Fire	0		53*	53*
HLS	Harvest		156		156
	Roads		10		10
	Fire				
LOW	Harvest	637	126		763
	Roads	62			62
	Fire		50		50
SPE	Harvest	1	150		151
	Roads	10			10
	Fire		3		3
UNC	Harvest				
	Roads				
	Fire				

Watershed Designations: LNS - Little North Fork; HLS - Headwaters Sub-basin; LOW - Lower Sub-basin; SPE - Specimen Creek Sub-basin; UNC - Uncles Creek Sub-basin

* Acres burnded at High to Medium intensity.

Little North Fork

Roads, Plantations & Wilderness

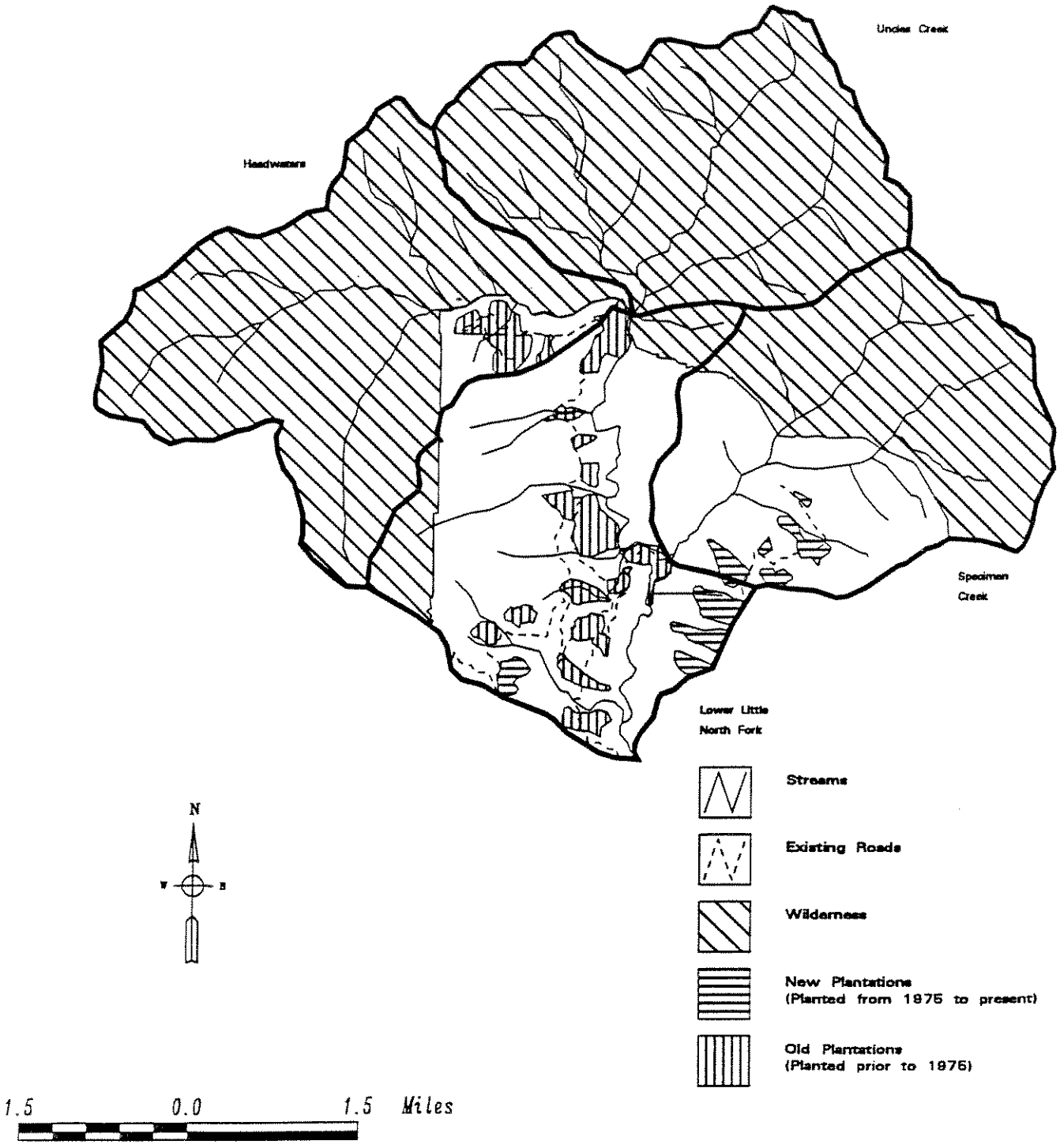


Figure E-7. Little North Fork streams, roads, wilderness and plantations.

Negro Creek

Roads, Plantations & Private Lands

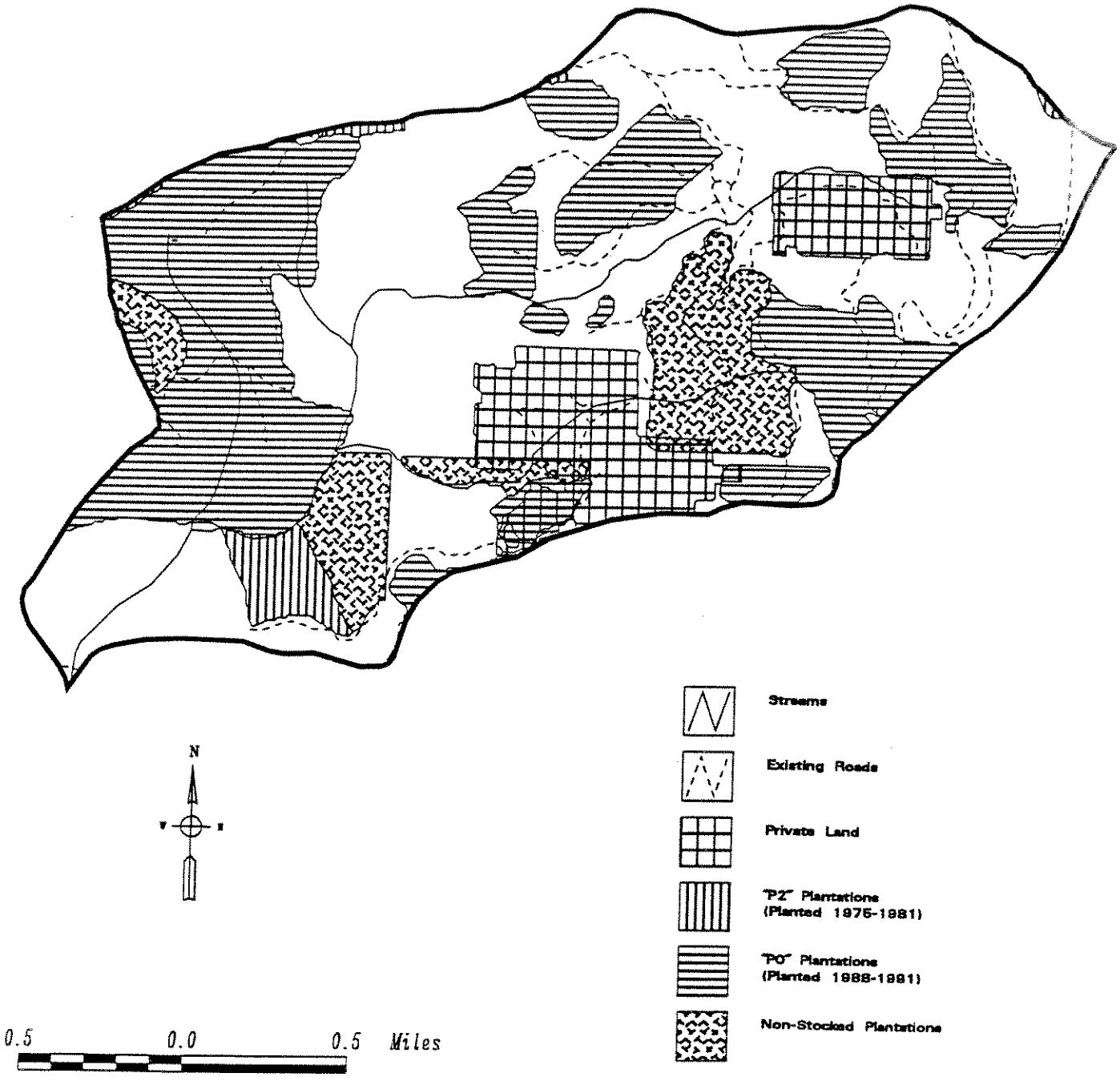


Figure E-8. Negro Creek Streams, existing roads, private land and plantations.

Negro Creek

Two data sources were used to compile information on timber harvest and plantation stocking activity in the watershed: the forest database and sequential air photograph analysis. The forest database indicates that plantations were stocked beginning in the period 1975-1981; in that period, 59.4 acres were planted **[Table E-11]**. In the period 1988-1991, after the 1987 fires, 826.5 acres were stocked. An additional 254.3 acres in the watershed are non-stocked, that is, either the plantation was not successfully regenerated or the area was not planted at all. The forest data base shows 1140.2 acres in plantation or non-stocked at the present time **[Table E-11; Figure E-8]**.

A cursory examination of air photos indicates that timbered stands were clear- or partially-cut prior to 1964 **[Table E-11]**. Acreages were calculated manually using a square grid scaled to the 7.5 minute orthophoto quadrangle maps, 1:15,840 scale. In the 1955-1964 period, approximately 126 acres were harvested in 5 units. In the 1964-1965 period, 89 acres were harvested in 2 units. In the 1965-1975 period, 101 acres were harvested from 9 units.

Table E-11. Areas (acres) of harvested land, roads, and land burned by fire, by period for Negro Creek watershed. Data is from the Forest data base, and air photo interpretations.

Class	0-1944	1944-1955	1955-1964	1964-1965	1965-1975	1975-1988	1988-1991	TOTAL
Harvest Stocked Plantations	0	0		126	89	101 59.4*	827	316 886
Roads	0	0	49	0	12	21	0	82
Fire	0	0	0	0	0	2530**	0	2530

* Forest data base shows 59.4 acres of stocked plantations in the period 1975-1981.
** Acres burned at high to medium intensity in the 1987 fires, excluding road acreage burned in the fire.

FIRE HISTORY

Little North Fork

The total number of acres in Little North Fork watershed burned in the 1987 fires is 520; of this total, 467 acres were burned at low intensity, 50 acres at medium intensity, and 3 acres at high intensity **[Table E-12; Figure E-9]**.

Table E-12. Summary of acreage burned in Little North Fork from the fires of 1987.

Watershed	Intensity	Acres	Percent Area
LNS	Low Medium High	467 50 3	2 < 1 < 1
HLS LOW SPE	Low Low Medium High	24 444 50 3	< 1 9 1 < 1

Watershed Designations: LNS - Little North Fork; HLS - Headwaters Sub-basin; LOW - Lower Sub-basin; SPE - Specimen Creek Sub-basin; UNC - Uncles Creek Sub-basin

Little North Fork

1987 Fire Intensities

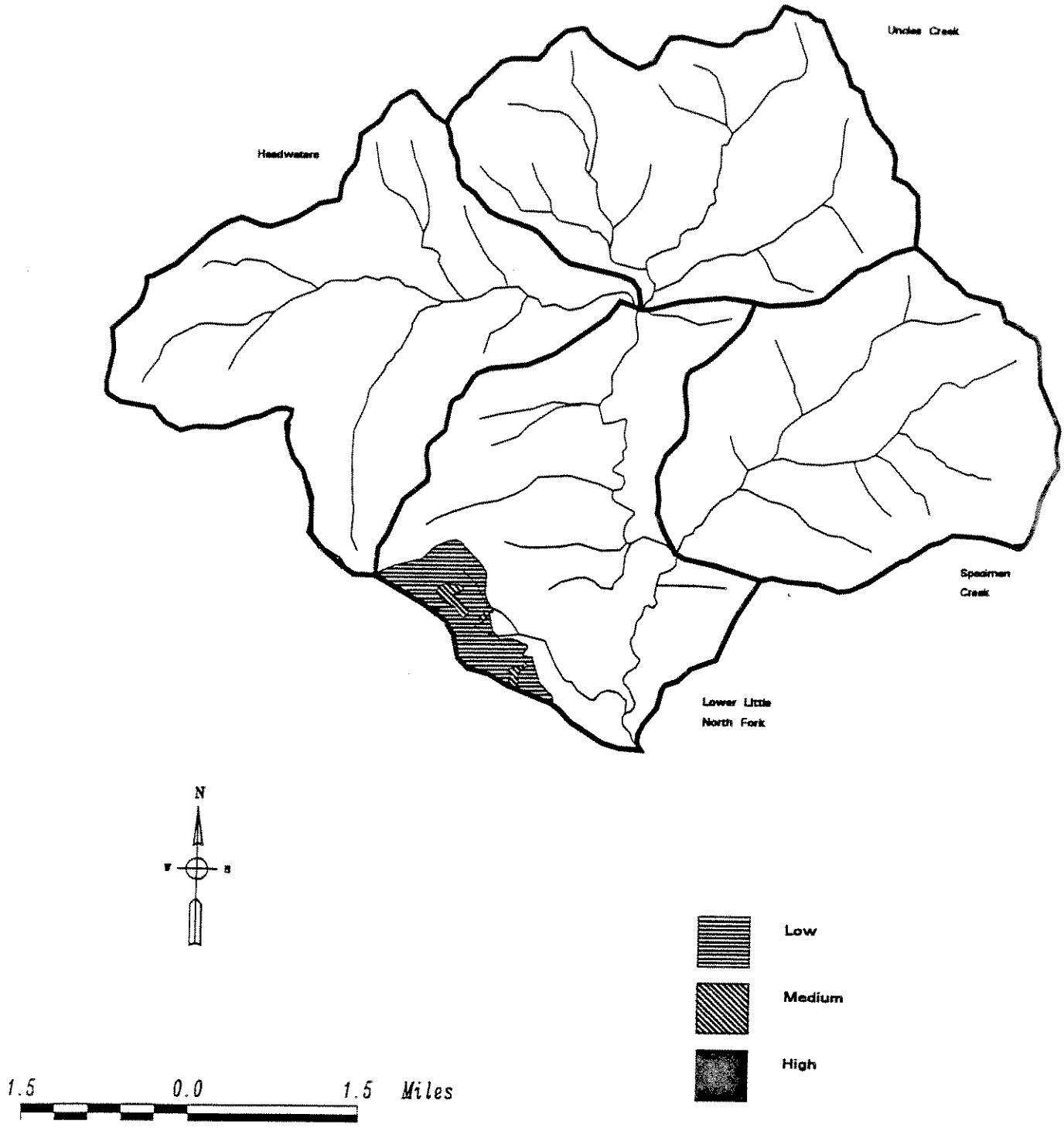


Figure E-9. Little North Fork fire intensity map, 1987 Fires.

Negro Creek

Negro Creek watershed was burned in the Hog fire of 1977 and more recently, in the fires of 1987. The entire watershed of 2617 acres was burned in the Hog fire, 1674 acres at high intensity **[Table E-13; Figure E-10]**. The fires of 1987 burned 2568 acres of the watershed, 1433 at high intensity. A total of 1841 acres of land that burned from high to medium intensity in the 1987 fire overlap with the Hog Fire area **[Table E-13; Figure E-11]**.

Table E-13. Summary of acres affected by the Hog and 1987 fires. Negro Creek watershed is 2617 acres.

Hog Fire

Intensity	Acres	% Area
Low	211	8
Medium	731	28
High	1674	64

1987 Fire

Low	726	28
Medium	409	16
High	1433	55

1987 Reburn of the Hog Fire Area

Hog Intensity	1987 Intensity	Acres	% Area
Low	Low	0	0
Low	Medium	0	0
Low	High	209	8
Medium	Low	275	11
Medium	Medium	177	7
Medium	High	275	11
High	Low	449	18
High	Medium	232	9
High	High	948	36
Total		2565	100

Negro Creek

1977 Hog Fire Intensities

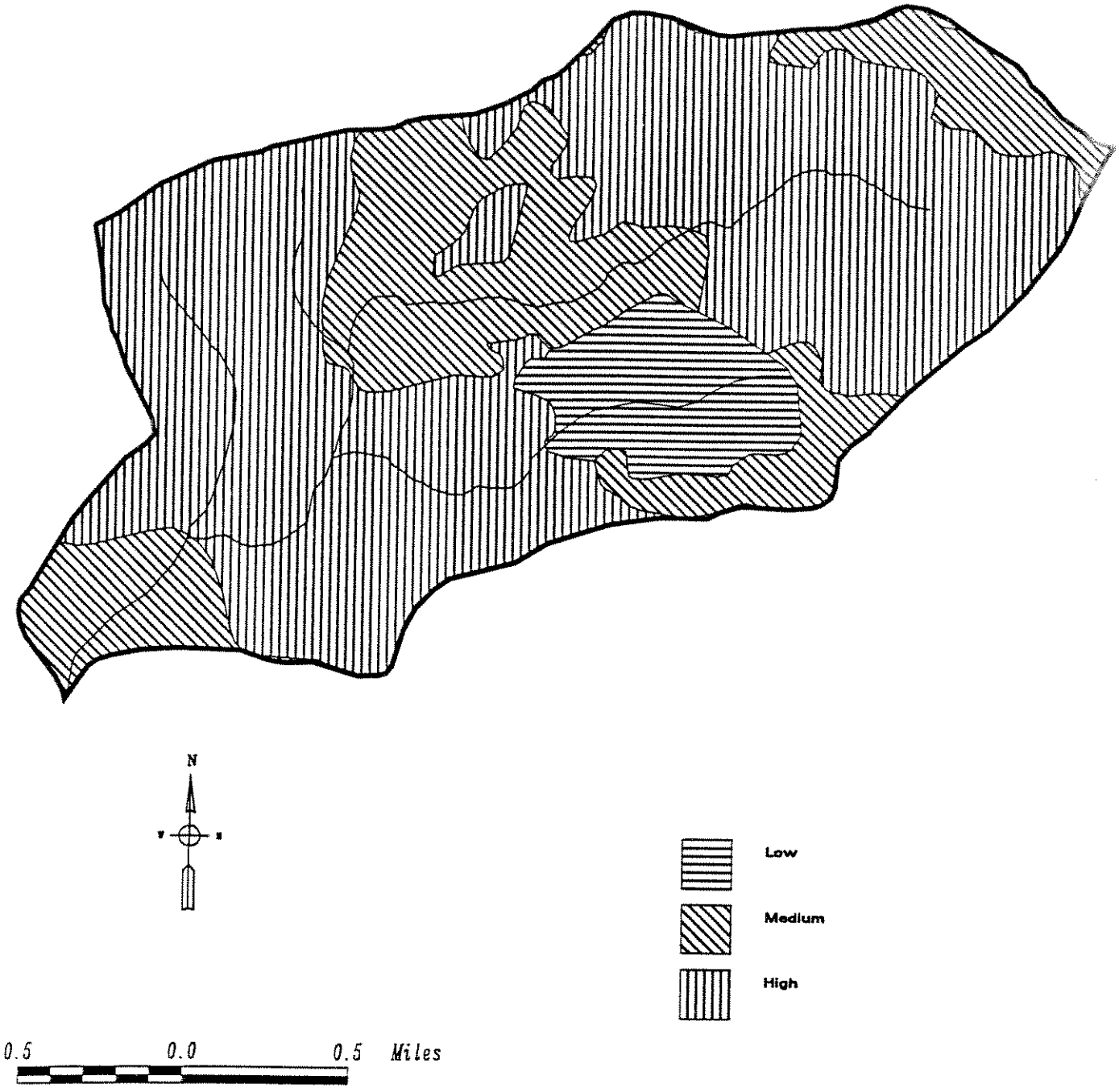


Figure E-10. Negro Creek Watershed, Hog Fire intensity map.

Negro Creek

1987 Fire Reburn of the Hog Fire Area

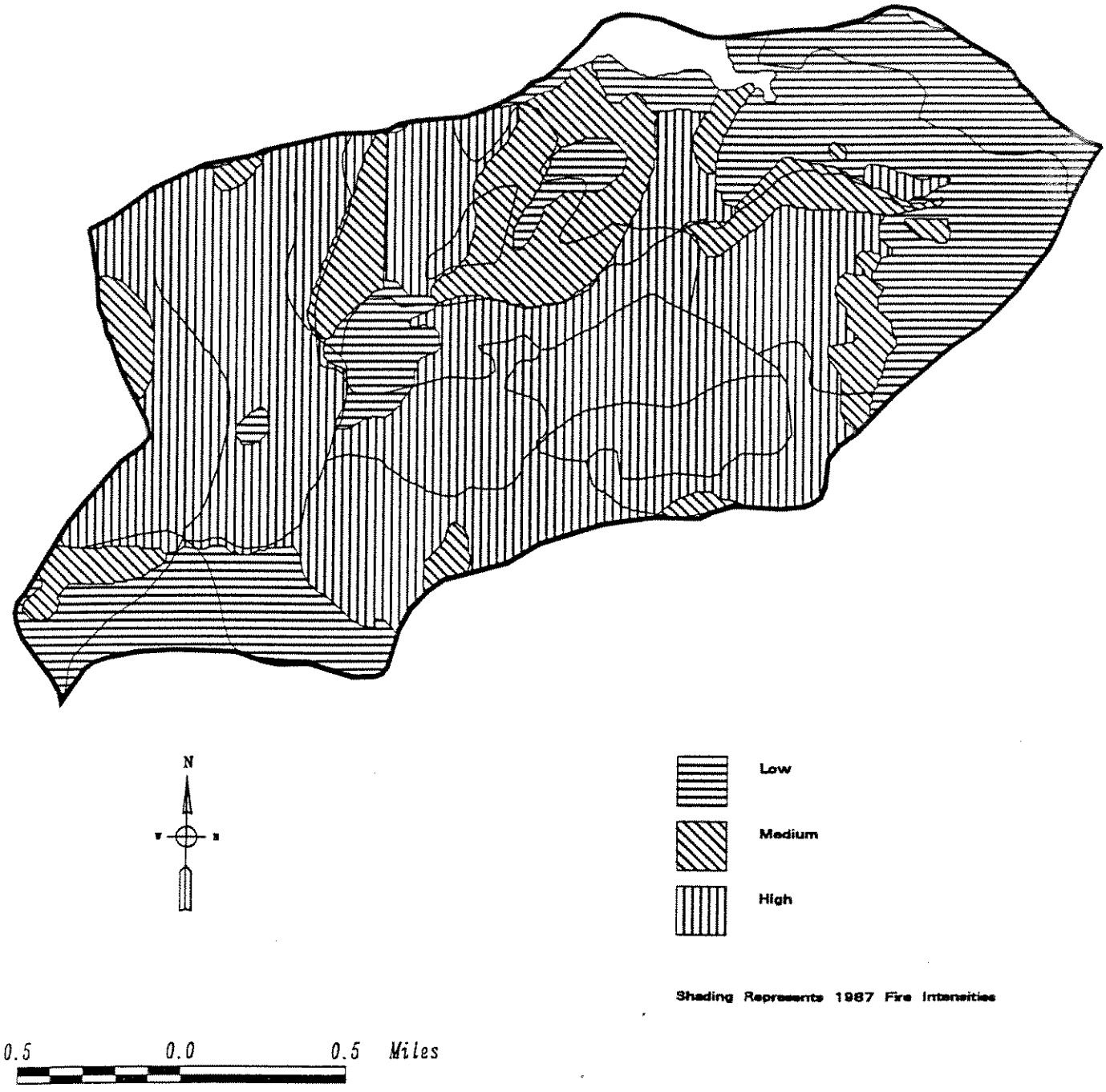


Figure E-11. Negro Creek Watershed, 1987 fire reburn of the Hog Fire area.

LANDSLIDE PRODUCING FLOOD AND STORM EVENTS

Landslide-producing events in the Little North Fork and Negro Creek watersheds include the major flood event of December 22, 1964 and various two-to four-day storm events from 1965 to 1988 resulting in greater than 4 inches of precipitation. The flood of 1955 was insignificant in terms of landslide production in both Little North Fork and Negro Creek watersheds.

The flood of 1964 was a significant event in Little North Fork as well as in other sub-watersheds of the Salmon Basin. The following description of the storm event is summarized from Department of Water Resources Bulletin No. 161, 1965. Heavy rainfall began on December 18, 1964 bringing snow to higher altitudes. After December 20, the freezing level rose to greater than 10,000 feet and caused high precipitation and rain. Rates in excess of 8 inches in 24 hours were recorded. Precipitation totals for a 5-day period December 19-24 exceeded 20 inches in many places, but ranged from a low of 10 inches to more than 30 inches.

Precipitation recorded at Sawyers Bar Ranger Station shows a total of 11.06 inches of rainfall during the period December 20-24; 18.56 inches was recorded over the period of December 20-31. Precipitation was probably much greater at higher elevations within the watershed. Precipitation records at Sawyers Bar Ranger Station and the Fire Station consisted of daily measurements from a rain gauge. Daily measurements were usually not made on weekends. Precipitation in the form of snow was not reported very accurately; if snow was present on the ground it was noted.

Water discharge data recorded December 22, 1964 at station 5224 North Fork Salmon River near Forks of Salmon, indicates a flood stage of 28.2 feet, and discharge of 30,000 cfs. [148 cfs/square mile; drainage area equals 203 square miles]. By comparison, the peak discharge from the 1955 flood event, recorded on December 22, 1955 at station 5223, South Fork Salmon River near Forks of Salmon, records a flood height of 12.2 feet and 24,200 cfs discharge [Young and Cruff, 1967].

Flood discharge data from the 1964 flood indicates that an approximate peak discharge for North Fork of the Salmon River is 200 cfs/square mile [Hicks, 1973; Pillsbury, 1976:5]. The drainage basin area of Little North Fork is 32.5 square miles. Using this information, peak flow for the Little North Fork is estimated to be 6,500 cfs. [200 cfs/square mile X 32.5 square miles] [Hicks, 1973; Pillsbury, 1976:5].

The two storm events of 1972 triggered numerous debris slides in Little North Fork watershed. The first storm event occurred over a three day period, January 21-23. Daily precipitation recorded at the Sawyers Bar Ranger Station was 2.47, 4.15 and 2.62 inches, an average of 3.08 inches per day over 3 days. This storm was preceded by four days of rain where precipitation was recorded. Daily precipitation totals over the period January 17-20 are 0.02, 0.84, 0.29, and 0.29 inches, respectively. Though the total number of landslides initiated by this storm is not known, debris slides in cut block #2 were initiated on January 23 [Pillsbury, 1976:7].

The second storm event occurred over a two day period, March 2-3, 1972. Daily precipitation totals recorded were 3.22 and 2.80 inches. This storm was preceded by 13 days where precipitation was recorded. Average daily rainfall over the 13 day period was 0.57 inches per day. During the period February 27-29, daily precipitation was 1.00, 1.00 and 0.96 inches. Major landslides occurred throughout the harvested areas as a result of the March storm. The total number of landslides occurring as a result of the two storm events was approximately 200.

Precipitation records at Sawyers Bar Ranger Station indicate that 3-to 4-day storm events with precipitation totals in excess of 4 inches are very common and generally occur at least once in a given water year **[Table E-14]**, [Hicks and others, 1973, Appendix A p.95-98; USFS Memo January 20, 1984]. Sawyers Bar rainfall data [1945-1979] indicates a 2 year return period for 3 day storm events

with a maximum precipitation of 5.74 inches over the duration **[Table E-15]**. Three day storm events with a maximum precipitation of 7.83 inches over the duration occur in a 5 year return period [California Department of Water Resources, 1981].

Since photos were taken in 1964, 1965, 1971 and 1972, landslides from the 1964 and 1972 storm events can be identified **[Table E-16]**. However, it is much more difficult to tie landslide occurrence with a single storm event during other time intervals, such as 1965-1971; and 1975 to 1988.

Table E-14. Three and four day storm events with precipitation greater than 4 inches, over the period 1966-1987. Data recorded at Sawyers Bar Ranger and Fire Station, California. Rainfall data is in inches. Note: R=Rain, S=Snow.

Year	*Month*	*Precipitation*	*Type*	*Storm Period*
1966	January	8.54	?	4 day
1968	February	6.33	?	4 day
1969	January December	5.80 4.31	? ?	3 day 3 day
1970	January	8.33	?	4 day
1971	January	5.17	?	3 day
1972	January March	9.24 6.51	R R	3 day 3 day
1973	November November	5.01 5.05	R R	4 day 4 day
1974	January March	5.38/6.61 5.02	R R	3 day/4 day 3 day
1975	March	6.93	R	3 day
1976	February	4.10	R	3 day
1977	December	6.55/8.06	R/S	3 day/4 day
1978	-	-	-	-
1979	January	4.97	R	3 day
1980	December	5.90	R	3 day
1981	November	5.56	R	3 day
1982	December	4.99	R	3 day
1983	January	4.92	R	3 day
1984 - No				
1985 - Yes				
1986 - Yes				
1987 - No				

Table E-15. Precipitation/Duration/Frequency table for Sawyers Bar, California from 1945 to 1979 [California Department of Water Resources, 1981].

Return Period [Years]	*Maximum Precipitation [inches] for Indicated Duration [D-Days]*			
	1D	2D	3D	4D
2	3.36	4.63	5.74	6.47
5	4.53	6.37	7.83	8.77
10	5.28	7.52	9.20	10.25
20	6.20	8.61	10.48	11.63
25	6.30	8.95	10.89	12.06

Table E-16. Recorded storm events for the period of record, 1944-1988, and occurrence of landslides known to have resulted from a given event.

Little North Fork

Photo Year First Appears	Photo Age Bracket	Number of Landslides	Storm/Flood Event
1944	0-1944	11	
1965	1964-1965	133	1964
1971	1965-1971	27	
1972	1971-1972	201	1972
1975	1972-1975	1	
TOTAL		373	

Negro Creek

Photo Year First Appears	Photo Age Bracket	Number of Landslides	Age Range	Storm/Flood Event
1944	0-1944	6		
1964	1955-1964	1		1955?
1965	1964-1965	12		1964
1971	1965-1971	8		
1975	1971-1975	2		
1980	1975-1980	28		
1982	1980-1982	2		
1986	1982-1986	1		
1987	1982-1987	6	1982-1985	82,83,85?
1987	1982-1987	9		
1988	1987-1988	10		
Zane Landslide	1989	1		
INDET	1975-1987	24	1977-1987	
INDET	1975-1988	4	1977-1988	
INDET	1980-1988	5	1980-1988	
TOTAL		119		

SLOPE-FORMING PROCESSES

Granitic Lands

Little North Fork watershed is underlain by metamorphic rock of the Western Paleozoic and Triassic Belt and granitic rock of the English Peak Batholith. Within the watershed, most of the slope stability problems and environmental damage has occurred within granitic lands. Granitic terranes like that of the English Peak Batholith are well-known to be areas of marginal slope stability. Several granitic bodies in the Klamath Mountains Province have well-documented slope stability problems as well as high landslide and erosion rates. These include the Ashland Pluton [Rolle and others, 1987; Smith and Hicks, 1982; Wilson and Hicks, 1975]; the Russian Peak Pluton [Sommarstrom and others, 1990]; Shasta Bally Batholith [USDA, SCS 1978, 1981, 1986]; and the English Peak Batholith [Hicks, 1973; Pillsbury 1976; Rice and Pillsbury 1982].

Slope stability and erosion rates in granitic lands are greatly influenced by bedrock weathering processes. Weathered and decomposed granitic bedrock and soils derived from the same are commonly referred to as D.G., decomposed granite. More correctly, the granular weathering product of granitic rock is termed grus. There are four generally recognized weathering stages common to granitic rocks. All four stages of granitic bedrock weathering are evident in Little North Fork watershed. The first stage, (lowest in profile section) is marked by fresh rock weathered along fracture systems which progress inward. In this stage the rock, while still hard and essentially fresh, takes on a white color (Wagner, 1991; Durgin, 1977). In stage two, granitic rock disintegrates, yielding grus, and core-stones. Core-stones are rounded boulders of intact rock that may be fresh or partially decomposed. At stage three, the rock has almost wholly disintegrated to grus with few remnant core-stones. The fourth and final stage is the weathering of grus to a clay-rich, sandy soil. Soil in this zone is a white to brown decomposed granite which grades upward to a red, lateritic layer that develops to deeper levels with time. The clay formed is usually kaolinite, and the sand grains are dominantly quartz. Feldspars and mafic minerals, such as hornblende, biotite, and pyroxene, are progressively altered in the decomposition process. Alteration products are commonly platy mica minerals and clay. The alteration of minerals involves a volume increase, which causes fractures to develop in the weathering rock mass. These fractures increase permeability and promote further chemical alteration. While the processes of weathering and decomposition increase permeability and porosity, the changes signficantly decrease bulk density and therefore rock strength. These physical changes and decreases in rock strength are key factors in the slope stability and erodibility of decomposed granitic rock.

Both residual and transported soils overlie granitic bedrock in Little North Fork. Residual soils are derived from the in-situ weathering of granitic bedrock. They are characterized by pervasive fabric disintegration, with only partial alteration of feldspars to clay. The zone of disintegration averages about 15 feet in thickness but may exceed 30 feet in highly fractured zones [Hicks, 1973].

Soils composed by transported granitic debris [by glacial-fluvial processes or creep] display extensive decomposition of primary minerals and are generally much thicker. Glacial deposits in the Headwaters sub-basin are comprised of unstratified terrace deposits composed of boulders, gravel, sand, and silt, overlying fractured granitic bedrock. These deposits may reach thicknesses of more than 60 feet.

The area in which the most severe environmental damage occurred from the storms of 1972, is located in the Lower sub-basin of Little North Fork, near the mouth. The soils are thick, and deeply weathered, typical of weathering stages four and three. The landform consists of a dense network of deeply incised drainage channels and streams, with steep slopes ranging up to 100%. The deeply weathered zone extends from stream base level at around 2000 feet to about 3000 feet in elevation. The upper part of the weathered zone contains deposits of thick red residual soils derived from

granitic parent material. The location and degree of weathering of the residual soil deposits along the margin of the present-day valley of the Little North Fork and North Fork Salmon River, suggests that it is an old remnant of an erosional surface associated with an ancient valley floor [de la Fuente, and Haessig, 1993 in press]. Rock types mapped in the area include gabbro, diorite and granodiorite; mafic mineral contents range from 20 to 60% and quartz contents range from 5 to 15 %. The susceptibility to weathering and decomposition increases as the per cent quartz content decreases, and as the proportion of mafic minerals such as biotite increase [Durgin, 1977]. However, the mineralogy and lithology of rock and soil deposits have not been mapped in detail to verify this premise.

Slope

Slope steepness influences the natural stability of all landscapes and is a factor in erosion rates. The angle of internal friction of granitic rock decreases as it decomposes, as does its strength and bulk density. Some decomposed granitic materials in the Idaho Batholith have friction angles ranging from 29 to 39 degrees, or 55 to 81% [Megahan, 1982; Gonsior and Gardner, 1971].

Steep slopes [greater than 65%, approximately 33 degrees] comprise 58% of the Little North Fork watershed. Slopes ranging from 35 to 65% comprise 33%, and slopes ranging from 0 to 35% comprise 9% of the watershed. The average slope gradient above the head scarp of landslides in undisturbed granitic lands in the Headwaters sub-basin is 53% [N=78]. The average elevation at the headscarp is 4413 feet [N=110]. Within undisturbed granitic lands of the the Lower sub-basin, the average elevation at the head scarp is 3135 feet [N=36] and the average slope gradient above the head scarp is 66% [N=36].

Landslide occurrence in Little North Fork is associated with swales near ridge crests in dissected, steep granitic mountain slopes, and along granitic inner gorges. Shallow debris slides occur in these steep terranes. Often, once initiated at the head of an inner gorge or swale, a shallow debris slide can result in a debris torrent that can scour the entire channel downslope.

Aspect

Aspect can play a role in erosion rates. In general, south- and west-facing slopes receive more rainfall due to influences of prevailing winds and routes of storm passage. Southerly slopes have increased runoff and erosion rates due to less vegetative cover, and thinner soils. A contrary view offered by Pillsbury [1976] is that since southerly aspects receive maximum solar radiation, they are drier, and their susceptibility to debris landslides is less. North-facing granitic slopes have been thought to be more stable in undisturbed conditions than south or east facing slopes [Hicks, 1973]. North aspects tend to have more vegetative cover and thicker soils, conditions which make them have a greater tendancy to fail by rotational mechanisms. Few landslides were noted on north-facing granitic mountain slopes, outside of the inner gorge.

The orientation of drainage channels, [flow direction of streams] controls the aspect or facing direction of landslides in Little North Fork watershed. Within the Headwaters sub-basin of Little North Fork, the main stem of Little North Fork flows east, and tributary streams flow north and south. The majority of landslides there, [77%] occur in inner gorges and face north and south. In the Lower sub-basin, the Little North Fork flows south and tributary streams flow east and west into the main channel. The majority of landslides [85%] occur in inner gorges and face east and west.

The majority of landslides in granitic deposits other than inner gorges [geomorphic terrane types 2, 3, 4 ,5, 12, and 13] occur on east-facing slopes.

Failure Mechanisms and Processes in Granitic Lands

Weathered and decomposed granitic material are susceptible to shallow debris slide-type failures. Soils derived from the decomposition of granitic parent material are essentially cohesionless. Sites where soils are shallow, and slope angles approach or exceed the angle of internal friction can be considered as potentially unstable sites. Various types of failures are often referred to in the literature and include debris avalanches, debris flows, and debris landslides. These failures are all translational failures initiated by saturation, and build up of pore pressure and/or seepage pressure. Perched water can be found in weathered zones of decomposed granite above fresh granite. The seepage of water in this zone can remove fine particles by processes of sapping and piping. Seepage forces build up after rainfall or snowmelt, and on steep slopes, can contribute to instability. In harvested lands or associated with roads, the loss of added strength from root support is another important factor promoting instability.

Most landslides measured in Little North Fork are shallow, typical of debris slides. The debris slides in harvested units measured by Pillsbury [1976] ranged from 2.3 to 4.8 feet in depth; average depth of the 21 landslides was 3.5 feet. Among all landslides measured in the field by this study, the average depth is 4.74 feet [N=158]. Granitic landslides in undisturbed lands resulting from the 1964 flood are somewhat deeper, averaging 5.21 feet [N=88]. The largest debris landslide that delivered the most volume of material was 1.8 acres in area, delivered 49,600 yds^3, and had an average depth of 20 feet.

Landslides on undisturbed lands contributed 80% of the total volume of material delivered to channels over the period of record, 1944-1988. Landslides in granitic, undisturbed lands contributed 59% of the total volume. The majority of landslides occurred in inner gorges and resulted from the 1964 flood. Many of the landslides resulting from the 1964 flood occurred in thick glacial terrace deposits composed of transported decomposed granitic material overlying well-jointed granitic rock. The fresh granitic rock exposed at the base of the deposits has prominent joint surfaces sub-parallel to the ground surface and dip at moderate angles toward the stream channel. One possible failure process for these landslides may be saturation followed by the build-up of a subsurface flow zone at the interface of fractured granite and the upper decomposed layer. High rainfall, or rain-on-snow events release large volumes of water that rapidly infiltrates the permeable soil surface and continues downward until it reaches the zone of fractured bedrock. At the interface, high seepage forces can initiate failure along the contact. Another possible cause of failure is the undercutting of stream banks and terraces by flood torrent flows.

Failures Associated With Roads in Granitic Lands

Road-related landslides in granitic terranes contributed 33% of the total volume over the period of record, 1944-1988. The types of failures included cut and fill failures, and other failures initiated by slope failures in nearby clear cut units. Failures due to logging and road construction interacted to produce much more severe damage than either would have individually caused [Hicks, 1973]. For example, landslide debris from a failure in a harvest unit can clog a culvert through a road fill. As the fill was not designed to act as a dam, eventually the fill and the mass of debris piled behind the dam fail. Mass wasting of cuts and fills, poor road drainage, and debris flow formation wherever water is discharged from roads and culverts are all examples of the types of failures and erosion problems associated with roads.

Failures Associated With Harvest Units in Granitic Lands

Failures in clear cut blocks in granitic terranes of Little North Fork, [geomorphic terranes 4, 5, and 10] account for 9% of the total volume over the period of record, 1944-1988]. Failures in harvested units occurred on slopes, natural channels,and in draws which were formed by older debris slides. Pre-existing topographic swales or draws were most likely to produce failures [Hicks, 1973; Pillsbury,

1976]. Piezometric heads are high in these existing swales, and the water gradient exerts a lateral pressure, termed seepage pressure, capable of subsurface erosion. High pore pressure and seepage rates which develop in topographic hollows tend to reduce slope stability and the soil in the drainage hollows often fails first [Hicks, 1973]. Failures occurred on slopes both steeper and gentler than 60% [about 31 degrees]. The debris landslides took place following periods of intense precipitation which saturated the loose, decomposed granitic material. At failure, the liquified material progressed down slope through the channel as a debris avalanche, scouring out more material from the channel walls.

Field investigation of debris avalanche sites in cut block 1 of Little North Fork [Hicks, 1973] indicate that:

1. Maximum depths at the heads of these failures ranged from 4 to 7 feet
2. Average slope of the failure surface ranged from 60 to 80%.
3. Decomposed granitic rock was observed at a minimum depth of 15 inches to a maximum depth of 70 inches.

Later investigations by Pillsbury [1976] indicate that a large number of the debris slides are adjacent to or within channels and many of the slides originate from or are associated with tree stumps and their root system.

Pillsbury [1976] evaluated the probability of landsliding after timber harvesting in Little North Fork. He found that the highest probability of landslide occurrence was positively related to slope steepness, moderately weathered soil, the occurrence of dominant overstory vegetation before harvesting, and the percent quartz in bedrock and inversely related to understory vegetation before harvesting and highly weathered soil. The most important variables of these were slope and density of dominant timber cover. Dense stands of timber may reflect high soil moisture conditions and greater probability that excess pore water pressures promoting slope failure might occur if the trees were removed. In addition, many of the stands of trees harvested were 300-400 years old, providing a mimimum age since landsliding had occurred at those sites.

Non-Granitic Lands

Slope-forming processes and landslide occurrence are more varied in lands underlain by metamorphic and ultramafic bedrock. Lands underlain by metamorphic bedrock, primarily metavolcanic and metasedimentary lithologies, comprise 48% of the total land area in Little North Fork watershed. Ultramafic bedrock, primarily peridotite and serpentinite, and metamorphic bedrock, primarily metamorphosed sedimentary and volcanic lithologies, comprise 98% of the Negro Creek watershed.

Several types of slope-forming processes occur: (1) rock slides and block glides, (2) rotational slumps and earthflows, (3) translational debris slides and flows, and (4) dormant landslide deposits. In the two watersheds studied, dormant landslide deposits occur more commonly in non-granitic terrane. They encompass large areas and are important to slope-forming processes. The dormant landslide deposits were formed by massive, slump-earthlow rotational failures that occur over a large area. The steep to gently-sloping, hummocky, bench-slope topogyaphy common in dormant landslide deposits was formed by landsliding which occurred in thick residual soils, tens to hundred of thousands of years ago. The deposits are are made up of unconsolidated rock, soil and organic debris, which often has a high clay content. The toe zones or margins of these large deposits commmonly terminate in inner gorges along streams, and are particularly sensitive to activation by debris slide mechanisms at the toe. Dormant slide deposits are complex terranes and are commonly consist of multiple earthflows enclosed by the larger slide mass. Multiple slide scarps, as well as benches and slide toe zones may occur within a major dormant slide deposit. Debris slides may occur within the larger dormant slide mass, situated within the body or at the toe.

The metamorphic terrane in Little North Fork watershed is more stable than the granitic terranes. Active landslides associated with metamorphic bedrock comprise 23% of the total landslide volume delivered over the record, 1944-1988. Active slides occur mainly in inner gorges (94%) and steep mountain slopes (5%). Active landslides initiated within non-granitic dormant landslide yeposits and on slopes of low to moderate steepness comprise 2%. Comparisons are based on the total volume delivered to channels. Slope failures associated with metamorphic terrane in Little North Fork are primarily translational debris slides in the inner gorge and along stream banks. Complex slides that include components of slump, debris slides and block gliding, also occur within the inner gorge region. Approximately 80% of the dormant landslide deposits [by area] are in metamorphic terrane. Dormant landslide deposits comprise only a small portion of the area in the watershed, about 2%.

Negro Creek watershed is composed largely of ultramafic and metamorphic lithologies, and contains large areas of dormant landslide deposits. Dormant landslide deposits encompass 1408 acres, or 54% of the area. The dormant landslide deposits are mainly large rotational slump-earthflows. Approximately 27% of the active landslides are associated with inner gorges developed in dormant landslide deposits, and another 8% of landslides occur within the body or toe zone of the dormant landslide deposits. The remainder of the active landslides in Negro Creek watershed are asssociated with inner gorges that are not part of the dormant landslides [63%] and 2% occur on slopes less than 65%.

In Negro Creek, slope failures associated with inner gorges are mainly translational debris slides; complex slides consisting of slumps and debris slides occur to a lesser extent. Slumps, slump-earthflows and complex slides are more common within dormant landslide deposits and on slopes less than 65%. Landslide occurrence and rock types such as chert, argillite, peridotite, serpentinite, and metavolcanics, are spread throughout all geomorphic terranes. That is, there is no tendency for slump-earthflows to be more common in serpentinite and peridotite than other lithologies.

Slope

Landslides measured in metamorphic terrane in Little North Fork have an average slope above the head scarp of 61%, or about 31 degrees, [N=16]. The average elevation of the head scarp 3718 feet, [N=52] and ranges from 2860 to 5100 feet. The average slope measured above the head scarp in Negro Creek watershed is 49%, or about 26 degrees, [N=119]. The elevation of head scarps of landslides ranges from 1460 to 4650 feet. The maximum slope observed in both areas was 100%, and minimum slope gradient was less than 5%. Soils on dormant landslide deposits in the Negro Creek area are typically fine-grained, gravelly clay loams [USCS classification CL to CH]. These soils are cohesive and their stability largely depends on their clay content and moisture content. When dry, the material has a fairly high shear strength, high cohesion, and high angle of internal friction, [probably greater than 30 degrees]. Increased moisture content causes the clay to absorb moisture and yecome plastic, or deformable. Mass failure depends more on moisture content and build up of pore pressures than slope gradient, as the failure surface can develop in gentle slopes of 2-3 degrees [5%], with creep, slump and earthflows being the dominant processes.

Aspect

Since the majority of landslides are situated along stream inner gorges, the orientation of drainages controls the aspect or facing direction of landslides. In Little North Fork watershed landslides in metamorphic terrane occur in the Lower, Headwaters, and Uncles Creek sub-basins. Considered together, 32% of the landslides are face east, 28% face north, 20% face south and 19% face west. By sub-basin, most of the landslides [50%, N=36] face east in Lower sub-basin and most of the landslides [65%] face north in the Headwaters sub-basin.

Landslides in Negro Creek watershed predominantly face west and south. Considered together, 44% face west, 25% face south, 18% face east, and 14% face north. Streams flow west and south in the basin.

Failure Mechanisms and Processes in Non-Granitic Lands

Most of the landslides in metamorphic terrane are shallow, typical of translational debris slides. The average depth of slides measured in Little North Fork is 4.3 feet [N=36] with depths ranging from 20 to 0.5 feet. The average depth of debris landslides in metamorphic and ultramafic lands in Negro Creek is more shallow, 3.7 feet, with maximum depth of 81 feet and a minimum depth of 0.5 feet [N=86]. The average depth of rotational landslides such as slumps, earthflows and complex slides in Negro Creek is 8.6 feet and ranges from 50 to 1.5 feet [N=33].

Landslides in undisturbed, metamorphic terrane in Little North Fork watershed contributed 21% of the total volume of material to channels over the entire period of record. The majority of the landslides occurred in inner gorges and resulted from the flood of 1964. Types of deposits in these failures include slope colluvium, jointed bedrock, and alluvial stream deposits.

Landslides in undisturbed, metamorphic and ultramafic lands in Negro Creek watershed contributed 61% of the total volume delivered to channels over the period of record, 1944-1988. The majority of landslides occurred in inner gorge terrane type 11, and are associated with the 1964 flood event. Most of the landslides are not associated with inner gorges developed in landslide deposits.

Failures Associated with Roads In Non-Granitic Lands

Road-related landslides in metamorphic terranes in Little North Fork contributed 1% of the total volume of material to channels over the entire period of record, 1944-1988. The majority of these were fill failures involving shallow soils and jointed bedrock, that failed after of the storms of 1972. Most of the landslides occurred on roads constructed in steep slopes, with a few occurring at stream crossings.

Landslides associated with roads crossing ultramafic and metamorphic terranes occurred mainly in dormant landslide deposits and on slopes of gentle to moderate gradients. Road-related landslides in ultramafic and metamorphic terranes contributed 4% of the total volume of material over the period of record 1944-1988. The majority of the landslide volume occurred in the 1975-1988 photo interval. Road-related slope failures are evident in 1964, 1965, 1971, 1975, and 1980 air photos. Failure types are most commonly slumps in road cuts, and debris slides and flows originating in the fill or cut slope.

Failures Associated with Harvest and Fire in Non-Granitic Lands

Landslides in clear cut blocks in non-granitic lands [metamorphic bedrock] in Little North Fork [geomorphic terrane types 3, 6, 8, 11] account for far less than 1% of the total volume delivered to channels over the period of record, 1944-1988.

Slope failures associated with areas burned by wildfire in Negro Creek are significant in terms of the number of landslides produced and volume delivered to channels. The landslide volume delivered to channels over the 1975-1988 period is 35% of the total volume over the period of record. The majority of these landslides occurred in inner gorges in metamorphic or ultramafic mountain slopes [geomorphic terrane #11] and inner gorges in landslide deposits [geomorphic terrane #9]. Landslide types are related to the geomorphic terrane they occur in. Debris slides and debris flows are common in the inner gorge, while slumps and earthflows commonly occur in dormant landslide deposits. Failed material associated with all landslides includes landslide deposits, slope colluvium, and less commonly, bedrock. The causes of these landslides are most likely related to combinations

of these factors: loss of root support, lower shear strength of soils developed in landslide deposits, increased infiltration of water into the soil, and excess pore water pressures in the soil.

LANDSLIDE TYPE AND DIMENSIONAL CHARACTERISTICS

Introduction

Landslides were classified by their dominant types of movement and material type using the landslide classification system of Varnes [1978]. The major slope movement types include slides and flows; material types include rock, debris [predominately coarse rock and soil], and earth,[predominately fine-grained soil]. Landslide types differentiated in the inventory include debris slides, debris flows, debris avalanches, rock block slides, debris slumps, and slump-earthflows. Complex slides included combinations of two or more types of movement or types of material. Dimensional attributes measured in the field and off of air photos include landslide slope and map length, width and depth [estimated on air photos].

Little North Fork

Landslide types were simplified into three types: debris slides, channel bank debris slides and complex slides. Of the 373 landslides inventoried, 67% are debris slides, 24% are channel bank debris slides, and the remaining 9% are complex slides. Together, debris slides and channel bank debris slides account for the majority of landslide types observed in the watershed [91%]. Debris flows, debris avalanches, and debris torrents are included in the debris slide category. Debris flows were most commonly observed and account for 85% of the landslides grouped into the debris slide category. Channel bank debris slides were recorded mainly along the main channel of the Little North Fork. These slides were initiated in the current active channel and along formerly active channel banks and older terrace deposits scoured by the flood of 1964. Complex slides contain components of rock block slide, debris slide, slump, and channel bank debris slide types. Commonly, complex slides originate as debris slumps in their head scarp areas, transition to debris slides in the body of the slide, and involve block sliding near the toe. The transitions relate to the degree of decomposition and weathering of the granitic bedrock. At or approaching the shear plane of these slides, the the decomposed granitic bedrock gradually becomes more competent in structure, with failure surfaces associated with favorably oriented joint systems of the granite. The distribution of landslide types by photo year indicates that most of the channel bank debris slides occurred as a result of the 1964 flood event, and the majority of the debris slides were related to the storm event of the 1965-1975 period.

Dimensional data on landslides inventoried in Little North Fork Watershed are presented below and relate to the 272 landslides inventoried in this study, exclusive of the 102 landslides by Pillsbury [1976].

The landslides inventoried have on average, a length of 98 feet [N = 266], width of 115 feet [N = 266], depth of 4 feet [N = 267], and map area of 0.352 acres [N = 271]. The smallest landslide measured in the field, [Inv. #81085] has a map area of 260 square feet [0.006 acres], a slope area of 360 square feet, and delivered 24 yds^3 of sediment to stream channels. The largest landslide measured in the field [Inv. #81131] has a map area of 145,040 square feet [3.330 acres], a mobilized volume of 120,000 yds^3, and delivered 6,000 yds^3 of sediment to the channel. The largest active landslide [Inv. #81222] has a map area of 39 acres, mobilized volume of 1,890,000 yds^3 and has delivered 20,400 yds^3 of sediment to channels.

Negro Creek

Landslides were simplified into six types: debris slides, channel bank debris slides, slumps, slump-earthflows, rock slides, and complex slides. Of the 199 landslides inventoried, 55% are debris slides,

15% are channel bank debris slides, 14% are complex slides, and 12% are slumps. Slump-earthflows and rock slides each comprise 2% of the total number. Together, channel bank debris slides and debris slides comprise the majority of the landslide types inventoried. Debris flows account for 32% of the landslides grouped in the debris slide category. Complex slides contain components of rock block slides, debris slides, slumps and earthflows. The distribution of landslide types by photo year indicates that the majority of the debris slides and channel bank debris slides occurred in the 1975 to 1988 period, and are attributed to the effects of wildfire.

Dimensional data on landslides in Negro Creek relate to the 199 landslides measured in the field. The landslides have on average, a length of 112 feet, [N = 118], width of 61 feet [N = 118], depth of 5 feet [N = 118], and map area of 0.177 acres [N = 119]. The smallest landslide [Inv. # 7010] measures 80 square feet in map area [0.002 acres], 450 square feet in slope area and delivered 20 yds^3 to the channel. The largest landslide measured [Inv. # 4013] has a map area of 152,000 square feet [3.501 acres], mobilized a volume of 378,000 yds^3 of sediment and delivered 33,000 yds^3 to channels. This landslide was activated in the 1964-1965 period. The second largest landslide, named Zane Landslide [Inv. #7008], has a map area of 2.608 acres, has mobilized 98,000 yds^3 of sediment and has delivered zero yds^3. The landslide was most recently activated in 1989.

