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THE FLOOD OF 1997 KLAMATH NATIONAL FOREST

PHASE I FINAL REPORT: NOVEMBER 24, 1998

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Photo #97-27-6A: Walker Creek road crossing taken out by debris flow. View from the head of a small slump activated by stream undercutting. Road formerly passed along the base of the slump. (J.d.l.F: 4-25-97).

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ABSTRACT

The Klamath National Forest is situated predominantly in the central Klamath Mountains, and entirely within the Klamath River basin of northern California (Map 1). The storm of 12-26-96 through 1-3-97 delivered up to 17 inches of precipitation to parts of the Klamath National Forest. At the onset of the storm, the snowpack was slightly above average and extended down to about 3,500 feet in elevation. The warm storm produced rain up to 7,200 feet in elevation, which is near the crests of the main mountain ranges. One station recorded over 5 inches in the last 18 hours of December 31. Total precipitation for December ranged from 1.7 to 4.2 times the norm for that month. Estimates of recurrence intervals for 1997 peak stream flows range from 14 to 37 years, and peak flows ranged from 51-84% of those measured for the 1964 flood (largest on record). Heavy precipitation came to an abrupt halt after January, and no large storms followed that spring.

Landslides, debris flows, and channel alterations, were concentrated in a SW-NE trending band across the Forest, which was about 20 miles wide by 40 miles long (Map 2), and most concentrations were above 4,000 feet in elevation (Map 8). It is not known if this pattern extends beyond the boundaries of the Forest due to lack of comparable information in adjoining areas. To date, infrastructure damage exceeds $27 million on Forest Service roads and facilities. This does not include damage to State Highways such as Hwy 96 and Highway 3. Effects on the Klamath National Forest were greatest in the Walker, Grider, Elk, Tompkins, Kelsey, Deep, and Ukonom Creek watersheds. Physical attributes of the landscape (bedrock, geomorphology, topography) and pre-flood disturbances to vegetation and soil (roads, timber harvest, wildfire) appear to have had a considerable effect on the distribution and effects of landslides and debris flows. Air photo inventory identified about 712 landslides and 446 miles of flood-altered channel. Landslide density (landslides per square mile) averaged 0.59 across the landscape. In road corridors, the density was 7.34, in timber harvest areas, it was 1.86. Old harvest (pre-1977) had a density of 0.80, and new harvest 2.96. In burned areas, (high or moderate intensity) it was 2.03, and in undisturbed areas, it was 0.26. High landslide concentrations occurred in the Rattlesnake Creek Terrane (0.84), and on landslide deposits (0.80), as well as at elevations from 5,000-5,500 feet (1.46). Debris flows were typically initiated by landslides at elevations in excess of 4,000 feet. These flows scoured upper channel reaches, removed riparian vegetation, and deposited sediment and large logs in lower reaches. Large debris flows developed on toe zones of dormant landslides. Colluvium filled hollows in granitic areas also produced many debris slides and debris flows.

Over 927 damage sites (mostly roads) qualified for Emergency Relief Federally Owned (ERFO) funding, and 712 were approved for funding as of March, 1998. About 60% of the ERFO sites occurred adjacent to streams. Road fills on steep hillslopes were important sources of sediment and points of origin for debris flows. Road cuts on toe zones of older landslide deposits initiated debris slides, and fills placed on the heads of dormant slumps caused some to reactivate. Cumulative effects occurred where multiple roads crossed hillslopes, and interacted hydrologically. Many debris flows originated on deforested areas, particularly on landslide deposits and on dissected granitic lands.

I. BACKGROUND

Assessment of the 1997 flood is being conducted in two parts, Phase I and Phase II.

Phase I Flood Assessment

Phase I is a reconnaissance level assessment commissioned by the Klamath National Forest Supervisor's Office. It is based on air photo interpretation (post-flood photos), data from damaged road sites collected by Forest Service Engineers, as well as field sampling. Phase I was completed in March of 1998, and final results are presented here. **Phase I objectives were to:**

1. Characterize the storm-related precipitation and stream flows of the 1997 flood.
2. Characterize the effects of the flood and where they occurred..
3. Identify the natural patterns of flood effects and influence of physical factors.
4. Identify possible influences of land management on flood effects.
5. Identify post-flood opportunities, and offer recommendations.
6. Evaluate the effectiveness of past mitigation measures addressing erosion and sedimentation.
7. Determine sedimentation rates and compare these to rates predicted by the Klamath Forest Land Management Plan.

Findings for each objective are summarized in the Executive Summary (Appendix E). Oral presentations of Phase I findings have been made previously at meetings of the Klamath National Forest leadership team (10-23-97 and 11-18-98), the Klamath Province Advisory Committee (10-30-97), and the Scott River Coordinated Resource Management Plan (CRMP) on 2-17-98. The Phase I Final Report of 11-24-98 replaces the **Draft Flood Assessment of April 25, 1997.**

Phase II Flood Assessment

Phase II is a detailed field level assessment which was commissioned and funded by the Regional Office of the Forest Service (Pacific Southwest Region), and is currently underway. It is being conducted jointly by the Klamath National Forest, and the Pacific Southwest Range and Experiment Station (Redwood Sciences Laboratory). Phase II carries on where Phase I left off, and involves detailed field investigations regarding the effects of roads and de-vegetation on landsliding, and the ways in which landslides affected stream channels. It will also quantify natural and management-related sediment in sample watersheds and examine the effects of the flood on stream channel conditions and fish assemblages. Some Phase II funding was used in completing the Phase I final report. A status report for Phase II will be completed in November, 1998, and the final report in 1999.

II. CHARACTER OF THE 1997 FLOOD

A summary description of precipitation and streamflow associated with the 1997 flood follows. For more detailed information, refer to Appendix F.

A. PRECIPITATION

The event which caused the flood was a warm tropical storm which occurred from December 26, 1996 through January 3, 1997, and traversed the forest in a northeasterly direction. This storm caused flooding from Idaho and Oregon to the Sierra Nevada Mountains (California Water Resources, 1997). Prior to the beginning of this storm, precipitation was above the norm for most recording stations on the forest. November precipitation ranged from 0.9 to 1.7 times the norm, while that for the water year from October 1, 1996 through January 3, 1997 was 1.5 to 2.2 times the norm. December precipitation was about double the norm for the month of December, ranging from 1.7 to 4.2 times the norm (Table 1). Most of the early December precipitation accumulated during a storm which occurred from December 5-10. Another cold storm brought snow below 2,000 feet from December 21-23, and set the stage for the New Years storm and flood. From December 26 to January 3, a series of warm storms traversed the Pacific northwest in an E-NE direction, and brought rain above 7,000 feet in elevation on the Klamath National Forest, and above 10,000 feet in the Sierra Nevada Mountains. Beginning December 30, rainfall intensified on the Klamath Forest. Snow pillow gages recorded intensities of 0.38-0.42 inches per hour at four stations over the last six hours of 1996, producing 6-hour totals of over 2 inches. During the last 18 hours of December 31, totals of four to more than five inches were recorded at stations in Big Flat, Mumbo Basin, Scott Mountain, and Highland Lake (Appendix E Figure 2C). This intensity and duration of precipitation exceeds that identified in several studies as necessary for the initiation of debris slides (Cannon, 1985). The shallow debris slides which occurred in Deep Creek and in the granitic portion of Elk Creek were of this type. Intense precipitation came to an abrupt halt on January 3, and no significant storms occurred during the spring of 1997. Had more storms occurred that spring, it is likely that more large slumps, activated by the flood, would have failed catastrophically.

Map 4 displays precipitation at forest stations, providing totals for the period 12-26-97 through 1-3-97, and the percent over the December norm. The entire west side of the forest seems to have received similar precipitation totals relative to the norm for December. Areas of exceptionally high precipitation are not apparent in the data. Higher precipitation was recorded immediately SE of the Klamath Forest, and in the Sierra Nevada Mountains (California Water Resources 1997). Anecdotal accounts by Forest personnel suggest that storm intensity varied considerably, even between adjacent drainages. This is based on observed differences in erosion of road ditches and cut slopes in adjacent watersheds. In addition, the concentration of damage in localized areas (Map 4) also suggests that the storm developed zones of higher intensity. Due to the dispersed nature of the

Figure 1: **Monthly & Event Precipitation Amounts from Forest Stations [inches]**

Station	Storm 12/26 - 1/3	December total	% norm Dec.	Water yr 10/1-1/3	Norm water yr to 1/3	% norm water yr to 1/3
Oak Knoll	8.65	12.50	262%	26.69	14.57	183%
Horse Creek	12.78	23.04				
Seiad Valley	17.12	31.51	344%			
Happy Camp	10.72	28.56	276%	51.92	31.86	163%
Slater Butte	12.26	23.72		42.53		
Somes Bar	13.93	23.64	225%	51.13	34.69	147%
Orleans		26.17	257%			
Sawyers Bar	10.17	22.54	281%	43.54	25.20	173%
Fort Jones	7.24	11.46	275%	22.25	12.44	181%
French Creek	9.72	15.45	422%			
Callahan		9.05	247%			
Goosenest	2.54	3.31	190%	8.72	5.76	151%
Yreka	7.80	9.67	276%	22.15	9.93	223%
Hornbrook	5.77	8.92	171%	19.79	13.18	150%
Weed	9.44	15.57	210%	33.08	19.42	170%

Blanks in the table indicate that no data are available

Figure 1: Precipitation Data

stations, and the fact that most are situated at low elevation along the main rivers, it is possible that local orographic cells did develop in some watersheds, but were not detected by the recording stations. Only five high elevation stations functioned during the storm, and are maintained by the

State of California on the divide between the Klamath and Trinity watersheds near Scott Mountain by Highway 3.

Doppler radar data were not available for this assessment, and such information might reveal the presence of high intensity cells.

B. THE SNOW PACK AND ITS CONTRIBUTION TO RUNOFF

Estimates of the contribution of snowmelt to total runoff can be made in two parts of the forest. The first is based on anecdotal accounts in the Scott River watershed of how much the snowpack receded as a result of the warm rain, and the second is from State of California snow pillow recording stations in the upper Trinity River basin and along the Salmon/Trinity and Scott/Trinity divides.

Anecdotal Accounts

Accounts by US Forest Service personnel indicate that the snowpack in mid-December extended down to about 3500 feet on north slopes, and 4000 feet on south slopes. Map 1 is a simulation of the pre-flood snow pack, generated from the USGS 30 meter digital elevation model. It is not based actual remote sensing imagery. Immediately after the storm, aerial reconnaissance revealed that the snowpack was gone on lightly vegetated south slopes up to about 5500 feet (Deep Creek area), and 4500 feet on north slopes (South Fork Scott River). This change in snowpack provides an indication of the amount of snow melt which contributed to flood flows in the areas described above. If it is assumed that snow averaged a foot in depth where it was removed by the warm storm, and snow water content was about 12% (average for new snow), this would equate to about 1.4 inches of additional water available for runoff during the height of the storm (December 31 to January 2). Since the total precipitation during those days ranged from 4-9 inches of rain, the snow melt added something like 16%-35% to the storm totals for these areas.

Observations of snow depth at the Mt. Ashland Ski Area along the northern boundary of the forest reveal an interesting pattern. Changes in recorded depths at two stations (one at 6500 feet, the other at 7050 feet) were consistent during the period from December 23 to January 4. Between December 25 & 26 snow depth declined by 10 inches, then grew by daily increases of 2 to 4 inches (for a four day total of 12 inches) until December 30. From December 31 to January 2, snow depth decreased at the lower elevation site (at 6500 feet) by 10 inches and by 6 inches at the higher elevation site (at 7050 feet). January 3, 10 inches of new snow accumulation was recorded. At 12% snow water content, snow melts of 10 inches would yield 1.2 inches of runoff. With three-day rain estimates of 7 inches to more than 8 inches, snow melt would have added 15%-20% to storm totals. These data are consistent with the anecdotal observations discussed above and the snow pillow data discussed below.

Snow Pillow Recording Stations

Actual measurements of the snow pack prior to and during the storm are limited to the California Department of Water Resources operated remote snow sensors ("snow pillows"). Snow pillows recorded the steady build up of the mountain snowpack, from almost none on Dec 1 to amounts ranging from 7.4" SWC at lower elevations (Big Flat, at 5,100 feet) to 14.6 inches & 15.6 inches SWC at higher elevations (Bonanza King and Peterson Flat, 6,450 feet & 7,150 feet). [SWC = snow water content; at density of 33% (typical for "settled" snow) implies snow depths of ~ 2 feet to 4 feet or deeper, with densities <33%]. Snow pillow sites are located in the upper Trinity River basin, north of Trinity Lake. There are stations along the Trinity-Scott divide, including ones at Scott Mtn (near Hwy 3), Middle Boulder Lake, Peterson Flat, Big Flat (near the FS campground on the upper South Fork of the Salmon River). Snowpack depths recorded around Dec 25 are moderately above normal for this time of the year.

Data from these snow pillows indicate that loss of water from the snowpack during the storm (12-26-96 through 1-3-97) varied by site and elevation. Losses in SWC ranged from 7.4 inches at Big Flat, approximately 2 inches at Highland Lakes and Middle Boulder 3, to less than an inch at Peterson Flat and Red Rock Mountain. The loss of 7.4 inches SWC at Big Flat during an 8 hour period was probably due to snow removal by physical means (such as avalanche or flowing water), rather than snow melt (Dave Hart, Ca. Dept. Water Resources, personal communication , 1997). Thus, snow melt may have contributed an additional 1-3 inches water (or more) to the storm runoff at elevations below 6,000 to 6,500 feet. Since an average of ~10 inches of precipitation was recorded from December 30 through January 1 at these snow pillow stations, snow melt may have contributed an additional 20-30% (or more) to 3-day totals in the vicinity of the stations.

Remote Sensing Data

Detailed pre and post flood satellite imagery was not available for this study to further refine estimates of snowmelt contribution to runoff.

C. PEAK STREAM FLOWS

Peak flows in rivers and streams on the Forest ranged from second to fifth highest on record (see chart below). This compares to record flows in some rivers of the Sierra Nevada Mountains, and possibly on Sacramento River tributaries. Estimated recurrence intervals for these peaks ranged from 16 years at Indian Creek (near Happy Camp), to 37 years at Salmon River. The recurrence interval for the 1997 Flood was 14 years on Scott River, 32 years on the Shasta River, 15 years on the Klamath River at Seiad, and 18 years on the Klamath River at Orleans. These intervals were computed by the Federal Emergency Management Act (FEMA) method: Recurrence interval T= (period of record + 1)/ranking. In the case of the Salmon River, the computation is: (73+1)/2 = 37. The graph below summarizes 1997 data, and also displays peaks for the 1964 and 1974 floods. Map

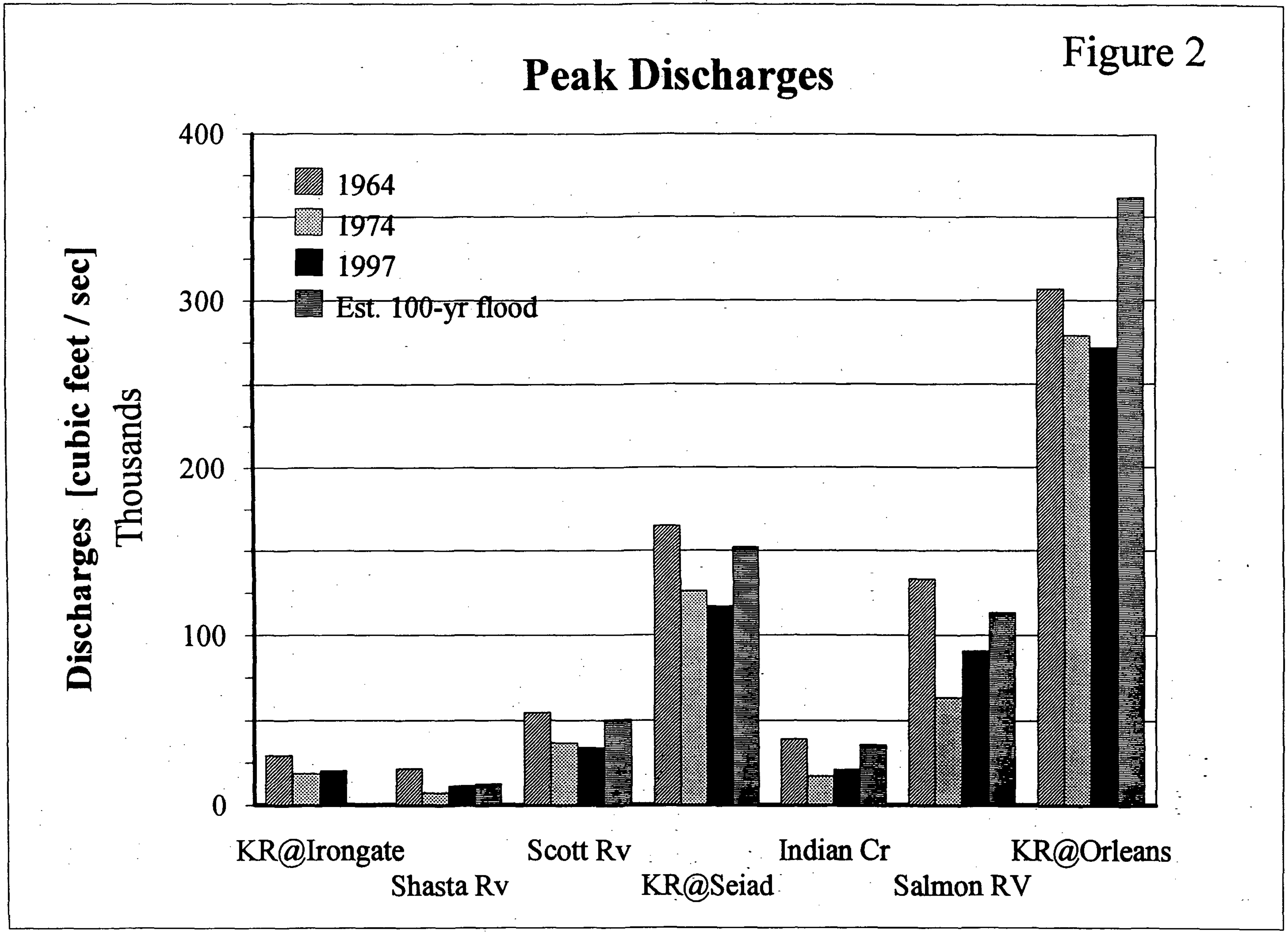


Figure 2
Peak Discharges
Discharges [cubic feet / sec]
Thousands
400
300
200
100
0
1964
1974
1997
Est. 100-yr flood
KR@Irongate
Shasta Rv
Scott Rv
KR@Seiad
Indian Cr
Salmon RV
KR@Orleans

Station Name:	Klam. River	Shasta River	Scott River	Klam. River	Indian Creek	Salmon River	Klam. River	Trinity River
Location:	below Irongate	near Yreka	below Ft Jones	at Seiad Valley	Happy Camp	Somes Bar	at Orleans	above Coffee
1997 FLOOD:								
Event Peak Flow cfs	20,500	11,400	34,000	117,000	21,200	91,000	272,000	20,400
Date	Jan 1	Jan 1	Jan 1	Jan 1	Jan 1	Jan 1	Jan 1	Jan 1
Time	7:00 PM	6:30 PM	5:50 PM	10:30 PM	8:45 PM	-------	4:45 PM	10:30 PM
Ranking of 97 Flow	2	2	4	4	3	2	4	3
1997 Recurrence Int	19.5	31.5	14.4	15.3	15.7	37.0	17.8	21.0
1997 as % of 1964	70%	53%	62%	71%	54%	68%	89%	77%
OTHER FLOODS:								
Max Q 1964 cfs	29,400	21,500	54,600	165,000	39,000	133,000	307,000	20,800
Max Q 1974 cfs	18,700	7,260	36,700	126,000	17,200	63,500	279,000	26,500

Figure 3: Peak Streamflow Data

5 shows the location of stations. Release rates from Irongate and Copco Reservoirs on the Klamath River may have influenced timing of peaks, but this factor was not assessed.

The variations in peak flows in some watersheds may have been influenced by the amount of the landscape which was logged, burned, or roaded. In Walker Creek, where flood effects were severe, about 3% of the watershed was occupied by roads (assuming a road corridor width of 50 feet), 6% harvested and burned, 22% harvested only, 2% burned only. Thus, about 33% of the watershed was in a disturbed condition. and 67% undisturbed (Map 17).

D. GEOGRAPHIC DISTRIBUTION AND CHARACTER OF 1997 FLOOD EFFECTS

Pacific Northwest

Heavy precipitation associated with the flood occurred throughout an area from the Sierra Nevada to Oregon and Idaho (California Department of Water Resources,1997). In California, the flood was most severe in the Sierra Nevada mountains, where record flows were measured on the Consumnes, South Fork American, and Napa Rivers (Lott and others, 1997). This compares to a maximum 37 year recurrence interval on the Klamath National Forest (Salmon River). In southern Oregon, a November storm in 1997 produced higher peak flows (recurrence interval of 50 years) than the December storm (recurrence interval of 25-50 years). The November storm produced only localized effects in northern California. The December storm caused more damage on the Klamath Forest than on adjacent forests (Harris and others, 1997). Figure 4 provides a summary of effects on forests in Southern Oregon and Northern California. It addresses: (1) Estimated recurrence interval; (2) The elevation at which most damage occurred; (3) Whether damage was linked to roads, harvested areas, or burned areas; (4) The number of landslides inventoried. ERFO sites are flood damaged sites qualifying for emergency federal funding (Emergency Relief, Federally Owned). Additional information on the effects of the 1997 flood on the National Forests listed above is contained in Appendix D.

Klamath National Forest

The majority of the damage to facilities and alteration of stream channels on the Klamath National Forest occurred in a band extending from Mt. Ashland in the NE part of the forest (about 20 miles NW of Hornbrook, CA) to Somes Bar in the southwest (Map 4). Flood effects were greatest in their headwaters of Walker, Deep, Ukonom, Tompkins, Grider, Kelsey, Middle, Portuguese, and Elk Creeks. These all experienced many landslides in headwaters, and debris flows in many of the tributary channels. Similar, but less severe effects occurred in the headwaters of Beaver, Thompson, and Indian Creeks. Immediately north of Beaver Creek, severe flood effects continued into the Ashland Watershed (Hicks, 1997). To the north of Portuguese and Thompson Creeks, damage visible on air photos continued into the Rogue National Forest. About 40 miles to the southeast of the main flood damaged area on the Forest, the Upper South Fork of the Salmon River also exhibited severe flood effects (Map 4). Considerable channel alteration occurred on the South Fork from Rush Creek to the East Fork of the Salmon River, where river bars were greatly modified, and deep pools filled with gravels. Small debris flows occurred in first order tributary channels above Big Flat Campground, and older debris slide scars along the inner gorge downstream from big flat appeared to have experienced local reactivations. This pattern of damage continued to the east across a broad area of the South Fork Trinity River adjacent to Highway 3. Two small landslide are known to have occurred in harvest units near Highway 3 on the South Fork of the Scott River.

FOREST	Sites	Cost	Storm	Eleva -tion	Road Effects	Harvest Effects	Fire Effects	Slides
	No.	mill $	recur	thou ft				No.
Region 5:								
El Dorado	80	2.8	100 +	6-7	Yes	?	Yes	300
Klamath	712	26.7	15-37	4-6	Yes	Yes	Yes	1100 +
LTBU	37	0.8	?	?	?	?	?	?
Mendocino	52	1.6	?	5-5.5	No	No	No	?
Modoc	0	0.5	20-50	4 +	Yes	No	No	?
Plumas	372	9.0	15-100	3-7	Yes	?	?	?
Sequoia	15	0.3	?	?	?	?	?	?
Shasta-T	194	4.9	25-100	4 +	Yes	Yes	No	?
Sierra	59	3.0	?	?	?	?	?	?
Six Rv.	66	1.0	15-25	2-4	No	Yes	No	?
Stanislaus	189	3.7	?	?	?	?	?	?
Tahoe	116	2.6	?	?	?	?	?	?
Region 5 Total	1916	56.3						
Region 6:								
Rogue	270	6.0	30-50	2-5.5	Yes	Yes	No	?
Siskiyou	?	?	25-50	4 +	Yes	?	?	?
Umpqua	110	6.3	25	1-3.5	Yes	Yes	No	?

Figure 4 Flood Effects in California and Oregon
(Number of sites and cost for California from Richard Harris, pers. comm. 3-5-98)

III. METHODS

A description of the methods used and steps taken in this assessment follow.

A. PRECIPITATION AND STREAM FLOW DATA

Precipitation data were obtained from Interagency Command Center (Yreka), U.S. Forest Service (District rain gauges & RAWS [Remote Automatic Weather Station]) and California Department of Water Resources (snow pillows), as well as private stations. Stream flow data were obtained from the U.S.G.S. WEB site (http://h2o.usgs.gov) and Mike Friebel (USGS Redding, personal communication, 12/5/97). Information on snow water content (as well precipitation and air temperature) is from California Department of Water Resources (snow pillow) recording stations (http://cdec.water.ca.gov and Dave Hart, personal communication, 1997). Other snowpack information is anecdotal accounts from various individuals.

B. ERFO ROAD DAMAGE SITE REPORTS

ERFO sites are damaged areas which qualify for Emergency Relief Federally Owned (ERFO) funding. A total of 927 ERFO sites have been identified by engineering personnel. As of March, 1998, 712 of these were approved for funding (Richard Harris, personal communication, 1998). Information on these sites has been collected on Damage Site Reports (DSR's), and entered into a spreadsheet and GIS layer. To qualify, a site must exceed $2,000 in damage. Inventory of ERFO sites was initiated immediately after the flood and continued through the fall of 1997. With the exception of a few spurs, the entire west side of the Forest has been inventoried.

For purposes of this assessment, a sample of 277 Damage Site Reports (DSR's) for ERFO sites were examined and stratified into 7 classes. They were selected randomly from DSR's which had been completed, but are concentrated on two Districts, Happy Camp and Scott River. The classes were: 1. Road Failures at **Stream crossings**; 2. **Landslides** away from streams; 3. Road **fill failures** away from streams; 4. **Stream undercuts** of road prisms away from stream crossings; 5. Failures of **road cuts**; 6. **Surface erosion and gullies**; 7. **Flooding**. These strata were designed to place ERFO sites into categories sharing common slope processes, which would lead to similar mitigation needs. A second sample of 297 sites was stratified later, but the two have not yet been combined. Phase II of this flood assessment will stratify the remainder of the sites (in progress).

C. INVENTORY OF LANDSLIDES AND ALTERED CHANNELS ON AIR PHOTOS

Color infrared air photos at a scale of 1:40,000 (#715050 USDA F 40) were taken on May 7, 1997. These photos were examined, and landslides (mapped as polygons) as well as altered channels (mapped as lines) were mapped on 1:24,000 topographic maps, digitized, and unique numbers assigned. The smallest landslides mapped were about 21 feet in maximum width, 45 feet long and 1 foot deep (about 35 cubic yards). Timber cover can easily obscure landslides this small, but in de-vegetated watersheds such as the headwaters of Walker and Tompkins Creeks, landslides this size are clearly visible. In order to identify landslides which may have occurred prior to 1997, air photos from 1995 (1:16,000 color, ID # 616050) were examined and landslides present before the flood identified. Many debris flows traveled through channels not classified as perennial or intermittent streams on USGS 7 ½ minute quadrangles. These channels were digitized and added to the altered channel layer. However, the altered portions of the major rivers (Klamath, Scott, part of Salmon) were inadvertently left out during digitizing, and thus were not available for use in Phase I. This involves roughly 90 miles of channel. Phase II of the flood assessment will update the landslide and altered channel inventories, correcting the problems described above. It will also look in detail at sample watersheds to assess the number of landslides likely missed by the air photo inventory. The area covered by post-flood air photos was about 771,000 acres (Map 2). This sample area was selected due to the concentration of effects there, and insufficient funds to fly the entire forest at this scale. Altered channels and landslides which were identified outside the air photo area (Map 2) were derived from local field investigations and consultation with Forest Service District personnel. The Phase II flood assessment will refine this number. Criteria used in photo mapping, limitations of the data, and overlap between landslides mapped on air photos and those recorded in ERFO inventories are addressed in Appendix A, Data Collection and Inventory.

D. FIELD OBSERVATIONS & CONSULTATION WITH FIELD PERSONNEL

All major watersheds with known effects were visited in the field by the authors, with the exception of upper Kidder and upper Beaver Creeks. A sample of active landslides were mapped in detail, and the extent of large slumps and earthflows better defined. Descriptions of some of the large landslides are contained in Appendix II. In addition to the stratification process, about 300 of the ERFO sites were inspected in the field, and other ERFO sites were discussed with Forest Earth Scientists and Engineers. Field inspection of ERFO sites usually allowed definitive assessments on cause/effect for those specific sites. Maps 9-12 and 17 display ERFO sites and roads across the Forest.

E. ANALYSIS OF FLOOD EFFECTS IN A GIS SYSTEM

Klamath National Forest GIS resource data layers were used in this assessment. They included: (1) **Bedrock** layer; (2) Geo-13 **Geomorphic** layer; (3) **Vegetation** layer (used to identify regeneration harvest; other types of harvest were considered un-logged); (4) **Fire intensity** layer identified **high, moderate, and low intensity** (see section F "Terminology" below); (5) **Road** layer; (6) **Stream** Layer (USGS perennial and intermittent streams from 7 ½ minute quadrangles); (7) Slope, aspect, and elevation were generated from the USGS 30 meter resolution digital elevation model **(DEM)**. New data layers were developed for: (1) **1997 landslides**; (2) **Flood altered channels**, and; (3) **ERFO sites**. These new layers were overlain with the Forest resource data layers (bedrock, geomorphology, roads, harvest, fire, and topography). Comma delimited data records were generated for manipulation in a Lotus spreadsheet and Paradox data base. The process used in analyzing the distribution of landslides relative to other factors was similar to that of Larsen (1996, and 1997). Refer to Appendix A for further information.

F. TERMINOLOGY

The landslide and flow terminology used here is modified from Pierson and Costa (1987), Bates and Jackson (1987), and Cruden and Varnes (1996). **Slumps** and **earthflows** are generally large (0.1-20.0 acres) deep-seated, slow-moving landslides which move along discrete failure planes and move as relatively coherent masses. **Debris slides** are small (0.01-2.00) acres, shallow, rapidly moving landslides which typically disaggregate as they move downslope. Most landslides observed in the field are actually complexes, and experienced a combination of slump, earthflow, and debris slide processes. **Colluvium** is the accumulation of soil and rock debris above bedrock which is typically involved in debris slides. **Debris flows** consist of sediment/water slurries which usually travel through channels, but may also traverse hillslopes away from channels. These flows may be generated by debris slides, slumps, earthflows, or by mobilization of channel bed and bank material during peak flows. **Surface erosion** and **gullying** consist of the mobilization and transport of the upper soil, mantle by raindrop impact, sheet wash, rilling, and gullying processes. The terms, **cumulative and cascading effects** are used here to describe the accumulation of multiple individual effects over time and space, in particular things such as hydrologic interaction between road segments on a hillslope. In this assessment, harvested areas are put into two simple classes, logged, and unlogged. The logged areas are where **timber harvest** involved regeneration prescriptions (**clearcut, shelterwood, overstory removal**) whereby all or most of the timber is removed. Shelterwood harvest may leave 5-15 trees per acre. Other prescriptions such as thinning and sanitation are treated as un-logged. **Wildfire intensity classes** high, medium and low are used in this assessment. Information on intensity is from the Forest Fire Intensity Layer which is derived from photo-interpretation of post-fire air photos. This layer was developed to identify where vegetation had been killed by the fires. Areas classified as **high intensity** are those where fire killed all above-ground vegetation (some species re-sprout from the roots after being burned) and also involved a fire through the crowns of vegetation. **Moderate intensity** areas are those where fire killed most or all the above ground vegetation, but the crowns remained unburned, and trees typically retained leaves or needles. Areas burned at **low intensity** are where fire killed only a small proportion of the vegetation. **ERFO sites** are places (mostly on roads) where flood damage qualifies for Emergency Relief Federally Owned Funding. **Flood processes** include all of the processes which interacted to produce the effects visible across the landscape following the flood, such as channel diversions, channel scour, debris slides, debris flows, slumps, etc. See APPENDIX B (Slope and Channel Processes) for more information.

IV. FINDINGS

A. EFFECTS OF THE FLOOD

1. SLOPE AND CHANNEL PROCESSES AND FEATURES

The flood of 1997 involved the movement of soil, rock, and organic debris from hillslopes to stream channels at a scale not experienced since 1974 (the most recent landslide episode) on the Klamath National Forest. Approximately **1100 landslides** were identified in Phase I. This included 712 landslides identified by air photo inventory, 25 by field investigation, and an additional 360 by ERFO site investigations (when 796 ERFO sites had been identified). The number of landslides will probably rise to about 1200 when all the ERFO sites are evaluated. A check of 1995 air photos revealed that of the 712 landslides identified on air photos, 6% predated the flood, 17% were present in 1995 and enlarged in 1997, 5% were not verified (either 1995 photos were unavailable, or the feature could not be seen on the 1995 photos), and 72% were entirely new 1997 landslides.

Air photo inventory identified about **446 miles of stream channels** which were altered (scour, deposition, or removal of riparian vegetation) by the flood. There are a total or 2660 miles of perennial or intermittent streams ~~within the~~ air photo area (on USGS 7 ½ minute quadrangles). Of these, 326 were identified as altered (12%). An additional 120 miles of channel (not shown on the USGS 7 ½ minute quadrangles as streams) were identified as altered. If these are included, the percentage of altered streams is raised to 16% ((326 + 120) / (2660 + 120) = 16%). However, these figures do not include the main stems of the Klamath Scott and lower Salmon Rivers which meet the criteria for altered channels but were inadvertently not digitized. These would add roughly 90 more miles to the total length of altered streams, raising the percentage to 19% ((446 + 90) / (2660 + 120) = 19%)).

Field observations revealed that **landsliding** was the dominant hillslope process associated with the flood. However, evidence of surface erosion was observed locally, primarily on poorly vegetated sites and on road cuts and fills. **Scour and deposition** are evident in many ephemeral channels which lacked these features prior to the flood. Large (about 20 acres) slumps and earthflows occurred in the Walker, Tompkins, Kelsey, and Thompson Creek watersheds. Some exhibited head scarps from 25-100 feet in height. They developed on older landslide deposits, pattern similar to that described previously by Nielsen (1975) in the San Francisco Bay area. **Debris slides** up to 2.0 acres in size occurred in Walker, Deep, Tompkins, Kelsey, Grider (primarily Rancheria fork), Elk, Ukonom and Thompson Creek watersheds. The largest of these originated on the toe zones of reactivated slumps and earthflows high in the watersheds. One on Road 46N61 in Walker Creek (Photos 4a & 4b) mobilized more than 300,000 cubic yards of material. Some were able to traverse long flat benches before reaching channels. Field observations of a debris flow in progress at Whitney Creek on the north flank of Mt. Shasta Volcano during the summer of 1997 demonstrated how efficient debris flows are at transporting debris across low gradient reaches in the absence of obstructions such as large trees or logs (de la Fuente, Elder, and Haessig, 1998). The observed association of large debris flows with the reactivated older slumps and earthflows during the 1997 flood contrasts with a recent report on the effects of 1997 floods in the San Francisco Bay area (Cannon and Others, 1998). This report describes most of the landslides as shallow debris slides. Similarly, recent mapping of 1997-1998 landslides in the Bay Area (Alameda County) indicates that 70-90% were shallow debris slides or soil slips (Jeff Coe, U.S. Geological Survey Denver, personal communication, 1998).

With the exception of Deep and Walker Creeks, most streams retained the majority of their 30 year old (post-1964 flood) alder stands growing within and adjacent to channels. These stands served to trap sediment and large logs. Streams such as Grider, Walker, Kelsey, Deep, Middle, Tompkins, and Ukonom Creeks delivered large volumes of sediment to the Klamath River, where remnants are still visible for a considerable distance downstream of their mouths. The final disposition and effects of this sediment on the Klamath river itself have not been assessed.

2. DAMAGE TO ROADS AND STRUCTURES

Damage to Roads

Flood damage on federal lands amounted to about $27 million as of March of 1998 (Richard Harris, personal communication, 1998), primarily on roads. At that time, 712 ERFO (Emergency Relief, Federally Owned) sites were approved for funding. The number of ERFO sites continuously grew during the course of this assessment, and computations involved 927 sites (Table 2). Figure 5 shows the number, cost, and sediment production of 277 ERFO sites which were stratified into the seven categories described in the METHODS section. Damage to roads was concentrated in three main geomorphic settings: (a) The stream channel environment, where roads crossed or paralleled streams (about 60% of ERFO sites); (b) On older landslide deposits; (c) Road fills on steep mountain slopes, particularly those placed in swales. Road damage at stream crossings was often the result of blocked culverts. Blockages were caused by numerous factors, including debris flows, woody debris and in a few cases, flows exceeding culvert capacity. Slumps and earthflows typically dropped the road inches or feet, occasionally taking out the entire prism. Loss of the prism occurred on toe zones of landslide deposits. Damage was made worse where multiple roads traversed the same hillslope, and where long road segments with inside ditches and cross drains were situated adjacent to stream crossings which experienced debris flows. Debris flows from small streams crossing Road 44N45 about a half mile SW of Indian Scotty Campground were diverted down the road ditch. Similarly, the capacity of the inside ditch was exceeded along a stretch of the County road (1C01) from Etna to Sawyers Bar about 2 miles north of Etna Summit. Another example of exceeded ditch capacity occurred on Highway 3, immediately south of Scott Mountain summit.

FIGURE 5

Type	Count	% of total	Costs	Volume to streams [cubic yards]	Total volume [cubic yards]
Stream Crossing	142	51.3%	$5,873,644.00	124,219.8	187,963.9
Landslide non-stream	51	18.4%	$2,503,353.00	51,148.3	515,304.8
Road Fill Failure	40	14.4%	$924,476.00	1,149.6	10,633.9
Stream Undercut	21	7.6%	$1,593,118.00	17,457.2	17,834.1
Rd. Cut Failure	17	6.1%	$114,697.00	470.0	8,567.0
Gully	3	1.1%	$120,639.00	174.0	346.9
Flooding	2	0.7%	$15,613.00	44.4	44.4
Totals:	**277**	**100.0%**	**$11,145,540.00**	**194,663.3**	**740,695.0**

Figure 5: ERFO Site Data: Initial Sample

In the fall of 1997, a sample of 74 stream crossings in the Walker, Grider, O'Neil, Kuntz, and Tompkins Creek watersheds were examined to identify possible relationships between culvert size and failure rate (Ledwith and others, 1998). This assessment examined relationships between hydraulic capacity of culverts, failure rate, failure mechanism, and it also evaluated the utility of using hydraulic models to predict stream crossing failures. Severely damaged road segments were selected, and 51 of the 74 crossings examined had failed. Failure was defined as water overtopping the top of the culvert inlet. Of the failures, 40% were attributed to sediment slugs, 22% to debris flows, 14% to hydraulic exceedence, and 10% plugging by woody debris. Stream diversions occurred at 35% of the failed crossings, while the potential for diversion was identified in 60% of all crossings examined, and the average distance of diversion for all sites was about 70 meters, and 57 meters for failed sites. Hydraulic capacity was measured for each culvert and it was found that 83% of failed culverts and 73% of unfailed culverts had a hydraulic capacity of less than a 25 year flood event. Failed pipes had a median of 8 years, and unfailed sites had a median of 11 years. No correlation was found between failure rate and: culvert size; site elevation; inlet basin characteristics; nor rustline height in culverts. Thus, the hydraulic parameters examined did not turn out to be good predictors of culvert failure. However, it was found that the consequences of failure could be predicted with reasonable accuracy.

3. DAMAGE TO OTHER FACILITIES

Several houses and other buildings were damaged or destroyed near the mouths of Walker and

Grider Creeks. The segment of Highway 96 from its junction with Highway 263 to Happy Camp was damaged in many segments due to undercutting. Damage to state highways was not addressed by this assessment. Debris flows from an old hydraulic mine cut damaged a Forest Service Building near Happy Camp. Near Horse Creek, a large landslide developed in the road cut and closed the highway numerous times during the spring of 1997. Upstream of Seiad Valley, undercutting, damaged the shoulder of the highway in many areas, exposing the recently-installed fiber optic communication line. This was likely the result of a combination of high flows and the seepage pressures which develop as water recedes in such situations. A Highway 96 bridge over the Klamath River near the Klamath River School was damaged by undercutting, and temporarily closed in July, 1997. Between Happy Camp and Orleans, several slumps and earthflows removed portions of Highway 96. A large earthflow below Happy Camp near Benjamin Creek extend down to the Klamath River, and it was repaired with a large rock buttress at the toe. Stream undercut damage also occurred on County roads along the Salmon and Scott Rivers, and two bridges on the county road were lost along the Scott River at Deep and Middle Creeks as a result of debris flows in the channels. Damage to highways created a large demand for large rock to be used as rip rap and landslide buttressing.

Several campgrounds were flooded, and river access roads were damaged by scour and deposition.. One Forest Service bridge over the Klamath River was lost near Horse Creek, and several others were damaged. Many cost share roads were damaged by the flood, requiring coordination between shareholders in repair projects. Several landslides occurred which affect multiple ownerships, that is, landslides on one ownership affected land under different ownerships downslope. Extensive damage was caused to the trail system by debris flows traveling down streams in upper Elk Creek, Ukonom Creek, and the Upper South Fork of the Salmon River. Additionally, log bridges along trails (Grider Creek) were lost.

4. EFFECTS ON STREAM CHANNELS

Most of the field observations and temperature data presented here were provided by Jon Grunbaum. A total of 446 miles of altered channel were identified by air photo inventory within the air photo study area. In addition roughly 90 miles of of the Klamath, Scott, and Salmon Rivers were altered within the photo area . Channel alterations were most severe in Walker and Deep Creeks, where major debris flows traversed the entire channel length. In these streams, the floodplain was significantly altered and most of the riparian vegetation removed. The alluvial fan at the mouth of Walker Creek was built up considerably. Effects were less pronounced at Tompkins, Grider, Kelsey, and Indian Creeks. See Map 2, and attached list of watershed names. In these streams, debris slides in steep headwaters generated debris flows in some tributaries, but most of the main stems appears to have experienced only hyperconcentrated flood flows, and most riparian vegetation survived there. Nonetheless, these creeks lost local patches of riparian vegetation, much of the floodplain was disturbed by deposition or scour, and large accumulations of woody debris were deposited. In some areas, logs were trapped by stands alders 20-30 years old. Based on observations of fisheries personnel, there appeared to be considerable **reduction in size, volume, and depth of pools** in Elk, Indian, Beaver, Grider, Tompkins, South Fork Salmon, and Walker

Creeks, and there is a **larger proportion of fine sediment in the substrate. Alluvial reaches were made shallower and wider** due to sedimentation. At the other end of the spectrum, Clear and Dillon Creeks were little affected by the flood. It appears that these streams experienced flood flows only, with some local debris flows in Clear Creek tributaries. Only a small amount of riparian vegetation was removed, and scour and deposition was mostly limited to the bankfull channel. They appear to have experienced high flows without a large influx of sediment. Map 2 shows the distribution of flood-altered channels identified to date on the Forest. Most were identified from post-flood air photos. A recent study by California Department of Fish and Game (1997) in Elk, Indian and Bogus Creeks revealed that the substrate contained a high proportion of fines, but no pre-flood data are available for comparison purposes.

Substrate Mobilization & Shade Loss

Mobilization of the substrate appears to have occurred in channels throughout the west side of the Forest, but in particular those mentioned above.. This process likely destroyed most of the 1996 crop of fish eggs in gravels. This widespread mobilization is also likely to have had an adverse effect on invertebrates and the larval stages of the Pacific Lamprey which spends several years years of its life cycle in the channel substrate. The post-flood gravels in many of the streams are unstable, and susceptible to mobilization later in the year, and to a lesser degree for several years to come. Such mobilization is most likely if continued landsliding and high flows occur within the next few years. Thus, the survival of the 1997 eggs in these new gravels is questionable over the next few years.

Water Temperature

Varying amounts of riparian vegetation were removed from channels, but quantitative data are not currently available. The potential for increased water temperatures due to **shade loss** are greatest in Walker, Tompkins, Elk, and Indian Creeks, and possibly the South Fork of the Salmon River. Similarly, channel aggradation which makes pools shallower and the channel wider can also result in increased summer temperatures. Preliminary assessment of continuously recorded temperature data from Elk Creek reveals that July and August temperatures in 1997 were considerably higher than the means from 1990-1995 in all categories measured (Jon Grunbaum, personal communication, 1998). The **instantaneous maximum** in 1997 was 74.5 degrees Farenheit, while the mean from 1990-1995 was 70.7 (with the highest being 72.3 in 1990 and 1994). The **7 day maximum average** in 1997 was 73.0 degrees in 1997, and the mean from 1990-1995 was 69.4 (with the highest being 71.2 degrees in 1990, 1992, and 1994). The **31 day maximum average** was 69.6 in 1997, compared to 67.0 for 1990-1995 (with the highest being 69.1 in 1990, 1991, and 1994). The **diurnal variation** in 1997 was 12.5 degrees compared to 7.6 degrees from 1990-1995 (with 1991 largest at 8.3 degrees). The **average 31 day** temperature in 1997 was 64.0 degrees Farenheit, and the mean from 1990-1995 was 63.5 degrees The 1997 temperatures were exceeded in 1991 (65.5 degrees), and 1994 (65.8 degrees). In summary, 1997 water temperature at Elk Creek showed an increase in 1997 relative to the period from 1990-1995. The largest differences were in the instantaneous maximum and in diurnal temperature variation. The fact that 31 day averages were only 0.5 degrees higher in 1997 than the 1990-1995 mean, and even cooler than in 1991 and 1994 is probably a result of higher diurnal variations in 1997 which would average out. The high diurnal variation was most likely due to the loss of shade and shallowing and widening of the channel which allows more efficient heating during the day, and rapid cooling in the evening.