LANDSLIDE OCCURRENCE AND ELEVATION ZONES

For both watersheds examined in this study, there is a correlation between landslide occurrence and elevation, over different periods of the photo record.

Little North Fork

Over the entire period of record, landslides occur in greatest numbers from 2000-5000 feet in elevation **[Figure E-12]**. Their full range extends from 2000-7000 feet. A peak in total landslide acres occurs at the 4500-5000 foot range, and the greatest sediment volume delivered to channels is from landslides in the 3500-4500 foot elevation zone.

Over the 1964-1965 period, a peak in the number of landslides occurs in the 4000-4500 foot elevation range **[Figure E-13]**. The peak in landslide area occurs in the 4500-5000 foot elevation, and a major volume of sediment delivered to channels occurs from landslides in the 3500-5000 foot elevation zone. Thus, the elevation data indicates that the 1964 flood event produced significant landslide effects in the 3500-5000 elevation range.

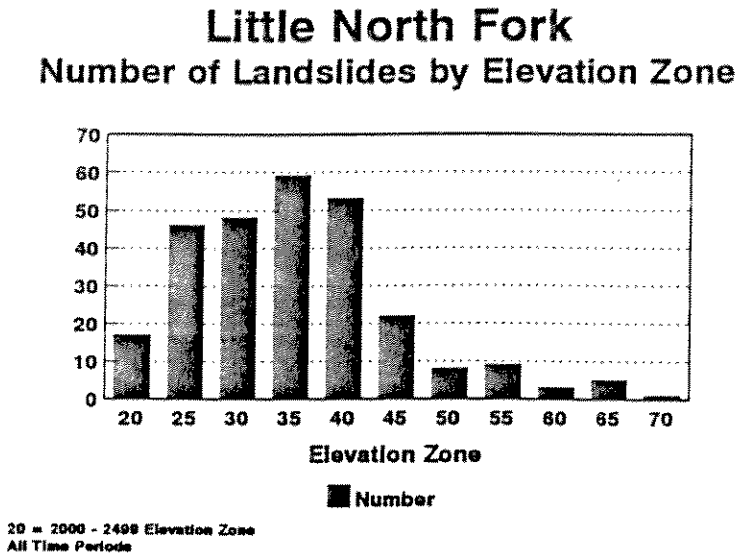
Over the 1965-1975 period, the greatest numbers of landslides occur in the elevation range of 2500-4000 feet **[Figure E-14]**. Landslide area appears to be broadly distributed from 2500-4500 feet in elevation. Volumes of sediment delivered by landslides is greatest in the 2000-4000 foot elevation. Thus, the storm events in the 1965-1975 period produced significant landslide effects at lower elevations than the 1964 flood, that is in the 2000-4000 foot elevation range.

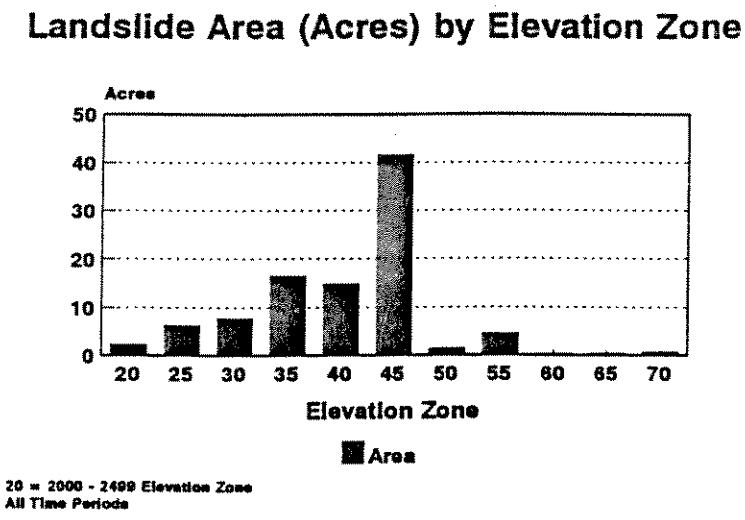
Negro Creek

Over the entire period of record, landslides extend over the elevation range from 1000 to 5000 feet **[Figure E-15]**. The majority of landslides are distributed from 2000 to 4000 feet in elevation. Landslide area is concentrated in the 2000 to 3000 foot elevation zone, as is volume of sediment delivered by landslides.

Over the 1975 to 1989 period, the number of landslides is concentrated in the 2000-4000 foot elevation zone **[Figure E-16]**. A peak in landslide area occurs in the 2000-2500 zone, and the greatest volume of sediment delivered to channels is from landslides in the 2000-3000 foot elevation zone.

Thus, in the recent period, 1975-1989, landslide occurrence and effects are most significant in low to intermediate elevation ranges of 2000-4000 feet. Their were not enough landslides occurring in other time periods to provide significant relationships.





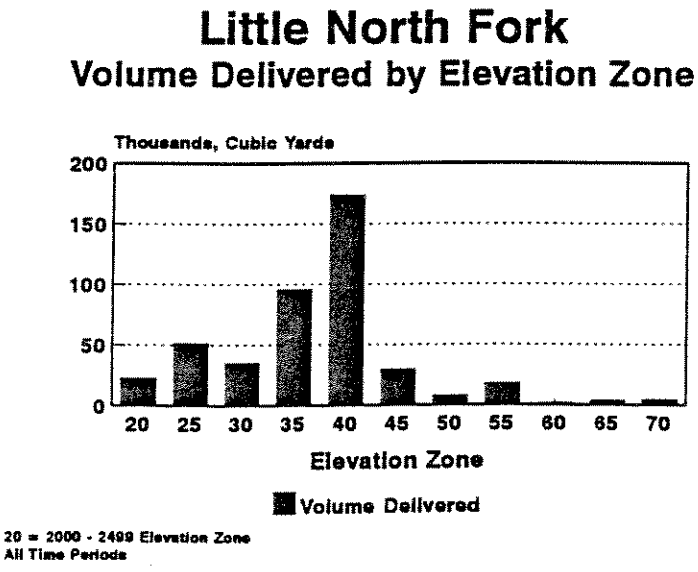
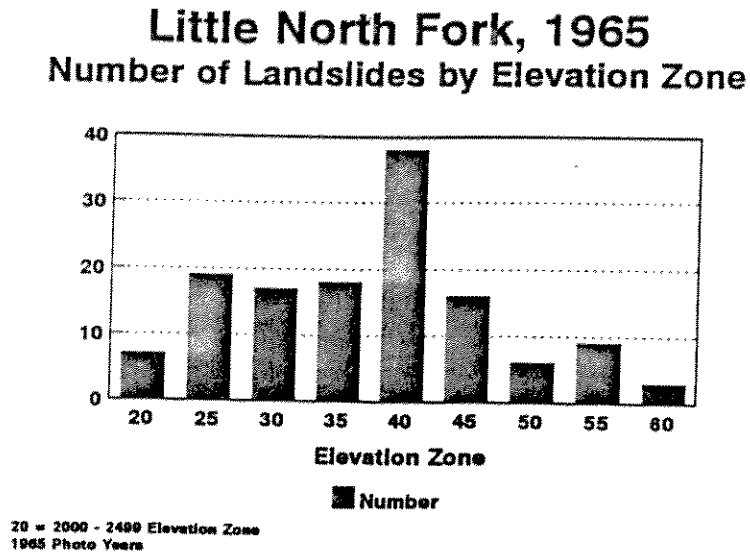
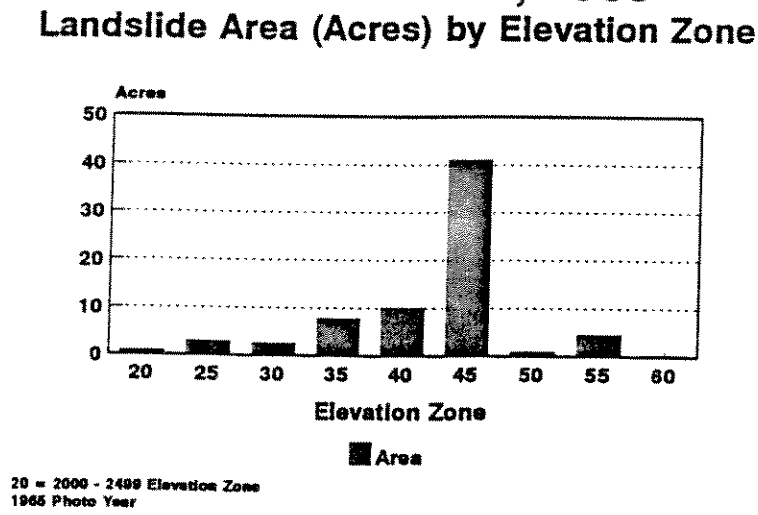


Figure E-12. Little North Fork watershed, number, area, and volume delivered by landslides by elevation zone.





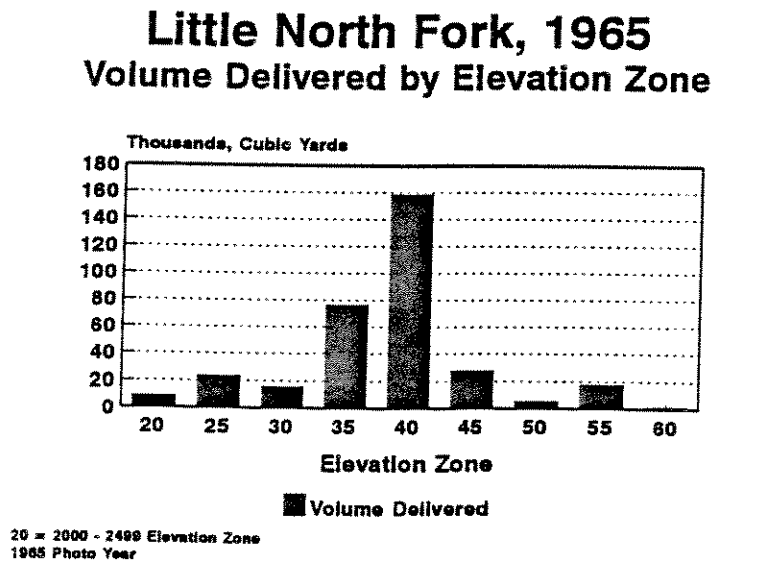
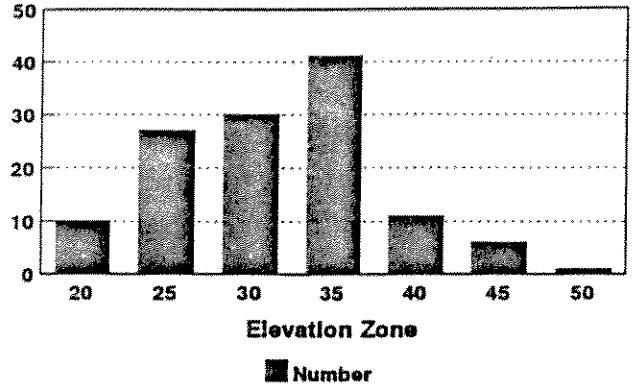


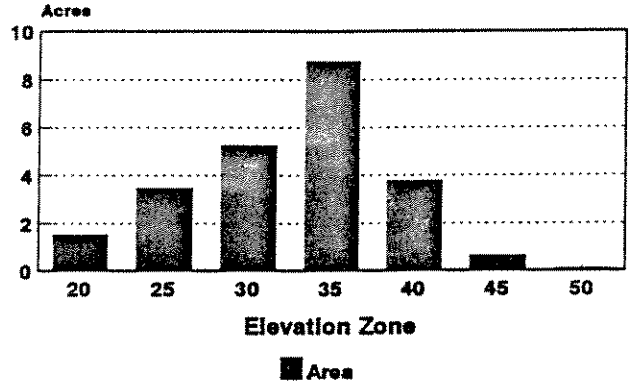
Figure E-13. Little North Fork, occurrence of landslides by elevation zone for the 1965 photo year.

Little North Fork, 1965-1975
Number of Landslides by Elevation Zone



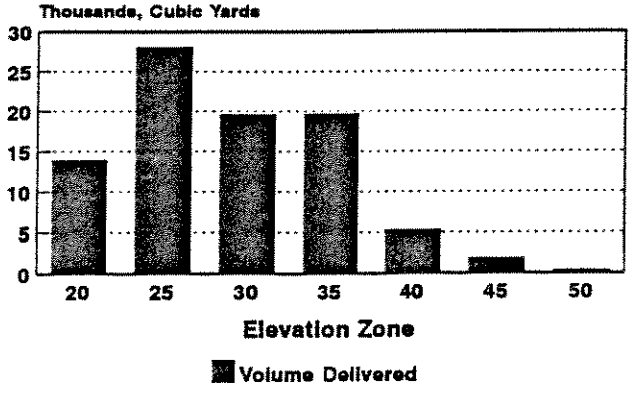
20 = 2000 - 2499 Elevation Zone
Photo Years 1971, 1972, 1975

Little North Fork, 1965-1975
Landslide Area (Acres) by Elevation Zone



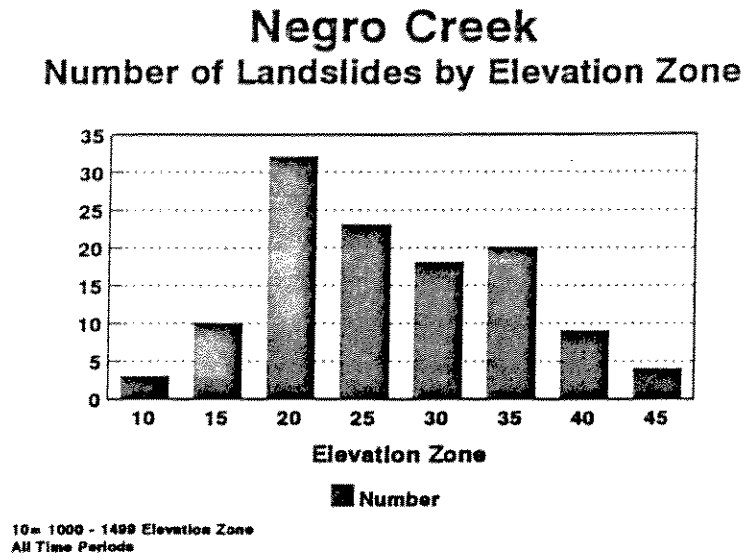
20 = 2000 - 2499 Elevation Zone
Photo Years, 1971, 1972, 1975

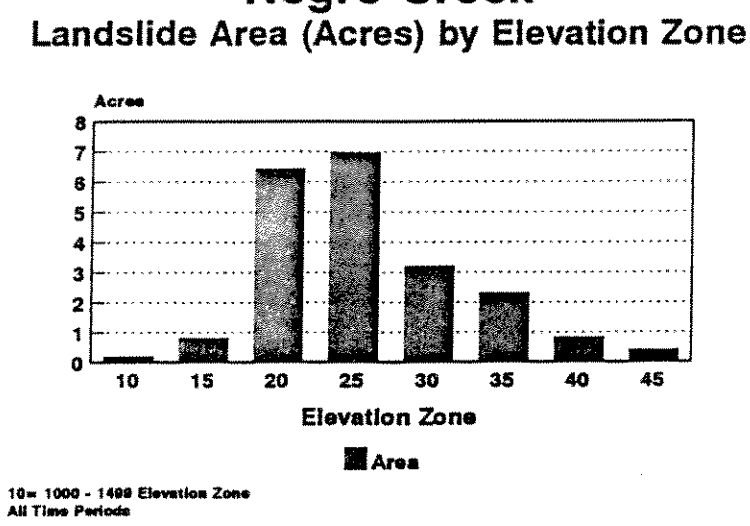
Little North Fork, 1965-1975
Volume Delivered by Elevation Zone



20 = 2000 - 2499 Elevation Zone
Photo Years 1972, 1972, 1075

Figure E-14. Little North Fork, occurrence of landslides by elevation zone for the 1965-1975 period.





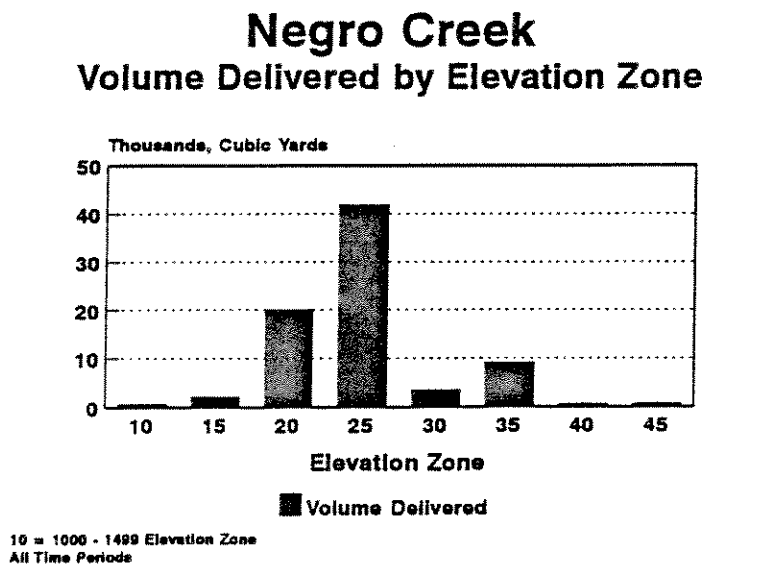
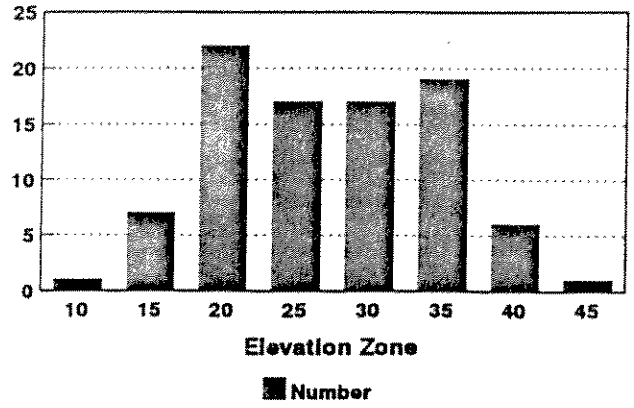


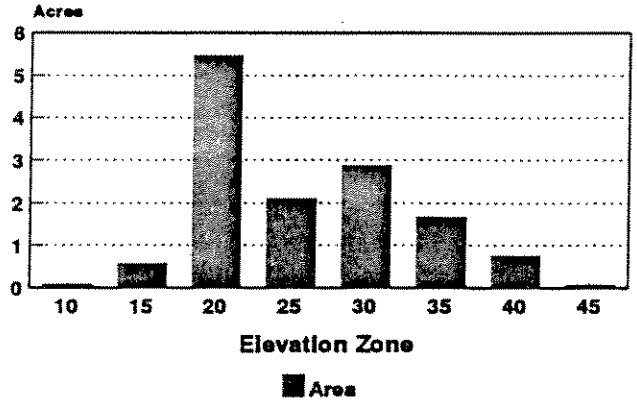
Figure E-15. Negro Creek watershed, number, area, and volume delivered by landslides by elevation zone.

Negro Creek, 1975-1988
Number of Landslides by Elevation Zone



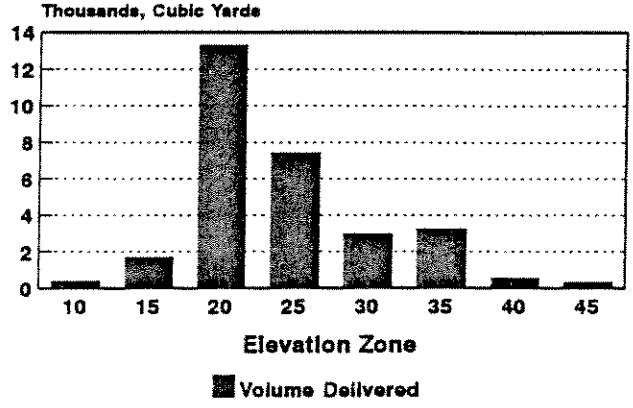
10= 1000 - 1499 Elevation Zone

Negro Creek, 1975-1988
Landslide Area (Acres) by Elevation Zone



10= 1000 - 1499 Elevation Zone

Negro Creek, 1975-1988
Volume Delivered by Elevation Zone



10 = 1000 - 1499 Elevation Zone

Figure E-16. Negro Creek watershed, occurrence of landslides by elevation zone, 1975-1988 period.

SEDIMENT PRODUCTION

A sediment budget is presented for the Little North Fork and Negro Creek watersheds. A sediment budget is a quantitative evaluation of rates of sediment production, delivery, transport, and storage in a basin. For this sediment budget, sediment production and delivery to stream systems is evaluated; transport or sediment routing and storage of sediment is not evaluated in this study.

Sediment production is defined here as any process of mobilization and delivery of sediment to a topographically-defined perennial, intermittent, and ephemeral channel. Sediment production for both watersheds was evaluated for two general processes: [1] landsliding, [2] surface erosion. A third process, channel erosion, was qualitatively evaluated. The three process constitute the major components of a sediment budget. The methods of data collection, analysis and interpretation of results are discussed for each of the three components separately.

Sediment Production from Landslides

Field and air photo inventories were utilized to measure landslide volumes. The sediment budget period extends from 1944 to 1988. Air photos from 1944 allowed identification of large landslides as far back as 1920, since debris slides are visible forymore than 20 years before vegetation growth obscures them. Landslides initiated over the budget period, are the primary producers of sediment in the two study basins.

Data Collection Methods and Analysis

To determine sediment production from landslides we evaluated total mobilized sediment, sediment stored within the landslide or below the slope, and sediment delivered to channels. The procedure to measure landslides in the field consisted of dividing the landslide scar into simple geometrical segments. The average length, width, and depth perpendicular to slope for each segment was measured and recorded. Measurements were commonly made with a tape or rangefinder; less commonly, dimensions were paced off, or estimated from across the inner gorge canyons. Landslide depth was considered in two ways to arrive at an estimate of delivered and total mobilized volume. Depth measured to calculate delivered volume consisted of the thickness of the evacuated portion of the landslide. Depth measured to calculate mobilized volume of the landslide consisted of the total thickness from the estimated original ground surface to the landslide shear plane. The volume delivered to the channel in most cases, was calculated as the difference between the evacuated portion of the landslide any material stored on the landslide slope, on the slide toe or below the landslide.

Units of measurement for landslide length, width and depth are in feet; areas are calculated in square feet and acres; volumes of sediment mobilized, stored, and delivered are expressed as yds^3. Sediment yield is expressed as volume per unit area or yds^3 per acre.

In addition to information about landslide area and volume, data was collected on a variety of landslide attributes such as slope steepness, aspect, disturbance class, bedrock type and geomorphic terrane type **[Figure E-2 ; Appendix E1]**.

A total of 373 landslides were inventoried in Little North Fork; of these, 158 were measured in the field; 113 were interpreted from air photos and 102 were evaluated by Pillsbury [1976]. A total of 119 landslides were inventoried in Negro Creek; all were measured in the field.

Quality Control of Measured Variables

Five workers measured a total of 277 landslides in the field, in both watersheds studied. Due to constraints of time and limited access, studies of reproducibility of field measurements by the different workers were not carried out. Two workers evaluated landslide areas, estimated depths and delivered volumes from air photographs in Little North Fork watershed. Estimates of landslide depth, or the thickness of evacuated portion, were made directly from air photo interpretation, applying professional judgement where necessary, and knowledge from measurement of similar landslides in the field. Pillsbury [1976] used a regression equation to determine landslide volume from map area.
A limited assessment of variation in measurement off of air photos of the same landslide by two different workers was carried out based on a sample of 11 landslides from Little North Fork. Though the sample is not statistically valid, the variation in landslide map area by the two workers varied from 0 to 60%. Estimates of the volume delivered varied from 14 to 41%.

A limited assessment of the variation in landslide map area and delivered volume between field measured and air photo-interpreted landslides was carried out on a sample of 10 landslides. Though the sample is not statistically valid, the variation in landslide map area varied from a low of 5% to a high of 49%. The variation observed in volume delivered was from a low of 1% to a high of 53%.

The landslides in clear cut units 1, 2, 3, 4, 5, and 6, evaluated by N. Pillsbury were re-evaluated as part of this study by one worker. Pillsbury used stereoplotter techniques and observed a total of 102 landslides in the six clear cuts, with a total landslide scar area of 8.2 acres and total volume of sediment delivered to channels of 42,305 yds^3. The re-evaluation of landslides in these clear cuts using scaling methods on 1972 air photos observed a total of 117 landslides in the harvest units, a landslides scar area of 7.5 acres and a total volume delivered of 48,550 yds^3 **[Table E-17]** . Though more landslides were counted, the landslide scar areas and total volume delivered are remarkably similar. Pillsbury [1976] did not measure or evaluate road-related landslides. As **Table E-17** indicates, road-related landslides within or bordering the clear cut units, as measured from the 1975 photos, scarred 1.8 acres and delivered 16,732 yds^3 of sediment. Fewer landslides were noted in the 1975 air photos as compared to the 1972 photos. The decrease in number, area, and volume delivered is attributed to the differences in the scale of the photos [1972, 1:12,000; 1975, 1:16,000], and the growth of vegetation on the debris slides.

Table E-17. Number of landslides, scar area [acres], and volume delivered [yds^3] from Pillsbury 1976, and from the 1972 and 1975 air photos used as part of this study.

LANDSLIDES IN HARVEST UNITS

Pillsbury			*1972 Photos*			*1975 Photos*		
Unit No.	**Area Acres**	**Vol. Del.**	**# Slides**	**Area Acres**	**Vol. Del.**	**# Slides**	**Area Acres**	**Vol. Del.**
1	2.109	10341	25	1.607	10370	19	1.276	8928
2	1.187	5947	11	0.707	4565	6	0.384	2688
3	1.909	11072	26	1.672	10790	10	0.640	4480
4a,b	1.549	7547	36	2.314	14940	14	1.172	1536
5a,c	1.144	5843	16	1.029	6640	5	0.425	2960
6	0.294	1555	3	0.193	1245	1	0.145	1008
TOTAL	8.192	42305	117	7.552	48550	55	4.042	28228

Table E-17 continued.

ROAD-RELATED LANDSLIDES
This Study, 1975 Photos

Unit No.	# Slides	Area Acres	Volume Delivered
1	1	0.110	768
2	1	0.080	840
3	-	-	-
4a,b	7	0.892	9388
5a,c	3	0.728	5736
6	-	-	-
TOTAL	12	1.810	16732

Comparison of Results of the Salmon Watershed Air Photo Study and Field Inventories

The results of the Salmon River Basin air photo inventory are compared to those obtained by detailed field inventories in Little North Fork, and Negro Creek in the following section.

The field inventory at Little North Fork identified a total of 483,169 yds³ of landslide-derived sediment from 1944-1988. Of this, 130,906 yds³ occurred from 1965-1975. This compares to 402,036 [1944-1988] and 140,510 yds³ [1965-1975] respectively in the basin-wide photo inventory. The photo inventory identified a total of 184 landslides, compared to 373 by the field inventory for 1944-1988.

The field inventory at Negro Creek identified a total of 78,145 yds³ of landslide material from 1944-1988, with 3,369 yds³ occurring in 1965-1975. The basin-wide photo study identified 43,102 and 5,824 yds³ respectively. The photo inventory identified 12 landslides from 1944-1988 compared to 119 for the field inventory.

The basin-wide photo inventory missed a large proportion of small inner gorge slumps and debris landslides in the sample watersheds. Landslides less than 500 yds³ in delivered volume account for 55% of the total number identified by the field inventory at Little North Fork, and 83% of the total at Negro Creek.

In summary, the basin-wide photo inventory underestimated landslide volumes over the period 1944-1988 in Little North Fork by about 17%, and by about 45% in Negro Creek. The number of slides was underestimated by 51% at Little North Fork, and 90% at Negro Creek. One reason that the results of the two inventories were more similar for the landslide volumes than for number of landslides was than many of the landslides missed by the photo inventory were very small. The majority of the landslides which were undetected during the photo interval were debris slides within the inner gorge and active slumps and earthflows. Debris slides in the inner gorge are obscured by timber canopy and active slump-earthflows which are difficult to detect on air photos unless they have debris slide components at the toe. Another factor influencing the number of undetected landslides was that larger scale photos were used in the field studies [for example, 1:10,000 at Little North Fork], and smaller scale photos were used for part of the basin-wide study [the scale of the 1988 photos is 1:40,000]. Previous field studies undertaken by the USFS during the winter of 1982-1983 in areas with slump and earthflow terrane [Horn Creek, Fong Wah Gulch, Lunch Creek, and Crapo Creek] revealed active slumping in areas which had burned in 1977. Some of this activity was not detected by the basin-wide photo inventory. Thus, the basin photo inventory may have underestimated landslide volume in slump-earthflow terrane disturbed prior to 1982 by as much as 50%.

SEDIMENT PRODUCTION BY LANDSLIDES

In the following sections, data is presented on the occurrence of landslides in the two study watersheds. Emphasis will be on the variation in landslide occurrence over time, with disturbance regime, and geomorphic terrane type.

Little North Fork : Landslide Distribution By Time Period, and Disturbance Class

Data on landslide area, and volume delivered to channels, grouped by time period and disturbance class is given in **Table E-18**. Time periods evaluated are defined by photo year and selected photo age brackets. Time periods used are 1944, 1964-1965, and 1965-1975. No landslides were observed in the field or on photos more recent than 1975. Landslides were found to occur within specific disturbance conditions in the basin: in harvest units, within the road prism, and in natural or undisturbed forested land.

Table E-18. Number of landslides, landslide area [acres], and delivered sediment volume [yds³] by time period and disturbance class for Little North Fork watershed.

Little North Fork

WS	Class	1944			1964-1965			1965-1975			1944-1988		
		#	A	V	#	A	V	#	A	V	#	A	V
LNS	Undisturbed Harvest Road	11	2.1	19673	133	69.9	332590	47 114 68	5.2 14.5 11.9	37285 45078 48544	191 114 68	77.3 14.5 11.9	389548 45078 48544
	TOTAL	11	2.1	19673	133	69.9	332590	229	31.6	130907	373	103.7	483170
HLS	Undisturbed Harvest Road	6	1.0	12662	81	24.5	255926	12 6 5	1.3 3.0 1.8	6931 903 1604	99 6 5	26.9 3.0 1.8	275519 903 1604
LOW	Undisturbed Harvest Road	1	0.1	0	38	44.1	62489	26 108 64	2.9 11.5 10.1	25623 44175 47172	65 108 64	47.0 11.5 10.1	88112 44175 47172
SPE	Undisturbed				2	0.2	2724	1	0.02	12	3	0.2	2736
UNC	Undisturbed	4	1.0	7011	12	1.1	11451	7	1.0	4486	23	3.2	22948

Notes: Watershed Designations are as follows:

LNS - Little North Fork
HLS - Headwaters Sub-basin
LOW - Lower Sub-basin
SPE - Specimen Creek Sub-basin
UNC - Uncles Creek Sub-basin

Over the entire period of record, 1944-1988, 373 landslides scarred 103.5 acres of land and delivered 483,170 yds³ of sediment to stream channels. **Figure E-17** graphically displays occurrence of landslides by photo year throughout Little North Fork watershed. The data indicates that 81% of the total volume delivered was from landslides on undisturbed slopes, 9% was from landslides in harvest units, and 10% was from landslides originating in the road prism.

The volume of material delivered by landsliding resulting from the flood of 1964 comprises 69% of the total record. All of the landslides occurred in undisturbed conditions. Landslides attributed to the 1964 flood event disturbed 69.9 acres of forested land and delivered 332,590 yds³ of sediment to stream channels. The flood-related damage from landslides was greatest in the Headwaters [HLS] and Lower [LOW] sub-basins.

During the period 1965-1975, 229 landslides scarred 31.6 acres of land and delivered 130,907 yds³ of sediment to stream channels. The total volume of material delivered comprises 27% of the entire record, 1944-1988. Landslides in harvested units scarred 14.5 acres of land and delivered 45,079 yds³ of sediment to stream channels. Landslides originating within the road prism damaged 11.9 acres of land and delivered 48,544 yds³ of material to stream channels. The majority of the landslides occurred in the LOW sub-basin. The distribution of delivered sediment by disturbance class shows that 28% of the total volume delivered was from landslides in undisturbed conditions, 34% from landslides in harvest units and 37% was from landslides related to roads. In the period 1965-1975, the acres of undisturbed, harvested and roaded land was 19,925, 794 and 82, respectively.

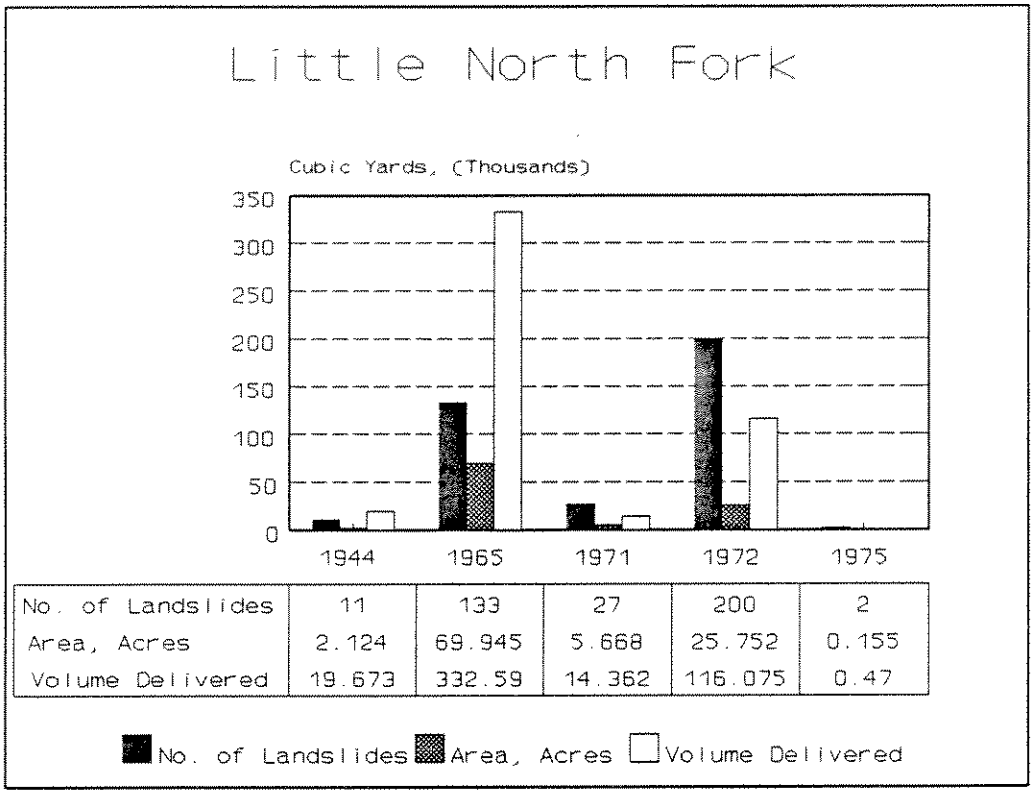
Little North Fork: Landslide Distribution by Geomorphic Terrane Types

The landscape of the Salmon River Basin has been subdivided into 12 geomorphic terrane types based on attributes of slope gradient, slope position, origin of deposits [e.g. glacial or slump-earthflow], and bedrock [de la Fuente, 1991]. The 12 geomorphic terrane types are described in **Table E-19**. Active landslides [terrane type #1] were not evaluated as a single geomorphic type in this analysis as active landslides may occur in all geomorphic terranes.

Table E-19. Descriptions of the 12 geomorphic terrane types.

Terrane #	Terrane Description
1•	Active Landslides
2	Toe Zones of Dormant Landslide Deposits
3	Dormant Landslide Deposits; Excluding Toe Zone and Inner Gorge
4	Mountain Slope; Granitic, Steep, (> 65%)
5	Mountain Slope; Granitic, Low to Moderate Slope, (0-65%)
6	Mountain Slope; Non-Granitic, Steep, (> 65%)
8	Mountain Slope, Non-Granitic, Low to Moderate Slope (0-65%). Also Includes Alluvium (Qal) and Lake Deposits
9	Inner Gorge Developed in Landslide, Glacial, or Terrace Deposits
10	Inner Gorge Developed in Granitic Mountain Slope
11	Inner Gorge Developed in Non-Granitic Slope
12	Debris Basins: Steep, > 65% Fan-Shaped Headwall Areas
13	Glacial, Terrace, and Fan Deposits, Excluding Inner Gorge

• Geomorphic terrane type 1 was excluded from analysis in this study.



	1944	1965	1971	1972	1975
No. of Landslides	11	133	27	200	2
Area, Acres	2.124	69.945	5.668	25.752	0.155
Volume Delivered	19.673	332.59	14.362	116.075	0.47

Figure E-17. Number of landslides, area in acres, and volume delivered to channels by photo year for Little North Fork Watershed.

The geomorphic terrane types and area in acres present in Little North Fork are listed in **Table E-20**. Inner gorges [including geomorphic terrane types 9, 10, and 11] encompass 3,274 acres, or 16 percent of the basin, **[Figure E-18]**. Steep granitic mountain slopes comprise 2939 acres [14%], and steep non-granitic mountain slopes comprise 5058 acres [24%], **[Figure E-19]**.

Table E-20. Summary of the distribution of geomorphic terrane types, area [acres], and percent area for Little North Fork.

Little North Fork

Geomorphic Type	Acres	Percent Area
2 Toe Zones Dormant Landslide Deposits	6	< 1
3 Dormant Landslide Deposits	356	1
4 Mountain Slope, Granitic, Steep	2939	14
5 Mountain Slope, Granitic, Low-Mod. Slope	4649	22
6 Mountain Slope, Non-Granitic, Steep	5058	24
8 Mountain Slope, Non-Granitic, Low-Mod. Slope	2104	10
9 Inner Gorge in Landslide, Glacial or Terrace Deposits	317	2
10 Inner Gorge in Granitic Mountain Slope	1152	6
11 Inner Gorge in Non-Granitic Mountain Slope	1805	9
12 Debris Basins	793	4
13 Glacial, Terrace, Fan Deposits	1622	9
TOTAL	20801	100

The distribution of landslides by geomorphic type and disturbance class is illustrated in **Table E-21**. The most common occurrence of landslides is in the inner gorge. Landslides within inner gorges are the most numerous, encompass the most area, and have delivered the most sediment to channels. Over the entire period of record, landslides within geomorphic terrane type 10, inner gorges developed in granitic mountain slopes, have contributed 58% of the total volume of sediment to channels; geomorphic terrane type 9, inner gorges developed in landslide, glacial or terrace deposits, 24%; geomorphic terrane type 11, inner gorges within non-granitic mountain slopes, 9%. Landslides occurring in steep granitic mountain slopes [geomorphic terrane type 4] have contributed 4% of the total volume.

The distribution of landslides in geomorphic terrane types, occurring as a result of the 1964 flood is similar to the pattern observed over the entire record: 57% of the volume delivered in 1964-1965 is from landslides in geomorphic terrane type 10; 29% is from geomorphic terrane type 9; and 10% is from geomorphic terrane type 10.

Landslide occurrence in the period 1965-1975 is spread across geomorphic terrane types and disturbance classes **[Table E-21]**. Once again, inner gorges areas in undisturbed land shows significant numbers of landslides; total volume delivered from geomorphic terrane type 10 is 10% of the total volume delivered from all disturbance classes in the time period. No landslides were noted associated with inner gorges developed in landslide, glacial or terrace deposits, in harvest or road disturbance conditions. The 102 landslides occurring in geomorphic terrane type 10, associated with harvested areas are from Pillsbury [1976]. The volume of sediment delivered is 32% of the total volume for this period. Landslides occurring in the road prism associated with geomorphic terrane type 10 account for 27% of the total volume; those in geomoorphic terrane type 4 account for 5%, and those in geomorphic terrane type 6 account for 3%.

Little North Fork

Inner Gorge Geomorphic Terranes

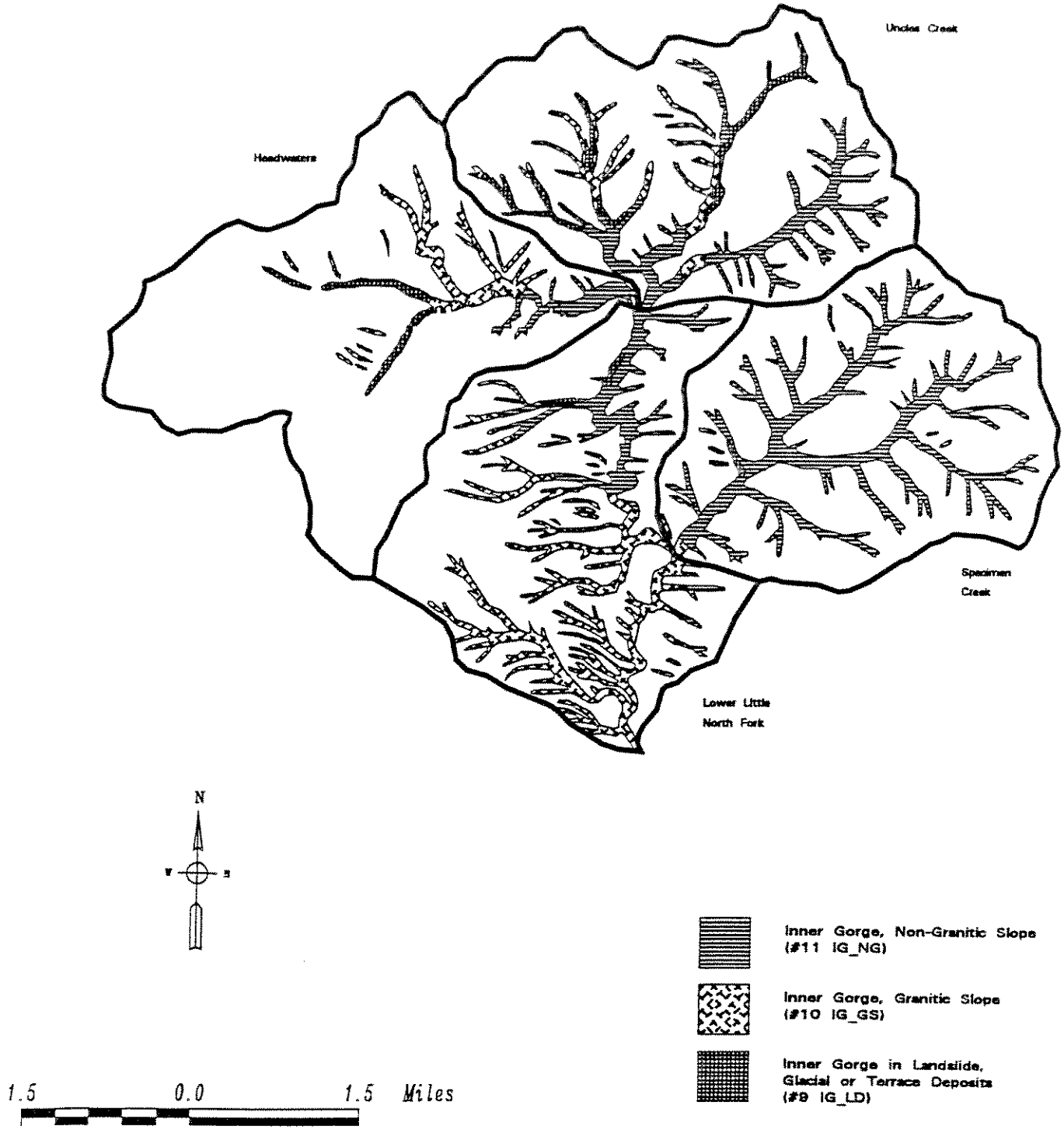


Figure E-18. Map of the Inner gorge geomorphic terranes of Little North Fork Watershed.

Little North Fork

Geomorphic Terranes

(Excluding Inner Gorge)

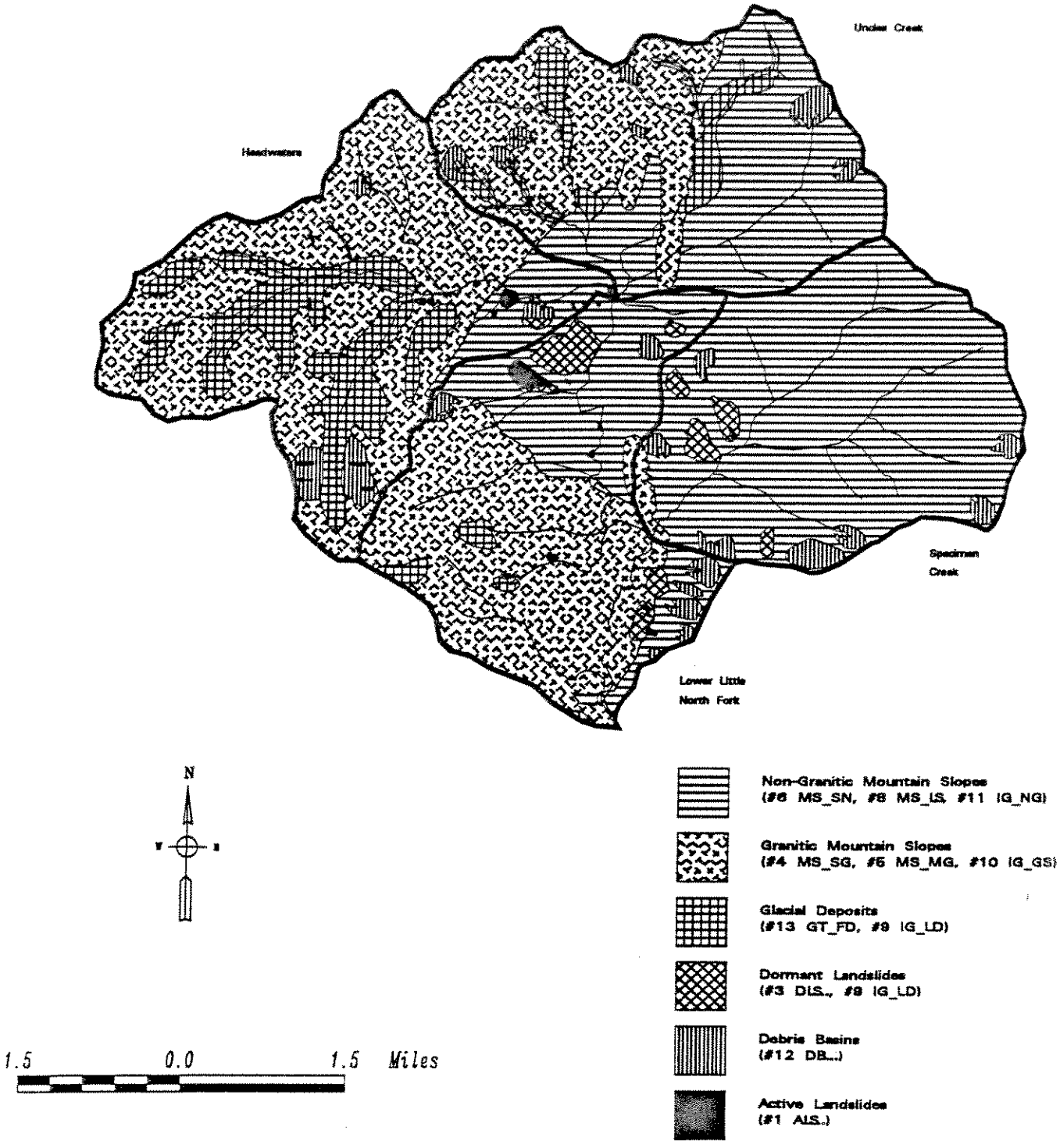


Figure E-19. Map of the geomorphic terranes of Little North Fork Watershed, excluding the inner gorge.

Table E-21. Number of landslides, landslide area [acres] and delivered sediment volume [yds³] by time period, disturbance class and geomorphic terrane type.

Little North Fork
1944 and 1964-1975

	1944			1964-1965		
Terrane Type	#	A	V	#	A	V
2						
3				0.5	35	0
4	2	0.1	748	6	0.6	3439
5	1	0.1	0	2	0.1	435
6				2	0.1	435
8				1	0.1	256
9	3	1.1	11855	41.5	13.4	96344
10				52	12.7	188673
11	1	0.1	233	23	4.2	34278
12	4	0.8	6837	3	0.2	1422
13				2	3.5	6729
TOTAL	11	2.1	19673	133	69.9	332590

Little North Fork
1965-1975

	Undisturbed			Harvest			Roads		
Terrane Type	#	A	V	#	A	V	#	A	V
2									
3				1	0.1	555	1	0.03	184
4	1	0.5	8200	3	0.2	1314	16	1.7	6309
5	2	0.1	152				7	0.5	1415
6	1	0.1	273	2	3.1	0	10	3.0	4262
8				1	0.02	57	1	0.1	286
9	10	1.3	8402						
10	23	2.2	13532	102	8.2	42306	30	6.3	34822
11	10	1.1	6726	5	3.0	846	3	0.3	1266
12									
13									
TOTAL	47	5.3	37285	114	14.6	45076	68	11.9	48544

Table E-21 continued.

Little North Fork
1944-1988

	Undisturbed			Harvest			Roads		
Terrane Type	#	A	V	#	A	V	#	A	V
2									
3	0.5	35	0	1	0.1	555	1	0.03	184
4	9	1.2	12387	3	0.2	1314	16	1.7	6309
5	5	0.3	587				7	0.5	1415
6	3	0.2	1287	2	3.1	0	10	3.0	4262
8	1	0.1	256	1	0.02	57	1	0.1	286
9	54.5	15.8	116601						
10	75	14.9	202205	102	8.2	42306	30	6.3	34822
11	34	5.4	41237	5	3.0	846	3	0.3	1266
12	7	1.0	8259						
13	2	3.5	6729						
TOTAL	191	77.4	389548	114	14.6	45078	68	11.9	48544

Little North Fork
1944-1988

	All Disturbance Classes		
Terrane Type	#	A	V
2	0	0	0
3	2.5	35.13	739
4	28	3.1	20010
5	12	0.8	2002
6	15	6.3	5549
8	3	0.2	599
9	54.5	15.8	116601
10	207	29.4	279333
11	42	8.7	43349
12	7	1.0	8259
13	2	3.5	6729
TOTAL	373	103.93	483,170

2 Toe Zones of Dormant Landslide Deposits
3 Dormant Landslide Deposits; Excluding Toe Zone and Inner Gorge
4 Mountain Slope; Granitic, Steep, (> 65%)
5 Mountain Slope; Granitic, Low to Moderate Slope, (0-65%)
6 Mountain Slope; Non-Granitic, Steep, (> 65%)
8 Mountain Slope, Non-Granitic, Low to Moderate Slope (0-65%). Also Includes Alluvium (Qal) and Lake Deposits
9 Inner Gorge Developed in Landslide, Glacial, or Terrace Deposits
10 Inner Gorge Developed in Granitic Mountain Slope
11 Inner Gorge Developed in Non-Granitic Slope
12 Debris Basins: Steep, > 65% Fan-Shaped Headwall Areas
13 Glacial, Terrace, and Fan Deposits, Excluding Inner Gorge

Negro Creek: Landslide Disturbance by Time Period, and Disturbance Class.

Data on landslide area and volume of material delivered to channels, grouped by time period and disturbance class is given in **Table E-22.** Time periods evaluated are defined by photo year and selected photograph age brackets. Time periods used are: 1944, 1955-1964, 1964-1965, and 1975-1988.

Table E-22. Number of landslides, area (acres) and sediment volume delivered to channels (yds³) grouped by time period and disturbance class for Negro Creek watershed.

NEGRO CREEK

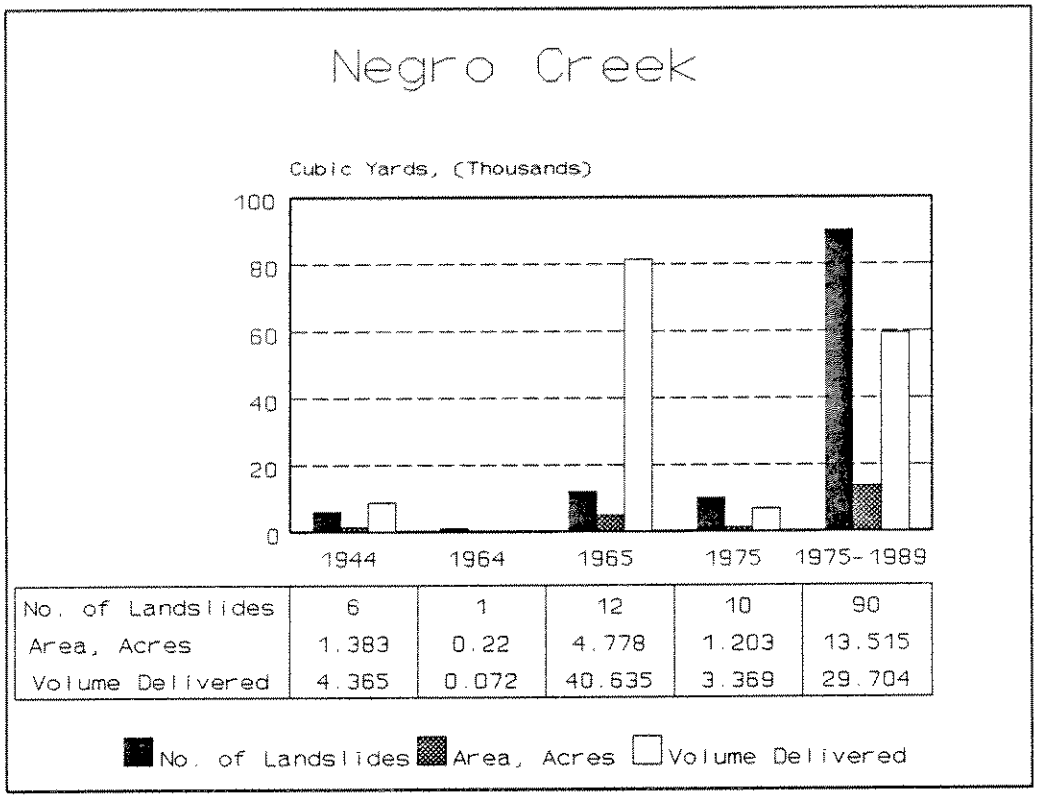
	1944			1955-1964			1964-1965		
Class	**#**	**A**	**V**	**#**	**A**	**V**	**#**	**A**	**V**
Undisturbed	6	1.4	4365				10	4.7	40448
Harvest									
Road				1	0.2	72	2	0.1	187
Fire									
TOTAL	6	1.4	4365	1	0.2	72	12	4.8	40635

	1965-1975			1975-1988			1944-1988		
Class	**#**	**A**	**V**	**#**	**A**	**V**	**#**	**A**	**V**
Undisturbed	6	0.9	3101				22	7.0	47914
Harvest									
Road	4	0.3	268	8	1.2	2575	15	1.8	3102
Fire				82	12.3	27129	82	12.3	27129
TOTAL	10	1.2	3369	90	13.5	29704	119	21.1	78145

Over the entire period of record, 1944-1988, 119 landslides encompassed 21.1 acres, mobilized 689,566 yds³, and delivered 78,145 yds³ of sediment to stream channels.

Figure E-20 graphically displays the occurence of landslides by photo year in Negro Creek Watershed. The data indicates that 61% of the total volume delivered was from landslides on undisturbed slopes, 4% was from landslides originating in the road prism and 35% was from landslides in areas burned by the Hog fire and the fires of 1987.

The volume of material delivered to streams from landslides resulting from the food of 1964 comprises 52% of the total record. Ten landslides occurred in undisturbed areas, and two landslides occurred associated with roads. The landslides activated 4.8 acres of land and delivered 40,635 yds³ of sediment to stream channels.



	1944	1964	1965	1975	1975-1989
No. of Landslides	6	1	12	10	90
Area, Acres	1.383	0.22	4.778	1.203	13.515
Volume Delivered	4.365	0.072	40.635	3.369	29.704

Figure E-20. Number of landslides, area in acres, and volume delivered to channels by photo year, Negro Creek Watershed.

During the period 1965-1975 ten landslides scarred 1.2 acres of land and delivered a total of 3,369 yds³ of sediment to stream channels. The total volume delivered comprises 4% of the entire record. Six landslides occurred in undisturbed conditions and four are associated with roads. The distribution of delivered sediment by disturbance class shows that 92% of the volume was from landslides in natural conditions and 8% was from landslides related to roads.

The period 1975 to 1988 is extremely significant in terms of landslide production rates with in the watershed. A total of 90 landslides occurred during this time period, and are attributed to the influence of fire, [1977 and 1987], and storm events, [1975 to 1988], and peak water flows observed in the entire Salmon basin. The timing and occurrence of storm events in the period are those known from precipitation records at Sawyers Bar Ranger Station and Fire Station. High peak discharges measured at the gaging station at Somes Bar are recorded during 1983 and 1986. One landslide, the Zane Landslide, began to show active movement in 1989; this landslide is included in the 1975-1988 age bracket.

Though the exact age of landsliding is indeterminate for many of the landslides **[Table E-16]**, the age of landslides in most cases can be firmly determined as post-dating the 1987 fires or occurring sometime during the period 1977-1987, based in field evidence.

During the period 1975-1988 a total of 90 landslides scarred and damaged 13.5 acres of land, mobilized 248,313 yds³ of material and delivered 29,704 yds³ of sediment to stream channels. The total volume delivered comprises 38% of the entire period of record. Eight landslides are associated with roads and 82 are associated with areas burned by fires. Approximately 91% of the volume delivered to channels was from fire-related landslides and the remainder was from landslides occurring within the road prism.

Negro Creek: Landslide Distribution by Geomorphic Terrane Types.

The areal distribution [acres] of geomorphic terrane types in Negro Creek watershed are listed in **Table E-23.** Inner gorges [including geomorphic terrane types 9 and 11] encompass 385 acres, or 15% of the basin. Steep non-granitic mountain slopes comprise 276 acres [10%] and non-granitic mountain slopes [0-65%], comprise 547 ycres [21%], **[Figure E-21]**.

Table E-23. Summary of distribution of geomorphic terrane types, area [acres], and percent area for Negro Creek.

Negro Creek

Geomorphic Type	Acres	Percent Area
2 Toe Zones Dormant Landslide Deposits	0	0
3 Dormant Landslide Deposits	1408	54
4 Mountain Slope, Granitic, Steep	0	0
5 Mountain Slope, Granitic, Low-Mod. Slope	0	0
6 Mountain Slope, Non-Granitic, Steep	276	10
8 Mountain Slope, Non-Granitic, Low-Mod. Slope	547	21
9 Inner Gorge, in Landslide, Glacial of Terrace Deposits	255	10
10 Inner Gorge in Granitic Mountain Slopes	0	0
11 Inner Gorge in Non-Granitic Mountain Slopes	130	5
12 Debris Basins	0	0
13 Glacial, Terrace, Fan Deposits	0	0
TOTAL	2616	100

The distribution of landslides by geomorphic type and disturbance class is illustrated in **Table E-24**. Landslides within the inner gorge are most numerous, encompass the most total area, and have delivered the most sediment to stream channels. Over the entire period of record, landslides originating within geomorphic terrane type 9, [inner gorge developed within landslide deposits], have contributed 31% of the total volume of sediment to channels; landslides originating in geomorphic terrane type 11, [inner gorges developed in non-granitic slopes] have contributed 63% of the total volume. Landslides within dormant slide deposits have delivered 4% of the total volume.

The distribution of landslides in geomorphic terrane types occurring as a result of the 1964 flood in undisturbed conditions is similar to the pattern observed over the entire record. Landslides occurring in geomorphic terrane type 11 delivered 86% of the total volume for the period; 14% is from geomorphic terrane type 9.

Landslide occurrence during the period 1965-1975 is restricted to geomorphic terrane types 8, 9, and 11 in undisturbed conditions, and geomorphic terrane types 3, 8, and 9 associated with roads. Landslides in inner gorge areas within landslide deposits [geomorphic terrane type 9] contributed 20% of the total volume over the period; landslides within non-granitic inner gorges [geomorphic terrane type 11] contributed 44% of the total volume delivered for the time period. Landslides occurring in non-granitic mountain slopes of low to moderate slope steepness [geomorphic terrane type 8] contributed 28% of the total volume of the period. Landslides occurring in the road prism associated with geomorphic terrane type 8 account for 5% of the total volume; those in geomorphic terrane type 3 account for 2% and those in geomorphic terrane type 9 account for less than 1%.

Landslide occurrence during the time period 1975-1988 is somewhat spread across geomorphic terrane types and restricted to fire and road disturbance classes. Landslides associated with areas burned in the Hog fire and the 1987 fires are significant in terms of numbers, areas disturbed [scarred] and in volumes of sediment delivered to streams. Landslides associated with burned areas in geomorphic terrane type 9 [inner gorge in landslide deposits] delivered 49% of the total sediment for the time period. Landslides occurring within burned inner gorges in non-granitic slopes account for 37% of the total volume delivered. Landslides originating in dormant landslide deposits [geomorphic terrane type 3] in burned areas account for 4% of the total volume of sediment delivered. Landslides associated with roads occurred in geomorphic terrane types 3, 8, 9, and 11. Landslides occurring in the road prism in geomorphic terrane type 3 account for 5% of the total volume delivered for that time period.

Negro Creek

Geomorphic Terranes

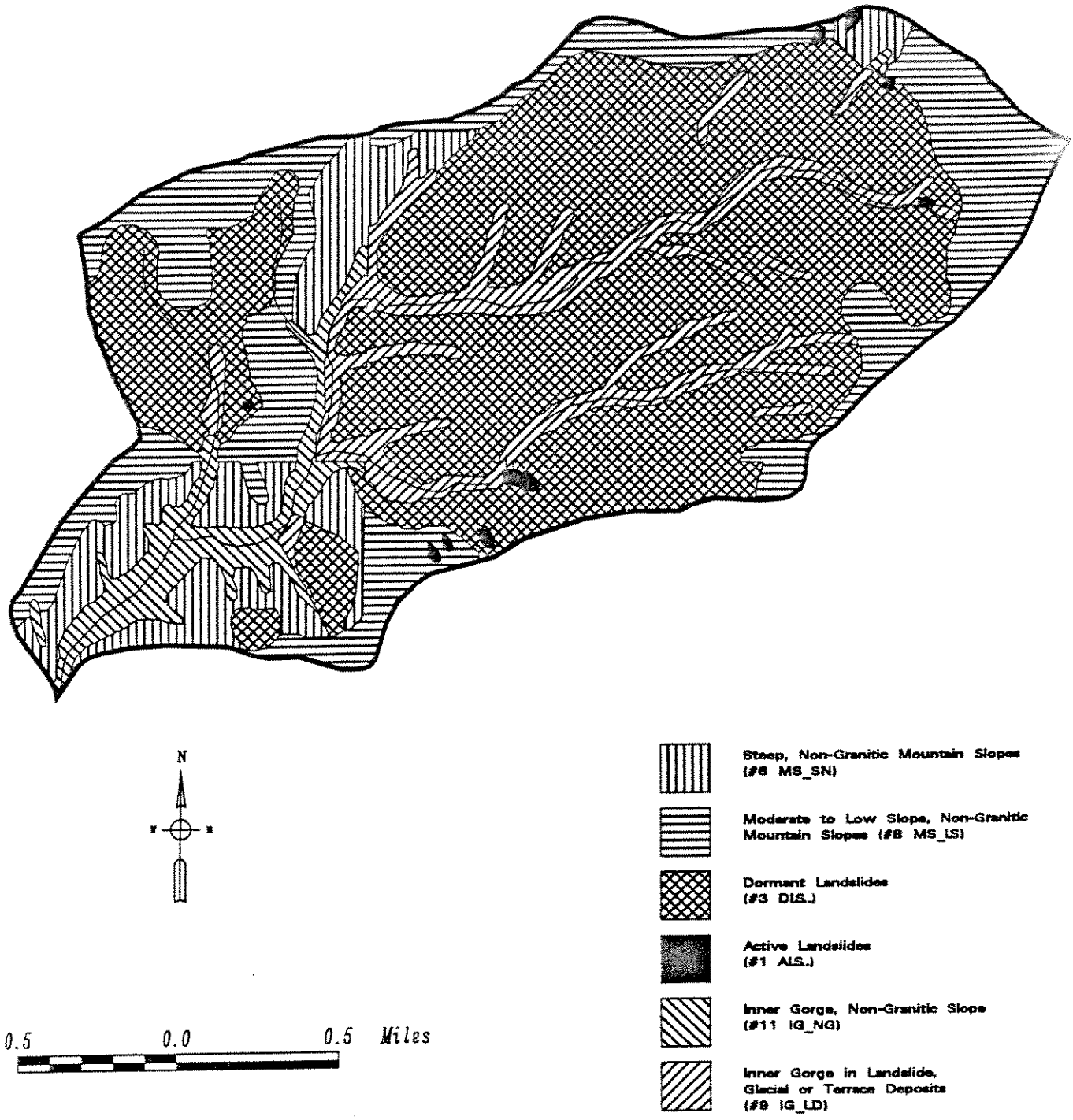


Figure E-21. Map of geomorphic terranes in Negro Creek Watershed. Active landslides represent those in the forest database as of 1991; new landslides inventoried by this study have not been added to the GIS layer.

Table E-24. Number of landslides, landslide area [acres] and delivered sediment volume [yds³] by time period, disturbance class and geomorphic terrane type for Negro Creek watershed.

Negro Creek
1944, 1955-1964

	1944, Undisturbed			1955-1964, Roads		
Geomorphic Terrane	**#**	**A**	**V**	**#**	**A**	**V**
2						
3	1	0.8	0			
4						
5						
6						
8				1	0.2	72
9	1	0.2	2400			
10						
11	4	0.3	1965			
12						
13						
TOTAL	6	1.4	4365	1	0.2	72

Negro Creek
1964-1965

	Undisturbed			Roads		
Geomorphic Terrane	**#**	**A**	**V**	**#**	**A**	**V**
2						
3						
4						
5						
6	0.5	1.8	0			
8				2	0.1	187
9	1	0.6	5800			
10						
11	8.5	2.3	34648			
12						
13						
TOTAL	10	4.7	40448	2	0.1	187

Table E-24 continued.

Negro Creek
1965-1975

	Undisturbed			Roads		
Geomorphic Terrane	#	A	V	#	A	V
2						
3				1	0.1	72
4						
5						
6						
8	1	0.3	935	1	0.2	181
9	2	0.4	690	2	0.04	15
10						
11	3	0.3	1476			
12						
13						
TOTAL	6	1.0	3101	4	0.3	268

Negro Creek
1975-1988

	Roads			Fire		
Geomorphic Terrane	#	A	V	#	A	V
2						
3	3	0.6	1523	5	2.3	1243
4						
5						
6						
8	2	0.4	417	2	0.1	330
9	2	0.1	275	52	4.2	14693
10						
11	1	0.1	360	21.75	2.8	10863
12						
13						
TOTAL	8	1.2	2575	82	12.3	27129

Table E-24, continued.

Negro Creek
1944-1989

	Undisturbed			Roads			Fire		
Geomorphic Terrane	#	A	V	#	A	V	#	A	V
2									
3	1	0.8	0	4	0.7	1595	5	2.3	1243
4									
5									
6	0.5	1.8	0				1.25	2.8	0
8	1	0.3	935	6	0.9	857	2	0.1	330
9	4	1.2	8890	4	0.14	290	52	4.2	14693
10									
11	15.5	2.9	38089	1	0.1	360	21.75	2.8	10863
12									
13									
TOTAL	22	7.0	47914	15	1.84	3102	82	12.2	27129

Negro Creek
1944-1989

	All Disturbance Classes		
Geomorphic Terrane	#	A	V
2			
3	10	3.8	2838
4			
5			
6	1.75	4.6	0
8	9	1.3	2122
9	60	5.5	23873
10			
11	38.25	5.8	49312
12			
13			
TOTAL	119	21.0	78145

2 Toe Zones of Dormant Landslide Deposits
3 Dormant Landslide Deposits; Excluding Toe Zone and Inner Gorge
4 Mountain Slope; Granitic, Steep, (> 65%)
5 Mountain Slope; Granitic, Low to Moderate Slope, (0-65%)
6 Mountain Slope; Non-Granitic, Steep, (> 65%)
8 Mountain Slope, Non-Granitic, Low to Moderate Slope (0-65%). Also Includes Alluvium (Qal) and Lake Deposits
9 Inner Gorge Developed in Landslide, Glacial, or Terrace Deposits
10 Inner Gorge Developed in Granitic Mountain Slopes
11 Inner Gorge Developed in Non-Granitic Slopes
12 Debris Basins: Steep, > 65% Fan-Shaped Headwall Areas
13 Glacial, Terrace, and Fan Deposits, Excluding Inner Gorge

SEDIMENT MODEL DEVELOPMENT AND THE USE OF LANDSLIDE-DERIVED SEDIMENT PRODUCTION COEFFICIENTS

Discussion

The landslide inventory of Little North Fork and Negro Creek Watersheds has produced data on the occurrence of landslides in specific geomorphic terrane types and disturbance classes. The volumes of sediment delivered by landslides initiated during the period 1965-1975 can be used to build a sediment model. The sediment model can be a tool to determine the volume of sediment [derived from landslides and surface erosion] that would enter the channel system under certain conditions. The first set of conditions relates to the disturbance regime in the watershed of which two classes are evaluated: [1] a natural or undisturbed condition and [2] a disturbed condition where the acres of harvested land, road, and areas burned by fire are known, for a particular time period of interest. The second condition relates to the type of climatic conditions evaluated. For this sediment model, the climatic regime that occurred during the period 1965-1975 in the Salmon River Watershed was chosen for modeling future landslide production rates. The magnitudes of the storm events during that period were on the order of a 10 to 20 year return storm event. This time period is also useful for analysis because significant disturbances, such as timber harvest and road construction had occurred by 1975.

Sediment production coefficients are one method used to develop a sediment model. A sediment production coefficient is a factor, expressed in units of yds³/per acre, that is unique for each geomorphic terrane, disturbance class, and watershed. A sediment production coefficient is calculated by dividing the total acres of a specific geomorphic terrane type in a specific disturbance class into the volume of sediment delivered by landslides in the same geomorphic terrane type and disturbance class.

LNF 1965-1975 Undisturbed Geo-Type 10 yds³		**LNF 1965-1975** Undisturbed Geo-Type 10 Acres	**LNF 1965-1975** Sediment Production Coefficient yds³/Acre
13532 c.y.	/	990 acres =	13.7 yds³/acre

Thus, the sediment production coefficient for landslides in geomorphic terrane type 10 [inner gorge developed in granitic deposits] in undisturbed conditions in Little North Fork Watershed is 13.7 yds³ per acre. The sediment production coefficient can be used in a model in the following way. Landslide inventory in Little North Fork watershed indicates that inner gorges within granitic mountain slopes in undisturbed conditions yield 13.7 yds³ per acre, given storm events similar to those occurring during the period 1965-1975 in the watershed.

The following sections describe landslide-derived sediment yield coefficients for Little North Fork and Negro Creek Watersheds. Coefficients are presented for the 1964-1965 period, the 1965-1975 period, and the 1975-1989 period where applicable. Important factors to consider when developing and applying sediment production coefficients to a sediment model are listed below.

1. The size of the sample is extremely important. For example, if roads occupy only one acre of a given terrane type, the coefficient may not be very representative of landslide production rates.

2. Some geomorphic terrane types may have few or no landslides occurring in them. Characterizing the probable sediment yield of a geomorphic terrane based on limited data will influence the accuracy of the model.

3. The coefficients may vary greatly from the sub-basin to the watershed level. Landslides as well as disturbances may be concentrated within a particular sub-basin and geomorphic terrane type, and if the volume of sediment delivered remains the same while acres of the geomorphic terrane type increase, the coefficient will decrease.

Little North Fork: Undisturbed, 1964-1965, 1965-1975.

Landslide-derived sediment yield coefficients for Little North Fork watershed over the periods 1964-1965 and 1965-1975 are detailed in **Tables E-25, E-26, E-27.** Coefficients are given for natural conditions and disturbance classes of harvest and roads.

The coefficients for geomorphic terrane types 4, 5, and 6 in undisturbed conditions in both periods are based on a very small numbers of landslides, [1 to 2 landslides] in a geomorphic terrane type, and are probably of limited use in refining coefficients **[Table E-21]**. At the least, they indicate that sediment yield per acre is low in these geomorphic terrane types. Sediment yield coefficients are similar for both time periods evaluated.

Sediment yield coefficients for inner gorge geomorphic terrane types 9, 10, and 11 are based on 10, 23, and 10 landslides respectively, and are fairly similar to the final Salmon Basin model coefficients. The coefficients for the same geomorphic terrane types from landslides resulting from the 1964 flood are 5 to 11 times higher. No landslides occurred in geomorphic terrane types 2, 3, 12, and 13 during the 1965-1975 period.

Table E-25. Little North Fork landslide coefficients yds³/acre, undisturbed conditions.

Geotype	Undisturbed 1964-1965	Undisturbed 1965-1975	Final Model Undisturbed
2	-	-	2.76
3	-	-	2.76
4	1.2	2.9	1.25
5	0.09	0.03	0.60
6	0.20	0.06	1.69
8	0.12	-	0.30
9	303.9	27.0	26.48
10	163.8	13.7	7.32
11	19.0	3.8	7.22
12	1.8	-	1.26
13	4.1	-	3.23

Notes: - No landslides occurred or no sediment was delivered in that disturbance class, geomorphic terrane type and time period.

2 Toe Zones of Dormant Landslide Deposits
3 Dormant Landslide Deposits; Excluding Toe Zone and Inner Gorge
4 Mountain Slope; Granitic, Steep, (> 65%)
5 Mountain Slope; Granitic, Low to Moderate Slope, (0-65%)
6 Mountain Slope; Non-Granitic, Steep, (> 65%)
8 Mountain Slope, Non-Granitic, Low to Moderate Slope (0-65%). Also Includes Alluvium (Qal) and Lake Deposits
9 Inner Gorge Developed in Landslide, Glacial, or Terrace Deposits
10 Inner Gorge Developed in Granitic Mountain Slopes
11 Inner Gorge Developed in Non-Granitic Slopes
12 Debris Basins: Steep, > 65% Fan-Shaped Headwall Areas
13 Glacial, Terrace, and Fan Deposits, Excluding Inner Gorge

Little North Fork: Harvest, 1965-1975

Sediment yield coefficients for landslides occurring in harvest units during 1965-1975 are detailed in **Table E-26**. The coefficients for geomorphic terrane types 3 and 8 are based on one landslide each. The coefficient for dormant landslide deposits [geomorphic terrane type 3] is 5.6 times the final model value. Landslide occurrence in inner gorge types 10 and 11 was quite significant in this watershed; note 102 out of 107 landslides occurred in LOW sub-basin. Sediment yield for inner gorges developed in granitic slopes is 278.3 yds³/acre which is more than 20 times the undisturbed landslide rate in this terrane. Note that the final model coefficient is 146.38 yds³/per acre. The high value is the result of debris flows in deeply weathered, extremely dissected granitic bedrock, terrane that was harvested from one to five years prior to the storm events of 1972.

This case is an example of the value of refining geomorphic terrane type designations. Inner gorges within extremely dissected granitic mountain slopes could be classified as a specific geomorphic terrane type.

The landslide-derived sediment production rate for inner gorges in non-granitic mountain slopes [geomorphic terrane type 11] has a coefficient of 16.9 yds³ per acre which is 4.45 times undisturbed rate and is 1.5 times the final model value of 4.20 yds³ per acre.

Table E-26. Little North Fork landslide coefficients [yds³/acre], harvest condition.

Geomorphic Terrane	Harvest 1965-1975	Increase Over Undisturbed 1965-1975	Final Model Harvest
2	-	-	3.20
3	17.9	ND	3.22
4	14.9	5.14X	11.81
5	-	-	11.26
6	-	-	3.26
8	0.59	ND	2.12
9	-	-	51.48
10	278.3	20.3X	146.38
11	16.9	4.45X	11.20
12	-	-	50.41
13	-	-	6.46

Notes: - No landslides occurred or no sediment was delivered in that disturbance class, geomorphic terrane type and time period.

ND No landslides occurred in that geomorphic terrane type in undisturbed land

2 Toe Zones of Dormant Landslide Deposits
3 Dormant Landslide Deposits; Excluding Toe Zone and Inner Gorge
4 Mountain Slope; Granitic, Steep, (> 65%)
5 Mountain Slope; Granitic, Low to Moderate Slope, (0-65%)
6 Mountain Slope; Non-Granitic, Steep, (> 65%)
8 Mountain Slope, Non-Granitic, Low to Moderate Slope (0-65%). Also Includes Alluvium (Qal) and Lake Deposits
9 Inner Gorge Developed in Landslide, Glacial, or Terrace Deposits
10 Inner Gorge Developed in Granitic Mountain Slopes
11 Inner Gorge Developed in Non-Granitic Slopes
12 Debris Basins: Steep, > 65% Fan-Shaped Headwall Areas
13 Glacial, Terrace, and Fan Deposits, Excluding Inner Gorge

Little North Fork: Roads, 1965-1975

Data on coefficients for landslides originating in the road prism during 1965-1975 is presented in **Table E-27**. The coefficients for geomorphic terrane types 3 and 8 are based on one landslide occurrence in these geomorphic terranes. The coefficients vary widely from the final Salmon River model values.

Landslides associated with roads in mountain slopes, geomorphic terrane types 4, 5, 6, and 8 have low to high sediment yield on a per-acre basis **[Table E-27]**. Road-related landslides in steep granitic mountain slopes yield 450.6 yds³ per acre, which is 155 times the natural rate. Road-related landslides on less steep [0-65% grade] granitic slopes [geomorphic terrane type 5] yield 54.4 yds³ per acre elevated from the final model value of 36.33 yds³ per acre. Road-related landslides on steep non-granitic slopes [geomorphic terrane type 6] yield 355 yds³ per acre which is surprisingly similar to the yield from steep granitic mountain slopes. The inventory value is 4.3 times the model value. It is clear that road-related landslides can mobilize and deliver large quantities of sediment especially when constructed on steep terrane. The data indicates that road-related landslides in inner gorge terrane have the highest sediment yields. Road-related landslides in granitic inner gorges have a sediment yield coefficient 3482 yds³ per acre, which is 254 times the natural sediment yield and nearly 1.5 times the preliminary model coefficient. The coefficient for inner gorges in non-granitic slopes [geomorphic terrane type 11] is 421.9 yds³ per acre which is 111 times the undisturbed rate and more than 6 times the final model value.

Table E-27. Little North Fork landslide coefficients [yds³/acre], roads.

Geomorphic Terrane	Roads 1965-1975	Increase Over Natural	Final Model Roads
2			225.00
3	36.8	ND	225.05
4	450.6	155.4	1005.48
5	54.4	ND	36.33
6	355.1	5918.3X	81.84
8	31.8	ND	18.72
9			378.58
10	3482.2	254.2X	1201.31
11	421.9	111.0X	285.28
12	-	-	25.20
13	-	-	7.45

Notes: - No landslides occurred or no sediment was delivered in that disturbance class, geomorphic terrane type and time period.

ND No landslides occurred in that geomorphic terrane type in natural disturbance class.

2 Toe Zones of Dormant Landslide Deposits
3 Dormant Landslide Deposits; Excluding Toe Zone and Inner Gorge
4 Mountain Slope; Granitic, Steep, (> 65%)
5 Mountain Slope; Granitic, Low to Moderate Slope, (0-65%)
6 Mountain Slope; Non-Granitic, Steep, (> 65%)
8 Mountain Slope, Non-Granitic, Low to Moderate Slope (0-65%). Also Includes Alluvium (Qal) and Lake Deposits
9 Inner Gorge Developed in Landslide, Glacial, or Terrace Deposits
10 Inner Gorge Developed in Granitic Mountain Slopes
11 Inner Gorge Developed in Non-Granitic Slopes
12 Debris Basins: Steep, > 65% Fan-Shaped Headwall Areas
13 Glacial, Terrace, and Fan Deposits, Excluding Inner Gorge

Landslide coefficients for the four sub-basins of Little North Fork [LOW, HLS, SPE, UNC] are given on **Table E-28**. These coefficients are either equal to or greater than the coefficient for the whole basin of 20,801 acres **[Table E-28]**. The difference in the coefficients between sub-basins and the entire basin is due to the smaller number of acres of geomorphic land types in a sub-basin, and depends on the volume of sediment delivered by landslides in a sub-basin. For example, the sediment yield for landslides in undisturbed conditions in geomorphic terrane type 9 in Little North Fork [LNF] is 27.0 yds^3 per acre; for LOW sub-basin, the sediment yield is 177.6 yds^3 per acre. The acres of undisturbed geomorphic terrane type 9 in LNF is 311.5; LOW equals 27.5. The volume of material delivered by landslides is 8402 yds^3 for LNF; 4885 yds^3 for LOW. Thus, applying the coefficient of 27.0 yds^3 per acre to acres of undisturbed geomorphic terrane type 9 in LOW sub-basin would underestimate sediment yield by a least 6.6 times. Thus, it is crucial to know the variation in number of landslides, volume delivered,and acres of geomorphic terrane types between sub-basins and the larger basin they comprise.

Table E-28. Landslide coefficients [yds^3/acre],of sub-basins in Little North Fork, over the period 1965-1975.

1965-1975

	Undisturbed				Harvest				Roads			
Terrane Type	LOW	HLS	SPE	UNC	LOW	HLS	SPE	UNC	LOW	HLS	SPE	UNC
2	-	-	-	-	-	-	-	-	-	-	-	-
3	-	-	-	-	20.6	-	-	-	61.3		-	-
4	8.2	-	-	-	14.9				450.6			
5	0.16	-	-	-	-	-	-	-	61.5	-	-	-
6	0.31	-	-	-	-	-	-	-	618.3	552.0	-	-
8	-	-	-	-	-	0.69	-	-	-	95.3	-	-
9	177.6	4.1	-	18.1	-	-	-	-	-	-	-	-
10	20.7	8.90	-	1.3	282.0	-	-	-	3482.2	-		
11	2.6	38.2	0.01	2.8	-	49.8	-	-	732.5	766.0	-	-
12	-	-	-	-	-	-	-	-	-	-	-	-
13		-	-	-	-	-	-	-	-	-	-	- -

Table E-28, continued.

LITTLE NORTH FORK, LANDSLIDE COEFFICIENT SUMMARY

1965-1975

Terrane Type	Undisturbed	Harvest	Roads
2	-	-	-
3	-	17.9	36.8
4	2.9	14.9	450.6
5	0.03	-	54.4
6	0.06	-	355.1
8	-	0.59	31.8
9	27.0	-	-
10	13.7	278.3	3482.2
11	3.8	16.9	421.9
12	-	-	-
13	-	-	-

2 Toe Zones of Dormant Landslide Deposits
3 Dormant Landslide Deposits; Excluding Toe Zone and Inner Gorge
4 Mountain Slope; Granitic, Steep, (> 65%)
5 Mountain Slope; Granitic, Low to Moderate Slope, (0-65%)
6 Mountain Slope; Non-Granitic, Steep, (> 65%)
8 Mountain Slope, Non-Granitic, Low to Moderate Slope (0-65%). Also Includes Alluvium (Qal) and Lake Deposits
9 Inner Gorge Developed in Landslide, Glacial, or Terrace Deposits
10 Inner Gorge Developed in Granitic Mountain Slopes
11 Inner Gorge Developed in Non-Granitic Slopes
12 Debris Basins: Steep, > 65% Fan-Shaped Headwall Areas
13 Glacial, Terrace, and Fan Deposits, Excluding Inner Gorge

Negro Creek Landslide Coefficients

Landslide coefficients for landslides occurring in Negro Creek watershed are detailed in **Tables E-29, E-30, and E-31**. The coefficients are developed for undisturbed, roads, and fire conditions; no landslides were directly attributed to harvest-related disturbance. Time periods include 1964-1965, 1965-1975 and 1975-1988.

Negro Creek: Undisturbed, 1964-1965, and 1965-1975

Landslides in both periods were noted in inner gorge geomorphic terrane types 9 and 11 **[Table E-29]**. The sediment yield for geotype 11 in the 1964-1965 period is 266.5 yds³ per acre. This large sediment yield coefficient is partly attributed to one landslide [Inv. #4013] which delivered 33,000 yds³ of material. This landslide is the largest active landslide measured in the watershed. The sediment yield for this geomorphic terrane type would be 12.7 yds³ per acre if this landslide were not considered. Only one landslide was noted in geomorphic terrane type 9, yielding 23.1 yds³ per acre. During the 1965-1975 period, only 6 landslides were noted, associated with geomorphic terrane types 8, 9, and 11. This single landslide noted in geomorphic terrane type 8 yields 1.8 yds³ per acre. The coefficients for geomorphic terrane types 9 and 11 are 2.8 and 11.4 respectively. The coefficients differ considerably from the final model coefficients. The landslide coefficient for inner gorge in non-granitics [11] is larger than that for inner gorge in landslide deposits [9], which is opposite than what was expected. This is probably due to the fact that there are fewer acres of geomorphic terrane type 11 than 9.

Table E-29. Negro Creek landslide coefficients, [yds³/acre], undisturbed condition.

Geomorphic Terrane	Undisturbed 1964-1965	Undisturbed 1965-1975	Final Model Undisturbed
2	-	-	2.76
3	-	-	2.76
4	-	-	1.25
5	-	-	0.60
6	-	-	1.69
8	-	1.8	0.30
9	23.1	2.8	26.48
10	-	-	7.32
11	266.5●	11.4	7.22
12	-	-	1.26
13	-	-	3.23

Notes: - No landslides occurred or no sediment was delivered in that disturbance class, geomorphic terrane type and time period.

● Includes landslide # 4013 which delivered 33,0000 yds³. Without considering this landslide, the coefficient would be 12.7 yds³.

2	Toe Zones of Dormant Landslide Deposits
3	Dormant Landslide Deposits; Excluding Toe Zone and Inner Gorge
4	Mountain Slope; Granitic, Steep, (> 65%)
5	Mountain Slope; Granitic, Low to Moderate Slope, (0-65%)
6	Mountain Slope; Non-Granitic, Steep, (> 65%)
8	Mountain Slope, Non-Granitic, Low to Moderate Slope (0-65%). Also Includes Alluvium (Qal) and Lake Deposits
9	Inner Gorge Developed in Landslide, Glacial, or Terrace Deposits
10	Inner Gorge Developed in Granitic Mountain Slopes
11	Inner Gorge Developed in Non-Granitic Slopes
12	Debris Basins: Steep, > 65% Fan-Shaped Headwall Areas
13	Glacial, Terrace, and Fan Deposits, Excluding Inner Gorge

Negro Creek: Roads, 1964-1965, 1965-1975, and 1975-1989

There are 2 landslides associated with roads in 1964-1965 period, 4 associated with the 1965-1975 period and 8 associated with the 1975 to 1989 period **[Table E-30]**.

Landslide coefficients for road-associated landslides in geomorphic terrane type 3, dormant landslide deposits, range from 1.8 to 28.7 yds³ per acre. The final model coefficient is 8 times greater than the 1975-1989 rate.

Road-associated landslides in geomorphic terrane type 8 have coefficients ranging from 12.7 to 21.1 yds³ per acre; the 1975-1989 coefficient is closest to the final model coefficient.

Interestingly, the coefficients for geomorphic terrane type 9 are much lower than the final model value, and range from 2.9 to 39.3 yds³ per acre. The model value totals 375.58 yds³ per acre.

Table E-30. Negro Creek landslide coefficients, [yds³/acre], associated with roads.

Geo-Type	Roads 1964-1965	Roads 1965-1975	Increase Over Undisturbed 1965-1975	Roads 1975-1989	Increase Over Undisturbed 1965-1975•	Final Model Roads
2	-	-	-	-	-	225.00
3	-	1.8	-	28.7	-	225.05
4	-	-	-	-	-	1005.48
5	-	-	-	-	-	36.33
6	-	-	-	-	-	81.84
8	16.4	12.7	7.1X	21.9	12.2X	18.72
9	-	2.9	1.0X	39.3	14.0X	375.58
10	-	-	-	-	-	1201.31
11	-	-	-	-	-	285.28
12	-	-	-	-	-	25.20
13	-	-	-	-		7.45

Notes: • The period 1965-1975 was used for comparison because no landslides occurred during 1975-1988 in undisturbed conditions.

2 Toe Zones of Dormant Landslide Deposits
3 Dormant Landslide Deposits; Excluding Toe Zone and Inner Gorge
4 Mountain Slope; Granitic, Steep, (> 65%)
5 Mountain Slope; Granitic, Low to Moderate Slope, (0-65%)
6 Mountain Slope; Non-Granitic, Steep, (> 65%)
8 Mountain Slope, Non-Granitic, Low to Moderate Slope (0-65%). Also Includes Alluvium (Qal) and Lake Deposits
9 Inner Gorge Developed in Landslide, Glacial, or Terrace Deposits
10 Inner Gorge Developed in Granitic Mountain Slopes
11 Inner Gorge Developed in Non-Granitic Slopes
12 Debris Basins: Steep, > 65% Fan-Shaped Headwall Areas
13 Glacial, Terrace, and Fan Deposits, Excluding Inner Gorge

Negro Creek: Fire, 1975-1989

The need to determine landslide rates and volumes of sediment delivered by landslides after a major fire episode was a principal reason why Negro Creek watershed was chosen for intensive field inventory.

Landslides are associated with geomorphic terrane types 3, 8, 9, and 11 in the watershed **[Table E-31]**. The data indicates the final model coefficients are fairly close to the landslide rates observed for those terranes. Geomorphic terrane type #11 is more than 7 times greater than the final Salmon basin model coefficient.

Table E-31. Negro Creek landslide coefficients, [yds³/acre], fire disturbance.

Geomorphic Terrane	Fire 1975-1988	Increase Over Undisturbed	Final Model Harvest/Fire
2	-	-	3.20
3	0.92	-	3.22
4	-	-	11.81
5	-	-	11.26
6	-	-	3.26
8	0.62	•	2.12
9	59.2	21.1 X	51.48
10	-	-	146.38
11	84.2	7.4 X	11.20
12	-	-	50.41
13	-	-	6.46

Notes: - No landslides occurred or no sediment was delivered in that disturbance class, geomorphic terrane type and time period.
• No increase; 34% reduction from undisturbed
2 Toe Zones of Dormant Landslide Deposits
3 Dormant Landslide Deposits; Excluding Toe Zone and Inner Gorge
4 Mountain Slope; Granitic, Steep, (> 65%)
5 Mountain Slope; Granitic, Low to Moderate Slope, (0-65%)
6 Mountain Slope; Non-Granitic, Steep, (> 65%)
8 Mountain Slope, Non-Granitic, Low to Moderate Slope (0-65%). Also Includes Alluvium (Qal) and Lake Deposits
9 Inner Gorge Developed in Landslide, Glacial, or Terrace Deposits
10 Inner Gorge Developed in Granitic Mountain Slopes
11 Inner Gorge Developed in Non-Granitic Slopes
12 Debris Basins: Steep, > 65% Fan-Shaped Headwall Areas
13 Glacial, Terrace, and Fan Deposits, Excluding Inner Gorge

SEDIMENT YIELD BY LANDSLIDES, 1965-1975 PERIOD: A COMPARISON OF MEASURED AND MODELED SEDIMENT YIELD

Field inventory and air photograph studies of Little North Fork and Negro Creek watersheds provide detailed data on sediment yield to stream channels by landslides over the 1965-1975 period. The 1965-1975 period is of critical interest because the storm events which occurred during this time were of moderate intensity, and ranged from 1 year return events to between a 5 and 10 year return event. This time period is of importance for several reasons: [a] landslide-producing storm events occurred during this time; [b] information is readily available on the occurrence of landslides and the timing of storm events; and [c] management activities such as road building and timber harvesting occurred prior to 1975. The inventories have also provided more information on the occurrence of landslides with respect to the 11 geomorphic terrane types. As one of the objectives of this project is to develop a sediment budget for the Salmon River and its tributaries, the measured sediment yield from Little North Fork and Negro Creek can be compared with the sediment yield predicted by coefficients used in a sediment budget for the Grider Creek watershed, [de la Fuente, 1991], and the coefficients derived from landslides evaluated from the Salmon Basin Air Photo study.

Information on the study of the Grider Creek watershed is provided below. The Grider Creek watershed is a 27,730 acre tributary basin to the Klamath River. The watershed is about 10 miles to the north and is geomorphically and climatically similar to the lower Salmon River basin. Both air photo and field measurement techniques were used to estimate volumes of material mobilized and delivered to streams by landslides. Measured landslide production from 1965-1975 was used to develop sediment yield coefficients for 12 geomorphic terrane types [de la Fuente, 1991]. As with the Salmon sub-basin sediment analysis, the coefficients reflect landslide production in response to a climatic sequence similar to that of the 1965-1975 period. The Grider Creek landslide coefficients are important in that they are currently used to model sediment production from landslides in the western part of the Klamath Forest for the Draft Land Management Plan. The Grider Creek landslide coefficients and total sediment yield are contrasted with those of the sample watersheds and final Salmon Basin coefficients in the following sections.

Landslide coefficients from Grider Creek, the air photo study of Little North Fork, and the Salmon Basin air photo study, are compared to the sediment yield coefficients from the field studies of Little North Fork and Negro Creek in **Table E-32**. The final landslide coefficients for the entire Salmon Basin are also presented.

Sediment yield to stream channels **predicted** by the using coefficients from the Grider Creek study, the Little North Fork air photo study, the Salmon Basin air photo study, and Final model coefficients are compared with field inventory data from both Little North Fork and Negro Creek in **Table E-33.** The comparison shows the difference between what the various models would predict and the actual sediment volumes measured, at disturbance levels present in the watersheds in 1975. To compute the sediment yield by landslides in the various disturbances classes over the 1965-1975 period, the acres of land in a geomorphic terrane type are multiplied by the sediment yield delivery coefficient [yds^3 per acre] to derive the total yield in yds^3 per acre.

The total field-measured sediment yield of 130,907 yds^3 from Little North Fork is almost 2 times greater than what the use of the Grider Creek coefficients predicted and is 87% of the sediment yield predicted from the photo study of Little North Fork watershed. The landslide coefficients from the Salmon Basin Photo study yield a volume of 93,889 yds^3, which is 72% of what the field inventory measured. The basin-wide coefficients would overestimate the undisturbed volume by 32%, underestimate the harvest/fire volume by 281% and underestimate the road-related volume by 169%. The final sediment model coefficients similarly overestimate the undisturbed landslide rate and underestimate both the harvest/fire and road-related landslide production rates. The final model predicts a sediment volume of 107,174 yds^3 which is 82% of what was measured in the field inventory.

Table E-32. Summary of sediment yield coefficients for the Salmon Basin and selected inventoried watersheds. Coefficients are presented from the Grider Creek study, the Salmon Basin Air Photo Study, and the air photo inventory of Little North Fork [LNS], as well as those from the field inventories at Negro Creek and Little North Fork.

Undisturbed Condition
1965-1975

Geomorphic Terrane	Grider Creek Study	LNS Photo Study	Salmon Basin Photo Study	Salmon Basin FINAL	Little North Fork	Negro Creek
2	6.00	-	-	2.76	-	-
3	1.40	17.92	2.76	2.76	-	-
4	4.00	0.57	1.07	1.25	2.9	-
5	1.50	-	0.60	0.60	0.03	-
6	0.70	-	1.69	1.69	0.06	-
8	0.10	-	0.29	0.30	1.8	1.8
9	35.00	2.06	25.74	26.48	27.0	2.8
10	8.00	8.37	6.99	7.32	13.7	-
11	3.30	16.56	7.19	7.22	3.8	11.4
12	3.50	-	1.26	1.26	-	-
13	0.4	-	3.23	3.23	-	-

Harvest/Fire
1965-1975

Geomorphic Terrane	Grider Creek Study	LNS Photo Study	Salmon Basin Photo Study	Salmon Basin FINAL	Little North Fork	Negro Creek•
2	30.00	-	-	3.20	-	-
3	7.00	15.24	3.17	3.22	17.9	0.92
4	20.00	38.70	11.81	11.81	14.9	-
5	7.50	33.99	11.26	11.26	-	-
6	3.50	42.94	3.26	3.26	-	-
8	0.50	-	2.09	2.12	0.59	0.62
9	175.00	-	-	51.48	-	59.2
10	40.00	136.32	71.77	146.38	278.3	-
11	16.50	99.29	11.20	11.20	16.9	84.2
12	17.50	-	50.41	50.41		-
13	2.00	-	-	6.46	-	-

Notes: • Coefficients for fire-related landslides occurring during the 1975-1989 period are given.

Table E-32, continued.

Roads
1965-1975

Geomor-phic Terrane	Grider Creek Study	LNS Photo Study	Salmon Basin Photo Study	Salmon Basin FINAL	Little North Fork	Negro Creek	1975-1988 Negro Creek•
2	120.00	-	-	225.00	-	-	-
3	28.00	204.00	224.93	225.05	36.8	1.8	28.7
4	80.00	1056.92	1005.48	1005.48	450.6	-	-
5	30.00	143.08	36.33	36.33	54.4	-	-
6	14.00	1640.76	81.84	81.84	355.1	-	-
8	2.00	-	18.33	18.72	31.8	12.7	21.9
9	700.00	-	375.31	375.58	-	2.9	39.3
10	160.00	2118.00	1011.86	1201.31	3482.2	-	-
11	66.00	630.00	285.28	285.28	421.9	-	360.0
12	70.00	-	-	25.20	-	-	-
13	8.00	-	7.45	7.45	-	-	-

Note: • Coefficients for road-related landslides occuring during the 1975-1988 period are given.

2 Toe Zones of Dormant Landslide Deposits
3 Dormant Landslide Deposits; Excluding Toe Zone and Inner Gorge
4 Mountain Slope; Granitic, Steep, (> 65%)
5 Mountain Slope; Granitic, Low to Moderate Slope, (0-65%)
6 Mountain Slope; Non-Granitic, Steep, (> 65%)
8 Mountain Slope, Non-Granitic, Low to Moderate Slope (0-65%). Also Includes Alluvium (Qal) and Lake Deposits
9 Inner Gorge Developed in Landslide, Glacial, or Terrace Deposits
10 Inner Gorge Developed in Granitic Mountain Slopes
11 Inner Gorge Developed in Non-Granitic Slopes
12 Debris Basins: Steep, > 65% Fan-Shaped Headwall Areas
13 Glacial, Terrace, and Fan Deposits, Excluding Inner Gorge

Table E-33. Comparison of measured field inventory sediment yield with predicted yield, using coefficients from several watersheds and studies.

Little North Fork
1965-1975

	Sediment Delivered to Channels by Landslides, [yds³]				
Disturbance Class	**Field Inventory**	**Grider Creek Study**	**LNS Photo Study**	**Salmon Basin Photo Study**	**Salmon Basin FINAL**
Undisturbed	37285	50060	45293	49194	50120
Harvest/Fire	45079	12121	42342	16043	27775
Roads	48543	4802	62296	28650	30574
Total	130907	66983	149931	93887	108460

Negro Creek
1965-1975

	Sediment Delivered to Channels by Landslides, [yds³]			
Disturbance Class	**Field Inventory**	**Grider Creek Study**	**Salmon Basin Photo Study**	**Salmon Basin FINAL**
Undisturbed	3101	11331	16929	16933
Harvest/Fire	0	0	0	0
Roads	268	4836	11283	11295
Total	3369	16167	28212	28228

Negro Creek
1975-1988

	Sediment Delivered to Channels by Landslides, [yds³]			
Disturbance Class	**Field Inventory**	**Grider Creek Study**	**Salmon Basin Photo Study**	**Salmon Basin FINAL**
Undisturbed	0	2.8	7	7
Harvest/Fire	27129	56223	7724	20575
Roads	2575	6516	15345	15361
Total	29704	62741	23077	35943

The total sediment yield of 3,369 yds^3 from Negro Creek is 21% of what the Grider Creek coefficients would have predicted and 12% of what the Salmon Basin photo study and final model coefficients would predict. Overall, the landslide production rate during 1965-1975 in Negro Creek is very low and coefficients derived from the basin-wide study overestimate total sediment yield by more than eight times. Since landslide production and sediment yield is significant in the 1975-1989 period, a comparison was made between the field study and what the Preliminary Model, the Salmon Basin Photo Study and the final model coefficients would predict **[Table E-33]**. The total sediment yield of 29,704 yds^3 from Negro Creek in 1975-1988, is 47% of what the Grider Creek coefficients for the 1965-1975 period would have predicted, is 29% higher than what the Salmon Basin photo study would predict, and is 83% of what the final sediment model would predict.

The delivered sediment volume for Negro Creek in the 1965-1975 period is significantly lower than what the final model coefficients would predict. The lower landslide rate during this period is most likely due to differences in storm intensity and hydrologic factors in the basin. However, during the 1975-1988 period, with the high level of disturbance in the basin [fire], and below normal precipitation, the landslide rate is near to what would be expected from the final model.

In summary, the final model coefficients overestimate the undisturbed landslide rate in both watersheds studied. In Little North Fork, the final model coefficients underestimate the landslide rate associated with harvest, fire, and roads; the final model overestimates the sediment yield from disturbance in Negro Creek watershed.

DAMAGE TO RIPARIAN AREAS BY LANDSLIDES

Field and air photo inventory of landslides in the Little North Fork watershed reveals significant damage to stream channels and and associated riparian areas resulting from landslides **[Table E-34]**. The damage occurrred as a result of processes of scour and deposition: scour of channel sediment to bedrock and deposition of sediment material causing channel aggradation. The processes of channel scour and deposition occur from debris slides, flows, and avalanches initiated in headwall areas of channels or along the main body of the channel. Channel types where riparian damage has occurred include first and second order perennial and intermittent streams and so-called zero order intermittent and ephemeral drainages. Some of the zero-order intermittent drainages are classified as inner gorges; others fall into the mountain slope or debris basin terrane types. The length and width of channel scour or deposition was scaled off of air photos to derive an area in acres of riparian damage. Evidence for channel scour and riparian damage is indicated by removal of vegetation along stream banks. On air photos, the damaged areas are marked by a white- or light brown-colored scar along the length of channel affected. As both processes of scour and deposition may occur and are not easily differentiated on air photos, volumes of material scoured and deposited were not calculated. The areas in acres listed are considered in general terms as areas where riparian vegetation has been removed or damaged.

The length of channels damaged for the period of record, 1944-1988, totals 100,770 feet or 19 miles; riparian areas damaged total 68.4 acres **[Table E-34]**. Landslides associated with damaged riparian areas number 158 and encompass a total of 27.2 acres in the watershed. For every acre of landslide associated with an inner gorge or channel drainage area, 2.5 acres of riparian area was damaged.

The greatest damage to channels and riparian areas occurred as a result of the 1964 flood event **[Table E-35]**. A total of 27 landslides in inner gorges, mountain slopes and debris basins [geomorphic terrane types 4, 5, 6, 8, 9, 10, 11, and 12] damaged 32.0 acres of riparian area. The ratio of riparian acres damaged to landslide acres is 3.6 **[Table E-35]**.

The storm events of 1972 also caused considerable damage to riparian areas. Combining data from photo years 1972 and 1975 **[Table E-34]**, 9 landslides in undisturbed areas damaged 4.1 acres of riparian area; 53 landslides in harvest areas damaged 9.0 acres of riparian area; and 52 landslides associated with roads damaged 16.8 acres. Ratios of riparian acres damaged to landslide acres for undisturbed, harvest and road conditions are 2.2, 2.2 and 1.8 riparian acre damaged per landslide acre **[Table E-35]**.

Damage to riparian areas was not restricted to inner gorge terrane types. Evidence of channel scour and deposition was found in zero-order draws within mountain slopes and debris basins **[Table E-34]**. Damage to riparian areas in steep and moderate granitic mountain slopes [geomorphic terrane types 4 and 5] was significant in the 1965 photo year. A total of eleven landslides encompassing 0.60 acres damaged 14.1 acres of riparian area. Landslides occurring in harvest areas in terrane type 4 and 5 totaled 20, encompassed 4.4 acres and damaged 3.8 acres or riparian area. Landslides associated with roads in terrane types 4 and 5 numbered 19, encompassed 1.8 acres and damaged 3.2 riparian acres.

Road- and harvest-associated landslides in granitic inner gorges [geomorphic terrane type 10] damaged more than 13 acres of riparian areas as a consequence of the 1972 storm events **[Table E-34]**. Specifically, ten acres of road in terrane type 10 are associated with 5.6 acres of landslide and 9.2 acres of riparian area damaged; 152 acres of harvested land in terrane type 10 are associated with 1.9 acres of landslide and 3.9 acres of riparian area damaged.

Table E-34. Acres of damaged riparian area associated with landslides in Little North Fork Watershed, photo years 1944, 1955, 1964, 1965, 1972 and 1975.

Little North Fork
Undisturbed

	1944		1955		1964		1965	
Terrane Type	#	Acres	#	Acres	#	Acres	#	Acres
4	3	1.54					7	4.86
5	2	0.30					4	9.26
6	1	0.37	1	0.07			3	1.11
8			1	0.32			1	0.21
9							2	4.00
10	1	0.74			2	0.51	5	6.64
11	1	0.18	2	0.32			1	0.37
12	4	2.23					4	5.52
TOTAL	12	5.27	4	0.71	2	0.51	27	31.97

	1972						1975					
	Undisturbed		Harvest		Roads		Undisturbed		Harvest		Roads	
Terrane Type	#	Acres	#	Acres	#	Acres	#	Acres	#	Acres	#	Acres
3			1	0.92								
4			3	0.55	12	2.41			2	0.6		
5	2	0.05			5	0.30			15	2.67	2	0.46
6	1	1.15			7	3.43			2	0.46	1	0.46
8			1	0.03	1	0.31						
9	1	0.05										
10					23	9.18	2	2.43	27	3.90		
11	1	0.23			1	0.27	2	0.21	2	0.41		
TOTAL	5	1.48	5	1.50	49	15.90	4	2.64	48	7.50	3	0.92

Summary
Little North Fork
1944-1988

	Undisturbed		Harvest		Roads	
	#	Acres	#	Acres	#	Acres
TOTAL	54	42.58	53	9.00	51	16.82

# = number of landslides
Acres = riparian acres damaged

Table E-35. Acres of landslide associated with acres of riparian areas damaged in Little North Fork.

Little North Fork
Undisturbed

	1944		1965	
	Landslide Acres	Riparian Acres	Landslide Acres	Ri-pari-an Acres
	1.9	5.3	9.0	32.0
Damaged Riparian Acres/ Landslide Acres	2.8		3.6	

1972 and 1975

Undisturbed		Harvest		Roads	
Landslide Acres	Riparian Acres	Landslide Acres	Riparian Acres	Landslide Acres	Riparian Acres
1.9	4.1	4.1	9.0	9.1	16.8

Damaged Riparian Acres/Landslide Acres

2.2	2.2	1.8

CHANNEL BANK EROSION

A limited assessment of stream channel erosion was conducted for Little North Fork and Negro Creek watershed. Stream channel and bank erosion includes processes of mobilization and transport of sediment from inner gorge and hill slope areas to active channel systems. Stream channel erosion commonly is associated with debris slides in headwall and inner gorge areas. In addition, stream channel and channel bank erosion also occurs unrelated to landsliding, as a result of flood or storm flows, cutting terrace deposits or undercutting steep channel banks.

Stream banks where stream scour and channel-bank erosion are observable were evaluated as part of the Salmon River Basin air photo inventory. Eroded channel segments were noted for the following photo years: 1944, 1955, 1964, 1965, 1975 and 1988. Lengths of eroded stream channel segments were measured by map wheel off of 1:15,840 scale maps. Thus, our limited assessment of channel bank erosion consists of the total length in miles of observable bank erosion, by photo year.

Field measurements of sample channels were not carried out as part of this study due to the complexity of stream terrace and channel bank systems, limited personnel, and lack of field time. Therefore, no quantifiable assessment has been made of sediment yield by bank erosion in the watersheds studied. A future study of channel bank erosion from the 1964 flood event, other storm events, and current annual sediment yield from channel bank erosion would be a valuable project in the Little North Fork Watershed. Field-developed cross sections of typical stream segments using sampling methodology could provide information on area of channel scoured and volume of sediment mobilized within the inner gorge area as a result of the 1964 flood event.