Aggradation and Channelization

Aggradation which occurred during the flood, and tractor channelization after the flood at the mouths of Grider, Walker, Oneil, Portuguese, and Independence Creeks could pose a problem to fish migrating from the river into these streams. These areas have not been evaluated on site.
Alterations in the Salmon River occurred primarily in the Upper South Fork where there was considerable alteration of bars (downstream of Blindhorse Creek) and filling of bedrock pools a mile upstream of its junction with the East Fork. In the Scott River, the South Fork and the Lower Scott seem most altered. No information has been obtained on changes to the Scott River through Scott Valley.

Log Accumulations in Streams

Accumulations of logs were deposited in the alluvial reaches of most of the flood altered channels, in particular in Elk, Grider, Tompkins, Indian, and Kelsey Creeks. Some of these channels had been cleared of logs following floods in the 1960's and 1970's. The issue of how large logs in creeks should be managed is important throughout Northern California. There is considerable pressure to remove logs along developed streams which are spanned by many bridges. Similarly, channelization of streams, particularly at road crossings near the mouths is an issue.
Some creeks, such as Beaver Creek had extensive damage to some headwater tributaries, but exhibited little effects from the flood in middle reaches. However the lower alluvial reaches were altered considerably by deposition and braiding of the channel.

Channel Migration

The Klamath River inundated a number of bars for the first time in several years, and appears to have changed courses in some areas to occupy channels which had previously carried high flows only (near Barkhouse Creek). Where tributaries enter the Klamath, deposits of coarse sediment which collected when the river was high, are in some cases retained near the mouths of the tributaries. A thorough assessment of alterations to the Klamath River channel has not been conducted. Migration of the channel occurred in segments of Grider, Tompkins, and Thompson Creeks.

Landslide Dams

A small landslide dam formed on the South Fork of the Scott River near the Callahan to Cecilville road. The dam was formed by a small (100 feet wide, 200 feet long) slump-earthflow on the toe of a larger dormant landslide deposit. The resulting pond was about 30 feet wide, 120 feet long, and a few feet deep. It is likely that the landslide occurred late in flood event, because the pond was not filled with sediment. In the Watershed of the North Fork of the Salmon River, remnants of an older landslide dam on North Russian Creek (de la Fuente, Snavely, and others, 1995) were removed by high flows, lowering the stream bed by 8 vertical feet. A small debris slide in Irving Creek (Ukonom District) formed a small temporary dam of a few feet in height.

5. DAMAGE TO FISH HABITAT IMPROVEMENT STRUCTURES

These structures include log clusters placed or cabled along streams, root wads, rock wiers, log wiers, boulder clusters etc. They have not been systematically assessed, but a few observations can be made. Large boulder clusters and weirs in Elk and Indian Creeks as well as the South Fork Salmon appear to have weathered the high flows, though some were moved or buried. Cabled log structures were more often damaged, raised out of the channel, or removed. A small sample of log structures examined in middle Beaver Creek survived the high flows. These were oriented perpendicular to flow direction, and were embedded in both banks.

Field observations (Al Olson and Pat Higgins personal communication, 1998) during the summer of 1997 resulted in the following qualitative evaluation:

General Observations

Boulder structures retained all or some habitat enhancing function despite their changed configuration after the flood. Structures associated with channel margins had a high survivability, while those in broad valley channels had high risks/benefits. Log structures will likely provide habitat benefits even if they were moved by the flood away from their original locations. Overall, in-channel structures can accelerate recovery of habitat complexity .

Structure Performance

Boulder structures had a high survival rate (>70%), and most remained functional, while boulder/rootwad structures had a moderate survival rate (>50% survived and remained functional). Complex log structures had a low survival rate (<30% were retained and remained functional), and channel-spanning structures exhibited variable success.

6. DAMAGE TO PREVIOUSLY STABILIZED SLOPES

The flood of 1997 provided the first test of the effectiveness of recently applied landslide and slope stabilization measures on Forest Service roads. The performance of these structures is currently being evaluated. Preliminary information indicates that virtually all of the reinforced fills installed over the past 5 years in Elk, Indian and Clear Creeks survived the saturated ground conditions associated with the flood. Similarly, landslide stabilization projects on the Sidewinder road (fabric reinforced fill), Zane Landing (a fill was excavated and removed from the head of a slump), West

Fork of Beaver (Hilfïcker welded wire retaining wall), Hungry Creek (drained rock fill), South Russian (hilficker welded wire wall), and a Hilficker wall on Beaver Creek have survived in good condition. The only known failures of such structures are a can wall in Walker Creek, and part of a fabric reinforced fill on the West Fork of Beaver Creek, where part of the fill failed, but the road prism remains intact. Several large landslides moved sufficiently to damage structures but not destroy them. Refer to Appendix B (Performance of Engineered Structures) for further information. A recently decommissioned road (involving removal of large fills) in the dissected granitic terrane of Steinacher Creek (tributary to Wooley Creek) emerged from the flood with only minor erosion damage.

B. HOW PHYSICAL FACTORS INFLUENCED FLOOD PROCESSES

Physical factors such as local variations in storm intensity, bedrock, geomorphology, elevation, slope, and aspect, appear to have played an important role in the way in which flood processes were manifest across the landscape. This section systematically examines these factors one at a time. Interactions between them are subsequently examined.

1. HYDROLOGIC FACTORS

The climate on the Klamath Forest is Mediterranean in character, with most precipitation occurring in winter. The permanent snowpack generally occurs above 4,000 feet, and precipitation ranges from 10 inches in the east to 130 inches in the west. Refer to Klamath National Forest Land and Resources Management Plan for additional information (USDA, Forest Service, Klamath National Forest, 1994).

One of the most important elements of this flood assessment is the attempt to accurately reconstruct precipitation and peak flow patterns, and how they varied across the Forest. Similarly, it is very important to identify variations in antecedent moisture conditions (pre-flood precipitation and snow pack). The better these factors are understood, the better we can assess the effects of natural land instability and land management on flood processes.

To date, no definitive correlations have been identified which link variations in precipitation intensity, snowpack, or peak flows to variation in severity of flood effects. Nonetheless, the concentration of road damage and flood altered channels in localized areas such as around Lake Mountain and upper Elk and Ukonom Creeks suggests that intense storm cells or variations in snowmelt did in fact occur. The Lake Mountain area experienced the most severe flood effects on the Klamath Forest (Map 10). This area is drained by Kelsey, Deep, Middle, and Tompkins Creeks, (tributaries to the Scott River), and Grider, and Walker Creeks (tributaries to the Klamath River above the Seiad). The peak flow in the Scott River had a 14 year recurrence interval, and the peak in the Klamath River below Seiad had a 15 year recurrence interval (Map 5). By contrast, the Salmon River experienced a peak flow with a much higher recurrence interval (37 years), but landsliding, channel alteration, and road damage there was much less severe than in the Lake Mountain Area. The only evidence for exceptionally high precipitation near Lake Mountain was recorded by a private station at Seiad. This station exceeded December norms by more than most other stations on the forest (Map 4). The observation that peak flows do not seem to mirror flood effects is likely influenced by the locations of the Scott and Klamath River gauges. The gauge on the Scott River (Map 5) is above the tributaries most affected by the flood (Kelsey, Deep, Middle, and Tompkins Creeks), and would not have shown effects of the high flows there. Similarly, the gauge in the Klamath River below Seiad may not have shown the effects of high flows from Grider, Walker, and adjacent tributaries because they are too small relative to the catchment area of the Klamath River upstream to significantly increase the total flow amount. There may also have been some local orographic effects. Precipitation data from the Pit River area during the 1997 flood (Steve Bachmann, personal communication, 1998) reveal that there was considerable variation in rainfall intensity and amount over relatively short distances.

The intensities of precipitation measured near Scott Mountain by snow pillow stations suggests that thresholds for debris slides described by Cannon (1985) were exceeded (see Appendix E). The storms appear to have been traversing the KNF in a northeasterly direction. This parallels the trend of maximum damage across the Forest (Map 4). However, the NE to SW trend of damage on the Forest may represent local responses only, since no data of similar detail are available in adjoining areas.

One way in which this question could be investigated further is by use of doppler radar data, which could identify areas of exceptionally heavy precipitation. Such data were not available for this investigation, but they are being pursued as part of Phase II of the flood assessment.

2. BEDROCK AND GEOMORPHIC TERRANES

Bedrock and geomorphic factors have been linked to landslide incidence by numerous recent studies in the northwestern United States (de la Fuente and Haessig, 1993, McClelland, Doug E., and others 1998). The influence of these factors on flood processes was examined by determining the density (number per square mile) of landslides and ERFO (Emergency Relief Federally Owned) sites, and the density (miles per square mile) of altered channels in different bedrock and geomorphic terranes. Graphs at the end of this section summarize findings: Figure 6 = Bedrock; Figure 7 = Geomorphic Terranes (Tables 1-5). Similar approaches were used recently on the Clearwater Forest (McClelland, Doug E., and others 1998) and in Puerto Rico (Larsen, 1996). Landslide and altered channel densities were computed over the land base of the photo study area (771,000 acres), whereas ERFO densities were computed over the 1.6 million acres on the west side of the Klamath National Forest. The reason for using different land bases was that the entire west side of the forest was inventoried for ERFO sites, whereas landslides and altered channels were systematically inventoried only within the air photo area.

Bedrock Terranes

The west side of the Klamath Forest lies entirely within the Klamath Mountains Physiographic Province. This province is comprised of a series of tectonostratigraphic terranes (referred to as bedrock terranes in this document) which were accreted to the western margin of North America over the past several hundred million years. They are rock units which share a common history of formation, internal coherence, mineral deposits, and rock assemblages. Rocks consist of metamorphosed Paleozoic and Mesozoic lavas and marine sediments such as chert, argillite, and marble, as well as mantle rocks (peridotite and serpentinite) and plutonic rock (mostly diorite). Bedrock Terranes used in this assessment are from the Klamath Forest bedrock layer (GIS). They consist of: cd- **Condrey Mountain**, cm- **Central Metamorphic**, pl- **Plutons** or granitic rock, rct- **Rattlesnake Creek**, sbt- **Sawyers Bar**, sbt?/sf?- **Sawyers Bar or Stuart Fork**, sf- **Stuart Fork**, sur- **Surficial Deposits**, wht- **Western Hayfork**, wj- **Western Jurassic**, yr- **Yreka**. Plutons and surficial deposits are not actual bedrock terranes as defined above, but were used because they were available as distinct units in the GIS layer. Map 6 shows the distribution of landslides, ERFO sites, and flood-altered channels relative to bedrock terranes, and Figure 6 graphs density for landslides, ERFO sites, and altered channels by bedrock terrane.

Landslides- Average flood-related landslide density (number per square mile) identified on air photos was 0.59, and on undisturbed land, it was 0.27. Landslides were most dense in two bedrock terranes, Rattlesnake Creek (0.84), and plutons (0.77). The concentration of landslides in these terranes supports previously identified instability in these rock units. Landslides in the Rattlesnake Creek Terrane are mostly debris slides on the toe zones of slump and earthflow deposits. Those in plutons are primarily shallow debris slides in steep, weathered and dissected areas (see Map 6). The overall high density in plutons was influenced by the concentration of landslides in plutons in the Elk and Ukonom Creek watersheds. In these watersheds, landslides are of two main affiliations, those associated with roads, and those associated with areas burned by wildfire in 1987. Density was lowest in the Sawyers Bar (0.26), Western Jurassic (0.17), and Condrey Mountain (0.27) Terranes. Figure 6 displays the density and number of landslides by bedrock terrane.

ERFO Sites- Average ERFO site density (sites per square mile) on the west side of the Forest is 0.37. ERFO sites are concentrated in surficial deposits (2.43), Condrey Mt. (0.65), and Rattlesnake Creek terranes (0.55 slides/sq mi). The lowest were Central Metamorphic (0.14) and Stuart Fork Terranes (0.14), and Plutons (0.31). Figure 6 displays the density and number of ERFO sites by bedrock terrane. The reason that surficial deposits are such a high density may be related to the fact that this unit includes alluvial deposits, and by nature, alluvial deposits are along streams. Consequently the high density may be due to the fact about 60% of ERFO sites were along streams. Further, surficial deposits comprise an insignificant part of the landbase (0.1%). The low concentration in plutons is influenced by the fact that a large proportion is in wilderness, where there are no roads. The low density of ERFO sites in plutons is likely due to the fact that much of the pluton area is in wilderness, where there are no roads.

Altered Channels- Altered channel density (miles per square mile) averages 0.37 across the photo area. The highest density of altered channels is 0.65 in plutons, and 0.40 in Rattlesnake Creek terrane. Map 6 reveals that these high numbers are the result large, far-reaching debris flows in Ukonom, Elk, and East Fork of Indian Creeks. In some cases (such as Walker Creek) debris slides originating in Rattlesnake Creek terrane carried downslope to the mainstem, which traverses mostly granitic terrane, giving the appearance that granitic bedrock is associated with dense altered channels, when if fact, it is merely receiving the effects of upslope processes. The lowest density of altered channels is within Sawyers Bar/Stuart Fork, Western Jurassic (0.22), and Condrey Mountain (0.18)Terranes. Figure 6 displays the density of altered channels by bedrock terrane.

Summary- The Rattlesnake Creek Terrane, previously recognized as landslide-prone, had the highest density of landslides and second highest density of ERFO sites and altered channels. Plutons, also recognized previously as being prone to shallow debris sliding, had the second highest landslide density, and the highest density of altered channels. However, it had the lowest density of ERFO sites. This is probably linked to the fact that much of the pluton area is in the wilderness, where there are no roads. Map 6 shows the concentration of landslides, ERFO sites and altered channels in the central part of the Rattlesnake Creek Terrane exposures. The lack of these effects in the the western portion may be due to the fact that this area has little vegetative disturbance and few roads.

Geomorphic Terranes

The Klamath Mountains Physiographic Province consists of steep, rugged mountains with glaciated uplands which are experiencing rapid uplift and are affected by periodic earthquakes originating in the adjacent Cascadia subduction zone to the west. During the Pleistocene Epoch, large landslides (slumps and earthflows) developed across much of the landscape, likely due in part in response to wetter climate than currently exists. These large ancient landslides occupy about 25% of the land area on west side of the Klamath National Forest, and are notably rare in plutons (Map 7). Due to this combination of factors, landsliding is a common process today, and much of the recent landsliding consists of localized slumps and earthflows (reactivations) and debris slides on the toes of slump and earthflow deposits. For purposes of this assessment, the Forest geomorphic layer was used which identifies 12 different geomorphic terranes. It incorporates elements of bedrock, slope, surficial deposits, and landform. These geomorphic terranes are land units which exhibit similar slope processes and landslide susceptibility. The terranes are:

#1. **Active Landslides** (slumps, earthflows and debris slides active prior to 1997)
#2. **Toe Zones** (the steep toe areas on distal margins and bodies of slump and earthflow deposits)
#3. **Landslide Deposits** (undifferentiated Slump and Earthflow deposits; not active)
#4. **Mountain Slopes: Granitic; Steep** (Plutons with slope gradients >65%)
#5. **Mountain Slopes: Granitic; Gentle to Moderate** (Plutons, slopes 0-65%)
#6. **Mountain Slopes: Non-Granitic; Steep** (slope gradients >65%)
#8. **Mountain Slopes: Non-Granitic; Gentle to Moderate** (slope gradients 0-65%)
#9. **Inner Gorge: Unconsolidated** (developed in landslide, glacial, or terrace deposits)
#10. **Inner Gorge: Granitic** (developed in granitic bedrock)
#11. **Inner Gorge: Non-Granitic** (developed in non-granitic bedrock)

#12. **Debris Basin** (steep fan-shaped amphitheater forming headwaters of 1st order stream)
#13. **Glacial, Terrace, and Alluvial Deposits**

For a more complete description of these terranes, refer to de la Fuente and Haessig, (1993). Together, terranes 4,5, and 10 are equivalent to Plutons on the bedrock terrane layer. Terranes 2,3, and most of 9 consist of dormant landslide deposits. Map 7 is a simplified display of the forest-wide distribution of 1997 landslides by geomorphic terrane, and Maps 10, 11,12, and 17 show the geomorphic terranes in the Lake Mountain, Thompson Creek, Ukonom Lake, and Walker Creek areas respectively. Figure 7 graphs densities for landslides, ERFO sites, and altered channels by geomorphic terrane.

Landslides- Average flood-related landslide density (number per square mile) identified on air photos was 0.59, and on undisturbed land, it was 0.27. The highest densities occurred in three geomorphic terranes, **active landslides** (5.63); **unconsolidated inner gorge** (1.35); and **landslide deposits** (0.72). Average for the three types of **inner gorge** (terrane #'s 9,10,11) was 0.82 (133 landslides), and for the three types of **dormant landslide deposits**, (terranes #2,3,9) it was 0.79, and included a total of 267 landslides. Air photo investigation and field observations reveal that most of the large debris flows originated on the **toe zones of landslide deposits**. This observation is not reflected in landslide density for toe zones, due to the fact that these features are not well-mapped on the geomorphic layer. Density was lowest in **debris basins** (0.25) and **glacial deposits** 0.10. Higher densities were anticipated in debris basins. A possible explanation for this may be that bedrock in these exceptionally steep areas may be stronger than adjacent areas. Glacial deposits were expected to have a low density since most of them occur on the floors of glaciated valleys, and exhibit low slope gradients. Figure 7 displays landslide density and number of landslides for all 12 geomorphic terranes. Concentration of landslides in geomorphic terranes varied considerably by individual watershed. In **Walker Creek** (Maps 10 and 17), there were few landslides in plutons while in **Elk Creek** (Map 12), they were dense (in Granite Fork), as previously mentioned. This may well be a function of vegetative disturbance, in that the pluton in Walker Creek is little disturbed, whereas in Elk Creek, much of the pluton was burned by wildfire in 1987, and many slides are road-related. Landslide concentrations in older landslide deposits are striking in Grider, Walker and Thompson Creeks (Maps 10-12).

ERFO Sites- Average density (sites per square mile) for ERFO (Emergency Relief Federally Owned) sites was 0.34. This value is slightly different than the value stated under bedrock (0.37), and it is due to some 6 ERFO sites which were used includes in bedrock computations, but could not be used here because geomorphic mapping is not available for that area. It was highest in previously identified **active landslides** (1.37), **granitic inner gorge** (0.97), and lowest in **debris basins** (0.03) and **steep non-granitic mountain slopes** (0.11), and **steep granitic mountain slopes** (0.10). The combined density for all three types of **inner gorge** was 1.59 (256 sites). The combined density of ERFO sites in the three types **dormant landslide** was 0.91 (307 sites). ERFO site density and numbers of sites for all geomorphic terranes are displayed in Figure 7. Field observations indicate that many more are actually located on smaller unmapped landslide deposits. However, there are still a small percentage of landslides which occur on mountain slopes with no evidence of past landsliding, such as large bedrock debris slides. Previously **active landslides** have a high concentration of ERFO sites (as well as new landslides) because the flood reactivated many of these landslides. A likely explanation for the high density of sites within the **inner gorge** is that about half of all EFFO sites were stream crossing failures, and a large proportion of streams have inner gorges. Thus, stream crossing failures such as a blocked culvert or loss of fill would show up here. The low density of ERFO sites in **debris basins** may be due to the fact that there are few roads across debris basins, and there were also very few landslides within debris basins forest wide. The difference in densities for ERFO sites and active landslides (ERFO density in inner gorge is relatively higher than active landslides) is influenced by the fact that slides in headwaters form debris flows which have downstream effects on roads. Figure 7 displays the density of ERFO sites by geomorphic terrane.

Altered Channels- Average density of altered channels was 0.37 miles per square mile over the air photo area. Density of altered channels by the identified geomorphic terranes is probably not very elucidating about flood processes because one of the geomorphic units. This is because the **inner gorge** is a stream unit which is virtually coincident with the stream, and is long and narrow. The overlap of altered channel with inner gorge is expected, since they both are channel features. In essence, it says there are many altered channels in channels. Broader terrane types would yield more meaningful in formation. The highest density of altered channels was in granitic inner gorge (3.08) and unconsolidated inner gorge (2.07), and non-granitic inner gorge (1.91). In active landslides it was 1.09. The lowest density was in gentle to moderate slope non-granitic mountain slopes (0.05), steep non granitic lands (0.06).

Summary- In summary, 1997 landslides were concentrated most in previously active landslides, landslide deposits, and inner gorges. Similarly, ERFO sites were concentrated in previously **active landslides**, and **inner gorges** and **dormant landslide deposits**. The density of altered channels by geomorphic terrane was not useful in characterizing landscape behavior. This is due to the fact that some of the terranes (inner gorges) virtually coincide with the streams.

3. ELEVATION, SLOPE, AND ASPECT

These factors have been shown to play an important role in landslide incidence. This assessment used elevation zones of: 0-2,000, 2,000-4,000, 4,000-6,000, and >6,000 feet. Slope classes were 0-20%, 20-40%, 40-65%, and >65%. Smaller classes of elevation and slope gradient were also examined, but are not displayed on figures 8-10. Aspects (azimuth) were north (310-70 degrees), East (70-130 degrees), South (130-250 degrees), and West (250-310 degrees). Aspect classes were selected from the U.S. Forest Service Region 5 Inventory and Analysis User's Guide (USFS, 1997) which is designed to delineate areas of similar insolation. All data for this part of the assessment were derived from the 30 meter digital elevation model. Findings are summarized in Figure 8 (Elevation), Figure 9 (Slope Gradient), and Figure 10 (Aspect). Refer to Tables 1-3 for additional detail.

Elevation

Landslides- Average flood-related landslide density (number per square mile) identified on air photos was 0.59, and on undisturbed land, it was 0.27. Landslide density at 0-2,000 feet was 0.17, from 2,000-4,000 feet it was (0.47), from 4,000-6,000, it was (1.09), and at >6,000 feet, it was 0.26. Examination of 500 foot elevation zones revealed that the highest densities occurred between elevations 5,000-5,500 feet (1.46) and 4,500-5,000 feet (1.37). Most of this information is displayed on Figure 8 and on Maps 8 and 13. In many of the flood-altered watersheds, there was a clear pattern of severe channel alteration in the upper half of the watershed (usually above 4,000 feet), and only minor alteration of the lower half (confined to the main channel). In such cases, many or most of the tributaries in the upper half experienced debris flows, whereas those in the lower half did not. Alteration to channels in the lower half was limited to the main stem. This pattern is displayed by Walker, Tompkins, Portuguese, Ukonom, Independence, and Portuguese Creeks (Maps 8 and 13).

The concentration of landslides at 4,500 to 5,500 feet in elevation suggests that snowmelt may have played an important role in peak hillslope saturation. Tributaries with lower elevation headwaters generally experienced fewer debris flows. This pattern contrasts with that on part of the Rogue Forest to the north, where the Ashland watershed had many debris flows at lower elevations (Hicks 1997), and on the Shasta Trinity National Forest to the south in the Salt Creek area tributary to Shasta Lake (Steve Bachmann, Abel Jasso, personal communication, 1998).

ERFO Sites- Average ERFO density (sites per square mile) in the air photo area was 0.62. It was highest at elevations 2,000-4,000 feet (0.79), and <2,000 feet (0.58). There were no ERFO sites > 6,000 feet, and the density was 0.49 at 4,000-6,000 feet. These patterns are displayed on Figure 8 and on Maps 8 and 13. The reason for this pattern is likely associated with the fact that many high elevation debris flows had downstream effects a considerable distance away. Also, cumulative runoff effects result in higher flow volumes lower in the watershed, and stream densities are usually higher. Since half of all ERFO sites were associated with stream crossings, and there are more stream crossings at lower elevations, it stands to reason that ERFO density would be higher at lower elevations. Also, roads are concentrated in the 2,000-4,000 foot elevation zone.

Altered Channels- The average altered channel density (miles per square mile) was 0.37. The highest density of altered channels was in the 0-2,000 (0.50), and 4,000-6,000 (0.42) elevation zone. The lowest density was in the > 6,000 foot zone (0.04), and from 2,000-4,000 feet, it was 0.34. One possible explanation for this pattern is that landslide density is highest in the 4,000-6,000 zone, and this is were debris flows originated. This could lead to higher concentration of altered channels below that elevation. However, lower values for the 2,000-4,000 zone are puzzling.

Summary- Landslides were concentrated in different elevation zones than ERFO sites. Landslides were concentrated in the 4,500-5,500 zone, but ERFO sites were concentrated the 2,000-4,000 zone. The highest densities of altered channels occurred in 0-2,000 and 4,000-6,000 elevation. At 0-2000 feet, channels are large and likely more visible on air photos.

Slope Gradient

Landslides- Average flood-related landslide density (number per square mile) identified on air photos was 0.59, and on undisturbed land, it was 0.27. Landslide density was highest in two slope classes, 40-65% (0.86), and >65% (0.77). At 20-40% it was 0.31, and at 0-20%, it was 0.12. This compares to area average of 0.59. These patterns are displayed on Map 14, and on Figure 9. The concentration of landslides at 40-65% slope, and to a lesser degree at >65% is likely due to the fact that most landslides inventoried were debris slides which typically occur on steeper slopes. Also, areas steeper than 65% may be underlain by stronger rock. Field observations suggest that the DEM tends to flatten slopes, and may understate the gradient by 10% or more. Examination of 5% slope increments revealed that the highest density was at 50-55% gradient (0.96).

ERFO Sites- Average ERFO site density (sites per square mile) in the air photo area 0.62, and across the entire west side of the Forest, it was 0.34. Density within the air photo area was highest in slope classes 0-20% and 20-40%, (0.86 and 0.74 respectively) and least common in the class >65% (0.25). The reason that the distribution of ERFO sites by slope gradient is so different from active landslides is likely related to the fact that more than half of all ERFO sites are associated with stream crossings, and many of these are low in the watershed on the floodplain, which has a low slope gradient. It stands to reason that ERFO density would be higher in such low gradient areas. Another factor may be that DEM's seem to artificially flatten some stream-crossing areas.

Altered Channels- The average density (miles per square mile) of altered channels in the photo area was 0.37). The highest density of altered channels is in the 0-20% (1.36) and 20-40% (0.43) slope classes. The lowest density was in the >65% slope (0.13).

Summary- Landslides are concentrated in steep areas (>40% slope), but ERFO sites in gentle ground (<40% slope). This pattern is probably linked to the fact that most ERFO sites (60%) occurred near streams which tend to be on flatter ground. Also, the digital elevation model appears to flatten out the terrain near streams, failing to catch the steep inner gorge slopes. The distribution of altered channels by slope gradient reveals that highest densities are in 0-20% class.

Slope Aspect

Landslides- Average flood-related landslide density (number per square mile) identified on air photos was 0.59, and on undisturbed land, it was 0.27. Landslide density was highest (Figure 10) in the north and east aspect classes (0.74 and 0.73 respectively). Density was lowest in the south and west classes (0.50 and 0.47 respectively). These patterns are displayed on Figure 10 and Map 15 for the Lake Mountain area. The concentration of landslides in aspect classes north and east suggests that snow accumulation and melt rate may have played an important role in saturating hillslopes, or thicker soils on north slopes may be more landslide prone.

ERFO Sites- Average ERFO site density (sites per square mile) in the air photo area 0.62, and

FIGURE 6

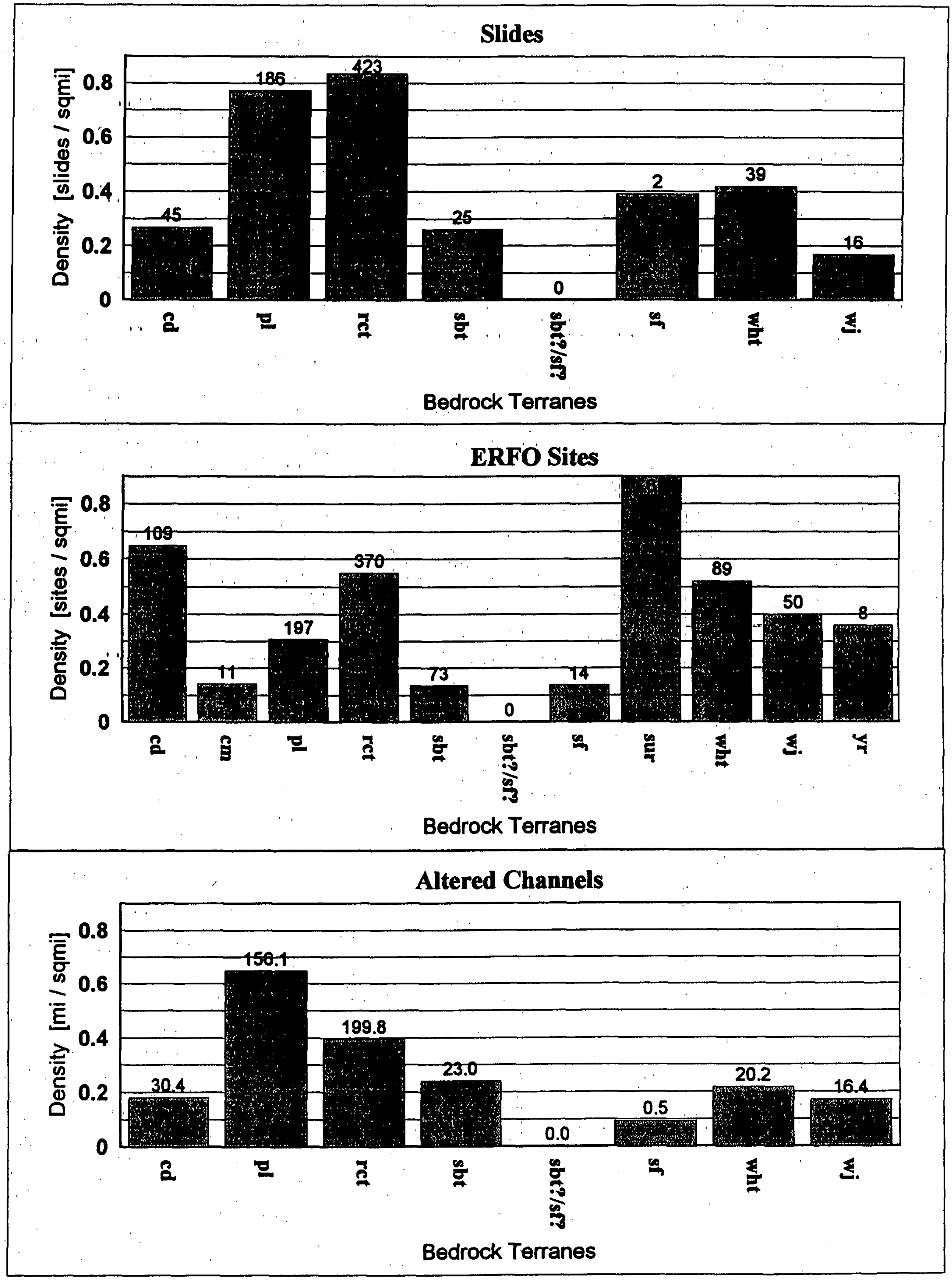
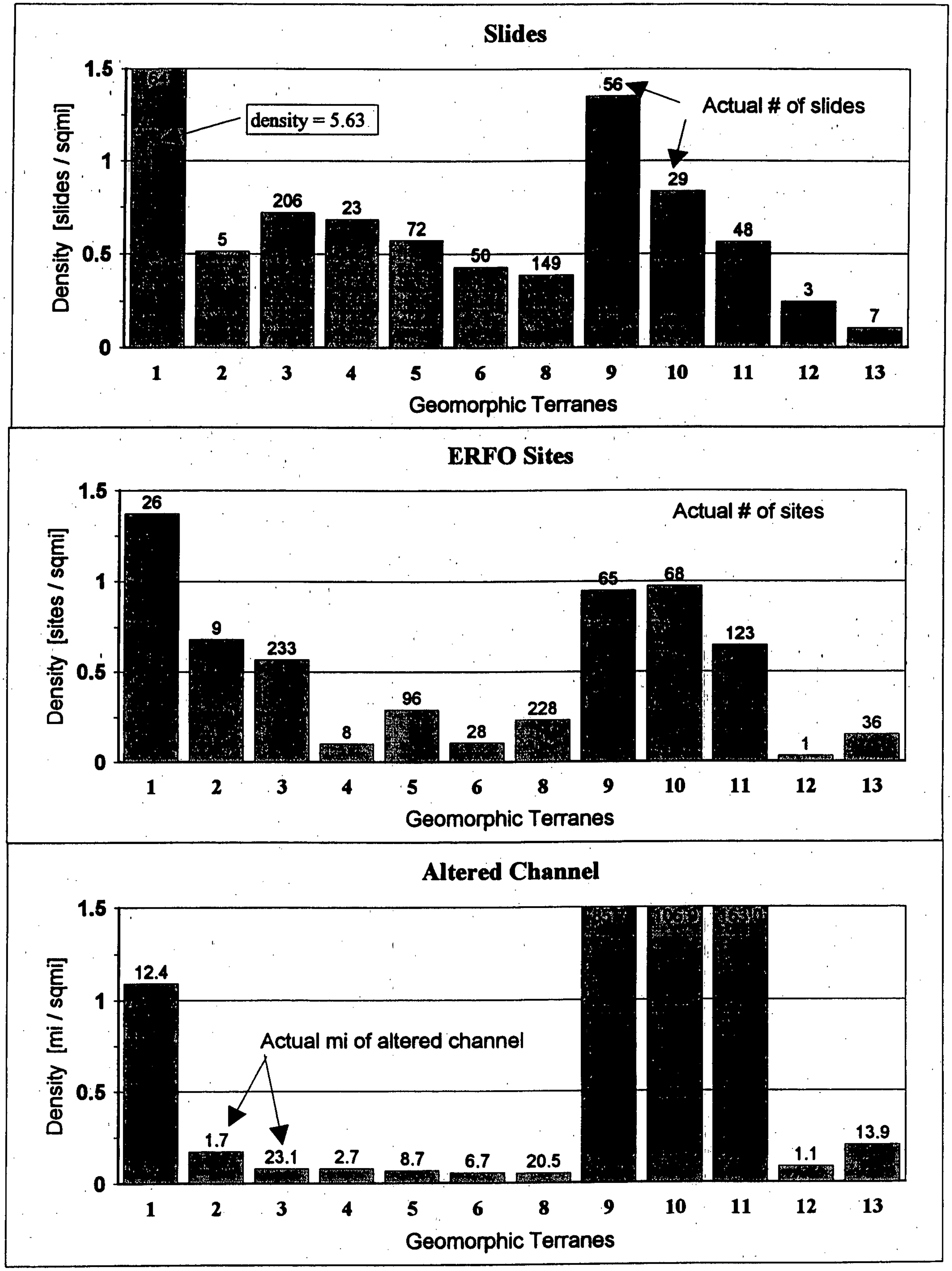
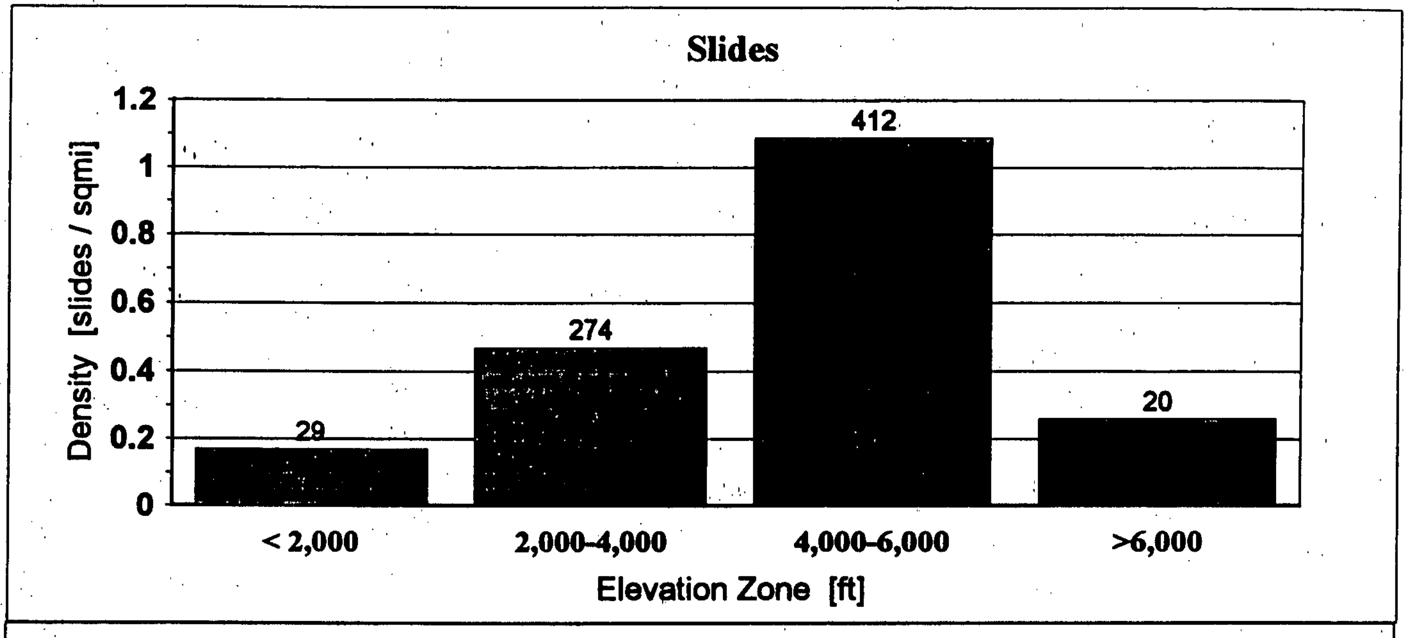
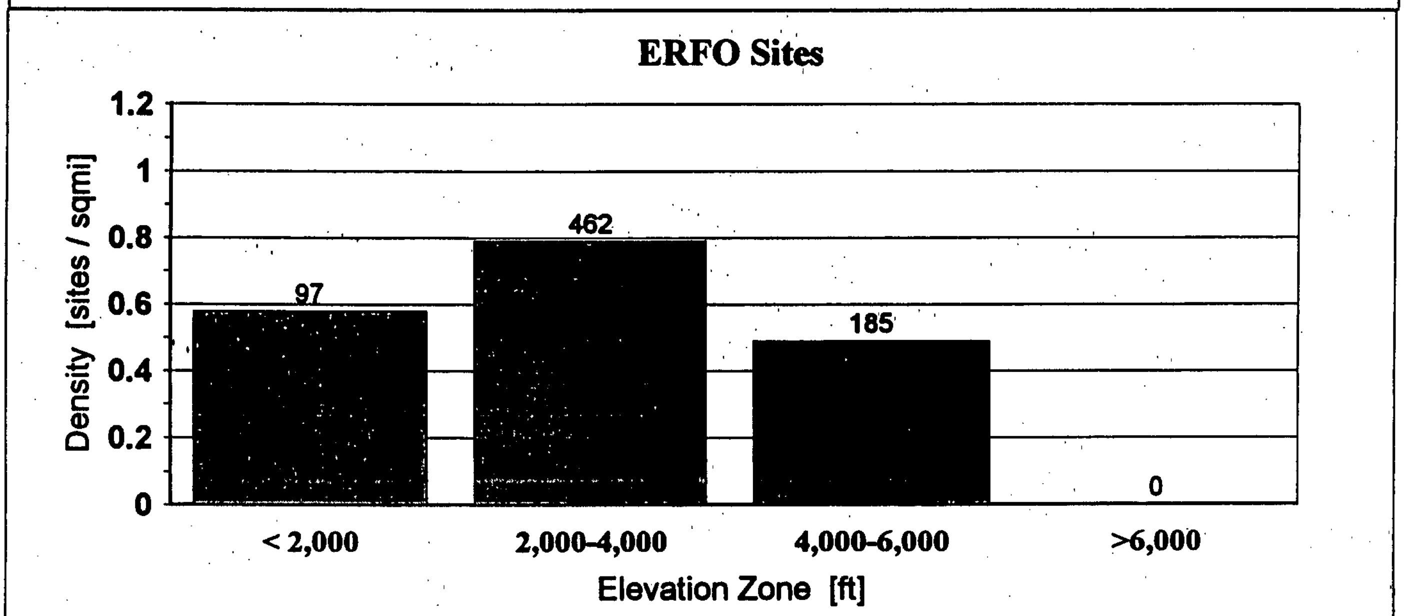

Slides
Density [slides / sqmi]
0.8
0.6
0.4
0.2
0
45
186
423
25
0
2
39
16
cd
pl
rct
sbt
sbt?/sf?
sf
wht
wj
Bedrock Terranes
ERFO Sites
Density [sites / sqmi]
0.8
0.6
0.4
0.2
0
109
11
197
370
73
0
14
89
50
8
cd
cm
pl
rct
sbt
sbt?/sf?
sf
sur
wht
wj
yr
Bedrock Terranes
Altered Channels
Density [mi / sqmi]
0.8
0.6
0.4
0.2
0
30.4
156.1
199.8
23.0
0.0
0.5
20.2
16.4
cd
pl
rct
sbt
sbt?/sf?
sf
wht
wj
Bedrock Terranes

FIGURE 7


Slides
Density [slides / sqmi]
1.5
1
0.5
0
density = 5.63
Actual # of slides
5
206
23
72
50
149
56
29
48
3
7
1
2
3
4
5
6
8
9
10
11
12
13
Geomorphic Terranes
ERFO Sites
Density [sites / sqmi]
1.5
1
0.5
0
Actual # of sites
26
9
233
8
96
28
228
65
68
123
1
36
1
2
3
4
5
6
8
9
10
11
12
13
Geomorphic Terranes
Altered Channel
Density [mi / sqmi]
1.5
1
0.5
0
12.4
Actual mi of altered channel
1.7
23.1
2.7
8.7
6.7
20.5
1.1
13.9
1
2
3
4
5
6
8
9
10
11
12
13
Geomorphic Terranes


Slides
Density [slides / sqmi]
1.2
1
0.8
0.6
0.4
0.2
0
29
274
412
20
< 2,000
2,000-4,000
4,000-6,000
>6,000
Elevation Zone [ft]


ERFO Sites
Density [sites / sqmi]
1.2
1
0.8
0.6
0.4
0.2
0
97
462
185
0
< 2,000
2,000-4,000
4,000-6,000
>6,000
Elevation Zone [ft]

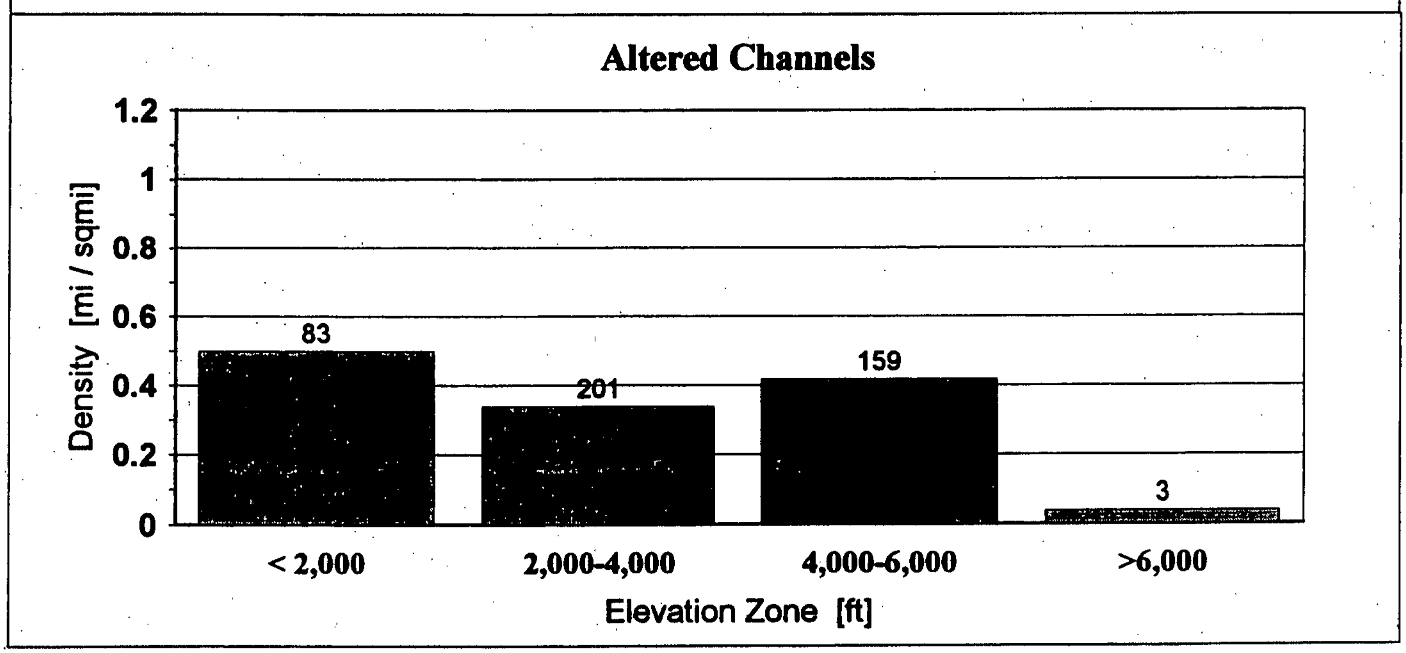
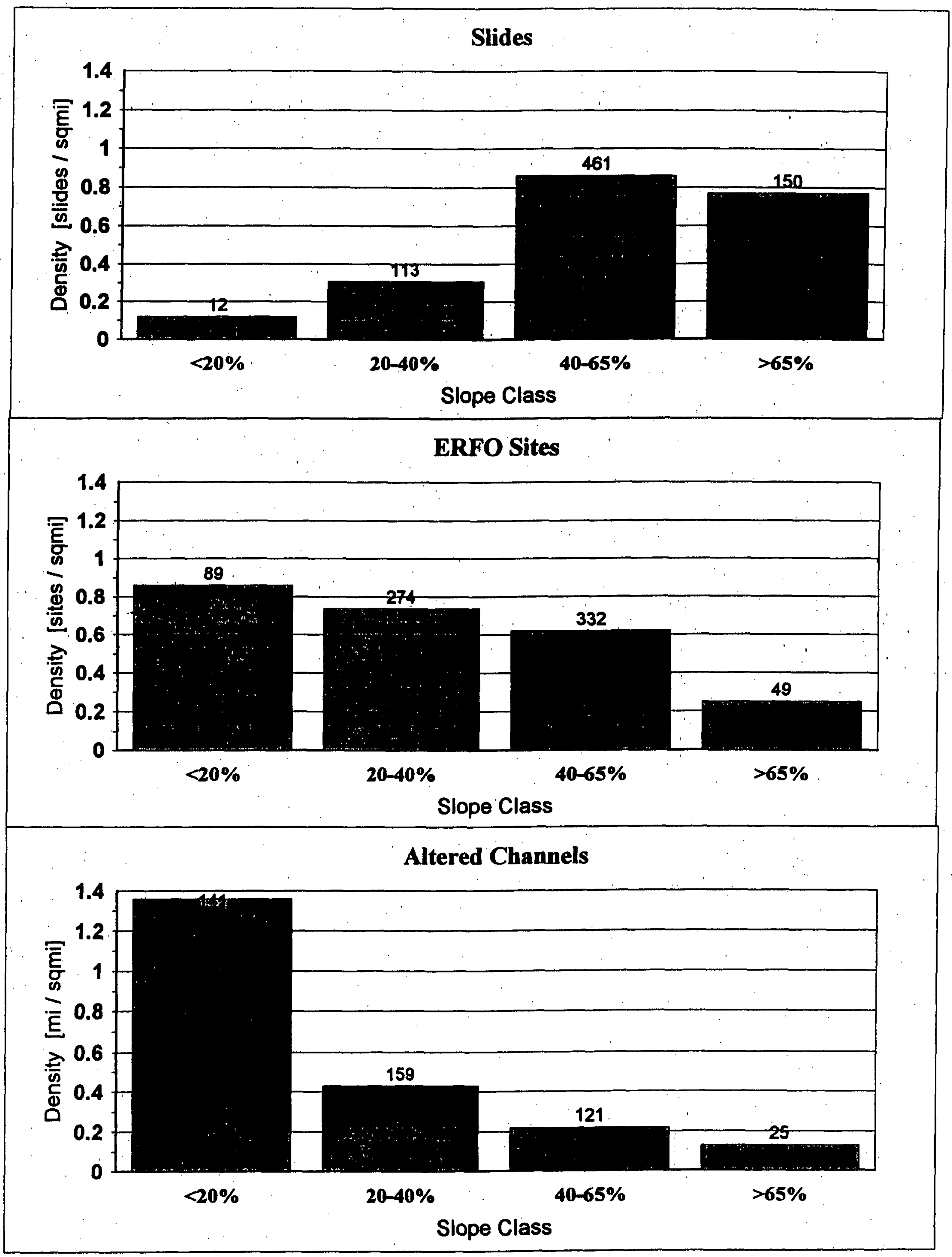
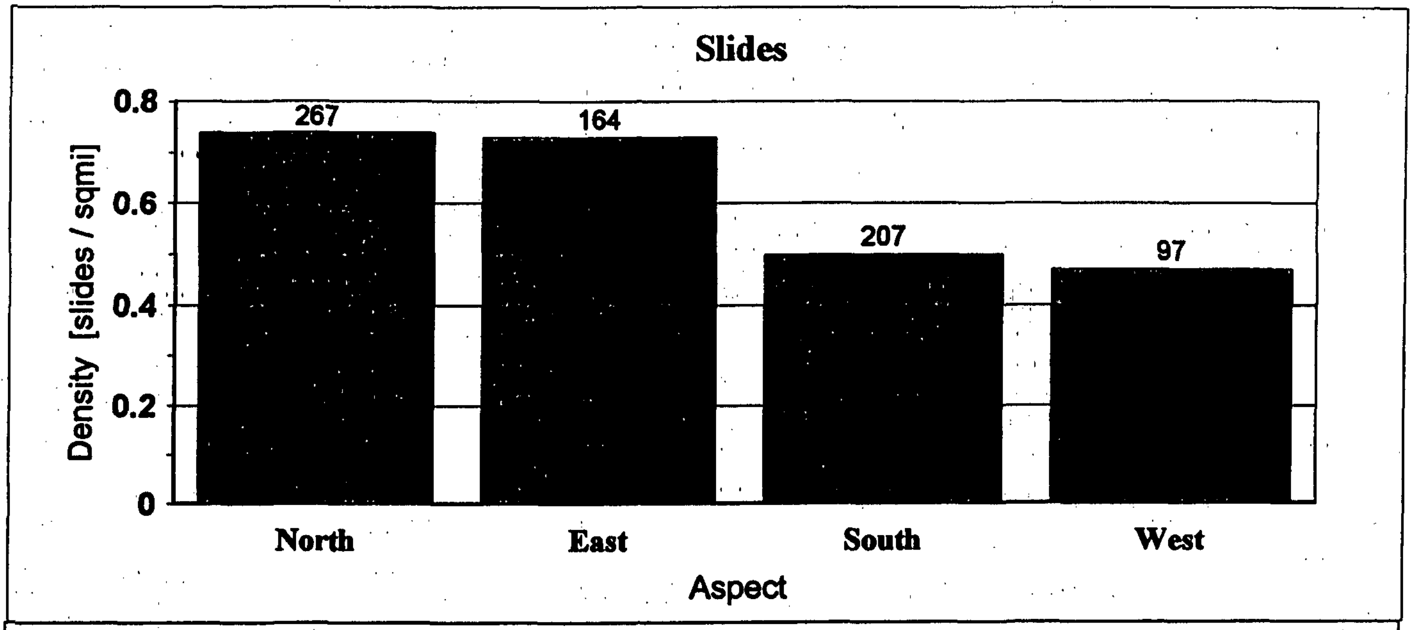
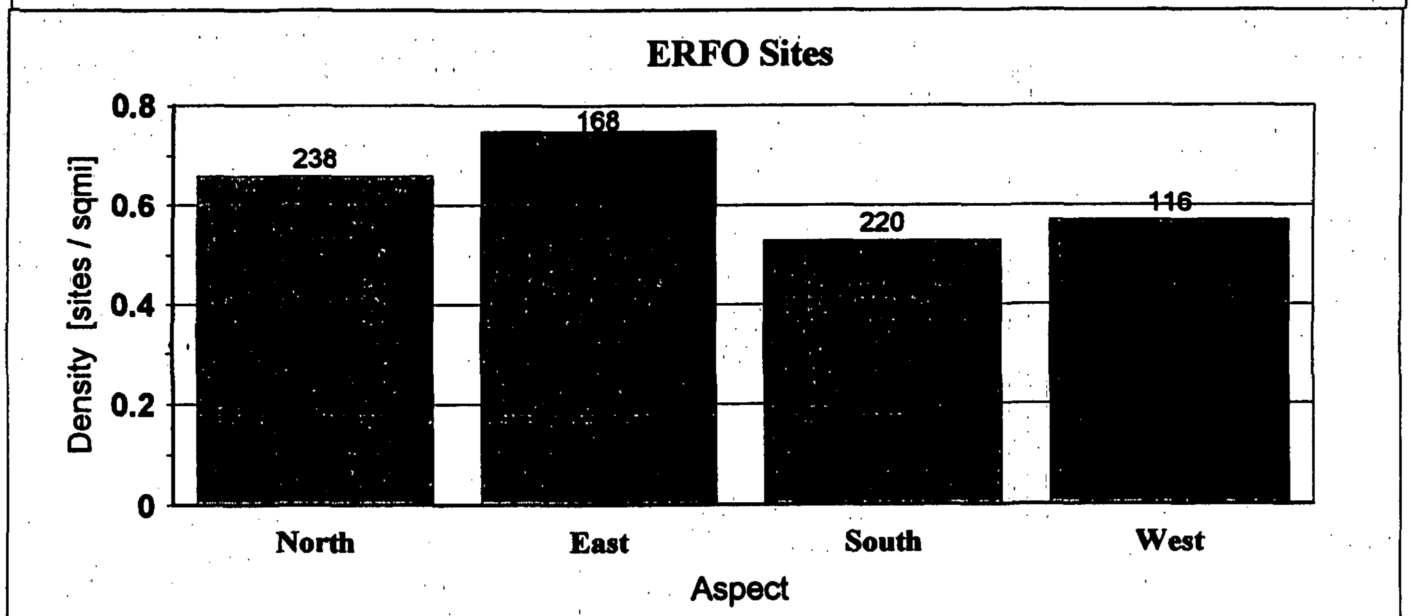
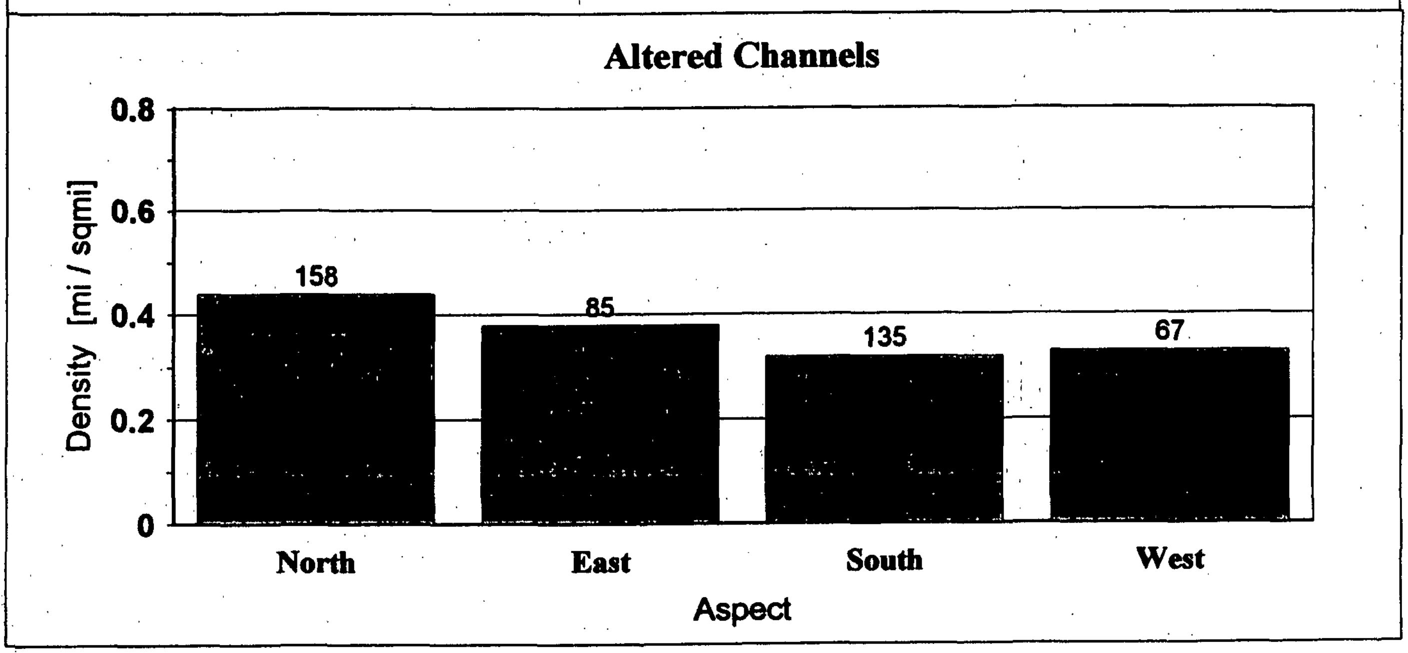

Altered Channels
Density [mi / sqmi]
1.2
1
0.8
0.6
0.4
0.2
0
83
201
159
3
< 2,000
2,000-4,000
4,000-6,000
>6,000
Elevation Zone [ft]

FIGURE 9


Slides
Density [slides / sqmi]
1.4
1.2
1
0.8
0.6
0.4
0.2
0
12
113
461
150
<20%
20-40%
40-65%
>65%
Slope Class
ERFO Sites
Density [sites / sqmi]
1.4
1.2
1
0.8
0.6
0.4
0.2
0
89
274
332
49
<20%
20-40%
40-65%
>65%
Slope Class
Altered Channels
Density [mi / sqmi]
1.4
1.2
1
0.8
0.6
0.4
0.2
0
159
121
25
<20%
20-40%
40-65%
>65%
Slope Class


Slides
Density [slides / sqmi]
0.8
0.6
0.4
0.2
0
267
164
207
97
North
East
South
West
Aspect


ERFO Sites
Density [sites / sqmi]
0.8
0.6
0.4
0.2
0
238
168
220
116
North
East
South
West
Aspect


Altered Channels
Density [mi / sqmi]
0.8
0.6
0.4
0.2
0
158
85
135
67
North
East
South
West
Aspect

across the entire west side of the Forest, it was 0.34. Similar to landslides, ERFO site density were concentrated on east and north aspects (0.75, and 0.66 respectively), and least common on west and south aspects (0.57 and 0.53 respectively).

Altered Channels- The average density (miles per square mile) of altered channels in the photo area was 0.37. It was slightly higher than average on north aspects (0.44). The other three aspect classes were near the norm (east = 0.38, south = 0.32, west = 0.33). One possible explanation for this pattern is that Walker, Grider and Elk mostly north aspect. An important question is how the algorithm classifies the stream when it separates two separate aspect classes. However this DEM generated aspect may be a function of how aspect is calculated in the algorithm

Summary- Landslides and ERFO sites were both concentrated on north and east aspects. This could be linked to snow accumulation differences or to soil differences. Altered channels did not show much aspect preference, other that north aspects were slightly denser.

C. HOW HUMAN ACTIVITIES AND FIRE INFLUENCED FLOOD PROCESSES

This section addresses how roads and other ecosystem disturbances (fire and harvest) influenced flood processes (hillslope erosion, sediment transport and deposition, flooding). A previous portion of this report (Section IV A 2; Damage to Roads and Structures) dealt with how the flood processes affected the facilities.

Forest ecosystem disturbances associated with management activities (road construction and timber harvest) and de-vegetation associated with fire had numerous effects on flood processes These effects can be placed into three categories: (1) Changes in hillslope and channel **hydrology**; (2) Changes in the **physical characteristics of the soil and colluvium**; (3) Changes in hillslope **mass balance**. These effects categories are addressed below for roads, timber harvest, and fire.

Effects of pre-flood disturbances to the ecosystem on flood processes were assessed by determining the frequency or density of landslides and ERFO sites (number per square mile) and altered channels (miles per square mile) in each disturbance category, and comparing them to undisturbed lands. Results are summarized in Figure 11 at the end of the section. Field observations were also utilized in describing effects..

1. ROADS: THEIR EFFECTS ON FLOOD PROCESSES

Road Effects

Of the common human activities in forested lands, roads undoubtedly have the greatest effects on slope stability (Sidle and others, 1985). The primary effects are: (a) Roads affect hillslope and channel **hydrology**; (b) Roads affect the density, permeability, and slope gradient of the **soil and colluvium**; (c) Roads affect **mass balance** by placing cuts and fills on hillslopes. A detailed description of these effects is contained in the DISCUSSION section of this report (Appendix B Item VI).

Road Fills, Cuts, and Surface Drainage

Road fills, cuts, and surface drainage were found to have had critical effects on flood processes as follows:

(1) **Road Fills-** Road fills had three key effect on flood process: (a) By disrupting channel configuration at stream crossings, and causing diversions; (b) By placing landslide-prone soil and rock on steep hillslopes; (c) By placing loads on the heads of slumps and earthflows.
(2) **Road Cuts-** Road cuts affected flood processes by intercepting subsurface flow, undermining slopes, and removing weight.
(3) **Road Surface Drainage-** The road surface, inside ditch, and cross drains altered slope hydrology by conveying the water intercepted by road stream crossings, road cuts, and the road surface itself, and delivering it to new sites on the landscape.

These three primary road components (fills, cuts, drainage) played different roles in different geomorphic settings as described below.

Geomorphic Setting

It was found that roads had their largest effects on flood processes and also experienced the most damage in three geomorphic settings:

(1)The **stream channel environment** where roads crossed or paralleled streams. Here, some road fills blocked passage of sediment and logs. Other fills failed, contributing sediment to streams. Road cuts into inner gorge walls initiated debris slides. Lastly, road ditches delivered additional water to crossings, and served as diversion channels;
(2) On **landslide terrane** (older landslide deposits geomorphic terranes 2,3,9) where roads undercut toe zones or loaded the heads of slumps and earthflows;
(3) On **steep mountain slopes**, where fills were placed in steep swales, or cuts undermined weak slopes..

Cumulative Effects

Two primary types of cumulative or cascading effects were identified relative to roads:

(1) Dense Road System- This situation is where multiple roads, one above the other, cross the same hillslope, resulting in complex interactions between the roads and geomorphic processes. (2) Long In-sloped Road Segments- Long road segments with inside ditches function basically as artificial stream networks. Even though flow is interrupted by cross drains and small drainages, unusually high discharges or cut bank failures can cause multiple cross drains to fail along a road segment, and even allow water to bypass small stream crossings if effective drainage safety valves are not designed into the road. These potential problems can be effectively identified by inventories.

Effects Assessment

The effects of roads on flood processes were analyzed by determining the landslide density (landslides per square mile) in road corridors, by stratifying two samples of the ERFO sites, and field observations.

Results of the Air Photo Inventory- Average landslide density (number per square mile) across the landscape was 0.59, and on undisturbed land, it was 0.27. A total of 182 landslides were identified by air photo inventory within the 50 foot wide road corridor, yielding a density of 7.34 (Figure 11). Therefore, the landslide density in the road corridor was **27 times** that in undisturbed land (7.34/0.27 = 27). This density figure does not account for differences in effects between different landslides (a singl~~e large~~ landslide may deliver more sediment than many smaller ones). Maps 9-12, and 17 display landslides and roads for various parts of the Forest, and Figure 11 graphs density. It is important to recognize that the presence of a landslide within a road corridor does not necessarily mean that it was caused by the road.

Results of the Stratification of ERFO Sites- An initial sample of 277 sites was stratified according to type failure mechanism etc., and results summarized in Figure 5. Later, a second sample (297 sites) was stratified, but the results of these two samples have not yet been combined. Consequently, the results of both samples are presented here. For example, the initial sample classified 60% of the ERFO sites as stream-related, while the second sample classified 50% as stream-related. In the following section, both values are presented and values from the initial sample are in bold type. In the above example, the figures for stream-related ERFO sites would be presented as a range (50-**60%**).

Road Stream Crossing Failures- Road crossings at streams accounted for 42-**51%** of the ERFO sites, highlighting the sensitivity of this part of the landscape (Photo #8 & 97-27-6A). Most of these involved blockage of culverts and overtopping and partial or complete failure of fills. About **66%** (Figure 5) of the **debris mobilized** at culvert crossing sites was delivered to streams while the remainder either remained in the road prism, or was deposited on hillslopes below. From **2**-7% **generated debris flows**. From **22**-29% of stream crossing failures resulted in **drainage diversions** which caused gullies and fill failures downslope. This compares to 35% reported by Ledwith and others (1998). Further, **water diverted to the site** by the road contributed to failure in **16**-24% of the stream crossing failures. **Debris flows** originating upstream from the failed road stream crossing accounted for 23% of the road stream crossing failures. A larger pipe would probably not have prevented failure at these sites. Ledwith and others (1998) found 22% of their sample experienced debris flows originating upstream. Many of these debris flows were of such size and composition (containing large logs and boulders) that the culverts would have failed even if they were designed to handle a 100 year recurrence interval flow of water through the pipe. Debris flows eroded through the entire prism in some cases, such as at Walker Creek where road 46N61A was severed by a debris flow which formed a gully 100 feet wide and about 60 feet deep, mobilizing on the order 300,000 cubic yards of debris (Photos 4a & 4b). From **6-23%** of road stream crossings involved **landsliding**.

Landslides Away From Stream Crossings- Landslides away from stream crossings accounted for **18-26%** of ERFO sites. **Water diverted to the site** by the road was identified as a factor contributing to failure in 26-**41%** of the landslides. Common landslide types included slumps and earthflows which dropped the road prism inches in some places, and tens of feet in others (Photo #6). Some of these removed the entire road, and making it very difficult to re-establish the road without further destabilizing the landslide. This has important road access implications on some arterial roads. Landslides ranged from road-caused to road influenced, to unrelated to the road. Some landslides were induced by placement of rock and soil waste on the head of a dormant landslide such as observed in the Horse Creek Watershed (Salt Gulch) as well as in Grider and Walker Creeks. In addition to the ERFO sites classified as "landslides", landslide processes played a role at many of the other ERFO strata. For example, landsliding was involved in **6-23%** of the stream crossing failures, **18-9**1% of the fill failures, an unknown proportion of the stream undercuts, and **76-93%** of the cut bank failures (assuming those >35 cubic yards are "landslides"). In summary, landsliding played a role in about **34-6**1% of all ERFO sites.

Road Fill Failures Away From Streams- Road fill failures way from streams (Photo #5) accounted for **15-18%** of the ERFO sites. Fill failures **generated debris flows** in 11% of the second sample, but none in the initial sample. In some cases, only the shoulder of the road was affected but in others, the entire road surface was removed. **Diverted water** was identified as a factor contributing to failure in 32-**48%** of the road fill failures.

Stream Undercuts- Stream Undercuts accounted for 7-**8%** of ERFO sites (Photo #7). Some sites involved only 10's of cubic yards, while others involved thousands. Examples of stream undercutting occur along Beaver Creek, Elk Creek, South Fork Salmon River, Horse Creek, Scott River, and the Klamath River. In most cases, at least one lane of the road survived. A considerable volume of debris was delivered by this process along the South Fork Salmon River.

Road Cut Failures- Road cut failures away from streams accounted for 5-**6%** of ERFO sites. The primary slope processes were shallow slumping and debris sliding. As such, these could all be classified as landslides, but only those greater than 35 cubic yards were called "landslides" in data summaries. Failed material was typically deposited on the road surface, and ranged in volume from a few tens of cubic yards to many hundred cubic yards.

Gullies, Rills and Sheet Wash- Gullies, rills and sheet wash linked to water concentration and diversion accounted for only 1% of the ERFO sample. Rill and gully erosion is common at many of the ERFO sites, but only a few were classified in this category, since they also involved other types of failure. In many cases, they were caused by diversions at stream crossings. Failure of cross drains on in-sloped roads had similar but generally smaller adverse effects.

Flooding and Inundation- Flooding accounted for only less than 1% of the ERFO sample. This includes the effects of floodplain inundation, such as deposition of fine sediment, water damage, or channel scour. In most cases, the road itself did not influence the flooding. Exceptions occurred where large fills were placed on the floodplain, influencing flood behavior.

Results of Field Observations at ERFO Sites

In some watersheds, such as in parts of Elk Creek, roads were a prominent source of many small debris flows generated by fill failures. Some hard to fix landslides are being treated by fixing the immediate problem and making the road passable, but ERFO does not provide funding to fix the larger active landslide complex. Fill Failures in granitic terrane often had cascading effects.

Summary Observations For Roads

Based on air photo mapping, the road corridor experienced landslides at a rate 27 times the undisturbed rate. Stream Crossing and undercuts account for about 60% of ERFO sites.. Landslides are very important and some are very costly, repairs are complex, and the potential for failure is long term. Once a large landslide is activated, it is difficult to stop. Stream crossings (non-landslide) are generally simpler to fix, but can be just as costly. On the most sensitive geomorphic terranes, (active landslides, toe zones, inner gorges) avoidance with roads is often the best strategy.

The study conducted by Ledwith and others (1998) in the Lake Mountain area found that 40% of stream crossing failures were caused by sediment slugs, 22% by debris flows, 14% by hydraulic exceedence, and 10% by plugging with woody debris. They also found that a large proportion of culverts inventoried are designed for 25 year or smaller recurrence interval flows. These findings point out the importance of maintenance and the need to inventory for upgrading crossings as the opportunity arises.

Some of the 1997 road-related landslides are obviously road-caused, such as where the landslide occurs entirely within a road fill, or where a large road cut undermines a slope and triggers a slump. For others, the link is more tenuous, such as when road cuts, fills, and drainage effects are small relative to the size of the landslide. There were many toe zone landslides and fill failures.

Rock Pits, Waste Areas and Timber Landings

These features behave similar to roads and involve the same types of features on the landscape (fills, cuts, and surface drainage features). However, they are often much larger. As a result, they can have significant effects on flood processes. Field investigations revealed that some waste areas and landings initiated slumps and debris flows. As a consequence of the flood, it was found that there was a need for a large volume of rock (rip rap in particular) as well as areas to dispose of waste rock and soil. Landslides along Highway 96 during the 1997 flood and the 1998 landslide at Ti Bar caused an emergency need for suitable waste areas. Another emergency project, the capping of mining tailings from the Gray Eagle Mine in Indian Creek north of Happy Camp, created a demand for earth material. These periodic demands for waste disposal and borrow material with specific characteristics indicate a need for a Forest waste and borrow management strategy.

2. EFFECTS OF TIMBER HARVEST AND SITE PREPARATION

Effects of Vegetation Removal (Timber Harvest)

Vegetation removal in itself affects slope and channel hydrology as well as soil properties, and to a minor degree, mass balance. Most of these effects increase landslide potential, but some reduce it. Key factors which can increase landslide potential include loss of root support, reduction in evapotranspiration, and changes in snow accumulation and melt rate. Further, removal of trees and logs affects debris flow behavior in channels and on hillslopes. Field observations suggest that logged high elevation sites had a snow cover at the time of landsliding, providing a smooth surface for movement of debris. The effects of deforestation are described further ~~in the~~Appendix B Item VI.

Effects of Yarding, Mechanical Site Preparation, and Site Preparation Burning

Timber yarding involves the transport of timber from hillslopes with tractors, cables, or helicopters to truck landing sites. Tractor yarding on steeper ground sometimes requires constructed skid trails which are essentially small roads. Cable yarding is usually less disturbing to the soil, but can created gouges when logs are not suspended above the ground. Site preparation involves preparing a site for planting by removing logging slash and brush. On gentler ground is done mechanically, that is, it is piled with tractors. In some cases terraces are constructed on hillslopes to facilitate conifer regeneration, and these also are essentially small roads. On steeper slopes, site preparation is usually accomplished by burning. These practices affect slope and channel hydrology as well as soil characteristics. Refer to Appendix B Item VI for a description of these effects.

Effects Assessment

This assessment measured the distribution of 1997 landslides, ERFO sites, and flood-altered channels in harvested land relative to undisturbed land. "Harvested" land includes all regeneration prescriptions such as clearcut and shelterwood. Less intense prescriptions such as thinning are treated as "undisturbed". Young harvest consists of areas logged in 1977 or more recently. Old

Harvest indicates areas logged prior to 1977. Figure 11 shows the density and number of landslides, ERFO sites, and altered channels on harvested land. Note that on Figure 11, individual landslides may show up in several disturbance categories. For example, a landslide within a road corridor which is also in a burned area and logged area is counted in all three categories "double counted". The assessment also utilized field observations of landslides on harvested lands. It is important to recognize that the mere presence of a landslide within a harvested area does not necessarily mean that it was caused by the logging.

Active Landslides From Air Photo Inventory- A total of 275 landslides were identified on harvested land (37% of the total). Of these, 60 were on old harvest (pre-1977) and 215 on new harvest (Table 1, Appendix C.III.). The landslide density on undisturbed land, was 0.27. On harvested land as a whole, it was 1.86, while on young harvest (1977 or younger) it was 2.96, and on old harvest (prior to 1977) it was 0.80 Thus, landslide density on new harvest was 11 times the undisturbed rate (2.96/0.27 = 11.0), and on old harvest, it was 3 times the undisturbed rate (0.80/0.27 = 3.0). However, these figures include all of the landslides visible on air photos, and those near roads may well be road-caused. Discounting landslides within the road corridor and burned areas, there were, 99 landslides in harvested areas (13% of the total), with 25 in old harvest, and 74 on new harvest (Table 4). Landslide densities exclusive of road corridors and burned areas are: All harvest = 0.89; New harvest = 1.61; Old harvest = 0.39. Thus, the average for harvested land was 3.3 times the undisturbed rate (0.89 / 0.27 = 3.3), for new harvest, it was 6 times the undisturbed rate, (1.61 / 0.27 = 6.0), and for old harvest, it was 1.4 times the undisturbed rate (0.39 / 0.27 = 1.4). A further breakdown of landslides outside the road corridor (but including overlap with burned areas) by plantation age revealed the following landslide densities: **(1)** 30-40 years = 0.45; **(2)** 20-30 years = 0.58; **(3)** 10-20 years = 0.95; **(4)** 0-10 years = 2.32. The fact that landslides are easier to map in open harvested versus timbered areas influences these results. See Figure 11 and Tables 1-4 for additional information.

ERFO Site Data- A total of 927 ERFO sites were evaluated (Table 2), and 227 of these occurred in harvested areas (24%). Of these, 96 were in old harvest units, and 131 in new harvest units. The density of ERFO sites (sites per square mile) on the west side of the forest was 0.37, within the photo study area it was 0.62. On undisturbed land (not harvested, not burned in high or moderate intensity fire) within the photo study area, it was 0.50. In harvested land on the west side of the Forest, it was 1.01 with little difference between new and old harvest (1.09 and 0.91 respectively). Thus, the density of ERFO sites in harvested areas (new and old) on the west side of the Forest was about 2 times the undisturbed land rate (1.01 / 0.5 = 2.02). See Table 2. Interpretation of these figures needs to take into account factors such as the fact that plantations are almost always accessed by roads, making roads more common there than in the rest of the landscape, and all ERFO sites are along roads. Thus, the high density is likely influenced by the road-related landslides in harvested areas.

Altered Channel Data From Air Photo Inventory- The average density (miles per square mile) of altered channels within the photo study area was 0.37. Altered channel data by harvest area may not be too useful since new harvest units typically exclude streams (buffers), making it unlikely that streams and debris flow tracks will overlap with young harvest units. Density was 0.28 in harvested areas (0.38 in young harvest, and 0.18 in old harvest), and 0.38 in non-harvested areas. Thus, the density in harvested land was lower than in undisturbed land, or 0.7 times the rate in non-harvested land (0.28/0.38 = 0.7).

Field Sampling- During the course of field sampling, many landslides were seen in harvest units, including shallow soil mantle debris slides to deep slumps and earthflows. Many of the large debris slides which generated debris flows originated on the toe zones of slump and earthflow deposits.

Summary For Harvest Effects- Harvested areas contained 37% of all landslides identified on air photos (13% if road corridor landslides are excluded). The landslide density on harvested land was 7 times the rate on undisturbed land (3 times if road corridor landslides are excluded). The rate for new harvest (1977 or younger) was 11 times the undisturbed rate (6 times if road corridor landslides are excluded). A total of 227 ERFO sites occurred on Harvested land (30% of the total), and ERFO sites were about 2 times more dense in harvested areas than on undisturbed land. Altered channels were less dense in harvested areas than in unharvested areas (the rate in harvested land was 0.7 times the undisturbed rate).

3. EFFECTS OF FIRE

The effects of high and moderate intensity fire are similar those of regeneration timber harvest accompanied by site preparation burning of logging slash. Refer to the timber harvest section for further information on this topic. Table 1 individually tracks high, moderate and low intensity burn for fires dating back to 1977 (most of the burned areas in the study area burned in 1987). Table 4 lumps high and moderate intensity as "burned", and low intensity as "unburned". Areas burned at low intensity are treated as unburned. The data on fire intensity is derived from the **Fire Intensity Layer**, which was developed by the Klamath Forest from photo-interpretation of post-fire air photos. High intensity is defined as an area where fire kills all above-ground vegetation (some species re-sprout from the roots after being burned) and also burns out the crowns of vegetation. Moderate intensity is defined as an area where fire kills all or most of the above ground vegetation, but the crowns remain unburned, and trees retain needles and leaves. Low intensity burn includes where fire killed only a small proportion of the vegetation. It is important to note that a brush field burned by a crown fire is classified the same as timber stand burned by a crown fire (high intensity). Obviously, the ground level temperatures in these two examples would be different. The primary differences between timber harvest and wildfire are: (a) Wildfire usually does not involve any ground disturbance (unless caused by fire suppression activities); (b). Wildfire typically leaves large standing trees. Some areas which burned at high intensity in 1987 were re-burned at high intensity several years later in order to prepare the site for planting conifers. However, no data on the distribution of these prescribed burns were available at the time of this assessment.

Effects Assessment

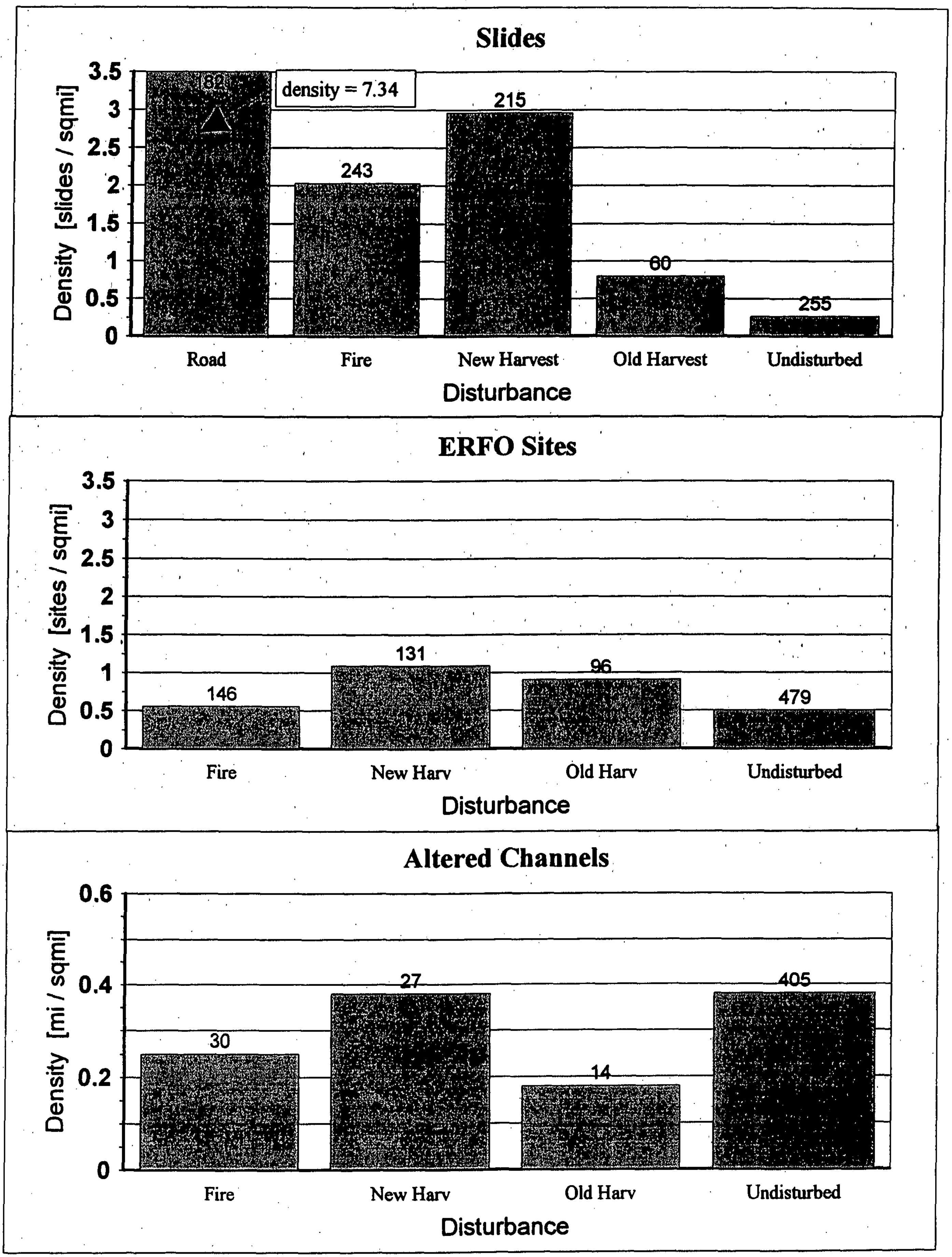
This assessment examines the possible effects of fire on flood processes by measuring the distribution of 1997 landslides, ERFO sites, and flood-altered channels in burned areas relative to undisturbed land. Figure 11 shows the density and number of landslides, ERFO sites, and altered channels on burned lands (data are from Table 4). Field observations of landslides and ERFO sites in burned areas were also utilized. It is important to recognize that the mere presence of a landslide within a burned area does not necessarily mean that it was caused by the fire.

Active Landslides From Air Photo Inventory- A total of 429 (58% of the total) landslides mapped by photo inventory were within the fire perimeter (Table 1). Of these, 243 were in areas burned at high or moderate intensity, and 186 in low intensity. Landslide densities (landslides per square mile) were 2.03 in High/Moderate intensity, 1.21 in low intensity, and 1.56 averaged in all intensities. This compares to a density of 0.27 for undisturbed land. Thus, landslide density in areas burned at high and moderate intensity was about 8 times the undisturbed rate (2.03/0.27 = 7.5), and low intensity about 5 times the undisturbed rate (1.21 / 0.27 = 4.5). All the previous density figures include landslides in the road corridor. If these are removed from the totals, the density for lands burned at high and moderate intensity becomes 1.58 (data from Table 4), or about 6 times the undisturbed rate (1.58/0.27 = 5.9). Granitic and landslide geomorphic terranes displayed a considerable increase in landslide density in comparing burned to unburned conditions. Burned granitic terrane displayed a density about 16 times (Table 4) the undisturbed rate (2.54/.163 = 15.6) for that terrane. Landslide terrane burned at high or moderate intensity exhibited a rate about 9 times the undisturbed rate (2.79/.32 = 8.7). These figures do not include road corridor landslides. Interpretation of these figures needs to take into account factors such as the higher visibility of landslides on air photos within burned areas than in the forested landscape.

ERFO Site Data- A total of 146 ERFO sites (16% of the total) were identified in areas burned at high or moderate intensity. The average density of ERFO sites (sites per square mile) on the west side of the Forest (1.6 million acres) was 0.37, within the photo study area (0.77 million acres), it was 0.62. The density of ERFO sites on undisturbed land (not harvest, not high or moderate intensity fire) in the photo study area was 0.50. On burned land (high or moderate intensity) it was 0.56. Thus, for lands burned in the 1987 fire, the density of high and medium intensity on the west side of the Forest is 0.79, and for high and moderate intensity burned land on the entire west side (including fires of 1977 and 1994), it is 0.56. Thus, the density of ERFO sites in lands burned in 1987 was about 2 times the undisturbed rate (0.79 / 0.50 = 1.58) rate for the air photo area. The density for all fire is nearly identical to the unburned rate (0.56 / 0.50 = 1.1). See Table 2, Appendix B III.C.

Altered Channel Data From Air Photo Inventory- The average density (miles per square mile) of altered channels in the photo study area was 0.37. In non burned areas, it was 0.28, and 0.68 in burned areas (1.01 in low intensity burn, 0.25 in high/moderate intensity burn).
The density of altered channels in burned areas was 2.4 times the rate in undisturbed lands (0.68/0.28 = 2.4). The rate in areas burned at high/moderate intensity was actually lower than unburned areas (0.90 times the unburned rate (0.25/0.28 = 0.90). This could be due to the fact that much of the altered channels consisted of lower reaches, and fire often burns at lower intensity there (Map 9).

FIGURE 11


Slides
Density [slides / sqmi]
3.5
3
2.5
2
1.5
1
0.5
0
82
density = 7.34
243
215
60
255
Road
Fire
New Harvest
Old Harvest
Undisturbed
Disturbance
ERFO Sites
Density [sites / sqmi]
3.5
3
2.5
2
1.5
1
0.5
0
146
131
96
479
Fire
New Harv
Old Harv
Undisturbed
Disturbance
Altered Channels
Density [mi / sqmi]
0.6
0.4
0.2
0
30
27
14
405
Fire
New Harv
Old Harv
Undisturbed
Disturbance

Results of Field Observations- Anecdotal information suggest that many of the large debris slides occurred in areas which burned at high or moderate intensity in 1987 wildfires. Similar to harvested areas, the mere presence of landslides in burned areas does not necessarily mean that the burn caused the landslide.

Summary Assessment For Fire- Areas burned at high and moderate intensity had about 8 times the density of landslides as undisturbed land, but if road corridor landslides are removed, the rate was 6 times the undisturbed rate. ERFO sites are about 2 times as dense on areas burned at high or medium intensity in 1987, but if all fires since 1977 are considered the rate is only 1.1 times the undisturbed rate. Altered channels exhibited a density in burned lands (average for all intensities) which was 2.4 times that in undisturbed lands. The rate in areas burned at high/moderate intensity was lower than that in undisturbed areas (0.9 times).

D. INTERACTIONS BETWEEN PHYSICAL AND HUMAN FACTORS; VARIATIONS IN EFFECTS BY WATERSHED

The patterns of landslides and altered channels evident on the landscape are assuredly the result of multiple interacting factors such as antecedent moisture conditions, snowpack, local storm intensity, bedrock geology, geomorphology, slope gradient, elevation, and disturbances to the soil and vegetation such as by fire, timber harvest, and road construction.

The highest landslide densities (landslides per square mile) were observed with certain combinations of physical factors and disturbances. For example, dormant landslide terrane at elevations from 4,000-6,000 feet, and burned in wildfire at high or moderate intensity exhibited a density of 7.4 (Table 4). In the Walker Creek watershed, areas with this same combination of attributes had a landslide density of 13.4 (Table 7). In Tompkins Creek, it was 16.3 (Table 6), and in Elk Creek it was 1.3 (Table 5). Road corridors (within the entire air photo area) on landslide deposits at elevations of 4000-6000 feet exhibited a landslide density of 11.51. In Walker Creek, the density for these same attributes was 91.87 (Table 7; Map 17). However, as more variables are considered, the sample size rapidly grows smaller, reducing the statistical validity of the results.

Tables 5-7 (Appendix B Item I) contain landslide densities for Elk, Walker, and Tompkins by elevation zone, by geomorphic terrane, by disturbance class (road/harvest/fire). The landslide density (landslides per square mile) **within the road corridor** by geomorphic terrane is as follows: **Terrane #1**- Density-34.0, Number of Landslides-10; **Terrane #2**- Density-3.9, Number of Landslides-1; **Terrane #3**- Density-6.4, Number of Landslides-55; **Terrane #4**- Density-20.4, Number of Landslides-3; **Terrane #5**- Density-13.4, Number of Landslides-29; **Terrane #6**- Density- 10.3, Number of Landslides-9; **Terrane #8**- Density-4.7, Number of Landslides-42; **Terrane #9-**, Density-8.2, Number of Landslides-6; **Terrane #10**- Density-25.2, Number of Landslides-10; **Terrane #11**- Density-12.3, Number of Landslides-16; **Terrane #12**- Density-0, Number of Landslides-0; **Terrane #13**- Density-0.8, Number of Landslides-1 (Table 4). Clearly, roads on previously active landslides (#1), steep granitic lands (#4), and granitic inner gorges (#10) have the highest density of landslides. The previous figures are for the photo study area.

Map 10 demonstrates how landslide terrane was a primary source for 1997 landslides and debris flows in Walker, Tompkins, Grider, Deep, and Kelsey Creeks. However, few landslides or ERFO sites are visible in granitic terrane (plutons) in these watersheds. **Map 11** shows 1997 landslides and ERFO sites similarly concentrated in landslide terrane in Thompson, and Indian Creeks. Concentrations are also evident in granitic terrane in the East Fork of Indian Creek. **Map 12** shows many landslides, ERFO sites, and altered channels in the granitic terrane of McCash, Independence, Titus, and the lower reaches of Elk Creek, near its confluence with Bear Creek.