Little North Fork: Channel Bank Erosion

Eroded channels in Little North Fork watershed are displayed in **Figures E-22, E-23 E-24, E-25, and E-26.** Locations and lengths of eroded channels are generalized for illustrative purposes. Lengths of stream channels eroded by photo year are summarized in **Table E-36.**

The Little North Fork has a history of channel erosion especially in higher elevation debris basins, inner gorges, and draws subject to debris flows and avalanches. Approximately 16.5 miles of channels show evidence of past channel erosion on the 1944 photos.

The most significant channel bank erosion occurred as a result of the 1964 flood event **[Figure E-25]**. Approximately 62.5 miles of stream channel were eroded, including main stem and tributaries to main stem in the Headwaters and Lower sub-basins. Along the main channel of Little North Fork in the Headwaters sub-basin, flood flows initiated landslides along channel banks and cut into glacial terrace deposits leaving exposed nearly vertical banks 30 to 100 feet in height. Debris torrents and debris flows in granitic mountain slopes, debris basins and granitic inner gorges contributed large volumes of sediment material and debris to the main channel. Today, there are many breached debris dams along the headwaters reaches of the Little North Fork. During the flood event, the formation and subsequent breaching of the debris dams produced flood surges that contributed to accelerated stream bank erosion and channel cutting downstream.

Approximately 13.0 miles of stream channels were eroded and damaged as a result of the 1972 storm events **[Figure E-26]**. Tributaries to the Little North Fork such as Garden Gulch, Titmouse Gulch and Cherry Creek were severely eroded, in part due to natural causes and road failures at stream crossings.

Little North Fork

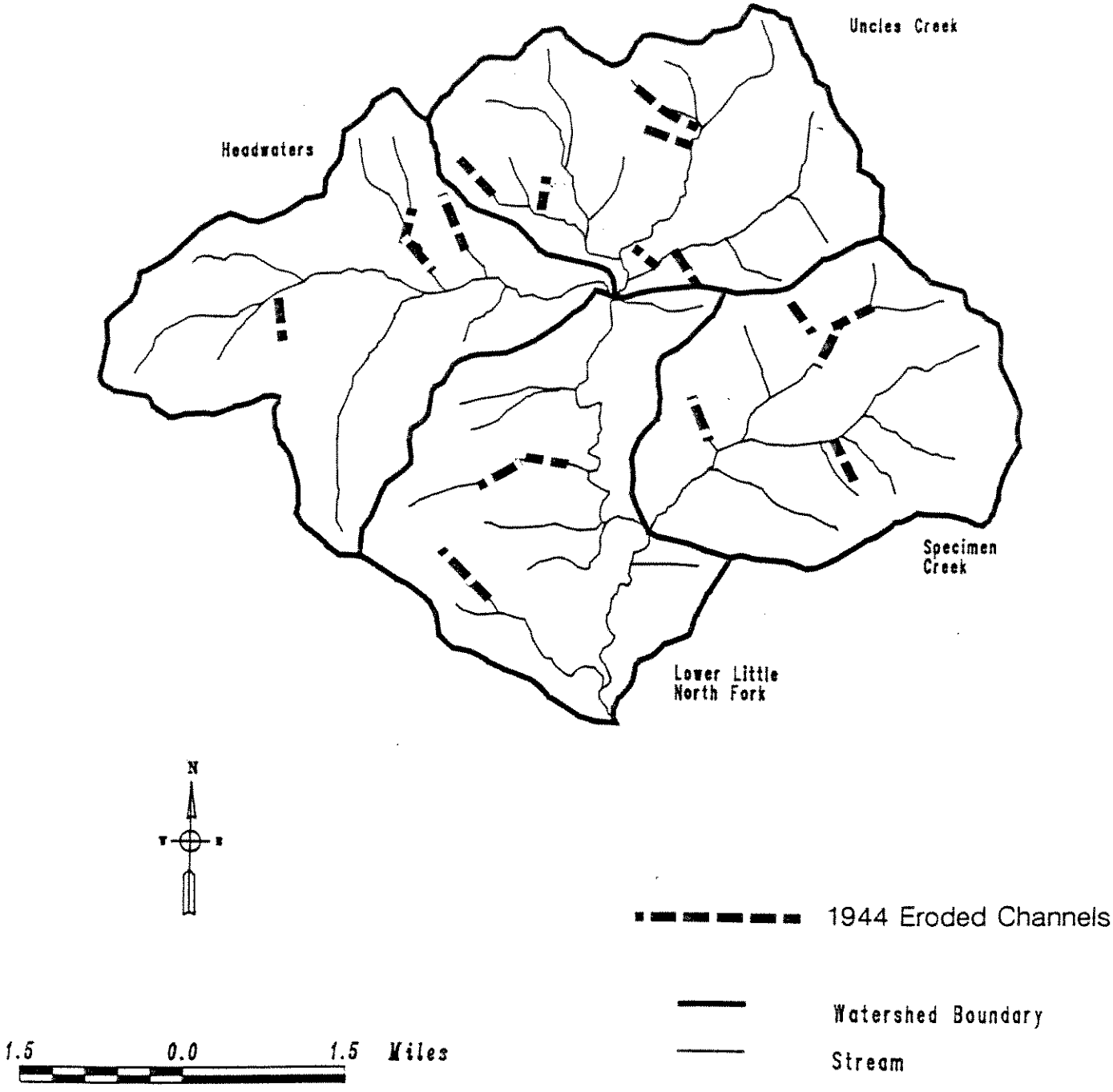


Figure E-22. Eroded channels from the 1944 photo year, Little North Fork Watershed.

Little North Fork

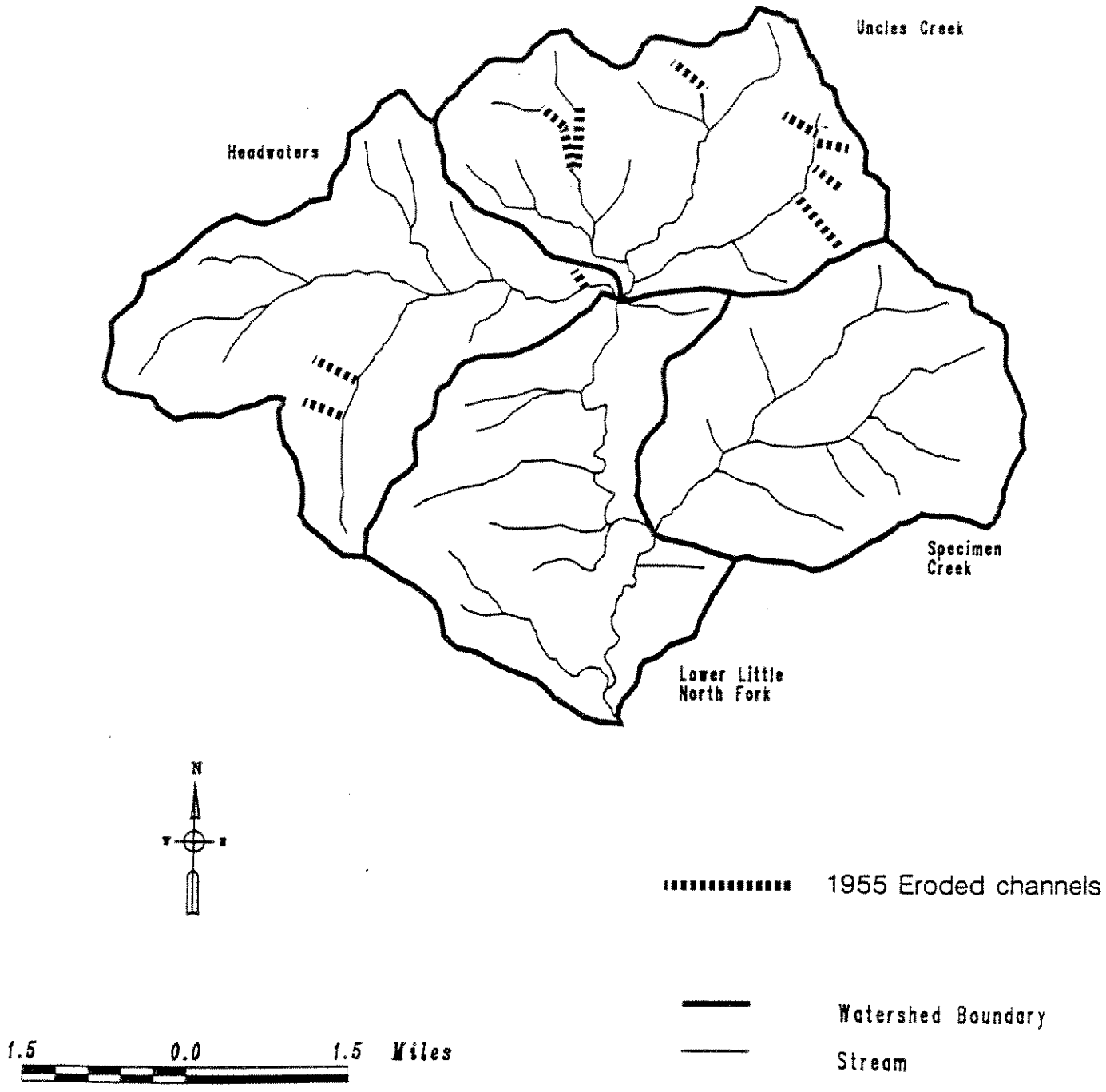


Figure E-23. Eroded channels from the 1955 photo year, Little North Fork Watershed.

Little North Fork

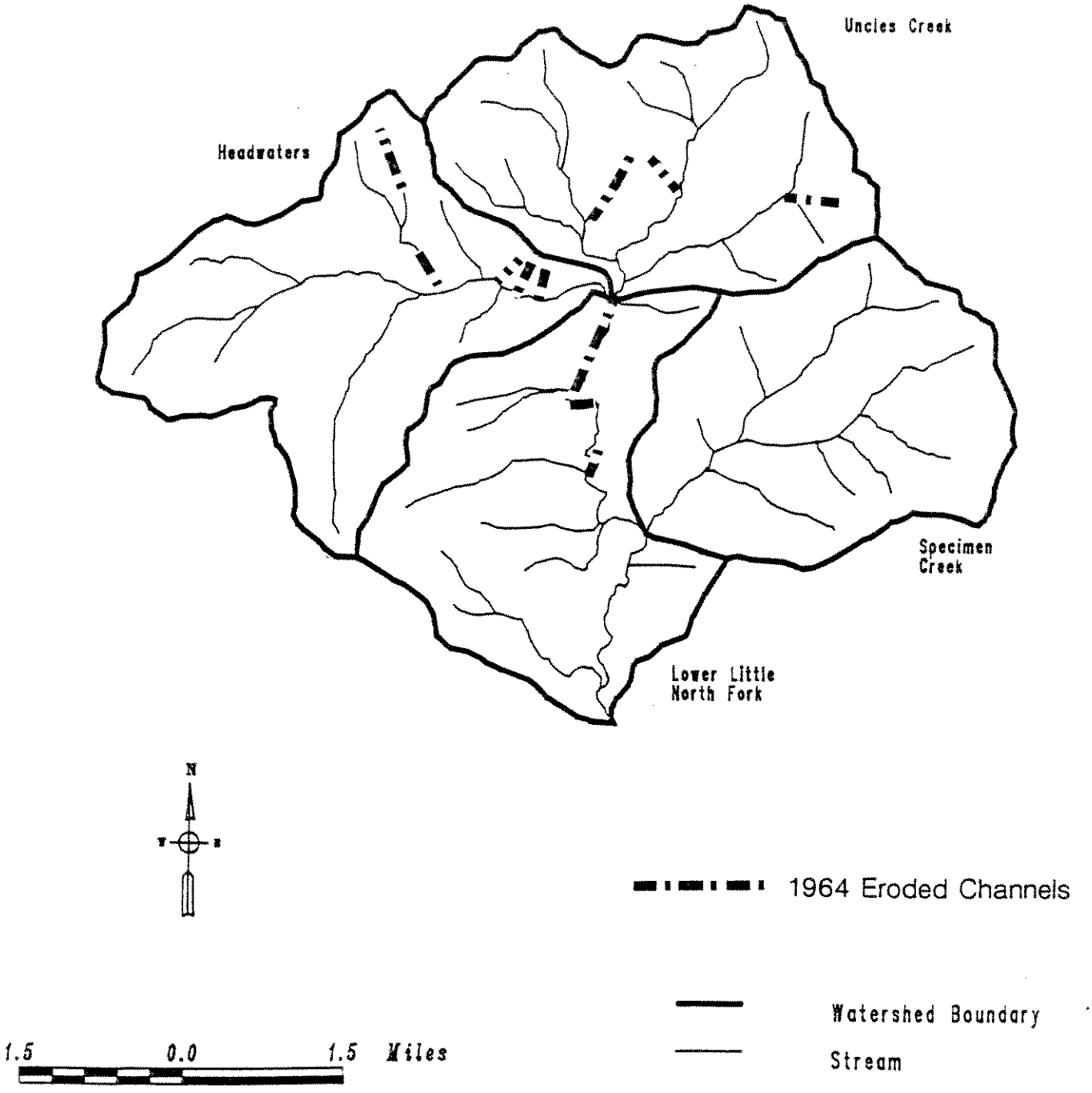


Figure E-24. Eroded channels from the 1964 photo year, Little North Fork Watershed.

Little North Fork

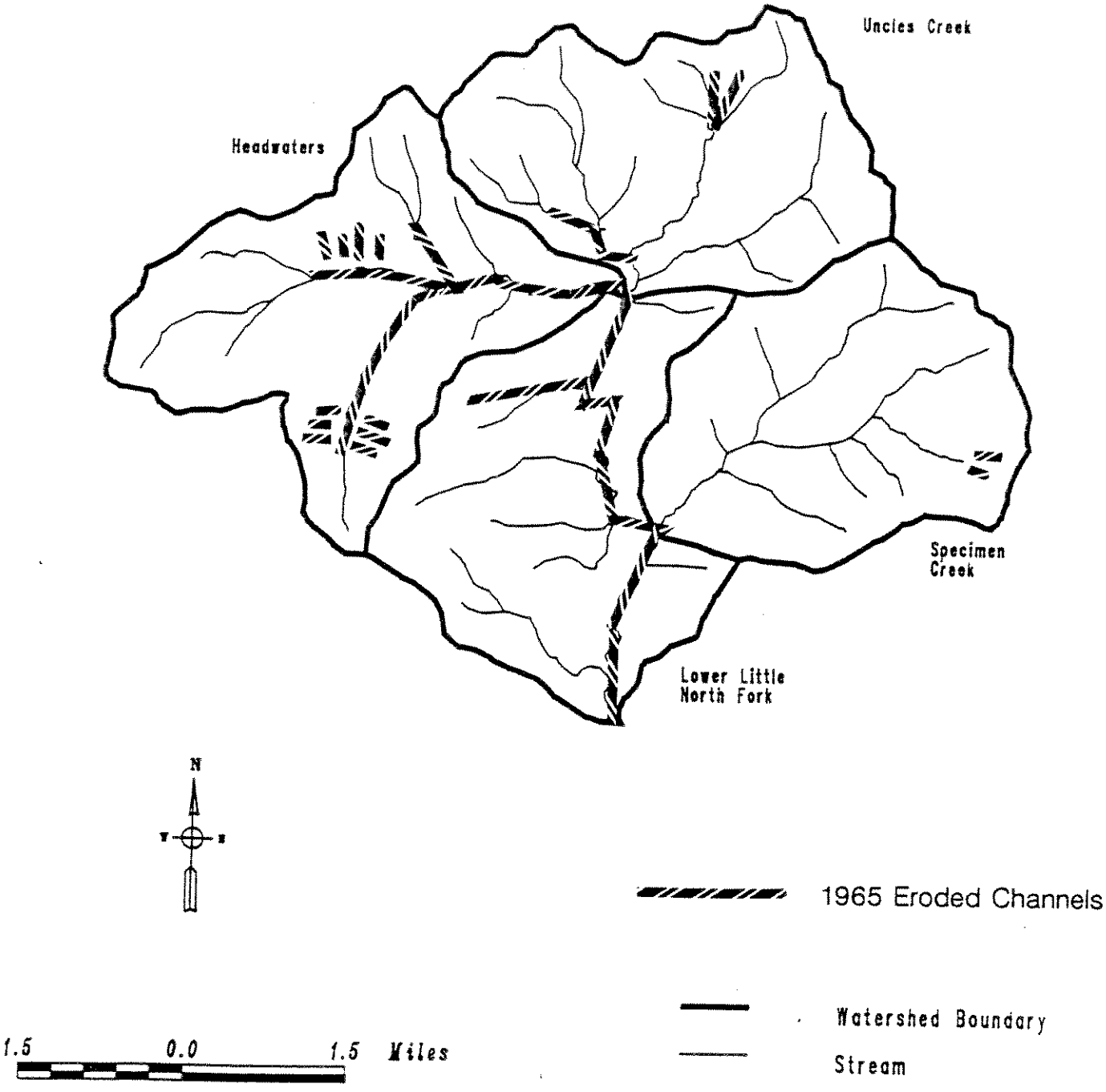


Figure E-25. Eroded channels from the 1965 photo year, Little North fork Watershed.

Little North Fork

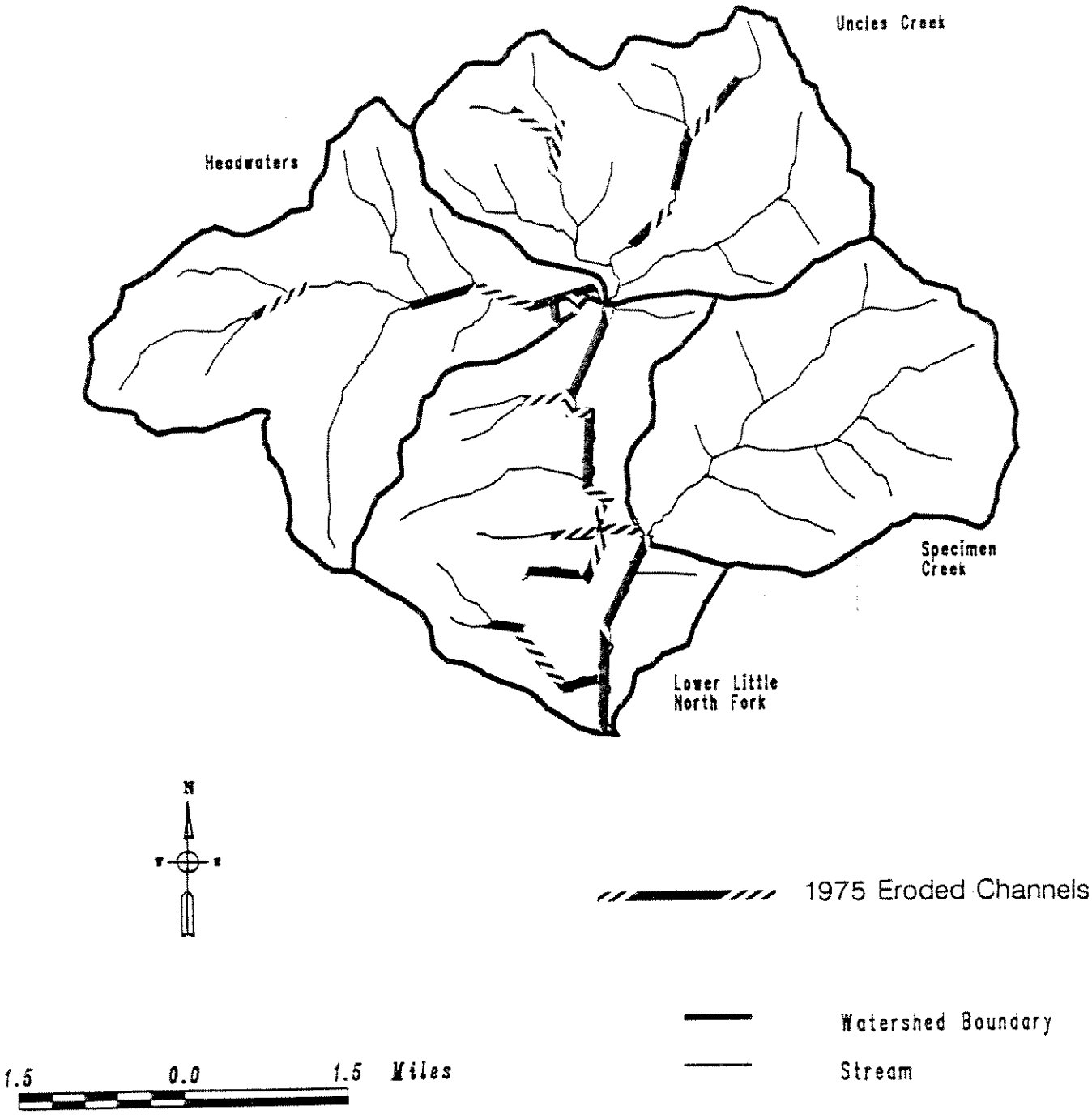


Figure E-26. Eroded channels from the 1975 photo year, Litle North Fork Watershed.

Table E-36. Channel erosion at Little North Fork and Negro Creek watersheds.

Little North Fork

Photo Year	Observed Length [miles] of Eroded Channels
1944	16.5
1955	11.5
1964	15.5
1965	62.5
1975	13.0
1988	0

Negro Creek

Photo Year	Observed Length [miles] of Eroded Channels
1944	0.4
1955	0.3
1964	0.1
1965	0
1975	0
1988	0

Negro Creek: Channel Bank Erosion

Negro Creek watershed shows evidence of channel erosion in the 1944, 1955 and 1964 photos **[Figure E-27 and Table E-36]**. The total length of stream channels eroded on the 1944, 1955 and 1964 photos are 0.4, 0.3 and 0.1 miles , respectively. Flood terraces and well-defined channel banks are not observed in stream channels in Negro Creek. Active stream channels are narrow, less than 20 feet in width, and valley walls are steep, having slopes greater than 60% grade, typical of valley inner gorges.

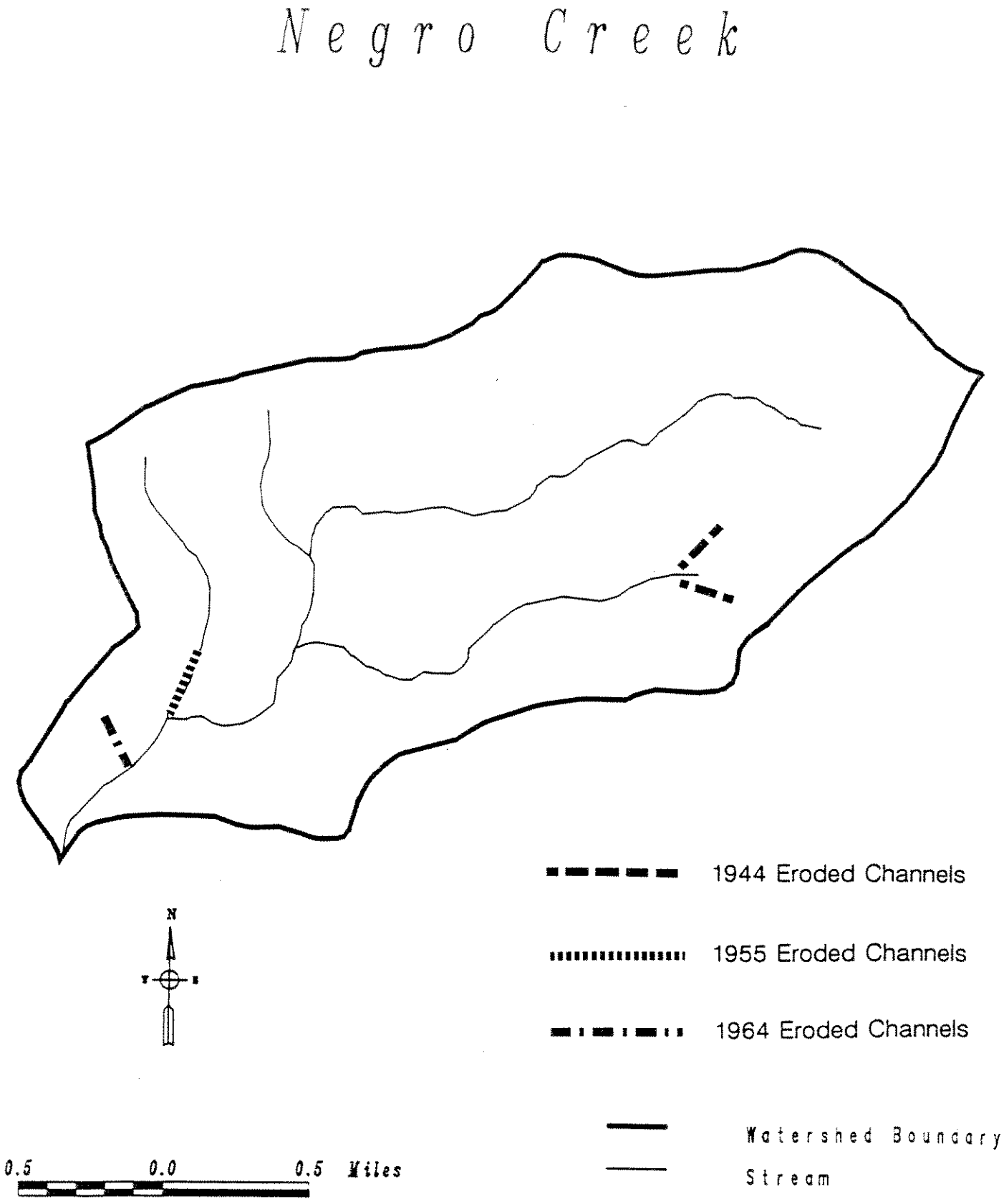


Figure E-27. Eroded channels from the 1944, 1955, and 1964 photo year, Negro Creek Watershed.

SURFACE EROSION

Surface erosion rates are presented for Little North Fork and Negro Creek watersheds for the periods 1965-1975, 1975-1988, and 1987-1988 post wildfire conditions **[Table E-37]**.

The methods used to model surface erosion are the same as those used in the Salmon basin, **[see Appendix D, this volume]**. The Universal Soil Loss Equation [USLE] was used to derive the volume of sediment mobilized from surface erosion processes. Land types [acres] were stratified by disturbance class, slope, and soil type. Erosion rates [yds³/acre] were calculated using the USLE based on combinations of soil type, disturbance class and slope. A delivery factor was then applied to the sediment yield from surface erosion. Four soil types were used, typical of granitic and non-granitic [including metamorphic and ultrabasic] parent materials. Disturbance classes include harvest, roads and fire [Hog and the fires of 1987]. Harvest units represent three age classes: 0-5 years, 6-10 years, and greater than 10 years. Slope classes included low [0-35%], moderate [35-65%] and high, [greater than 65%].

Total surface erosion for the period 1965-1975 reflects nine years of average annual precipitation and one year reflecting the occurrence of elevated surface erosion from a 25-year return frequency precipitation event. To model this, the R value was increased by a factor of 1.31. Total surface erosion for the period 1975-1988 reflects ten years of average annual precipitation.

Data tables and methods used to calculate sediment yield and delivery factors from surface erosion for Little North Fork and Negro Creek watersheds are found in **Appendix D, Surface Erosion Model for the Salmon River Watershed**, this volume.

Table E-37. Surface erosion in Little North Fork and Negro Creek watersheds. Total sediment yield [yds³] and yield per acre of watershed [yds³/acre] and given.

	1965-1975			1975-1987			1987-1988, Post Wildfire		
Watershed	Total Yield	Yield/ Acre/ Year	Annual Ave.	Total Yield	Yield/ Acre/ Year	Annual Ave.	Total Yield	Yield/ Acre/ Year	Annual Ave.
Little North Fork	4164	0.020	416.4	3228	0.013	269	1056	0.051	1056
Negro Creek	1261	0.048	126	—	—	—	3412	1.30	3412

Surface erosion rates for both watersheds are greatest in the one year period after the wildfires of 1987. Negro Creek watershed had a modeled erosion rate of 1.30 yds³/acre which is the highest in the Salmon River watershed for this time interval. The high rate is due the fact that the watershed was severely burned in 1977 as well as 1987.

SUMMARY AND CONCLUSIONS

In the following sections, results of the landslide inventory and sediment analysis for Little North Fork and Negro Creek watersheds are summarized. Topics summarized include (a) total sediment production and sediment sources; (b) distribution of landslides by geomorphic terrane and (c) landslide rates.

Sediment Production and Sediment Sources, Little North Fork

Over the period 1944-1988, landslides delivered a total of 483,1070 yds^3 to stream channels of Little North Fork watershed **[Figure E-28]**. Landslides occurring as a result of the 1964 flood delivered 332,590 yds^3, or 69% of the total volume. Landslides occurring during the period 1965-1975 delivered 130,907 yds^3. Landslides in undisturbed lands are the primary sediment sources prior to 1965. Following 1965, landslides associated with roads and harvest units contributed 48,544 and 45,078 yds^3 respectively. Landslides in undisturbed lands delivered 37,285 yds^3 **[Figure E-28]**.

The average annual landslide-related sediment volume delivered over the 10 year period 1965-1975 is approximately 13,090 yds^3, or 0.63 yds^3/acre/year. Surface erosion sources are estimated to have delivered approximately 4164 yds^3 over the 1965-1975 period [0.020 yds^3/acre/year], and 4284 yds^3, or 0.016 yds^3/acre/year over the 1975-1988 period.

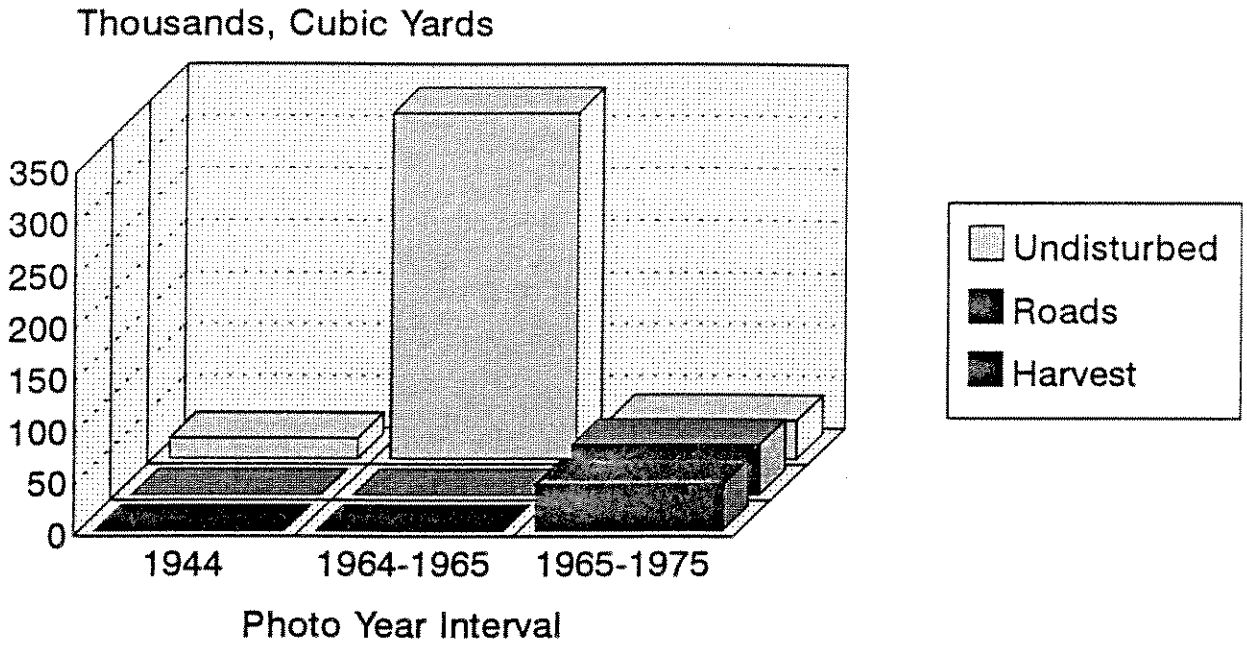
The length of riparian channels damaged by landslide events totals approximately 19 miles; total riparian areas damaged total 68.4 acres over the period 1944-1988. The flood of 1964 and storm events of 1972 damaged 32 and 16 acres respectively.

Geomorphic Distribution of Landslides, Little North Fork

Terrane stratification of the landscape within Little North Fork indicates that landslide production is greatest within inner gorge terranes [geomorphic terranes 9, 10, and 11], contributing 91% of the total volume delivered to channels **[Figure E-29]**.

Landslides in 1965-1975 are found in most of the geomorphic terrane types, and disturbance classes **[Figures E-28, E-30]**. Landslide occurrence is greatest in the inner gorge terranes accounting for 22% of the total landslide-related sediment production [1944-1988], **[Figure E-30]**. Landslides associated with harvested lands in granitic inner gorges account for 9% of the total sediment production [1944-1988]. Road-related landslides in the granitic inner gorge accounted for 7% of the total sediment production [1944-1988]. The high landslide rate in the unconsolidated inner gorge [geomorphic terrane #9] resulted mainly from the 1964 flood, which caused considerable damage to the Headwaters sub-basin.

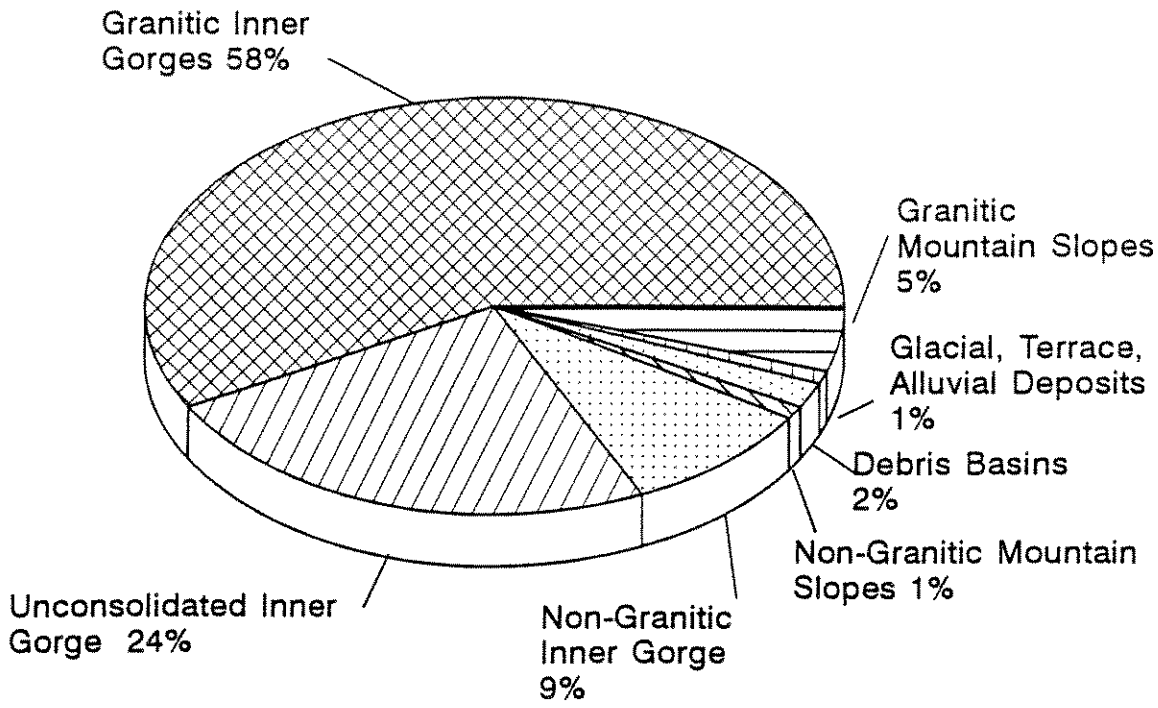
Distribution of Landslides in Little North Fork by Volume Delivered, Photo Year and Disturbance Class



Total Volume Delivered by Landslides = 483,170 c.yds.
Surface Erosion, 1965-1975 = 4164 c.yds.
Surface Erosion, 1975-1988 = 3228 c.yds.

Figure E-28. Distribution of landslides in Little North Fork by volume delivered, photo year and disturbance class.

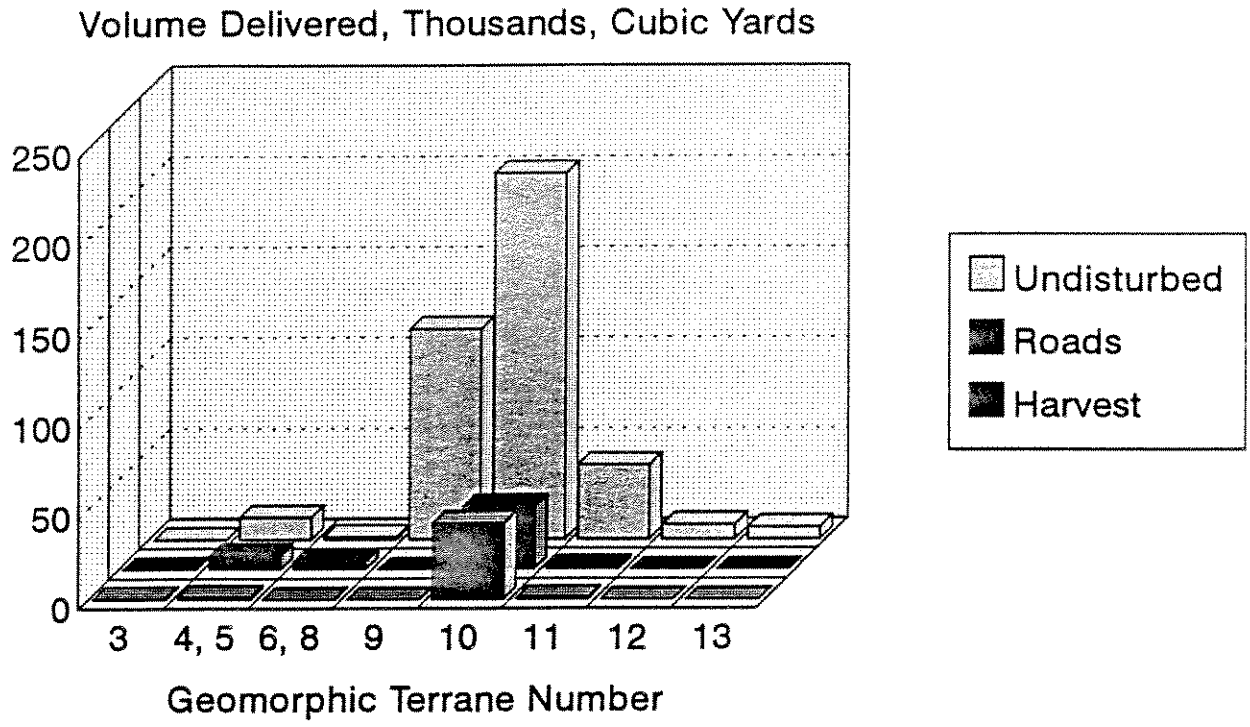
Distribution of Landslides by Geomorphic Terrane
Little North Fork, 1944-1988



Total Volume = 483,170 cubic yards

Figure E-29. Distribution of landslides by geomorphic terrane in Little North Fork.

Distribution of Landslides in Little North Fork by Geomorphic Terrane and Disturbance Type



Little North Fork, 1944-1988

Figure E-30. Distribution of landslides in Little North Fork by geomorphic terrane and disturbance type.

Landslide Rates, Little North Fork

During the 1965-1975 period, landslide rates for undisturbed lands, harvested land and roads are 1.9, 56.8 and 595.6 yds^3. Road-related landslides show an increase in sediment production 313 times the undisturbed rate; harvest-related landslides show an increase of 30 times the undisturbed rate.

Flood Event	Type of Disturbance	Landslide Rate [yds^3/acre]	Increase over Undisturbed Rate
1964 Event	Undisturbed	15.9	
1965-75 Events	Roads Harvest Undisturbed	595.6 56.8 1.9	X 313 X 30 X 1

Notes: Acres used in the calculations are watershed acres by disturbance class.

Sediment Production and Sediment Sources, Negro Creek

Over the period 1944-1988, landslides delivered a total of 78,145 yds^3 to stream channels in the watershed **[Figure E-31]**. The greatest volume delivered occurred in the period, 1964-1965, and is attributed to effects of the 1964 flood. Landslides occurring as a result of the 1964 flood delivered 40,635 yds^3 to channels. Landslides occurring in undisturbed lands are the primary sources of sediment prior to about 1977. After that, conditions resulting from the Hog Fire of 1977 and the wildfires of 1987 initiated the majority of landslides observed. In the period 1965-1975, 3,369 yds^3 was delivered to channels. In the period 1975-1988, 29,704 yds^3 was delivered, mainly from fire- and road-related landslides.

The average annual landslide-related sediment volume delivered over the period 1965-1975 is approximately 337 yds^3/year, or 0.129 yds^3/acre/year. Surface erosion is estimated to have delivered about 1261 yds^3 over the same period, or 0.048 yds^3/acre/year. For the 1975-1988 period the average annual landslide-related sediment volume delivered is estimated to be 2,285 yds^3/year, or 0.873 yds^3/acre/year. After the wildfires of 1987, sediment delivered by surface erosion processes amounted to about 3412 yds^3, or 1.30 yds^3/acre in the 1987-1988 period.

Geomorphic Distribution of Landslides, Negro Creek

Landslide production in Negro Creek was greatest in the inner gorge geomorphic terranes, contributing about 94% of the total volume delivered to channels **[Figure E-32]**. Landslides originating in dormant landslide deposits and non-granitic mountain slopes contributed the remainder of the sediment volume.

Landslide occurrence in 1964-1965 occurs in the two inner gorge terranes, unconsolidated and non-granitic types. Landslide occurrence in the period 1965-1975 is similarly distributed, but an additional number of landslides occur on non-granitic mountain slopes. In the 1975-1988 period, landslides are distributed across the five terrane types, with the majority of landslides occurring in the inner gorges, and related to fire and road disturbance types **[Figure E-32]**.

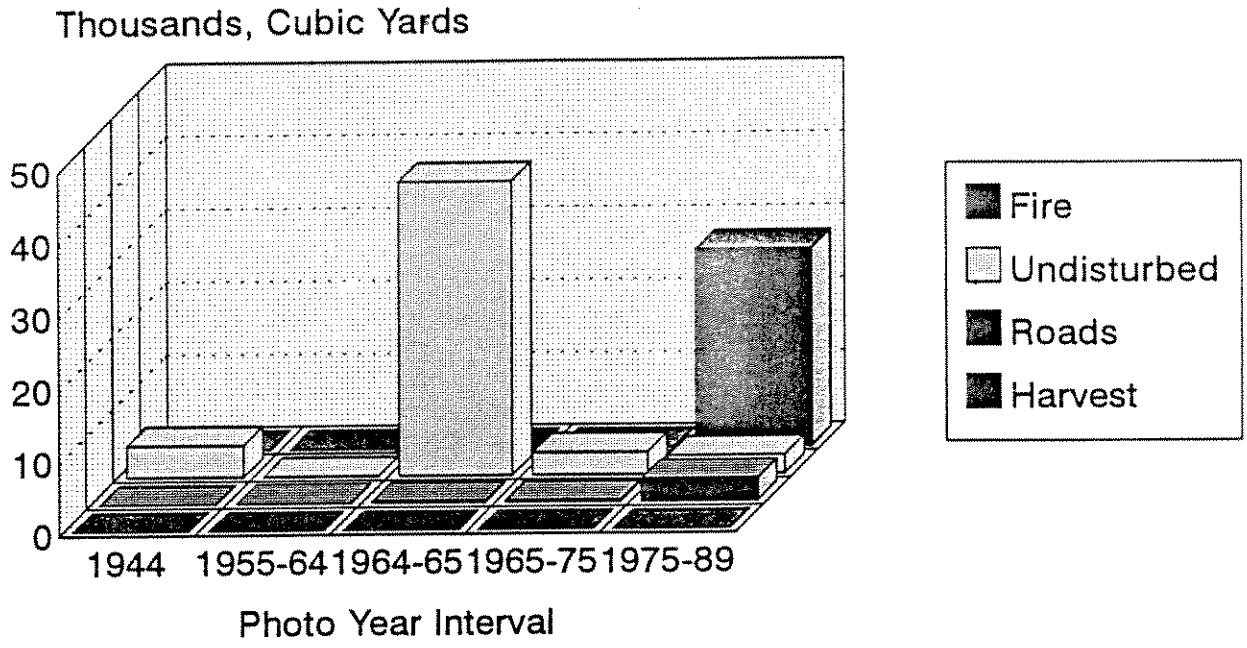
Landslide Rates, Negro Creek

The undisturbed landslide rate is greater than that for roads prior to 1975. After that time, when the watershed saw an increase in disturbance due to wildfire and new road construction, road-related landslides show an increase in sediment production 31 times the undisturbed rate, and fire-related landslides show an increase of nearly 11 times the undisturbed rate.

Time Period	Type of Disturbance	Landslide Rate [yds^3/acre]
1964-1965	Roads Undisturbed	3.84 15.8
1965-1975	Roads Undisturbed	4.4 12.1
1975-1988	Roads Fire Undisturbed	31.4 10.7 0

Notes: Acres used in the calculations are watershed acres by disturbance type.

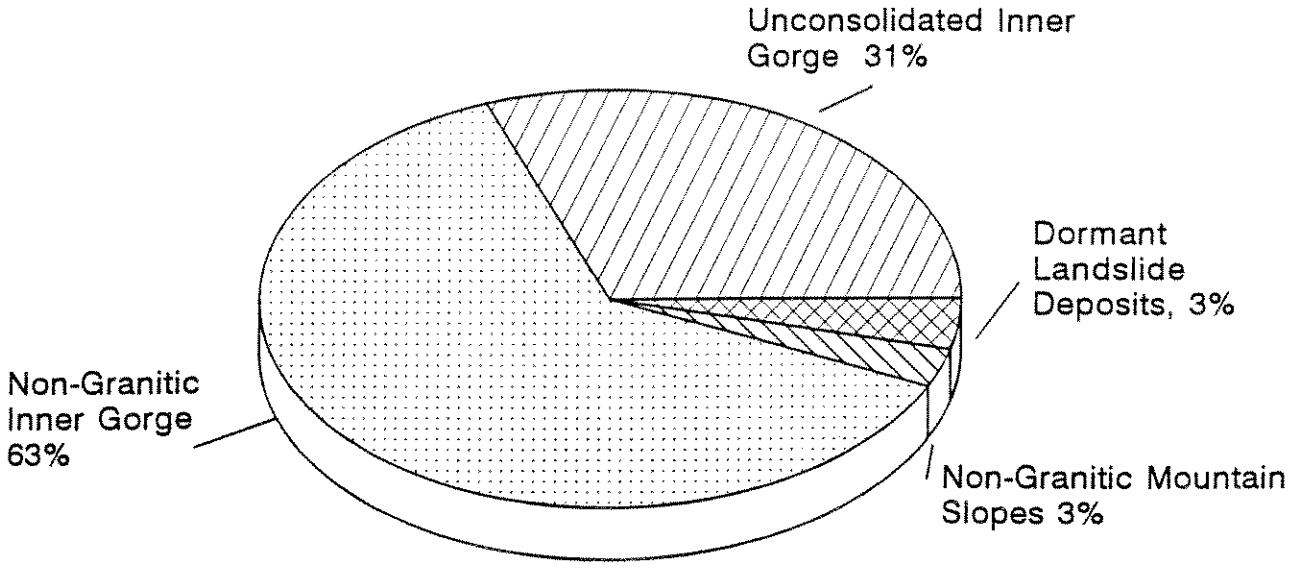
Distribution of Landslides in Negro Creek by Volume Delivered, Photo Year and Disturbance Class



Total Volume Delivered by Landslides = 78,145 c.yds.
Surface Erosion, 1965-1975 = 1261 c.yds.
Surface Erosion, 1987-1988 = 1056 c.yds.

Figure E-31. Distribution of landslides in Negro Creek by volume delivered, photo year and disturbance class.

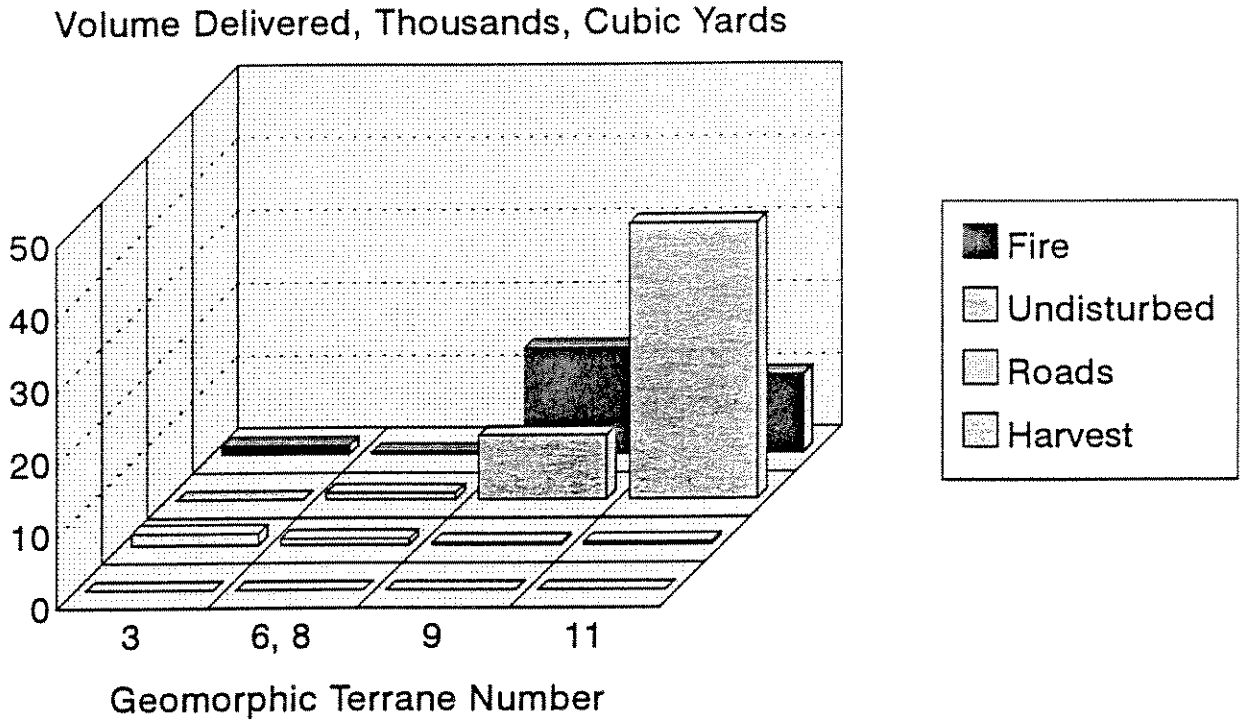
Distribution of Landslides by Geomorphic Terrane
Negro Creek, 1944-1988



Total Volume = 78,145 cubic yards

Figure E-32. Distribution of landslides by geomorphic terrane in Negro Creek.

Distribution of Landslides in Negro Creek by Geomorphic Terrane and Disturbance Type



Negro Creek, 1944-1989

Figure E-33. Distribution of landslides in Negro Creek by geomorphic terrane and disturbance type.

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APPENDIX E-1

Landslide Data Tables for Little North Fork and Negro Creek Watersheds

Table E-1-1. Little North Fork Data Summary.

LITTLE NORTH FORK (LNS) 0-1944 PERIOD

GEO-TYPE NO.	GEO-TYPE AC	Total: all disturbance classes: GEO-TYPE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	undisturbed/unfailed lands: UNDIS. UNFLD' AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides in harvested land: HAR. AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides assoc. w/ roads: ROAD AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD C.Y./AC
TZ_DS 2	6	6					6														
DLS.. 3	356	356					356														
MS_SG 4	2939	2939	2	0.091	748	0.3	2939	2	0.091	748	0.3										
MS_MG 5	4649	4649	1	0.072	0	0.0	4649	1	0.072	0	0.0										
MS_SN 6	5058	5058					5058														
MS_LS 8	2104	2104					2104														
IG_LD 9	317	317	3	1.138	11855	37.4	317	3	1.138	11855	37.4										
IG_GS 10	1152	1152					1152														
IG_NG 11	1805	1805	1	0.056	233	0.1	1805	1	0.056	233	0.1										
DB... 12	793	793	4	0.767	6837	8.6	793	4	0.767	6837	8.6										
GT_FD 13	1622	1622					1622														
TOTAL	20801	20801	11	2.124	19673		20801	11	2.1243	19673											

LITTLE NORTH FORK 1964-1965 PERIOD

GEO-TYPE NO.	GEO-TYPE AC	Total: all disturbance classes: GEO-TYPE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	undisturbed/unfailed lands: UNDIS. UNFLD' AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides in harvested land: HAR. AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides assoc. w/ roads: ROAD AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD C.Y./AC
TZ_DS 2	6	6					6														
DLS.. 3	356	356	0.5	35.000	0	0.0	356	0.5	35	0	0.0										
MS_SG 4	2939	2939	6	0.649	3439	1.2	2939	6	0.649	3439	1.2										
MS_MG 5	4649	4649	2	0.081	435	0.1	4649	2	0.081	435	0.1										
MS_SN 6	5058	5058	2	0.139	1014	0.2	5058	2	0.139	1014	0.2										
MS_LS 8	2104	2104	1	0.055	256	0.1	2104	1	0.055	256	0.1										
IG_LD 9	317	317	41.5	13.442	96344	303.9	317	41.5	13.442	96344	303.9						2 TRAIL SLIDES				
IG_GS 10	1152	1152	52	12.723	188673	163.8	1152	52	12.723	188673	163.8						USED UNDISTURBED ACRE FIGURE				
IG_NG 11	1805	1805	23	4.230	34278	18.2	1805	21	4.072	32688	18.1						1805	2	0.158	1590	0.9
DB... 12	793	793	3	0.171	1422	1.8	793	3	0.171	1422	1.8										
GT_FD 13	1622	1622	2	3.454	6729	4.1	1622	2	3.454	6729	4.1										
TOTAL	20801	20801	133	69.945	332590		20801	131	69.787	331000							1805	2	0.1579	1590	

LITTLE NORTH FORK 1965-1975

GEO-TYPE NO.	GEO-TYPE AC	Total: all disturbance classes: GEO-TYPE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	undisturbed/unfailed lands: UNDIS. UNFLD' AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides in harvested land: HAR. AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides assoc. w/ roads: ROAD AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD C.Y./AC
TZ_DS 2	6	6					6														
DLS.. 3	356	356	2	0.084	739	2.1	320					31	1	0.056	555	17.9	5	1	0.028	184	36.8
MS_SG 4	2939	2939	20	2.403	15823	5.4	2837	1	0.482	8200	2.9	88	3	0.188	1314	14.9	14	16	1.733	6309	450.6
MS_MG 5	4649	4649	9	0.526	1567	0.3	4362	2	0.061	152	0.0	261					26	7	0.465	1415	54.4
MS_SN 6	5058	5058	13	6.084	4535	0.9	4955	1	0.052	273	0.1	91	2	3.054	0	0.0	12	10	2.978	4262	355.1
MS_LS 8	2104	2104	2	0.094	343	0.2	1999					96	1	0.018	57	0.6	9	1	0.076	286	31.8
IG_LD 9	317	317	10	1.345	8402	26.5	311.5	10	1.345	8402	27.0	5					0.5				
IG_GS 10	1152	1152	155	16.694	90660	78.7	990	23	2.189	13532	13.7	152	102	8.179	42306	278.3	10	30	6.326	34822	3482.2
IG_NG 11	1805	1805	18	4.344	8838	4.9	1752	10	1.091	6726	3.8	50	5	3.001	846	16.9	3	3	0.252	1266	421.9
DB... 12	793	793					792										1				
GT_FD 13	1622	1622					1601					20					1				
TOTAL	20801	20801	229	31.574	130907		19925	47	5.221	37285		794	114	14.496	45079		81.5	68	11.856	48543	

LITTLE NORTH FORK 0-1988 PERIOD OF RECORD

TOTAL	20801		373	103.643	483170			189	77.132	387957			114	14.496	45079			82	70	12	50133

Table E-1-1, continued. Little North Fork Data Summary.