V. CONCLUSIONS: PHASE I

Summary conclusions are presented first, followed by specific topics, and general conclusions last. Additional rationale for conclusions is provided for some of the conclusions in Appendix B item VI under the same headings.

Summary

Three primary conclusions are drawn, all of which have direct implications to future management of the Klamath National Forest. These are: **(1) Sensitive Lands-** Certain land types displayed particularly high landslide and debris flow rates under flood conditions; **(2) Roads-** Of the typical forest management practices, roads exhibited the largest directly observable effects on flood processes; **(3) De-vegetation-** Widespread de-vegetation of some watersheds by a combination of wildfire and timber harvest was associated with high rates of landslides and debris flows, particularly when it occured on sensitive land types.

These three conclusions point toward changing some past management practices and keeping (reinforcing) others **(Adaptive Management)**. This report offers recommendations which will greatly reduce the cost of repairing roads in future floods, and also greatly reduce the adverse watershed effects caused by forest management. Many of these practices are already in effect, and full application is recommended.

1. Sensitive Lands- A disproportionate number of landslides and damaged road sites occurred on certain geomorphic terranes: previously active landslides; inner gorges, portions of older landslide deposits, particularly toe zones; and dissected granitic terrane. This pattern affirms the classification of much of this land as Riparian Reserve due to its instability. **Adaptive Management** practices which would address this issue include accurately delineating sensitive lands (a subset of Riparian Reserves), developing desired conditions for these lands, and managing toward these desired conditions.

2. Roads- Roads experienced a disproportionate number of landslides, particularly on previously active landslides, inner gorge slopes, and on older landslide deposits. About 60% of ERFO sites (those qualifying for Emergency Relief, Federally Owned funding) involved stream crossings or where the road was near a stream. Road-related landslides contributed to overall flood effects. Failure of road fills was a common problem. The technology exists to greatly reduce the adverse effects of roads in future floods. **Adaptive Management** practices to accomplish this include continuing and improving on a concerted program for fixing ERFO sites in a way which reduces the risk of failure in future storms (see **Appendix C Guidelines**, attached) and inventorying problem roads in order to prioritize upgrading, decommissioning, and maintenance in a way which maximizes watershed benefits.

3. **De-vegetated Areas-** Harvested or burned areas experienced a high density of landslides, and were the sites of origin of many large debris slides and debris flows, particularly on sensitive geomorphic terranes. **Adaptive Management** practices which would address this issue include conducting timber management, fire suppression, and prescribed fire in a way which emphasizes keeping vegetation on sensitive lands.

Precipitation and Stream Flow

4. **Magnitude of the 1997 Flood-** The 1997 Flood was a significant event, similar to the flood of 1974. However, its effects were much less severe and less widespread than the flood of 1964, which is the largest on record in this area.
5. **Cells of Intense Precipitation-** Local cells of intense precipitation probably developed and had a strong influence on the concentration of flood effects in localized areas. However, evidence supporting this conclusion is limited. Further investigation of doppler radar data may yield useful information.

Roads, Landings, Rock Pits & Waste Areas

6. **The Effect of Roads on Landslide Rates-** Roads obviously had a large effect on flood processes. About 25% of all landslides identified on air photos (182) occurred in the road corridor, and the landslide density (landslides per square mile) in road corridors was about 27 times that on undisturbed land. However, this association does not confirm cause/effect relationships, since densities were derived by a GIS query which identified all landslides within a certain distance of a road, and systematic field-based assessments of causes were not conducted in Phase I.
7. **Contribution of Road-Related Landslides to Total Sediment-** Information is not presently available to quantify the actual sediment volume, nor the length of channel altered by road-related landslides. This will be addressed in the Phase II flood assessment.
8. **Interactions Between Roads and Flood Processes-** Some clear patterns were identified regarding the effects of the three road components **(fills, cuts, and surface drainage)** on flood processes. Roads had considerable effects on channel and hillslope **hydrology**, **soil properties**, and **mass balance**. Fills and sidecast are very important, and they are usually controllable. These effects were expressed in different ways in different geomorphic settings. Roads interacted most with flood processes in the **vicinity of streams**, on older **landslide deposits**, and on **steep mountain slopes** (road fill failures). Where multiple roads crossed the same hillslope, they often interacted hydrologically (water concentrated by an upper road affecting a road downslope), producing cumulative effects. Many culverts failed and a large proportion were found to be sized for storms with recurrence intervals of less than 25 years. This emphasizes the importance of maintenance, and inventorying of potential road problems. Laser generated DEMs show promise in better mapping potential problems such as unstable fills and stream crossings.
9. **Mitigation of Road Effects-** Relatively simple and effective mitigation measures were identified as part of this assessment which can remedy many of the adverse effects of roads on flood processes. However, in some settings, avoidance of the site is the only effective mitigation. These mitigation

measures are contained in **Appendix C** of this report, "Road Guidelines".
10. Rock Pits, Landings, and Waste Areas- Rock pits and waste areas often involve very large cuts and fills (up to several hundred thousand cubic yards) and have the potential to destabilize hillslopes and alter drainage patterns. The large fills associated with landings and waste areas initiated a number of landslides. The flood of 1997 created a need for large volumes of rock and earth material as well as for waste areas to dispose of landslide debris. This is a long term issue, with demand for rock peaking during landslide events such as in 1997, and associated with large individual landslides such as the Sisters Landslide and Ti Bar Landslides on Highway 96 between Happy Camp and Somes Bar.

Timber Harvest and Fire

11. The Effect of Timber Harvest and Fire on Landslide Rates- De-vegetated areas (logged areas or areas burned at high to moderate intensity) experienced landslides at a rate 6 times that of undisturbed land (exclusive of landslides in road corridors). This association strongly suggests that de-vegetation increased landslide potential, but does not establish a cause/effect relationship. Field observations of higher elevation clearcuts suggested that the smooth, snow-covered surface of the logged areas facilitated the movement of debris flows across gentle topography. Landslides in logged and burned areas were concentrated on toe zones and colluvium filled hollows. Laser generated DEM's show promise to better identify these features.
12. Contribution of Landslides Originating in De-vegetated Areas to Total Sediment- Information is not presently available to quantify the actual sediment volume originating in de-vegetated areas.

Flood Processes and Effects Patterns

13. Toe Zones in Headwater Areas as Primary Debris Flow Initiation Sites- Landslides originating on toe zones high in steep watersheds generated many large debris flows. These debris flows mobilized channel bed material, and had very large effects on downstream channels. Shallow debris slides in colluvium-filled hollows in headwaters also generated debris flows, but usually smaller than those from toe zones. In several cases, debris flows from toe zones were able to cross low gradient flats before reaching well-defined high gradient channels.
14. Predicting Landslide Sites- Many of the 1997 landslides occurred in areas with well-defined landslide features, such as on toe zones with well-fined slope breaks or on steep swales with clearly defined boundaries which would have identifiable as having a high landslide potential prior to the flood. However, some occurred in areas where evidence of previous landsliding was subtle, and poorly-defined, and it would have been difficult to have predicted a landslide of the magnitude which occurred at the site in 1997. Examples of debris slides in poorly defined swales were observed at McCash and Deep Creeks where debris slides occurred on 55% slopes. Similarly, subtle slump features were reactivated in Tompkins and Grider Creeks.
15. Variations in Effect Patterns by Watershed- Damage in some watersheds was dominated by road-related landsliding, while in others, the primary channel alteration was initiated by landslides in burned or undisturbed areas (Table 5 Appendix B).

Effects of the Flood on Fish Habitat

16. Channel Characteristics- Channels with the greatest flood effects exhibited considerable shallowing, filling of pools, widening of the channel, and increase in finer substrate particles.. These streams lost all fish eggs present in the channel in January, and the associated fish.
17. Temperature- Channel widening, shallowing, and loss of riparian vegetation led to summer water temperatures increases in Elk Creek, and possibly other affected streams. Systematic analysis of temperature changes on other streams is needed.

Physical Factors & Interactions Influencing the Flood

18. Flood Effects and Interactions- There is a strong correlation between the distribution of flood effects (landsliding and road damage sites) and physical attributes of the landscape. This was particularly true with geomorphic terrane, and elevation, and to a lesser degree with slope, and aspect.
19. Combinations of Factors- Pre-flood disturbance to the soil and vegetation (roads, harvest, fire) exerted considerable influence on flood effects. Areas of concentrated de-vegetation and roads likely experienced cumulative effects, or the results of multiple individual effects that accumulated over time and space.
20. Threshold Conditions- Field observations revealed that all types of landslides (shallow debris slides, deep-seated slumps and earthflows and debris slides on road fills) occurred together in watersheds like Walker and Tompkins Creeks. This suggests that high groundwater conditions were attained at a variety of depths.

General

21. Limitations of This Assessment- This assessment compares landslide density (landslides per square mile) in undisturbed areas to those in roaded, logged, and burned areas. It does not quantify the effects of landslides originating on the different lands, nor does it establish cause/effect relationships.
22. Extrapolation of Findings to Other Areas- Findings regarding the effects of roads on landslide and erosion processes have widespread application to the entire Klamath Mountains Province, and to the Pacific Northwest. However, findings regarding the effects of geologic and physiographic factors on landslides and erosion have more limited application.
23. Opportunities- Opportunities exist to learn from the 1997 flood, fix damages to roads in a way that they will be much more likely to survive future floods. This same information can be applied to new roads and decommissioning opportunities as well as to vegetation management. Other opportunities include: conducting joint flood research with other agencies and organizations, establishment of high elevation precipitation gages, and maintenance or increasing the number of stream gages.

24. Data Sources- Small scale air photos and damage site reports for individual ERFO sites constitute some of the best and most efficient data for assessing effects of a flood such as this one.
25. Future Flood Effects- Future floods are likely to display the same patterns of concentrated landsliding in road corridors and de-vegetated areas as presented here. Similarly, steamside areas as well as certain geomorphic terranes such as inner gorges, landslide deposits, toe zones, and dissected granitic terrane are likely to experience a large proportion of the effects. However, it is very likely that the elevation zones and possibly slope aspects experiencing the most effects will vary by storm in the future as they have in the past.
26. How We Can Influence Effects of Future Floods- The pattern of concentrated flood effects and damage to roads could be significantly altered in future storms if: (a) The road guidelines being recommended in this report (Appendix C) are applied to ERFO fixes and also to new roads, road upgrading, decommissioning, and maintenance; (b) Vegetation management guidelines recommended here are applied.

VI. RECOMMENDATIONS

Recommendations are offered under the same headings as used in the Conclusions section.

Summary

1. **Sensitive Lands- (a) Identify** and delineate sensitive lands (Riparian Reserves) at the watershed (during Watershed Analysis) and site levels (when projects are done). Utilize sound proven tools such as topographic maps, 30 meter digital elevation models (DEM), air photos, and field investigations as well as new developments such as high resolution laser-generated DEM's; **(b) Develop** vegetative and soil objectives for Riparian Reserve lands; **(c) Manage** Riparian Reserves toward obtaining the stated objectives.

2. **Roads-** (a) Repair ERFO sites in accordance with guidelines in Appendix C of this report; (b) Decommission high risk, un-needed roads; (c) Focus road maintenance where most needed to prevent watershed damage, and with attention to repairing road drainage and diversion problems; (d) Avoid unstable lands when new roads are constructed, and utilize state of the art geotechnical techniques in landslide terrane and at stream crossings; (e) Place special attention on constructing stable fills, whether for ERFO repair, new roads, waste areas, landings, etc.; (f) Initiate a process for inventorying high risk road segments and sites; (g) Prioritize road repair, upgrading, maintenance, and decommissioning projects on a watershed basis to maximize the benefit to aquatic resources; (h) Seek funding from multiple sources.

3. **Vegetation Management- (a)** Assure that **timber harvest** avoids unstable lands and other Riparian Reserves by utilizing skilled technical personnel during field layout; **(b)** In **combating wildfire**, employ strategies to minimize the amount of high and moderate intensity fire on Riparian Reserves; **(c)** Design **prescribed fire** to avoid high and moderate intensity fire on Riparian Reserves.

Precipitation and Streamflow

4. **Doppler Radar-** Continue Doppler Radar investigation to see if areas of higher precipitation can be identified.
5. **Stream Gages-** Continue or add stream gages to the existing network..
6. **Precipitation Gages-** Establish high elevation precipitation gages in cooperation with other agencies and Forest Service Functions (fire). We need such gages to understand how intensities influence flood effects.
7. **Map of Peak Flood Levels-** Prepare a simple map and photographs showing maximum water levels which occurred during the 1997 flood on the Klamath River and some major tributaries.

Roads, Landings, Rock Pits, and Waste Areas

The Forest Watershed & Fisheries and Engineering groups are developing guidelines and recommended management practices for: **(1)** Road **decommissioning**; **(2) Inventorying** potential sedimentation problems on roads and prioritizing them for repair; **(3)** These efforts, along with the **ERFO repair guidelines** developed by the Phase I flood assessment and presented here **(Appendix C)** will provide sound guidance for minimizing road-related watershed problems on the Forest in the future. The guidance from these three sources will need to be thoroughly integrated, and updated as new information and mitigation measures become available.

8. Appendix C Guidelines- Apply Road Guidelines (Appendix C, this report) to all ERFO repairs and to future road construction, decommissioning, and maintenance. Combine these guidelines with those being developed for decommissioning projects and inventory of potential road erosion sites. A brief summary of **Appendix C Guidelines** follows:

APPENDIX C: SUMMARY

(a) General Recommendations-
In repairing damaged roads: (1) Maintain or improve the stability of the site. ~~Avoid~~ actions which destabilize the site or increase the potential for adverse watershed effects; (2) Address all important factors which contributed to the failure; (3) Consider relocation or abandonment as an option on all sites in unstable areas or other types of Riparian Reserve. In most situations, avoidance of unstable areas is the best policy.

(b) Recommendations for Road Components (Fills, Cuts, Surface Drainage)-
(1) **Road Fills-** Assess foundation stability, and design and construct strong, stable fills, including reinforcement and drainage as appropriate; armor fills subject to overtopping. Minimize fill size, and also, the fine particle component of the fill which is susceptible to erosion. Avoid sidecasting on steep slopes where the potential for slope failure of sedimentation exists.
(2) **Road Cuts-** Stabilize road cuts (buttress or horizontal drains) which are prone to failure and consequences of failure are high.
(3) **Road Surface Drainage-** Outslope roads and eliminate inside road ditches unless a site specific need for a ditch is identified. Install positive dips and water bars on long, uninterrupted road segments with multiple cross drains to prevent failure of road ditches along in-sloped roads. Prevent stream diversions.
(4) **Cumulative Effects-** Reduce road density (decommissioning) in areas where multiple roads cross hillslopes and interact hydrologically.

(c) Recommendations for Specific Geomorphic Settings-
(1) **Stream Environment-** (1) Minimize the number of road stream crossings (particularly multiple crossings on the same stream) and length of road on floodplains or paralleling streams. (2) At stream crossings, maintain the natural channel geometry (horizontal and vertical) within road design

constraints. Size culverts for 100 year events. (3) Design crossings to accommodate 100 year flows and debris flows. In the event of debris flows, they should: (a) Survive overtopping without failing catastrophically; (b) Minimize the contribution of fine sediment to the stream; (c) Avoid causing stream diversions; (d) Minimize the volume of sediment which would be trapped upstream of the crossing if the culvert fails; (4) Roads paralleling streams should minimize constrictions to the channel and facilitate natural floodplain inundation. (5) Roads susceptible to stream undercut should be armored.

(2) **Landslide Deposits-** Minimize the length of roads in this environment, particularly on active portions and toe zones. Roads in landslide deposits should maintain favorable mass balance (fostering stability of the slope), avoid placing fills on heads of slumps, avoid cuts on toe zones. They should also maintain natural drainage patterns, and avoid diverting off-site water to unstable parts of the landslide.

(3) **Steep Mountain Slopes-** Minimize the number and size of fills on steep mountain slopes particularly those on sandy soils in topographic swales with evidence of groundwater. Where avoidance is not possible, make the design responsive to site conditions, including compaction, reinforcement, subsurface drainage. Avoid sidecasting. Minimize high road cuts into areas with unconsolidated deposits, evidence of shallow groundwater, or adverse structural features in bedrock. Where avoidance is not possible, cuts should be buttressed or drained as appropriate. This is particularly true where failures could deliver sediment to streams, or obstruct road surface drainage.

9. Future Road Management (New Construction or Upgrading, Decommissioning, Maintenance, Prioritizing for Restoration)- The following recommendations should be applied to future management of the road system.

(a) New Construction- Avoid unstable areas as the preferred mitigation measure. Ridge top settings are generally most stable. Where this is not possible, apply state of the art geotechnical techniques to assure that the road does increase the risk of landsliding.

(b) Decommissioning- Use decommissioning as a tool to remove those roads with little utility to the transportation system and with the greatest potential for adverse watershed effects, both at the site specific level, and in terms of cumulative effects.

(c) Maintenance and Upgrading- Since many ERFO sites were associated with culvert failure, maintenance of these structures is essential Maintenance and upgrading should be focused in areas with the following characteristics: (1) Roads with the greatest need as part of the transportation network; (2) Roads posing the highest environmental risk in high value watersheds; (3) Roads with problems which are known or can be easily located; (4) Roads with problems which are fixable and with a high cost/benefit ratio. Corrective measures with the highest likelihood of success include reducing the risk of fill failures by reinforcing and draining them, reducing the risk of stream diversions at road stream crossings by lowering fill height, dips in the road etc., reducing the risk of culverts clogging by modifying the collecting basin, reducing the risk of long road ditches diverting and concentrating water by installing prominent dips, and reducing the risk concentrated surface runoff by outsloping.

(d) Inventory For Restoration Sites- Inventory should be focused in areas with the same characteristics as those described above under Maintenance and Upgrading (item c, above). Recent work on the Klamath National Forest (Ledwith and others, 1998) revealed that while it was not possible to predict which stream crossings were going to fail in 1997, it was possible to accurately predict consequences of such failures. This argues that we inventory fills and landings with the greatest potential for adverse effects (such as affecting multiple road crossings downslope), identify undersized culverts, and prioritize for repair. A good example of such an inventory project is: **Road/Stream crossing Inventory & Risk Assessment**, Klamath National Forest, November 5, 1998, a contract proposal submitted by the Klamath National Fores to the California Department of Fish and Game.

10. Rock Pits & Waste Areas- Develop a Forest inventory of rock pits in particular, identifying rip rap sources. Identify (Interdisciplinary Team) potential waste areas in the Happy Camp to Somes Bar corridor of the Klamath River, adjacent to Highway 96. A process is underway, but needs to be completed. Inventory landings with potential to generate landslides. Conduct geologic investigations, including stability analyses as needed for rock pits and waste areas, attaining favorable mass balance, and drainage configurations. Design final configuration of the slope and re-vegetate as appropriate.

Timber Harvest & Other Vegetation Management

11. Vegetation Management- In Riparian Reserves, develop and apply vegetation management objectives and guidelines for unstable lands and other types of Riparian Reserve. **Outside of Riparian Reserves**, apply the following vegetation management guidelines: Avoid regeneration harvesting and intense site preparation fire on landslide deposits and granitic terrane over large contiguous drainage areas. This can be accomplished by utilizing skilled earth scientists during layout. Avoid denuding discrete swales which may be prone to debris slides in granitic terrane. Avoid de-vegetation of large contiguous area of landslide deposits, particularly within the same local hydrologic catchment. Maintain down logs to interact with future debris flows, in balance with desired fuel loading. Review pre-existing timber sales and find whether trees are marked within Riparian Reserves associated with landslides and altered channels associated with the 1997 flood. Use this process to refine Riparian Reserve mapping.

Fire & Fuel Management-

12. Fire Suppression & Fuel Management- During fire suppression of wildfire, take aggressive steps to prevent high and moderate intensity fire in landslide deposits, dissected granitic terrane, inner gorge, and other unstable land. Apply watershed skills in the Resource Advisor role during suppression. During prescribed burns, prevent high and moderate intensity fire on landslide deposits and toe zones and dissected granitic lands (particularly the swales) by appropriate mitigation measures such as pre-burning or hand piling fuel accumulations in these areas. This requires some field delineation of unstable lands such as toe zones and dissected granitic lands where there is a high risk of intense prescribed fire. Apply vegetation management guidelines developed for Riparian Reserves.

Fish Habitat

13. Fish Habitat Improvement Structures- Systematically assess the response of fish habitat improvement structures to the flood of 1997, and develop recommendations for future placement, maintenance, and monitoring as appropriate. Recommendations on monitoring of temperature and channel conditions are found below under "Monitoring".

Phase II Flood Assessment

Incorporate the following items into the Phase II Flood assessment:

14. Cause/Effect, Geomorphic Mapping, Cooperation- Determine which landslides are actually road-caused by detailed investigation in sample watersheds. Refine geomorphic mapping and digital elevation data. Coordinate with adjacent Forests in Phase II of the flood assessment in order to develop adaptive management recommendations which apply Province-wide.
15. Sediment Volumes- Determine the proportion of sediment which originates in, harvested areas, burned areas, and undisturbed areas, how much is road-related in some sample watersheds, and how much large wood was delivered.
16. ERFO Site Damage Site Reports- Stratify all the remaining ERFO Damage Site Reports by type, contributing factors and effects.
17. Sediment Model- Test the Klamath Forest Landslide Sediment Model.
18. Develop a Strategy for Future Floods- Set up a framework for addressing future floods which would include cooperation with adjacent forests. Develop a Damage Site Report form which would incorporate information allowing queries about cause/effect, sediment volumes etc., and could be applied across Forest boundaries. This would require standardized terminology.
19. Use of Laser DEM as a Tool to Delineate Riparian Reserves- Evaluate the utility of using high resolution laser-generated DEM's to delineate Riparian Reserves, particularly toe zones and colluvium filled hollows..

Research

20. Cooperation- Cooperate with USGS and PSW (Riverside Fire Sciences Lab) on fire research and seek funding for joint projects. Cooperate with University of California Berkeley, Region Five (Pleasant Hill Engineering Center) and PSW (Redwood Sciences Laboratory) on Sediment Routing (Walker Creek), and refinement of toe zone and dissected granitic terrane mapping.

Monitoring

21. ERFO Sites- Design and implement a monitoring plan (coordinated with on-going BMP monitoring) for ERFO repair addressing: Design; Implementation (Appendix C Road Guidelines); Effectiveness. Monitoring should address success in making the road system resistant to future storms, and success in minimizing adverse watershed effects. Also, success of landslide stabilization

measures
22. Decommissioning- Design and implement a monitoring plan to address decommissioning progress and success in response to future storms.
23. Channel Recovery- Design and implement a monitoring plan on the Forest to address stream channel and habitat evolution. Re-run profiles in Indian, Canyon, Tompkins, Walker, and Grider Creeks.
24. Fish Assemblages- Continue implementation of a plan to address post-flood fish assemblage response.
25. Temperature- Systematically collect and analyze existing temperature data for critical streams. Continue to monitor stream temperature as channels re-vegetate, particularly in Elk, Indian, Tompkins, Upper South Fork Salmon River.
26. Re-vegetation- Monitor rate and character of natural re-vegetation with photo points.

VII. CONTRIBUTIONS FROM OTHERS; REMOTE SENSING DATA

A. CONTRIBUTIONS FROM OTHERS

The following individuals contributed to this report. The nature of their involvement is described in Appendix A (Methods: Contributions From Others).

Klamath National Forest- Richard Ashe, Ken Baldwin, Bill Bemis, Jim Blanchard, Larry Brahmsteadt, Nels Brownell, Rick Claypole, Cal Conklin, Juan de la Fuente, Jim Davis, Orion Dix, Don Elder, Pat Garrahan, Brent Greenhalgh, Jon Grunbaum, Polly Haessig, Bob Jester, Jim Kilgore, Jim McGinnis, Dave Jones, Al Olson, Brenda Olson, Jim Kilgore, Sharon Koorda, Tom Laurent, Dave Payne, Jay Power, Ed Rose, Harry Sampson, William Snavely, Allen Tanner, Richard Van de Water, Roberta Van de Water, Bob Varga, Gene Virtue.

Geotechnical and Civil Engineers US Forest Service Region 5- Bill Huff, Pleasant Hill Engineering Center, Ken Inoye, Pleasant Hill Engineering Center, Gordon Keller, Plumas National Forest, Jim Mckean, Pleasant Hill Engineering Center, Richard Wisehart, Stanislaus National Forest, Richard Harris, Regional Office Engineering.

Geologists and Hydrologists on Adjacent National Forests- Steve Bachman, hydrologist, Shasta Trinity National Forest; Bob Faust, hydrologist, Mendocino National Forest; Abel Jasso, geologist, Shasta Trinity National Forest; Cindy Ricks, geologist Siskiyou National Forest; Randy Sharp, geologist, Modoc National Forest; Sue Becker, Hydrologist, Modoc National Forest, Dan Sitton, geologist, Rogue River National Forest; Mark Smith, geologist, Six Rivers National Forest; Paul Uncapher, geologist, Umpqua National Forest.

US Fish and Wildlife Service- Mark Maghini, widlife biologist, US Fish and Wildlife Service, Yreka, California; Tom Reed, wildlife biologist, US Fish and Wildlife Service, Yreka, California.

Klamath Province Advisory Committee- Pat Higgins: Fisheries Resource Advocate, Klamath Province Advisory Committee.

B. VIDEO TAPES

The following video tapes were taken by Klamath Forest employees during and after the flood of 1997.

1-3-97: Fixed Wing Aircraft. Richard Ashe, Dennis Brown, ------------ (Pilot). Flight of west side of Klamath National Forest focusing on damage to roads and structures. There may also be footage for a January 6 flight.
2-10-97: (Approximate Date) Helicopter. Carl Varak, ------------ , --------------- (pilot). Flight of west side of Oak Knoll District, Seiad, Horse, Beaver Creek Drainages, and some of Walker Creek.
2-14-97: Fixed Wing Aircraft. Juan de la Fuente and Al Olson (Pilot). Flight of Beaver, Horse, Portuguese, Thompson, Elk, Tompkins, Kelsey, and Deep Creeks.
3-4-97: Fixed Wing Aircraft. Juan de la Fuente, Polly Haessig, Cal Conklin, Terry Weathers (Pilot). Flight over Walker, Grider, Thompson, Elk, Canyon, Deep, and Isinglass Creeks.
9-4-97: Fixed Wing Aircraft. Juan de la Fuente, Don Elder, Al Olson, Richard Frank (Pilot). Flight over Canyon, Elk, Klamath River and Whitney Creek (Mt. Shasta).
January, 1997: Video coverage of the flood at Horse Creek by Rick Claypole.
Spring, 1997: Post-flood video coverage of the Elk Creek trail to Granite Creek by Pat Garrahan.
1-7-98: Video coverage along Highway 96, Elk Creek, and Indian Creek by Juan de la Fuente.

C. AIR PHOTOS

The following air photos were acquired as part of this project:

1:40,000 CIR - **May 7, 1997** covering 771,000 acres West Side of Klamath National Forest
1:6,000 Color - **October 23, 1997** along Ukonom, Elk, Indian, and Portuguese Creeks
1:3,000 Color - **October 1997** along Grider and Walker Creeks
1:10,000 Color - **October 20, 1997** the area around Lake Mountain
1:24,000 CIR - **October 20, 1997** along the Upper South Fork Salmon River
1:3,000 Color - **Spring 1998** along Grider and Walker Creeks

D. DOPPLER RADAR

U.S. Weather Bureau Data taken during the 1997 Flood. This information was not available for the Phase I assessment. It is currently being evaluated as part of Phase II.

E. LASER GENERATED DIGITAL ELEVATION DATA

1998 Collected in August, 1998 For Walker Creek. Not available for Phase I Investigation.

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Photos #1a & 1b: Debris Slide- Large debris slide (about 250 feet wide, 1000 feet long) occurred in the Marble Mountain Wilderness in Granite Creek, a tributary to Elk Creek, Happy Camp Ranger District. It is on the timbered wall of a U-shaped glaciated valley which had not been affected by the fires in 1987. The ensuing debris flow caused severe channel alteration for several miles downstream, and also formed log jams. Photo 1a is viewing upslope, and 1b downslope. Photo summer of 1997 by J.d.l.F.

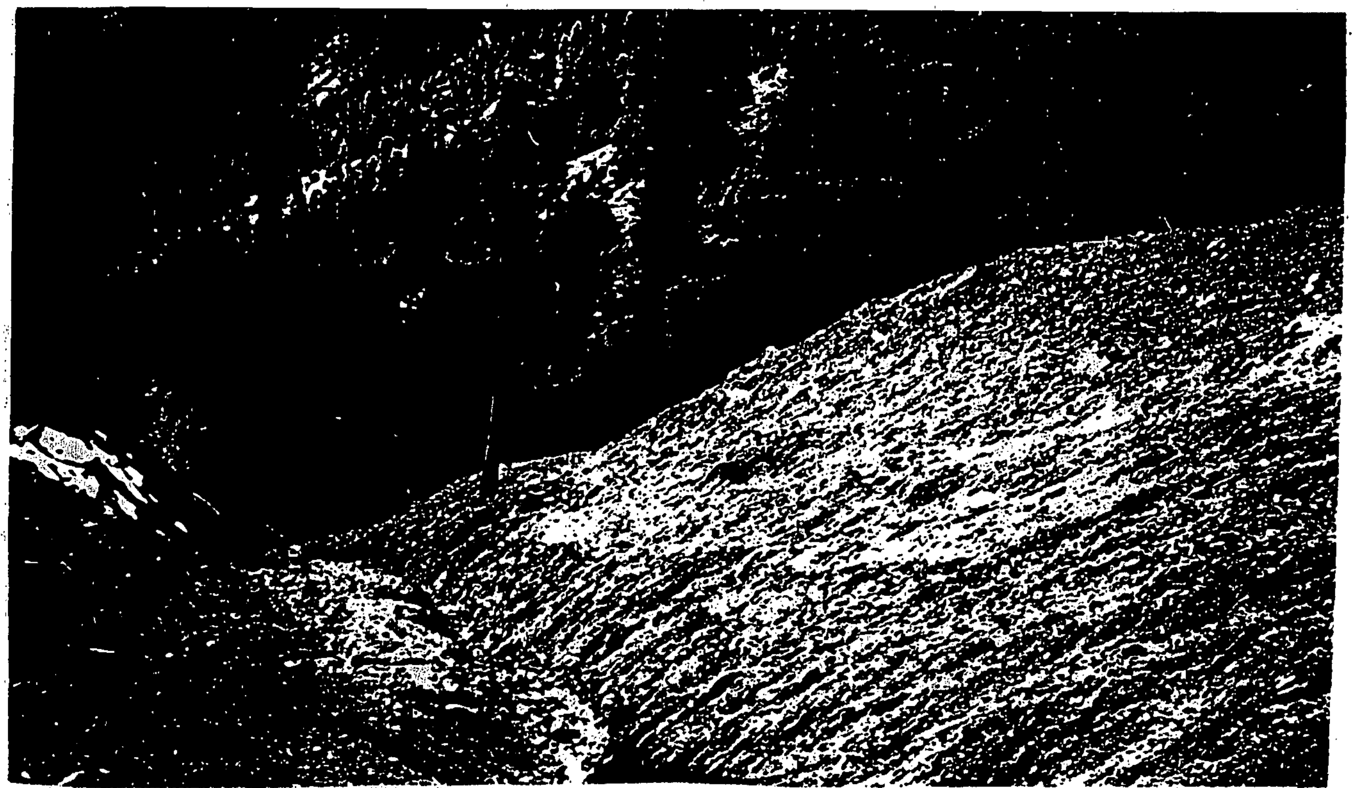

Photo #2: Debris Flow- View downstream of a debris flow track in the Tompkins Creek watershed, Scott River Ranger District. The debris flow rode up on the right bank of the channel at this point, plastering mud and debris about 100 vertical feet above the channel bottom. The large lone tree in the left center of the photo is a sugar pine, four feet in diameter. The top of this tree was snapped out by the impact of the debris. Photo by J.d.l.F. Spring, 1997.

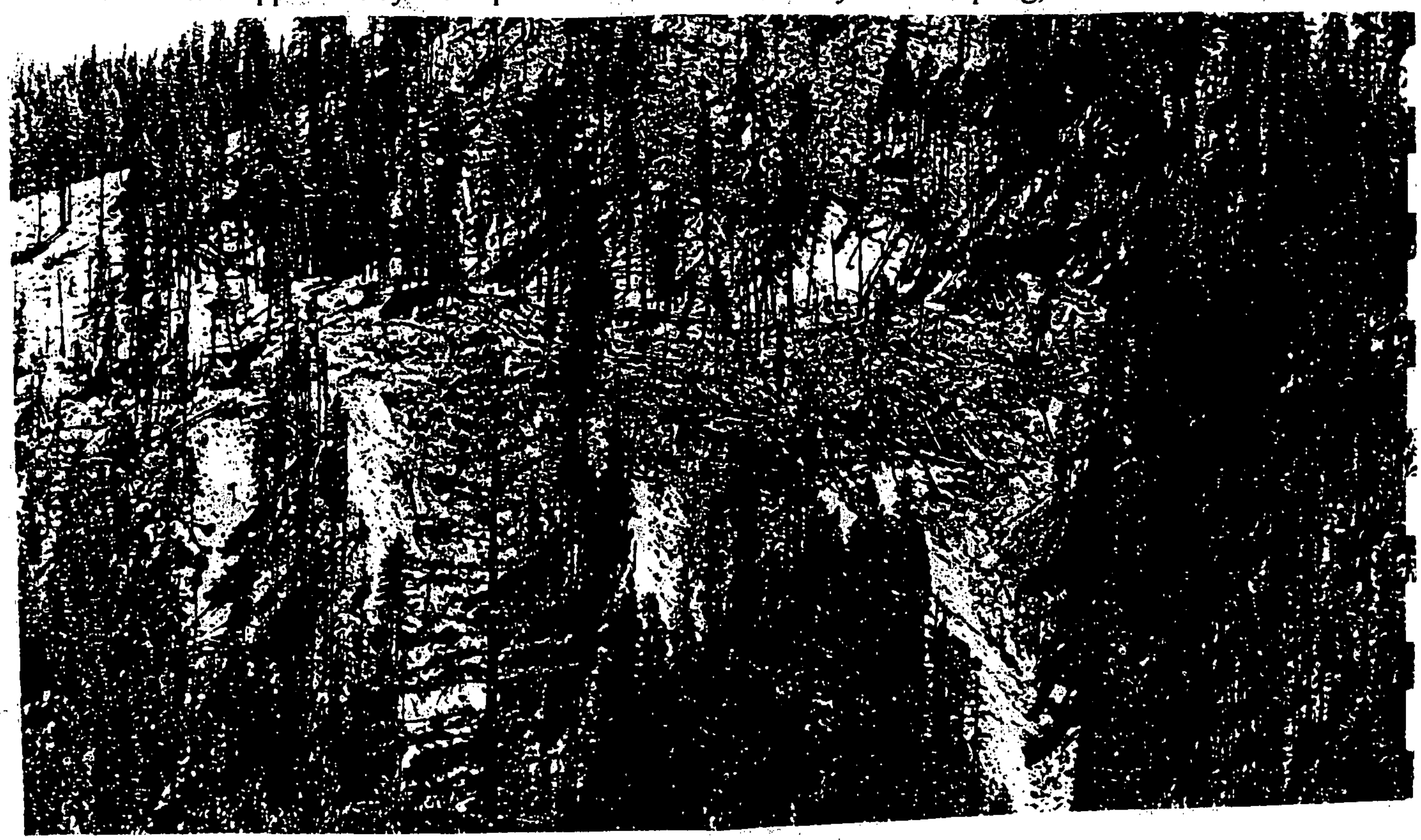

Photo # 3: Slump- Large (about 1000 feet wide) activated slump in the Walker Creek watershed, above an abandoned portion of Road 46N61A, Happy Camp Ranger District. The landslide does not appear to have been influenced by the road (the slip surface daylights a considerable distance above the road). However, it was burned by the fires of 1987, and was subsequently salvage logged. Photo by J.d.l.F. summer, 1997.

Photos #4a (top) & 4b (bottom) Gully and Slump- Photo 1a is a view up a large gully (100 feet wide, 50 feet deep) which was cut by a debris flow in the Walker Creek watershed, Happy Camp Ranger District. The debris flow was initiated by a debris slide on the toe of a larger slump/earthflow on Road 46N61. Photo 4b is another view of the gully (traversing photo from top left to lower right). This photo also shows a 300 foot wide slump (white area in right center of photo) which was undercut by the gully. The horizontal line in the center of the photo is Road 46N61A which was taken out by the slump. These landslides and gullies delivered more than 300,000 cubic yards of debris to Walker Creek. Photo by J.d.l.F. summer, 1997.

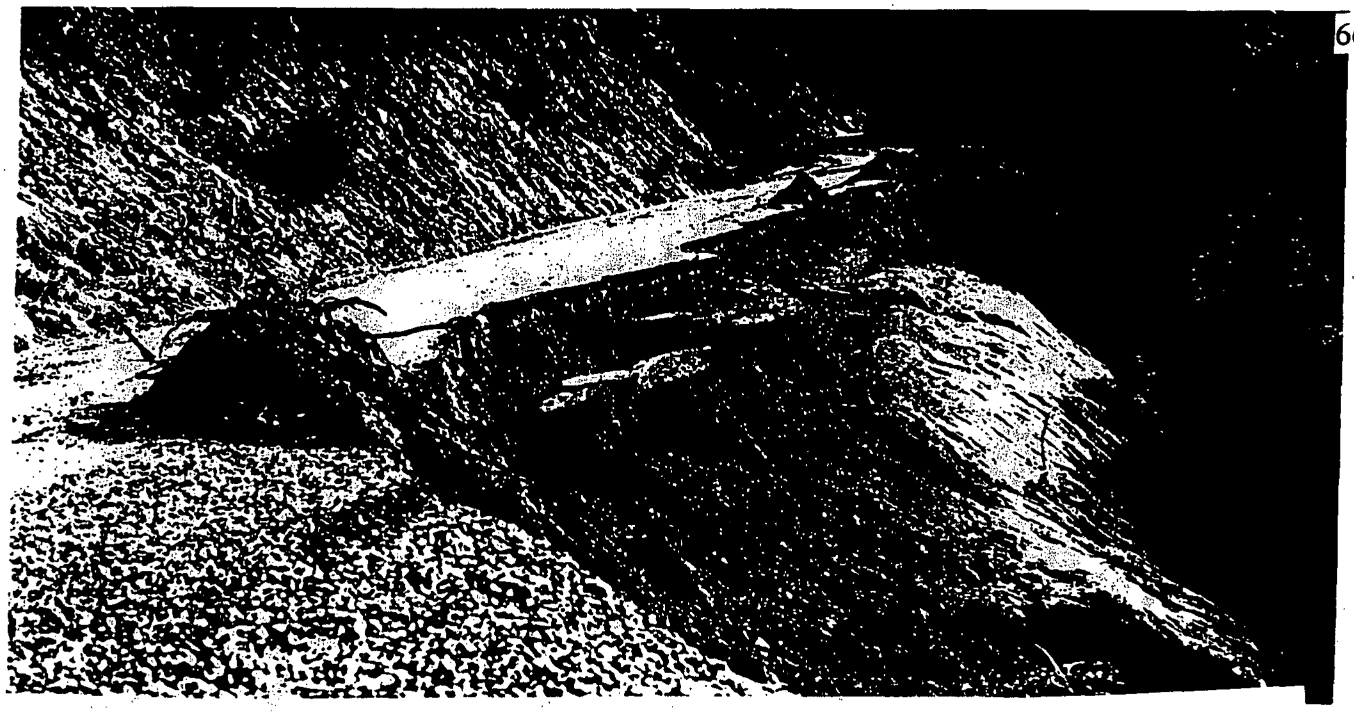

Photo #5: Fill Failure- This fill failure is on Road 44N45 in the Canyon Creek Watershed, Scott River Ranger District. Failure was a result of fill saturation with some additional water contributed to the site by the inside road ditch. Photograph by Ed Rose, spring, 1997. This site was subsequently repaired with a retaining wall.

Photo #6: Landslide- This slump/earthflow closed road 46N64 in the Walker Creek watershed, Happy Camp Ranger District. A cellular retaining wall (note corrugated metal) had been installed at this site several years before the 1997 flood. The entire area consists of the toe of a large old landslide deposit. Photo by J.d.l.F., February, 1997.

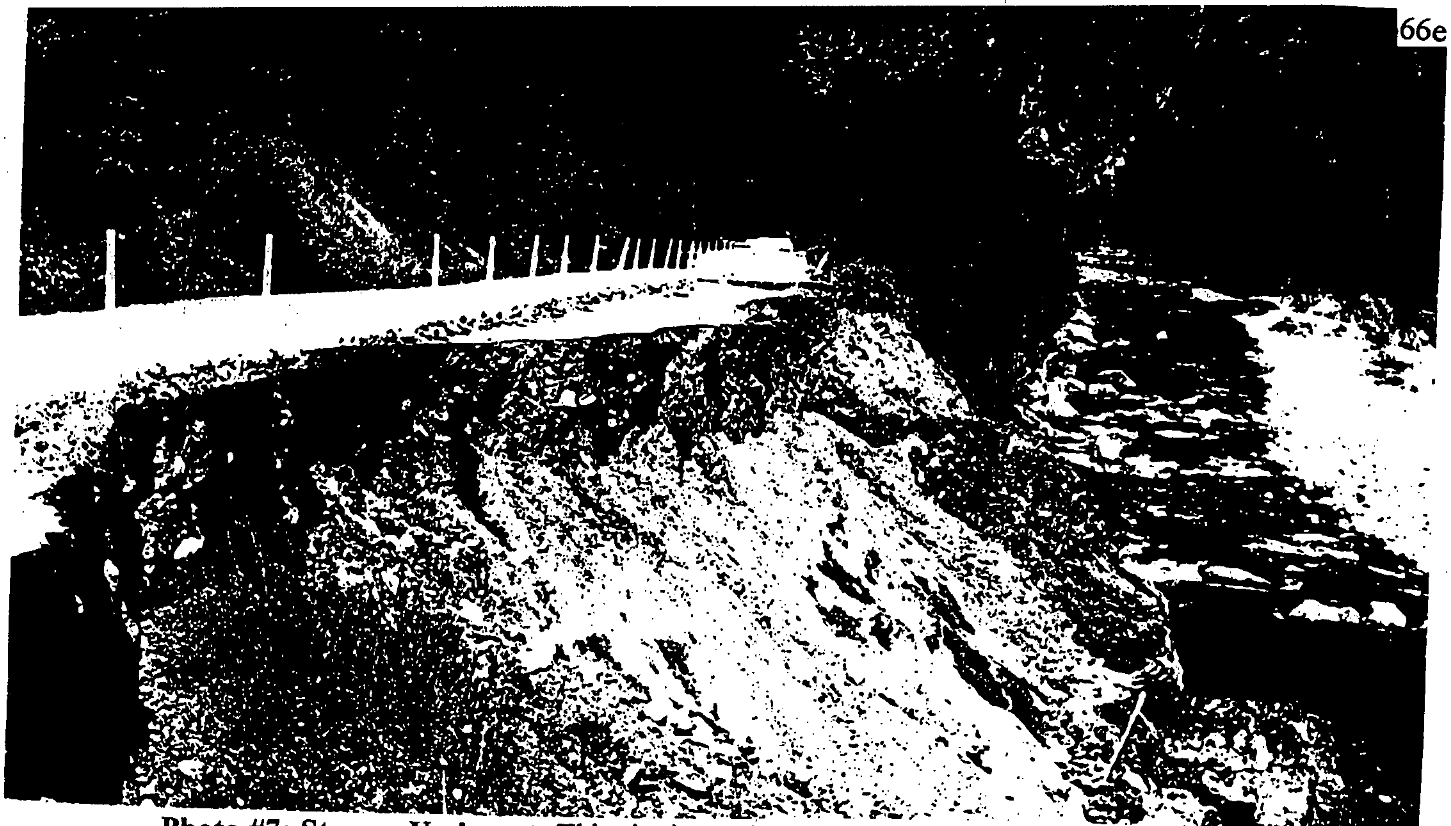

Photo #7: Stream Undercut- This site is on the Salmon River Ranger District, on the South Fork of the Salmon River, where the river undercut the county road. Photo by J.d.l.F, spring, 1998.

Photo #8: Stream Crossing Failure- This road stream crossing is on Road 15N75 in the Elk Creek Watershed (Doolittle tributary), Happy Camp Ranger District. Failure of the fill was caused by a debris flow which originated by a small fill failure on the same road where it crossed the head of the debris flow channel. Photo summer of 1997 by J.d.l.F.