HEADWATERS, LITTLE NORTH FORK (HLS) 0-1944 PERIOD

GEO-TYPE NO.	GEO-TYPE AC	all disturbance classes: GEO-TYPE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	undisturbed/unfailed lands: UNDIS. UNFLD' AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides in harvested land: HAR. AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides assoc. w/ roads: ROAD AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC
TZ_DS 2																					
DLS.. 3	14	14					14														
MS_SG 4	997	997	1	0.043	370	0.4	997	1	0.043	370	0.4										
MS_MG 5	2424	2424					2424														
MS_SN 6	55	55					55														
MS_LS 8	281	281					281														
IG_LD 9	94	94	2	0.770	9722	103.4	94	2	0.770	9722	103.4										
IG_GS 10	230	230					230														
IG_NG 11	136	136					136														
DB... 12	202	202	3	0.198	2570	12.7	202	3	0.198	2570	12.7										
GT_FD 13	1210	1210					1210														
TOTAL	5643	5643	6	1.011	12662		5643	6	1.011	12662											

HEADWATERS, LITTLE NORTH FORK (HLS) 1964-1965 PERIOD

GEO-TYPE NO.	GEO-TYPE AC	all disturbance classes: GEO-TYPE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	undisturbed/unfailed lands: UNDIS. UNFLD' AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides in harvested land: HAR. AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides assoc. w/ roads: ROAD AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC
TZ_DS 2																					
DLS.. 3	14	14					14														
MS_SG 4	997	997	4	0.602	2941	2.9	997	4	0.602	2941	2.9										
MS_MG 5	2424	2424	1	0.056	294	0.1	2424	1	0.056	294	0.1										
MS_SN 6	55	55					55														
MS_LS 8	281	281	1	0.055	256	0.9	281	1	0.055	256	0.9										
IG_LD 9	94	94	38	9.156	74193	789.3	94	38	9.156	74193	789.3										
IG_GS 10	230	230	24	8.959	153955	669.4	230	24	8.959	153955	669.4										
IG_NG 11	136	136	9	2.218	16876	124.1	136	9	2.218	16876	124.1										
DB... 12	202	202	3	0.171	1422	7.0	202	3	0.171	1422	7.0										
GT_FD 13	1210	1210	1	3.330	5989	4.9	1210	1	3.330	5989	4.9										
TOTAL	5643	5643	81	24.547	255926		5643	81	24.547	255926											

HEADWATERS, LITTLE NORTH FORK (HLS) 1965-1975 PERIOD

GEO-TYPE NO.	GEO-TYPE AC	all disturbance classes: GEO-TYPE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	undisturbed/unfailed lands: UNDIS. UNFLD' AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides in harvested land: HAR. AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides assoc. w/ roads: ROAD AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC
TZ_DS 2																					
DLS.. 3	14	14					9					4					1				
MS_SG 4	997	997					997														
MS_MG 5	2424	2424					2388					33					3				
MS_SN 6	55	55	3	1.653	552	10.0	42					12					1	3	1.653	552	552.0
MS_LS 8	281	281	2	0.094	343	1.2	196					82	1	0.018	57	0.7	3	1	0.076	286	95.3
IG_LD 9	94	94	2	0.104	390	4.1	94	2	0.104	390	4.1										
IG_GS 10	230	230	7	0.662	2034	8.8	229	7	0.662	2034	8.9	1									
IG_NG 11	136	136	9	3.611	6119	45.0	118	3	0.535	4507	38.2	17	5	3.001	846	49.8	1	1	0.076	766	766.0
DB... 12	202	202					202														
GT_FD 13	1210	1210					1202					7					1				
TOTAL	5643	5643	23	6.125	9438		5477	12	1.301	6931		156	6	3.019	903		10	5	1.805	1604	

HEADWATERS, LITTLE NORTH FORK 0-1988 PERIOD OF RECORD

TOTAL	5643		110	31.6830	278026			99	26.859	275519			6	3.019	903			5	2	1604	

Table E-1-1, continued. Little North Fork Data Summary.

LOWER, LITTLE NORTH FORK, (LOW) 0-1944 PERIOD

GEO-TYPE NO.	GEO-TYPE AC	all disturbance classes: GEO-TYPE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	undisturbed/unfailed lands: UNDIS. UNFLD' AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides in harvested land: HAR. AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides assoc. w/ roads: ROAD AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC
TZ_DS 2	1	1																			
DLS.. 3	217	217																			
MS_SG 4	1096	1096																			
MS_MG 5	1203	1203	1	0.072	0	0.0	1203	1	0.072	0	0.0										
MS_SN 6	984	984																			
MS_LS 8	226	226																			
IG_LD 9	33	33																			
IG_GS 10	703	703																			
IG_NG 11	376	376																			
DB... 12	158	158																			
GT_FD 13	123	123																			
TOTAL	5120	5120	1	0.072	0			1	0.072	0											

LOWER, LITTLE NORTH FORK, (LOW) 1964-1965 PERIOD

GEO-TYPE NO.	GEO-TYPE AC	all disturbance classes: GEO-TYPE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	undisturbed/unfailed lands: UNDIS. UNFLD' AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides in harvested land: HAR. AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides assoc. w/ roads: ROAD AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC
TZ_DS 2	1	1					1														
DLS.. 3	217	217					217	0.5	35	0	0.0										
MS_SG 4	1096	1096					1096														
MS_MG 5	1203	1203					1203														
MS_SN 6	984	984	2	0.139	1014	1.0	984	2	0.139	1014	1.0										
MS_LS 8	226	226					226														
IG_LD 9	33	33	2	39.093	20863	632.2	33	1.5	4.093	20863	632.2										
IG_GS 10	703	703	21	2.962	24010	34.2	703	21	2.962	24010	34.2										
IG_NG 11	376	376	13	1.884	16602	44.2	376	11	1.7255	15012	39.9						TRAIL; USED NATURAL ACRES				
DB... 12	158	158					158										376	2	0.158	1590	4.2
GT_FD 13	123	123					123														
TOTAL	5120	5120	38	44.078	62489			36	43.919	60899							376	2	0.158	1590	4.2

LOWER, LITTLE NORTH FORK, (LOW) 1965-1975 PERIOD

GEO-TYPE NO.	GEO-TYPE AC	all disturbance classes: GEO-TYPE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	undisturbed/unfailed lands: UNDIS. UNFLD' AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides in harvested land: HAR. AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides assoc. w/ roads: ROAD AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD C.Y./AC
TZ_DS 2	1	1					1														
DLS.. 3	217	217	2	0.084	739	3.4	187					27	1	0.056	555	20.6	3	1	0.028	184	61.3
MS_SG 4	1096	1096	20	2.403	15823	14.4	994	1	0.482	8200	8.2	88	3	0.188	1314	14.9	14	16	1.733	6309	450.6
MS_MG 5	1203	1203	9	0.526	1567	1.3	952	2	0.061	152	0.2	228					23	7	0.465	1415	61.5
MS_SN 6	984	984	10	4.431	3983	4.0	899	1	0.052	273	0.3	79	2	3.054	0	0.0	6	7	1.325	3710	618.3
MS_LS 8	226	226					209					14					3				
IG_LD 9	33	33	5	0.640	4885	148.0	27.5	5	0.640	4885	177.6	5					0.5				
IG_GS 10	703	703	147	15.904	88366	125.7	543	15	1.399	11238	20.7	150	102	8.179	42306	282.0	10	30	6.326	34822	3482.2
IG_NG 11	376	376	5	0.458	1607	4.3	342	2	0.230	875	2.6	33					1	3	0.227	732	732.5
DB... 12	158	158					158														
GT_FD 13	123	123					109.5					13					0.5				
TOTAL	5120	5120	198	24.4449	116970		4422	26	2.864	25623		637	108	11.477	44175		61	64	10.103	47172	

LOWER LITTLE NORTH FORK, 0-1988 PERIOD OF RECORD

TOTAL	5120		237	68.5945	179459		4422	63	46.855	86521.		637	108	11.477	44175			66	10.261	48761.	

Table E-1-1, continued. Little North Fork Data Summary.

SPECIMEN CREEK, LITTLE NORTH FORK (SPE) 0-1944 PERIOD

GEO-TYPE NO.	GEO-TYPE AC	all disturbance classes: GEO-TYPE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	undisturbed/unfailed lands: UNDIS. UNFLD' AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides in harvested land: HAR. AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides assoc. w/ roads: ROAD AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD C.Y./AC
TZ_DS 2	3	3					3														
DLS.. 3	125	125					125														
MS_SG 4	48	48					48														
MS_MG 5	23	23					23														
MS_SN 6	3093	3093					3093														
MS_LS 8	608	608					608														
IG_LD 9	16	16					16														
IG_GS 10	14	14					14														
IG_NG 11	844	844					844														
DB... 12	241	241					241														
GT_FD 13																					
TOTAL	5015	5015																			

SPECIMEN CREEK, LITTLE NORTH FORK (SPE) 1964-1965 PERIOD

GEO-TYPE NO.	GEO-TYPE AC	all disturbance classes: GEO-TYPE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	undisturbed/unfailed lands: UNDIS. UNFLD' AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides in harvested land: HAR. AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides assoc. w/ roads: ROAD AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD C.Y./AC
TZ_DS 2	3	3					3														
DLS.. 3	125	125					125														
MS_SG 4	48	48					48														
MS_MG 5	23	23					23														
MS_SN 6	3093	3093					3093														
MS_LS 8	608	608					608														
IG_LD 9	16	16					16														
IG_GS 10	14	14	2	0.178	2724	194.6	14	2	0.178	2724	194.6										
IG_NG 11	844	844					844														
DB... 12	241	241					241														
GT_FD 13																					
TOTAL	5015	5015	2	0.178	2724		5015	2	0.178	2724											

SPECIMEN CREEK, LITTLE NORTH FORK (SPE) 1965-1975 PERIOD

GEO-TYPE NO.	GEO-TYPE AC	all disturbance classes: GEO-TYPE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	undisturbed/unfailed lands: UNDIS. UNFLD' AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides in harvested land: HAR. AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides assoc. w/ roads: ROAD AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD C.Y./AC
TZ_DS 2	3	3					3														
DLS.. 3	125	125					125														
MS_SG 4	48	48					48														
MS_MG 5	23	23					23														
MS_SN 6	3093	3093					3089											4			
MS_LS 8	608	608					605											3			
IG_LD 9	16	16					16														
IG_GS 10	14	14					12.5					1					0.5				
IG_NG 11	844	844	1	0.028	12	0.0	843.5	1	0.028	12	0.0						0.5				
DB... 12	241	241					240										1				
GT_FD 13																					
TOTAL	5015	5015	1	0.028	12		5005	1	0.028	12		1	0	0	0		9	0	0	0	

SPECIMEN CREEK 0-1988 PERIOD OF RECORD

TOTAL	5015		3	0.206	2736			3	0.206	2736			0	0	0			0	0	0	

Table E-1-1, continued. Little North Fork Data Summary.

UNCLES CREEK, LITTLE NORTH FORK (UNC) 0-1944 PERIOD

GEO-TYPE NO.	GEO-TYPE AC	all disturbance classes: GEO-TYPE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL: C.Y./AC	undisturbed/unfailed lands: UNDIS. UNFLD' AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL: C.Y./AC	landslides in harvested land: HAR. AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL: C.Y./AC	landslides assoc. w/ roads: ROAD AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD: C.Y./AC
TZ_DS 2	2	2					2														
DLS.. 3																					
MS_SG 4	798	798	1	0.048	378	0.5	798	1	0.048	378	0.5										
MS_MG 5	999	999					999														
MS_SN 6	925	925					925														
MS_LS 8	989	989					989														
IG_LD 9	173	173	1	0.367	2133	12.3	173	1	0.367	2133	12.3										
IG_GS 10	206	206					206														
IG_NG 11	449	449	1	0.056	233	0.5	449	1	0.056	233	0.5										
DB... 12	192	192	1	0.569	4267	22.2	192	1	0.569	4267	22.2										
GT_FD 13	288	288					288														
TOTAL	5021	5021	4	1.041	7011		5021	4	1.0412	7011											

UNCLES CREEK, LITTLE NORTH FORK (UNC) 1964-1965 PERIOD

GEO-TYPE NO.	GEO-TYPE AC	all disturbance classes: GEO-TYPE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL: C.Y./AC	undisturbed/unfailed lands: UNDIS. UNFLD' AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL: C.Y./AC	landslides in harvested land: HAR. AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL: C.Y./AC	landslides assoc. w/ roads: ROAD AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD: C.Y./AC
TZ_DS 2	2	2					2														
DLS.. 3																					
MS_SG 4	798	798	2	0.047	498	0.6	798	2	0.047	498	0.6										
MS_MG 5	999	999	1	0.025	141	0.1	999	1	0.025	141	0.1										
MS_SN 6	925	925					925														
MS_LS 8	989	989					989														
IG_LD 9	173	173	2	0.193	1288	7.4	173	2	0.193	1288	7.4										
IG_GS 10	206	206	5	0.625	7984	38.8	206	5	0.625	7984	38.8										
IG_NG 11	449	449	1	0.129	800	1.8	449	1	0.129	800	1.8										
DB... 12	192	191					192														
GT_FD 13	288	288	1	0.124	740	2.6	288	1	0.124	740	2.6										
TOTAL	5021	5021	12	1.142	11451		5021	12	1.142	11451											

UNCLES CREEK, LITTLE NORTH FORK (UNC) 1965-1975 PERIOD

GEO-TYPE NO.	GEO-TYPE AC	all disturbance classes: GEO-TYPE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL: C.Y./AC	undisturbed/unfailed lands: UNDIS. UNFLD' AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL: C.Y./AC	landslides in harvested land: HAR. AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL: C.Y./AC	landslides assoc. w/ roads: ROAD AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD: C.Y./AC
TZ_DS 2	2	2					2														
DLS.. 3																					
MS_SG 4	798	798					798														
MS_MG 5	999	999					999														
MS_SN 6	925	925					925														
MS_LS 8	989	989					989														
IG_LD 9	173	173	3	0.601	3127	18.1	173	3	0.601	3127	18.1										
IG_GS 10	206	205	1	0.129	260	1.3	206	1	0.129	260	1.3										
IG_NG 11	449	449	3	0.246	1099	2.4	449	3	0.246	1099	2.8										
DB... 12	192	192					192														
GT_FD 13	288	288					288														
TOTAL	5021	5021	7	0.976	4486		5021	7	0.976	4486											
UNCLES CREEK WATERSHED TOTALS	5021	5021	23	3.160	22948			23	3.1595	22948											

Table E-1-2. Negro Creek Data Summary.

NEGRO CREEK (SFSNEG) 0-1944 PERIOD

GEO-TYPE NO.	GEO-TYPE AC	all disturbance classes: GEO-TYPE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD. C.Y./AC	undisturbed/unfailed lands: UNDIS. UNFLD' AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD. C.Y./AC	landslides harvest units: HAR. AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD. C.Y./AC	landslides assoc. w/ roads: ROAD AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD. C.Y./AC	landslides assoc. w/ fire: FIRE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD C.Y./AC
TZ_DS 2																										
DLS.. 3	1408	1408	1	0.843	0	0.0	1408	1	0.843	0	0.0															
MS_SG 4																										
MS_MG 5																										
MS_SN 6	276	276					276																			
MS_LS 8	547	547					547																			
IG_LD 9	255	255	1	0.232	2400	9.4	255	1	0.232	2400	9.4															
IG_GS 10																										
IG_NG 11	130	130	4	0.308	1965	15.1	130	4	0.308	1965	15.1															
DB... 12																										
GT_FD 13																										
TOTAL	2616	2616	6	1.383	4365		2616	6	1.383	4365																

NEGRO CREEK (SFSNEG) 1955-1964 PERIOD

GEO-TYPE NO.	GEO-TYPE AC	all disturbance classes: GEO-TYPE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD. C.Y./AC	undisturbed/unfailed lands: UNDIS. UNFLD' AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD. C.Y./AC	landslides harvest units: HAR. AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD. C.Y./AC	landslides assoc. w/ roads: ROAD AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD. C.Y./AC	landslides assoc. w/ fire: FIRE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD C.Y./AC
TZ_DS 2																										
DLS.. 3	1408	1408					1376.2										31.8									
MS_SG 4																										
MS_MG 5																										
MS_SN 6	276	276					274.8										1.2									
MS_LS 8	547	547	1	0.220	72	0.1	535.6										11.4	1	0.220	72	6.3					
IG_LD 9	255	255					250.8										4.2									
IG_GS 10																										
IG_NG 11	130	130					130																			
DB... 12																										
GT_FD 13																										
TOTAL	2616	2616	1	0.22	72		2567.4										48.6	1	0.22	72						

NEGRO CREEK (SFSNEG) 1964-1965 PERIOD

GEO-TYPE NO.	GEO-TYPE AC	all disturbance classes: GEO-TYPE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD. C.Y./AC	undisturbed/unfailed lands: UNDIS. UNFLD' AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD. C.Y./AC	landslides harvest units: HAR. AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD. C.Y./AC	landslides assoc. w/ roads: ROAD AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD. C.Y./AC	landslides assoc. w/ fire: FIRE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD C.Y./AC
TZ_DS 2																										
DLS.. 3	1408	1408					1376.2										31.8									
MS_SG 4																										
MS_MG 5																										
MS_SN 6	276	276	0.5	1.751	0	0.0	274.8	0.5	1.751	0	0.0						1.2									
MS_LS 8	547	547	.2	0.077	187	0.3	535.6										11.4	2	0.077	187	16.4					
IG_LD 9	255	255	1	0.646	5800	22.7	250.8	1	0.646	5800	23.1						4.2									
IG_GS 10																										
IG_NG 11	130	130	8.5	2.304	34648	266.5	130.0	8.5	2.304	34648	266.5															
DB... 12																										
GT_FD 13																										
TOTAL	2616	2616	12	4.778	40635		2567.4	10	4.701	40448							48.6	2	0.077	187						

Table E-1-2, continued. Negro Creek Data Summary.

NEGRO CREEK (SFSNEG) 1965-1975 PERIOD

GEO-TYPE NO.	GEO-TYPE AC	all disturbance classes: GEO-TYPE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD. C.Y./AC	undisturbed/unfailed lands: UNDIS. UNFLD' AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD. C.Y./AC	landslides harvest units: # HAR. AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD. C.Y./AC	landslides assoc. w/ roads: ROAD AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD. C.Y./AC	landslides assoc. w/ fire: FIRE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD C.Y./AC
TZ_DS 2																										
DLS.. 3	1408	1408	1	0.092	72	0.1	1368.2																			
MS_SG 4																	39.75	1	0.092	72	1.8					
MS_MG 5																										
MS_SW 6	276	276					274.5																			
MS_LS 8	547	547	2	0.436	1116	2.0	532.75	1	0.278	935	1.8						1.5									
IG_LD 9	255	255	4	0.390	705	2.8	249.75	2	0.351	690	2.8						14.25	1	0.158	181	12.7					
IG_GS 10																	5.25	2	0.039	15	2.9					
IG_NG 11	130	130	3	0.285	1476	11.4	130	3	0.285	1476	11.4															
DB... 12																										
GT_FD 13																										
TOTAL	2616	2616	10	1.203	3369		2555.2	6	0.914	3101							60.75	4	0.289	268						

NEGRO CREEK (SFSNEG) 1975-1988 PERIOD

GEO-TYPE NO.	GEO-TYPE AC	all disturbance classes: GEO-TYPE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD. C.Y./AC	undisturbed/unfailed lands: UNDIS. UNFLD' AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD. C.Y./AC	landslides harvest units: # HAR. AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD. C.Y./AC	landslides assoc. w/ roads: ROAD AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD. C.Y./AC	landslides assoc. w/ fire: FIRE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD C.Y./AC
TZ_DS 2																										
DLS.. 3	1408	1408	8	2.899	2766	2.0	0										53	3	0.6	1523	28.7	1355	5	2.299	1243	0.9
MS_SG 4																										
MS_MG 5																										
MS_SW 6	276	276	1.25	2.817	0	0.0	4										2				0.0	270	1.25	2.817	0	0.0
MS_LS 8	547	547	4	0.560	747	1.4	0										19	2	0.429	417	21.9	528	2	0.131	330	0.6
IG_LD 9	255	255	54	4.367	14968	58.7	0										7	2	0.139	275	39.3	248	52	4.228	14693	59.2
IG_GS 10																										
IG_NG 11	130	130	22.75	2.872	11223	86.3	0										1	1	0.074	360	360.0	129	21.75	2.798	10863	84.2
DB... 12																										
GT_FD 13																										
TOTAL	2616	2616	90	13.515	29704		4										82	8	1.242	2575		2530	82	12.273	27129	

NEGRO CREEK ALL PERIODS

SUM TOTAL	2616	2616	119	21.099	78145			22	6.998	47914		0			15	1.828	3102					82	12.273	27129		

Tables E-1-1 and E-1-2 Notes.

Geomorphic Terrane Types

Geomorphic Terrane	Code	Terrane No.
Slump/Earthflow Toe Zones	TZ_DS	2
Slump/Earthflow Deposits	DLS..	3
Granitic Mountain Slopes >65%	MS_SG	4
Granitic Mountain Slopes <65%	MS_MG	5
Non-Granitic Mountain Slopes >65%	MS_SN	6
Non-Granitic Mountain Slopes <65%	MS_LN	8
Inner Gorge in Landslide, Terrace or Glacial Deposits	IG_LD	9
Inner Gorge in Granitic Bedrock & Mt. Slopes	IG_GS	10
Inner Gorge in Non-Granitic Bedrock & Mt. Slopes	IG_NG	11
Debris Basins [Headwalls]	DB..	12
Glacial, Terrace & Fan Deposits	GT_FD	13

Table E-1-3. Selected data from the Little North Fork Landslide Inventory.

Selected data from the Little North Fork Landslide Inventory.
File: SUMLNF1

Row	Water-shed	Sub-Water-shed	Inven-tory Number	Meth-od	Photo Year	Slide Type	Bed-rock Type	Geo-morphic Terrane Type	Dis-tur-bance Class	Maxi-mum Eleva-tion	Mini-mum Eleva-tion	As-pect	Map Acres	Mobil-ized Vol-ume	Deliv-ered Vol-ume	Remain-ing Vol-ume	Stored Vol-ume
1	NFS	LNSHLS	81120	F	1965	CBDS	G	9	NAT	4460	4440	W	0.034	285	200	85	
2	NFS	LNSHLS	81121	F	1965	CBDS	G	9	NAT	4510	4500	E	0.023	100	100		
3	NFS	LNSHLS	81122	F	1965	DS	G	12	NAT	6320	6280	E	0.053	533	533		
4	NFS	LNSHLS	81123	F	1965	DS	G	12	NAT	6060	6020	W	0.061	530	371	159	
5	NFS	LNSHLS	81124	A	1965	DS	G	4	NAT	5760	5690	E	0.202	815	815		
6	NFS	LNSHLS	81125	A	1965	DS	G	12	NAT	5810	5760	W	0.057	518	518		
7	NFS	LNSHLS	81126	A	1944	DS	G	12	NAT	6570	6510	W	0.095	815	815		
8	NFS	LNSHLS	81127	A	1944	DS	G	12	NAT	6800	6710	W	0.069	1444	1444		
9	NFS	LNSHLS	81128	A	1944	DS	G	12	NAT	6830	6760	W	0.034	311	311		
10	NFS	LNSHLS	81129	A	1944	DS	G	4	NAT	6580	6510	W	0.043	370	370		
11	NFS	LNSHLS	81131	F	1965	DS	G	13	NAT	5650	5370	W	3.330	119778	5989	41922	71867
12	NFS	LNSHLS	81260	A	1965	DS	M	8	NAT	4660		N	0.055	427	256	171	
13	NFS	LNSHLS	81261	A	1972	DS	M	8	HAR	4600		N	0.018	71	57	14	
14	NFS	LNSHLS	88001	F	1971	DS	G	9	NAT	4260	4240	N	0.044	267	200	67	
15	NFS	LNSHLS	88002	F	1971	CBDS	G	9	NAT	4245	4210	N	0.060	237	190	47	
16	NFS	LNSHLS	88003	F	1965	CBDS	G	10	NAT	4280	4130	N	0.979	30000	22500	7500	
17	NFS	LNSHLS	88004	F	1965	CS	G	10	NAT	4240	4120	N	1.805	62000	49600	12400	
18	NFS	LNSHLS	88005	F	1965	CS	G	10	NAT	4230	4120	S	0.730	21926	16445	5481	
19	NFS	LNSHLS	88006	F	1965	CBDS	G	10	NAT	4160	4100	S	0.165	1889	1511	378	
20	NFS	LNSHLS	88007	F	1965	DS	M	11	NAT	3880	3740	N	0.568	9722	7777	1945	
21	NFS	LNSHLS	88008	F	1965	DS	M	11	NAT	3860	3700	N	0.312	1393	455	938	
22	NFS	LNSHLS	88009	F	1971	CS	M	11	HAR	4000	3750	E	2.755	106667	0	106667	
23	NFS	LNSHLS	88010	F	1965	CS	G	10	NAT	4135	4040	N	0.801	23111	13867	9244	
24	NFS	LNSHLS	88011	F	1965	CBDS	G	10	NAT	4130	4020	N	0.326	7435	5200	2235	
25	NFS	LNSHLS	88012	F	1965	DS	G	10	NAT	4140	4000	N	0.124	2273	1818	455	
26	NFS	LNSHLS	88013	F	1965	CBDS	G	10	NAT	4095	3990	N	0.613	20444	14310	6134	
27	NFS	LNSHLS	88014	F	1965	CBDS	G	10	NAT	3950	3920	N	0.054	333	200	133	
28	NFS	LNSHLS	88015	F	1965	CBDS	G	10	NAT	3940	3880	E	0.080	1283	962	321	
29	NFS	LNSHLS	88016	F	1965	CBDS	G	10	NAT	3935	3875	S	0.184	1200	720	480	
30	NFS	LNSHLS	88017	F	1965	CBDS	G	10	NAT	4000	3880	E	0.096	378	378		
31	NFS	LNSHLS	88018	F	1965	CBDS	G	10	NAT	3915	3870	S	0.259	2763	2487	276	
32	NFS	LNSHLS	88019	F	1965	CBDS	G	10	NAT	3880	3840	N	0.222	3862	3283	579	
33	NFS	LNSHLS	88020	F	1965	CS	G	10	NAT	3920	3810	N	0.697	9176	8258	918	
34	NFS	LNSHLS	88021	F	1972	CBDS	G	10	NAT	3740	3720	S	0.076	375	319	56	
35	NFS	LNSHLS	88022	F	1965	CS	G/M	10	NAT	3835	3760	E	0.133	1555	1089	466	
36	NFS	LNSHLS	88023	F	1965	CBDS	M	11	NAT	3755	3730	S	0.095	586	352	234	
37	NFS	LNSHLS	88024	F	1965	CS	M	9	NAT	3780	3500	N	2.258	141415	26289	115126	
38	NFS	LNSHLS	88025	F	1965	DS	M	9	NAT	3700	3520	N	0.850	10584	7860	2724	
39	NFS	LNSHLS	88026	F	1965	CBDS	G	10	NAT	3595	3540	S	0.351	3889	3145	744	
40	NFS	LNSHLS	88027	F	1965	DS	G	9	NAT	3780	3580	N	0.735	8747	5404	3343	

Table E-1-3, continued. Selected data from the Little North Fork Landslide Inventory.

Selected data from the Little North Fork Landslide Inventory.
File: SUMLNF1

Row	Water-shed	Sub-Water-shed	Inven-tory Number	Meth-od	Photo Year	Slide Type	Bed-rock Type	Geo-morphic Terrane Type	Dis-tur-bance Class	Maxi-mum Eleva-tion	Mini-mum Eleva-tion	As-pect	Map Acres	Mobil-ized Vol-ume	Deliv-ered Vol-ume	Remain-ing Vol-ume	Stored Vol-ume
41	NFS	LNSHLS	88028	F	1971	DS	G	10	NAT	3780	3600	N	0.014	74	52	22	
42	NFS	LNSHLS	88029	F	1971	DS	G	10	NAT	3650	3600	N	0.023	52	52		
43	NFS	LNSHLS	88030	F	1971	DS	G	10	NAT	3670	3600	N	0.078	351	263	88	
44	NFS	LNSHLS	88031	F	1971	CS	M	11	NAT	3650	3550	N	0.145	806	484	322	
45	NFS	LNSHLS	88032	F	1971	CS	M	11	NAT	3650	3520	N	0.344	4562	3650	912	
46	NFS	LNSHLS	88033	F	1965	CBDS	M	11	NAT	3620	3500	S	0.716	9333	6533	2800	
47	NFS	LNSHLS	88034	F	1965	DS	M	11	NAT	3550	3500	N	0.076	667	533	134	
48	NFS	LNSHLS	88035	FA	1972	CS	M	6	R	3960	3420	N	1.550	9444	472	8972	
49	NFS	LNSHLS	88036	F	1965	CS	G	10	NAT	3480	3400	N	0.270	1800	1260	540	
50	NFS	LNSHLS	88037	F	1965	DS	M	11	NAT	3420	3380	S	0.247	1017	610	203	204
51	NFS	LNSHLS	88038	F	1965	CBDS	M	11	NAT	3480	3460	S	0.088	110	100	10	
52	NFS	LNSHLS	88039	F	1965	DS	M	11	NAT	3390	3370	S	0.032	156	156		
53	NFS	LNSHLS	88040	F	1965	CBDS	M	11	NAT	3340	3320	W	0.083	400	360	40	
54	NFS	LNSHLS	88044	F	1965	CBDS	G	9	NAT	4325	4300	E	0.267	1695	1017	678	
55	NFS	LNSHLS	88045	F	1965	CBDS	G	9	NAT	4330	4300	S	0.135	563	282	281	
56	NFS	LNSHLS	88046	F	1965	CBDS	G	9	NAT	4330	4300	N	0.118	683	171	512	
57	NFS	LNSHLS	88047	F	1965	CBDS	G	9	NAT	4340	4320	S	0.037	156	78	78	
58	NFS	LNSHLS	88048	F	1965	CS	G	9	NAT	4400	4240	N	0.698	27489	7283	17778	2428
59	NFS	LNSHLS	88049	F	1965	CBDS	G	9	NAT	4340	4320	S	0.021	68	68		
60	NFS	LNSHLS	88050	F	1944	DS	G	9	NAT	4400	4270	N	0.366	6481	5833	648	
61	NFS	LNSHLS	88051	F	1965	CBDS	G	9	NAT	4350	4320	S	0.045	193	193		
62	NFS	LNSHLS	88052	F	1965	DS	G	9	NAT	4380	4320	N	0.229	7083	6375	708	
63	NFS	LNSHLS	88053	F	1965	CBDS	G	9	NAT	4380	4360	S	0.043	195	98	97	
64	NFS	LNSHLS	88054	F	1944	CS	G	9	NAT	4410	4325	N	0.404	10111	3889	6222	
65	NFS	LNSHLS	88055	F	1965	CS	G	9	NAT	4460	4420	S	0.118	3267	913	2354	
66	NFS	LNSHLS	88056	F	1965	CBDS	G	9	NAT	4420	4320	N	0.367	7644	4968	2676	
67	NFS	LNSHLS	88057	F	1965	CS	G	9	NAT	4440	4340	S	0.510	3230	2515	715	
68	NFS	LNSHLS	88058	F	1965	CBDS	G	9	NAT	4380	4340	N	0.125	879	703	176	
69	NFS	LNSHLS	88059	F	1965	CBDS	G	9	NAT	4480	4390	S	0.334	1409	1127	282	
70	NFS	LNSHLS	88060	F	1965	CBDS	G	9	NAT	4460	4390	N	0.193	1496	1122	374	
71	NFS	LNSHLS	88061	F	1965	CBDS	G	9	NAT	4420	4390	S	0.068	467	350	117	
72	NFS	LNSHLS	88062	F	1965	CBDS	G	9	NAT	4450	4430	N	0.105	619	495	124	
73	NFS	LNSHLS	88063	F	1965	CBDS	G	9	NAT	4570	4540	S	0.171	1072	750	322	
74	NFS	LNSHLS	88064	F	1965	CBDS	G	9	NAT	4490	4440	N	0.113	889	711	178	
75	NFS	LNSHLS	88065	F	1965	CBDS	G	9	NAT	4620	4580	S	0.312	1317	1054	263	
76	NFS	LNSHLS	88066	F	1965	CBDS	G	9	NAT	4595	4580	N	0.094	400	360	40	
77	NFS	LNSHLS	88067	F	1965	CBDS	G	9	NAT	4645	4610	S	0.108	444	400	44	
78	NFS	LNSHLS	88068	F	1965	CBDS	G	9	NAT	4615	4600	W	0.174	743	669	74	
79	NFS	LNSHLS	88069	F	1965	CBDS	G	9	NAT	4690	4680	S	0.043	92	74	18	
80	NFS	LNSHLS	88070	F	1965	CBDS	G	9	NAT	4660	4650	N	0.379	560	504	56	
81	NFS	LNSHLS	88071	F	1965	CBDS	G	9	NAT	4780	4750	S	0.075	467	280	187	

Table E-1-3, continued. Selected data from the Little North Fork Landslide Inventory.

Selected data from the Little North Fork Landslide Inventory.
File: SUMLNF1

Row	Water-shed	Sub-Water-shed	Inven-tory Number	Meth-od	Photo Year	Slide Type	Bed-rock Type	Geo-morphic Terrane Type	Dis-tur-bance Class	Maxi-mum Eleva-tion	Mini-mum Eleva-tion	As-pect	Map Acres	Mobil-ized Vol-ume	Deliv-ered Vol-ume	Remain-ing Vol-ume	Stored Vol-ume
82	NFS	LNSHLS	88072	F	1965	CBDS	G	10	NAT	4260	4230	N	0.121	1067	960	107	
83	NFS	LNSHLS	88073	F	1965	CBDS	G	9	NAT	4805	4780	S	0.047	278	195	83	
84	NFS	LNSHLS	88074	F	1965	DS	G	4	NAT	5200	4900	S	0.194	746	671	75	
85	NFS	LNSHLS	88075	F	1965	DS	G	10	NAT	5600	5330	S	0.214	2956	2660	296	
86	NFS	LNSHLS	88076	F	1965	DS	G	4	NAT	5600	5490	S	0.149	1222	1161	61	
87	NFS	LNSHLS	88077	F	1971	DS	M	11	NAT	3620	3550	E	0.046	533	373	160	
88	NFS	LNSHLS	88078	F	1965	CBDS	G	10	NAT	4140	3920	S	0.160	348	348		
89	NFS	LNSHLS	88079	F	1965	CBDS	G	10	NAT	4080	4040	S	0.097	222	222		
90	NFS	LNSHLS	88081	F	1965	CBDS	G	9	NAT	4270	4240	S	0.020	124	75	49	
91	NFS	LNSHLS	88082	F	1965	CBDS	G	9	NAT	4290	4260	S	0.036	161	113	48	
92	NFS	LNSHLS	88083	F	1965	CBDS	G	9	NAT	4345	4325	E	0.037	241	193	48	
93	NFS	LNSHLS	88084	F	1965	CBDS	G	9	NAT	4390	4370	SW	0.034	344	241	103	
94	NFS	LNSHLS	88085	F	1965	CS	G	9	NAT	4425	4400	W	0.077	778	389	389	
95	NFS	LNSHLS	88086	F	1965	CBDS	G	9	NAT	4430	4410	W	0.124	956	574	382	
96	NFS	LNSHLS	88087	F	1965	CS	G	10	NAT	5110	4880	E	0.344	3470	2429	1041	
97	NFS	LNSHLS	88088	F	1971	CS	G	10	NAT	4950	4840	N	0.317	1086	1032	54	
98	NFS	LNSHLS	88089	F	1971	CS	G	10	NAT	4820	4780	N	0.051	122	79	43	
99	NFS	LNSHLS	88090	F	1975	CS	G	10	NAT	4740	4700	S	0.104	237	237		
100	NFS	LNSHLS	88091	FA	1965	CS	G	10	NAT	4840	4760	W	0.133	303	303		
101	NFS	LNSHLS	88117	A	1971	DS	M	11	HAR	3950	3880	N	0.155	302	302		
102	NFS	LNSHLS	88118	A	1971	DS	M	11	HAR	3920	3880	E	0.041	237	237		
103	NFS	LNSHLS	88119	A	1971	DS	M	11	HAR	4080	4040	N	0.041	247	247		
104	NFS	LNSHLS	88120	A	1972	DS	M	11	HAR	4140	4120	N	0.009	60	60		
105	NFS	LNSHLS	88123	A	1972	DS	M	6	R	3920		N	0.052	200	40	160	
106	NFS	LNSHLS	88124	A	1972	DS	M	6	R	3920		N	0.052	200	40	160	
107	NFS	LNSHLS	88125	A	1972	DS	M	8	R	4560		N	0.076	440	286	154	
108	NFS	LNSHLS	88126	A	1972	DS	M	11	R	4320		N	0.076	807	766	40	
109	NFS	LNSHLS	88128	A	1965	DS	G	5	NAT	5280		S	0.056	327	294	33	
110	NFS	LNSHLS	88129	A	1965	DS	G	4	NAT	5640		S	0.056	327	294	33	
111	NFS	LNSLOW	81063	F	1965	DS	G	10	NAT	2760	2720	W	0.073	467	467		
112	NFS	LNSLOW	81064	F	1965	DS	G	10	NAT	2760	2720	N	0.047	150	150		
113	NFS	LNSLOW	81065	F	1944	DS	G	5	T	4000	3125	E	0.072	2222			2222
114	NFS	LNSLOW	81066	F	1965	CBDS	G	10	NAT	2360	2320	W	0.117	681	681		
115	NFS	LNSLOW	81067	F	1965	CBDS	G	10	NAT	2300	2290	E	0.101	597	597		
116	NFS	LNSLOW	81068	F	1965	CS	G	10	NAT	2340	2290	W	0.171	9259	3087	3086	3086
117	NFS	LNSLOW	81069	F	1972	DS	G	4	NAT	2480	2160	W	0.482	13800	8200	2800	2800
118	NFS	LNSLOW	81070	F	1971	DS	G	10	NAT	2060	2040	W	0.195	1155	1040	115	
119	NFS	LNSLOW	81071	F	1971	DS	G	10	T	2100	2030	W	0.204	1400	1400		
120	NFS	LNSLOW	81072	F	1972	DS	G	10	NAT	2160	2100	W	0.053	237	237		
121	NFS	LNSLOW	81073	F	1971	DS	G	10	NAT	2200	2150	W	0.055	270	216	54	
122	NFS	LNSLOW	81076	F	1965	DS	G	10	NAT	2500	2360	S	0.597	12037	9027	3010	
123	NFS	LNSLOW	81077	F	1965	DS	G	10	NAT	2430	2730	S	0.095	433	303	130	

Table E-1-3, continued. Selected data from the Little North Fork Landslide Inventory.

Selected data from the Little North Fork Landslide Inventory.
File: SUMLNF1

Row	Water-shed	Sub-Water-shed	Inven-tory Number	Meth-od	Photo Year	Slide Type	Bed-rock Type	Geo-morphic Terrane Type	Dis-tur-bance Class	Maxi-mum Eleva-tion	Mini-mum Eleva-tion	As-pect	Map Acres	Mobil-ized Vol-ume	Deliv-ered Vol-ume	Remain-ing Vol-ume	Stored Vol-ume
124	NFS	LNSLOW	81078	F	1971	DS	G	10	NAT	2410	2380	S	0.049	207	166	41	
125	NFS	LNSLOW	81079	F	1972	CBDS	G	10	NAT	2385	2380	S	0.015	33	7	26	
126	NFS	LNSLOW	81080	F	1965	DS	G	10	NAT	2495	2470	S	0.074	1333	1200	133	
127	NFS	LNSLOW	81081	F	1972	CBDS	G	10	NAT	2490	2460	S	0.057	260	208	52	
128	NFS	LNSLOW	81082	F	1972	CBDS	G	10	NAT	2550	2500	S	0.461	2500	2250	250	
129	NFS	LNSLOW	81083	F	1965	CBDS	G	10	NAT	2735	2705	S	0.108	1100	1000	100	
130	NFS	LNSLOW	81084	F	1972	CBDS	G	10	NAT	2650	2620	E	0.030	200	180	20	
131	NFS	LNSLOW	81085	F	1972	DS	G	10	NAT	2800	2790	S	0.006	27	24	3	
132	NFS	LNSLOW	81086	F	1972	CBDS	G	10	NAT	2680	2610	E	0.073	490	390	100	
133	NFS	LNSLOW	81087	F	1972	DS	G	10	NAT	2810	2725	E	0.053	244	220	24	
134	NFS	LNSLOW	81088	F	1971	CBDS	G	10	NAT	2730	2660	W	0.053	281	267	14	
135	NFS	LNSLOW	81089	F	1965	DS	G	10	NAT	2765	2660	S	0.081	652	587	65	
136	NFS	LNSLOW	81090	F	1965	CS	G	10	NAT	2760	2705	N	0.051	458	435	23	
137	NFS	LNSLOW	81091	F	1965	CBDS	G	10	NAT	2750	2730	N	0.070	833	750	83	
138	NFS	LNSLOW	81092	F	1972	CBDS	G	10	NAT	2725	2710	S	0.025	222	155	67	
139	NFS	LNSLOW	81093	F	1965	CBDS	G	10	NAT	2930	2815	E	0.125	944	661	283	
140	NFS	LNSLOW	81094	F	1965	CBDS	G	10	NAT	2835	2815	E	0.029	250	150	100	
141	NFS	LNSLOW	81095	F	1972	DS	G	10	T	2800	2740	E	0.041	192	172	20	
142	NFS	LNSLOW	81096	F	1965	DS	G	10	NAT	2880	2720	W	0.259	1533	767		766
143	NFS	LNSLOW	81097	F	1965	DS	G	10	NAT	2790	2740	NE	0.130	870	783	87	
144	NFS	LNSLOW	81098	F	1965	CS	M	11	T	2860	2840	W	0.053	175	17	158	
145	NFS	LNSLOW	81099	F	1965	CS	M	11	NAT	2880	2800	NE	0.291	4594	4135	459	
146	NFS	LNSLOW	81100	F	1965	CS	G	10	NAT	2880	2860	W	0.030	214	161	53	
147	NFS	LNSLOW	81101	F	1965	CBDS	M	11	NAT	2880	2860	W	0.028	394	394		
148	NFS	LNSLOW	81102	F	1972	CS	G	10	NAT	2860	2800	E	0.218	9696	5818	3878	
149	NFS	LNSLOW	81103	F	1965	CS	G	10	NAT	2870	2820	E	0.085	720	540	180	
150	NFS	LNSLOW	81104	F	1965	CS	G	10	NAT	2940	2810	E	0.265	3447	1206	2241	
151	NFS	LNSLOW	81105	F	1965	CS	M	11	NAT	2890	2850	S	0.128	1020	816	204	
152	NFS	LNSLOW	81106	F	1965	CBDS	G	10	NAT	3160	3120	W	0.128	693	416	277	
153	NFS	LNSLOW	81107	F	1965	CBDS	G	9	NAT	3170	3110	E	0.093	560	448	112	
154	NFS	LNSLOW	81108	F	1972	DS	G	9	NAT	3200	3100	E	0.071	244	158	86	
155	NFS	LNSLOW	81109	F	1972	CBDS	M	10	NAT	3120	3100	W	0.055	239	60	179	
156	NFS	LNSLOW	81110	F	1972	CS	M	9	NAT	3160	3130	E	0.157	2600	2080	520	
157	NFS	LNSLOW	81111	F	1971	CBDS	M	9	NAT	3240	3200	W	0.034	217	130	87	
158	NFS	LNSLOW	81112	F	1971	CBDS	M	9	NAT	3230	3200	E	0.055	239	239		
159	NFS	LNSLOW	81113	F	1965	CS	M	11	NAT	3230	3200	E	0.050	778	272	506	
160	NFS	LNSLOW	81114	F	1972	CS	M	11	NAT	3240	3210	S	0.186	1437	719	718	
161	NFS	LNSLOW	81115	F	1965	CBDS	M	11	NAT	3380	3300	E	0.299	5440	3264	2176	
162	NFS	LNSLOW	81116	F	1965	CBDS	M	11	NAT	3390	3300	E	0.259	6222	3733	2489	
163	NFS	LNSLOW	81117	F	1965	CBDS	M	11	NAT	3320	3300	W	0.129	544	435	109	
164	NFS	LNSLOW	81118	F	1965	CBDS	M	11	NAT	3195	3160	W	0.157	712	712		
165	NFS	LNSLOW	81119	F	1965	CBDS	M	11	NAT	3260	3240	W	0.067	407	407		

Table E-1-3, continued. Selected data from the Little North Fork Landslide Inventory.

Selected data from the Little North Fork Landslide Inventory.
File: SUMLNF1

Row	Water-shed	Sub-Water-shed	Inven-tory Number	Meth-od	Photo Year	Slide Type	Bed-rock Type	Geo-morphic Terrane Type	Dis-tur-bance Class	Maxi-mum Eleva-tion	Mini-mum Eleva-tion	As-pect	Map Acres	Mobil-ized Vol-ume	Deliv-ered Vol-ume	Remain-ing Vol-ume	Stored Vol-ume
166	NFS	LNSLOW	81130	F	1965	DS	G	10	NAT	2880	2720	W	0.327	2083	1042		1041
167	NFS	LNSLOW	81222	A	1965	CS	M	9	NAT	4720	3360	S	39.000	1887600	20415	1867185	
168	NFS	LNSLOW	81223	A	1972	DS	G	10	R	2500		E	0.088	2292	2063	229	
169	NFS	LNSLOW	81224	A	1972	DS	G	10	R	2480		E	0.344	2972	2378	594	
170	NFS	LNSLOW	81225	A	1972	DS	G	4	R	2540		E	0.064	504	302	201	
171	NFS	LNSLOW	81226	A	1972	DS	G	10	R	2540		E	0.051	196	78	117	
172	NFS	LNSLOW	81227	A	1972	DS	G	10	R	2580		E	0.107	3870	3793	77	
173	NFS	LNSLOW	81228	A	1972	DS	G	10	R	2600		E	0.046	956	764	191	
174	NFS	LNSLOW	81229	A	1972	DS	G	10	R	2640		E	0.283	1618	1132	485	
175	NFS	LNSLOW	81230	A	1972	DS	G	10	R	2640		E	0.278	1043	626	417	
176	NFS	LNSLOW	81231	A	1972	DS	G	10	R	2640		E	0.113	420	252	168	
177	NFS	LNSLOW	81232	A	1972	DS	G	10	R	2640		E	0.844	4900	3430	1470	
178	NFS	LNSLOW	81233	A	1972	DS	G	10	R	2650		S	0.202	699	559	140	
179	NFS	LNSLOW	81234	A	1972	DS	G	10	R	2880		N	0.048	284	256	28	
180	NFS	LNSLOW	81235	A	1972	DS	G	10	R	2880		N	0.041	243	219	24	
181	NFS	LNSLOW	81236	A	1972	DS	G	10	R	2880		N	0.137	4722	4486	236	
182	NFS	LNSLOW	81237	A	1972	DS	G	4	R	2880		E	0.064	378	340	38	
183	NFS	LNSLOW	81238	A	1972	DS	G	5	R	2890		E	0.034	133	80	53	
184	NFS	LNSLOW	81239	A	1972	DS	G	5	R	3120		N	0.073	391	332	59	
185	NFS	LNSLOW	81240	A	1972	DS	G	5	R	3120		N	0.073	276	234	41	
186	NFS	LNSLOW	81241	A	1972	DS	G	10	R	3120		E	2.250	12756	7653	5102	
187	NFS	LNSLOW	81242	A	1972	DS	G	10	R	3140		E	0.284	1589	1112	477	
188	NFS	LNSLOW	81243	A	1972	DS	G	4	R	3200		E	0.220	1244	747	498	
189	NFS	LNSLOW	81244	A	1972	DS	G	4	R	3200		E	0.220	1244	747	498	
190	NFS	LNSLOW	81245	A	1972	DS	G	10	R	3200		E	0.195	1385	970	416	
191	NFS	LNSLOW	81246	A	1972	DS	G	10	R	3210		E	0.080	296	178	119	
192	NFS	LNSLOW	81247	A	1972	DS	G	10	R	3240		E	0.064	222	156	67	
193	NFS	LNSLOW	81248	A	1972	DS	M	11	R	3360		E	0.069	244	220	24	
194	NFS	LNSLOW	81249	A	1972	DS	M	6	R	3400		E	0.129	498	299	199	
195	NFS	LNSLOW	81250	A	1972	DS	M	6	R	3400		E	0.161	900	540	360	
196	NFS	LNSLOW	81251	A	1972	DS	M	11	R	3480		E	0.107	1397	279	1118	
197	NFS	LNSLOW	81252	A	1972	DS	M	6	R	3500		E	0.064	342	68	274	
198	NFS	LNSLOW	81253	A	1972	DS	M	6	R	3600		N	0.276	1067	107	960	
199	NFS	LNSLOW	81254	A	1972	DS	M	6	R	3620		N	0.253	1956	1369	587	
200	NFS	LNSLOW	81255	A	1972	DS	M	6	R	3700		E	0.367	1419	851	567	
201	NFS	LNSLOW	81256	A	1972	DS	M	9	NAT	3500		E	0.322	3797	2278	1519	
202	NFS	LNSLOW	81257	A	1972	DS	M	6	R	3680		E	0.076	595	476	119	
203	NFS	LNSLOW	81258	A	1972	DS	M	3	HAR	3800		S	0.056	653	555	98	
204	NFS	LNSLOW	81259	A	1972	DS	M	3	R	3680		S	0.028	204	184	20	
205	NFS	LNSLOW	81262	A	1972	DS	M	11	NAT	4840		E	0.045	173	156	17	
206	NFS	LNSLOW	81263	A	1972	DS	M	6	NAT	5100		E	0.052	303	273	30	
207	NFS	LNSLOW	81264	A	1965	DS	M	6	NAT	4800		S	0.051	385	347	38	

Table E-1-3, continued. Selected data from the Little North Fork Landslide Inventory.

Selected data from the Little North Fork Landslide Inventory.
File: SUMLNF1

Row	Water-shed	Sub-Water-shed	Inventory Number	Method	Photo Year	Slide Type	Bedrock Type	Geomorphic Terrane Type	Disturbance Class	Maximum Elevation	Minimum Elevation	Aspect	Map Acres	Mobilized Volume	Delivered Volume	Remaining Volume	Stored Volume
208	NFS	LNSLOW	81265	A	1965	DS	M	6	NAT	4320		S	0.088	1027	667	359	
209	NFS	LNSLOW	81266	A	1972	DS	G	4	R	3640		E	0.124	707	495	212	
210	NFS	LNSLOW	81267	A	1972	DS	G	4	R	3560		E	0.034	129	103	26	
211	NFS	LNSLOW	81268	A	1972	DS	G	10	R	3500		E	0.037	133	80	53	
212	NFS	LNSLOW	81269	A	1972	DS	G	10	R	3500		E	0.075	400	260	140	
213	NFS	LNSLOW	81270	A	1972	DS	G	4	R	3600		E	0.139	1084	704	379	
214	NFS	LNSLOW	81271	A	1972	DS	G	4	R	3540		E	0.080	344	224	121	
215	NFS	LNSLOW	81272	A	1972	DS	G	4	R	3540		E	0.017	74	48	26	
216	NFS	LNSLOW	81273	A	1972	DS	G	4	R	3600		E	0.351	2627	1707	919	
217	NFS	LNSLOW	81274	A	1972	DS	G	4	R	3520		E	0.045	247	160	86	
218	NFS	LNSLOW	81275	A	1972	DS	G	10	R	3520		E	0.045	160	112	48	
219	NFS	LNSLOW	81276	A	1972	DS	G	10	R	3440		E	0.088	676	440	237	
220	NFS	LNSLOW	81277	A	1972	DS	G	10	R	3440		E	0.116	879	835	44	
221	NFS	LNSLOW	81278	A	1972	DS	G	4	R	3400		E	0.082	318	207	111	
222	NFS	LNSLOW	81279	A	1972	DS	G	10	R	3360		E	0.031	173	130	43	
223	NFS	LNSLOW	81280	A	1972	DS	G	10	R	3280		W	0.062	360	216	144	
224	NFS	LNSLOW	81281	A	1972	DS	G	5	R	3240		E	0.088	513	257	257	
225	NFS	LNSLOW	81282	A	1972	DS	G	5	R	3230		E	0.082	477	191	286	
226	NFS	LNSLOW	81283	A	1972	DS	G	5	R	3080		E	0.044	167	50	117	
227	NFS	LNSLOW	81284	A	1972	DS	G	10	R	3080		E	0.031	231	139	92	
228	NFS	LNSLOW	81285	A	1972	DS	G	4	R	2980		E	0.031	120	36	84	
229	NFS	LNSLOW	81286	A	1972	DS	G	10	R	3700		E	0.103	800	640	160	
230	NFS	LNSLOW	81287	A	1972	DS	G	4	R	3720		E	0.077	300	180	120	
231	NFS	LNSLOW	81288	A	1972	DS	G	4	R	3750		E	0.069	269	134	134	
232	NFS	LNSLOW	81289	A	1972	DS	G	5	R	3920		S	0.069	417	271	146	
233	NFS	LNSLOW	81290	A	1972	DS	G	10	R	4000		E	0.037	326	293	33	
234	NFS	LNSLOW	81291	A	1972	DS	G	4	HAR	3800		S	0.032	244	196	49	
235	NFS	LNSLOW	81292	A	1972	DS	G	4	HAR	3720		E	0.037	289	246	43	
236	NFS	LNSLOW	81293	A	1972	DS	G	4	HAR	3600		E	0.119	1343	873	470	
237	NFS	LNSLOW	81294	A	1972	DS	G	5	NAT	2500		S	0.038	147	88	59	
238	NFS	LNSLOW	81295	A	1972	DS	G	5	NAT	2560		E	0.023	91	64	27	
239	NFS	LNSLOW	88041	F	1965	DS	M	11	T	3440	3370	W	0.104	1573	1573		
240	NFS	LNSLOW	88042	F	0	DS	M	11	T	3450	3370	N	0.051	233	233		
241	NFS	LNSLOW	88043	F	1965	CBDS	G/M	11	NAT	3385	3370	E	0.178	568	511		57
242	NFS	LNSLOW	88080	A	1965	CBDS	M	11	NAT	3235	3220	E	0.139	333	333		
243	NFS	LNSLOW	88121	A	1972	DS	M	6	HAR	3640	3280	E	0.409	2889			2889
244	NFS	LNSLOW	88122	FA	1972	DS	M	6	HAR	3720	3300	E	2.645	7644		2675	4969
245	NFS	LNSLOW	88127	A	1972	DS	G	4	R	3480		E	0.113	871	174	697	
246	NFS	LNSSPE	81062	F	1971	CS	G/M	11	NAT	2470	2370	W	0.028	118	12	106	
247	NFS	LNSSPE	81074	F	1965	DS	G	10	NAT	2450	2320	W	0.146	2592	2592		
248	NFS	LNSSPE	81075	F	1965	DS	G	10	NAT	2410	2350	W	0.032	176	132	44	
249	NFS	LNSUNC	88094	F	1971	CBDS	M	9	NAT	4200	4140	W	0.413	2980	2700	280	

Table E-1-3, continued. Selected data from the Little North Fork Landslide Inventory.

Selected data from the Little North Fork Landslide Inventory.
File: SUMLNF1

Row	Water-shed	Sub-Water-shed	Inven-tory Number	Meth-od	Photo Year	Slide Type	Bed-rock Type	Geo-morphic Terrane Type	Dis-tur-bance Class	Maxi-mum Eleva-tion	Mini-mum Eleva-tion	As-pect	Map Acres	Mobil-ized Vol-ume	Deliv-ered Vol-ume	Remain-ing Vol-ume	Stored Vol-ume
250	NFS	LNSUNC	88095	FA	1971	CBDS	M	9	NAT	4320	4310	W	0.037	83	83		
251	NFS	LNSUNC	88096	F	1971	CBDS	M	9	NAT	4330	4310	W	0.151	344	344		
252	NFS	LNSUNC	88097	FA	1971	CBDS	M	11	NAT	4330	4310	E	0.151	344	344		
253	NFS	LNSUNC	88098	A	1944	CBDS	M	11	NAT	4360	4340	S	0.056	233	233		
254	NFS	LNSUNC	88099	FA	1971	CBDS	G	10	NAT	3540	3520	N	0.129	260	260		
255	NFS	LNSUNC	88100	A	1965	DS	G	10	NAT	5050	4980	E	0.114	1042	1042		
256	NFS	LNSUNC	88101	A	1965	DS	G	10	NAT	5580	5460	S	0.276	3811	3811		
257	NFS	LNSUNC	88102	A	1965	DS	G	10	NAT	5960	5880	S	0.129	2087	2087		
258	NFS	LNSUNC	88103	A	1965	DS	G	10	NAT	4920	4840	E	0.093	1000	1000		
259	NFS	LNSUNC	88104	A	1965	DS	G	4	NAT	5520	5440	S	0.041	463	463		
260	NFS	LNSUNC	88105	A	1965	DS	G	4	NAT	5055	5040	E	0.006	35	35		
261	NFS	LNSUNC	88106	A	1965	DS	G	5	NAT	6160	6145	E	0.025	141	141		
262	NFS	LNSUNC	88107	A	1944	DS	G	12	NAT	7080	6720	E	0.569	4267	4267		
263	NFS	LNSUNC	88108	A	1944	DS	G	4	NAT	6780	6730	E	0.048	378	378		
264	NFS	LNSUNC	88109	F	1972	CBDS	G	11	NAT	3820	3780	W	0.079	722	722		
265	NFS	LNSUNC	88110	F	1965	CBDS	G	10	NAT	3790	3780	W	0.014	44	44		
266	NFS	LNSUNC	88111	F	1972	CBDS	M	11	NAT	3340	3320	W	0.016	33	33		
267	NFS	LNSUNC	88112	F	1965	CBDS	M	11	NAT	3410	3360	S	0.129	800	800		
268	NFS	LNSUNC	88113	A	1944	CBDS	G	9	NAT	5100	5020	W	0.367	2133	2133		
269	NFS	LNSUNC	88114	A	1965	CBDS	G	9	NAT	5270	5240	W	0.125	861	861		
270	NFS	LNSUNC	88115	A	1965	CBDS	G	13	NAT	4800	4720	W	0.124	740	740		
271	NFS	LNSUNC	88116	A	1965	CBDS	G	9	NAT	3960	3940	W	0.069	427	427		
Data from Pillsbury (1976).																	
	NFS	LNSLOW	88999	FA	1972	DS	G	10	HAR				8.179	42306	42306	0	0
											TOTAL		103.64	2868112	483168	2292614	92329

Table E-1-4. Selected data from the Negro Creek Landslide Inventory.

Selected data from the Negro Creek Landslide Inventory
File: Sumneg1.wk1

Row	Water-shed	Inv. No.	Meth-od	Photo Year	Est. Yr. Range	Slide Type	Rock Type	Geomor-phic Terrane Type	Distur-bance Class	Max. Eleva-tion	Min-. Eleva-tion	As-pect	Map Acres	Mobil-ized Volume	Deliv-ered Volume	On-Site Volume	Stored Volume Off-site
1	SFSNEG	4001	F	1982	77-87	S EF	U	3	FIRE	2590	2480	W	0.471	8290	0	6632	1658
2	SFSNEG	4002	F	1982	77-87	S	U	3	ROAD	2440	2400	W	0.070	538	0	484	54
3	SFSNEG	4003	F	1988		DS	U	9	FIRE	2400	2370	S	0.004	8	8		
4	SFSNEG	4004	F	1988		DS	U	9	FIRE	2420	2400	S	0.004	93	10	10	23
5	SFSNEG	4005	F	1988		DS	U	9	FIRE	2420	2320	S	0.003	30	15	15	
6	SFSNEG	4006	F	1988		CBDS	M	9	FIRE	2200	2180	W	0.066	297	202	95	
7	SFSNEG	4007	F	1988		CBDS	M	9	FIRE	2185	2180	E	0.009	19	14	5	
8	SFSNEG	4008	F	1988		CBDS	M	9	FIRE	2190	2180	W	0.015	17	7		10
9	SFSNEG	4009	F	1944		DS	M	11	NAT	2330	2210	S	0.225	1360	1360		
10	SFSNEG	4010	F	1944		DS	M	11	NAT	2260	2200	S	0.033	205	205		
11	SFSNEG	4011	F	1944		DS	M	11	NAT	2220	2190	S	0.016	100	100		
12	SFSNEG	4012	F	1980	77-87	DF	M	11	FIRE	2440	2400	W	0.040	167	142	25	
13	SFSNEG	4013	F	1965		BG S DS	M/U	11	NAT	2600	2320	W	3.501	378000	33000	345000	
14	SFSNEG	4014	F	1980	77-87	CBDS	M	9	FIRE	2420	2400	E	0.004	30	30		
15	SFSNEG	4015	F	1980	77-87	CBDS	M	9	FIRE	3380	3360	E	0.019	82	82		
16	SFSNEG	4016	F	1980	77-87	DF	M	9	FIRE	2360	2340	E	0.011	70	21	49	
17	SFSNEG	4017	F	1980		DS	M	8	ROAD	3360	3310	E	0.108	667	267	400	
18	SFSNEG	4018	F	1944		BG	M	3	NAT	2720	2610	E	0.843	7361	0	4785	2576
19	SFSNEG	4019	F	1980	77-87	DS	M	11	FIRE	2400	2380	E	0.036	36	36		
20	SFSNEG	4020	F	1980		CBDS	M	11	FIRE	2250	2220	E	0.025	113	100	11	2
21	SFSNEG	4021	F	1980	77-87	CBDS	M	11	FIRE	2830	2825	S	0.003	7	7		
22	SFSNEG	4022	F	1980		DS	M	11	FIRE	2340	2250	E	0.050	260	247	13	
23	SFSNEG	4023	F	1965		DS	M/U	11	NAT	2230	2100	W	0.184	950	810	140	
24	SFSNEG	4024	F	1965		DS	M	11	NAT	2130	2080	W	0.031	150	142	8	
25	SFSNEG	4025	F	1987		S DS	M	8	FIRE	2480	2440	S	0.085	370	19	222	129
26	SFSNEG	4026	F	1980	77-87	DF	M	11	FIRE	2820	2780	SE	0.293	1931	1216	715	
27	SFSNEG	7001	F	1987		DS	M	11	FIRE	2140	2080	W	0.055	252	50	127	75
28	SFSNEG	7002	F	1987		DS DF	M	2	FIRE	2180	1980	W	0.320	5050	3150	1900	
29	SFSNEG	7003	F	1944		DS DF	M	9	NAT	2050	1930	E	0.232	2500	2400	100	
30	SFSNEG	7004	F	1980		DS DF	M	9	FIRE	1990	1930	E	0.060	500	450	50	
31	SFSNEG	7005	F	1980		DS DF	M	9	FIRE	1970	1940	E	0.029	200	180	20	
32	SFSNEG	7006	F	1980		DS DF	M	9	FIRE	1990	1965	E	0.014	90	85	5	
33	SFSNEG	7007	F	1980		S DS	M	9	FIRE	1935	1930	E	0.033	389	195	194	
34	SFSNEG	7008	F	1980		S BG DS	M	6	FIRE	2420	1930	E	2.608	98111	0	98111	
35	SFSNEG	7009	F	1988		CBDS	M/U	9	FIRE	2130	2125	W	0.015	61	55		6
36	SFSNEG	7010	F	1988	80-88	CBDS	M	11	FIRE	1950	1940	W	0.002	25	20	5	
37	SFSNEG	7011	F	1988	80-88	S EF DS	U	9	FIRE	2220	2100	S	0.128	840	410	430	
38	SFSNEG	7012	F	1988	80-88	DS	U	9	FIRE	1960	1920	E	0.085	185	61	124	
39	SFSNEG	7013	F	1965		DS	M	11	NAT	1460	1440	E	0.082	337	135	202	
40	SFSNEG	7014	F	1965		CBDS	M	11	NAT	1490	1460	E	0.022	133	127	6	

Table E-1-4, continued. Selected data from the Negro Creek Landslide Inventory.

Selected data from the Negro Creek Landslide Inventory
File: Sumneg1.wk1

Row	Water-shed	Inv. No.	Meth-od	Photo Year	Est. Yr. Range	Slide Type	Rock Type	Geomor-phic Terrane Type	Distur-bance Class	Max. Eleva-tion	Min-. Eleva-tion	As-pect	Map Acres	Mobil-ized Volume	Deliv-ered Volume	On-Site Volume	Stored Volume Off-site
41	SFSNEG	7015	F	1965		CBDS	M	11	NAT	1500	1480	E	0.008	116	87	29	
42	SFSNEG	7016	F	1965		DS	M	11	NAT	1620	1580	W	0.143	622	187	435	
43	SFSNEG	7017	F	1980		RS	M	11	FIRE	2160	1560	W	1.722	28444	7111	21333	
44	SFSNEG	7018	F	1980		RS DS	M	11	FIRE	1820	1670	N	0.344	2133	704	1429	
45	SFSNEG	7019	F	1971	65-71	DS RS	M	11	NAT	1740	1695	S	0.094	489	211	278	
46	SFSNEG	7020	F	1980		DS	M	11	ROAD	1470	1430	W	0.074	600	360	240	
47	SFSNEG	7021	F	1980		DF	M	3	ROAD	2950	2720	W	0.510	3936	1508	2261	167
48	SFSNEG	7022	F	1971	65-71	S	G	8	ROAD	2930	2870	W	0.158	606	181	425	
49	SFSNEG	79001	F	1987	82-85	S EF DF	M	3	FIRE	3050	2860	W	1.413	37949	1033	36916	
50	SFSNEG	79002	F	1971		DF	M	8	NAT	2970	2580	N	0.278	935	935		
51	SFSNEG	79003	F	1980		S EF DF	M	9	FIRE	3040	2800	W	0.929	8352	1111	7241	
52	SFSNEG	79004	F	1980		DS	U	9	FIRE	2590	2520	W	0.068	635	605	30	
53	SFSNEG	79005	F	1980	80-87	CBDS	U	9	FIRE	2480	2450	N	0.011	333	323	10	
54	SFSNEG	79006	F	1987	82-85	DS	M	9	FIRE	2450	2360	N	0.166	1890	1320	570	
55	SFSNEG	79007	F	1971		CBDS	M	11	NAT	2300	2260	W	0.026	230	220	10	
56	SFSNEG	79008	F	1987	82-85	DS	U	9	FIRE	2770	2690	N	0.184	1925	1900	25	
57	SFSNEG	79009	F	1987	82-85	DF	U	9	FIRE	2710	2680	S	0.034	167	167		
58	SFSNEG	79010	F	1987	82-85	DS	U	9	FIRE	2860	2780	N	0.103	925	725	200	
59	SFSNEG	79011	F	1987	82-85	DS	U	9	FIRE	2870	2790	N	0.051	300	270	30	
60	SFSNEG	79012	F	1988		CBDS	U	9	FIRE	2900	2880	E	0.018	111	111		
61	SFSNEG	81001	F	1987		CBDS	U	9	FIRE	3250	3240	E	0.007	44	15	29	
62	SFSNEG	81002	F	1988		CBDS	M	11	FIRE	3230	3220	W	0.004	12	12		
63	SFSNEG	81003	F	1988		CBDS	U	9	FIRE	3250	3210	S	0.115	127	97	30	
64	SFSNEG	81004	F	1987		DS	U	11	FIRE	3180	3140	N	0.049	119	89	30	
65	SFSNEG	81005	F	1987		DF	U	11	FIRE	3160	3140	N	0.006	14	8	6	
66	SFSNEG	81006	F	1980		DF	U	9	FIRE	3120	3080	S	0.039	83	56	27	
67	SFSNEG	81007	F	INDET	77-88	DS	U	9	FIRE	3080	3060	S	0.009	24	16	8	
68	SFSNEG	81008	F	INDET	77-88	DS	U	11	FIRE	2940	2900	N	0.056	33	31	2	
69	SFSNEG	81009	F	INDET	77-88	DF	U	11	FIRE	2965	2920	S	0.036	112	78	34	
70	SFSNEG	81010	F	INDET	77-88	DF	U	11	FIRE	2920	2910	S	0.013	78	66	12	
71	SFSNEG	81011	F	1965		S DS	U	11	NAT	2920	2900	S	0.073	200	100	100	
72	SFSNEG	81012	F	INDET	1965	CBDS	U	11	NAT	2900	2880	N	0.010	80	60	20	
73	SFSNEG	81013	F	INDET	77-87	DF	M/U	11	FIRE	2820	2780	S	0.061	417	278	139	
74	SFSNEG	81015	F	1965		S DS	M/U	9	NAT	3760	3630	W	0.646	38300	5800	32500	
75	SFSNEG	81016	F	1988	80-88	DF	M	9	FIRE	3750	3680	W	0.025	139	125	14	
76	SFSNEG	81017	F	1987		DS	M	9	FIRE	3790	3740	W	0.116	500	300	200	
77	SFSNEG	81018	F	1980		DS	M	9	FIRE	3790	3775	S	0.010	22	11	7	4
78	SFSNEG	81019	F	1980		DS	M	9	FIRE	3840	3775	W	0.097	555	358	197	
79	SFSNEG	81020	F	1980		DF	M	11	FIRE	3860	3780	S	0.026	109	82	27	
80	SFSNEG	81021	F	1980		DS	M	11	FIRE	3860	3800	S	0.090	533	285	248	
81	SFSNEG	81022	F	1980		DS	M	9	FIRE	3900	3815	W	0.188	972	778	194	

Table E-1-4, continued. Selected data from the Negro Creek Landslide Inventory.

Selected data from the Negro Creek Landslide Inventory
File: Sumneg1.wk1

Row	Water-shed	Inv. No.	Meth-od	Photo Year	Est. Yr. Range	Slide Type	Rock Type	Geomor-phic Terrane Type	Distur-bance Class	Max. Eleva-tion	Min-. Eleva-tion	As-pect	Map Acres	Mobil-ized Volume	Deliv-ered Volume	On-Site Volume	Stored Volume Off-site
82	SFSNEG	81023	F	1987	80-88	DS	M	11	FIRE	3850	3815	S	0.051	222	200	22	
83	SFSNEG	81024	F	1987	80-88	DS	M	11	FIRE	3820	3800	SE	0.012	56	45	11	
84	SFSNEG	81025	F	1980		S DS	U	11	FIRE	2820	2815	S	0.033	187	56	131	
85	SFSNEG	81026	F	1980		DS	M	9	FIRE	3825	3820	N	0.020	43	43		
86	SFSNEG	81027	F	1980		S EF DS	M	9	FIRE	2880	2870	W	0.052	344	231	113	
87	SFSNEG	81028	F	1986		S	M	8	FIRE	4605	4590	W	0.046	444	311	133	
88	SFSNEG	81029	F	1964	55-64	DS	M	8	ROAD	4620	4590	W	0.220	360	72	288	
89	SFSNEG	81030	F	1971	55-80	S	M	3	ROAD	4620	4575	S	0.092	360	72	288	
90	SFSNEG	81031	F	1980		S	M/G	9	ROAD	4375	4330	W	0.059	2750	275	1650	825
91	SFSNEG	81032	F	1980		DS	G	9	FIRE	4250	4245	W	0.023	90	54	36	
92	SFSNEG	81033	F	1971		S	G	9	NAT	3370	3350	N	0.331	5666	600	5066	
93	SFSNEG	81034	F	INDET	80-87	DS	U	9	FIRE	3400	3390	W	0.009	39	35	4	
94	SFSNEG	81035	F	INDET	80-87	DS	G	9	FIRE	3500	3495	N	0.004	18	14	4	
95	SFSNEG	81036	F	1988		DS	U	9	FIRE	3880	3870	W	0.021	44	13	31	
96	SFSNEG	81038	F	1982		DF	M	3	FIRE	4410	4280	W	0.230	1620	50	1570	
97	SFSNEG	81039	F	1987		DF	M/G	9	FIRE	3455	3420	S	0.022	210	10	100	100
98	SFSNEG	81040	F	1980	77-87	DS	M	9	FIRE	3250	3240	W	0.008	23	20	3	
99	SFSNEG	81041	F	1980	77-87	DS	M	9	FIRE	3270	3260	W	0.015	50	15	35	
100	SFSNEG	81042	F	1980	77-87	DS	M/G	9	FIRE	3300	2280	W	0.006	17	17		
101	SFSNEG	81043	F	1971		DS	M	11	NAT	2360	2250	W	0.165	1065	1045	20	
102	SFSNEG	81044	F	1971		DS	M	9	NAT	2280	2240	N	0.020	90	90		
103	SFSNEG	81045	F	1944		DS	M	11	NAT	2350	2320	W	0.034	300	300		
104	SFSNEG	81046	F	1965		S	M	8	ROAD	4650	4630	W	0.042	250	187	63	
105	SFSNEG	81047	F	1980		BG DF	M	8	ROAD	4250	4160	N	0.321	1700	150	1400	150
106	SFSNEG	81048	F	1987		S DF	M	9	FIRE	4200	4160	W	0.041	222	0	222	
107	SFSNEG	81049	F	1965		S	M/U	8	ROAD	4410	4400	W	0.034	295	0	220	75
108	SFSNEG	81050	F	1982		S DF	M/U	9	ROAD	4240	4180	W	0.080	1430	0	1000	430
109	SFSNEG	81051	F	1975		S	U	9	ROAD	4250	4230	S	0.026	133	0	93	40
110	SFSNEG	81052	F	1975		DS	M	9	ROAD	4050	4020	W	0.013	60	15	45	
111	SFSNEG	81053	F	1980		DF	M	9	FIRE	3720	3700	W	0.010	19	19		
112	SFSNEG	81054	F	1980	77-87	DS	M	9	FIRE	3700	3690	W	0.017	74	44	30	
113	SFSNEG	81055	F	1980	77-87	S DS	M	9	FIRE	3700	3680	W	0.069	1200	375	825	
114	SFSNEG	81056	F	1980	77-87	S	M	9	FIRE	3590	3570	W	0.115	1100	440	660	
115	SFSNEG	81057	F	1980		EF	U	3	FIRE	3500	3460	S	0.075	800	8	792	
116	SFSNEG	81058	F	1980	77-87	S	M/U	3	ROAD	3590	3575	S	0.021	330	15	315	
117	SFSNEG	81059	F	1980		S	U	9	FIRE	3400	3350	W	0.115	2200	50	2150	
118	SFSNEG	81060	F	1980		S	U	9	FIRE	3620	3535	W	0.689	22000	50	21950	
119	SFSNEG	81061	F	1980		S	M/U	3	FIRE	2880	2845	S	0.110	760	152	532	76
											TOTAL		21.099	689566	78145	604971	6400

Table E-1-3 and E-1-4 Notes.

Method

F = Field measured
A = Air photo interpreted
FA = Partially field measured (or observed) and air photo interpreted.

Slide Type

DS = Debris slide
CBDS = Channel bank debris slide
CS = complex slide
DF = Debris flow
BG = Block glide
S = Slump
EF = Earthflow

Bedrock Type

G = Granitic
M = Non-granitic (metamorphic)
U = Ultramafic

Geomorphic Terrane Types

2 Slump/Earthflow Toe Zones
3 Slump/Earthflow Deposits
4 Granitic Mountain Slopes >65%
5 Granitic Mountain Slopes <65%
6 Non-Granitic Mountain Slopes >65%
8 Non-Granitic Mountain Slopes <65%
9 Inner Gorge in Landslide, Terrace or Glacial Deposits
10 Inner Gorge in Granitic Bedrock & Mt. Slopes
11 Inner Gorge in Non-Granitic Bedrock & Mt. Slopes
12 Debris Basins [Headwalls]
13 Glacial, Terrace & Fan Deposits

Disturbance CLasses

NAT = Undisturbed
R = Road-related
HAR = Harvest-related
T = Trail-related
Fire = Fire-related

Maximum and Minimum Elevation Zones: units are in feet
Mobilized, Delivered, Remaining (on site), and Stored (offsite) Volume: units are in acres.

DAMAGE TO RIPARIAN AREAS BY LANDSLIDES

Field and air photo inventory of landslides in the Little North Fork watershed reveals significant damage to stream channels and and associated riparian areas resulting from landslides **[Table E-34]**. The damage occurrred as a result of processes of scour and deposition: scour of channel sediment to bedrock and deposition of sediment material causing channel aggradation. The processes of channel scour and deposition occur from debris slides, flows, and avalanches initiated in headwall areas of channels or along the main body of the channel. Channel types where riparian damage has occurred include first and second order perennial and intermittent streams and so-called zero order intermittent and ephemeral drainages. Some of the zero-order intermittent drainages are classified as inner gorges; others fall into the mountain slope or debris basin terrane types. The length and width of channel scour or deposition was scaled off of air photos to derive an area in acres of riparian damage. Evidence for channel scour and riparian damage is indicated by removal of vegetation along stream banks. On air photos, the damaged areas are marked by a white- or light brown-colored scar along the length of channel affected. As both processes of scour and deposition may occur and are not easily differentiated on air photos, volumes of material scoured and deposited were not calculated. The areas in acres listed are considered in general terms as areas where riparian vegetation has been removed or damaged.

The length of channels damaged for the period of record, 1944-1988, totals 100,770 feet or 19 miles; riparian areas damaged total 68.4 acres **[Table E-34]**. Landslides associated with damaged riparian areas number 158 and encompass a total of 27.2 acres in the watershed. For every acre of landslide associated with an inner gorge or channel drainage area, 2.5 acres of riparian area was damaged.

The greatest damage to channels and riparian areas occurred as a result of the 1964 flood event **[Table E-35]**. A total of 27 landslides in inner gorges, mountain slopes and debris basins [geomorphic terrane types 4, 5, 6, 8, 9, 10, 11, and 12] damaged 32.0 acres of riparian area. The ratio of riparian acres damaged to landslide acres is 3.6 **[Table E-35]**.

The storm events of 1972 also caused considerable damage to riparian areas. Combining data from photo years 1972 and 1975 **[Table E-34]**, 9 landslides in undisturbed areas damaged 4.1 acres of riparian area; 53 landslides in harvest areas damaged 9.0 acres of riparian area; and 52 landslides associated with roads damaged 16.8 acres. Ratios of riparian acres damaged to landslide acres for undisturbed, harvest and road conditions are 2.2, 2.2 and 1.8 riparian acre damaged per landslide acre **[Table E-35]**.

Damage to riparian areas was not restricted to inner gorge terrane types. Evidence of channel scour and deposition was found in zero-order draws within mountain slopes and debris basins **[Table E-34]**. Damage to riparian areas in steep and moderate granitic mountain slopes [geomorphic terrane types 4 and 5] was significant in the 1965 photo year. A total of eleven landslides encompassing 0.60 acres damaged 14.1 acres of riparian area. Landslides occurring in harvest areas in terrane type 4 and 5 totaled 20, encompassed 4.4 acres and damaged 3.8 acres or riparian area. Landslides associated with roads in terrane types 4 and 5 numbered 19, encompassed 1.8 acres and damaged 3.2 riparian acres.

Road- and harvest-associated landslides in granitic inner gorges [geomorphic terrane type 10] damaged more than 13 acres of riparian areas as a consequence of the 1972 storm events **[Table E-34]**. Specifically, ten acres of road in terrane type 10 are associated with 5.6 acres of landslide and 9.2 acres of riparian area damaged; 152 acres of harvested land in terrane type 10 are associated with 1.9 acres of landslide and 3.9 acres of riparian area damaged.

Table E-34. Acres of damaged riparian area associated with landslides in Little North Fork Watershed, photo years 1944, 1955, 1964, 1965, 1972 and 1975.

Little North Fork
Undisturbed

	1944		1955		1964		1965	
Terrane Type	#	Acres	#	Acres	#	Acres	#	Acres
4	3	1.54					7	4.86
5	2	0.30					4	9.26
6	1	0.37	1	0.07			3	1.11
8			1	0.32			1	0.21
9							2	4.00
10	1	0.74			2	0.51	5	6.64
11	1	0.18	2	0.32			1	0.37
12	4	2.23					4	5.52
TOTAL	12	5.27	4	0.71	2	0.51	27	31.97

	1972						1975					
	Undisturbed		Harvest		Roads		Undisturbed		Harvest		Roads	
Terrane Type	#	Acres	#	Acres	#	Acres	#	Acres	#	Acres	#	Acres
3			1	0.92								
4			3	0.55	12	2.41			2	0.6		
5	2	0.05			5	0.30			15	2.67	2	0.46
6	1	1.15			7	3.43			2	0.46	1	0.46
8			1	0.03	1	0.31						
9	1	0.05										
10					23	9.18	2	2.43	27	3.90		
11	1	0.23			1	0.27	2	0.21	2	0.41		
TOTAL	5	1.48	5	1.50	49	15.90	4	2.64	48	7.50	3	0.92

Summary
Little North Fork
1944-1988

	Undisturbed		Harvest		Roads	
	#	Acres	#	Acres	#	Acres
TOTAL	54	42.58	53	9.00	51	16.82

# = number of landslides
Acres = riparian acres damaged

Table E-35. Acres of landslide associated with acres of riparian areas damaged in Little North Fork.

Little North Fork
Undisturbed

	1944		1965	
	Landslide Acres	Riparian Acres	Landslide Acres	Ri-pari-an Acres
	1.9	5.3	9.0	32.0
Damaged Riparian Acres/ Landslide Acres	2.8		3.6	

1972 and 1975

Undisturbed		Harvest		Roads	
Landslide Acres	Riparian Acres	Landslide Acres	Riparian Acres	Landslide Acres	Riparian Acres
1.9	4.1	4.1	9.0	9.1	16.8

Damaged Riparian Acres/Landslide Acres

2.2	2.2	1.8

CHANNEL BANK EROSION

A limited assessment of stream channel erosion was conducted for Little North Fork and Negro Creek watershed. Stream channel and bank erosion includes processes of mobilization and transport of sediment from inner gorge and hill slope areas to active channel systems. Stream channel erosion commonly is associated with debris slides in headwall and inner gorge areas. In addition, stream channel and channel bank erosion also occurs unrelated to landsliding, as a result of flood or storm flows, cutting terrace deposits or undercutting steep channel banks.

Stream banks where stream scour and channel-bank erosion are observable were evaluated as part of the Salmon River Basin air photo inventory. Eroded channel segments were noted for the following photo years: 1944, 1955, 1964, 1965, 1975 and 1988. Lengths of eroded stream channel segments were measured by map wheel off of 1:15,840 scale maps. Thus, our limited assessment of channel bank erosion consists of the total length in miles of observable bank erosion, by photo year.

Field measurements of sample channels were not carried out as part of this study due to the complexity of stream terrace and channel bank systems, limited personnel, and lack of field time. Therefore, no quantifiable assessment has been made of sediment yield by bank erosion in the watersheds studied. A future study of channel bank erosion from the 1964 flood event, other storm events, and current annual sediment yield from channel bank erosion would be a valuable project in the Little North Fork Watershed. Field-developed cross sections of typical stream segments using sampling methodology could provide information on area of channel scoured and volume of sediment mobilized within the inner gorge area as a result of the 1964 flood event.

Little North Fork: Channel Bank Erosion

Eroded channels in Little North Fork watershed are displayed in **Figures E-22, E-23 E-24, E-25, and E-26.** Locations and lengths of eroded channels are generalized for illustrative purposes. Lengths of stream channels eroded by photo year are summarized in **Table E-36.**

The Little North Fork has a history of channel erosion especially in higher elevation debris basins, inner gorges, and draws subject to debris flows and avalanches. Approximately 16.5 miles of channels show evidence of past channel erosion on the 1944 photos.

The most significant channel bank erosion occurred as a result of the 1964 flood event **[Figure E-25]**. Approximately 62.5 miles of stream channel were eroded, including main stem and tributaries to main stem in the Headwaters and Lower sub-basins. Along the main channel of Little North Fork in the Headwaters sub-basin, flood flows initiated landslides along channel banks and cut into glacial terrace deposits leaving exposed nearly vertical banks 30 to 100 feet in height. Debris torrents and debris flows in granitic mountain slopes, debris basins and granitic inner gorges contributed large volumes of sediment material and debris to the main channel. Today, there are many breached debris dams along the headwaters reaches of the Little North Fork. During the flood event, the formation and subsequent breaching of the debris dams produced flood surges that contributed to accelerated stream bank erosion and channel cutting downstream.

Approximately 13.0 miles of stream channels were eroded and damaged as a result of the 1972 storm events **[Figure E-26]**. Tributaries to the Little North Fork such as Garden Gulch, Titmouse Gulch and Cherry Creek were severely eroded, in part due to natural causes and road failures at stream crossings.

Little North Fork

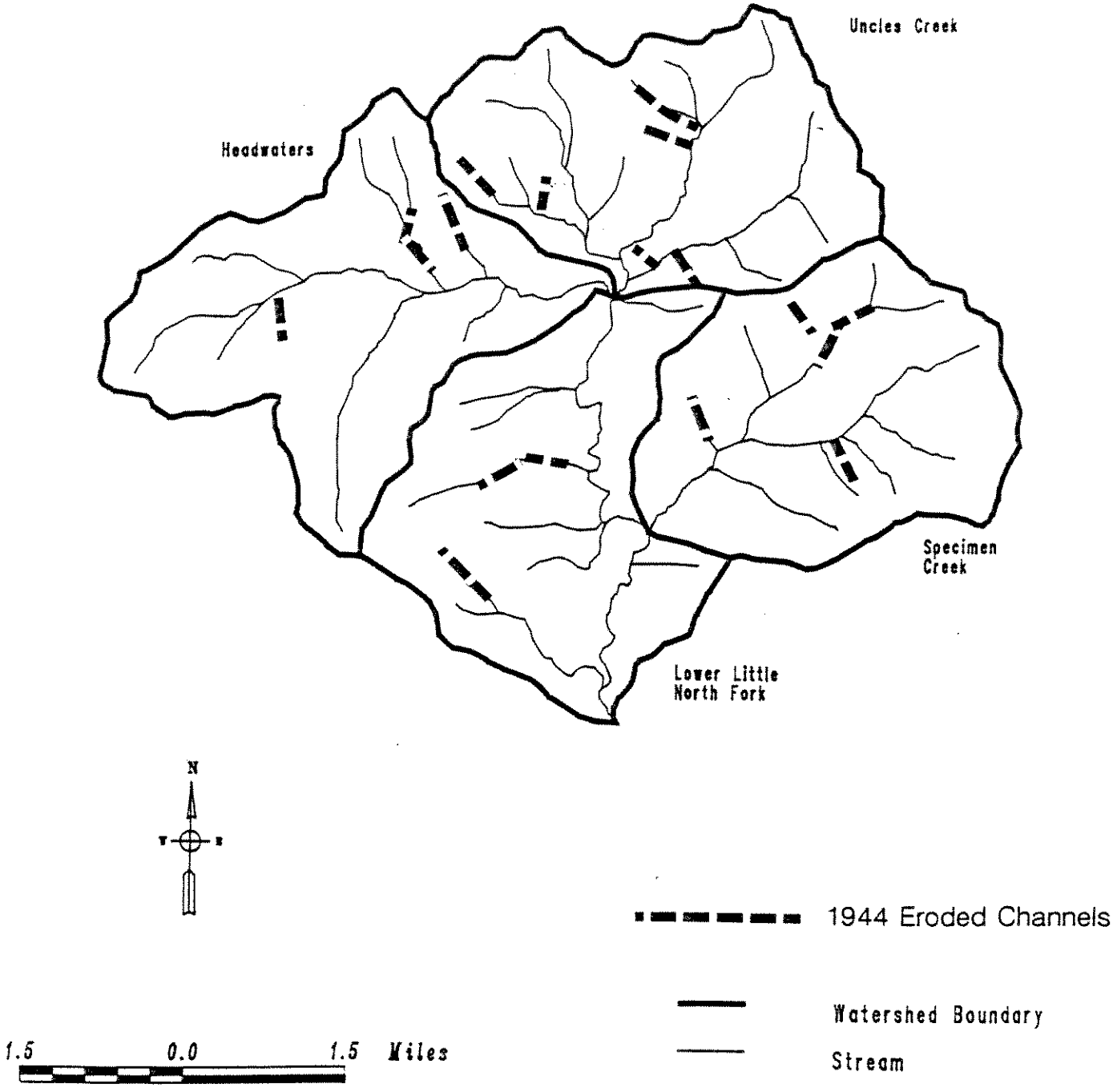


Figure E-22. Eroded channels from the 1944 photo year, Little North Fork Watershed.

Little North Fork

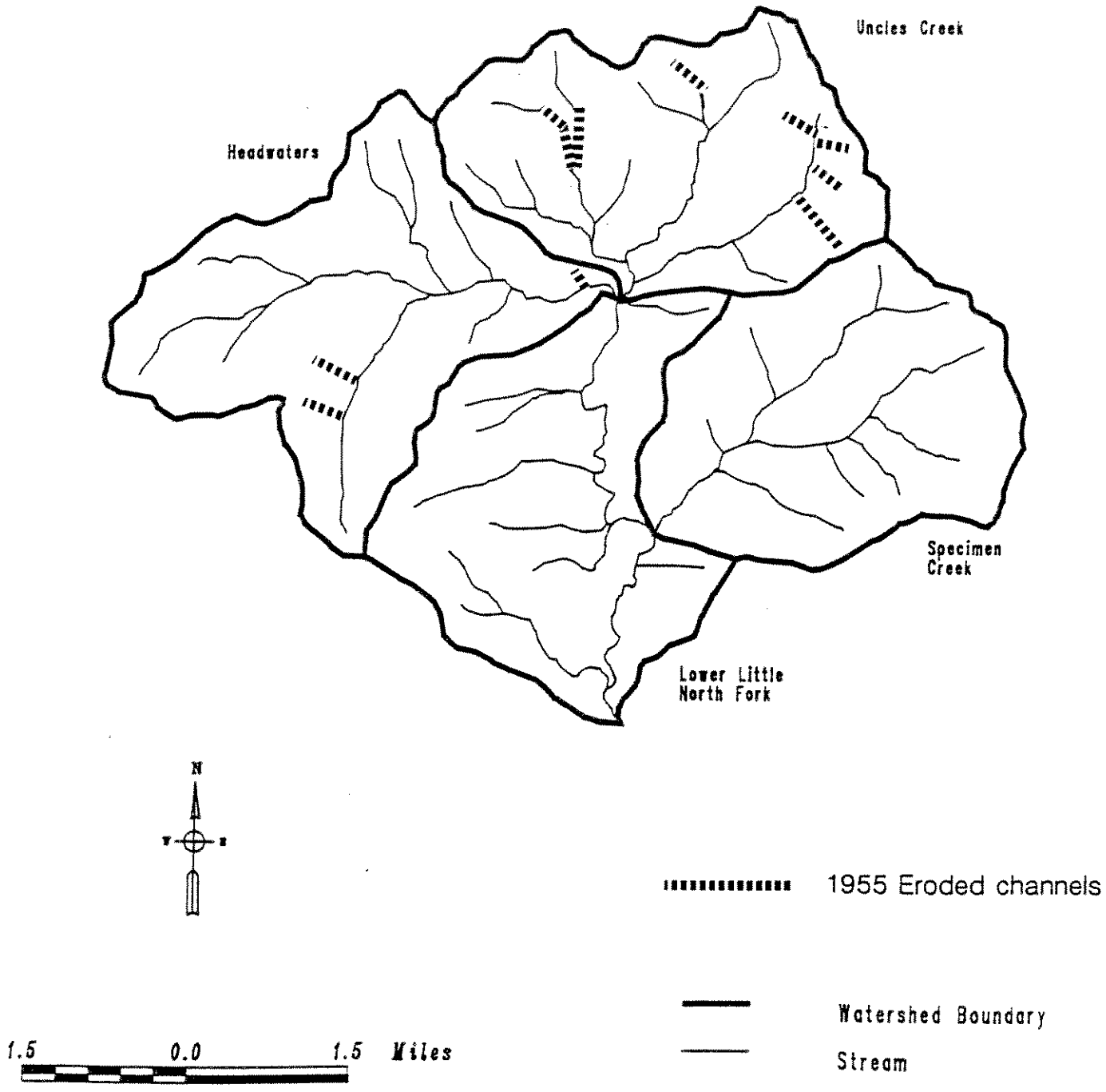


Figure E-23. Eroded channels from the 1955 photo year, Little North Fork Watershed.

Little North Fork

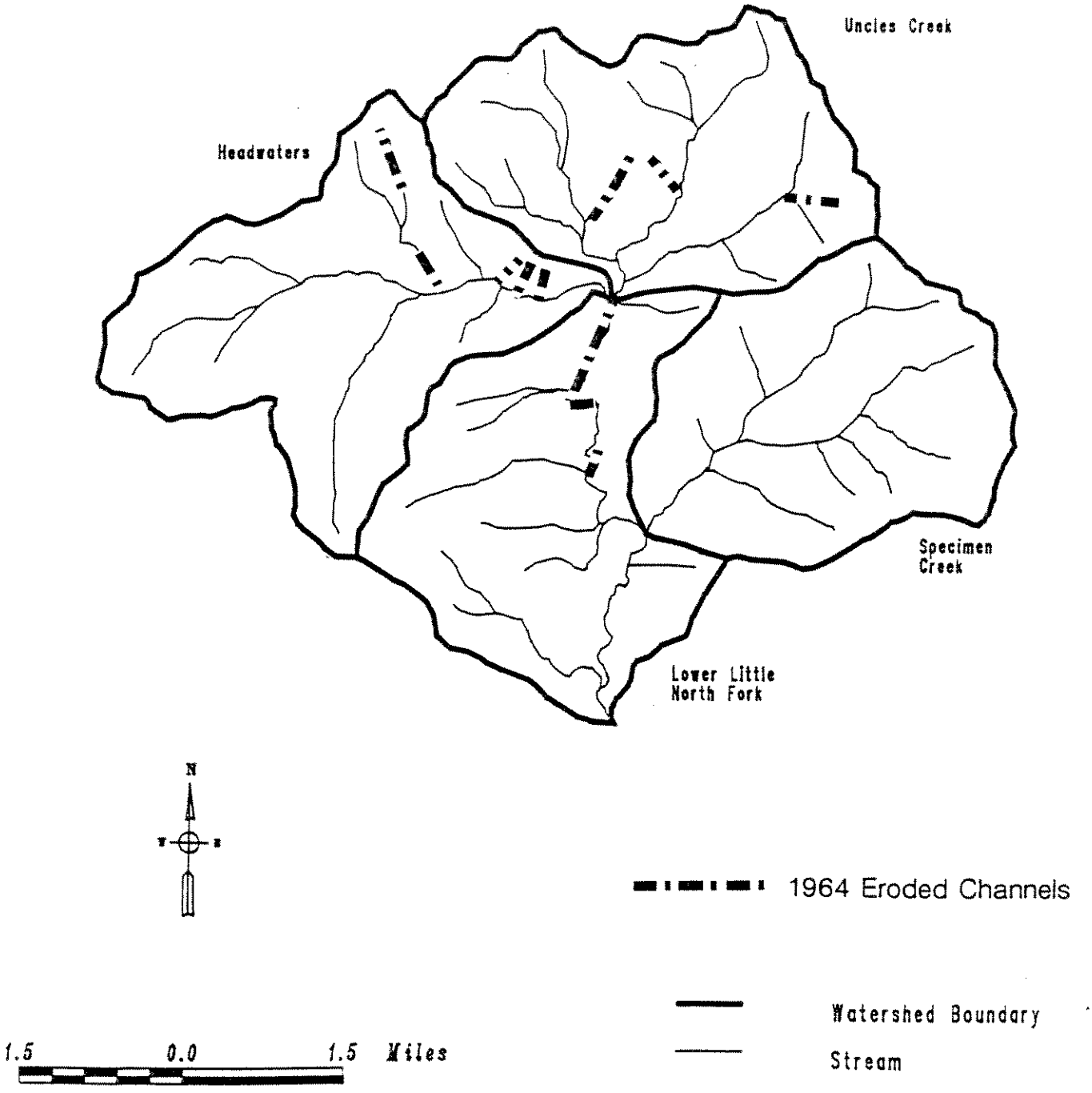


Figure E-24. Eroded channels from the 1964 photo year, Little North Fork Watershed.

Little North Fork

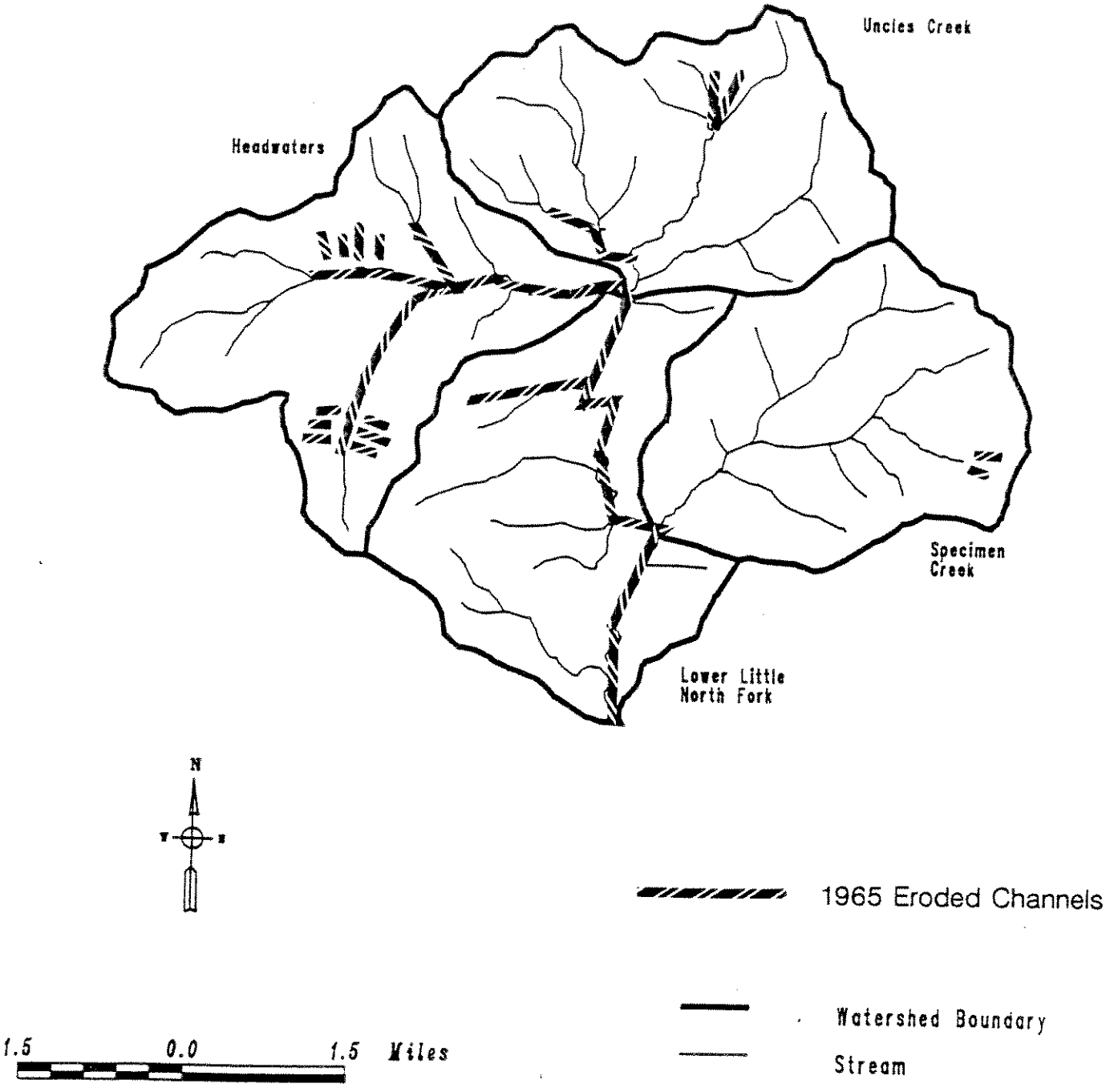


Figure E-25. Eroded channels from the 1965 photo year, Little North fork Watershed.

Little North Fork

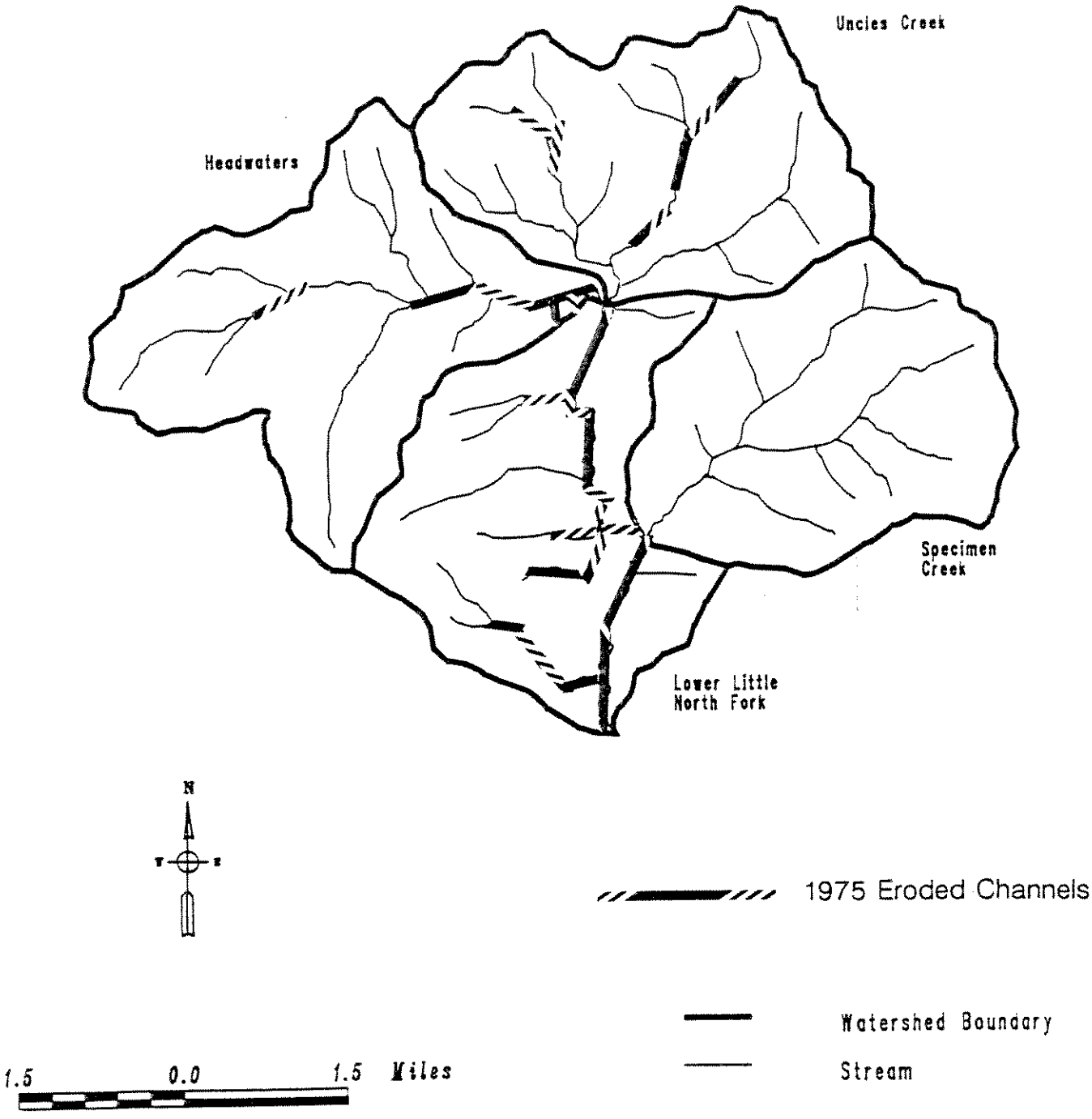


Figure E-26. Eroded channels from the 1975 photo year, Litle North Fork Watershed.

Table E-36. Channel erosion at Little North Fork and Negro Creek watersheds.

Little North Fork

Photo Year	Observed Length [miles] of Eroded Channels
1944	16.5
1955	11.5
1964	15.5
1965	62.5
1975	13.0
1988	0

Negro Creek

Photo Year	Observed Length [miles] of Eroded Channels
1944	0.4
1955	0.3
1964	0.1
1965	0
1975	0
1988	0

Negro Creek: Channel Bank Erosion

Negro Creek watershed shows evidence of channel erosion in the 1944, 1955 and 1964 photos **[Figure E-27 and Table E-36]**. The total length of stream channels eroded on the 1944, 1955 and 1964 photos are 0.4, 0.3 and 0.1 miles , respectively. Flood terraces and well-defined channel banks are not observed in stream channels in Negro Creek. Active stream channels are narrow, less than 20 feet in width, and valley walls are steep, having slopes greater than 60% grade, typical of valley inner gorges.

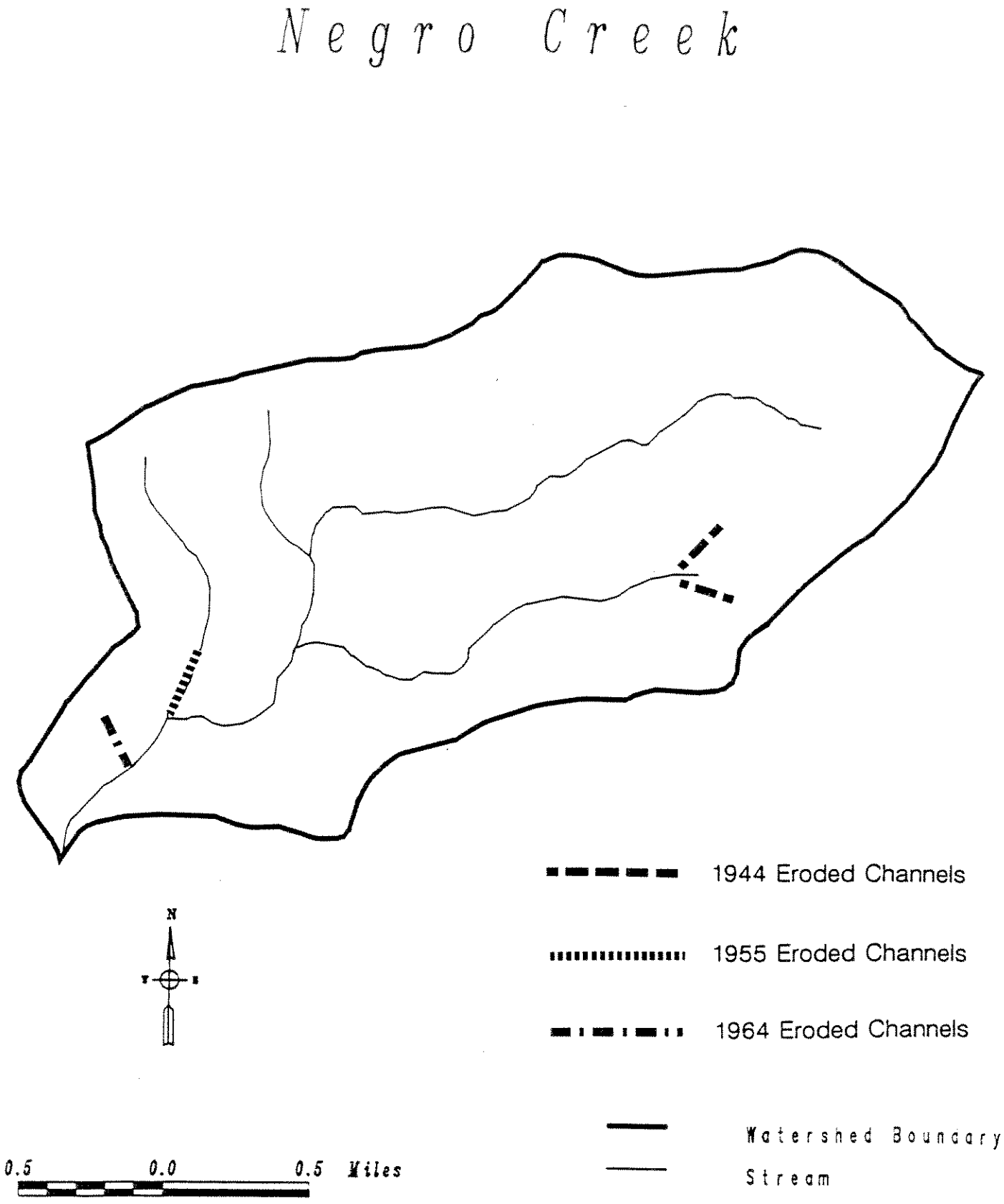


Figure E-27. Eroded channels from the 1944, 1955, and 1964 photo year, Negro Creek Watershed.