Geo - Hydro:

["area" ~= photo area for all]

GEO13

Geo13 #	Description	# of slides	acres	slides/sqmi	acres % tot	b(k; n, p)*	most likely	b(k; n, p)**
1	active slides	64	7,271	5.63	0.01	0.000	7	1.000
2	toe zones	5	6,204	0.52	0.01	0.678	6	0.490
3	dormant slides	206	182,429	0.72	0.24	0.001	168	0.999
4	granitic lands [steep, >65%]	23	21,411	0.69	0.03	0.259	20	0.806
5	granitic lands [slopes, <65%]	72	80,270	0.57	0.10	0.619	74	0.429
6	non-granitic lands [>65%]	50	74,380	0.43	0.10	0.994	69	0.008
8	non-granitic lands [<65%]	149	245,171	0.39	0.32	1.000	226	0.000
9	inner gorge in unconsolidated	56	26,502	1.35	0.03	0.000	24	1.000
10	inner gorge in granitic lands	29	22,240	0.83	0.03	0.043	21	0.973
11	inner gorge in non-granitics	48	54,488	0.56	0.07	0.652	50	0.404
12	debris basins	3	7,790	0.25	0.01	0.975	7	0.071
13	surficial deposits [Qg, Qt, Q]	7	43,185	0.10	0.06	1.000	40	0.000
	TOTALS	712	771,341	0.59	1.00		712	

BEDROCK TERRANE

'ter'	Description	# of slides	acres	slides/sqmi	acres % tot	b(k; n, p)*	most likely	b(k; n, p)**
cd	Condrey Mountain	45	107,383	0.27	0.14	1.000	102	0.000
pl	plutons	186	154,170	0.77	0.20	0.000	147	1.000
rct	Rattlesnake Creek	423	323,534	0.84	0.42	0.000	309	1.000
sbt	Sawyers Bar	25	61,291	0.26	0.08	1.000	58	0.000
sbt?/sf?	Sawyers Bar or Stuart Fork ?	0	1,216	0.00	0.00	1.000	1	0.313
sf	Stuart Fork	2	3,285	0.39	0.00	0.821	3	0.393
wht	Western Hayfork	39	59,837	0.42	0.08	0.996	57	0.006
wj	Western Jurassic	16	60,835	0.17	0.08	1.000	58	0.000
	TOTALS	736	771,551	0.61	1.00		736	

RIPARIAN RESERVE

Description	# of slides	acres	slides/sqmi
Geologically defined [geo13: 1,2,9,10,11]	202	116,705	1.11
Hydrologically defined	158		
Combined [Riparian reserve by either]]	248		
Total	737	33.6%	= % of slides in riparian reserve

Physical:

ELEVATION

Description	# of slides	acres	slides/sqmi	acres % tot	b(k; n, p)*	most likely
0 - 2,000'	29	107,266	0.17	0.14	1.000	102
2,000' - 4,000'	274	373,989	0.47	0.48	1.000	356
4,000' - 6,000'	412	240,885	1.09	0.31	0.000	229
> 6,000'	20	49,443	0.26	0.06	1.000	47
TOTALS	735	771,583	0.61	1.00		735

SLOPE

Description	# of slides	acres	slides/sqmi	acres % tot	b(k; n, p)*	most likely
0 - 20%	12	66,468	0.12	0.09	1.000	63
20 - 40%	113	235,990	0.31	0.31	1.000	225
40 - 65%	461	344,127	0.86	0.45	0.000	328
> 65%	150	124,998	0.77	0.16	0.002	119
TOTALS	736	771,583	0.61	1.00		736

ASPECT

Description		# of slides	acres	slides/sqmi	acres % tot	b(k; n, p)*	most likely
Flat		0	718	0.00	0.00	1.000	1
North	[310 - 70 degrees]	267	231,087	0.74	0.30	0.000	220
East	[70 - 130 degrees]	164	142,907	0.73	0.19	0.006	136
South	[130 - 250 degrees]	207	265,756	0.50	0.34	1.000	253
West	[250 - 310 degrees]	97	131,114	0.47	0.17	0.998	125
	TOTALS	735	771,582	0.61	1.00		735

* b(k;n,p) = probability density function for binomial distribution; probability of (at LEAST) 'k' successes in 'n' Bernoulli trials with probability ['p'] of success for each trial

** b(k;n,p) = probability density function for binomial distribution; probability of (at MOST) 'k' successes in 'n' Bernoulli trials with probability ['p'] of success for each trial

OR = overstory removal
NS = non-stocked
SW = shelter wood

TABLE 1

Geo - Hydro:

GEO13 *[area=westside]*

Geo13 #	Description	# of sites	acres	sites/sqmi	acres % tot	b(k; n, p)*	most likely
1	active slides	26	12,118	1.37	0.01	0.000	7
2	toe zones	9	8,429	0.68	0.00	0.042	5
3	dormant slides	233	262,253	0.57	0.15	0.000	141
4	granitic lands [steep, >65%]	8	49,392	0.10	0.03	1.000	27
5	granitic lands [slopes, <65%]	96	208,678	0.29	0.12	0.959	112
6	non-granitic lands [>65%]	28	166,230	0.11	0.10	1.000	90
8	non-granitic lands [<65%]	228	620,215	0.24	0.36	1.000	334
9	inner gorge in unconsolidated	65	43,896	0.95	0.03	0.000	24
10	inner gorge in granitic lands	68	44,709	0.97	0.03	0.000	24
11	inner gorge in non-granitics	123	121,343	0.65	0.07	0.000	65
12	debris basins	1	19,235	0.03	0.01	1.000	10
13	surficial deposits [Qg, Qt, Q]	36	152,259	0.15	0.09	1.000	82
	TOTALS	921	1,708,757	0.34	1.00		921

BEDROCK TERRANE *[area=westside]*

'ter'	Description	# of sites	acres	sites/sqmi	acres % tot	b(k; n, p)*	most likely
cd	Condrey Mountain	109	107,383	0.65	0.07	0.000	62
cm	Central Metamorphic	11	49,221	0.14	0.03	1.000	28
pl	plutons	197	409,363	0.31	0.25	0.998	235
rct	Rattlesnake Creek	370	430,000	0.55	0.27	0.000	247
sbt	Sawyers Bar	73	344,416	0.14	0.21	1.000	198
sbt?/sf?	Sawyers Bar or Stuart Fork ?	0	5,326	0.00	0.00	1.000	3
sf	Stuart Fork	14	64,748	0.14	0.04	1.000	37
sur	surficial deposits	6	1,579	2.43	0.00	0.000	1
wht	Western Hayfork	89	109,554	0.52	0.07	0.001	63
wj	Western Jurassic	50	80,000	0.40	0.05	0.287	46
yr	Yreka	8	14,213	0.36	0.01	0.569	8
	TOTALS	927	1,615,803	0.37	1.00		927

RIPARIAN RESERVE *[area=westside]*

Description	# of sites	acres	sites/sqmi
Geologically defined [geo13: 1,2,9,10,11]	168	116,705	0.92
Hydrologically defined	360		
Combined [Riparian reserve by either]]	401		
Total	939	42.7%	= % of slides in riparian reserve

Disturbance:

FIRE *[area=westside]*

	Description	# of sites	acres	sites/sqmi	acres % tot	b(k; n, p)*	most likely
1987	burn intensity 'hi' or 'med'	140	113,645	0.79	0.07	0.000	66
Hog	"	6	44,420	0.09	0.03	1.000	26
Dillon	"	0	7,160	0.00	0.00	1.000	4
Specimen	"	0	3,134	0.00	0.00	1.000	2
Total		146	168,360	0.56	0.10		

HARVEST *[area=westside]*

Description	# of sites	acres	sites/sqmi	acres % tot	b(k; n, p)*	most likely
Plantations older than 1977	96	67,317	0.91	0.04	0.000	39
1977 & younger [includes OR, NS, SW]	131	76,830	1.09	0.05	0.000	45
TOTALS	227	144,147	1.01	0.09		

"UNDISTURBED" *[area=photo area]*

Description	# of sites	acres	sites/sqmi	acres % tot	b(k; n, p)**	most likely
Sites: [i] not within H or M fire burn intensity, and [ii] not within old or young harvest areas	479 (of 744 sites)	609,074	0.50	0.79	0.000	562

Physical:

ELEVATION

Description	# of sites	acres	sites/sqmi	*[area=photo area]* acres % tot	b(k; n, p)*	most likely
0 - 2,000'	97	107,266	0.58	0.14	0.767	103
2,000' - 4,000'	462	373,989	0.79	0.48	0.000	361
4,000' - 6,000'	185	240,885	0.49	0.31	1.000	232
> 6,000'	0	49,443	0.00	0.06	1.000	48
TOTALS	744	771,583	0.62			744

SLOPE

Description	# of sites	acres	sites/sqmi	*[area=photo area]* acres % tot	b(k; n, p)*	most likely
0 - 20%	89	66,468	0.86	0.09	0.001	64
20 - 40%	274	235,990	0.74	0.31	0.000	228
40 - 65%	332	344,127	0.62	0.45	0.509	332
> 65%	49	124,998	0.25	0.16	1.000	121
TOTALS	744	771,583	0.62			744

ASPECT

Description		# of sites	acres	sites/sqmi	*[area=photo area]* acres % tot	b(k; n, p)*	most likely
Flat		2	718	1.78	0.00	0.151	1
North	[310 - 70 degrees]	238	231,087	0.66	0.30	0.085	220
East	[70 - 130 degrees]	168	142,907	0.75	0.19	0.002	136
South	[130 - 250 degrees]	220	265,756	0.53	0.34	0.996	253
West	[250 - 310 degrees]	116	131,114	0.57	0.17	0.826	125
	TOTALS	744	771,582	0.62			

* b(k;n,p) = probability density function for binomial distribution; probability of (at LEAST) 'k' successes in 'n' Bernoulli trials with probability ['p'] of success for each trial

** b(k;n,p) = probability density function for binomial distribution; probability of (at MOST) 'k' successes in 'n' Bernoulli trials with probability ['p'] of success for each trial

OR = overstory removal
NS = non-stocked
SW = shelter wood

TABLE 2

TABLE 3

ALTERED CHANNELS - RELATED TO THE 97 FLOOD 11/12/98

["area" ~= photo area for all]

Geo - Hydro:

GEO13

Geo13 #	Description	altered mi	unaltered mi	total mi	acres	density*	% altered
1	active slides	12.40	40.44	52.84	7,271	1.09	23.5%
2	toe zones	1.69	7.13	8.82	6,204	0.17	19.2%
3	dormant slides	23.05	220.96	244.01	182,429	0.08	9.4%
4	granitic lands [steep, >65%]	2.73	0.97	3.70	21,411	0.08	73.8%
5	granitic lands [slopes, <65%]	8.71	47.01	55.72	80,270	0.07	15.6%
6	non-granitic lands [>65%]	6.70	5.40	12.10	74,380	0.06	55.4%
8	non-granitic lands [<65%]	20.48	127.52	148.00	245,171	0.05	13.8%
9	inner gorge in unconsolidated	85.72	519.77	605.49	26,502	2.07	14.2%
10	inner gorge in granitic lands	106.87	267.62	374.49	22,240	3.08	28.5%
11	inner gorge in non-granitics	162.97	992.54	1155.51	54,488	1.91	14.1%
12	debris basins	1.07	3.07	4.14	7,790	0.09	25.8%
13	surficial deposits [Qg, Qt, Q]	13.85	101.43	115.28	43,185	0.21	12.0%
	TOTALS	446.24	2333.86	2780.10	771,341	0.37	16.1%

BEDROCK TERRANE

'ter'	Description	altered mi	unaltered mi	total mi	acres	density*	% altered
cd	Condrey Mountain	30.40	374.86	405.26	107,383	0.18	7.5%
pl	plutons	156.06	425.59	581.65	154,170	0.65	26.8%
rct	Rattlesnake Creek	199.76	895.50	1095.26	323,534	0.40	18.2%
sbt	Sawyers Bar	23.00	194.52	217.52	61,291	0.24	10.6%
sbt?/sf?	Sawyers Bar or Stuart Fork ?	0.00	4.87	4.87	1,216	0.00	0.0%
sf	Stuart Fork	0.48	8.73	9.21	3,285	0.09	5.2%
wht	Western Hayfork	20.19	196.51	216.70	59,837	0.22	9.3%
wj	Western Jurassic	16.35	233.27	249.62	60,835	0.17	6.5%
	TOTALS	446.24	2,333.85	2,780.09	771,551	0.37	16.1%

Disturbance:

FIRE

Description	altered mi	unaltered mi	total mi	acres	density*	% altered
Burn intensity 'hi' or 'med'	30.40	374.86	405.26	76,692	0.25	7.5%
Burn intensity 'low'	156.06	425.59	581.65	98,751	1.01	26.8%
Unburned	259.78	1533.40	1793.18	596,108	0.28	14.5%
[Hog, 87 Fires, Dillon, Specimen combined]]		[note:	'acres' figures include all four fires]			
Totals within burned areas	186.46	800.45	986.91	175,443	0.68	18.9%

HARVEST

Description	altered mi	unaltered mi	total mi	acres	density*	% altered
1977 & younger [includes OR, NS, SW]	27.32	56.31	83.63	46,547	0.38	32.7%
Plantations older than 1977	13.81	77.90	91.71	48,089	0.18	15.1%
Non-harvested areas	405.11	2199.64	2604.75	676,915	0.38	15.6%
Totals within harvested areas	41.13	134.21	175.34	94,636	0.28	23.5%

Physical:

ELEVATION

Description	altered mi	unaltered mi	total mi	acres	density*	% altered
0 - 2,000'	83.13	665.65	748.78	107,266	0.50	11.1%
2,000' - 4,000'	201.36	1089.29	1290.65	373,989	0.34	15.6%
4,000' - 6,000'	158.72	525.75	684.47	240,885	0.42	23.2%
> 6,000'	3.06	52.93	55.99	49,443	0.04	5.5%
TOTALS	446.27	2,333.62	2,779.89	771,583	0.37	16.1%

SLOPE

Description	altered mi	unaltered mi	total mi	acres	density*	% altered
0 - 20%	140.87	753.20	894.07	66,468	1.36	15.8%
20 - 40%	159.03	1076.45	1235.48	235,990	0.43	12.9%
40 - 65%	120.98	461.93	582.91	344,127	0.22	20.8%
> 65%	25.46	42.32	67.78	124,998	0.13	37.6%
TOTALS	446.34	2333.90	2780.24	771,583	0.37	16.1%

Note: slope class is NOT indicative of channel gradient, but reflects steepest side wall

ASPECT

Description		altered mi	unaltered mi	total mi	acres	density*	% altered
Flat		1.22	10.98	12.20	718	1.09	10.0%
North	[310 - 70 degrees]	158.27	759.26	917.53	231,087	0.44	17.2%
East	[70 - 130 degrees]	85.41	449.41	534.82	142,907	0.38	16.0%
South	[130 - 250 degrees]	134.79	753.78	888.57	265,756	0.32	15.2%
West	[250 - 310 degrees]	66.64	360.40	427.04	131,114	0.33	15.6%
	TOTALS	446.33	2333.83	2780.16	771,582	0.37	16.1%

* density measured in 'altered miles' of channel per sq mile

Photo Area SLIDES MULTIPLE FACTORS special.123 11/12/98

Geo13	Elevation	ROADS			FIRE			HARVEST						UNDISTURBED			*TOTALS*			FIRE+HARVEST		
Geo13	Elevation	ls	Rd_buf	den	ls	Fire	den	ls	Harv77	den	ls	Harv76	den	ls	None	den	ls	Acres	den	ls	Fire_Harv	den
[geo13 #]	[range, ft]	[#]	[acres]	[ls/sqmi]	[#]	[acres]	[ls/sqmi]	[#]	[acres]	[ls/sqmi]	[#]	[acres]	[ls/sqmi]	[#]	[acres]	[ls/sqmi]	[#]		[ls/sqmi]	[#]	[acres]	[ls/sqmi]
1	0-2000		65.7	0.00	2	113.1	11.32		27.5	0.00		115.9	0.00	5	2,093.2	1.53	7	2,415.4	1.85		21.1	0.00
1	2000-4000	8	96.2	53.22	2	279.7	4.58		119.6	0.00	4	545.9	4.69	13	2,186.0	3.81	27	3,227.4	5.35		97.7	0.00
1	4000-6000	2	26.2	48.85	7	242.8	18.45	1	27.7	23.10	2	167.3	7.65	17	1,105.3	9.84	29	1,569.3	11.83	4	16.6	154.22
1	>6000		0.3	0.00		0.1	0.00		0.9	0.00		0.1	0.00	1	51.6	12.40	1	53.0	12.08		0.0	ERR
	Total	10	188.4	33.97	11	635.7	11.07	1	175.7	3.64	6	829.2	4.63	36	5,436.1	4.24	64	7,265.1	5.64	4	135.4	18.91
2	0-2000	1	62.4	10.26		20.9	0.00		141.5	0.00		45.3	0.00	1	2,521.7	0.25	2	2,791.8	0.46		1.2	0.00
2	2000-4000		78.8	0.00		51.2	0.00		144.7	0.00		232.6	0.00	2	2,064.4	0.62	2	2,571.7	0.50		5.1	0.00
2	4000-6000		24.5	0.00		56.5	0.00		13.7	0.00	1	16.3	39.26		719.2	0.00	1	830.2	0.77		7.6	0.00
2	>6000		0.0	ERR		0.0	ERR		0.0	ERR		0.0	ERR		8.3	0.00	0	8.3	0.00		0.0	ERR
	Total	1	165.7	3.86	0	128.6	0.00	0	299.9	0.00	1	294.2	2.18	3	5,313.6	0.36	5	6,202.0	0.52	0	13.9	0.00
3	0-2000	1	691.4	0.93		846.1	0.00		1,274.8	0.00		1,796.6	0.00		20,409.7	0.00	1	25,018.6	0.03		157.3	0.00
3	2000-4000	24	3,051.9	5.03	9	7,759.7	0.74	4	6,860.7	0.37	1	12,463.6	0.05	20	68,596.5	0.19	58	98,732.4	0.38	4	2,154.8	1.19
3	4000-6000	30	1,668.2	11.51	46	3,974.3	7.41	15	3,649.6	2.63	7	3,499.6	1.28	42	39,855.4	0.67	140	52,647.1	1.70	21	892.6	15.06
3	>6000		84.8	0.00		33.6	0.00	2	295.1	4.34		197.8	0.00	5	5,381.2	0.59	7	5,992.5	0.75		6.6	0.00
	Total	55	5,496.3	6.40	55	12,613.7	2.79	21	12,080.2	1.11	8	17,957.6	0.29	67	134,242.8	0.32	206	182,390.6	0.72	25	3,211.3	4.98
4	0-2000		2.2	0.00		223.6	0.00		5.3	0.00		0.0	ERR		1,114.9	0.00	0	1,346.0	0.00		4.1	0.00
4	2000-4000	2	63.7	20.09	7	1,722.9	2.60		249.9	0.00		173.4	0.00	5	8,809.1	0.36	14	11,019.0	0.81	1	108.2	5.91
4	4000-6000	1	26.7	23.97	5	640.8	4.99	1	75.3	8.50		68.4	0.00	1	6,312.0	0.10	8	7,123.2	0.72	2	94.4	13.56
4	>6000		0.7	0.00	1	58.0	11.03		0.0	ERR		0.2	0.00		1,852.4	0.00	1	1,911.3	0.33		0.4	0.00
	Total	3	93.3	20.58	13	2,645.3	3.15	1	330.5	1.94	0	242.0	0.00	6	18,088.4	0.21	23	21,399.5	0.69	3	207.1	9.27
5	0-2000	3	59.6	32.21		414.0	0.00		47.7	0.00		22.8	0.00		3,762.6	0.00	3	4,306.7	0.45		0.9	0.00
5	2000-4000	20	858.5	14.91	9	4,242.1	1.36		1,635.3	0.00	1	2,479.6	0.26	6	28,573.8	0.13	36	37,789.3	0.61	4	431.9	5.93
5	4000-6000	6	451.8	8.50	18	3,173.7	3.63	3	942.7	2.04		1,196.3	0.00	5	25,986.3	0.12	32	31,750.8	0.65	7	686.1	6.53
5	>6000		18.9	0.00	1	445.1	1.44		42.5	0.00		7.9	0.00		5,879.8	0.00	1	6,394.2	0.10		25.9	0.00
	Total	29	1,388.8	13.36	28	8,274.9	2.17	3	2,668.2	0.72	1	3,706.6	0.17	11	64,202.5	0.11	72	80,241.0	0.57	11	1,144.8	6.15
6	0-2000	1	42.1	15.20	1	869.4	0.74		178.0	0.00		133.1	0.00		7,410.2	0.00	2	8,632.8	0.15	1	126.6	5.06
6	2000-4000	1	411.4	1.56	7	6,920.0	0.65	5	1,170.4	2.73	2	1,605.5	0.80	6	30,439.0	0.13	21	40,546.3	0.33	2	1,299.3	0.99
6	4000-6000	7	105.6	42.42	7	2,927.9	1.53	6	359.3	10.69		134.0	0.00	5	17,262.6	0.19	25	20,789.4	0.77	2	308.8	4.15
6	>6000		0.3	0.00		36.3	0.00		2.6	0.00		0.4	0.00	2	4,352.7	0.29	2	4,392.3	0.29		0.4	0.00
	Total	9	559.4	10.30	15	10,753.6	0.89	11	1,710.3	4.12	2	1,873.0	0.68	13	59,464.5	0.14	50	74,360.8	0.43	5	1,735.1	1.84
8	0-2000	1	685.3	0.93		1,981.1	0.00		863.2	0.00		1,196.8	0.00		22,543.7	0.00	1	27,270.1	0.02		335.2	0.00
8	2000-4000	12	3,152.8	2.44	12	18,293.5	0.42	9	5,273.7	1.09	3	8,831.0	0.22	13	84,639.7	0.10	49	120,190.7	0.26	6	4,635.4	0.83
8	4000-6000	29	1,655.8	11.21	21	9,693.9	1.39	17	3,322.3	3.27	3	3,071.7	0.63	21	59,256.5	0.23	91	77,000.2	0.76	17	2,042.7	5.33
8	>6000		195.8	0.00	1	351.9	1.82	2	330.1	3.88		270.2	0.00	5	19,436.8	0.16	8	20,584.8	0.25		58.4	0.00
	Total	42	5,689.7	4.72	34	30,320.4	0.72	28	9,789.3	1.83	6	13,369.7	0.29	39	185,876.7	0.13	149	245,045.8	0.39	23	7,071.7	2.08
9	0-2000	1	140.8	4.55		201.8	0.00		104.9	0.00		219.9	0.00	6	5,993.6	0.64	7	6,661.0	0.67		30.2	0.00
9	2000-4000	2	236.6	5.41	5	795.1	4.02		338.2	0.00		682.9	0.00	16	10,418.6	0.98	23	12,471.4	1.18	1	94.8	6.75
9	4000-6000	3	93.3	20.58	4	245.4	10.43	4	95.3	26.86		143.3	0.00	15	6,514.3	1.47	26	7,091.6	2.35	2	26.3	48.67
9	>6000		0.6	0.00		0.0	ERR		0.0	ERR		0.0	ERR		265.9	0.00	0	266.5	0.00		0.0	ERR
	Total	6	471.3	8.15	9	1,242.3	4.64	4	538.4	4.75	0	1,046.1	0.00	37	23,192.4	1.02	56	26,490.5	1.35	3	151.3	12.69

TABLE 4

Photo Area SLIDES MULTIPLE FACTORS special.123 11/12/98

Geo13	Elevation	ROADS ls	ROADS Rd_buf	ROADS den	FIRE ls	FIRE Fire	FIRE den	HARVEST ls	HARVEST Harv77	HARVEST den	HARVEST ls	HARVEST Harv76	HARVEST den	UNDISTURBED ls	UNDISTURBED None	UNDISTURBED den	*TOTALS* ls	*TOTALS* Acres	*TOTALS* den	FIRE+HARVEST ls	FIRE+HARVEST Fire_Harv	FIRE+HARVEST den
10	0-2000	1	55.5	11.53		265.8	0.00		20.5	0.00		7.0	0.00		3,721.1	0.00	1	4,069.9	0.16		7.0	0.00
10	2000-4000	8	174.8	29.29	4	1,185.4	2.16		288.3	0.00		376.9	0.00	5	12,493.7	0.26	17	14,519.1	0.75	1	57.1	11.21
10	4000-6000	1	23.4	27.35	5	265.6	12.05		55.5	0.00	1	62.0	10.32	4	3,215.9	0.80	11	3,622.4	1.94		14.0	0.00
10	>6000		0.0	ERR		0.3	0.00		0.0	ERR		-0.0	ERR		20.4	0.00	0	20.7	0.00		0.0	ERR
	Total	10	253.7	25.23	9	1,717.1	3.35	0	364.3	0.00	1	445.9	1.44	9	19,451.1	0.30	29	22,232.1	0.83	1	78.1	8.19
11	0-2000	2	359.3	3.56	5	839.5	3.81		278.7	0.00		272.4	0.00	2	14,969.5	0.09	9	16,719.4	0.34		116.8	0.00
11	2000-4000	7	340.2	13.17		3,556.9	0.00	1	489.3	1.31		955.6	0.00	8	23,377.2	0.22	16	28,719.2	0.36	2	428.4	2.99
11	4000-6000	7	92.2	48.59	2	792.8	1.61	4	215.6	11.87		100.7	0.00	10	7,660.3	0.84	23	8,861.6	1.66	1	80.9	7.91
11	>6000		0.0	ERR		0.0	ERR		0.4	0.00		0.0	ERR		168.5	0.00	0	168.9	0.00		0.0	ERR
	Total	16	791.7	12.93	7	5,189.2	0.86	5	984.0	3.25	0	1,328.7	0.00	20	46,175.5	0.28	48	54,469.1	0.56	3	626.1	3.07
12	0-2000		0.0	ERR		2.2	0.00		0.0	ERR		0.4	0.00		67.5	0.00	0	70.1	0.00		0.0	ERR
12	2000-4000		0.0	ERR		271.3	0.00		18.0	0.00		0.0	ERR		1,175.6	0.00	0	1,464.9	0.00		0.0	ERR
12	4000-6000		1.9	0.00	2	380.8	3.36		17.4	0.00		5.3	0.00	1	3,545.7	0.18	3	3,951.1	0.49		2.8	0.00
12	>6000		0.5	0.00		4.6	0.00		0.0	ERR		0.0	ERR		2,294.0	0.00	0	2,299.1	0.00		0.0	ERR
	Total	0	2.4	0.00	2	658.9	1.94	0	35.4	0.00	0	5.7	0.00	1	7,082.8	0.09	3	7,785.2	0.25	0	2.8	0.00
13	0-2000		556.1	0.00		91.1	0.00		46.6	0.00		32.6	0.00	1	7,211.6	0.09	1	7,938.0	0.08		2.9	0.00
13	2000-4000		88.2	0.00		129.9	0.00		80.4	0.00		40.5	0.00		2,271.8	0.00	0	2,610.8	0.00		29.7	0.00
13	4000-6000	1	86.9	7.36	3	780.3	2.46		253.6	0.00		182.8	0.00	2	24,074.5	0.05	6	25,378.1	0.15		81.7	0.00
13	>6000		31.2	0.00		83.5	0.00		117.4	0.00		21.4	0.00		6,989.9	0.00	0	7,243.4	0.00		0.0	ERR
	Total	1	762.4	0.84	3	1,084.8	1.77	0	498.0	0.00	0	277.3	0.00	3	40,547.8	0.05	7	43,170.3	0.10	0	114.3	0.00
Totals:		182	15,863.1	7.34	186	75,264.5	1.58	74	29,474.2	1.61	25	41,376.0	0.39	245	609,074.2	0.26	712	771,052.0	0.59	78	14,491.9	3.44
Totals:	0-2000	11	2,720.4	2.59	8	5,868.6	0.87	0	2,988.7	0.00	0	3,842.8	0.00	15	91,819.3	0.10	34	107,239.8	0.20	1	803.3	0.80
	2000-4000	84	8,553.1	6.29	55	45,207.7	0.78	19	16,668.5	0.73	11	28,387.5	0.25	94	275,045.4	0.22	263	373,862.2	0.45	21	9,342.4	1.44
	4000-6000	87	4,256.5	13.08	120	23,174.8	3.31	51	9,028.0	3.62	14	8,647.7	1.04	123	195,508.0	0.40	395	240,615.0	1.05	56	4,254.5	8.42
	>6000	0	333.1	0.00	3	1,013.4	1.89	4	789.0	3.24	0	498.0	0.00	13	46,701.5	0.18	20	49,335.0	0.26	0	91.7	0.00

KEY

- rd_buf — within 50' wide road prism [see note below]
- fire — outside 50' wide road prism; within fire burn intensity = H or M [from Hog, Fire87, Dillon, Specimen fires]
- harv77 — outside 50' road prism; outside H or M fire burn intensity within harvested area YOUNGER than 1977 [includes NS, OR, SW]
- harv76 — outside 50' road prism; outside H or M fire burn intensity within harvested area OLDER than 1977
- none — within "undisturbed" area; outside road prism, outside H or M fire burn intensity, outside harvested area [old (pre-1977) or new (post-1977)]
- fire_harv — outside road buffer within fire burn intensity H or M and within "newly" harvested area [younger than 1977, NS]

<u>Note:</u> Assumptions used concerning the count of slides & corresponding acres:
If the "labelpoint" of a slide was within 150' of a road, it was considered to be "road-related" and counted under the "Roads" section. However, in computing density of slides, a corridor 50' wide [~= road prism] was used, rather than one 300' wide (150' x 2).
If labelpoint of a slide was greater than 150' from a road, it was considered NOT to be "road-related" and counted elsewhere. Acre figures were calculated as described above.

TABLE 4

Disturbance:

ROADS

Description	# of slides	acres*	slides/sqmi	acres % tot	b(k; n, p)*	most likely
Within 150' [300'-wide strip]	182	95,891	1.21	0.12	0.000	92
Within 200'	217	127,855	1.09	0.17	0.000	122
Within 500'	354	319,636	0.71	0.41	0.000	305

[* 2,637 mi of road within study area; x300 ', x400' & x1000' = acres]

FIRE

Description	# of slides	acres	slides/sqmi	acres % tot	b(k; n, p)*	most likely
Fires of 1987 - burn intensity 'hi' or 'med'	243	76,692	2.03	0.10	0.000	73
Fires of 1987 - burn intensity 'low'	186	98,751	1.21	0.13	0.000	94
[No slides in Dillon, Specimen, or Hog]		[note:	'acres' figure includes all four fires]			
	429	175,443	1.56	0.23		

HARVEST

Description	# of slides	acres	slides/sqmi	acres % tot	b(k; n, p)*	most likely
Plantations older than 1977	60	48,089	0.80	0.06	0.022	44
1977 & younger [includes OR, NS, SW]	215	46,547	2.96	0.06	0.000	43
TOTALS	275	94,636	1.86	0.12		

UNDISTURBED

Description	# of slides	acres	slides/sqmi	acres % tot	b(k; n, p)**	most likely
Slides: [i] >200' from a road, and [ii] not within H or M fire burn intensity, and [iii] not within old or young harvest area	255 (of 737 slides)	609,074	0.27	0.79	0.000	562

TABLE 1

Physical:

ELEVATION

Description	# of slides	acres	slides/sqmi	acres % tot	b(k; n, p)*	most likely
0 - 2,000'	29	107,266	0.17	0.14	1.000	102
2,000' - 4,000'	274	373,989	0.47	0.48	1.000	356
4,000' - 6,000'	412	240,885	1.09	0.31	0.000	229
> 6,000'	20	49,443	0.26	0.06	1.000	47
TOTALS	735	771,583	0.61	1.00		735

SLOPE

Description	# of slides	acres	slides/sqmi	acres % tot	b(k; n, p)*	most likely
0 - 20%	12	66,468	0.12	0.09	1.000	63
20 - 40%	113	235,990	0.31	0.31	1.000	225
40 - 65%	461	344,127	0.86	0.45	0.000	328
> 65%	150	124,998	0.77	0.16	0.002	119
TOTALS	736	771,583	0.61	1.00		736

ASPECT

Description		# of slides	acres	slides/sqmi	acres % tot	b(k; n, p)*	most likely
Flat		0	718	0.00	0.00	1.000	1
North	[310 - 70 degrees]	267	231,087	0.74	0.30	0.000	220
East	[70 - 130 degrees]	164	142,907	0.73	0.19	0.006	136
South	[130 - 250 degrees]	207	265,756	0.50	0.34	1.000	253
West	[250 - 310 degrees]	97	131,114	0.47	0.17	0.998	125
TOTALS		735	771,582	0.61	1.00		735

* b(k;n,p) = probability density function for binomial distribution; probability of (at LEAST) 'k' successes in 'n' Bernoulli trials with probability ['p'] of success for each trial

** b(k;n,p) = probability density function for binomial distribution; probability of (at MOST) 'k' successes in 'n' Bernoulli trials with probability ['p'] of success for each trial

OR = overstory removal
NS = non-stocked
SW = shelter wood

TABLE 1

ERFO SITES - RELATED TO THE 97 FLOOD summary.123 11/12/98

Geo - Hydro:

GEO13 *[area=westside]*

Geo13 #	Description	# of sites	acres	sites/sqmi	acres % tot	b(k; n, p)*	most likely
1	active slides	26	12,118	1.37	0.01	0.000	7
2	toe zones	9	8,429	0.68	0.00	0.042	5
3	dormant slides	233	262,253	0.57	0.15	0.000	141
4	granitic lands [steep, >65%]	8	49,392	0.10	0.03	1.000	27
5	granitic lands [slopes, <65%]	96	208,678	0.29	0.12	0.959	112
6	non-granitic lands [>65%]	28	166,230	0.11	0.10	1.000	90
8	non-granitic lands [<65%]	228	620,215	0.24	0.36	1.000	334
9	inner gorge in unconsolidated	65	43,896	0.95	0.03	0.000	24
10	inner gorge in granitic lands	68	44,709	0.97	0.03	0.000	24
11	inner gorge in non-granitics	123	121,343	0.65	0.07	0.000	65
12	debris basins	1	19,235	0.03	0.01	1.000	10
13	surficial deposits [Qg, Qt, Q]	36	152,259	0.15	0.09	1.000	82
	TOTALS	921	1,708,757	0.34	1.00		921

BEDROCK TERRANE *[area=westside]*

'ter'	Description	# of sites	acres	sites/sqmi	acres % tot	b(k; n, p)*	most likely
cd	Condrey Mountain	109	107,383	0.65	0.07	0.000	62
cm	Central Metamorphic	11	49,221	0.14	0.03	1.000	28
pl	plutons	197	409,363	0.31	0.25	0.998	235
rct	Rattlesnake Creek	370	430,000	0.55	0.27	0.000	247
sbt	Sawyers Bar	73	344,416	0.14	0.21	1.000	198
sbt?/sf?	Sawyers Bar or Stuart Fork ?	0	5,326	0.00	0.00	1.000	3
sf	Stuart Fork	14	64,748	0.14	0.04	1.000	37
sur	surficial deposits	6	1,579	2.43	0.00	0.000	1
wht	Western Hayfork	89	109,554	0.52	0.07	0.001	63
wj	Western Jurassic	50	80,000	0.40	0.05	0.287	46
yr	Yreka	8	14,213	0.36	0.01	0.569	8
	TOTALS	927	1,615,803	0.37	1.00		927

RIPARIAN RESERVE *[area=westside]*

Description	# of sites	acres	sites/sqmi
Geologically defined [geo13: 1,2,9,10,11]	168	116,705	0.92
Hydrologically defined	360		
Combined [Riparian reserve by either]]	401		
Total	939	42.7%	= % of slides in riparian reserve

Disturbance:

FIRE *[area=westside]*

Description		# of sites	acres	sites/sqmi	acres % tot	b(k; n, p)*	most likely
1987	burn intensity 'hi' or 'med'	140	113,645	0.79	0.07	0.000	66
Hog	"	6	44,420	0.09	0.03	1.000	26
Dillon	"	0	7,160	0.00	0.00	1.000	4
Specimen	"	0	3,134	0.00	0.00	1.000	2
Total		146	168,360	0.56	0.10		

HARVEST *[area=westside]*

Description	# of sites	acres	sites/sqmi	acres % tot	b(k; n, p)*	most likely
Plantations older than 1977	96	67,317	0.91	0.04	0.000	39
1977 & younger [includes OR, NS, SW]	131	76,830	1.09	0.05	0.000	45
TOTALS	227	144,147	1.01	0.09		

"UNDISTURBED" *[area=photo area]*

Description	# of sites	acres	sites/sqmi	acres % tot	b(k; n, p)**	most likely
Sites: [i] not within H or M fire burn intensity, and [ii] not within old or young harvest areas	479 (of 744 sites)	609,074	0.50	0.79	0.000	562

Physical:

ELEVATION

Description	# of sites	acres	sites/sqmi	*[area=photo area]* acres % tot	b(k; n, p)*	most likely
0 - 2,000'	97	107,266	0.58	0.14	0.767	103
2,000' - 4,000'	462	373,989	0.79	0.48	0.000	361
4,000' - 6,000'	185	240,885	0.49	0.31	1.000	232
> 6,000'	0	49,443	0.00	0.06	1.000	48
TOTALS	744	771,583	0.62			744

SLOPE

Description	# of sites	acres	sites/sqmi	*[area=photo area]* acres % tot	b(k; n, p)*	most likely
0 - 20%	89	66,468	0.86	0.09	0.001	64
20 - 40%	274	235,990	0.74	0.31	0.000	228
40 - 65%	332	344,127	0.62	0.45	0.509	332
> 65%	49	124,998	0.25	0.16	1.000	121
TOTALS	744	771,583	0.62			744

ASPECT

Description		# of sites	acres	sites/sqmi	*[area=photo area]* acres % tot	b(k; n, p)*	most likely
Flat		2	718	1.78	0.00	0.151	1
North	[310 - 70 degrees]	238	231,087	0.66	0.30	0.085	220
East	[70 - 130 degrees]	168	142,907	0.75	0.19	0.002	136
South	[130 - 250 degrees]	220	265,756	0.53	0.34	0.996	253
West	[250 - 310 degrees]	116	131,114	0.57	0.17	0.826	125
TOTALS		744	771,582	0.62			

* b(k;n,p) = probability density function for binomial distribution; probability of (at LEAST) 'k' successes in 'n' Bernoulli trials with probability ['p'] of success for each trial

** b(k;n,p) = probability density function for binomial distribution; probability of (at MOST) 'k' successes in 'n' Bernoulli trials with probability ['p'] of success for each trial

OR = overstory removal
NS = non-stocked
SW = shelter wood

TABLE 2

TABLE 3

ALTERED CHANNELS - RELATED TO THE 97 FLOOD 11/12/98

["area" ~= photo area for all]

Geo - Hydro:

GEO13

Geo13 #	Description	altered mi	unaltered mi	total mi	acres	density*	% altered
1	active slides	12.40	40.44	52.84	7,271	1.09	23.5%
2	toe zones	1.69	7.13	8.82	6,204	0.17	19.2%
3	dormant slides	23.05	220.96	244.01	182,429	0.08	9.4%
4	granitic lands [steep, >65%]	2.73	0.97	3.70	21,411	0.08	73.8%
5	granitic lands [slopes, <65%]	8.71	47.01	55.72	80,270	0.07	15.6%
6	non-granitic lands [>65%]	6.70	5.40	12.10	74,380	0.06	55.4%
8	non-granitic lands [<65%]	20.48	127.52	148.00	245,171	0.05	13.8%
9	inner gorge in unconsolidated	85.72	519.77	605.49	26,502	2.07	14.2%
10	inner gorge in granitic lands	106.87	267.62	374.49	22,240	3.08	28.5%
11	inner gorge in non-granitics	162.97	992.54	1155.51	54,488	1.91	14.1%
12	debris basins	1.07	3.07	4.14	7,790	0.09	25.8%
13	surficial deposits [Qg, Qt, Q]	13.85	101.43	115.28	43,185	0.21	12.0%
	TOTALS	446.24	2333.86	2780.10	771,341	0.37	16.1%

BEDROCK TERRANE

'ter'	Description	altered mi	unaltered mi	total mi	acres	density*	% altered
cd	Condrey Mountain	30.40	374.86	405.26	107,383	0.18	7.5%
pl	plutons	156.06	425.59	581.65	154,170	0.65	26.8%
rct	Rattlesnake Creek	199.76	895.50	1095.26	323,534	0.40	18.2%
sbt	Sawyers Bar	23.00	194.52	217.52	61,291	0.24	10.6%
sbt?/sf?	Sawyers Bar or Stuart Fork ?	0.00	4.87	4.87	1,216	0.00	0.0%
sf	Stuart Fork	0.48	8.73	9.21	3,285	0.09	5.2%
wht	Western Hayfork	20.19	196.51	216.70	59,837	0.22	9.3%
wj	Western Jurassic	16.35	233.27	249.62	60,835	0.17	6.5%
	TOTALS	446.24	2,333.85	2,780.09	771,551	0.37	16.1%

Disturbance:

FIRE

Description	altered mi	unaltered mi	total mi	acres	density*	% altered
Burn intensity 'hi' or 'med'	30.40	374.86	405.26	76,692	0.25	7.5%
Burn intensity 'low'	156.06	425.59	581.65	98,751	1.01	26.8%
Unburned	259.78	1533.40	1793.18	596,108	0.28	14.5%
[Hog, 87 Fires, Dillon, Specimen combined]]		[note:	'acres' figures include all four fires]			
Totals within burned areas	186.46	800.45	986.91	175,443	0.68	18.9%

HARVEST

Description	altered mi	unaltered mi	total mi	acres	density*	% altered
1977 & younger [includes OR, NS, SW]	27.32	56.31	83.63	46,547	0.38	32.7%
Plantations older than 1977	13.81	77.90	91.71	48,089	0.18	15.1%
Non-harvested areas	405.11	2199.64	2604.75	676,915	0.38	15.6%
Totals within harvested areas	41.13	134.21	175.34	94,636	0.28	23.5%

TABLE 3

Physical:

ELEVATION

Description	altered mi	unaltered mi	total mi	acres	density*	% altered
0 - 2,000'	83.13	665.65	748.78	107,266	0.50	11.1%
2,000' - 4,000'	201.36	1089.29	1290.65	373,989	0.34	15.6%
4,000' - 6,000'	158.72	525.75	684.47	240,885	0.42	23.2%
> 6,000'	3.06	52.93	55.99	49,443	0.04	5.5%
TOTALS	446.27	2,333.62	2,779.89	771,583	0.37	16.1%

SLOPE

Description	altered mi	unaltered mi	total mi	acres	density*	% altered
0 - 20%	140.87	753.20	894.07	66,468	1.36	15.8%
20 - 40%	159.03	1076.45	1235.48	235,990	0.43	12.9%
40 - 65%	120.98	461.93	582.91	344,127	0.22	20.8%
> 65%	25.46	42.32	67.78	124,998	0.13	37.6%
TOTALS	446.34	2333.90	2780.24	771,583	0.37	16.1%

Note: slope class is NOT indicative of channel gradient, but reflects steepest side wall

ASPECT

Description		altered mi	unaltered mi	total mi	acres	density*	% altered
Flat		1.22	10.98	12.20	718	1.09	10.0%
North	[310 - 70 degrees]	158.27	759.26	917.53	231,087	0.44	17.2%
East	[70 - 130 degrees]	85.41	449.41	534.82	142,907	0.38	16.0%
South	[130 - 250 degrees]	134.79	753.78	888.57	265,756	0.32	15.2%
West	[250 - 310 degrees]	66.64	360.40	427.04	131,114	0.33	15.6%
TOTALS		446.33	2333.83	2780.16	771,582	0.37	16.1%

* density measured in 'altered miles' of channel per sq mile

Photo Area

SLIDES MULTIPLE FACTORS special.123 11/12/98

Geo13	Elevation	ROADS			FIRE			HARVEST						UNDISTURBED			*TOTALS*			FIRE+HARVEST		
Geo13 [geo13 #]	Elevation [range, ft]	ls [#]	Rd_buf [acres]	den [ls/sqmi]	ls [#]	Fire [acres]	den [ls/sqmi]	ls [#]	Harv77 [acres]	den [ls/sqmi]	ls [#]	Harv76 [acres]	den [ls/sqmi]	ls [#]	None [acres]	den [ls/sqmi]	ls [#]	Acres	den [ls/sqmi]	ls [#]	Fire_Harv [acres]	den [ls/sqmi]
1	0-2000		65.7	0.00	2	113.1	11.32		27.5	0.00		115.9	0.00	5	2,093.2	1.53	7	2,415.4	1.85		21.1	0.00
1	2000-4000	8	96.2	53.22	2	279.7	4.58		119.6	0.00	4	545.9	4.69	13	2,186.0	3.81	27	3,227.4	5.35		97.7	0.00
1	4000-6000	2	26.2	48.85	7	242.8	18.45	1	27.7	23.10	2	167.3	7.65	17	1,105.3	9.84	29	1,569.3	11.83	4	16.6	154.22
1	>6000		0.3	0.00		0.1	0.00		0.9	0.00		0.1	0.00	1	51.6	12.40	1	53.0	12.08		0.0	ERR
	Total	**10**	**188.4**	**33.97**	**11**	**635.7**	**11.07**	**1**	**175.7**	**3.64**	**6**	**829.2**	**4.63**	**36**	**5,436.1**	**4.24**	**64**	**7,265.1**	**5.64**	**4**	**135.4**	**18.91**
2	0-2000	1	62.4	10.26		20.9	0.00		141.5	0.00		45.3	0.00	1	2,521.7	0.25	2	2,791.8	0.46		1.2	0.00
2	2000-4000		78.8	0.00		51.2	0.00		144.7	0.00		232.6	0.00	2	2,064.4	0.62	2	2,571.7	0.50		5.1	0.00
2	4000-6000		24.5	0.00		56.5	0.00		13.7	0.00	1	16.3	39.26		719.2	0.00	1	830.2	0.77		7.6	0.00
2	>6000		0.0	ERR		0.0	ERR		0.0	ERR		0.0	ERR		8.3	0.00	0	8.3	0.00		0.0	ERR
	Total	**1**	**165.7**	**3.86**	**0**	**128.6**	**0.00**	**0**	**299.9**	**0.00**	**1**	**294.2**	**2.18**	**3**	**5,313.6**	**0.36**	**5**	**6,202.0**	**0.52**	**0**	**13.9**	**0.00**
3	0-2000	1	691.4	0.93		846.1	0.00		1,274.8	0.00		1,796.6	0.00		20,409.7	0.00	1	25,018.6	0.03		157.3	0.00
3	2000-4000	24	3,051.9	5.03	9	7,759.7	0.74	4	6,860.7	0.37	1	12,463.6	0.05	20	68,596.5	0.19	58	98,732.4	0.38	4	2,154.8	1.19
3	4000-6000	30	1,668.2	11.51	46	3,974.3	7.41	15	3,649.6	2.63	7	3,499.6	1.28	42	39,855.4	0.67	140	52,647.1	1.70	21	892.6	15.06
3	>6000		84.8	0.00		33.6	0.00	2	295.1	4.34		197.8	0.00	5	5,381.2	0.59	7	5,992.5	0.75		6.6	0.00
	Total	**55**	**5,496.3**	**6.40**	**55**	**12,613.7**	**2.79**	**21**	**12,080.2**	**1.11**	**8**	**17,957.6**	**0.29**	**67**	**134,242.8**	**0.32**	**206**	**182,390.6**	**0.72**	**25**	**3,211.3**	**4.98**
4	0-2000		2.2	0.00		223.6	0.00		5.3	0.00		0.0	ERR		1,114.9	0.00	0	1,346.0	0.00		4.1	0.00
4	2000-4000	2	63.7	20.09	7	1,722.9	2.60		249.9	0.00		173.4	0.00	5	8,809.1	0.36	14	11,019.0	0.81	1	108.2	5.91
4	4000-6000	1	26.7	23.97	5	640.8	4.99	1	75.3	8.50		68.4	0.00	1	6,312.0	0.10	8	7,123.2	0.72	2	94.4	13.56
4	>6000		0.7	0.00	1	58.0	11.03		0.0	ERR		0.2	0.00		1,852.4	0.00	1	1,911.3	0.33		0.4	0.00
	Total	**3**	**93.3**	**20.58**	**13**	**2,645.3**	**3.15**	**1**	**330.5**	**1.94**	**0**	**242.0**	**0.00**	**6**	**18,088.4**	**0.21**	**23**	**21,399.5**	**0.69**	**3**	**207.1**	**9.27**
5	0-2000	3	59.6	32.21		414.0	0.00		47.7	0.00		22.8	0.00		3,762.6	0.00	3	4,306.7	0.45		0.9	0.00
5	2000-4000	20	858.5	14.91	9	4,242.1	1.36		1,635.3	0.00	1	2,479.6	0.26	6	28,573.8	0.13	36	37,789.3	0.61	4	431.9	5.93
5	4000-6000	6	451.8	8.50	18	3,173.7	3.63	3	942.7	2.04		1,196.3	0.00	5	25,986.3	0.12	32	31,750.8	0.65	7	686.1	6.53
5	>6000		18.9	0.00	1	445.1	1.44		42.5	0.00		7.9	0.00		3,879.8	0.00	1	6,394.2	0.10		25.9	0.00
	Total	**29**	**1,388.8**	**13.36**	**28**	**8,274.9**	**2.17**	**3**	**2,668.2**	**0.72**	**1**	**3,706.6**	**0.17**	**11**	**64,202.5**	**0.11**	**72**	**80,241.0**	**0.57**	**11**	**1,144.8**	**6.15**
6	0-2000	1	42.1	15.20	1	869.4	0.74		178.0	0.00		133.1	0.00		7,410.2	0.00	2	8,632.8	0.15	1	126.6	5.06
6	2000-4000	1	411.4	1.56	7	6,920.0	0.65	5	1,170.4	2.73	2	1,605.5	0.80	6	30,439.0	0.13	21	40,546.3	0.33	2	1,299.3	0.99
6	4000-6000	7	105.6	42.42	7	2,927.9	1.53	6	359.3	10.69		134.0	0.00	5	17,262.6	0.19	25	20,789.4	0.77	2	308.8	4.15
6	>6000		0.3	0.00		36.3	0.00		2.6	0.00		0.4	0.00	2	4,352.7	0.29	2	4,392.3	0.29		0.4	0.00
	Total	**9**	**559.4**	**10.30**	**15**	**10,753.6**	**0.89**	**11**	**1,710.3**	**4.12**	**2**	**1,873.0**	**0.68**	**13**	**59,464.5**	**0.14**	**50**	**74,360.8**	**0.43**	**5**	**1,735.1**	**1.84**
8	0-2000	1	685.3	0.93		1,981.1	0.00		863.2	0.00		1,196.8	0.00		22,543.7	0.00	1	27,270.1	0.02		335.2	0.00
8	2000-4000	12	3,152.8	2.44	12	18,293.5	0.42	9	5,273.7	1.09	3	8,831.0	0.22	13	84,639.7	0.10	49	120,190.7	0.26	6	4,635.4	0.83
8	4000-6000	29	1,655.8	11.21	21	9,693.9	1.39	17	3,322.3	3.27	3	3,071.7	0.63	21	59,256.5	0.23	91	77,000.2	0.76	17	2,042.7	5.33
8	>6000		195.8	0.00	1	351.9	1.82	2	330.1	3.88		270.2	0.00	5	19,436.8	0.16	8	20,584.8	0.25		58.4	0.00
	Total	**42**	**5,689.7**	**4.72**	**34**	**30,320.4**	**0.72**	**28**	**9,789.3**	**1.83**	**6**	**13,369.7**	**0.29**	**39**	**185,876.7**	**0.13**	**149**	**245,045.8**	**0.39**	**23**	**7,071.7**	**2.08**
9	0-2000	1	140.8	4.55		201.8	0.00		104.9	0.00		219.9	0.00	6	5,993.6	0.64	7	6,661.0	0.67		30.2	0.00
9	2000-4000	2	236.6	5.41	5	795.1	4.02		338.2	0.00		682.9	0.00	16	10,418.6	0.98	23	12,471.4	1.18	1	94.8	6.75
9	4000-6000	3	93.3	20.58	4	245.4	10.43	4	95.3	26.86		143.3	0.00	15	6,514.3	1.47	26	7,091.6	2.35	2	26.3	48.67
9	>6000		0.6	0.00		0.0	ERR		0.0	ERR		0.0	ERR		265.9	0.00	0	266.5	0.00		0.0	ERR
	Total	**6**	**471.3**	**8.15**	**9**	**1,242.3**	**4.64**	**4**	**538.4**	**4.75**	**0**	**1,046.1**	**0.00**	**37**	**23,192.4**	**1.02**	**56**	**26,490.5**	**1.35**	**3**	**151.3**	**12.69**

Photo Area SLIDES MULTIPLE FACTORS special.123 11/12/98

		ROADS			FIRE			HARVEST						UNDISTURBED			*TOTALS*			FIRE+HARVEST		
Geo13	Elevation	ls	Rd_buf	den	ls	Fire	den	ls	Harv77	den	ls	Harv76	den	ls	None	den	ls	Acres	den	ls	Fire_Harv	den
10	0-2000	1	55.5	11.53		265.8	0.00		20.5	0.00		7.0	0.00		3,721.1	0.00	1	4,069.9	0.16		7.0	0.00
10	2000-4000	8	174.8	29.29	4	1,185.4	2.16		288.3	0.00		376.9	0.00	5	12,493.7	0.26	17	14,519.1	0.75	1	57.1	11.21
10	4000-6000	1	23.4	27.35	5	265.6	12.05		55.5	0.00	1	62.0	10.32	4	3,215.9	0.80	11	3,622.4	1.94		14.0	0.00
10	>6000		0.0	ERR		0.3	0.00		0.0	ERR		0.0	ERR		20.4	0.00	0	20.7	0.00		0.0	ERR
	Total	10	253.7	25.23	9	1,717.1	3.35	0	364.3	0.00	1	445.9	1.44	9	19,451.1	0.30	29	22,232.1	0.83	1	78.1	8.19
11	0-2000	2	359.3	3.56	5	839.5	3.81		278.7	0.00		272.4	0.00	2	14,969.5	0.09	9	16,719.4	0.34		116.8	0.00
11	2000-4000	7	340.2	13.17		3,556.9	0.00	1	489.3	1.31		955.6	0.00	8	23,377.2	0.22	16	28,719.2	0.36	2	428.4	2.99
11	4000-6000	7	92.2	48.59	2	792.8	1.61	4	215.6	11.87		100.7	0.00	10	7,660.3	0.84	23	8,861.6	1.66	1	80.9	7.91
11	>6000		0.0	ERR		0.0	ERR		0.4	0.00		0.0	ERR		168.5	0.00	0	168.9	0.00		0.0	ERR
	Total	16	791.7	12.93	7	5,189.2	0.86	5	984.0	3.25	0	1,328.7	0.00	20	46,175.5	0.28	48	54,469.1	0.56	3	626.1	3.07
12	0-2000		0.0	ERR		2.2	0.00		0.0	ERR		0.4	0.00		67.5	0.00	0	70.1	0.00		0.0	ERR
12	2000-4000		0.0	ERR		271.3	0.00		18.0	0.00		0.0	ERR		1,175.6	0.00	0	1,464.9	0.00		0.0	ERR
12	4000-6000		1.9	0.00	2	380.8	3.36		17.4	0.00		5.3	0.00	1	3,545.7	0.18	3	3,951.1	0.49		2.8	0.00
12	>6000		0.5	0.00		4.6	0.00		0.0	ERR		0.0	ERR		2,294.0	0.00	0	2,299.1	0.00		0.0	ERR
	Total	0	2.4	0.00	2	658.9	1.94	0	35.4	0.00	0	5.7	0.00	1	7,082.8	0.09	3	7,785.2	0.25	0	2.8	0.00
13	0-2000		556.1	0.00		91.1	0.00		46.6	0.00		32.6	0.00	1	7,211.6	0.09	1	7,938.0	0.08		2.9	0.00
13	2000-4000		88.2	0.00		129.9	0.00		80.4	0.00		40.5	0.00		2,271.8	0.00	0	2,610.8	0.00		29.7	0.00
13	4000-6000	1	86.9	7.36	3	780.3	2.46		253.6	0.00		182.8	0.00	2	24,074.5	0.05	6	25,378.1	0.15		81.7	0.00
13	>6000		31.2	0.00		83.5	0.00		117.4	0.00		21.4	0.00		6,989.9	0.00	0	7,243.4	0.00		0.0	ERR
	Total	1	762.4	0.84	3	1,084.8	1.77	0	498.0	0.00	0	277.3	0.00	3	40,547.8	0.05	7	43,170.3	0.10	0	114.3	0.00
Totals:		182	15,863.1	7.34	186	75,264.5	1.58	74	29,474.2	1.61	25	41,376.0	0.39	245	609,074.2	0.26	712	771,052.0	0.59	78	14,491.9	3.44
	0-2000	11	2,720.4	2.59	8	5,868.6	0.87	0	2,988.7	0.00	0	3,842.8	0.00	15	91,819.3	0.10	34	107,239.8	0.20	1	803.3	0.80
Totals:	2000-4000	84	8,553.1	6.29	55	45,207.7	0.78	19	16,668.5	0.73	11	28,387.5	0.25	94	275,045.4	0.22	263	373,862.2	0.45	21	9,342.4	1.44
	4000-6000	87	4,256.5	13.08	120	23,174.8	3.31	51	9,028.0	3.62	14	8,647.7	1.04	123	195,508.0	0.40	395	240,615.0	1.05	56	4,254.5	8.42
	>6000	0	333.1	0.00	3	1,013.4	1.89	4	789.0	3.24	0	498.0	0.00	13	46,701.5	0.18	20	49,335.0	0.26	0	91.7	0.00

KEY

rd_buf — within 50' wide road prism [see note below]
fire — outside 50' wide road prism; within fire burn intensity = H or M [from Hog, Fire87, Dillon, Specimen fires]
harv77 — outside 50' road prism; outside H or M fire burn intensity within harvested area YOUNGER than 1977 [includes NS, OR, SW]
harv76 — outside 50' road prism; outside H or M fire burn intensity within harvested area OLDER than 1977
none — within "undisturbed" area; outside road prism, outside H or M fire burn intensity, outside harvested area [old (pre-1977) or new (post-1977)]
fire_harv — outside road buffer within fire burn intensity H or M and within "newly" harvested area [younger than 1977, NS]

<u>Note:</u> Assumptions used concerning the count of slides & corresponding acres:
If the "labelpoint" of a slide was within 150' of a road, it was considered to be "road-related" and counted under the "Roads" section. However, in computing density of slides, a corridor 50' wide [~= road prism] was used, rather than one 300' wide (150' x 2).
If labelpoint of a slide was greater than 150' from a road, it was considered NOT to be "road-related" and counted elsewhere. Acre figures were calculated as described above.

TABLE 4

APPENDICES

THE FLOOD OF 1997: KLAMATH NATIONAL FOREST

PHASE I FINAL REPORT: NOVEMBER 24, 1998

CONTENTS

APPENDIX A

METHODS & CONTRIBUTIONS FROM OTHERS

Methods used in this assessment include: 1. Compilation and interpretation of precipitation and stream flow records; 2. Examination of Damage Site Reports for ERFO (Emergency Relief, Federally Owned) sites; 3. Inventory of landslides and altered channels on post-flood air photos; 4. Field observations of a sample of ERFO sites, landslides, and altered channels; 5.Consultation with field personnel; 6. Spacial analysis of flood effects in a GIS. The GIS analysis included development of new data layers containing 1997 landslides, flood altered channels, and ERFO sites. These new layers were overlain with existing forest-wide layers, such as bedrock, geomorphology, roads, harvest, fire, and topography from a digital elevation model (DEM).

I. DATA COLLECTION AND INVENTORY

A. PRECIPITATION AND STREAM FLOW DATA

Precipitation data were obtained from U.S. Forest Service and State of California Water Resource records (snow pillow stations), as well as private stations. Stream flow data were obtained from the U.S.G.S. WEB site (http://h2o.usgs.gov) and Mike Friebel (USGS Redding, personal communication, 12/5/97). Information on snow water content (as well precipitation and air temperature) is from California Department of Water Resources (snow pillow) recording stations (http://cdec.water.ca.gov and Dave Hart, personal communication, 1997). Other snowpack information is anecdotal accounts from various individuals.

B. ERFO SITE INVENTORIES

ERFO sites are damaged areas which qualify for Emergency Relief Federally Owned (ERFO) funding. A total of 712 ERFO sites (with a total cost of $27 million) have been recorded by engineering personnel and approved for funding as of March, 1998. These Data have been entered into a spreadsheet and GIS layer. To qualify, a site must exceed $2,000 in damage. Inventory of ERFO sites was initiated immediately after the flood and continued through the fall

of 1997. The entire west side of the Forest has been inventoried with the exception of minor spurs.
For purposes of this assessment, a sample of 277 Damage Site Reports were stratified into 7 primary types: 1. Stream crossing failures; 2. Landslides; 3. Fill failures away from streams; 4. Stream undercuts; 5. Road cut failures; 6. Surface erosion and gullies; 7. Flooding. Phase II of this flood assessment will stratify the remainder of the sites.

Rationale for ERFO Strata

These strata were designed to place sites into categories sharing common slope processes, and as a result, common mitigation needs. For example, stream crossing failures usually share common processes such as clogging of culverts with debris, overtopping and scour of fill, diversion of surface water, and saturation failure of fill. These processes lend themselves to common mitigation measures such as designing crossings to survive overtopping, making fills resistant to debris flow scour and saturation fill failure, and preventing diversion of surface flow. Recommended mitigation measures were linked directly to Aquatic Conservation Strategy Objectives (from the Northwest Forest Plan), as were guidelines for ERFO site repair in Recommendation section. Similarly, fill failures away from stream crossings share a number of common factors such as steep slopes, presence of groundwater, and sandy soils, and are often initiation sites for debris flows, whereas, cut slope failures were found to be less likely to initiate debris flows.

Stratification requires some generalization, in that many sites are very complex, and could be placed in several of the strata. Their placement into a given stratum has important implications to conclusions which are drawn from the data, and recommendations which are developed to address common problems. For example, stratification of the sites revealed that road failures at stream crossings make up 51% of the total ERFO sites. However, road stream crossing failures included everything from fills taken out by debris flows originating high in the watershed (unrelated to the road) to large earthflows which damaged or removed the entire road prism. It is clear that these differences must be identified. Also, fill failures may play an important role in other strata like undercuts and stream crossings, and we must not lose sight of the need to construct stable fills in the future, since these are events which would definitely not happen were the road not in place. Descriptions of the strata follow. The percentages listed below are from the initial stratification sample.

Road Stream Crossing Failures (51%)- These sites involve failure of road crossings on perennial, intermittent or ephemeral streams. Damage ranged from minor filling of catch basins with sediment, to catastrophic loss of the fill and culvert. Failure processes included, scour and wash, debris flow, and in some cases, slump and earthflow. Where landsliding affected the foundation beneath the road fill, the site was classified as a stream crossing failure, but also coded in the data base as involving landslide processes.

Landslides Away From Stream Crossings (18%)- These are sites away from stream crossings, where landsliding affected the road prism and also the foundation below. They include debris slides, slumps, earthflows, and complexes. Simple fill failures which did not include the foundation (natural ground), and small cut failures were placed in separate strata, Fill Failures, and Road Cut Failures respectively.

Fill Failures Away From Streams (14%)- This category consists of landsliding in artificial fill away from stream crossings. Failure is limited in extent to the road fill, but may involve a minor component of natural ground beneath the fill. It was selected as one of the strata in order to capture the many fill failures which were observed on hillslopes (often in swales) away from stream crossings, quite often in sandy soils. Slope processes are primarily debris slide, scour by debris flows, gullying, channel wash. Where substantial landslide failure of the foundation occurs in the foundation below the fill, the site was classified as a landslide.

Stream Undercuts of Road Prisms (8%)- This category consists predominantly of landsliding induced by stream undercutting. Most sites occur where the road parallels the stream, and very high flows or channel deflections result in undercutting of the road prism, or structures such as bridge abutments. Failure process is primarily mass wasting induced by stream scour and wash, but may include piping associated with high seepage pressures which develop as flood waters recede. Some sites involved only 10's of cubic yards, while others involved thousands. Some of these sites, such as large earthflows undercut by the stream were classified as landslides.

Road Cut Failures Away From Streams (6%)- These are small slumps and earthflows on road cuts. They are confined for the most part to the cut slope above the road, and do not involve the road bed (the failure plane daylights above the road surface). They may extend to the land above the original road cut, but where they extend for more than one additional cut height into the natural ground, the site is placed in the landslide category.

Gullies, Rills and Sheet Wash Linked to Water Concentration and Diversion (1%)- These sites are erosional sites formed by flowing water or water and debris. Landslide processes are only of secondary importance. In many cases, they were caused by diversions at stream crossings. During the process of recording ERFO sites, some gullies were lumped with stream crossing failures, while others were recorded as individual sites. Failure of cross drains on in-sloped roads had similar but generally smaller adverse effects, since they typically diverted less water.

Flooding (1%)- This includes the effects of floodplain inundation, such as deposition of fine sediment, and water damage.

A second sample of 297 sites was subsequently stratified, and preliminary results given in section IV. C.1. of this report (effects assessment for roads). These data will be combined with the initial sample in Phase II of the flood assessment.

C. INVENTORY OF AIR PHOTOS

Air Photos

Color infrared air photos at a scale of 1:40,000 (#715050 USDA F 40) were taken on May 7, 1997. These photos were examined, and landslides as well as altered channels were mapped on photo overlays under a stereoscope, and manually transferred to 1:24,000 topographic maps and digitized. The area covered by post-flood air photos was about 771,000 acres (Map 2). The area covered by post-flood air photos was about 771,000 acres (Map 2). This sample area was selected due to the concentration of effects there, and insufficient funds to fly the entire forest. Altered channels and landslides which were mapped outside the air photo area (Map 2) were identified by local field investigations and consultation with District personnel. Additional air photos (scales ranging from 1:300 to 1:24000) were flown in October, 1998, but were not available in time to be used in this assessment. They will be used in Phase II.

Criteria Used in Air Photo Inventory

Inventory criteria were: a. All landslides with scarps devoid of vegetation and judged to be new were mapped. Altered channels were similarly mapped. Those in which much of the riparian vegetation was recently removed/damaged, or exhibited obvious new deposition were identified as altered channels. Some creeks, such as Clear, Dillon, and Wooley Creeks exhibited only minor scour of confined bedrock reaches, but were also identified as altered channels, since their channels had the appearance of being newly disturbed and were different from adjacent channels. The main stem of the Klamath River from Beaver Creek to Somes Bar, and the Scott River from Canyon Creek to its mouth, and the lower Salmon River from Wooley Creek to the mouth exhibited sufficient alteration on air photos to be identified as flood-altered, but were not digitized in time to be included in these results. Thus, the totals for altered channels do not include them. Together, these would add about 90 miles to the total of 446. Some of the mapped landslides and altered channels likely predate the 1997 flood. Landslides were checked against 1995 air photos and those which were present prior to the flood were identified. The results are given below in "Limitations of the Air Photo Data". Mapping of altered channels and identification of pre-1997 landslides is being refined in Phase II of the flood study. To date, 712 landslides have been and digitized from air photos, with 25 added from field observations.

Limitations of Air Photo Data

It is important to note that ERFO sites consist of all road-related problems, ranging from a clogged culvert to the catastrophic failure of a large fill. Some of the landslides identified in the air photo survey coincide with ERFO sites, and there are many landslides identified by the ERFO survey which ware not visible on the air photos.

Note that landslides are more visible in openings such as in clearcuts, burned areas, and along roads, and as a result, air photo inventories will often skew the distribution of landslides, since fewer are visible under a timber canopy. Landslides as small as 20 feet wide were visible in openings from the 1:40000 air photos used in this assessment. This was made possible by the sharp contrast between barren areas and areas covered by low vegetation on the CIR photos. However, field work revealed that some grassy glades within forest openings were mapped as landslides on the air photo inventory. It is estimated that less than 5% of mapped slides fall in this category, since the check of 1995 air photos was able to verify about 95% as landslides. A photo check of pre-flood air photos (color, 1:16,000 1995) was made to identify landslides predating the flood. This check revealed that about **6% of the landslides actually predated the 1997 flood, 17% were visible on 1995 photos but enlarged in 1997, 5% could not be verified because the 1995 air photos were not available, or could not be found on the 1995 photos, and 72% were confirmed as new 1997 landslides.**

Overlap: Landslides Mapped on Air Photos and ERFO Sites

The air photo inventory was done independent of the ERFO inventory. Some of the air photo identified landslides coincide with ERFO sites, but the overlap has not yet been addressed. Therefore, it is necessary to analyze photo inventory data on active landslides, and ERFO data separately. An approximation of the number of ERFO sites which involve landsliding was derived from the information gained by stratifying 277 ERFO sites (Table 5). The numbers and assumptions are stated below.

Air photo inventory identified 712 landslides, 25 were identified by field survey in Salmon River, and it is estimated that ERFO sites identified an additional 460 landslides (when 796 ERFO sites had been identified), or a total of 1197. However, it is estimated that there is an overlap of about 100 landslides between air photo identified landslides and ERFO sites. This results in approximately 1100 landslides in total identified by this assessment. Rationale for these numbers follow.

1. Stream crossing failures comprise about 51% of ERFO sites, and it is estimated that roughly 30% of these involve landsliding (about 120).
2. ERFO sites which were classified as landslides comprise about 18% of ERFO sites, totaling 120.
3. Fill failures are about 90% debris slides, and comprise 14% of all ERFO sites. This adds up to110.
4. Stream undercut failures comprise about 8% of ERFO aites and it is estimated that roughly 60% of these involve landsliding. This adds up to 60.
5. Cut Slope failures are predominantly debris slides and shallow slumps by nature, and comprise 6% of ERFO sites, equaling about 50.

The sum of items 1-5 above is 460, or 58% of ERFO sites (460 / 796 = 0.58).

The previous figures were derived from the initial sample of 796 ERFO sites which were stratified. A second sample yields a higher proportion of fill failures away from streams which likely involve landslide processes. If the sample of ERFO sites used for later computations (927 sites) is considered, then ERFO sites would add 533 landslides (927 x 58% = 533). Phase II will combine these samples and present a summary.

Thus, about 460 landslide-related ERFO sites. Offsetting this figure is an estimated of 100 landslides identified on air photos which coincide with ERFO sites. Thus, the total number of landslides from both inventories is probably on the order of 1100 (712 from air photos, + 25 from a field survey, + 460 ERFO sites - 100 overlap = 1097).

The photo inventory of landslides did not classify them as road-related or not road-related. The GIS was used to identify those which are within 150 feet of a road, and thus most likely to be road related. It is important to note that ERFO sites consist of all road-related problems, ranging from a clogged culvert to the catastrophic failure of a large fill. Some of the landslides identified in the air photo survey coincide with ERFO sites, and there are many landslides identified by the ERFO survey which ware not visible on the air photos.

D. FIELD INVESTIGATIONS AND OBSERVATIONS

All major watersheds with known effects were visited in the field by the authors, with the exception of upper Kidder and Beaver Creeks. A sample of active landslides were mapped in detail, and the extent of large slumps and earthflows better defined. Descriptions of some of the large landslides are contained in Appendix 3.

E. CONTRIBUTIONS FROM OTHERS

Klamath National Forest

Richard Ashe: Engineer, Supervisor's Office. Preparation of Damage Site Reports, field discussions, review of road guidelines (Appendix C).
Ken Baldwin: Geologist, Happy Camp. Field discussions, doppler radar search, landslide inventory, descriptions of effects in Indian, Elk, and Thompson Creeks, report review.
Bill Bemis: Fish Biologist, Happy Camp. Consultation and field review.
Jim Blanchard: Discussions on ERFO sites.
Larry Brahmsteadt: Engineer, Supervisor's Office. Preparation of Damage Site Reports, field discussions, review of road repair guidelines.
Nels Brownell: Fisheries Technician, Supervisor's Office. Consultation.
Rick Claypole: Timber Preparation, Happy Camp District Office. Video of the flood at Horse Creek, upstream of Seiad Valley.
Cal Conklin: Hydrologist, Supervisor's Office. Consultation and field review, draft report review.

Jim Davis: Biologist/Engineer, review of draft road guidelines.
Juan de la Fuente: Geologist, Supervisor's Office. Air photo inventory, field investigations, stratifying Damage Site Reports, final report, road guidelines.
Orion Dix: Fisheries Biologist, Salmon River District. Consultation and field review, descriptions of effects in north and South Fork Salmon River.
Don Elder: Geologist, Supervisor's Office. Appendix --- Climatological factors (including precipitation, snowpack and peak discharge stream data), field investigations, digitizing flood-related landslides and altered channels, all database development, data queries, graphs and tables.
Pat Garrahan: Recreation Technician, Happy Camp. Trail assessment and video in Elk Creek.
Brent Greenhalgh: Watershed Technician, Salmon River Ranger District. Landslide inventory.
Jon Grunbaum: Fisheries Biologist, Consultation and Field Review, Report review, Writeup of effects of the flood on fish habitat in Elk and Indian Creeks, water temperature comparisons in Elk Creek, assessment of fish habitat improvement structures.
Polly Haessig: Geologist, Supervisor's Office. Consultation and field review, landslide inventory, review of road standards
Richard Harris: Civil Engineer, Pleasant Hill Engineering Center; ERFO damage sites and costs associated with the 1997 flood in the California Region of the Forest Service.
Bob Jester: GIS Technician, Supervisor's Office. Produced maps 1-2 in this report.
Dave Jones: Engineer, Happy Camp Office. Field discussions, Draft Report review.
Jim McGinnis: GIS Technician, Supervisor's Office. Produced maps 3-17 in this report.
Al Olson: Fisheries Biologist, Supervisor's Office. Consultation and field review; assessment of fish habitat improvement structures.
Brenda Olson: Consultation on flood effects in the Salmon River.
Jim Kilgore: Fisheries Biologist, Scott River District. Consultation and field review, and description of effects in Tompkins Creek.
Sharon Koorda: Hydrologist, Scott River District. Consultation and field review, writeup on channel changes in Beaver Creek and the Klamath River
Tom Laurent: Air photo review of 1995 photography to identify pre-flood landslides.
Dave Payne: Recreation Technician, Happy Camp. Channel assessments in Clear, Elk, and Ukonom Creeks.
Jay Power: Hydrologist, Scott River District. Consultation, aerial observations of flood effects, landslides, and snowpack.
Ed Rose: Geotechnical Engineer, Supervisor's Office. Review of geotechnical design, writeup on how pre-1997 slope stabilization projects responded to the flood.
Harry Sampson: Engineer, Supervisor's Office. Field discussions, review of road repair guidelines.
William Snavely: Hydrologist, Ukonom District. Consultation and field review, landslide inventory, descriptions of effects in Irving, McCash, Cedar, and Ukonom Creeks, and large landslides along Klamath River, report review.
Allen Tanner: Fisheries Technician, Scott River District. Consultation.,
Richard Van de Water: GIS Technician, Scott River District. Conducted GIS data layer queries.
Roberta Van de Water: Hydrologist, Salmon River District. Consultation and field review in

the Salmon River watershed, descriptions of effects in North and South Fork Salmon River, landslide inventory.
Bob Varga: Engineer, Supervisor's Office. Field discussions, review of road repair guidelines.
Gene Virtue: Engineer, Happy Camp District. Field discussions, review of road repair guidelines.

Geotechnical Engineers US Forest Service Region 5

Bill Huff: Geotechnical Engineer, Pleasant Hill Engineering Center. Review of Geotechnical Design, Stratification of Damage Site Reports.
Ken Inoye: Geotechnical Engineer, Pleasant Hill Engineering Center. Review of Geotechnical Design, Stratification of Damage Site Reports.
Gordon Keller: Geotechnical Engineer, Plumas National Forest. Review of Geotechnical Design, Stratification of Damage Site Reports.
Jim Mckean: Geotechnical Engineer, Pleasant Hill Engineering Center. Review of Geotechnical Design, Stratification of Damage Site Reports.
Richard Wisehart: Geotechnical Engineer, Stanislaus National Forest. Review of Geotechnical Design, Stratification of Damage Site Reports.

Adjacent National Forests

The following individuals provided information on flood effects in National Forests surrounding the Klamath National Forest:

Steve Bachmann: Hydrologist, Shasta Trinity National Forest,
Sue Becker: Hydrologist, Modoc National Forest
Bob Faust: Hydrologist, Mendocino National Forest
Abel Jasso: Geologist, Shasta Trinity National Forest,
Gordon Keller: Geotechnical Engineer, Plumas National Forest.
Cindy Ricks: Geologist Siskiyou National Forest.
Randy Sharp: Geologist, Modoc National Forest
Dan Sitton: Geologist Rogue River National Forest.
Mark Smith: Geologist Six Rivers National Forest.
Paul Uncapher: Geologist Umpqua National Forest

US Fish and Wildlife Service

Mark Maghini: Wildlife Biologist, US Fish and Wildlife Service. Consultation, field review, draft report review.
Tom Reed: Wildlife Biologist, US Fish and Wildlife Service. Consultation, field review, draft report review.

Klamath Province Advisory Committee

Pat Higgins: Fisheries Resource Advocate, Klamath Province Advisory Committee. Assessment of fish habitat improvement structures.

Other

Jeff Hanson: Mountain Manager, Mt. Ashland Ski Area. Recorded snow depths (December 23, 1996 to January 4, 1997) at two locations within the Mt. Ashland Ski Area.

II. DATA ANALYSIS

Klamath National Forest GIS resource data layers were used in this assessment. They included: 1. Bedrock layer; 2. Geomorphic layer; 3. Inner Gorge Layer; 4. Active Landslide Layer; 5. Derived Geo-13 layer; 6. Vegetation layer; 7. Fire intensity layer; 8. Road layer; 9. Stream Layer. Slope, aspect, and elevation were generated from the USGS 30 meter resolution digital elevation model. Together with the new landslide, altered channel and ERFO layers, the Forest layers were overlain, and attributed, coma delimited data records were generated for manipulation in a data base (PARADOX). The process used was similar to that of Larsen (1996, and 1997).

Landslides were mapped within the air photo inventory area (Map 2) and the GIS was used to determine whether landslides were within the road corridor. The label point for each landslide polygon was used as the point location for each landslide. Those within 150 feet are assumed to be "road-related". This does not account for the fact that some slides above roads may be unrelated to the road, but this is offset by the fact that larger landslides will appear to be more that 150 feet from the road (due to the location of the label point) when in fact they may be road-related. In computing landslide densities, the road corridor was assumed to be 50 feet wide. Larsen (1997) addresses the issue of how roads can influence landslide incidence in a wide corridor, and how selection of corridor width influences computed landslide densities.

In comparing landslide density by physical factors and disturbance, landslides identified by the air photo inventory were used exclusively (with the exception that some field-identified landslides were added). The reason for this was that the air photo inventory was applied uniformly across the landscape, and allowed a fair comparison of how different kinds of land responded. The ERFO inventory does not allow this, since it involved detailed field inventory of virtually the entire road system, but did not identify any landslides which did not directly affect roads. Note that Figure 11 double counts landslides, that is, a landslide which falls in several disturbance categories is included in each category. Total stream miles were determined from the stream layer and include all perennial and intermittent stream from USGS 7 ½ minute quadrangles. Total altered channel miles do not include the altered portions of the main rivers (Klamath, Scott, and portions of the Salmon). Together, they would add about 90 miles to the altered channel total. Debris flow tracks not on streams identified on the USGS maps were digitized and added to the altered channel layer. This amounted to about 120 miles of channel.

APPENDIX B
FINDINGS

I. TABLES

Tables 1-4 are contained in the main body of the report, after References (pp. 67-76). Tables 1-3 involve double counting of landslides and ERFO sites by disturbance class.

Table 1: Landslide Densities (slides/sq mi) by Geomorphic Terrane, Bedrock, Riparian Reserve, and disturbance class (road, fire, harvest, undisturbed), and slope, elevation and aspect. Involves double counting of landslides which occur in multiple disturbance classes, eg. road and fire.
Table 2: ERFO Densities (ERFO sites/sq mi) by Geomorphic Terrane, Bedrock, Riparian Reserve, and disturbance class (fire, harvest, undisturbed) and slope, elevation and aspect.
Table 3: Altered Channel Densities (miles/sq mi) by Geomorphic Terrane, Bedrock, Riparian Reserve, and Disturbance Class (harvest, fire, undisturbed) and slope, elevation and aspect.
Table 4: Landslide Densities by geomorphic terrane by elevation by disturbance class (photo area only). Does not involve double counting of landslides by disturbance class. The values are hierarchical in the following order: Roads; Fire; Old Harvest; New Harvest; Undisturbed.
Table 5 (p. 13): Same as Table 4, but displays ERFO sites in photo area instead of landslides.
Table 6 (p. 15): Same as Table 4, but includes landslide data from Elk Creek only.
Table 7 (p. 17): Same as Table 4, but includes landslide data from Tompkins Creek only.
Table 8 (19): Same as Table 4, but includes landslide data from Walker Creek only.
Table 9 (p. 21): Same as Table 5, but includes ERFO site data from Elk Creek only.
Table 10 (p. 23): Same as Table 5, but includes ERFO data from Tompkins Creek only.
Table 11 (p. 25): Same as Table 5, but includes ERFO data from Walker Creek only.
Table 12 (p. 27): Landslides, ERFO sites and altered channels by watershed.
Table 13 (p. P31): Acre adjustments by Watershed (accounts for area outside photo study area).
Table 14 (p. 32): Landslides, ERFO sites and altered channels by aggregated watershed.

Photo Area

ERFO SITES MULTIPLE FACTORS

special.123 11/12/98

Geo13	Elevation	FIRE Sites	Fire	den	HARVEST Sites	Harv77	den	Sites	Harv76	den	UNDISTURBED Sites	None	den	*TOTALS* Sites	Acres	den	FIRE+HARVEST Sites	Fire_Harv	den
[geo13 #]	[range, ft]	[#]	[acres]	[ls/sqmi]	[#]	[acres]	[ls/sqmi]	[#]	[acres]	[ls/sqmi]	[#]	[acres]	[ls/sqmi]	[#]		[ls/sqmi]	[#]	[acres]	[ls/sqmi]
1	0-2000		113.1	0.00		27.5	0.00		115.9	0.00	7	2,093.2	2.14	7	2,349.7	1.91		21.1	0.00
1	2000-4000	3	279.7	6.86		119.6	0.00		545.9	0.00	7	2,186.0	2.05	10	3,131.2	2.04	1	97.7	6.55
1	4000-6000		242.8	0.00		27.7	0.00	1	167.3	3.83	4	1,105.3	2.32	5	1,543.1	2.07		16.6	0.00
1	>6000		0.1	0.00		0.9	0.00		0.1	0.00		51.6	0.00	0	52.7	0.00		0.0	ERR
	Total	3	635.7	3.02	0	175.7	0.00	1	829.2	0.77	18	5,436.1	2.12	22	7,076.7	1.99	1	135.4	4.73
2	0-2000		20.9	0.00		141.5	0.00		45.3	0.00	5	2,521.7	1.27	5	2,729.4	1.17		1.2	0.00
2	2000-4000		51.2	0.00		144.7	0.00		232.6	0.00	3	2,064.4	0.93	3	2,492.9	0.77		5.1	0.00
2	4000-6000		56.5	0.00		13.7	0.00		16.3	0.00		719.2	0.00	0	805.7	0.00		7.6	0.00
2	>6000		0.0	ERR		0.0	ERR		0.0	ERR		8.3	0.00	0	8.3	0.00		0.0	ERR
	Total	0	128.6	0.00	0	299.9	0.00	0	294.2	0.00	8	5,313.6	0.96	8	6,036.3	0.85	0	13.9	0.00
3	0-2000	1	846.1	0.76	2	1,274.8	1.00	5	1,796.6	1.78	18	20,409.7	0.56	26	24,327.2	0.68		157.3	0.00
3	2000-4000	25	7,759.7	2.06	8	6,860.7	0.75	15	12,463.6	0.77	80	68,596.5	0.75	128	95,680.5	0.86	11	2,154.8	3.27
3	4000-6000	13	3,974.3	2.09	15	3,649.6	2.63	6	3,499.6	1.10	26	39,855.4	0.42	60	50,978.9	0.75	3	892.6	2.15
3	>6000		33.6	0.00		295.1	0.00		197.8	0.00		5,381.2	0.00	0	5,907.7	0.00		6.6	0.00
	Total	39	12,613.7	1.98	25	12,080.2	1.32	26	17,957.6	0.93	124	134,242.8	0.59	214	176,894.3	0.77	14	3,211.3	2.79
4	0-2000		223.6	0.00		5.3	0.00		0.0	ERR		1,114.9	0.00	0	1,343.8	0.00		4.1	0.00
4	2000-4000	2	1,722.9	0.74	2	249.9	5.12		173.4	0.00	2	8,809.1	0.15	6	10,955.3	0.35		108.2	0.00
4	4000-6000		640.8	0.00		75.3	0.00		68.4	0.00		6,312.0	0.00	0	7,096.5	0.00		94.4	0.00
4	>6000		58.0	0.00		0.0	ERR		0.2	0.00		1,852.4	0.00	0	1,910.6	0.00		0.4	0.00
	Total	2	2,645.3	0.48	2	330.5	3.87	0	242.0	0.00	2	18,088.4	0.07	6	21,306.2	0.18	0	207.1	0.00
5	0-2000		414.0	0.00		47.7	0.00		22.8	0.00	3	3,762.6	0.51	3	4,247.1	0.45		0.9	0.00
5	2000-4000	8	4,242.1	1.21	3	1,635.3	1.17	5	2,479.6	1.29	32	28,573.8	0.72	48	36,930.8	0.83	3	431.9	4.45
5	4000-6000	3	3,173.7	0.60		942.7	0.00	4	1,196.3	2.14	5	25,986.3	0.12	12	31,299.0	0.25	2	686.1	1.87
5	>6000		445.1	0.00		42.5	0.00		7.9	0.00		5,879.8	0.00	0	6,375.3	0.00		25.9	0.00
	Total	11	8,274.9	0.85	3	2,668.2	0.72	9	3,706.6	1.55	40	64,202.5	0.40	63	78,852.2	0.51	5	1,144.8	2.80
6	0-2000		869.4	0.00		178.0	0.00		133.1	0.00	1	7,410.2	0.09	1	8,590.7	0.07		126.6	0.00
6	2000-4000	2	6,920.0	0.18	2	1,170.4	1.09	5	1,605.5	1.99	10	30,439.0	0.21	19	40,134.9	0.30	1	1,299.3	0.49
6	4000-6000		2,927.9	0.00	1	359.3	1.78	1	134.0	4.78	5	17,262.6	0.19	7	20,683.8	0.22		308.8	0.00
6	>6000		36.3	0.00		2.6	0.00		0.4	0.00		4,352.7	0.00	0	4,392.0	0.00		0.4	0.00
	Total	2	10,753.6	0.12	3	1,710.3	1.12	6	1,873.0	2.05	16	59,464.5	0.17	27	73,801.4	0.23	1	1,735.1	0.37
8	0-2000	1	1,981.1	0.32	4	863.2	2.97		1,196.8	0.00	12	22,543.7	0.34	17	26,584.8	0.41		335.2	0.00
8	2000-4000	43	18,293.5	1.50	5	5,273.7	0.61	11	8,831.0	0.80	63	84,639.7	0.48	122	117,037.9	0.67	14	4,635.4	1.93
8	4000-6000	8	9,693.9	0.53	10	3,322.3	1.93	1	3,071.7	0.21	28	59,256.5	0.30	47	75,344.4	0.40	7	2,042.7	2.19
8	>6000		351.9	0.00		330.1	0.00		270.2	0.00		19,436.8	0.00	0	20,389.0	0.00		58.4	0.00
	Total	52	30,320.4	1.10	19	9,789.3	1.24	12	13,369.7	0.57	103	185,876.7	0.35	186	239,356.1	0.50	21	7,071.7	1.90