SURFACE EROSION

Surface erosion rates are presented for Little North Fork and Negro Creek watersheds for the periods 1965-1975, 1975-1988, and 1987-1988 post wildfire conditions **[Table E-37]**.

The methods used to model surface erosion are the same as those used in the Salmon basin, **[see Appendix D, this volume]**. The Universal Soil Loss Equation [USLE] was used to derive the volume of sediment mobilized from surface erosion processes. Land types [acres] were stratified by disturbance class, slope, and soil type. Erosion rates [yds³/acre] were calculated using the USLE based on combinations of soil type, disturbance class and slope. A delivery factor was then applied to the sediment yield from surface erosion. Four soil types were used, typical of granitic and non-granitic [including metamorphic and ultrabasic] parent materials. Disturbance classes include harvest, roads and fire [Hog and the fires of 1987]. Harvest units represent three age classes: 0-5 years, 6-10 years, and greater than 10 years. Slope classes included low [0-35%], moderate [35-65%] and high, [greater than 65%].

Total surface erosion for the period 1965-1975 reflects nine years of average annual precipitation and one year reflecting the occurrence of elevated surface erosion from a 25-year return frequency precipitation event. To model this, the R value was increased by a factor of 1.31. Total surface erosion for the period 1975-1988 reflects ten years of average annual precipitation.

Data tables and methods used to calculate sediment yield and delivery factors from surface erosion for Little North Fork and Negro Creek watersheds are found in **Appendix D, Surface Erosion Model for the Salmon River Watershed**, this volume.

Table E-37. Surface erosion in Little North Fork and Negro Creek watersheds. Total sediment yield [yds³] and yield per acre of watershed [yds³/acre] and given.

	1965-1975			1975-1987			1987-1988, Post Wildfire		
Watershed	Total Yield	Yield/ Acre/ Year	Annual Ave.	Total Yield	Yield/ Acre/ Year	Annual Ave.	Total Yield	Yield/ Acre/ Year	Annual Ave.
Little North Fork	4164	0.020	416.4	3228	0.013	269	1056	0.051	1056
Negro Creek	1261	0.048	126	—	—	—	3412	1.30	3412

Surface erosion rates for both watersheds are greatest in the one year period after the wildfires of 1987. Negro Creek watershed had a modeled erosion rate of 1.30 yds³/acre which is the highest in the Salmon River watershed for this time interval. The high rate is due the fact that the watershed was severely burned in 1977 as well as 1987.

SUMMARY AND CONCLUSIONS

In the following sections, results of the landslide inventory and sediment analysis for Little North Fork and Negro Creek watersheds are summarized. Topics summarized include (a) total sediment production and sediment sources; (b) distribution of landslides by geomorphic terrane and (c) landslide rates.

Sediment Production and Sediment Sources, Little North Fork

Over the period 1944-1988, landslides delivered a total of 483,1070 yds^3 to stream channels of Little North Fork watershed **[Figure E-28]**. Landslides occurring as a result of the 1964 flood delivered 332,590 yds^3, or 69% of the total volume. Landslides occurring during the period 1965-1975 delivered 130,907 yds^3. Landslides in undisturbed lands are the primary sediment sources prior to 1965. Following 1965, landslides associated with roads and harvest units contributed 48,544 and 45,078 yds^3 respectively. Landslides in undisturbed lands delivered 37,285 yds^3 **[Figure E-28]**.

The average annual landslide-related sediment volume delivered over the 10 year period 1965-1975 is approximately 13,090 yds^3, or 0.63 yds^3/acre/year. Surface erosion sources are estimated to have delivered approximately 4164 yds^3 over the 1965-1975 period [0.020 yds^3/acre/year], and 4284 yds^3, or 0.016 yds^3/acre/year over the 1975-1988 period.

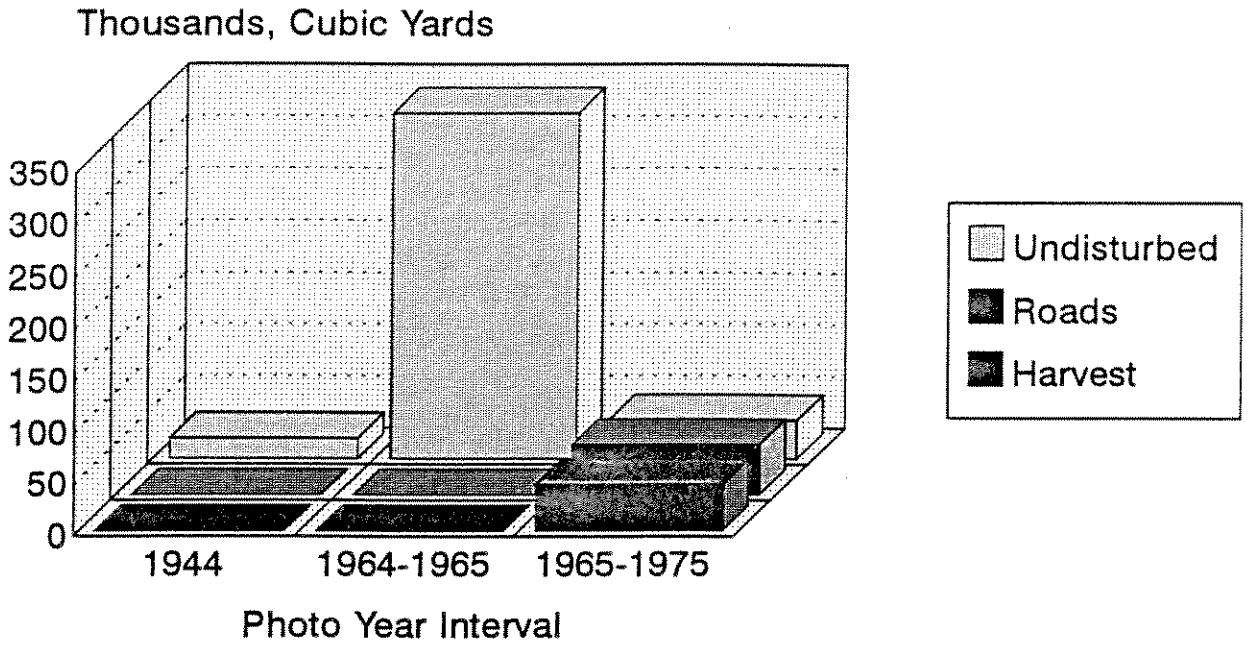
The length of riparian channels damaged by landslide events totals approximately 19 miles; total riparian areas damaged total 68.4 acres over the period 1944-1988. The flood of 1964 and storm events of 1972 damaged 32 and 16 acres respectively.

Geomorphic Distribution of Landslides, Little North Fork

Terrane stratification of the landscape within Little North Fork indicates that landslide production is greatest within inner gorge terranes [geomorphic terranes 9, 10, and 11], contributing 91% of the total volume delivered to channels **[Figure E-29]**.

Landslides in 1965-1975 are found in most of the geomorphic terrane types, and disturbance classes **[Figures E-28, E-30]**. Landslide occurrence is greatest in the inner gorge terranes accounting for 22% of the total landslide-related sediment production [1944-1988], **[Figure E-30]**. Landslides associated with harvested lands in granitic inner gorges account for 9% of the total sediment production [1944-1988]. Road-related landslides in the granitic inner gorge accounted for 7% of the total sediment production [1944-1988]. The high landslide rate in the unconsolidated inner gorge [geomorphic terrane #9] resulted mainly from the 1964 flood, which caused considerable damage to the Headwaters sub-basin.

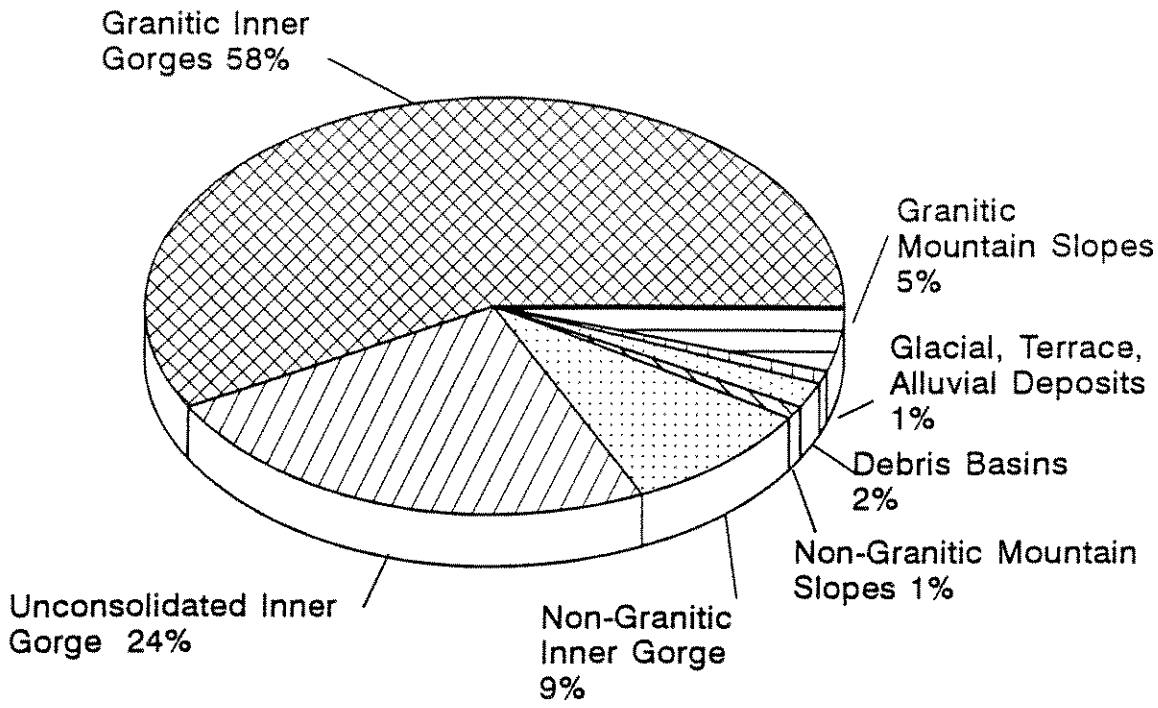
Distribution of Landslides in Little North Fork by Volume Delivered, Photo Year and Disturbance Class



Total Volume Delivered by Landslides = 483,170 c.yds.
Surface Erosion, 1965-1975 = 4164 c.yds.
Surface Erosion, 1975-1988 = 3228 c.yds.

Figure E-28. Distribution of landslides in Little North Fork by volume delivered, photo year and disturbance class.

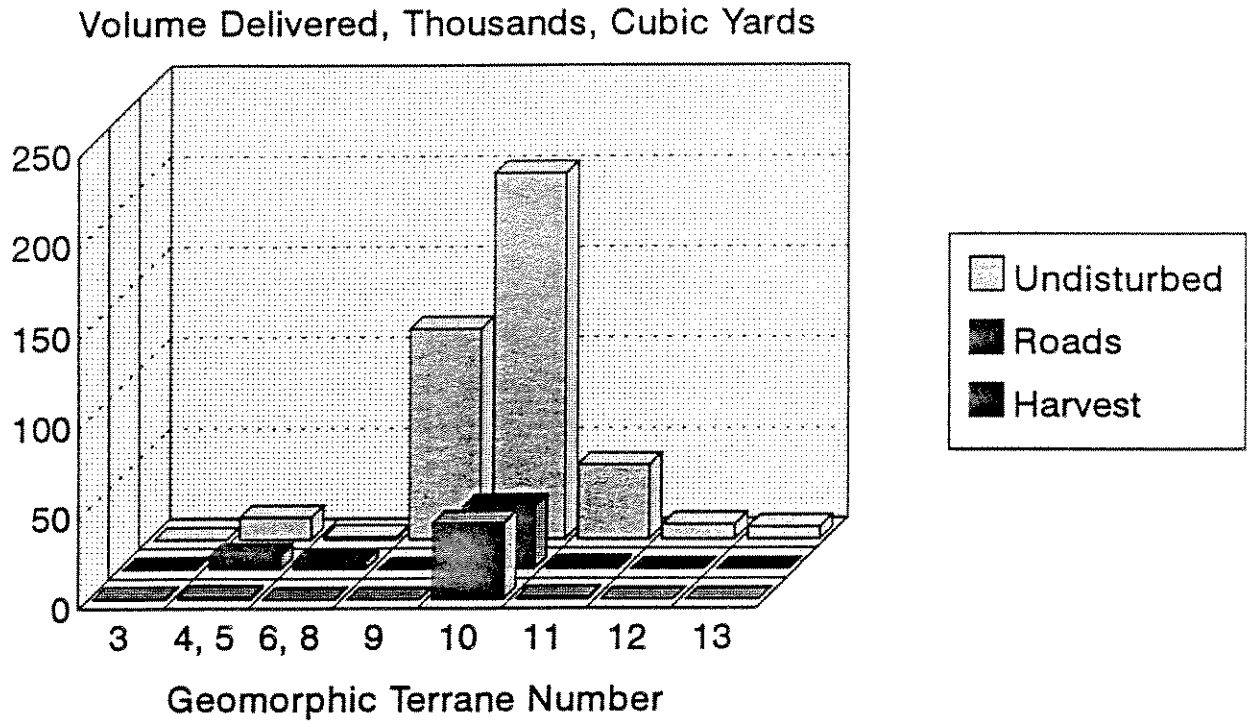
Distribution of Landslides by Geomorphic Terrane
Little North Fork, 1944-1988



Total Volume = 483,170 cubic yards

Figure E-29. Distribution of landslides by geomorphic terrane in Little North Fork.

Distribution of Landslides in Little North Fork by Geomorphic Terrane and Disturbance Type



Little North Fork, 1944-1988

Figure E-30. Distribution of landslides in Little North Fork by geomorphic terrane and disturbance type.

Landslide Rates, Little North Fork

During the 1965-1975 period, landslide rates for undisturbed lands, harvested land and roads are 1.9, 56.8 and 595.6 yds^3. Road-related landslides show an increase in sediment production 313 times the undisturbed rate; harvest-related landslides show an increase of 30 times the undisturbed rate.

Flood Event	Type of Disturbance	Landslide Rate [yds^3/acre]	Increase over Undisturbed Rate
1964 Event	Undisturbed	15.9	
1965-75 Events	Roads Harvest Undisturbed	595.6 56.8 1.9	X 313 X 30 X 1

Notes: Acres used in the calculations are watershed acres by disturbance class.

Sediment Production and Sediment Sources, Negro Creek

Over the period 1944-1988, landslides delivered a total of 78,145 yds^3 to stream channels in the watershed **[Figure E-31]**. The greatest volume delivered occurred in the period, 1964-1965, and is attributed to effects of the 1964 flood. Landslides occurring as a result of the 1964 flood delivered 40,635 yds^3 to channels. Landslides occurring in undisturbed lands are the primary sources of sediment prior to about 1977. After that, conditions resulting from the Hog Fire of 1977 and the wildfires of 1987 initiated the majority of landslides observed. In the period 1965-1975, 3,369 yds^3 was delivered to channels. In the period 1975-1988, 29,704 yds^3 was delivered, mainly from fire- and road-related landslides.

The average annual landslide-related sediment volume delivered over the period 1965-1975 is approximately 337 yds^3/year, or 0.129 yds^3/acre/year. Surface erosion is estimated to have delivered about 1261 yds^3 over the same period, or 0.048 yds^3/acre/year. For the 1975-1988 period the average annual landslide-related sediment volume delivered is estimated to be 2,285 yds^3/year, or 0.873 yds^3/acre/year. After the wildfires of 1987, sediment delivered by surface erosion processes amounted to about 3412 yds^3, or 1.30 yds^3/acre in the 1987-1988 period.

Geomorphic Distribution of Landslides, Negro Creek

Landslide production in Negro Creek was greatest in the inner gorge geomorphic terranes, contributing about 94% of the total volume delivered to channels **[Figure E-32]**. Landslides originating in dormant landslide deposits and non-granitic mountain slopes contributed the remainder of the sediment volume.

Landslide occurrence in 1964-1965 occurs in the two inner gorge terranes, unconsolidated and non-granitic types. Landslide occurrence in the period 1965-1975 is similarly distributed, but an additional number of landslides occur on non-granitic mountain slopes. In the 1975-1988 period, landslides are distributed across the five terrane types, with the majority of landslides occurring in the inner gorges, and related to fire and road disturbance types **[Figure E-32]**.

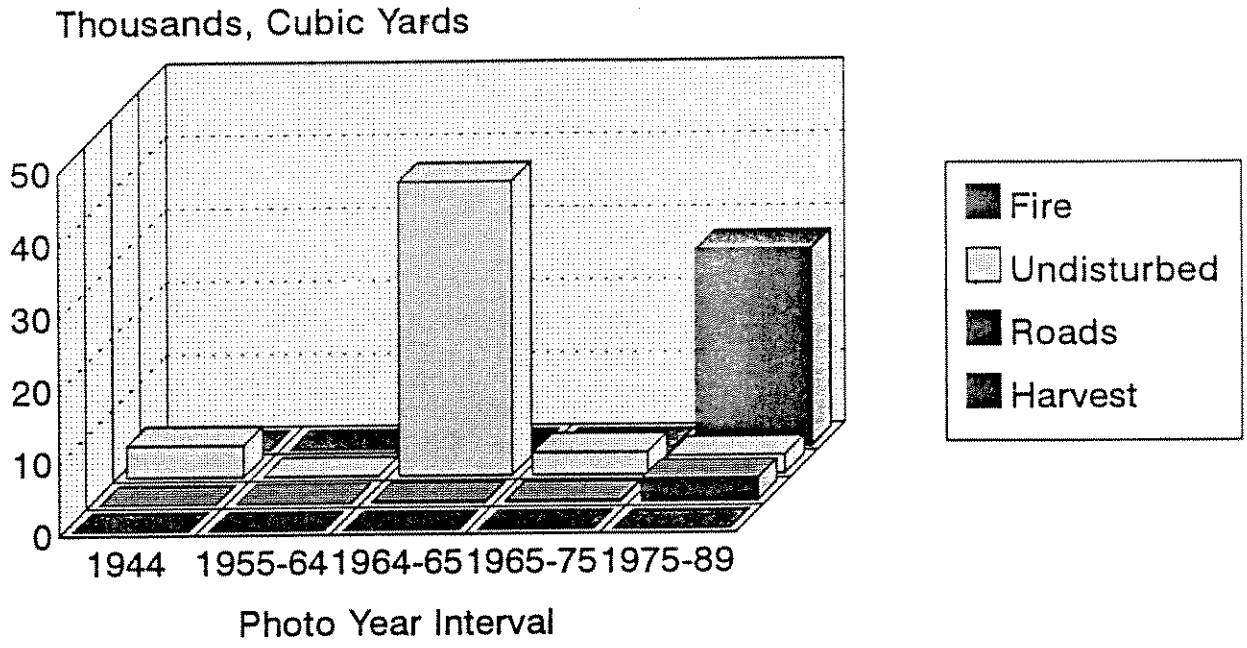
Landslide Rates, Negro Creek

The undisturbed landslide rate is greater than that for roads prior to 1975. After that time, when the watershed saw an increase in disturbance due to wildfire and new road construction, road-related landslides show an increase in sediment production 31 times the undisturbed rate, and fire-related landslides show an increase of nearly 11 times the undisturbed rate.

Time Period	Type of Disturbance	Landslide Rate [yds^3/acre]
1964-1965	Roads Undisturbed	3.84 15.8
1965-1975	Roads Undisturbed	4.4 12.1
1975-1988	Roads Fire Undisturbed	31.4 10.7 0

Notes: Acres used in the calculations are watershed acres by disturbance type.

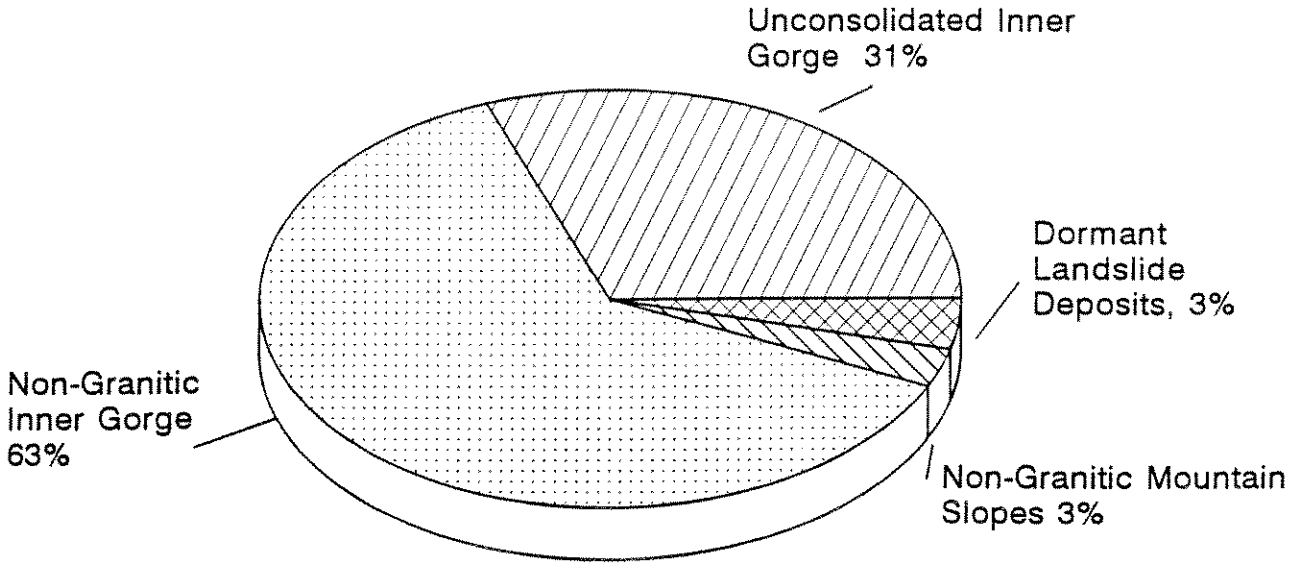
Distribution of Landslides in Negro Creek by Volume Delivered, Photo Year and Disturbance Class



Total Volume Delivered by Landslides = 78,145 c.yds.
Surface Erosion, 1965-1975 = 1261 c.yds.
Surface Erosion, 1987-1988 = 1056 c.yds.

Figure E-31. Distribution of landslides in Negro Creek by volume delivered, photo year and disturbance class.

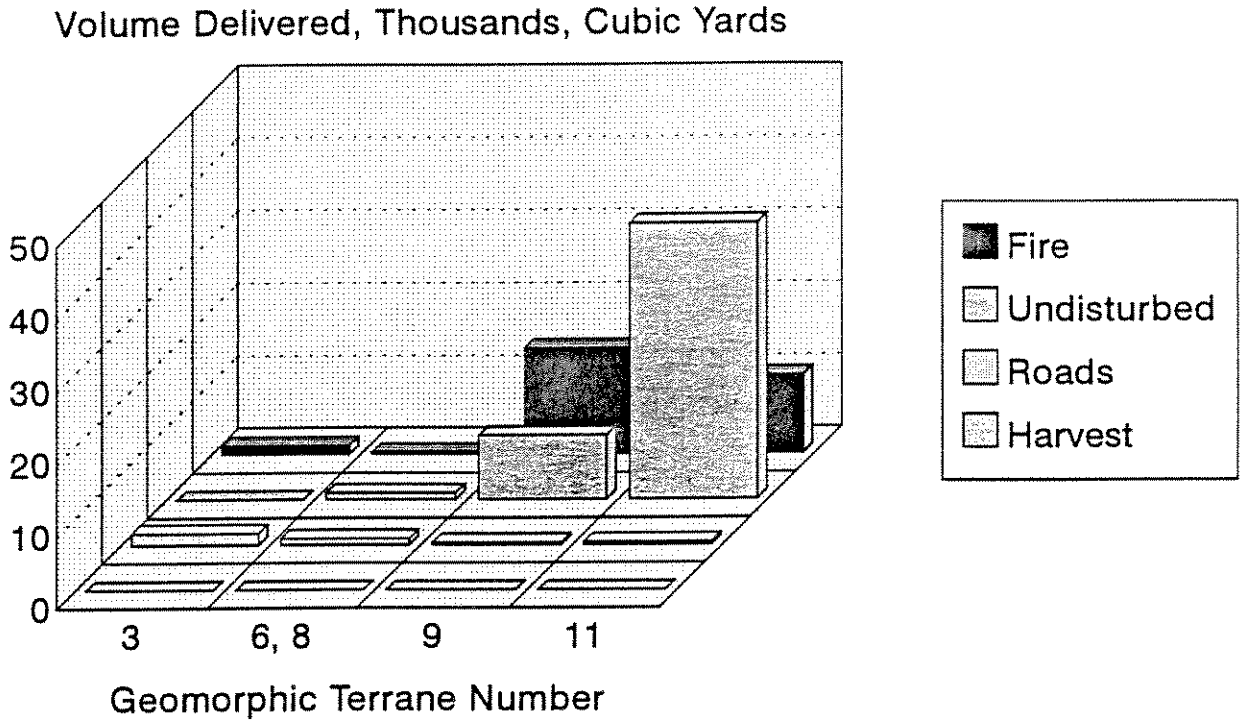
Distribution of Landslides by Geomorphic Terrane
Negro Creek, 1944-1988



Total Volume = 78,145 cubic yards

Figure E-32. Distribution of landslides by geomorphic terrane in Negro Creek.

Distribution of Landslides in Negro Creek by Geomorphic Terrane and Disturbance Type



Negro Creek, 1944-1989

Figure E-33. Distribution of landslides in Negro Creek by geomorphic terrane and disturbance type.

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APPENDIX E-1

Landslide Data Tables for Little North Fork and Negro Creek Watersheds

Table E-1-1. Little North Fork Data Summary.

LITTLE NORTH FORK (LNS) 0-1944 PERIOD

GEO-TYPE NO.	GEO-TYPE AC	Total: all disturbance classes: GEO-TYPE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	undisturbed/unfailed lands: UNDIS. UNFLD' AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides in harvested land: HAR. AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides assoc. w/ roads: ROAD AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD C.Y./AC
TZ_DS 2	6	6					6														
DLS.. 3	356	356					356														
MS_SG 4	2939	2939	2	0.091	748	0.3	2939	2	0.091	748	0.3										
MS_MG 5	4649	4649	1	0.072	0	0.0	4649	1	0.072	0	0.0										
MS_SN 6	5058	5058					5058														
MS_LS 8	2104	2104					2104														
IG_LD 9	317	317	3	1.138	11855	37.4	317	3	1.138	11855	37.4										
IG_GS 10	1152	1152					1152														
IG_NG 11	1805	1805	1	0.056	233	0.1	1805	1	0.056	233	0.1										
DB... 12	793	793	4	0.767	6837	8.6	793	4	0.767	6837	8.6										
GT_FD 13	1622	1622					1622														
TOTAL	20801	20801	11	2.124	19673		20801	11	2.1243	19673											

LITTLE NORTH FORK 1964-1965 PERIOD

GEO-TYPE NO.	GEO-TYPE AC	Total: all disturbance classes: GEO-TYPE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	undisturbed/unfailed lands: UNDIS. UNFLD' AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides in harvested land: HAR. AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides assoc. w/ roads: ROAD AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD C.Y./AC
TZ_DS 2	6	6					6														
DLS.. 3	356	356	0.5	35.000	0	0.0	356	0.5	35	0	0.0										
MS_SG 4	2939	2939	6	0.649	3439	1.2	2939	6	0.649	3439	1.2										
MS_MG 5	4649	4649	2	0.081	435	0.1	4649	2	0.081	435	0.1										
MS_SN 6	5058	5058	2	0.139	1014	0.2	5058	2	0.139	1014	0.2										
MS_LS 8	2104	2104	1	0.055	256	0.1	2104	1	0.055	256	0.1										
IG_LD 9	317	317	41.5	13.442	96344	303.9	317	41.5	13.442	96344	303.9						2 TRAIL SLIDES				
IG_GS 10	1152	1152	52	12.723	188673	163.8	1152	52	12.723	188673	163.8						USED UNDISTURBED ACRE FIGURE				
IG_NG 11	1805	1805	23	4.230	34278	18.2	1805	21	4.072	32688	18.1						1805	2	0.158	1590	0.9
DB... 12	793	793	3	0.171	1422	1.8	793	3	0.171	1422	1.8										
GT_FD 13	1622	1622	2	3.454	6729	4.1	1622	2	3.454	6729	4.1										
TOTAL	20801	20801	133	69.945	332590		20801	131	69.787	331000							1805	2	0.1579	1590	

LITTLE NORTH FORK 1965-1975

GEO-TYPE NO.	GEO-TYPE AC	Total: all disturbance classes: GEO-TYPE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	undisturbed/unfailed lands: UNDIS. UNFLD' AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides in harvested land: HAR. AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides assoc. w/ roads: ROAD AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD C.Y./AC
TZ_DS 2	6	6					6														
DLS.. 3	356	356	2	0.084	739	2.1	320					31	1	0.056	555	17.9	5	1	0.028	184	36.8
MS_SG 4	2939	2939	20	2.403	15823	5.4	2837	1	0.482	8200	2.9	88	3	0.188	1314	14.9	14	16	1.733	6309	450.6
MS_MG 5	4649	4649	9	0.526	1567	0.3	4362	2	0.061	152	0.0	261					26	7	0.465	1415	54.4
MS_SN 6	5058	5058	13	6.084	4535	0.9	4955	1	0.052	273	0.1	91	2	3.054	0	0.0	12	10	2.978	4262	355.1
MS_LS 8	2104	2104	2	0.094	343	0.2	1999					96	1	0.018	57	0.6	9	1	0.076	286	31.8
IG_LD 9	317	317	10	1.345	8402	26.5	311.5	10	1.345	8402	27.0	5					0.5				
IG_GS 10	1152	1152	155	16.694	90660	78.7	990	23	2.189	13532	13.7	152	102	8.179	42306	278.3	10	30	6.326	34822	3482.2
IG_NG 11	1805	1805	18	4.344	8838	4.9	1752	10	1.091	6726	3.8	50	5	3.001	846	16.9	3	3	0.252	1266	421.9
DB... 12	793	793					792										1				
GT_FD 13	1622	1622					1601					20					1				
TOTAL	20801	20801	229	31.574	130907		19925	47	5.221	37285		794	114	14.496	45079		81.5	68	11.856	48543	

LITTLE NORTH FORK 0-1988 PERIOD OF RECORD

TOTAL	20801		373	103.643	483170			189	77.132	387957			114	14.496	45079			82	70	12	50133

Table E-1-1, continued. Little North Fork Data Summary.

HEADWATERS, LITTLE NORTH FORK (HLS) 0-1944 PERIOD

GEO-TYPE NO.	GEO-TYPE AC	all disturbance classes: GEO-TYPE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	undisturbed/unfailed lands: UNDIS. UNFLD' AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides in harvested land: HAR. AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides assoc. w/ roads: ROAD AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC
TZ_DS 2																					
DLS.. 3	14	14					14														
MS_SG 4	997	997	1	0.043	370	0.4	997	1	0.043	370	0.4										
MS_MG 5	2424	2424					2424														
MS_SN 6	55	55					55														
MS_LS 8	281	281					281														
IG_LD 9	94	94	2	0.770	9722	103.4	94	2	0.770	9722	103.4										
IG_GS 10	230	230					230														
IG_NG 11	136	136					136														
DB... 12	202	202	3	0.198	2570	12.7	202	3	0.198	2570	12.7										
GT_FD 13	1210	1210					1210														
TOTAL	5643	5643	6	1.011	12662		5643	6	1.011	12662											

HEADWATERS, LITTLE NORTH FORK (HLS) 1964-1965 PERIOD

GEO-TYPE NO.	GEO-TYPE AC	all disturbance classes: GEO-TYPE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	undisturbed/unfailed lands: UNDIS. UNFLD' AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides in harvested land: HAR. AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides assoc. w/ roads: ROAD AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC
TZ_DS 2																					
DLS.. 3	14	14					14														
MS_SG 4	997	997	4	0.602	2941	2.9	997	4	0.602	2941	2.9										
MS_MG 5	2424	2424	1	0.056	294	0.1	2424	1	0.056	294	0.1										
MS_SN 6	55	55					55														
MS_LS 8	281	281	1	0.055	256	0.9	281	1	0.055	256	0.9										
IG_LD 9	94	94	38	9.156	74193	789.3	94	38	9.156	74193	789.3										
IG_GS 10	230	230	24	8.959	153955	669.4	230	24	8.959	153955	669.4										
IG_NG 11	136	136	9	2.218	16876	124.1	136	9	2.218	16876	124.1										
DB... 12	202	202	3	0.171	1422	7.0	202	3	0.171	1422	7.0										
GT_FD 13	1210	1210	1	3.330	5989	4.9	1210	1	3.330	5989	4.9										
TOTAL	5643	5643	81	24.547	255926		5643	81	24.547	255926											

HEADWATERS, LITTLE NORTH FORK (HLS) 1965-1975 PERIOD

GEO-TYPE NO.	GEO-TYPE AC	all disturbance classes: GEO-TYPE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	undisturbed/unfailed lands: UNDIS. UNFLD' AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides in harvested land: HAR. AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides assoc. w/ roads: ROAD AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC
TZ_DS 2																					
DLS.. 3	14	14					9					4					1				
MS_SG 4	997	997					997														
MS_MG 5	2424	2424					2388					33					3				
MS_SN 6	55	55	3	1.653	552	10.0	42					12					1	3	1.653	552	552.0
MS_LS 8	281	281	2	0.094	343	1.2	196					82	1	0.018	57	0.7	3	1	0.076	286	95.3
IG_LD 9	94	94	2	0.104	390	4.1	94	2	0.104	390	4.1										
IG_GS 10	230	230	7	0.662	2034	8.8	229	7	0.662	2034	8.9	1									
IG_NG 11	136	136	9	3.611	6119	45.0	118	3	0.535	4507	38.2	17	5	3.001	846	49.8	1	1	0.076	766	766.0
DB... 12	202	202					202														
GT_FD 13	1210	1210					1202					7					1				
TOTAL	5643	5643	23	6.125	9438		5477	12	1.301	6931		156	6	3.019	903		10	5	1.805	1604	

HEADWATERS, LITTLE NORTH FORK 0-1988 PERIOD OF RECORD

TOTAL	5643		110	31.6830	278026			99	26.859	275519			6	3.019	903			5	2	1604	

Table E-1-1, continued. Little North Fork Data Summary.

LOWER, LITTLE NORTH FORK, (LOW) 0-1944 PERIOD

GEO-TYPE NO.	GEO-TYPE AC	all disturbance classes: GEO-TYPE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	undisturbed/unfailed lands: UNDIS. UNFLD' AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides in harvested land: HAR. AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides assoc. w/ roads: ROAD AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC
TZ_DS 2	1	1																			
DLS.. 3	217	217																			
MS_SG 4	1096	1096																			
MS_MG 5	1203	1203	1	0.072	0	0.0	1203	1	0.072	0	0.0										
MS_SN 6	984	984																			
MS_LS 8	226	226																			
IG_LD 9	33	33																			
IG_GS 10	703	703																			
IG_NG 11	376	376																			
DB... 12	158	158																			
GT_FD 13	123	123																			
TOTAL	5120	5120	1	0.072	0			1	0.072	0											

LOWER, LITTLE NORTH FORK, (LOW) 1964-1965 PERIOD

GEO-TYPE NO.	GEO-TYPE AC	all disturbance classes: GEO-TYPE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	undisturbed/unfailed lands: UNDIS. UNFLD' AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides in harvested land: HAR. AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides assoc. w/ roads: ROAD AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC
TZ_DS 2	1	1					1														
DLS.. 3	217	217					217	0.5	35	0	0.0										
MS_SG 4	1096	1096					1096														
MS_MG 5	1203	1203					1203														
MS_SN 6	984	984	2	0.139	1014	1.0	984	2	0.139	1014	1.0										
MS_LS 8	226	226					226														
IG_LD 9	33	33	2	39.093	20863	632.2	33	1.5	4.093	20863	632.2										
IG_GS 10	703	703	21	2.962	24010	34.2	703	21	2.962	24010	34.2										
IG_NG 11	376	376	13	1.884	16602	44.2	376	11	1.7255	15012	39.9						TRAIL; USED NATURAL ACRES				
DB... 12	158	158					158										376	2	0.158	1590	4.2
GT_FD 13	123	123					123														
TOTAL	5120	5120	38	44.078	62489			36	43.919	60899							376	2	0.158	1590	4.2

LOWER, LITTLE NORTH FORK, (LOW) 1965-1975 PERIOD

GEO-TYPE NO.	GEO-TYPE AC	all disturbance classes: GEO-TYPE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	undisturbed/unfailed lands: UNDIS. UNFLD' AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides in harvested land: HAR. AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides assoc. w/ roads: ROAD AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD C.Y./AC
TZ_DS 2	1	1					1														
DLS.. 3	217	217	2	0.084	739	3.4	187					27	1	0.056	555	20.6	3	1	0.028	184	61.3
MS_SG 4	1096	1096	20	2.403	15823	14.4	994	1	0.482	8200	8.2	88	3	0.188	1314	14.9	14	16	1.733	6309	450.6
MS_MG 5	1203	1203	9	0.526	1567	1.3	952	2	0.061	152	0.2	228					23	7	0.465	1415	61.5
MS_SN 6	984	984	10	4.431	3983	4.0	899	1	0.052	273	0.3	79	2	3.054	0	0.0	6	7	1.325	3710	618.3
MS_LS 8	226	226					209					14					3				
IG_LD 9	33	33	5	0.640	4885	148.0	27.5	5	0.640	4885	177.6	5					0.5				
IG_GS 10	703	703	147	15.904	88366	125.7	543	15	1.399	11238	20.7	150	102	8.179	42306	282.0	10	30	6.326	34822	3482.2
IG_NG 11	376	376	5	0.458	1607	4.3	342	2	0.230	875	2.6	33					1	3	0.227	732	732.5
DB... 12	158	158					158														
GT_FD 13	123	123					109.5					13					0.5				
TOTAL	5120	5120	198	24.4449	116970		4422	26	2.864	25623		637	108	11.477	44175		61	64	10.103	47172	

LOWER LITTLE NORTH FORK, 0-1988 PERIOD OF RECORD

TOTAL	5120		237	68.5945	179459		4422	63	46.855	86521.		637	108	11.477	44175			66	10.261	48761.	

Table E-1-1, continued. Little North Fork Data Summary.

SPECIMEN CREEK, LITTLE NORTH FORK (SPE) 0-1944 PERIOD

GEO-TYPE NO.	GEO-TYPE AC	all disturbance classes: GEO-TYPE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	undisturbed/unfailed lands: UNDIS. UNFLD' AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides in harvested land: HAR. AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides assoc. w/ roads: ROAD AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD C.Y./AC
TZ_DS 2	3	3					3														
DLS.. 3	125	125					125														
MS_SG 4	48	48					48														
MS_MG 5	23	23					23														
MS_SN 6	3093	3093					3093														
MS_LS 8	608	608					608														
IG_LD 9	16	16					16														
IG_GS 10	14	14					14														
IG_NG 11	844	844					844														
DB... 12	241	241					241														
GT_FD 13																					
TOTAL	5015	5015																			

SPECIMEN CREEK, LITTLE NORTH FORK (SPE) 1964-1965 PERIOD

GEO-TYPE NO.	GEO-TYPE AC	all disturbance classes: GEO-TYPE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	undisturbed/unfailed lands: UNDIS. UNFLD' AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides in harvested land: HAR. AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides assoc. w/ roads: ROAD AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD C.Y./AC
TZ_DS 2	3	3					3														
DLS.. 3	125	125					125														
MS_SG 4	48	48					48														
MS_MG 5	23	23					23														
MS_SN 6	3093	3093					3093														
MS_LS 8	608	608					608														
IG_LD 9	16	16					16														
IG_GS 10	14	14	2	0.178	2724	194.6	14	2	0.178	2724	194.6										
IG_NG 11	844	844					844														
DB... 12	241	241					241														
GT_FD 13																					
TOTAL	5015	5015	2	0.178	2724		5015	2	0.178	2724											

SPECIMEN CREEK, LITTLE NORTH FORK (SPE) 1965-1975 PERIOD

GEO-TYPE NO.	GEO-TYPE AC	all disturbance classes: GEO-TYPE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	undisturbed/unfailed lands: UNDIS. UNFLD' AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides in harvested land: HAR. AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL C.Y./AC	landslides assoc. w/ roads: ROAD AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD C.Y./AC
TZ_DS 2	3	3					3														
DLS.. 3	125	125					125														
MS_SG 4	48	48					48														
MS_MG 5	23	23					23														
MS_SN 6	3093	3093					3089											4			
MS_LS 8	608	608					605											3			
IG_LD 9	16	16					16														
IG_GS 10	14	14					12.5					1					0.5				
IG_NG 11	844	844	1	0.028	12	0.0	843.5	1	0.028	12	0.0						0.5				
DB... 12	241	241					240										1				
GT_FD 13																					
TOTAL	5015	5015	1	0.028	12		5005	1	0.028	12		1	0	0	0		9	0	0	0	

SPECIMEN CREEK 0-1988 PERIOD OF RECORD

TOTAL	5015		3	0.206	2736			3	0.206	2736			0	0	0			0	0	0	

Table E-1-1, continued. Little North Fork Data Summary.

UNCLES CREEK, LITTLE NORTH FORK (UNC) 0-1944 PERIOD

GEO-TYPE NO.	GEO-TYPE AC	all disturbance classes: GEO-TYPE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL: C.Y./AC	undisturbed/unfailed lands: UNDIS. UNFLD' AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL: C.Y./AC	landslides in harvested land: HAR. AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL: C.Y./AC	landslides assoc. w/ roads: ROAD AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD: C.Y./AC
TZ_DS 2	2	2					2														
DLS.. 3																					
MS_SG 4	798	798	1	0.048	378	0.5	798	1	0.048	378	0.5										
MS_MG 5	999	999					999														
MS_SN 6	925	925					925														
MS_LS 8	989	989					989														
IG_LD 9	173	173	1	0.367	2133	12.3	173	1	0.367	2133	12.3										
IG_GS 10	206	206					206														
IG_NG 11	449	449	1	0.056	233	0.5	449	1	0.056	233	0.5										
DB... 12	192	192	1	0.569	4267	22.2	192	1	0.569	4267	22.2										
GT_FD 13	288	288					288														
TOTAL	5021	5021	4	1.041	7011		5021	4	1.0412	7011											

UNCLES CREEK, LITTLE NORTH FORK (UNC) 1964-1965 PERIOD

GEO-TYPE NO.	GEO-TYPE AC	all disturbance classes: GEO-TYPE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL: C.Y./AC	undisturbed/unfailed lands: UNDIS. UNFLD' AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL: C.Y./AC	landslides in harvested land: HAR. AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL: C.Y./AC	landslides assoc. w/ roads: ROAD AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD: C.Y./AC
TZ_DS 2	2	2					2														
DLS.. 3																					
MS_SG 4	798	798	2	0.047	498	0.6	798	2	0.047	498	0.6										
MS_MG 5	999	999	1	0.025	141	0.1	999	1	0.025	141	0.1										
MS_SN 6	925	925					925														
MS_LS 8	989	989					989														
IG_LD 9	173	173	2	0.193	1288	7.4	173	2	0.193	1288	7.4										
IG_GS 10	206	206	5	0.625	7984	38.8	206	5	0.625	7984	38.8										
IG_NG 11	449	449	1	0.129	800	1.8	449	1	0.129	800	1.8										
DB... 12	192	191					192														
GT_FD 13	288	288	1	0.124	740	2.6	288	1	0.124	740	2.6										
TOTAL	5021	5021	12	1.142	11451		5021	12	1.142	11451											

UNCLES CREEK, LITTLE NORTH FORK (UNC) 1965-1975 PERIOD

GEO-TYPE NO.	GEO-TYPE AC	all disturbance classes: GEO-TYPE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL: C.Y./AC	undisturbed/unfailed lands: UNDIS. UNFLD' AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL: C.Y./AC	landslides in harvested land: HAR. AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YL: C.Y./AC	landslides assoc. w/ roads: ROAD AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD: C.Y./AC
TZ_DS 2	2	2					2														
DLS.. 3																					
MS_SG 4	798	798					798														
MS_MG 5	999	999					999														
MS_SN 6	925	925					925														
MS_LS 8	989	989					989														
IG_LD 9	173	173	3	0.601	3127	18.1	173	3	0.601	3127	18.1										
IG_GS 10	206	205	1	0.129	260	1.3	206	1	0.129	260	1.3										
IG_NG 11	449	449	3	0.246	1099	2.4	449	3	0.246	1099	2.8										
DB... 12	192	192					192														
GT_FD 13	288	288					288														
TOTAL	5021	5021	7	0.976	4486		5021	7	0.976	4486											
UNCLES CREEK WATERSHED TOTALS	5021	5021	23	3.160	22948			23	3.1595	22948											

Table E-1-2. Negro Creek Data Summary.

NEGRO CREEK (SFSNEG) 0-1944 PERIOD

GEO-TYPE NO.	GEO-TYPE AC	all disturbance classes: GEO-TYPE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD. C.Y./AC	undisturbed/unfailed lands: UNDIS. UNFLD' AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD. C.Y./AC	landslides harvest units: HAR. AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD. C.Y./AC	landslides assoc. w/ roads: ROAD AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD. C.Y./AC	landslides assoc. w/ fire: FIRE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD C.Y./AC
TZ_DS 2																										
DLS.. 3	1408	1408	1	0.843	0	0.0	1408	1	0.843	0	0.0															
MS_SG 4																										
MS_MG 5																										
MS_SN 6	276	276					276																			
MS_LS 8	547	547					547																			
IG_LD 9	255	255	1	0.232	2400	9.4	255	1	0.232	2400	9.4															
IG_GS 10																										
IG_NG 11	130	130	4	0.308	1965	15.1	130	4	0.308	1965	15.1															
DB... 12																										
GT_FD 13																										
TOTAL	2616	2616	6	1.383	4365		2616	6	1.383	4365																

NEGRO CREEK (SFSNEG) 1955-1964 PERIOD

GEO-TYPE NO.	GEO-TYPE AC	all disturbance classes: GEO-TYPE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD. C.Y./AC	undisturbed/unfailed lands: UNDIS. UNFLD' AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD. C.Y./AC	landslides harvest units: HAR. AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD. C.Y./AC	landslides assoc. w/ roads: ROAD AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD. C.Y./AC	landslides assoc. w/ fire: FIRE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD C.Y./AC
TZ_DS 2																										
DLS.. 3	1408	1408					1376.2										31.8									
MS_SG 4																										
MS_MG 5																										
MS_SN 6	276	276					274.8										1.2									
MS_LS 8	547	547	1	0.220	72	0.1	535.6										11.4	1	0.220	72	6.3					
IG_LD 9	255	255					250.8										4.2									
IG_GS 10																										
IG_NG 11	130	130					130																			
DB... 12																										
GT_FD 13																										
TOTAL	2616	2616	1	0.22	72		2567.4										48.6	1	0.22	72						

NEGRO CREEK (SFSNEG) 1964-1965 PERIOD

GEO-TYPE NO.	GEO-TYPE AC	all disturbance classes: GEO-TYPE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD. C.Y./AC	undisturbed/unfailed lands: UNDIS. UNFLD' AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD. C.Y./AC	landslides harvest units: HAR. AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD. C.Y./AC	landslides assoc. w/ roads: ROAD AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD. C.Y./AC	landslides assoc. w/ fire: FIRE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD C.Y./AC
TZ_DS 2																										
DLS.. 3	1408	1408					1376.2										31.8									
MS_SG 4																										
MS_MG 5																										
MS_SN 6	276	276	0.5	1.751	0	0.0	274.8	0.5	1.751	0	0.0						1.2									
MS_LS 8	547	547	.2	0.077	187	0.3	535.6										11.4	2	0.077	187	16.4					
IG_LD 9	255	255	1	0.646	5800	22.7	250.8	1	0.646	5800	23.1						4.2									
IG_GS 10																										
IG_NG 11	130	130	8.5	2.304	34648	266.5	130.0	8.5	2.304	34648	266.5															
DB... 12																										
GT_FD 13																										
TOTAL	2616	2616	12	4.778	40635		2567.4	10	4.701	40448							48.6	2	0.077	187						

Table E-1-2, continued. Negro Creek Data Summary.

NEGRO CREEK (SFSNEG) 1965-1975 PERIOD

GEO-TYPE NO.	GEO-TYPE AC	all disturbance classes: GEO-TYPE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD. C.Y./AC	undisturbed/unfailed lands: UNDIS. UNFLD' AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD. C.Y./AC	landslides harvest units: # HAR. AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD. C.Y./AC	landslides assoc. w/ roads: ROAD AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD. C.Y./AC	landslides assoc. w/ fire: FIRE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD C.Y./AC
TZ_DS 2																										
DLS.. 3	1408	1408	1	0.092	72	0.1	1368.2																			
MS_SG 4																	39.75	1	0.092	72	1.8					
MS_MG 5																										
MS_SW 6	276	276					274.5																			
MS_LS 8	547	547	2	0.436	1116	2.0	532.75	1	0.278	935	1.8						1.5									
IG_LD 9	255	255	4	0.390	705	2.8	249.75	2	0.351	690	2.8						14.25	1	0.158	181	12.7					
IG_GS 10																	5.25	2	0.039	15	2.9					
IG_NG 11	130	130	3	0.285	1476	11.4	130	3	0.285	1476	11.4															
DB... 12																										
GT_FD 13																										
TOTAL	2616	2616	10	1.203	3369		2555.2	6	0.914	3101							60.75	4	0.289	268						

NEGRO CREEK (SFSNEG) 1975-1988 PERIOD

GEO-TYPE NO.	GEO-TYPE AC	all disturbance classes: GEO-TYPE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD. C.Y./AC	undisturbed/unfailed lands: UNDIS. UNFLD' AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD. C.Y./AC	landslides harvest units: # HAR. AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD. C.Y./AC	landslides assoc. w/ roads: ROAD AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD. C.Y./AC	landslides assoc. w/ fire: FIRE AC	# OF SLD	SLD AC	VOL. DEL. C.Y.	SED.YLD C.Y./AC
TZ_DS 2																										
DLS.. 3	1408	1408	8	2.899	2766	2.0	0										53	3	0.6	1523	28.7	1355	5	2.299	1243	0.9
MS_SG 4																										
MS_MG 5																										
MS_SW 6	276	276	1.25	2.817	0	0.0	4										2				0.0	270	1.25	2.817	0	0.0
MS_LS 8	547	547	4	0.560	747	1.4	0										19	2	0.429	417	21.9	528	2	0.131	330	0.6
IG_LD 9	255	255	54	4.367	14968	58.7	0										7	2	0.139	275	39.3	248	52	4.228	14693	59.2
IG_GS 10																										
IG_NG 11	130	130	22.75	2.872	11223	86.3	0										1	1	0.074	360	360.0	129	21.75	2.798	10863	84.2
DB... 12																										
GT_FD 13																										
TOTAL	2616	2616	90	13.515	29704		4										82	8	1.242	2575		2530	82	12.273	27129	

NEGRO CREEK ALL PERIODS

SUM TOTAL	2616	2616	119	21.099	78145			22	6.998	47914		0			15	1.828	3102					82	12.273	27129		

Tables E-1-1 and E-1-2 Notes.

Geomorphic Terrane Types

Geomorphic Terrane	Code	Terrane No.
Slump/Earthflow Toe Zones	TZ_DS	2
Slump/Earthflow Deposits	DLS..	3
Granitic Mountain Slopes >65%	MS_SG	4
Granitic Mountain Slopes <65%	MS_MG	5
Non-Granitic Mountain Slopes >65%	MS_SN	6
Non-Granitic Mountain Slopes <65%	MS_LN	8
Inner Gorge in Landslide, Terrace or Glacial Deposits	IG_LD	9
Inner Gorge in Granitic Bedrock & Mt. Slopes	IG_GS	10
Inner Gorge in Non-Granitic Bedrock & Mt. Slopes	IG_NG	11
Debris Basins [Headwalls]	DB..	12
Glacial, Terrace & Fan Deposits	GT_FD	13

Table E-1-3. Selected data from the Little North Fork Landslide Inventory.

Selected data from the Little North Fork Landslide Inventory.
File: SUMLNF1

Row	Water-shed	Sub-Water-shed	Inven-tory Number	Meth-od	Photo Year	Slide Type	Bed-rock Type	Geo-morphic Terrane Type	Dis-tur-bance Class	Maxi-mum Eleva-tion	Mini-mum Eleva-tion	As-pect	Map Acres	Mobil-ized Vol-ume	Deliv-ered Vol-ume	Remain-ing Vol-ume	Stored Vol-ume
1	NFS	LNSHLS	81120	F	1965	CBDS	G	9	NAT	4460	4440	W	0.034	285	200	85	
2	NFS	LNSHLS	81121	F	1965	CBDS	G	9	NAT	4510	4500	E	0.023	100	100		
3	NFS	LNSHLS	81122	F	1965	DS	G	12	NAT	6320	6280	E	0.053	533	533		
4	NFS	LNSHLS	81123	F	1965	DS	G	12	NAT	6060	6020	W	0.061	530	371	159	
5	NFS	LNSHLS	81124	A	1965	DS	G	4	NAT	5760	5690	E	0.202	815	815		
6	NFS	LNSHLS	81125	A	1965	DS	G	12	NAT	5810	5760	W	0.057	518	518		
7	NFS	LNSHLS	81126	A	1944	DS	G	12	NAT	6570	6510	W	0.095	815	815		
8	NFS	LNSHLS	81127	A	1944	DS	G	12	NAT	6800	6710	W	0.069	1444	1444		
9	NFS	LNSHLS	81128	A	1944	DS	G	12	NAT	6830	6760	W	0.034	311	311		
10	NFS	LNSHLS	81129	A	1944	DS	G	4	NAT	6580	6510	W	0.043	370	370		
11	NFS	LNSHLS	81131	F	1965	DS	G	13	NAT	5650	5370	W	3.330	119778	5989	41922	71867
12	NFS	LNSHLS	81260	A	1965	DS	M	8	NAT	4660		N	0.055	427	256	171	
13	NFS	LNSHLS	81261	A	1972	DS	M	8	HAR	4600		N	0.018	71	57	14	
14	NFS	LNSHLS	88001	F	1971	DS	G	9	NAT	4260	4240	N	0.044	267	200	67	
15	NFS	LNSHLS	88002	F	1971	CBDS	G	9	NAT	4245	4210	N	0.060	237	190	47	
16	NFS	LNSHLS	88003	F	1965	CBDS	G	10	NAT	4280	4130	N	0.979	30000	22500	7500	
17	NFS	LNSHLS	88004	F	1965	CS	G	10	NAT	4240	4120	N	1.805	62000	49600	12400	
18	NFS	LNSHLS	88005	F	1965	CS	G	10	NAT	4230	4120	S	0.730	21926	16445	5481	
19	NFS	LNSHLS	88006	F	1965	CBDS	G	10	NAT	4160	4100	S	0.165	1889	1511	378	
20	NFS	LNSHLS	88007	F	1965	DS	M	11	NAT	3880	3740	N	0.568	9722	7777	1945	
21	NFS	LNSHLS	88008	F	1965	DS	M	11	NAT	3860	3700	N	0.312	1393	455	938	
22	NFS	LNSHLS	88009	F	1971	CS	M	11	HAR	4000	3750	E	2.755	106667	0	106667	
23	NFS	LNSHLS	88010	F	1965	CS	G	10	NAT	4135	4040	N	0.801	23111	13867	9244	
24	NFS	LNSHLS	88011	F	1965	CBDS	G	10	NAT	4130	4020	N	0.326	7435	5200	2235	
25	NFS	LNSHLS	88012	F	1965	DS	G	10	NAT	4140	4000	N	0.124	2273	1818	455	
26	NFS	LNSHLS	88013	F	1965	CBDS	G	10	NAT	4095	3990	N	0.613	20444	14310	6134	
27	NFS	LNSHLS	88014	F	1965	CBDS	G	10	NAT	3950	3920	N	0.054	333	200	133	
28	NFS	LNSHLS	88015	F	1965	CBDS	G	10	NAT	3940	3880	E	0.080	1283	962	321	
29	NFS	LNSHLS	88016	F	1965	CBDS	G	10	NAT	3935	3875	S	0.184	1200	720	480	
30	NFS	LNSHLS	88017	F	1965	CBDS	G	10	NAT	4000	3880	E	0.096	378	378		
31	NFS	LNSHLS	88018	F	1965	CBDS	G	10	NAT	3915	3870	S	0.259	2763	2487	276	
32	NFS	LNSHLS	88019	F	1965	CBDS	G	10	NAT	3880	3840	N	0.222	3862	3283	579	
33	NFS	LNSHLS	88020	F	1965	CS	G	10	NAT	3920	3810	N	0.697	9176	8258	918	
34	NFS	LNSHLS	88021	F	1972	CBDS	G	10	NAT	3740	3720	S	0.076	375	319	56	
35	NFS	LNSHLS	88022	F	1965	CS	G/M	10	NAT	3835	3760	E	0.133	1555	1089	466	
36	NFS	LNSHLS	88023	F	1965	CBDS	M	11	NAT	3755	3730	S	0.095	586	352	234	
37	NFS	LNSHLS	88024	F	1965	CS	M	9	NAT	3780	3500	N	2.258	141415	26289	115126	
38	NFS	LNSHLS	88025	F	1965	DS	M	9	NAT	3700	3520	N	0.850	10584	7860	2724	
39	NFS	LNSHLS	88026	F	1965	CBDS	G	10	NAT	3595	3540	S	0.351	3889	3145	744	
40	NFS	LNSHLS	88027	F	1965	DS	G	9	NAT	3780	3580	N	0.735	8747	5404	3343	

Table E-1-3, continued. Selected data from the Little North Fork Landslide Inventory.

Selected data from the Little North Fork Landslide Inventory.
File: SUMLNF1

Row	Water-shed	Sub-Water-shed	Inven-tory Number	Meth-od	Photo Year	Slide Type	Bed-rock Type	Geo-morphic Terrane Type	Dis-tur-bance Class	Maxi-mum Eleva-tion	Mini-mum Eleva-tion	As-pect	Map Acres	Mobil-ized Vol-ume	Deliv-ered Vol-ume	Remain-ing Vol-ume	Stored Vol-ume
41	NFS	LNSHLS	88028	F	1971	DS	G	10	NAT	3780	3600	N	0.014	74	52	22	
42	NFS	LNSHLS	88029	F	1971	DS	G	10	NAT	3650	3600	N	0.023	52	52		
43	NFS	LNSHLS	88030	F	1971	DS	G	10	NAT	3670	3600	N	0.078	351	263	88	
44	NFS	LNSHLS	88031	F	1971	CS	M	11	NAT	3650	3550	N	0.145	806	484	322	
45	NFS	LNSHLS	88032	F	1971	CS	M	11	NAT	3650	3520	N	0.344	4562	3650	912	
46	NFS	LNSHLS	88033	F	1965	CBDS	M	11	NAT	3620	3500	S	0.716	9333	6533	2800	
47	NFS	LNSHLS	88034	F	1965	DS	M	11	NAT	3550	3500	N	0.076	667	533	134	
48	NFS	LNSHLS	88035	FA	1972	CS	M	6	R	3960	3420	N	1.550	9444	472	8972	
49	NFS	LNSHLS	88036	F	1965	CS	G	10	NAT	3480	3400	N	0.270	1800	1260	540	
50	NFS	LNSHLS	88037	F	1965	DS	M	11	NAT	3420	3380	S	0.247	1017	610	203	204
51	NFS	LNSHLS	88038	F	1965	CBDS	M	11	NAT	3480	3460	S	0.088	110	100	10	
52	NFS	LNSHLS	88039	F	1965	DS	M	11	NAT	3390	3370	S	0.032	156	156		
53	NFS	LNSHLS	88040	F	1965	CBDS	M	11	NAT	3340	3320	W	0.083	400	360	40	
54	NFS	LNSHLS	88044	F	1965	CBDS	G	9	NAT	4325	4300	E	0.267	1695	1017	678	
55	NFS	LNSHLS	88045	F	1965	CBDS	G	9	NAT	4330	4300	S	0.135	563	282	281	
56	NFS	LNSHLS	88046	F	1965	CBDS	G	9	NAT	4330	4300	N	0.118	683	171	512	
57	NFS	LNSHLS	88047	F	1965	CBDS	G	9	NAT	4340	4320	S	0.037	156	78	78	
58	NFS	LNSHLS	88048	F	1965	CS	G	9	NAT	4400	4240	N	0.698	27489	7283	17778	2428
59	NFS	LNSHLS	88049	F	1965	CBDS	G	9	NAT	4340	4320	S	0.021	68	68		
60	NFS	LNSHLS	88050	F	1944	DS	G	9	NAT	4400	4270	N	0.366	6481	5833	648	
61	NFS	LNSHLS	88051	F	1965	CBDS	G	9	NAT	4350	4320	S	0.045	193	193		
62	NFS	LNSHLS	88052	F	1965	DS	G	9	NAT	4380	4320	N	0.229	7083	6375	708	
63	NFS	LNSHLS	88053	F	1965	CBDS	G	9	NAT	4380	4360	S	0.043	195	98	97	
64	NFS	LNSHLS	88054	F	1944	CS	G	9	NAT	4410	4325	N	0.404	10111	3889	6222	
65	NFS	LNSHLS	88055	F	1965	CS	G	9	NAT	4460	4420	S	0.118	3267	913	2354	
66	NFS	LNSHLS	88056	F	1965	CBDS	G	9	NAT	4420	4320	N	0.367	7644	4968	2676	
67	NFS	LNSHLS	88057	F	1965	CS	G	9	NAT	4440	4340	S	0.510	3230	2515	715	
68	NFS	LNSHLS	88058	F	1965	CBDS	G	9	NAT	4380	4340	N	0.125	879	703	176	
69	NFS	LNSHLS	88059	F	1965	CBDS	G	9	NAT	4480	4390	S	0.334	1409	1127	282	
70	NFS	LNSHLS	88060	F	1965	CBDS	G	9	NAT	4460	4390	N	0.193	1496	1122	374	
71	NFS	LNSHLS	88061	F	1965	CBDS	G	9	NAT	4420	4390	S	0.068	467	350	117	
72	NFS	LNSHLS	88062	F	1965	CBDS	G	9	NAT	4450	4430	N	0.105	619	495	124	
73	NFS	LNSHLS	88063	F	1965	CBDS	G	9	NAT	4570	4540	S	0.171	1072	750	322	
74	NFS	LNSHLS	88064	F	1965	CBDS	G	9	NAT	4490	4440	N	0.113	889	711	178	
75	NFS	LNSHLS	88065	F	1965	CBDS	G	9	NAT	4620	4580	S	0.312	1317	1054	263	
76	NFS	LNSHLS	88066	F	1965	CBDS	G	9	NAT	4595	4580	N	0.094	400	360	40	
77	NFS	LNSHLS	88067	F	1965	CBDS	G	9	NAT	4645	4610	S	0.108	444	400	44	
78	NFS	LNSHLS	88068	F	1965	CBDS	G	9	NAT	4615	4600	W	0.174	743	669	74	
79	NFS	LNSHLS	88069	F	1965	CBDS	G	9	NAT	4690	4680	S	0.043	92	74	18	
80	NFS	LNSHLS	88070	F	1965	CBDS	G	9	NAT	4660	4650	N	0.379	560	504	56	
81	NFS	LNSHLS	88071	F	1965	CBDS	G	9	NAT	4780	4750	S	0.075	467	280	187	

Table E-1-3, continued. Selected data from the Little North Fork Landslide Inventory.

Selected data from the Little North Fork Landslide Inventory.
File: SUMLNF1

Row	Water-shed	Sub-Water-shed	Inven-tory Number	Meth-od	Photo Year	Slide Type	Bed-rock Type	Geo-morphic Terrane Type	Dis-tur-bance Class	Maxi-mum Eleva-tion	Mini-mum Eleva-tion	As-pect	Map Acres	Mobil-ized Vol-ume	Deliv-ered Vol-ume	Remain-ing Vol-ume	Stored Vol-ume
82	NFS	LNSHLS	88072	F	1965	CBDS	G	10	NAT	4260	4230	N	0.121	1067	960	107	
83	NFS	LNSHLS	88073	F	1965	CBDS	G	9	NAT	4805	4780	S	0.047	278	195	83	
84	NFS	LNSHLS	88074	F	1965	DS	G	4	NAT	5200	4900	S	0.194	746	671	75	
85	NFS	LNSHLS	88075	F	1965	DS	G	10	NAT	5600	5330	S	0.214	2956	2660	296	
86	NFS	LNSHLS	88076	F	1965	DS	G	4	NAT	5600	5490	S	0.149	1222	1161	61	
87	NFS	LNSHLS	88077	F	1971	DS	M	11	NAT	3620	3550	E	0.046	533	373	160	
88	NFS	LNSHLS	88078	F	1965	CBDS	G	10	NAT	4140	3920	S	0.160	348	348		
89	NFS	LNSHLS	88079	F	1965	CBDS	G	10	NAT	4080	4040	S	0.097	222	222		
90	NFS	LNSHLS	88081	F	1965	CBDS	G	9	NAT	4270	4240	S	0.020	124	75	49	
91	NFS	LNSHLS	88082	F	1965	CBDS	G	9	NAT	4290	4260	S	0.036	161	113	48	
92	NFS	LNSHLS	88083	F	1965	CBDS	G	9	NAT	4345	4325	E	0.037	241	193	48	
93	NFS	LNSHLS	88084	F	1965	CBDS	G	9	NAT	4390	4370	SW	0.034	344	241	103	
94	NFS	LNSHLS	88085	F	1965	CS	G	9	NAT	4425	4400	W	0.077	778	389	389	
95	NFS	LNSHLS	88086	F	1965	CBDS	G	9	NAT	4430	4410	W	0.124	956	574	382	
96	NFS	LNSHLS	88087	F	1965	CS	G	10	NAT	5110	4880	E	0.344	3470	2429	1041	
97	NFS	LNSHLS	88088	F	1971	CS	G	10	NAT	4950	4840	N	0.317	1086	1032	54	
98	NFS	LNSHLS	88089	F	1971	CS	G	10	NAT	4820	4780	N	0.051	122	79	43	
99	NFS	LNSHLS	88090	F	1975	CS	G	10	NAT	4740	4700	S	0.104	237	237		
100	NFS	LNSHLS	88091	FA	1965	CS	G	10	NAT	4840	4760	W	0.133	303	303		
101	NFS	LNSHLS	88117	A	1971	DS	M	11	HAR	3950	3880	N	0.155	302	302		
102	NFS	LNSHLS	88118	A	1971	DS	M	11	HAR	3920	3880	E	0.041	237	237		
103	NFS	LNSHLS	88119	A	1971	DS	M	11	HAR	4080	4040	N	0.041	247	247		
104	NFS	LNSHLS	88120	A	1972	DS	M	11	HAR	4140	4120	N	0.009	60	60		
105	NFS	LNSHLS	88123	A	1972	DS	M	6	R	3920		N	0.052	200	40	160	
106	NFS	LNSHLS	88124	A	1972	DS	M	6	R	3920		N	0.052	200	40	160	
107	NFS	LNSHLS	88125	A	1972	DS	M	8	R	4560		N	0.076	440	286	154	
108	NFS	LNSHLS	88126	A	1972	DS	M	11	R	4320		N	0.076	807	766	40	
109	NFS	LNSHLS	88128	A	1965	DS	G	5	NAT	5280		S	0.056	327	294	33	
110	NFS	LNSHLS	88129	A	1965	DS	G	4	NAT	5640		S	0.056	327	294	33	
111	NFS	LNSLOW	81063	F	1965	DS	G	10	NAT	2760	2720	W	0.073	467	467		
112	NFS	LNSLOW	81064	F	1965	DS	G	10	NAT	2760	2720	N	0.047	150	150		
113	NFS	LNSLOW	81065	F	1944	DS	G	5	T	4000	3125	E	0.072	2222			2222
114	NFS	LNSLOW	81066	F	1965	CBDS	G	10	NAT	2360	2320	W	0.117	681	681		
115	NFS	LNSLOW	81067	F	1965	CBDS	G	10	NAT	2300	2290	E	0.101	597	597		
116	NFS	LNSLOW	81068	F	1965	CS	G	10	NAT	2340	2290	W	0.171	9259	3087	3086	3086
117	NFS	LNSLOW	81069	F	1972	DS	G	4	NAT	2480	2160	W	0.482	13800	8200	2800	2800
118	NFS	LNSLOW	81070	F	1971	DS	G	10	NAT	2060	2040	W	0.195	1155	1040	115	
119	NFS	LNSLOW	81071	F	1971	DS	G	10	T	2100	2030	W	0.204	1400	1400		
120	NFS	LNSLOW	81072	F	1972	DS	G	10	NAT	2160	2100	W	0.053	237	237		
121	NFS	LNSLOW	81073	F	1971	DS	G	10	NAT	2200	2150	W	0.055	270	216	54	
122	NFS	LNSLOW	81076	F	1965	DS	G	10	NAT	2500	2360	S	0.597	12037	9027	3010	
123	NFS	LNSLOW	81077	F	1965	DS	G	10	NAT	2430	2730	S	0.095	433	303	130	

Table E-1-3, continued. Selected data from the Little North Fork Landslide Inventory.

Selected data from the Little North Fork Landslide Inventory.
File: SUMLNF1

Row	Water-shed	Sub-Water-shed	Inven-tory Number	Meth-od	Photo Year	Slide Type	Bed-rock Type	Geo-morphic Terrane Type	Dis-tur-bance Class	Maxi-mum Eleva-tion	Mini-mum Eleva-tion	As-pect	Map Acres	Mobil-ized Vol-ume	Deliv-ered Vol-ume	Remain-ing Vol-ume	Stored Vol-ume
124	NFS	LNSLOW	81078	F	1971	DS	G	10	NAT	2410	2380	S	0.049	207	166	41	
125	NFS	LNSLOW	81079	F	1972	CBDS	G	10	NAT	2385	2380	S	0.015	33	7	26	
126	NFS	LNSLOW	81080	F	1965	DS	G	10	NAT	2495	2470	S	0.074	1333	1200	133	
127	NFS	LNSLOW	81081	F	1972	CBDS	G	10	NAT	2490	2460	S	0.057	260	208	52	
128	NFS	LNSLOW	81082	F	1972	CBDS	G	10	NAT	2550	2500	S	0.461	2500	2250	250	
129	NFS	LNSLOW	81083	F	1965	CBDS	G	10	NAT	2735	2705	S	0.108	1100	1000	100	
130	NFS	LNSLOW	81084	F	1972	CBDS	G	10	NAT	2650	2620	E	0.030	200	180	20	
131	NFS	LNSLOW	81085	F	1972	DS	G	10	NAT	2800	2790	S	0.006	27	24	3	
132	NFS	LNSLOW	81086	F	1972	CBDS	G	10	NAT	2680	2610	E	0.073	490	390	100	
133	NFS	LNSLOW	81087	F	1972	DS	G	10	NAT	2810	2725	E	0.053	244	220	24	
134	NFS	LNSLOW	81088	F	1971	CBDS	G	10	NAT	2730	2660	W	0.053	281	267	14	
135	NFS	LNSLOW	81089	F	1965	DS	G	10	NAT	2765	2660	S	0.081	652	587	65	
136	NFS	LNSLOW	81090	F	1965	CS	G	10	NAT	2760	2705	N	0.051	458	435	23	
137	NFS	LNSLOW	81091	F	1965	CBDS	G	10	NAT	2750	2730	N	0.070	833	750	83	
138	NFS	LNSLOW	81092	F	1972	CBDS	G	10	NAT	2725	2710	S	0.025	222	155	67	
139	NFS	LNSLOW	81093	F	1965	CBDS	G	10	NAT	2930	2815	E	0.125	944	661	283	
140	NFS	LNSLOW	81094	F	1965	CBDS	G	10	NAT	2835	2815	E	0.029	250	150	100	
141	NFS	LNSLOW	81095	F	1972	DS	G	10	T	2800	2740	E	0.041	192	172	20	
142	NFS	LNSLOW	81096	F	1965	DS	G	10	NAT	2880	2720	W	0.259	1533	767		766
143	NFS	LNSLOW	81097	F	1965	DS	G	10	NAT	2790	2740	NE	0.130	870	783	87	
144	NFS	LNSLOW	81098	F	1965	CS	M	11	T	2860	2840	W	0.053	175	17	158	
145	NFS	LNSLOW	81099	F	1965	CS	M	11	NAT	2880	2800	NE	0.291	4594	4135	459	
146	NFS	LNSLOW	81100	F	1965	CS	G	10	NAT	2880	2860	W	0.030	214	161	53	
147	NFS	LNSLOW	81101	F	1965	CBDS	M	11	NAT	2880	2860	W	0.028	394	394		
148	NFS	LNSLOW	81102	F	1972	CS	G	10	NAT	2860	2800	E	0.218	9696	5818	3878	
149	NFS	LNSLOW	81103	F	1965	CS	G	10	NAT	2870	2820	E	0.085	720	540	180	
150	NFS	LNSLOW	81104	F	1965	CS	G	10	NAT	2940	2810	E	0.265	3447	1206	2241	
151	NFS	LNSLOW	81105	F	1965	CS	M	11	NAT	2890	2850	S	0.128	1020	816	204	
152	NFS	LNSLOW	81106	F	1965	CBDS	G	10	NAT	3160	3120	W	0.128	693	416	277	
153	NFS	LNSLOW	81107	F	1965	CBDS	G	9	NAT	3170	3110	E	0.093	560	448	112	
154	NFS	LNSLOW	81108	F	1972	DS	G	9	NAT	3200	3100	E	0.071	244	158	86	
155	NFS	LNSLOW	81109	F	1972	CBDS	M	10	NAT	3120	3100	W	0.055	239	60	179	
156	NFS	LNSLOW	81110	F	1972	CS	M	9	NAT	3160	3130	E	0.157	2600	2080	520	
157	NFS	LNSLOW	81111	F	1971	CBDS	M	9	NAT	3240	3200	W	0.034	217	130	87	
158	NFS	LNSLOW	81112	F	1971	CBDS	M	9	NAT	3230	3200	E	0.055	239	239		
159	NFS	LNSLOW	81113	F	1965	CS	M	11	NAT	3230	3200	E	0.050	778	272	506	
160	NFS	LNSLOW	81114	F	1972	CS	M	11	NAT	3240	3210	S	0.186	1437	719	718	
161	NFS	LNSLOW	81115	F	1965	CBDS	M	11	NAT	3380	3300	E	0.299	5440	3264	2176	
162	NFS	LNSLOW	81116	F	1965	CBDS	M	11	NAT	3390	3300	E	0.259	6222	3733	2489	
163	NFS	LNSLOW	81117	F	1965	CBDS	M	11	NAT	3320	3300	W	0.129	544	435	109	
164	NFS	LNSLOW	81118	F	1965	CBDS	M	11	NAT	3195	3160	W	0.157	712	712		
165	NFS	LNSLOW	81119	F	1965	CBDS	M	11	NAT	3260	3240	W	0.067	407	407		

Table E-1-3, continued. Selected data from the Little North Fork Landslide Inventory.

Selected data from the Little North Fork Landslide Inventory.
File: SUMLNF1

Row	Water-shed	Sub-Water-shed	Inven-tory Number	Meth-od	Photo Year	Slide Type	Bed-rock Type	Geo-morphic Terrane Type	Dis-tur-bance Class	Maxi-mum Eleva-tion	Mini-mum Eleva-tion	As-pect	Map Acres	Mobil-ized Vol-ume	Deliv-ered Vol-ume	Remain-ing Vol-ume	Stored Vol-ume
166	NFS	LNSLOW	81130	F	1965	DS	G	10	NAT	2880	2720	W	0.327	2083	1042		1041
167	NFS	LNSLOW	81222	A	1965	CS	M	9	NAT	4720	3360	S	39.000	1887600	20415	1867185	
168	NFS	LNSLOW	81223	A	1972	DS	G	10	R	2500		E	0.088	2292	2063	229	
169	NFS	LNSLOW	81224	A	1972	DS	G	10	R	2480		E	0.344	2972	2378	594	
170	NFS	LNSLOW	81225	A	1972	DS	G	4	R	2540		E	0.064	504	302	201	
171	NFS	LNSLOW	81226	A	1972	DS	G	10	R	2540		E	0.051	196	78	117	
172	NFS	LNSLOW	81227	A	1972	DS	G	10	R	2580		E	0.107	3870	3793	77	
173	NFS	LNSLOW	81228	A	1972	DS	G	10	R	2600		E	0.046	956	764	191	
174	NFS	LNSLOW	81229	A	1972	DS	G	10	R	2640		E	0.283	1618	1132	485	
175	NFS	LNSLOW	81230	A	1972	DS	G	10	R	2640		E	0.278	1043	626	417	
176	NFS	LNSLOW	81231	A	1972	DS	G	10	R	2640		E	0.113	420	252	168	
177	NFS	LNSLOW	81232	A	1972	DS	G	10	R	2640		E	0.844	4900	3430	1470	
178	NFS	LNSLOW	81233	A	1972	DS	G	10	R	2650		S	0.202	699	559	140	
179	NFS	LNSLOW	81234	A	1972	DS	G	10	R	2880		N	0.048	284	256	28	
180	NFS	LNSLOW	81235	A	1972	DS	G	10	R	2880		N	0.041	243	219	24	
181	NFS	LNSLOW	81236	A	1972	DS	G	10	R	2880		N	0.137	4722	4486	236	
182	NFS	LNSLOW	81237	A	1972	DS	G	4	R	2880		E	0.064	378	340	38	
183	NFS	LNSLOW	81238	A	1972	DS	G	5	R	2890		E	0.034	133	80	53	
184	NFS	LNSLOW	81239	A	1972	DS	G	5	R	3120		N	0.073	391	332	59	
185	NFS	LNSLOW	81240	A	1972	DS	G	5	R	3120		N	0.073	276	234	41	
186	NFS	LNSLOW	81241	A	1972	DS	G	10	R	3120		E	2.250	12756	7653	5102	
187	NFS	LNSLOW	81242	A	1972	DS	G	10	R	3140		E	0.284	1589	1112	477	
188	NFS	LNSLOW	81243	A	1972	DS	G	4	R	3200		E	0.220	1244	747	498	
189	NFS	LNSLOW	81244	A	1972	DS	G	4	R	3200		E	0.220	1244	747	498	
190	NFS	LNSLOW	81245	A	1972	DS	G	10	R	3200		E	0.195	1385	970	416	
191	NFS	LNSLOW	81246	A	1972	DS	G	10	R	3210		E	0.080	296	178	119	
192	NFS	LNSLOW	81247	A	1972	DS	G	10	R	3240		E	0.064	222	156	67	
193	NFS	LNSLOW	81248	A	1972	DS	M	11	R	3360		E	0.069	244	220	24	
194	NFS	LNSLOW	81249	A	1972	DS	M	6	R	3400		E	0.129	498	299	199	
195	NFS	LNSLOW	81250	A	1972	DS	M	6	R	3400		E	0.161	900	540	360	
196	NFS	LNSLOW	81251	A	1972	DS	M	11	R	3480		E	0.107	1397	279	1118	
197	NFS	LNSLOW	81252	A	1972	DS	M	6	R	3500		E	0.064	342	68	274	
198	NFS	LNSLOW	81253	A	1972	DS	M	6	R	3600		N	0.276	1067	107	960	
199	NFS	LNSLOW	81254	A	1972	DS	M	6	R	3620		N	0.253	1956	1369	587	
200	NFS	LNSLOW	81255	A	1972	DS	M	6	R	3700		E	0.367	1419	851	567	
201	NFS	LNSLOW	81256	A	1972	DS	M	9	NAT	3500		E	0.322	3797	2278	1519	
202	NFS	LNSLOW	81257	A	1972	DS	M	6	R	3680		E	0.076	595	476	119	
203	NFS	LNSLOW	81258	A	1972	DS	M	3	HAR	3800		S	0.056	653	555	98	
204	NFS	LNSLOW	81259	A	1972	DS	M	3	R	3680		S	0.028	204	184	20	
205	NFS	LNSLOW	81262	A	1972	DS	M	11	NAT	4840		E	0.045	173	156	17	
206	NFS	LNSLOW	81263	A	1972	DS	M	6	NAT	5100		E	0.052	303	273	30	
207	NFS	LNSLOW	81264	A	1965	DS	M	6	NAT	4800		S	0.051	385	347	38	

Table E-1-3, continued. Selected data from the Little North Fork Landslide Inventory.

Selected data from the Little North Fork Landslide Inventory.
File: SUMLNF1

Row	Water-shed	Sub-Water-shed	Inventory Number	Method	Photo Year	Slide Type	Bedrock Type	Geomorphic Terrane Type	Disturbance Class	Maximum Elevation	Minimum Elevation	Aspect	Map Acres	Mobilized Volume	Delivered Volume	Remaining Volume	Stored Volume
208	NFS	LNSLOW	81265	A	1965	DS	M	6	NAT	4320		S	0.088	1027	667	359	
209	NFS	LNSLOW	81266	A	1972	DS	G	4	R	3640		E	0.124	707	495	212	
210	NFS	LNSLOW	81267	A	1972	DS	G	4	R	3560		E	0.034	129	103	26	
211	NFS	LNSLOW	81268	A	1972	DS	G	10	R	3500		E	0.037	133	80	53	
212	NFS	LNSLOW	81269	A	1972	DS	G	10	R	3500		E	0.075	400	260	140	
213	NFS	LNSLOW	81270	A	1972	DS	G	4	R	3600		E	0.139	1084	704	379	
214	NFS	LNSLOW	81271	A	1972	DS	G	4	R	3540		E	0.080	344	224	121	
215	NFS	LNSLOW	81272	A	1972	DS	G	4	R	3540		E	0.017	74	48	26	
216	NFS	LNSLOW	81273	A	1972	DS	G	4	R	3600		E	0.351	2627	1707	919	
217	NFS	LNSLOW	81274	A	1972	DS	G	4	R	3520		E	0.045	247	160	86	
218	NFS	LNSLOW	81275	A	1972	DS	G	10	R	3520		E	0.045	160	112	48	
219	NFS	LNSLOW	81276	A	1972	DS	G	10	R	3440		E	0.088	676	440	237	
220	NFS	LNSLOW	81277	A	1972	DS	G	10	R	3440		E	0.116	879	835	44	
221	NFS	LNSLOW	81278	A	1972	DS	G	4	R	3400		E	0.082	318	207	111	
222	NFS	LNSLOW	81279	A	1972	DS	G	10	R	3360		E	0.031	173	130	43	
223	NFS	LNSLOW	81280	A	1972	DS	G	10	R	3280		W	0.062	360	216	144	
224	NFS	LNSLOW	81281	A	1972	DS	G	5	R	3240		E	0.088	513	257	257	
225	NFS	LNSLOW	81282	A	1972	DS	G	5	R	3230		E	0.082	477	191	286	
226	NFS	LNSLOW	81283	A	1972	DS	G	5	R	3080		E	0.044	167	50	117	
227	NFS	LNSLOW	81284	A	1972	DS	G	10	R	3080		E	0.031	231	139	92	
228	NFS	LNSLOW	81285	A	1972	DS	G	4	R	2980		E	0.031	120	36	84	
229	NFS	LNSLOW	81286	A	1972	DS	G	10	R	3700		E	0.103	800	640	160	
230	NFS	LNSLOW	81287	A	1972	DS	G	4	R	3720		E	0.077	300	180	120	
231	NFS	LNSLOW	81288	A	1972	DS	G	4	R	3750		E	0.069	269	134	134	
232	NFS	LNSLOW	81289	A	1972	DS	G	5	R	3920		S	0.069	417	271	146	
233	NFS	LNSLOW	81290	A	1972	DS	G	10	R	4000		E	0.037	326	293	33	
234	NFS	LNSLOW	81291	A	1972	DS	G	4	HAR	3800		S	0.032	244	196	49	
235	NFS	LNSLOW	81292	A	1972	DS	G	4	HAR	3720		E	0.037	289	246	43	
236	NFS	LNSLOW	81293	A	1972	DS	G	4	HAR	3600		E	0.119	1343	873	470	
237	NFS	LNSLOW	81294	A	1972	DS	G	5	NAT	2500		S	0.038	147	88	59	
238	NFS	LNSLOW	81295	A	1972	DS	G	5	NAT	2560		E	0.023	91	64	27	
239	NFS	LNSLOW	88041	F	1965	DS	M	11	T	3440	3370	W	0.104	1573	1573		
240	NFS	LNSLOW	88042	F	0	DS	M	11	T	3450	3370	N	0.051	233	233		
241	NFS	LNSLOW	88043	F	1965	CBDS	G/M	11	NAT	3385	3370	E	0.178	568	511		57
242	NFS	LNSLOW	88080	A	1965	CBDS	M	11	NAT	3235	3220	E	0.139	333	333		
243	NFS	LNSLOW	88121	A	1972	DS	M	6	HAR	3640	3280	E	0.409	2889			2889
244	NFS	LNSLOW	88122	FA	1972	DS	M	6	HAR	3720	3300	E	2.645	7644		2675	4969
245	NFS	LNSLOW	88127	A	1972	DS	G	4	R	3480		E	0.113	871	174	697	
246	NFS	LNSSPE	81062	F	1971	CS	G/M	11	NAT	2470	2370	W	0.028	118	12	106	
247	NFS	LNSSPE	81074	F	1965	DS	G	10	NAT	2450	2320	W	0.146	2592	2592		
248	NFS	LNSSPE	81075	F	1965	DS	G	10	NAT	2410	2350	W	0.032	176	132	44	
249	NFS	LNSUNC	88094	F	1971	CBDS	M	9	NAT	4200	4140	W	0.413	2980	2700	280	

Table E-1-3, continued. Selected data from the Little North Fork Landslide Inventory.

Selected data from the Little North Fork Landslide Inventory.
File: SUMLNF1

Row	Water-shed	Sub-Water-shed	Inven-tory Number	Meth-od	Photo Year	Slide Type	Bed-rock Type	Geo-morphic Terrane Type	Dis-tur-bance Class	Maxi-mum Eleva-tion	Mini-mum Eleva-tion	As-pect	Map Acres	Mobil-ized Vol-ume	Deliv-ered Vol-ume	Remain-ing Vol-ume	Stored Vol-ume
250	NFS	LNSUNC	88095	FA	1971	CBDS	M	9	NAT	4320	4310	W	0.037	83	83		
251	NFS	LNSUNC	88096	F	1971	CBDS	M	9	NAT	4330	4310	W	0.151	344	344		
252	NFS	LNSUNC	88097	FA	1971	CBDS	M	11	NAT	4330	4310	E	0.151	344	344		
253	NFS	LNSUNC	88098	A	1944	CBDS	M	11	NAT	4360	4340	S	0.056	233	233		
254	NFS	LNSUNC	88099	FA	1971	CBDS	G	10	NAT	3540	3520	N	0.129	260	260		
255	NFS	LNSUNC	88100	A	1965	DS	G	10	NAT	5050	4980	E	0.114	1042	1042		
256	NFS	LNSUNC	88101	A	1965	DS	G	10	NAT	5580	5460	S	0.276	3811	3811		
257	NFS	LNSUNC	88102	A	1965	DS	G	10	NAT	5960	5880	S	0.129	2087	2087		
258	NFS	LNSUNC	88103	A	1965	DS	G	10	NAT	4920	4840	E	0.093	1000	1000		
259	NFS	LNSUNC	88104	A	1965	DS	G	4	NAT	5520	5440	S	0.041	463	463		
260	NFS	LNSUNC	88105	A	1965	DS	G	4	NAT	5055	5040	E	0.006	35	35		
261	NFS	LNSUNC	88106	A	1965	DS	G	5	NAT	6160	6145	E	0.025	141	141		
262	NFS	LNSUNC	88107	A	1944	DS	G	12	NAT	7080	6720	E	0.569	4267	4267		
263	NFS	LNSUNC	88108	A	1944	DS	G	4	NAT	6780	6730	E	0.048	378	378		
264	NFS	LNSUNC	88109	F	1972	CBDS	G	11	NAT	3820	3780	W	0.079	722	722		
265	NFS	LNSUNC	88110	F	1965	CBDS	G	10	NAT	3790	3780	W	0.014	44	44		
266	NFS	LNSUNC	88111	F	1972	CBDS	M	11	NAT	3340	3320	W	0.016	33	33		
267	NFS	LNSUNC	88112	F	1965	CBDS	M	11	NAT	3410	3360	S	0.129	800	800		
268	NFS	LNSUNC	88113	A	1944	CBDS	G	9	NAT	5100	5020	W	0.367	2133	2133		
269	NFS	LNSUNC	88114	A	1965	CBDS	G	9	NAT	5270	5240	W	0.125	861	861		
270	NFS	LNSUNC	88115	A	1965	CBDS	G	13	NAT	4800	4720	W	0.124	740	740		
271	NFS	LNSUNC	88116	A	1965	CBDS	G	9	NAT	3960	3940	W	0.069	427	427		
Data from Pillsbury (1976).																	
	NFS	LNSLOW	88999	FA	1972	DS	G	10	HAR				8.179	42306	42306	0	0
											TOTAL		103.64	2868112	483168	2292614	92329

Table E-1-4. Selected data from the Negro Creek Landslide Inventory.

Selected data from the Negro Creek Landslide Inventory
File: Sumneg1.wk1

Row	Water-shed	Inv. No.	Meth-od	Photo Year	Est. Yr. Range	Slide Type	Rock Type	Geomor-phic Terrane Type	Distur-bance Class	Max. Eleva-tion	Min-. Eleva-tion	As-pect	Map Acres	Mobil-ized Volume	Deliv-ered Volume	On-Site Volume	Stored Volume Off-site
1	SFSNEG	4001	F	1982	77-87	S EF	U	3	FIRE	2590	2480	W	0.471	8290	0	6632	1658
2	SFSNEG	4002	F	1982	77-87	S	U	3	ROAD	2440	2400	W	0.070	538	0	484	54
3	SFSNEG	4003	F	1988		DS	U	9	FIRE	2400	2370	S	0.004	8	8		
4	SFSNEG	4004	F	1988		DS	U	9	FIRE	2420	2400	S	0.004	93	10	10	23
5	SFSNEG	4005	F	1988		DS	U	9	FIRE	2420	2320	S	0.003	30	15	15	
6	SFSNEG	4006	F	1988		CBDS	M	9	FIRE	2200	2180	W	0.066	297	202	95	
7	SFSNEG	4007	F	1988		CBDS	M	9	FIRE	2185	2180	E	0.009	19	14	5	
8	SFSNEG	4008	F	1988		CBDS	M	9	FIRE	2190	2180	W	0.015	17	7		10
9	SFSNEG	4009	F	1944		DS	M	11	NAT	2330	2210	S	0.225	1360	1360		
10	SFSNEG	4010	F	1944		DS	M	11	NAT	2260	2200	S	0.033	205	205		
11	SFSNEG	4011	F	1944		DS	M	11	NAT	2220	2190	S	0.016	100	100		
12	SFSNEG	4012	F	1980	77-87	DF	M	11	FIRE	2440	2400	W	0.040	167	142	25	
13	SFSNEG	4013	F	1965		BG S DS	M/U	11	NAT	2600	2320	W	3.501	378000	33000	345000	
14	SFSNEG	4014	F	1980	77-87	CBDS	M	9	FIRE	2420	2400	E	0.004	30	30		
15	SFSNEG	4015	F	1980	77-87	CBDS	M	9	FIRE	3380	3360	E	0.019	82	82		
16	SFSNEG	4016	F	1980	77-87	DF	M	9	FIRE	2360	2340	E	0.011	70	21	49	
17	SFSNEG	4017	F	1980		DS	M	8	ROAD	3360	3310	E	0.108	667	267	400	
18	SFSNEG	4018	F	1944		BG	M	3	NAT	2720	2610	E	0.843	7361	0	4785	2576
19	SFSNEG	4019	F	1980	77-87	DS	M	11	FIRE	2400	2380	E	0.036	36	36		
20	SFSNEG	4020	F	1980		CBDS	M	11	FIRE	2250	2220	E	0.025	113	100	11	2
21	SFSNEG	4021	F	1980	77-87	CBDS	M	11	FIRE	2830	2825	S	0.003	7	7		
22	SFSNEG	4022	F	1980		DS	M	11	FIRE	2340	2250	E	0.050	260	247	13	
23	SFSNEG	4023	F	1965		DS	M/U	11	NAT	2230	2100	W	0.184	950	810	140	
24	SFSNEG	4024	F	1965		DS	M	11	NAT	2130	2080	W	0.031	150	142	8	
25	SFSNEG	4025	F	1987		S DS	M	8	FIRE	2480	2440	S	0.085	370	19	222	129
26	SFSNEG	4026	F	1980	77-87	DF	M	11	FIRE	2820	2780	SE	0.293	1931	1216	715	
27	SFSNEG	7001	F	1987		DS	M	11	FIRE	2140	2080	W	0.055	252	50	127	75
28	SFSNEG	7002	F	1987		DS DF	M	2	FIRE	2180	1980	W	0.320	5050	3150	1900	
29	SFSNEG	7003	F	1944		DS DF	M	9	NAT	2050	1930	E	0.232	2500	2400	100	
30	SFSNEG	7004	F	1980		DS DF	M	9	FIRE	1990	1930	E	0.060	500	450	50	
31	SFSNEG	7005	F	1980		DS DF	M	9	FIRE	1970	1940	E	0.029	200	180	20	
32	SFSNEG	7006	F	1980		DS DF	M	9	FIRE	1990	1965	E	0.014	90	85	5	
33	SFSNEG	7007	F	1980		S DS	M	9	FIRE	1935	1930	E	0.033	389	195	194	
34	SFSNEG	7008	F	1980		S BG DS	M	6	FIRE	2420	1930	E	2.608	98111	0	98111	
35	SFSNEG	7009	F	1988		CBDS	M/U	9	FIRE	2130	2125	W	0.015	61	55		6
36	SFSNEG	7010	F	1988	80-88	CBDS	M	11	FIRE	1950	1940	W	0.002	25	20	5	
37	SFSNEG	7011	F	1988	80-88	S EF DS	U	9	FIRE	2220	2100	S	0.128	840	410	430	
38	SFSNEG	7012	F	1988	80-88	DS	U	9	FIRE	1960	1920	E	0.085	185	61	124	
39	SFSNEG	7013	F	1965		DS	M	11	NAT	1460	1440	E	0.082	337	135	202	
40	SFSNEG	7014	F	1965		CBDS	M	11	NAT	1490	1460	E	0.022	133	127	6	

Table E-1-4, continued. Selected data from the Negro Creek Landslide Inventory.

Selected data from the Negro Creek Landslide Inventory
File: Sumneg1.wk1

Row	Water-shed	Inv. No.	Meth-od	Photo Year	Est. Yr. Range	Slide Type	Rock Type	Geomor-phic Terrane Type	Distur-bance Class	Max. Eleva-tion	Min-. Eleva-tion	As-pect	Map Acres	Mobil-ized Volume	Deliv-ered Volume	On-Site Volume	Stored Volume Off-site
41	SFSNEG	7015	F	1965		CBDS	M	11	NAT	1500	1480	E	0.008	116	87	29	
42	SFSNEG	7016	F	1965		DS	M	11	NAT	1620	1580	W	0.143	622	187	435	
43	SFSNEG	7017	F	1980		RS	M	11	FIRE	2160	1560	W	1.722	28444	7111	21333	
44	SFSNEG	7018	F	1980		RS DS	M	11	FIRE	1820	1670	N	0.344	2133	704	1429	
45	SFSNEG	7019	F	1971	65-71	DS RS	M	11	NAT	1740	1695	S	0.094	489	211	278	
46	SFSNEG	7020	F	1980		DS	M	11	ROAD	1470	1430	W	0.074	600	360	240	
47	SFSNEG	7021	F	1980		DF	M	3	ROAD	2950	2720	W	0.510	3936	1508	2261	167
48	SFSNEG	7022	F	1971	65-71	S	G	8	ROAD	2930	2870	W	0.158	606	181	425	
49	SFSNEG	79001	F	1987	82-85	S EF DF	M	3	FIRE	3050	2860	W	1.413	37949	1033	36916	
50	SFSNEG	79002	F	1971		DF	M	8	NAT	2970	2580	N	0.278	935	935		
51	SFSNEG	79003	F	1980		S EF DF	M	9	FIRE	3040	2800	W	0.929	8352	1111	7241	
52	SFSNEG	79004	F	1980		DS	U	9	FIRE	2590	2520	W	0.068	635	605	30	
53	SFSNEG	79005	F	1980	80-87	CBDS	U	9	FIRE	2480	2450	N	0.011	333	323	10	
54	SFSNEG	79006	F	1987	82-85	DS	M	9	FIRE	2450	2360	N	0.166	1890	1320	570	
55	SFSNEG	79007	F	1971		CBDS	M	11	NAT	2300	2260	W	0.026	230	220	10	
56	SFSNEG	79008	F	1987	82-85	DS	U	9	FIRE	2770	2690	N	0.184	1925	1900	25	
57	SFSNEG	79009	F	1987	82-85	DF	U	9	FIRE	2710	2680	S	0.034	167	167		
58	SFSNEG	79010	F	1987	82-85	DS	U	9	FIRE	2860	2780	N	0.103	925	725	200	
59	SFSNEG	79011	F	1987	82-85	DS	U	9	FIRE	2870	2790	N	0.051	300	270	30	
60	SFSNEG	79012	F	1988		CBDS	U	9	FIRE	2900	2880	E	0.018	111	111		
61	SFSNEG	81001	F	1987		CBDS	U	9	FIRE	3250	3240	E	0.007	44	15	29	
62	SFSNEG	81002	F	1988		CBDS	M	11	FIRE	3230	3220	W	0.004	12	12		
63	SFSNEG	81003	F	1988		CBDS	U	9	FIRE	3250	3210	S	0.115	127	97	30	
64	SFSNEG	81004	F	1987		DS	U	11	FIRE	3180	3140	N	0.049	119	89	30	
65	SFSNEG	81005	F	1987		DF	U	11	FIRE	3160	3140	N	0.006	14	8	6	
66	SFSNEG	81006	F	1980		DF	U	9	FIRE	3120	3080	S	0.039	83	56	27	
67	SFSNEG	81007	F	INDET	77-88	DS	U	9	FIRE	3080	3060	S	0.009	24	16	8	
68	SFSNEG	81008	F	INDET	77-88	DS	U	11	FIRE	2940	2900	N	0.056	33	31	2	
69	SFSNEG	81009	F	INDET	77-88	DF	U	11	FIRE	2965	2920	S	0.036	112	78	34	
70	SFSNEG	81010	F	INDET	77-88	DF	U	11	FIRE	2920	2910	S	0.013	78	66	12	
71	SFSNEG	81011	F	1965		S DS	U	11	NAT	2920	2900	S	0.073	200	100	100	
72	SFSNEG	81012	F	INDET	1965	CBDS	U	11	NAT	2900	2880	N	0.010	80	60	20	
73	SFSNEG	81013	F	INDET	77-87	DF	M/U	11	FIRE	2820	2780	S	0.061	417	278	139	
74	SFSNEG	81015	F	1965		S DS	M/U	9	NAT	3760	3630	W	0.646	38300	5800	32500	
75	SFSNEG	81016	F	1988	80-88	DF	M	9	FIRE	3750	3680	W	0.025	139	125	14	
76	SFSNEG	81017	F	1987		DS	M	9	FIRE	3790	3740	W	0.116	500	300	200	
77	SFSNEG	81018	F	1980		DS	M	9	FIRE	3790	3775	S	0.010	22	11	7	4
78	SFSNEG	81019	F	1980		DS	M	9	FIRE	3840	3775	W	0.097	555	358	197	
79	SFSNEG	81020	F	1980		DF	M	11	FIRE	3860	3780	S	0.026	109	82	27	
80	SFSNEG	81021	F	1980		DS	M	11	FIRE	3860	3800	S	0.090	533	285	248	
81	SFSNEG	81022	F	1980		DS	M	9	FIRE	3900	3815	W	0.188	972	778	194	

Table E-1-4, continued. Selected data from the Negro Creek Landslide Inventory.

Selected data from the Negro Creek Landslide Inventory
File: Sumneg1.wk1

Row	Water-shed	Inv. No.	Meth-od	Photo Year	Est. Yr. Range	Slide Type	Rock Type	Geomor-phic Terrane Type	Distur-bance Class	Max. Eleva-tion	Min-. Eleva-tion	As-pect	Map Acres	Mobil-ized Volume	Deliv-ered Volume	On-Site Volume	Stored Volume Off-site
82	SFSNEG	81023	F	1987	80-88	DS	M	11	FIRE	3850	3815	S	0.051	222	200	22	
83	SFSNEG	81024	F	1987	80-88	DS	M	11	FIRE	3820	3800	SE	0.012	56	45	11	
84	SFSNEG	81025	F	1980		S DS	U	11	FIRE	2820	2815	S	0.033	187	56	131	
85	SFSNEG	81026	F	1980		DS	M	9	FIRE	3825	3820	N	0.020	43	43		
86	SFSNEG	81027	F	1980		S EF DS	M	9	FIRE	2880	2870	W	0.052	344	231	113	
87	SFSNEG	81028	F	1986		S	M	8	FIRE	4605	4590	W	0.046	444	311	133	
88	SFSNEG	81029	F	1964	55-64	DS	M	8	ROAD	4620	4590	W	0.220	360	72	288	
89	SFSNEG	81030	F	1971	55-80	S	M	3	ROAD	4620	4575	S	0.092	360	72	288	
90	SFSNEG	81031	F	1980		S	M/G	9	ROAD	4375	4330	W	0.059	2750	275	1650	825
91	SFSNEG	81032	F	1980		DS	G	9	FIRE	4250	4245	W	0.023	90	54	36	
92	SFSNEG	81033	F	1971		S	G	9	NAT	3370	3350	N	0.331	5666	600	5066	
93	SFSNEG	81034	F	INDET	80-87	DS	U	9	FIRE	3400	3390	W	0.009	39	35	4	
94	SFSNEG	81035	F	INDET	80-87	DS	G	9	FIRE	3500	3495	N	0.004	18	14	4	
95	SFSNEG	81036	F	1988		DS	U	9	FIRE	3880	3870	W	0.021	44	13	31	
96	SFSNEG	81038	F	1982		DF	M	3	FIRE	4410	4280	W	0.230	1620	50	1570	
97	SFSNEG	81039	F	1987		DF	M/G	9	FIRE	3455	3420	S	0.022	210	10	100	100
98	SFSNEG	81040	F	1980	77-87	DS	M	9	FIRE	3250	3240	W	0.008	23	20	3	
99	SFSNEG	81041	F	1980	77-87	DS	M	9	FIRE	3270	3260	W	0.015	50	15	35	
100	SFSNEG	81042	F	1980	77-87	DS	M/G	9	FIRE	3300	2280	W	0.006	17	17		
101	SFSNEG	81043	F	1971		DS	M	11	NAT	2360	2250	W	0.165	1065	1045	20	
102	SFSNEG	81044	F	1971		DS	M	9	NAT	2280	2240	N	0.020	90	90		
103	SFSNEG	81045	F	1944		DS	M	11	NAT	2350	2320	W	0.034	300	300		
104	SFSNEG	81046	F	1965		S	M	8	ROAD	4650	4630	W	0.042	250	187	63	
105	SFSNEG	81047	F	1980		BG DF	M	8	ROAD	4250	4160	N	0.321	1700	150	1400	150
106	SFSNEG	81048	F	1987		S DF	M	9	FIRE	4200	4160	W	0.041	222	0	222	
107	SFSNEG	81049	F	1965		S	M/U	8	ROAD	4410	4400	W	0.034	295	0	220	75
108	SFSNEG	81050	F	1982		S DF	M/U	9	ROAD	4240	4180	W	0.080	1430	0	1000	430
109	SFSNEG	81051	F	1975		S	U	9	ROAD	4250	4230	S	0.026	133	0	93	40
110	SFSNEG	81052	F	1975		DS	M	9	ROAD	4050	4020	W	0.013	60	15	45	
111	SFSNEG	81053	F	1980		DF	M	9	FIRE	3720	3700	W	0.010	19	19		
112	SFSNEG	81054	F	1980	77-87	DS	M	9	FIRE	3700	3690	W	0.017	74	44	30	
113	SFSNEG	81055	F	1980	77-87	S DS	M	9	FIRE	3700	3680	W	0.069	1200	375	825	
114	SFSNEG	81056	F	1980	77-87	S	M	9	FIRE	3590	3570	W	0.115	1100	440	660	
115	SFSNEG	81057	F	1980		EF	U	3	FIRE	3500	3460	S	0.075	800	8	792	
116	SFSNEG	81058	F	1980	77-87	S	M/U	3	ROAD	3590	3575	S	0.021	330	15	315	
117	SFSNEG	81059	F	1980		S	U	9	FIRE	3400	3350	W	0.115	2200	50	2150	
118	SFSNEG	81060	F	1980		S	U	9	FIRE	3620	3535	W	0.689	22000	50	21950	
119	SFSNEG	81061	F	1980		S	M/U	3	FIRE	2880	2845	S	0.110	760	152	532	76
											TOTAL		21.099	689566	78145	604971	6400

Table E-1-3 and E-1-4 Notes.

Method

F = Field measured
A = Air photo interpreted
FA = Partially field measured (or observed) and air photo interpreted.

Slide Type

DS = Debris slide
CBDS = Channel bank debris slide
CS = complex slide
DF = Debris flow
BG = Block glide
S = Slump
EF = Earthflow

Bedrock Type

G = Granitic
M = Non-granitic (metamorphic)
U = Ultramafic

Geomorphic Terrane Types

2 Slump/Earthflow Toe Zones
3 Slump/Earthflow Deposits
4 Granitic Mountain Slopes >65%
5 Granitic Mountain Slopes <65%
6 Non-Granitic Mountain Slopes >65%
8 Non-Granitic Mountain Slopes <65%
9 Inner Gorge in Landslide, Terrace or Glacial Deposits
10 Inner Gorge in Granitic Bedrock & Mt. Slopes
11 Inner Gorge in Non-Granitic Bedrock & Mt. Slopes
12 Debris Basins [Headwalls]
13 Glacial, Terrace & Fan Deposits

Disturbance CLasses

NAT = Undisturbed
R = Road-related
HAR = Harvest-related
T = Trail-related
Fire = Fire-related

Maximum and Minimum Elevation Zones: units are in feet
Mobilized, Delivered, Remaining (on site), and Stored (offsite) Volume: units are in acres.