TABLE 5

ERFO SITES MULTIPLE FACTORS

special.123 11/12/98

Photo Area

Geo13	Elevation	FIRE Sites	FIRE Fire	FIRE den	HARVEST Sites	HARVEST Harv77	HARVEST den	HARVEST Sites	HARVEST Harv76	HARVEST den	UNDISTURBED Sites	UNDISTURBED None	UNDISTURBED den	*TOTALS* Sites	*TOTALS* Acres	*TOTALS* den	FIRE+HARVEST Sites	FIRE+HARVEST Fire_Harv	FIRE+HARVEST den
[geo13 #]	[range, ft]	[#]	[acres]	[ls/sqmi]	[#]	[acres]	[ls/sqmi]	[#]	[acres]	[ls/sqmi]	[#]	[acres]	[ls/sqmi]	[#]		[ls/sqmi]	[#]	[acres]	[ls/sqmi]
9	0-2000	1	201.8	3.17		104.9	0.00		219.9	0.00	10	5,993.6	1.07	11	6,520.2	1.08		30.2	0.00
9	2000-4000	3	795.1	2.41	1	338.2	1.89	3	682.9	2.81	22	10,418.6	1.35	29	12,234.8	1.52		94.8	0.00
9	4000-6000		245.4	0.00	2	95.3	13.43	2	143.3	8.93	10	6,514.3	0.98	14	6,998.3	1.28		26.3	0.00
9	>6000		0.0	ERR		0.0	ERR		0.0	ERR		265.9	0.00	0	265.9	0.00		0.0	ERR
	Total	4	1,242.3	2.06	3	538.4	3.57	5	1,046.1	3.06	42	23,192.4	1.16	54	26,019.2	1.33	0	151.3	0.00
10	0-2000		265.8	0.00	1	20.5	31.22		7.0	0.00	2	3,721.1	0.34	3	4,014.4	0.48		7.0	0.00
10	2000-4000	3	1,185.4	1.62	1	288.3	2.22	3	376.9	5.09	32	12,493.7	1.64	39	14,344.3	1.74	1	57.1	11.21
10	4000-6000		265.6	0.00		55.5	0.00		62.0	0.00	5	3,215.9	1.00	5	3,599.0	0.89		14.0	0.00
10	>6000		0.3	0.00		0.0	ERR		0.0	ERR		20.4	0.00	0	20.7	0.00		0.0	ERR
	Total	3	1,717.1	1.12	2	364.3	3.51	3	445.9	4.31	39	19,451.1	1.28	47	21,978.4	1.37	1	78.1	8.19
11	0-2000		839.5	0.00		278.7	0.00		272.4	0.00	10	14,969.5	0.43	10	16,360.1	0.39		116.8	0.00
11	2000-4000	11	3,556.9	1.98	2	489.3	2.62	6	955.6	4.02	36	23,377.2	0.99	55	28,379.0	1.24	7	428.4	10.46
11	4000-6000	2	792.8	1.61	5	215.6	14.84	1	100.7	6.36	25	7,660.3	2.09	33	8,769.4	2.41	1	80.9	7.91
11	>6000		0.0	ERR		0.4	0.00		0.0	ERR		168.5	0.00	0	168.9	0.00		0.0	ERR
	Total	13	5,189.2	1.60	7	984.0	4.55	7	1,328.7	3.37	71	46,175.5	0.98	98	53,677.4	1.17	8	626.1	8.18
12	0-2000		2.2	0.00		0.0	ERR		0.4	0.00		67.5	0.00	0	70.1	0.00		0.0	ERR
12	2000-4000		271.3	0.00		18.0	0.00		0.0	ERR		1,175.6	0.00	0	1,464.9	0.00		0.0	ERR
12	4000-6000		380.8	0.00		17.4	0.00		5.3	0.00	1	3,545.7	0.18	1	3,949.2	0.16		2.8	0.00
12	>6000		4.6	0.00		0.0	ERR		0.0	ERR		2,294.0	0.00	0	2,298.6	0.00		0.0	ERR
	Total	0	658.9	0.00	0	35.4	0.00	0	5.7	0.00	1	7,082.8	0.09	1	7,782.8	0.08	0	2.8	0.00
13	0-2000		91.1	0.00	1	46.6	13.73	1	32.6	19.63	12	7,211.6	1.06	14	7,381.9	1.21		2.9	0.00
13	2000-4000	1	129.9	4.93		80.4	0.00		40.5	0.00	2	2,271.8	0.56	3	2,522.6	0.76		29.7	0.00
13	4000-6000		780.3	0.00		253.6	0.00		182.8	0.00	1	24,074.5	0.03	1	25,291.2	0.03		81.7	0.00
13	>6000		83.5	0.00		117.4	0.00		21.4	0.00		6,989.9	0.00	0	7,212.2	0.00		0.0	ERR
	Total	1	1,084.8	0.59	1	498.0	1.29	1	277.3	2.31	15	40,547.8	0.24	18	42,407.9	0.27	0	114.3	0.00
Totals:		130	75,264.5	1.11	65	29,474.2	1.41	70	41,376.0	1.08	479	609,074.2	0.50	744	755,188.9	0.63	51	14,491.9	2.25
Totals:	0-2000	3	5,868.6	0.33	8	2,988.7	1.71	6	3,842.8	1.00	80	91,819.3	0.56	97	104,519.4	0.59	0	803.3	0.00
	2000-4000	101	45,207.7	1.43	24	16,668.5	0.92	48	28,387.5	1.08	289	275,045.4	0.67	462	365,309.1	0.81	38	9,342.4	2.60
	4000-6000	26	23,174.8	0.72	33	9,028.0	2.34	16	8,647.7	1.18	110	195,508.0	0.36	185	236,358.5	0.50	13	4,254.5	1.96
	>6000	0	1,013.4	0.00	0	789.0	0.00	0	498.0	0.00	0	46,701.5	0.00	0	49,001.9	0.00	0	91.7	0.00

fire — within fire burn intensity = H or M [from Hog, Fire87, Dillon, Specimen fires]

harv77 — outside H or M fire burn intensity; within harvested area YOUNGER than 1977 [includes NS, OR, SW]

harv76 — outside H or M fire burn intensity; within harvested areas OLDER than 1977

none — within "undisturbed" area; outside H or M fire burn intensity, outside harvested area [old (pre-1977) or new (post-1977)]

fire_harv — within fire burn intensity H or M and within "newly" harvested area [younger than 1977, NS]

TABLE 5

Elk Creek | **SLIDES** | **MULTIPLE FACTORS** | elk.123 | 11/12/98

Geo13 [geo13 #]	Elevation [range, ft]	ROADS ls [#]	Rd_buf [acres]	den [ls/sqmi]	FIRE ls [#]	Fire [acres]	den [ls/sqmi]	HARVEST ls [#]	Harv77 [acres]	den [ls/sqmi]	ls [#]	Harv76 [acres]	den [ls/sqmi]	UNDISTURBED ls [#]	None [acres]	den [ls/sqmi]	*TOTALS* ls [#]	Acres	den [ls/sqmi]	FIRE+HARVEST ls [#]	Fire_Harv [acres]	den [ls/sqmi]
1	0-2000		1.8	0.00			ERR			ERR		3.0	0.00		20.3	0.00	0	25.1	0.00			ERR
1	2000-4000	1	5.1	125.49		39.8	0.00		3.5	0.00		12.8	0.00	1	87.9	7.28	2	149.1	8.58		15.8	0.00
1	4000-6000		0.8	0.00	1	6.7	95.52		1.9	0.00		10.1	0.00	1	48.3	13.25	2	67.8	18.88		0.3	0.00
1	>6000			ERR			ERR			ERR			ERR		5.6	0.00	0	5.6	0.00			ERR
	Total	1	7.7	83.12	1	46.5	13.76	0	5.4	0.00	0	25.9	0.00	2	162.1	7.90	4	247.6	10.34	0	16.1	0.00
2	0-2000	1	9.9	64.65			ERR			ERR		9.9	0.00		99.1	0.00	1	118.9	5.38			ERR
2	2000-4000		1.5	0.00		0.4	0.00			ERR		13.1	0.00		52.0	0.00	0	67.0	0.00			ERR
2	4000-6000			ERR			ERR			ERR			ERR		29.5	0.00	0	29.5	0.00			ERR
2	>6000			ERR			ERR			ERR			ERR			ERR	0	0.0	ERR			ERR
	Total	1	11.4	56.14	0	0.4	0.00	0	0.0	ERR	0	23.0	0.00	0	180.6	0.00	1	215.4	2.97	0	0.0	ERR
3	0-2000		14.2	0.00		49.0	0.00		0.8	0.00		47.3	0.00		384.6	0.00	0	495.9	0.00			ERR
3	2000-4000	3	105.4	18.22	1	784.9	0.82	1	238.6	2.68		318.8	0.00	4	1,486.4	1.72	9	2,934.1	1.96	1	380.4	1.68
3	4000-6000		23.5	0.00	1	118.5	5.40	2	98.5	12.99	1	146.2	4.38		1,525.5	0.00	4	1,912.2	1.34	1	68.7	9.32
3	>6000			ERR			ERR			ERR			ERR		526.1	0.00	0	526.1	0.00			ERR
	Total	3	143.1	13.42	2	952.4	1.34	3	337.9	5.68	1	512.3	1.25	4	3,922.6	0.65	13	5,868.3	1.42	2	449.1	2.85
4	0-2000			ERR			ERR			ERR			ERR		3.8	0.00	0	3.8	0.00			ERR
4	2000-4000	1	3.3	193.94	6	262.6	14.62		5.1	0.00		8.5	0.00	2	867.8	1.47	9	1,147.3	5.02		12.5	0.00
4	4000-6000	1		ERR		92.1	0.00		0.1	0.00		0.7	0.00	1	2,098.4	0.30	2	2,191.3	0.58			ERR
4	>6000			ERR		3.6	0.00			ERR			ERR		557.6	0.00	0	561.2	0.00			ERR
	Total	2	3.3	387.88	6	358.3	10.72	0	5.2	0.00	0	9.2	0.00	3	3,527.6	0.54	11	3,903.6	1.80	0	12.5	0.00
5	0-2000		0.6	0.00			ERR			ERR			ERR		9.6	0.00	0	10.2	0.00			ERR
5	2000-4000	13	79.2	105.05	4	805.3	3.18		45.5	0.00		143.2	0.00		2,942.2	0.00	17	4,015.4	2.71	1	70.7	9.05
5	4000-6000		8.5	0.00	5	802.9	3.99		11.8	0.00		15.8	0.00	1	4,363.8	0.15	6	5,202.8	0.74		6.3	0.00
5	>6000			ERR		126.3	0.00			ERR			ERR		1,188.8	0.00	0	1,315.1	0.00			ERR
	Total	13	88.3	94.22	9	1,734.5	3.32	0	57.3	0.00	0	159.0	0.00	1	8,504.4	0.08	23	10,543.5	1.40	1	77.0	8.31
6	0-2000		2.7	0.00	1	89.1	7.18		17.3	0.00		20.4	0.00		347.9	0.00	1	477.4	1.34	1	31.2	20.51
6	2000-4000		39.7	0.00	2	1,125.4	1.14	1	72.6	8.82		104.8	0.00		1,552.3	0.00	3	2,894.8	0.66	2	333.5	3.84
6	4000-6000		7.7	0.00		99.1	0.00		20.5	0.00		4.8	0.00		1,652.0	0.00	0	1,784.1	0.00		32.7	0.00
6	>6000			ERR			ERR			ERR			ERR		589.4	0.00	0	589.4	0.00			ERR
	Total	0	50.1	0.00	3	1,313.6	1.46	1	110.4	5.80	0	130.0	0.00	0	4,141.6	0.00	4	5,745.7	0.45	3	397.4	4.83
8	0-2000		73.8	0.00		272.2	0.00		112.6	0.00		105.0	0.00		1,522.7	0.00	0	2,086.3	0.00		45.4	0.00
8	2000-4000	4	325.8	7.86	3	4,747.2	0.40		390.2	0.00		524.4	0.00	1	5,050.7	0.13	8	11,038.3	0.46	1	1,358.9	0.47
8	4000-6000		114.5	0.00	2	966.7	1.32		163.2	0.00		232.0	0.00		4,501.5	0.00	2	5,977.9	0.21	1	399.1	1.60
8	>6000			ERR			ERR			ERR			ERR		2,014.1	0.00	0	2,014.1	0.00			ERR
	Total	4	514.1	4.98	5	5,986.1	0.53	0	666.0	0.00	0	861.4	0.00	1	13,089.0	0.05	10	21,116.6	0.30	2	1,803.4	0.71
9	0-2000		2.7	0.00		2.4	0.00		0.4	0.00		3.5	0.00		48.3	0.00	0	57.3	0.00			ERR
9	2000-4000	1	4.6	139.13	2	80.5	15.90		18.2	0.00		11.3	0.00	4	225.6	11.35	7	340.2	13.17		21.4	0.00
9	4000-6000	1	1.3	492.31	1	8.7	73.56	1	1.6	400.00		5.8	0.00	1	649.7	0.99	4	667.1	3.84		0.4	0.00
9	>6000			ERR			ERR			ERR			ERR		18.1	0.00	0	18.1	0.00			ERR
	Total	2	8.6	148.84	3	91.6	20.96	1	20.2	31.68	0	20.6	0.00	5	941.7	3.40	11	1,082.7	6.50	0	21.8	0.00

TABLE 6

Elk Creek **SLIDES** **MULTIPLE FACTORS** elk.123 11/12/98

		ROADS			FIRE			HARVEST						UNDISTURBED			*TOTALS*			FIRE+HARVEST		
Geo13	**Elevation**	**ls**	**Rd_buf**	**den**	**ls**	**Fire**	**den**	**ls**	**Harv77**	**den**	**ls**	**Harv76**	**den**	**ls**	**None**	**den**	**ls**	**Acres**	**den**	**ls**	**Fire_Harv**	**den**
10	0-2000			ERR			ERR			ERR			ERR		4.9	0.00	0	4.9	0.00			ERR
10	2000-4000	3	16.3	117.79	3	268.5	7.15		12.8	0.00		45.2	0.00	1	1,559.0	0.41	7	1,901.8	2.36		16.9	0.00
10	4000-6000	1	0.3	2,133.33	4	64.3	39.81		0.6	0.00		0.2	0.00		663.5	0.00	5	728.9	4.39			ERR
10	>6000			ERR			ERR			ERR			ERR		6.8	0.00	0	6.8	0.00			ERR
	Total	4	16.6	154.22	7	332.8	13.46	0	13.4	0.00	0	45.4	0.00	1	2,234.2	0.29	12	2,642.4	2.91	0	16.9	0.00
11	0-2000		33.2	0.00		105.5	0.00		25.9	0.00		33.3	0.00		928.5	0.00	0	1,126.4	0.00		10.2	0.00
11	2000-4000	3	33.3	57.66		794.8	0.00	1	56.2	11.39		71.5	0.00		1,320.7	0.00	4	2,276.5	1.12		114.8	0.00
11	4000-6000		1.9	0.00		39.9	0.00		9.4	0.00		2.6	0.00		796.5	0.00	0	850.3	0.00		13.9	0.00
11	>6000			ERR			ERR			ERR			ERR		57.0	0.00	0	57.0	0.00			ERR
	Total	3	68.4	28.07	0	940.2	0.00	1	91.5	6.99	0	107.4	0.00	0	3,102.7	0.00	4	4,310.2	0.59	0	138.9	0.00
12	0-2000			ERR		2.2	0.00			ERR			ERR			ERR	0	2.2	0.00			ERR
12	2000-4000			ERR		20.9	0.00			ERR			ERR		5.8	0.00	0	26.7	0.00			ERR
12	4000-6000			ERR			ERR			ERR			ERR		513.5	0.00	0	513.5	0.00			ERR
12	>6000			ERR			ERR			ERR			ERR		639.2	0.00	0	639.2	0.00			ERR
	Total	0	0.0	ERR	0	23.1	0.00	0	0.0	ERR	0	0.0	ERR	0	1,158.5	0.00	0	1,181.6	0.00	0	0.0	ERR
13	0-2000		21.7	0.00		1.3	0.00		3.5	0.00			ERR		209.5	0.00	0	236.0	0.00			ERR
13	2000-4000			ERR		140.6	0.00			ERR			ERR		19.8	0.00	0	160.4	0.00			ERR
13	4000-6000			ERR	2	6.6	193.94			ERR			ERR		3,023.5	0.00	2	3,030.1	0.42			ERR
13	>6000			ERR			ERR			ERR			ERR		397.4	0.00	0	397.4	0.00			ERR
	Total	0	21.7	0.00	2	148.5	8.62	0	3.5	0.00	0	0.0	ERR	0	3,650.2	0.00	2	3,823.9	0.33	0	0.0	ERR
Totals:		33	933.3	22.63	38	11,928.0	2.04	6	1,310.8	2.93	1	1,894.2	0.34	17	44,615.2	0.24	95	60,681.5	1.00	8	2,933.1	1.75

KEY

rd_buf — within 50' wide road prism [see note below]

fire — outside 50' wide road prism; within fire burn intensity = H or M [from Hog, Fire87, Dillon, Specimen fires]

harv77 — outside 50' road prism; outside H or M fire burn intensity within harvested area YOUNGER than 1977 [includes NS, OR, SW]

harv76 — outside 50' road prism; outside H or M fire burn intensity within harvested area OLDER than 1977

none — within "undisturbed" area; outside road prism; outside H or M fire burn intensity, outside harvested area [old (pre-1977) or new (post-1977)]

fire_harv — outside road buffer; within fire burn intensity H or M and within "newly" harvested area [younger than 1977, NS]

__Note:__ Assumptions used concerning the count of slides & corresponding acres:

If the "labelpoint" of a slide was within 150' of a road, it was considered to be "road-related" and counted under the "Roads" section. However, in computing density of slides, a corridor 50' wide [~= road prism] was used, rather than one 300' wide (150' x 2).

If labelpoint of a slide was greater than 150' from a road, it was considered NOT to be "road-related" and counted elsewhere. Acre figures were calculated as described above.

TABLE 6

Tompkins Creek SLIDES MULTIPLE FACTORS tompkins.123 11/12/98

TABLE 7

		ROADS			FIRE			HARVEST						UNDISTURBED			*TOTALS*			FIRE+HARVEST		
Geo13 [geo13 #]	Elevation [range, ft]	ls [#]	Rd_buf [acres]	den [ls/sqmi]	ls [#]	Fire [acres]	den [ls/sqmi]	ls [#]	Harv77 [acres]	den [ls/sqmi]	ls [#]	Harv76 [acres]	den [ls/sqmi]	ls [#]	None [acres]	den [ls/sqmi]	ls [#]	Acres	den [ls/sqmi]	ls [#]	Fire_Harv [acres]	den [ls/sqmi]
1	0-2000			ERR			ERR			ERR			ERR			ERR	0	0.0	ERR			ERR
1	2000-4000			ERR			ERR			ERR			ERR		6.9	0.00	0	6.9	0.00			ERR
1	4000-6000		0.9	0.00	1	12.8	50.00		0.3	0.00		1.4	0.00		48.3	0.00	1	63.7	10.05		0.9	0.00
1	>6000			ERR			ERR			ERR		0.1	0.00		0.7	0.00	0	0.8	0.00			ERR
	Total	0	0.9	0.00	1	12.8	50.00	0	0.3	0.00	0	1.5	0.00	0	55.9	0.00	1	71.4	8.96	0	0.9	0.00
2	0-2000			ERR			ERR			ERR			ERR			ERR	0	0.0	ERR			ERR
2	2000-4000		2.3	0.00		4.8	0.00		0.1	0.00			ERR		13.6	0.00	0	20.8	0.00		1.8	0.00
2	4000-6000			ERR			ERR			ERR			ERR		2.7	0.00	0	2.7	0.00			ERR
2	>6000			ERR			ERR			ERR			ERR			ERR	0	0.0	ERR			ERR
	Total	0	2.3	0.00	0	4.8	0.00	0	0.1	0.00	0	0.0	ERR	0	16.3	0.00	0	23.5	0.00	0	1.8	0.00
3	0-2000			ERR			ERR			ERR			ERR			ERR	0	0.0	ERR			ERR
3	2000-4000		6.5	0.00		53.5	0.00		19.3	0.00		3.5	0.00		220.9	0.00	0	303.7	0.00		49.6	0.00
3	4000-6000	4	52.2	49.04	11	361.4	19.48	1	175.9	3.64	1	140.2	4.56	7	703.2	6.37	24	1,432.9	10.72	8	227.7	22.49
3	>6000		1.9	0.00		16.7	0.00	1	6.9	92.75		0.4	0.00	2	98.0	13.06	3	123.9	15.50		4.2	0.00
	Total	4	60.6	42.24	11	431.6	16.31	2	202.1	6.33	1	144.1	4.44	9	1,022.1	5.64	27	1,860.5	9.29	8	281.5	18.19
4	0-2000			ERR			ERR			ERR			ERR			ERR	0	0.0	ERR			ERR
4	2000-4000		1.2	0.00		2.9	0.00		2.2	0.00		0.2	0.00		260.7	0.00	0	267.2	0.00			ERR
4	4000-6000		1.2	0.00		62.2	0.00		17.1	0.00			ERR		198.4	0.00	0	278.9	0.00		10.0	0.00
4	>6000		0.7	0.00		0.8	0.00			ERR		0.2	0.00		16.3	0.00	0	18.0	0.00			ERR
	Total	0	3.1	0.00	0	65.9	0.00	0	19.3	0.00	0	0.4	0.00	0	475.4	0.00	0	564.1	0.00	0	10.0	0.00
5	0-2000			ERR			ERR			ERR			ERR			ERR	0	0.0	ERR			ERR
5	2000-4000		19.7	0.00		14.9	0.00		35.2	0.00		8.8	0.00		850.1	0.00	0	928.7	0.00		4.5	0.00
5	4000-6000	1	11.8	54.24		311.9	0.00		62.1	0.00		13.4	0.00		466.9	0.00	1	866.1	0.74		142.5	0.00
5	>6000		3.5	0.00		31.1	0.00		4.0	0.00		0.8	0.00		112.8	0.00	0	152.2	0.00		3.6	0.00
	Total	1	35.0	18.29	0	357.9	0.00	0	101.3	0.00	0	23.0	0.00	0	1,429.8	0.00	1	1,947.0	0.33	0	150.6	0.00
6	0-2000			ERR			ERR			ERR			ERR			ERR	0	0.0	ERR			ERR
6	2000-4000			ERR			ERR		9.1	0.00			ERR		221.2	0.00	0	230.3	0.00			ERR
6	4000-6000	3	13.0	147.69	1	71.9	8.90	1	37.8	16.93		5.9	0.00		448.6	0.00	5	577.2	5.54		26.7	0.00
6	>6000			ERR		19.8	0.00		0.2	0.00		0.4	0.00		62.9	0.00	0	83.3	0.00		0.1	0.00
	Total	3	13.0	147.69	1	91.7	6.98	1	47.1	13.59	0	6.3	0.00	0	732.7	0.00	5	890.8	3.59	0	26.8	0.00
8	0-2000			ERR			ERR			ERR			ERR			ERR	0	0.0	ERR			ERR
8	2000-4000	1	17.6	36.36			ERR	2	27.1	47.23		3.0	0.00	2	685.9	1.87	5	733.6	4.36			ERR
8	4000-6000	6	51.0	75.29	4	301.0	8.50	3	130.9	14.67		49.8	0.00	3	962.3	2.00	16	1,495.0	6.85	4	179.4	14.27
8	>6000		6.4	0.00		113.3	0.00	2	29.6	43.24		7.2	0.00	2	216.8	5.90	4	373.3	6.86		9.4	0.00
	Total	7	75.0	59.73	4	414.3	6.18	7	187.6	23.88	0	60.0	0.00	7	1,865.0	2.40	25	2,601.9	6.15	4	188.8	13.56
9	0-2000			ERR			ERR			ERR			ERR			ERR	0	0.0	ERR			ERR
9	2000-4000		0.7	0.00		0.1	0.00			ERR			ERR		59.3	0.00	0	60.1	0.00			ERR
9	4000-6000		1.0	0.00		1.8	0.00		1.6	0.00			ERR	1	74.9	8.54	1	79.3	8.07			ERR
9	>6000			ERR			ERR			ERR			ERR			ERR	0	0.0	ERR			ERR
	Total	0	1.7	0.00	0	1.9	0.00	0	1.6	0.00	0	0.0	ERR	1	134.2	4.77	1	139.4	4.59	0	0.0	ERR

Tompkins Creek | **SLIDES** | **MULTIPLE FACTORS** | tompkins.123 | 11/12/98

		ROADS			FIRE			HARVEST						UNDISTURBED			*TOTALS*			FIRE+HARVEST		
Geo13	Elevation	ls	Rd_buf	den	ls	Fire	den	ls	Harv77	den	ls	Harv76	den	ls	None	den	ls	Acres	den	ls	Fire_Harv	den
10	0-2000			ERR			ERR			ERR			ERR			ERR	0	0.0	ERR			ERR
10	2000-4000	2	6.7	191.04		1.7	0.00		5.5	0.00		0.7	0.00		368.5	0.00	2	383.1	3.34			ERR
10	4000-6000		0.5	0.00		26.0	0.00		2.9	0.00			ERR	1	175.2	3.65	1	204.6	3.13		0.5	0.00
10	>6000			ERR		0.3	0.00			ERR			ERR			ERR	0	0.3	0.00			ERR
	Total	**2**	**7.2**	**177.78**	**0**	**28.0**	**0.00**	**0**	**8.4**	**0.00**	**0**	**0.7**	**0.00**	**1**	**543.7**	**1.18**	**3**	**588.0**	**3.27**	**0**	**0.5**	**0.00**
11	0-2000			ERR			ERR			ERR			ERR			ERR	0	0.0	ERR			ERR
11	2000-4000		2.1	0.00			ERR		4.5	0.00		2.0	0.00		263.2	0.00	0	271.8	0.00			ERR
11	4000-6000	2	3.6	355.56		11.5	0.00		11.7	0.00			ERR		186.7	0.00	2	213.5	6.00		4.3	0.00
11	>6000			ERR			ERR			ERR			ERR			ERR	0	0.0	ERR			ERR
	Total	**2**	**5.7**	**224.56**	**0**	**11.5**	**0.00**	**0**	**16.2**	**0.00**	**0**	**2.0**	**0.00**	**0**	**449.9**	**0.00**	**2**	**485.3**	**2.64**	**0**	**4.3**	**0.00**
12	0-2000			ERR			ERR			ERR			ERR			ERR	0	0.0	ERR			ERR
12	2000-4000			ERR			ERR			ERR			ERR		0.3	0.00	0	0.3	0.00			ERR
12	4000-6000		0.8	0.00		19.9	0.00		16.9	0.00			ERR	1	48.2	13.28	1	85.8	7.46		2.8	0.00
12	>6000		0.5	0.00		4.6	0.00			ERR			ERR		12.3	0.00	0	17.4	0.00			ERR
	Total	**0**	**1.3**	**0.00**	**0**	**24.5**	**0.00**	**0**	**16.9**	**0.00**	**0**	**0.0**	**ERR**	**1**	**60.8**	**10.53**	**1**	**103.5**	**6.18**	**0**	**2.8**	**0.00**
13	0-2000			ERR			ERR			ERR			ERR			ERR	0	0.0	ERR			ERR
13	2000-4000		1.5	0.00			ERR			ERR			ERR		9.7	0.00	0	11.2	0.00			ERR
13	4000-6000	1	1.0	640.00		14.1	0.00		5.0	0.00			ERR		4.2	0.00	1	24.3	26.34		7.1	0.00
13	>6000			ERR			ERR			ERR			ERR			ERR	0	0.0	ERR			ERR
	Total	**1**	**2.5**	**256.00**	**0**	**14.1**	**0.00**	**0**	**5.0**	**0.00**	**0**	**0.0**	**ERR**	**0**	**13.9**	**0.00**	**1**	**35.5**	**18.03**	**0**	**7.1**	**0.00**
Totals:		**20**	**208.3**	**61.45**	**17**	**1,459.0**	**7.46**	**10**	**605.9**	**10.56**	**1**	**238.0**	**2.69**	**19**	**6,799.7**	**1.79**	**67**	**9,310.9**	**4.61**	**12**	**675.1**	**11.38**

KEY

rd_buf — within 50' wide road prism [see note below]

fire — outside 50' wide road prism; within fire burn intensity = H or M [from Hog, Fire87, Dillon, Specimen fires]

harv77 — outside 50' road prism; outside H or M fire burn intensity within harvested area YOUNGER than 1977 [includes NS, OR, SW]

harv76 — outside 50' road prism; outside H or M fire burn intensity within harvested area OLDER than 1977

none — within "undisturbed" area outside road prism; outside H or M fire burn intensity, outside harvested area [old (pre-1977) or new (post-1977)]

fire_harv — outside road buffer within fire burn intensity H or M and within "newly" harvested area [younger than 1977, NS]

__Note:__ Assumptions used concerning the count of slides & corresponding acres:

If the "labelpoint" of a slide was within 150' of a road, it was considered to be "road-related" and counted under the "Roads" section. However, in computing density of slides, a corridor 50' wide [~= road prism] was used, rather than one 300' wide (150' x 2).

If labelpoint of a slide was greater than 150' from a road, it was considered NOT to be "road-related" and counted elsewhere. Acre figures were calculated as described above.

TABLE 7

3

Walker Creek SLIDES MULTIPLE FACTORS walker.123 11/12/98

		ROADS			FIRE			HARVEST						UNDISTURBED			*TOTALS*			FIRE+HARVEST		
Geo13 [geo13 #]	Elevation [range, ft]	ls [#]	Rd_buf [acres]	den [ls/sqmi]	ls [#]	Fire [acres]	den [ls/sqmi]	ls [#]	Harv77 [acres]	den [ls/sqmi]	ls [#]	Harv76 [acres]	den [ls/sqmi]	ls [#]	None [acres]	den [ls/sqmi]	ls [#]	Acres	den [ls/sqmi]	ls [#]	Fire_Harv [acres]	den [ls/sqmi]
1	0-2000			ERR			ERR			ERR			ERR			ERR	0	0.0	ERR			ERR
1	2000-4000		0.4	0.00			ERR			ERR		5.4	0.00		6.4	0.00	0	12.2	0.00			ERR
1	4000-6000		2.4	0.00		5.6	0.00		7.2	0.00	1	11.0	58.18	1	16.3	39.26	2	42.5	30.12		3.1	0.00
1	>6000			ERR			ERR			ERR			ERR		1.1	0.00	0	1.1	0.00			ERR
	Total	0	2.8	0.00	0	5.6	0.00	0	7.2	0.00	1	16.4	39.02	1	23.8	26.89	2	55.8	22.94	0	3.1	0.00
2	0-2000			ERR			ERR			ERR			ERR			ERR	0	0.0	ERR			ERR
2	2000-4000			ERR			ERR			ERR			ERR			ERR	0	0.0	ERR			ERR
2	4000-6000			ERR			ERR			ERR			ERR			ERR	0	0.0	ERR			ERR
2	>6000			ERR			ERR			ERR			ERR			ERR	0	0.0	ERR			ERR
	Total	0	0.0	ERR	0	0.0	ERR	0	0.0	ERR	0	0.0	ERR	0	0.0	ERR	0	0.0	ERR	0	0.0	ERR
3	0-2000			ERR			ERR			ERR			ERR			ERR	0	0.0	ERR			ERR
3	2000-4000		14.7	0.00		3.0	0.00		72.9	0.00		111.8	0.00		251.9	0.00	0	454.3	0.00		0.2	0.00
3	4000-6000	6	41.8	91.87	5	219.0	14.61	5	199.8	16.02	4	241.2	10.61	12	368.5	20.84	32	1,070.3	19.13	4	82.4	31.07
3	>6000			ERR		16.7	0.00			ERR			ERR		22.9	0.00	0	39.6	0.00		2.5	0.00
	Total	6	56.5	67.96	5	238.7	13.41	5	272.7	11.73	4	353.0	7.25	12	643.3	11.94	32	1,564.2	13.09	4	85.1	30.08
4	0-2000			ERR			ERR			ERR			ERR		4.6	0.00	0	4.6	0.00			ERR
4	2000-4000	1	10.8	59.26		3.6	0.00		9.9	0.00		47.9	0.00		602.5	0.00	1	674.7	0.95			ERR
4	4000-6000		6.1	0.00		0.9	0.00		3.0	0.00		27.1	0.00		116.5	0.00	0	153.6	0.00			ERR
4	>6000			ERR			ERR			ERR			ERR			ERR	0	0.0	ERR			ERR
	Total	1	16.9	37.87	0	4.5	0.00	0	12.9	0.00	0	75.0	0.00	0	723.6	0.00	1	832.9	0.77	0	0.0	ERR
5	0-2000		7.8	0.00			ERR			ERR		1.6	0.00		156.8	0.00	0	166.2	0.00			ERR
5	2000-4000		49.5	0.00		2.5	0.00		38.8	0.00		96.2	0.00	1	1,360.6	0.47	1	1,547.6	0.41			ERR
5	4000-6000		27.9	0.00		10.5	0.00		10.2	0.00		91.2	0.00		237.4	0.00	0	377.2	0.00		0.7	0.00
5	>6000			ERR		6.2	0.00		0.6	0.00			ERR		8.0	0.00	0	14.8	0.00			ERR
	Total	0	85.2	0.00	0	19.2	0.00	0	49.6	0.00	0	189.0	0.00	1	1,762.8	0.36	1	2,105.8	0.30	0	0.7	0.00
6	0-2000			ERR			ERR			ERR			ERR			ERR	0	0.0	ERR			ERR
6	2000-4000			ERR			ERR		0.8	0.00		1.4	0.00		5.6	0.00	0	7.8	0.00			ERR
6	4000-6000	2	9.8	130.61	1	54.9	11.66	5	103.2	31.01		20.9	0.00	1	174.9	3.66	9	363.7	15.84	1	39.2	16.33
6	>6000			ERR		1.5	0.00		2.4	0.00			ERR		7.8	0.00	0	11.7	0.00		0.3	0.00
	Total	2	9.8	130.61	1	56.4	11.35	5	106.4	30.08	0	22.3	0.00	1	188.3	3.40	9	383.2	15.03	1	39.5	16.20
8	0-2000			ERR			ERR			ERR			ERR			ERR	0	0.0	ERR			ERR
8	2000-4000		1.2	0.00			ERR		4.2	0.00		0.2	0.00		15.4	0.00	0	21.0	0.00			ERR
8	4000-6000	7	50.8	88.19	2	232.7	5.50	3	249.9	7.68		93.2	0.00	3	394.1	4.87	15	1,020.7	9.41	2	150.0	8.53
8	>6000		1.1	0.00		36.4	0.00		25.3	0.00		6.1	0.00		80.6	0.00	0	149.5	0.00		11.5	0.00
	Total	7	53.1	84.37	2	269.1	4.76	3	279.4	6.87	0	99.5	0.00	3	490.1	3.92	15	1,191.2	8.06	2	161.5	7.93
9	0-2000		0.7	0.00			ERR			ERR			ERR		12.4	0.00	0	13.1	0.00			ERR
9	2000-4000		1.8	0.00			ERR		15.0	0.00		9.0	0.00	3	93.1	20.62	3	118.9	16.15			ERR
9	4000-6000		1.8	0.00		5.9	0.00	2	16.1	79.50		12.4	0.00		54.2	0.00	2	90.4	14.16		0.4	0.00
9	>6000			ERR			ERR			ERR			ERR		0.1	0.00	0	0.1	0.00			ERR
	Total	0	4.3	0.00	0	5.9	0.00	2	31.1	41.16	0	21.4	0.00	3	159.8	12.02	5	222.5	14.38	0	0.4	0.00

TABLE 8

Walker Creek | SLIDES | MULTIPLE FACTORS | walker.123 | 11/12/98

Geo13	Elevation	ROADS			FIRE			HARVEST						UNDISTURBED			*TOTALS*			FIRE+HARVEST		
Geo13 [geo13 #]	Elevation [range, ft]	ls [#]	Rd_buf [acres]	den [ls/sqmi]	ls [#]	Fire [acres]	den [ls/sqmi]	ls [#]	Harv77 [acres]	den [ls/sqmi]	ls [#]	Harv76 [acres]	den [ls/sqmi]	ls [#]	None [acres]	den [ls/sqmi]	ls [#]	Acres	den [ls/sqmi]	ls [#]	Fire_Harv [acres]	den [ls/sqmi]
10	0-2000		3.7	0.00			ERR			ERR		0.1	0.00		74.8	0.00	0	78.6	0.00			ERR
10	2000-4000	2	21.3	60.09		1.4	0.00		10.8	0.00		28.3	0.00	1	837.9	0.76	3	899.7	2.13			ERR
10	4000-6000		2.7	0.00		3.1	0.00		0.8	0.00	1	8.3	77.11		33.4	0.00	1	48.3	13.25			ERR
10	>6000		0.0	ERR			ERR			ERR			ERR			ERR	0	0.0	ERR			ERR
	Total	2	27.7	46.21	0	4.5	0.00	0	11.6	0.00	1	36.7	17.44	1	946.1	0.68	4	1,026.6	2.49	0	0.0	ERR
11	0-2000			ERR			ERR			ERR			ERR			ERR	0	0.0	ERR			ERR
11	2000-4000		0.8	0.00			ERR		0.1	0.00		0.8	0.00		15.8	0.00	0	17.5	0.00			ERR
11	4000-6000	2	4.4	290.91		18.7	0.00	3	57.1	33.63		5.2	0.00	4	105.7	24.22	9	191.1	30.14		10.9	0.00
11	>6000			ERR			ERR		0.4	0.00			ERR		1.4	0.00	0	1.8	0.00			ERR
	Total	2	5.2	246.15	0	18.7	0.00	3	57.6	33.33	0	6.0	0.00	4	122.9	20.83	9	210.4	27.38	0	10.9	0.00
12	0-2000			ERR			ERR			ERR			ERR			ERR	0	0.0	ERR			ERR
12	2000-4000			ERR			ERR			ERR			ERR			ERR	0	0.0	ERR			ERR
12	4000-6000			ERR			ERR			ERR			ERR			ERR	0	0.0	ERR			ERR
12	>6000			ERR			ERR			ERR			ERR			ERR	0	0.0	ERR			ERR
	Total	0	0.0	ERR	0	0.0	ERR	0	0.0	ERR	0	0.0	ERR	0	0.0	ERR	0	0.0	ERR	0	0.0	ERR
13	0-2000		4.1	0.00			ERR			ERR			ERR		39.0	0.00	0	43.1	0.00			ERR
13	2000-4000			ERR			ERR			ERR			ERR			ERR	0	0.0	ERR			ERR
13	4000-6000			ERR			ERR			ERR			ERR			ERR	0	0.0	ERR			ERR
13	>6000			ERR			ERR			ERR			ERR			ERR	0	0.0	ERR			ERR
	Total	0	4.1	0.00	0	0.0	ERR	0	0.0	ERR	0	0.0	ERR	0	39.0	0.00	0	43.1	0.00	0	0.0	ERR
Totals:		20	265.6	48.19	8	622.6	8.22	18	828.5	13.90	6	819.3	4.69	26	5,099.7	3.26	78	7,635.7	6.54	7	301.2	14.87

KEY

rd_buf — within 50' wide road prism [see note below]

fire — outside 50' wide road prism; within fire burn intensity = H or M [from Hog, Fire87, Dillon, Specimen fires]

harv77 — outside 50' road prism; outside H or M fire burn intensity within harvested area YOUNGER than 1977 [includes NS, OR, SW]

harv76 — outside 50' road prism; outside H or M fire burn intensity within harvested area OLDER than 1977

none — within "undisturbed" area outside road prism; outside H or M fire burn intensity, outside harvested area [old (pre-1977) or new (post-1977)]

fire_harv — outside road buffer within fire burn intensity H or M and within "newly" harvested area [younger than 1977, NS]

__Note:__ Assumptions used concerning the count of slides & corresponding acres:

If the "labelpoint" of a slide was within 150' of a road, it was considered to be "road-related" and counted under the "Roads" section. However, in computing density of slides, a corridor 50' wide [~= road prism] was used, rather than one 300' wide (150' x 2).

If labelpoint of a slide was greater than 150' from a road, it was considered NOT to be "road-related" and counted elsewhere. Acre figures were calculated as described above.

TABLE 8

ERFO SITES **MULTIPLE FACTORS** elk.123 11/12/98

Elk Creek

		FIRE			HARVEST						UNDISTURBED			*TOTALS*			FIRE+HARVEST		
Geo13 [geo13 #]	Elevation [range, ft]	Sites [#]	Fire [acres]	den [ls/sqmi]	Sites [#]	Harv77 [acres]	den [ls/sqmi]	Sites [#]	Harv76 [acres]	den [ls/sqmi]	Sites [#]	None [acres]	den [ls/sqmi]	Sites [#]	Acres	den [ls/sqmi]	Sites [#]	Fire_Harv [acres]	den [ls/sqmi]
1	0-2000			ERR			ERR		3.0	0.00		20.3	0.00	0	23.3	0.00			ERR
1	2000-4000		39.8	0.00		3.5	0.00		12.8	0.00		87.9	0.00	0	144.0	0.00		15.8	0.00
1	4000-6000		6.7	0.00		1.9	0.00		10.1	0.00		48.3	0.00	0	67.0	0.00		0.3	0.00
1	>6000			ERR			ERR			ERR		5.6	0.00	0	5.6	0.00			ERR
	Total	0	46.5	0.00	0	5.4	0.00	0	25.9	0.00	0	162.1	0.00	0	239.9	0.00	0	16.1	0.00
2	0-2000			ERR			ERR		9.9	0.00	4	99.1	25.83	4	109.0	23.49			ERR
2	2000-4000		0.4	0.00			ERR		13.1	0.00		52.0	0.00	0	65.5	0.00			ERR
2	4000-6000			ERR			ERR			ERR		29.5	0.00	0	29.5	0.00			ERR
2	>6000			ERR			ERR			ERR			ERR	0	0.0	ERR			ERR
	Total	0	0.4	0.00	0	0.0	ERR	0	23.0	0.00	4	180.6	14.17	4	204.0	12.55	0	0.0	ERR
3	0-2000	1	49.0	13.06		0.8	0.00	1	47.3	13.53		384.6	0.00	2	481.7	2.66			ERR
3	2000-4000	5	784.9	4.08		238.6	0.00	3	318.8	6.02	1	1,486.4	0.43	9	2,828.7	2.04	4	380.4	6.73
3	4000-6000	2	118.5	10.80	1	98.5	6.50	1	146.2	4.38	1	1,525.5	0.42	5	1,888.7	1.69	1	68.7	9.32
3	>6000			ERR			ERR			ERR		526.1	0.00	0	526.1	0.00			ERR
	Total	8	952.4	5.38	1	337.9	1.89	5	512.3	6.25	2	3,922.6	0.33	16	5,725.2	1.79	5	449.1	7.13
4	0-2000			ERR			ERR			ERR		3.8	0.00	0	3.8	0.00			ERR
4	2000-4000		262.6	0.00		5.1	0.00		8.5	0.00	2	867.8	1.47	2	1,144.0	1.12		12.5	0.00
4	4000-6000		92.1	0.00		0.1	0.00		0.7	0.00		2,098.4	0.00	0	2,191.3	0.00			ERR
4	>6000		3.6	0.00			ERR			ERR		557.6	0.00	0	561.2	0.00			ERR
	Total	0	358.3	0.00	0	5.2	0.00	0	9.2	0.00	2	3,527.6	0.36	2	3,900.3	0.33	0	12.5	0.00
5	0-2000			ERR			ERR			ERR		9.6	0.00	0	9.6	0.00			ERR
5	2000-4000	2	805.3	1.59	1	45.5	14.07	3	143.2	13.41	22	2,942.2	4.79	28	3,936.2	4.55		70.7	0.00
5	4000-6000	1	802.9	0.80		11.8	0.00	2	15.8	81.01		4,363.8	0.00	3	5,194.3	0.37		6.3	0.00
5	>6000		126.3	0.00			ERR			ERR		1,188.8	0.00	0	1,315.1	0.00			ERR
	Total	3	1,734.5	1.11	1	57.3	11.17	5	159.0	20.13	22	8,504.4	1.66	31	10,455.2	1.90	0	77.0	0.00
6	0-2000		89.1	0.00		17.3	0.00		20.4	0.00		347.9	0.00	0	474.7	0.00		31.2	0.00
6	2000-4000	2	1,125.4	1.14		72.6	0.00		104.8	0.00	1	1,552.3	0.41	3	2,855.1	0.67	1	333.5	1.92
6	4000-6000		99.1	0.00		20.5	0.00		4.8	0.00		1,652.0	0.00	0	1,776.4	0.00		32.7	0.00
6	>6000			ERR			ERR			ERR		589.4	0.00	0	589.4	0.00			ERR
	Total	2	1,313.6	0.97	0	110.4	0.00	0	130.0	0.00	1	4,141.6	0.15	3	5,695.6	0.34	1	397.4	1.61
8	0-2000	1	272.2	2.35	1	112.6	5.68		105.0	0.00	3	1,522.7	1.26	5	2,012.5	1.59		45.4	0.00
8	2000-4000	19	4,747.2	2.56	2	390.2	3.28	1	524.4	1.22	13	5,050.7	1.65	35	10,712.5	2.09	6	1,358.9	2.83
8	4000-6000		966.7	0.00	1	163.2	3.92		232.0	0.00	3	4,501.5	0.43	4	5,863.4	0.44		399.1	0.00
8	>6000			ERR			ERR			ERR		2,014.1	0.00	0	2,014.1	0.00			ERR
	Total	20	5,986.1	2.14	4	666.0	3.84	1	861.4	0.74	19	13,089.0	0.93	44	20,602.5	1.37	6	1,803.4	2.13

TABLE 9

ERFO SITES MULTIPLE FACTORS

elk.123 11/12/98

Elk Creek

Geo13 [geo13 #]	Elevation [range, ft]	FIRE Sites [#]	FIRE Fire [acres]	FIRE den [ls/sqmi]	HARVEST Sites [#]	HARVEST Harv77 [acres]	HARVEST den [ls/sqmi]	HARVEST Sites [#]	HARVEST Harv76 [acres]	HARVEST den [ls/sqmi]	UNDISTURBED Sites [#]	UNDISTURBED None [acres]	UNDISTURBED den [ls/sqmi]	*TOTALS* Sites [#]	*TOTALS* Acres	*TOTALS* den [ls/sqmi]	FIRE+HARVEST Sites [#]	FIRE+HARVEST Fire_Harv [acres]	FIRE+HARVEST den [ls/sqmi]
9	0-2000		2.4	0.00		0.4	0.00		3.5	0.00		48.3	0.00	0	54.6	0.00			ERR
9	2000-4000		80.5	0.00		18.2	0.00		11.3	0.00		225.6	0.00	0	335.6	0.00		21.4	0.00
9	4000-6000		8.7	0.00		1.6	0.00		5.8	0.00	1	649.7	0.99	1	665.8	0.96		0.4	0.00
9	>6000			ERR			ERR			ERR		18.1	0.00	0	18.1	0.00			ERR
	Total	0	91.6	0.00	0	20.2	0.00	0	20.6	0.00	1	941.7	0.68	1	1,074.1	0.60	0	21.8	0.00
10	0-2000			ERR			ERR			ERR		4.9	0.00	0	4.9	0.00			ERR
10	2000-4000		268.5	0.00	1	12.8	50.00	3	45.2	42.48	12	1,559.0	4.93	16	1,885.5	5.43		16.9	0.00
10	4000-6000		64.3	0.00		0.6	0.00		0.2	0.00	1	663.5	0.96	1	728.6	0.88			ERR
10	>6000			ERR			ERR			ERR		6.8	0.00	0	6.8	0.00			ERR
	Total	0	332.8	0.00	1	13.4	47.76	3	45.4	42.29	13	2,234.2	3.72	17	2,625.8	4.14	0	16.9	0.00
11	0-2000		105.5	0.00		25.9	0.00		33.3	0.00	3	928.5	2.07	3	1,093.2	1.76		10.2	0.00
11	2000-4000	7	794.8	5.64	1	56.2	11.39	1	71.5	8.95	4	1,320.7	1.94	13	2,243.2	3.71	5	114.8	27.87
11	4000-6000		39.9	0.00		9.4	0.00		2.6	0.00	1	796.5	0.80	1	848.4	0.75		13.9	0.00
11	>6000			ERR			ERR			ERR		57.0	0.00	0	57.0	0.00			ERR
	Total	7	940.2	4.76	1	91.5	6.99	1	107.4	5.96	8	3,102.7	1.65	17	4,241.8	2.56	5	138.9	23.04
12	0-2000		2.2	0.00			ERR			ERR			ERR	0	2.2	0.00			ERR
12	2000-4000		20.9	0.00			ERR			ERR		5.8	0.00	0	26.7	0.00			ERR
12	4000-6000			ERR			ERR			ERR		513.5	0.00	0	513.5	0.00			ERR
12	>6000			ERR			ERR			ERR		639.2	0.00	0	639.2	0.00			ERR
	Total	0	23.1	0.00	0	0.0	ERR	0	0.0	ERR	0	1,158.5	0.00	0	1,181.6	0.00	0	0.0	ERR
13	0-2000		1.3	0.00		3.5	0.00			ERR		209.5	0.00	0	214.3	0.00			ERR
13	2000-4000		140.6	0.00			ERR			ERR		19.8	0.00	0	160.4	0.00			ERR
13	4000-6000		6.6	0.00			ERR			ERR		3,023.5	0.00	0	3,030.1	0.00			ERR
13	>6000			ERR			ERR			ERR		397.4	0.00	0	397.4	0.00			ERR
	Total	0	148.5	0.00	0	3.5	0.00	0	0.0	ERR	0	3,650.2	0.00	0	3,802.2	0.00	0	0.0	ERR
Totals:		40	11,928.0	2.15	8	1,310.8	3.91	15	1,894.2	5.07	72	44,615.2	1.03	135	59,748.2	1.45	17	2,933.1	3.71

KEY

fire — within fire burn intensity = H or M [from Hog, Fire87, Dillon, Specimen fires]

harv77 — outside H or M fire burn intensity
within harvested area YOUNGER than 1977 [includes NS, OR, SW]

harv76 — outside H or M fire burn intensity; within harvested areas OLDER than 1977

none — within "undisturbed" area; outside H or M fire burn intensity,
outside harvested area [old (pre-1977) or new (post-1977)]

fire_harv — within fire burn intensity H or M and
within "newly" harvested area [younger than 1977, NS]

TABLE 9

TABLE 10

ERFO SITES MULTIPLE FACTORS

tompkinsl.123 11/12/98

Tompkins Creek

Geo13	Elevation	FIRE Sites	Fire	den	HARVEST Sites	Harv77	den	Sites	Harv76	den	UNDISTURBED Sites	None	den	*TOTALS* Sites	Acres	den	FIRE+HARVEST Sites	Fire_Harv	den
[geo13 #]	[range, ft]	[#]	[acres]	[ls/sqmi]	[#]	[acres]	[ls/sqmi]	[#]	[acres]	[ls/sqmi]	[#]	[acres]	[ls/sqmi]	[#]		[ls/sqmi]	[#]	[acres]	[ls/sqmi]
1	0-2000			ERR			ERR			ERR			ERR	0	0.0	ERR			ERR
1	2000-4000			ERR			ERR			ERR		6.9	0.00	0	6.9	0.00			ERR
1	4000-6000		12.8	0.00		0.3	0.00		1.4	0.00		48.3	0.00	0	62.8	0.00		0.9	0.00
1	>6000			ERR			ERR		0.1	0.00		0.7	0.00	0	0.8	0.00			ERR
	Total	0	12.8	0.00	0	0.3	0.00	0	1.5	0.00	0	55.9	0.00	0	70.5	0.00	0	0.9	0.00
2	0-2000			ERR			ERR			ERR			ERR	0	0.0	ERR			ERR
2	2000-4000		4.8	0.00		0.1	0.00			ERR		13.6	0.00	0	18.5	0.00		1.8	0.00
2	4000-6000			ERR			ERR			ERR		2.7	0.00	0	2.7	0.00			ERR
2	>6000			ERR			ERR			ERR			ERR	0	0.0	ERR			ERR
	Total	0	4.8	0.00	0	0.1	0.00	0	0.0	ERR	0	16.3	0.00	0	21.2	0.00	0	1.8	0.00
3	0-2000			ERR			ERR			ERR			ERR	0	0.0	ERR			ERR
3	2000-4000		53.5	0.00		19.3	0.00		3.5	0.00	2	220.9	5.79	2	297.2	4.31		49.6	0.00
3	4000-6000	3	361.4	5.31		175.9	0.00		140.2	0.00		703.2	0.00	3	1,380.7	1.39		227.7	0.00
3	>6000		16.7	0.00		6.9	0.00		0.4	0.00		98.0	0.00	0	122.0	0.00		4.2	0.00
	Total	3	431.6	4.45	0	202.1	0.00	0	144.1	0.00	2	1,022.1	1.25	5	1,799.9	1.78	0	281.5	0.00
4	0-2000			ERR			ERR			ERR			ERR	0	0.0	ERR			ERR
4	2000-4000		2.9	0.00		2.2	0.00		0.2	0.00		260.7	0.00	0	266.0	0.00			ERR
4	4000-6000		62.2	0.00		17.1	0.00			ERR		198.4	0.00	0	277.7	0.00		10.0	0.00
4	>6000		0.8	0.00			ERR		0.2	0.00		16.3	0.00	0	17.3	0.00			ERR
	Total	0	65.9	0.00	0	19.3	0.00	0	0.4	0.00	0	475.4	0.00	0	561.0	0.00	0	10.0	0.00
5	0-2000			ERR			ERR			ERR			ERR	0	0.0	ERR			ERR
5	2000-4000		14.9	0.00		35.2	0.00		8.8	0.00	3	850.1	2.26	3	909.0	2.11		4.5	0.00
5	4000-6000		311.9	0.00		62.1	0.00		13.4	0.00	1	466.9	1.37	1	854.3	0.75		142.5	0.00
5	>6000		31.1	0.00		4.0	0.00		0.8	0.00		112.8	0.00	0	148.7	0.00		3.6	0.00
	Total	0	357.9	0.00	0	101.3	0.00	0	23.0	0.00	4	1,429.8	1.79	4	1,912.0	1.34	0	150.6	0.00
6	0-2000			ERR			ERR			ERR			ERR	0	0.0	ERR			ERR
6	2000-4000			ERR		9.1	0.00			ERR		221.2	0.00	0	230.3	0.00			ERR
6	4000-6000		71.9	0.00		37.8	0.00		5.9	0.00	1	448.6	1.43	1	564.2	1.13		26.7	0.00
6	>6000		19.8	0.00		0.2	0.00		0.4	0.00		62.9	0.00	0	83.3	0.00		0.1	0.00
	Total	0	91.7	0.00	0	47.1	0.00	0	6.3	0.00	1	732.7	0.87	1	877.8	0.73	0	26.8	0.00
8	0-2000			ERR			ERR			ERR			ERR	0	0.0	ERR			ERR
8	2000-4000			ERR		27.1	0.00		3.0	0.00	2	685.9	1.87	2	716.0	1.79			ERR
8	4000-6000	2	301.0	4.25	4	130.9	19.56		49.8	0.00	1	962.3	0.67	7	1,444.0	3.10	2	179.4	7.13
8	>6000		113.3	0.00		29.6	0.00		7.2	0.00		216.8	0.00	0	366.9	0.00		9.4	0.00
	Total	2	414.3	3.09	4	187.6	13.65	0	60.0	0.00	3	1,865.0	1.03	9	2,526.9	2.28	2	188.8	6.78

Tompkins Creek

		FIRE			HARVEST						UNDISTURBED			*TOTALS*			FIRE+HARVEST		
Geo13 [geo13 #]	Elevation [range, ft]	Sites [#]	Fire [acres]	den [ls/sqmi]	Sites [#]	Harv77 [acres]	den [ls/sqmi]	Sites [#]	Harv76 [acres]	den [ls/sqmi]	Sites [#]	None [acres]	den [ls/sqmi]	Sites [#]	Acres	den [ls/sqmi]	Sites [#]	Fire_Harv [acres]	den [ls/sqmi]
9	0-2000			ERR			ERR			ERR			ERR	0	0.0	ERR			ERR
9	2000-4000		0.1	0.00			ERR			ERR		59.3	0.00	0	59.4	0.00			ERR
9	4000-6000		1.8	0.00		1.6	0.00			ERR	2	74.9	17.09	2	78.3	16.35			ERR
9	>6000			ERR			ERR			ERR			ERR	0	0.0	ERR			ERR
	Total	0	1.9	0.00	0	1.6	0.00	0	0.0	ERR	2	134.2	9.54	2	137.7	9.30	0	0.0	ERR
10	0-2000			ERR			ERR			ERR			ERR	0	0.0	ERR			ERR
10	2000-4000		1.7	0.00		5.5	0.00		0.7	0.00	3	368.5	5.21	3	376.4	5.10			ERR
10	4000-6000		26.0	0.00		2.9	0.00			ERR	1	175.2	3.65	1	204.1	3.14		0.5	0.00
10	>6000		0.3	0.00			ERR			ERR			ERR	0	0.3	0.00			ERR
	Total	0	28.0	0.00	0	8.4	0.00	0	0.7	0.00	4	543.7	4.71	4	580.8	4.41	0	0.5	0.00
11	0-2000			ERR			ERR			ERR			ERR	0	0.0	ERR			ERR
11	2000-4000			ERR		4.5	0.00		2.0	0.00	1	263.2	2.43	1	269.7	2.37			ERR
11	4000-6000		11.5	0.00		11.7	0.00			ERR	2	186.7	6.86	2	209.9	6.10		4.3	0.00
11	>6000			ERR			ERR			ERR			ERR	0	0.0	ERR			ERR
	Total	0	11.5	0.00	0	16.2	0.00	0	2.0	0.00	3	449.9	4.27	3	479.6	4.00	0	4.3	0.00
12	0-2000			ERR			ERR			ERR			ERR	0	0.0	ERR			ERR
12	2000-4000			ERR			ERR			ERR		0.3	0.00	0	0.3	0.00			ERR
12	4000-6000		19.9	0.00		16.9	0.00			ERR	1	48.2	13.28	1	85.0	7.53		2.8	0.00
12	>6000		4.6	0.00			ERR			ERR		12.3	0.00	0	16.9	0.00			ERR
	Total	0	24.5	0.00	0	16.9	0.00	0	0.0	ERR	1	60.8	10.53	1	102.2	6.26	0	2.8	0.00
13	0-2000			ERR			ERR			ERR			ERR	0	0.0	ERR			ERR
13	2000-4000			ERR			ERR			ERR		9.7	0.00	0	9.7	0.00			ERR
13	4000-6000		14.1	0.00		5.0	0.00			ERR		4.2	0.00	0	23.3	0.00		7.1	0.00
13	>6000			ERR			ERR			ERR			ERR	0	0.0	ERR			ERR
	Total	0	14.1	0.00	0	5.0	0.00	0	0.0	ERR	0	13.9	0.00	0	33.0	0.00	0	7.1	0.00
Totals:		5	1,459.0	2.19	4	605.9	4.23	0	238.0	0.00	20	6,799.7	1.88	29	9,102.6	2.04	2	675.1	1.90

KEY

fire — within fire burn intensity = H or M [from Hog, Fire87, Dillon, Specimen fires]

harv77 — outside H or M fire burn intensity
within harvested area YOUNGER than 1977 [includes NS, OR, SW]

harv76 — outside H or M fire burn intensity; within harvested areas OLDER than 1977

none — within "undisturbed" area; outside H or M fire burn intensity,
outside harvested area [old (pre-1977) or new (post-1977)]

fire_harv — within fire burn intensity H or M and
within "newly" harvested area [younger than 1977, NS]

TABLE 10

ERFO SITES MULTIPLE FACTORS

walker.123 11/12/98

Walker Creek

Geo13	Elevation	FIRE Sites	FIRE Fire	FIRE den	HARVEST Sites	HARVEST Harv77	HARVEST den	HARVEST Sites	HARVEST Harv76	HARVEST den	UNDISTURBED Sites	UNDISTURBED None	UNDISTURBED den	TOTALS Sites	TOTALS Acres	TOTALS den	FIRE+HARVEST Sites	FIRE+HARVEST Fire_Harv	FIRE+HARVEST den
[geo13 #]	[range, ft]	[#]	[acres]	[ls/sqmi]	[#]	[acres]	[ls/sqmi]	[#]	[acres]	[ls/sqmi]	[#]	[acres]	[ls/sqmi]	[#]		[ls/sqmi]	[#]	[acres]	[ls/sqmi]
1	0-2000			ERR			ERR			ERR			ERR	**0**	**0.0**	**ERR**			ERR
1	2000-4000			ERR			ERR		5.4	0.00		6.4	0.00	**0**	**11.8**	**0.00**			ERR
1	4000-6000		5.6	0.00		7.2	0.00	1	11.0	58.18	1	16.3	39.26	**2**	**40.1**	**31.92**		3.1	0.00
1	>6000			ERR			ERR			ERR		1.1	0.00	**0**	**1.1**	**0.00**			ERR
	Total	**0**	**5.6**	**0.00**	**0**	**7.2**	**0.00**	**1**	**16.4**	**39.02**	**1**	**23.8**	**26.89**	**2**	**53.0**	**24.15**	**0**	**3.1**	**0.00**
2	0-2000			ERR			ERR			ERR			ERR	**0**	**0.0**	**ERR**			ERR
2	2000-4000			ERR			ERR			ERR			ERR	**0**	**0.0**	**ERR**			ERR
2	4000-6000			ERR			ERR			ERR			ERR	**0**	**0.0**	**ERR**			ERR
2	>6000			ERR			ERR			ERR			ERR	**0**	**0.0**	**ERR**			ERR
	Total	**0**	**0.0**	**ERR**	**0**	**0.0**	**ERR**	**0**	**0.0**	**ERR**	**0**	**0.0**	**ERR**	**0**	**0.0**	**ERR**	**0**	**0.0**	**ERR**
3	0-2000			ERR			ERR			ERR			ERR	**0**	**0.0**	**ERR**			ERR
3	2000-4000		3.0	0.00		72.9	0.00		111.8	0.00		251.9	0.00	**0**	**439.6**	**0.00**		0.2	0.00
3	4000-6000	3	219.0	8.77	4	199.8	12.81	1	241.2	2.65	4	368.5	6.95	**12**	**1,028.5**	**7.47**		82.4	0.00
3	>6000		16.7	0.00			ERR			ERR		22.9	0.00	**0**	**39.6**	**0.00**		2.5	0.00
	Total	**3**	**238.7**	**8.04**	**4**	**272.7**	**9.39**	**1**	**353.0**	**1.81**	**4**	**643.3**	**3.98**	**12**	**1,507.7**	**5.09**	**0**	**85.1**	**0.00**
4	0-2000			ERR			ERR			ERR		4.6	0.00	**0**	**4.6**	**0.00**			ERR
4	2000-4000		3.6	0.00		9.9	0.00		47.9	0.00		602.5	0.00	**0**	**663.9**	**0.00**			ERR
4	4000-6000		0.9	0.00		3.0	0.00		27.1	0.00		116.5	0.00	**0**	**147.5**	**0.00**			ERR
4	>6000			ERR			ERR			ERR			ERR	**0**	**0.0**	**ERR**			ERR
	Total	**0**	**4.5**	**0.00**	**0**	**12.9**	**0.00**	**0**	**75.0**	**0.00**	**0**	**723.6**	**0.00**	**0**	**816.0**	**0.00**	**0**	**0.0**	**ERR**
5	0-2000			ERR			ERR		1.6	0.00		156.8	0.00	**0**	**158.4**	**0.00**			ERR
5	2000-4000		2.5	0.00		38.8	0.00		96.2	0.00	2	1,360.6	0.94	**2**	**1,498.1**	**0.85**			ERR
5	4000-6000		10.5	0.00		10.2	0.00		91.2	0.00		237.4	0.00	**0**	**349.3**	**0.00**		0.7	0.00
5	>6000		6.2	0.00		0.6	0.00			ERR		8.0	0.00	**0**	**14.8**	**0.00**			ERR
	Total	**0**	**19.2**	**0.00**	**0**	**49.6**	**0.00**	**0**	**189.0**	**0.00**	**2**	**1,762.8**	**0.73**	**2**	**2,020.6**	**0.63**	**0**	**0.7**	**0.00**
6	0-2000			ERR			ERR			ERR			ERR	**0**	**0.0**	**ERR**			ERR
6	2000-4000			ERR		0.8	0.00		1.4	0.00		5.6	0.00	**0**	**7.8**	**0.00**			ERR
6	4000-6000		54.9	0.00		103.2	0.00	1	20.9	30.62	1	174.9	3.66	**2**	**353.9**	**3.62**		39.2	0.00
6	>6000		1.5	0.00		2.4	0.00			ERR		7.8	0.00	**0**	**11.7**	**0.00**		0.3	0.00
	Total	**0**	**56.4**	**0.00**	**0**	**106.4**	**0.00**	**1**	**22.3**	**28.70**	**1**	**188.3**	**3.40**	**2**	**373.4**	**3.43**	**0**	**39.5**	**0.00**
8	0-2000			ERR			ERR			ERR			ERR	**0**	**0.0**	**ERR**			ERR
8	2000-4000	1		ERR		4.2	0.00		0.2	0.00		15.4	0.00	**1**	**19.8**	**32.32**			ERR
8	4000-6000		232.7	0.00	2	249.9	5.12		93.2	0.00	3	394.1	4.87	**5**	**969.9**	**3.30**	2	150.0	8.53
8	>6000		36.4	0.00		25.3	0.00		6.1	0.00		80.6	0.00	**0**	**148.4**	**0.00**		11.5	0.00
	Total	**1**	**269.1**	**2.38**	**2**	**279.4**	**4.58**	**0**	**99.5**	**0.00**	**3**	**490.1**	**3.92**	**6**	**1,138.1**	**3.37**	**2**	**161.5**	**7.93**

TABLE 11

ERFO SITES MULTIPLE FACTORS

walker.123 11/12/98

Walker Creek

Geo13 [geo13 #]	Elevation [range, ft]	FIRE Sites [#]	FIRE Fire [acres]	FIRE den [ls/sqmi]	HARVEST Sites [#]	HARVEST Harv77 [acres]	HARVEST den [ls/sqmi]	HARVEST Sites [#]	HARVEST Harv76 [acres]	HARVEST den [ls/sqmi]	UNDISTURBED Sites [#]	UNDISTURBED None [acres]	UNDISTURBED den [ls/sqmi]	*TOTALS* Sites [#]	*TOTALS* Acres	*TOTALS* den [ls/sqmi]	FIRE+HARVEST Sites [#]	FIRE+HARVEST Fire_Harv [acres]	FIRE+HARVEST den [ls/sqmi]
9	0-2000			ERR			ERR			ERR		12.4	0.00	**0**	**12.4**	**0.00**			ERR
9	2000-4000			ERR		15.0	0.00		9.0	0.00		93.1	0.00	**0**	**117.1**	**0.00**			ERR
9	4000-6000		5.9	0.00	2	16.1	79.50		12.4	0.00	3	54.2	35.42	**5**	**88.6**	**36.12**		0.4	0.00
9	>6000			ERR			ERR			ERR		0.1	0.00	**0**	**0.1**	**0.00**			ERR
	Total	**0**	**5.9**	**0.00**	**2**	**31.1**	**41.16**	**0**	**21.4**	**0.00**	**3**	**159.8**	**12.02**	**5**	**218.2**	**14.67**	**0**	**0.4**	**0.00**
10	0-2000			ERR			ERR		0.1	0.00	1	74.8	8.56	**1**	**74.9**	**8.54**			ERR
10	2000-4000		1.4	0.00		10.8	0.00		28.3	0.00	9	837.9	6.87	**9**	**878.4**	**6.56**			ERR
10	4000-6000		3.1	0.00		0.8	0.00		8.3	0.00	1	33.4	19.16	**1**	**45.6**	**14.04**			ERR
10	>6000			ERR			ERR			ERR			ERR	**0**	**0.0**	**ERR**			ERR
	Total	**0**	**4.5**	**0.00**	**0**	**11.6**	**0.00**	**0**	**36.7**	**0.00**	**11**	**946.1**	**7.44**	**11**	**998.9**	**7.05**	**0**	**0.0**	**ERR**
11	0-2000			ERR			ERR			ERR			ERR	**0**	**0.0**	**ERR**			ERR
11	2000-4000			ERR		0.1	0.00		0.8	0.00	1	15.8	40.51	**1**	**16.7**	**38.32**			ERR
11	4000-6000	1	18.7	34.22	4	57.1	44.83	1	5.2	123.08	4	105.7	24.22	**10**	**186.7**	**34.28**		10.9	0.00
11	>6000			ERR		0.4	0.00			ERR		1.4	0.00	**0**	**1.8**	**0.00**			ERR
	Total	**1**	**18.7**	**34.22**	**4**	**57.6**	**44.44**	**1**	**6.0**	**106.67**	**5**	**122.9**	**26.04**	**11**	**205.2**	**34.31**	**0**	**10.9**	**0.00**
12	0-2000			ERR			ERR			ERR			ERR	**0**	**0.0**	**ERR**			ERR
12	2000-4000			ERR			ERR			ERR			ERR	**0**	**0.0**	**ERR**			ERR
12	4000-6000			ERR			ERR			ERR			ERR	**0**	**0.0**	**ERR**			ERR
12	>6000			ERR			ERR			ERR			ERR	**0**	**0.0**	**ERR**			ERR
	Total	**0**	**0.0**	**ERR**	**0**	**0.0**	**ERR**	**0**	**0.0**	**ERR**	**0**	**0.0**	**ERR**	**0**	**0.0**	**ERR**	**0**	**0.0**	**ERR**
13	0-2000			ERR			ERR			ERR		39.0	0.00	**0**	**39.0**	**0.00**			ERR
13	2000-4000			ERR			ERR			ERR			ERR	**0**	**0.0**	**ERR**			ERR
13	4000-6000			ERR			ERR			ERR			ERR	**0**	**0.0**	**ERR**			ERR
13	>6000			ERR			ERR			ERR			ERR	**0**	**0.0**	**ERR**			ERR
	Total	**0**	**0.0**	**ERR**	**0**	**0.0**	**ERR**	**0**	**0.0**	**ERR**	**0**	**39.0**	**0.00**	**0**	**39.0**	**0.00**	**0**	**0.0**	**ERR**
Totals:		**5**	**622.6**	**5.14**	**12**	**828.5**	**9.27**	**4**	**819.3**	**3.12**	**30**	**5,099.7**	**3.76**	**51**	**7,370.1**	**4.43**	**2**	**301.2**	**4.25**

KEY

fire — within fire burn intensity = H or M [from Hog, Fire87, Dillon, Specimen fires]

harv77 — outside H or M fire burn intensity
within harvested area YOUNGER than 1977 [includes NS, OR, SW]

harv76 — outside H or M fire burn intensity; within harvested areas OLDER than 1977

none — within "undisturbed" area; outside H or M fire burn intensity,
outside harvested area [old (pre-1977) or new (post-1977)]

fire_harv — within fire burn intensity H or M and
within "newly" harvested area [younger than 1977, NS]

TABLE 11

FLOOD EFFECTS BY WATERSHED	SLIDES			ERFO SITES						ALTERED CHANNEL				
Watershed Name	acres [photo area]	# of slides	slides/ sqmi	acres [watershed]	road miles	rd mi/ sqmi	# of sites	sites/ sqmi	sites/ rd mi	altered [mi]	unaltered [mi]	total [mi]	density [altered mi /sqmi]	% altered
Aubrey Reach Klamath Rv	5,913		0.00	5,913	13.0	1.40	1	0.11	0.08	2.01	22.70	24.71	0.22	8.1%
Barkhouse Creek	9,995	9	0.58	10,208	34.9	2.19	1	0.06	0.03	4.99	37.17	42.16	0.32	11.8%
Beans Reach Rock Cr	3,952		0.00	9,834	17.6	1.15	1	0.07	0.06	0.72	10.74	11.46	0.12	6.3%
Bear Creek	6,740	16	1.52	6,740	11.0	1.04	34	3.23	3.10	8.86	13.70	22.56	0.84	39.3%
Benjamin Reach Klam Rv	7,101	4	0.36	7,101	24.6	2.22	9	0.81	0.37	0.03	25.66	25.69	0.00	0.1%
Big Ferry Reach Scott	3,326	1	0.19	7,642	9.7	0.81		0.00	0.00	0.13	18.36	18.49	0.03	0.7%
Big Meadows Reach Wooley	6,475	1	0.10	10,193		0.00		0.00		6.86	16.57	23.43	0.68	29.3%
Blue Heron Reach Klam Rv	6,372	7	0.70	6,372	25.4	2.55	2	0.20	0.08	0.22	25.78	26.00	0.02	0.8%
Boulder Reach Scott	8,694	13	0.96	8,694	34.0	2.50	9	0.66	0.26	2.07	19.97	22.04	0.15	9.4%
Bridge Creek	8,589	2	0.15	9,967	2.4	0.15	1	0.06	0.42	6.23	24.50	30.73	0.46	20.3%
Browns Reach Klam Rv	5,130		0.00	5,130	23.4	2.93	4	0.50	0.17	0.48	24.94	25.42	0.06	1.9%
Buckhorn Reach Beaver	10,062	4	0.25	12,095	61.5	3.25	3	0.16	0.05	0.45	48.92	49.37	0.03	0.9%
Buckhorn Reach Horse	10,306	1	0.06	10,306	54.3	3.37	4	0.25	0.07	2.26	27.38	29.64	0.14	7.6%
Bumblebee Reach Beaver	10,087	7	0.44	10,087	12.1	0.77	9	0.57	0.75	0.29	5.84	6.13	0.02	4.7%
Butler Creek	462		0.00	4,355	0.7	0.10		0.00	0.00		2.09	2.09	0.00	0.0%
Cade Reach Klamath Rv	12,923	4	0.20	12,923	91.7	4.54	21	1.04	0.23	2.77	44.97	47.74	0.14	5.8%
Caroline Reach Klam Rv	1,960		0.00	1,960	10.5	3.44	1	0.33	0.09	1.00	8.77	9.77	0.33	10.2%
Cedar Reach Thompson	9,213	17	1.18	9,213	18.4	1.28	20	1.39	1.09	13.16	10.96	24.12	0.91	54.6%
Cedar/Mill Reach Dillon	2,140		0.00	8,009	5.1	0.41	5	0.40	0.98	2.69	4.61	7.30	0.80	36.8%
China Creek	6,190	11	1.14	6,190	52.9	5.47	32	3.31	0.61	5.47	17.15	22.62	0.57	24.2%
Clauson Rch So Fk Indian	9,299		0.00	9,299	35.3	2.43	6	0.41	0.17	5.68	29.48	35.16	0.39	16.2%
Cliff Valley Reach Grider	5,033	5	0.64	5,033	16.2	2.05		0.00	0.00	3.44	16.52	19.96	0.44	17.2%
Collins Reach Klamath Rv	7,191	1	0.09	7,191	43.0	3.83	5	0.45	0.12	0.12	30.89	31.01	0.01	0.4%
Coon Reach Indian Cr	6,624	1	0.10	6,624	28.2	2.73	11	1.06	0.39	4.08	16.21	20.29	0.39	20.1%
Coon Reach Klam Rv	3,613		0.00	3,613	11.3	2.00	3	0.53	0.27	0.35	13.71	14.06	0.06	2.5%
Cow Creek	8,151	13	1.02	8,151	27.3	2.14	12	0.94	0.44	5.32	19.91	25.23	0.42	21.1%
Crawford Reach Klamath Rv	5,030	1	0.13	5,030	14.9	1.90	2	0.25	0.13	0.16	21.38	21.54	0.02	0.7%
Dead Horse Rch Wooley	1,440		0.00	8,181		0.00		0.00		0.54	4.42	4.96	0.24	10.9%
Deep Creek	691	19	17.60	691	4.4	4.03	5	4.63	1.15	4.40	0.10	4.50	4.08	97.8%
Doggett Creek	7,727		0.00	7,727	46.9	3.89	1	0.08	0.02		24.32	24.32	0.00	0.0%
Doolittle Reach Elk	10,966	5	0.29	10,966	48.5	2.83	28	1.63	0.58	6.48	38.85	45.33	0.38	14.3%
Doolittle Reach Indian	8,068		0.00	8,068	55.7	4.42	6	0.48	0.11	1.12	27.26	28.38	0.09	3.9%
Duncan Reach Salmon	3,826	2	0.33	3,994	11.1	1.78	1	0.16	0.09		14.57	14.57	0.00	0.0%
East Fork Elk Creek	10,291	11	0.68	10,291	47.4	2.95	32	1.99	0.68	3.21	34.63	37.84	0.20	8.5%
East Fork Indian Cr	10,324	10	0.62	11,729	39.3	2.14	18	0.98	0.46	8.94	21.92	30.86	0.55	29.0%
Five Mile Reach Clear Cr	7,992	3	0.24	7,992	2.2	0.18	2	0.16	0.90	4.10	24.71	28.81	0.33	14.2%
Fort Goff Creek	8,252	10	0.78	8,252	0.1	0.01		0.00	0.00	5.56	12.90	18.46	0.43	30.1%
Fourmile Reach Thompson	5,585	2	0.23	5,585	30.6	3.50	4	0.46	0.13	1.75	12.70	14.45	0.20	12.1%

TABLE 12

FLOOD EFFECTS BY WATERSHED	SLIDES			ERFO SITES						ALTERED CHANNEL				
Watershed Name	acres [photo area]	# of slides	slides/ sqmi	acres [watershed]	road miles	rd mi/ sqmi	# of sites	sites/ sqmi	sites/ rd mi	altered [mi]	unaltered [mi]	total [mi]	density [altered mi /sqmi]	% altered
Franklin Reach Scott	6,447	2	0.20	6,447	9.3	0.93		0.00	0.00		24.28	24.28	0.00	0.0%
Gates Reach Wooley Cr	6,025	1	0.11	6,466	0.6	0.06		0.00	0.00	5.63	17.33	22.96	0.60	24.5%
Granite Creek	7,525	9	0.77	7,525		0.00		0.00		11.50	18.57	30.07	0.98	38.2%
Haypress Creek	5,470		0.00	5,470	8.6	1.01	1	0.12	0.12	4.53	12.55	17.08	0.53	26.5%
Headwaters Elk Cr	5,854		0.00	5,854		0.00		0.00		5.00	14.18	19.18	0.55	26.1%
Headwaters Indian Cr	7,797	2	0.16	8,575	44.0	3.28	16	1.19	0.36	3.12	20.49	23.61	0.26	13.2%
Headwaters NF Salmon	896		0.00	11,741		0.00		0.00			1.72	1.72	0.00	0.0%
Headwaters Wooley Cr	9,579	2	0.13	9,579		0.00		0.00		6.56	26.26	32.82	0.44	20.0%
Hoop&Devil Reach Elk	3,074	1	0.21	3,074	15.5	3.22	1	0.21	0.06	4.37	9.86	14.23	0.91	30.7%
Hummingbird Reach Elk	7,067	24	2.17	7,067	0.0	0.00		0.00	0.00	16.14	14.92	31.06	1.46	52.0%
Independence Creek	11,497	16	0.89	11,497	25.5	1.42	18	1.00	0.71	12.34	28.65	40.99	0.69	30.1%
Irving Creek	5,423	1	0.12	5,423	28.8	3.40	1	0.12	0.03	0.03	18.04	18.07	0.00	0.2%
Jackass Reach NF Dillon	470		0.00	10,306	1.7	0.11	6	0.37	3.50		1.33	1.33	0.00	0.0%
Jaynes Canyon	7,007		0.00	7,007	45.1	4.12	9	0.82	0.20	4.58	23.52	28.10	0.42	16.3%
Joe Miles Reach Klam Rv	6,270	3	0.31	6,270	23.5	2.40	4	0.41	0.17	0.39	21.50	21.89	0.04	1.8%
Kennedy Reach Klam Rv	7,512		0.00	7,512	37.2	3.17	10	0.85	0.27	1.03	27.99	29.02	0.09	3.5%
King Creek	3,656		0.00	3,656	7.3	1.29	1	0.18	0.14		10.90	10.90	0.00	0.0%
Kohl Reach Klamath Rv	8,452	1	0.08	8,452	51.1	3.87	1	0.08	0.02	0.48	37.09	37.57	0.04	1.3%
Ladds Reach Klam Rv	4,747		0.00	4,747	13.9	1.88	1	0.13	0.07		16.39	16.39	0.00	0.0%
Little Grider Reach Klam Rv	6,327	1	0.10	6,327	32.6	3.29	6	0.61	0.18	0.01	25.11	25.12	0.00	0.0%
Little Humbug Cr	1,368		0.00	6,215	9.0	0.92		0.00	0.00	2.70	5.25	7.95	1.26	34.0%
Little South Fork Indian	6,103		0.00	6,103	25.0	2.62	5	0.52	0.20		21.42	21.42	0.00	0.0%
Lower Canyon Creek	6,544	4	0.39	6,544	17.6	1.72	23	2.25	1.31	3.60	18.20	21.80	0.35	16.5%
Lower Grider Creek	9,613	28	1.86	9,613	21.1	1.40	9	0.60	0.43	13.26	12.93	26.19	0.88	50.6%
Lower Mill Cr [Scott Bar]	3,819		0.00	7,096	14.4	1.29	4	0.36	0.28		11.47	11.47	0.00	0.0%
Lower Seiad Creek	7,829	2	0.16	7,829	5.6	0.46		0.00	0.00	3.20	22.68	25.88	0.26	12.4%
Lower Shackleford Cr	2,200	1	0.29	7,559		0.00	5	0.42			2.11	2.11	0.00	0.0%
Lower Ukonom Creek	6,815	3	0.28	6,815	11.8	1.11		0.00	0.00	5.37	16.69	22.06	0.50	24.3%
Lower West Fork Beaver	8,263	5	0.39	8,274	56.2	4.35	19	1.47	0.34	6.99	31.47	38.46	0.54	18.2%
Luther Reach Indian	7,797	2	0.16	7,797	44.1	3.62	5	0.41	0.11	3.94	25.23	29.17	0.32	13.5%
Main Kelsey	899	9	6.41	899	2.9	2.06	1	0.71	0.35	2.81	0.52	3.33	2.00	84.4%
McCarthy Reach Scott	11,622	2	0.11	11,622	24.0	1.32	3	0.17	0.12	4.42	38.60	43.02	0.24	10.3%
McCash/Cub Reach Ukonom	8,395	18	1.37	8,395	18.5	1.41	5	0.38	0.27	8.02	19.93	27.95	0.61	28.7%
McKinney Creek	7,284	1	0.09	7,284	45.9	4.04	4	0.35	0.09		36.40	36.40	0.00	0.0%
Merrill Reach Salmon	3,682		0.00	3,682	15.2	2.64	2	0.35	0.13		14.69	14.69	0.00	0.0%
Middle Creek [Horse Cr]	8,037	5	0.40	8,037	61.9	4.93	4	0.32	0.06	0.15	13.20	13.35	0.01	1.1%
Middle Creek [Scott]	4,461	13	1.87	4,461	16.2	2.32	15	2.15	0.93	9.87	8.34	18.21	1.42	54.2%
Middle Horse Creek	9,221	9	0.62	9,221	53.6	3.72	12	0.83	0.22	2.93	27.15	30.08	0.20	9.7%

TABLE 12

FLOOD EFFECTS BY WATERSHED	SLIDES			ERFO SITES						ALTERED CHANNEL				
Watershed Name	acres [photo area]	# of slides	slides/ sqmi	acres [watershed]	road miles	rd mi/ sqmi	# of sites	sites/ sqmi	sites/ rd mi	altered [mi]	unaltered [mi]	total [mi]	density [altered mi /sqmi]	% altered
Middle Kidder Creek	6,000	9	0.96	9,409		0.00		0.00			0.36	0.36	0.00	0.0%
Middle Reach Scott Rv	3,045		0.00	3,045	10.7	2.24	6	1.26	0.56		12.10	12.10	0.00	0.0%
Mill Creek [Indian Cr]	6,271	5	0.51	6,271	29.4	3.00	18	1.84	0.61	3.74	15.16	18.90	0.38	19.8%
Mill Creek [Quartz Valley]	6,000	2	0.21	11,398		0.00		0.00			3.60	3.60	0.00	0.0%
North Fork Kelsey Cr	5,160	22	2.73	5,160	1.3	0.16	1	0.12	0.79	9.57	13.45	23.02	1.19	41.6%
North Fork Wooley Cr	14,113		0.00	14,113		0.00		0.00		5.25	45.84	51.09	0.24	10.3%
O-Neil Creek	2,437	3	0.79	2,437	11.9	3.12	5	1.31	0.42	2.68	4.76	7.44	0.70	36.0%
O-Neil Reach Klam Rv	5,787		0.00	8,231	25.0	1.94	2	0.16	0.08	0.02	16.81	16.83	0.00	0.1%
Oak Flat/Wingate Reach KR	7,537	2	0.17	7,537	25.2	2.14	5	0.42	0.20	0.33	25.16	25.49	0.03	1.3%
Panther Reach Seiad Cr	3,734		0.00	3,734	18.3	3.13	2	0.34	0.11		7.15	7.15	0.00	0.0%
Portuguese Creek	5,604	13	1.48	5,604	0.8	0.10		0.00	0.00	7.17	10.71	17.88	0.82	40.1%
Portuguese Reach Salmon	1,389		0.00	5,072	2.1	0.27		0.00	0.00		8.14	8.14	0.00	0.0%
Quigleys Reach Klam Rv	5,968		0.00	6,242	27.2	2.79	2	0.21	0.07	0.10	32.66	32.76	0.01	0.3%
Rancheria Creek	4,398	37	5.38	4,398	9.6	1.39	6	0.87	0.63	12.63	4.95	17.58	1.84	71.8%
Red Hill Reach Clear Cr	1,647		0.00	12,400		0.00		0.00		1.29	4.24	5.53	0.50	23.3%
Red Rock Creek	4,124	1	0.16	4,124		0.00		0.00		1.71	9.59	11.30	0.27	15.1%
Reynolds Reach Klam Rv	13,553	9	0.42	13,815	58.5	2.71	5	0.23	0.09	0.91	52.47	53.38	0.04	1.7%
Right Hand Fk NF Salmon	3,499		0.00	12,706		0.00		0.00			12.89	12.89	0.00	0.0%
Rogers Creek	4,286	2	0.30	4,286	28.4	4.25	2	0.30	0.07	0.39	12.00	12.39	0.06	3.1%
Sandy Bar Reach Klam Rv	11,054	2	0.12	11,054	64.2	3.72	3	0.17	0.05	0.09	38.85	38.94	0.01	0.2%
Slippery Reach Clear Cr	5,961		0.00	5,961	19.1	2.05	4	0.43	0.21	5.01	13.80	18.81	0.54	26.6%
Sniktaw Cr	129		0.00	3,600		0.00		0.00						
Snow Reach Scott Riv	4,234	4	0.60	4,234	0.1	0.01		0.00	0.00					
Somes Reach Salmon Rv	5,951		0.00	6,505	10.4	1.03		0.00	0.00		20.97	20.97	0.00	0.0%
South Fork Clear Creek	7,870	1	0.08	7,870	26.5	2.15	3	0.24	0.11	1.60	23.05	24.65	0.13	6.5%
South Fork Kelsey	5,364	19	2.27	5,364	12.6	1.50	14	1.67	1.11	9.39	12.38	21.77	1.12	43.1%
South Fork Wooley Cr	5,659	1	0.11	6,080		0.00		0.00		3.52	13.75	17.27	0.40	20.4%
Stanza Reach Elk Creek	9,259	29	2.00	9,259	36.0	2.49	40	2.76	1.11	13.03	32.93	45.96	0.90	28.4%
Steinacher Creek	1,712	1	0.37	9,203	5.8	0.41	5	0.35	0.86	0.46	6.71	7.17	0.17	6.4%
Swillup Creek	5,562		0.00	5,562	13.2	1.52	2	0.23	0.15		23.18	23.18	0.00	0.0%
Ten Mile Creek	10,088	2	0.13	10,088	0.0	0.00		0.00		0.66	32.93	33.59	0.04	2.0%
Ti Creek	6,056		0.00	6,056	39.7	4.19	8	0.85	0.20	0.12	21.15	21.27	0.01	0.6%
Titus Creek	5,548	6	0.69	5,548	15.0	1.74	10	1.15	0.66	2.42	18.12	20.54	0.28	11.8%
Tom Martin Reach Klam Rv	13,788	6	0.28	13,788	34.5	1.60	7	0.32	0.20	3.47	44.22	47.69	0.16	7.3%
Tompkins Creek	9,321	67	4.60	9,321	35.1	2.41	29	1.99	0.83	22.92	20.27	43.19	1.57	53.1%
Twin Valley Creek	4,255		0.00	8,744		0.00		0.00		1.74	14.52	16.26	0.26	10.7%
Upper Canyon Creek	5,140	2	0.25	5,140	0.2	0.03		0.00	0.00	2.26	17.08	19.34	0.28	11.7%
Upper Grider Creek	8,486	11	0.83	8,486	7.7	0.58	2	0.15	0.26	11.96	16.14	28.10	0.90	42.6%

TABLE 12

FLOOD EFFECTS BY WATERSHED	SLIDES			ERFO SITES						ALTERED CHANNEL				
Watershed Name	acres [photo area]	# of slides	slides/ sqmi	acres [watershed]	road miles	rd mi/ sqmi	# of sites	sites/ sqmi	sites/ rd mi	altered [mi]	unaltered [mi]	total [mi]	density [altered mi /sqmi]	% altered
Upper Horse Creek	11,382	5	0.28	11,393	61.1	3.43	7	0.39	0.11	3.03	28.61	31.64	0.17	9.6%
Upper Humbug Creek	50		0.00	8,001		0.00		0.00			0.14	0.14	0.00	0.0%
Upper Indian Creek	2,102		0.00	6,121	15.9	1.66	1	0.10	0.06		11.30	11.30	0.00	0.0%
Upper Kidder Creek	6,383	2	0.20	6,383		0.00		0.00		3.42	11.54	14.96	0.34	22.9%
Upper McAdams Cr	1,643		0.00	10,020	14.4	0.92	11	0.70	0.76		5.79	5.79	0.00	0.0%
Upper Mill Cr	7,156		0.00	7,156	44.0	3.94	3	0.27	0.07		27.29	27.29	0.00	0.0%
Upper Rock Cr	18		0.00	11,508	0.3	0.02	5	0.28	17.83					
Upper Seiad Creek	6,895	10	0.93	6,895	18.4	1.71	14	1.30	0.76	12.71	10.82	23.53	1.18	54.0%
Upper Shackleford Cr	7,069	1	0.09	8,607	0.4	0.03	3	0.22	7.91	2.56	11.39	13.95	0.23	18.4%
Upper South Fork Indian	7,647	4	0.33	7,647	12.8	1.07	2	0.17	0.16		20.24	20.24	0.00	0.0%
Upper Thompson Creek	7,830	5	0.41	8,409	5.5	0.42	7	0.53	1.27	6.24	17.42	23.66	0.51	26.4%
Upper Ukonom Creek	5,743	15	1.67	5,743	0.0	0.00		0.00		9.47	7.71	17.18	1.06	55.1%
Upper West Fork Beaver	4,817	9	1.20	4,817	32.7	4.35	15	1.99	0.46	2.98	12.15	15.13	0.40	19.7%
Vesa Reach Klam Rv	33		0.00	9,692	0.3	0.02		0.00	0.00		0.47	0.47	0.00	0.0%
Walker Creek	7,651	78	6.52	7,651	44.3	3.71	51	4.27	1.15	21.53	5.12	26.65	1.80	80.8%
West Branch Indian Cr	5,399	1	0.12	5,399	20.5	2.43	5	0.59	0.24	0.54	16.29	16.83	0.06	3.2%
West Grider Reach Klam Rv	4,145	5	0.77	4,145	25.1	3.88	5	0.77	0.20	0.47	13.23	13.70	0.07	3.4%
TOTALS:	806,732	736	0.58	973,222	2,617.4	1.72	794	0.52	0.30	446.30	2,333.82	2,780.12	0.35	16.1%
	3,265 sqkm		0.23 /sqkm	3,939 sqkm	4,211.4 km	1.07 km/sqkm	794	0.20 sites/sqkm	0.19 sites/ rd km	718.1 km	3,755.1 km	4,473.2 km	0.22 alt_km/ sqkm	

TABLE 12

Acreage Adjustments:

Watersheds were adjusted to include acres within the photo coverage, but outside the Forest, & hence outside the area of Forest GIS coverages.

Adjustments were also made to include areas within the Forest, yet outside the "clipped" photo area [i.e., along the margins]

Watershed	Photo area	Used here	Acres added
Boulder Reach Scott	8,138	8,694	556
Bumblebee Reach Beaver	1,720	10,087	8,367
Cow Creek	6,467	8,151	1,684
Lower Shackleford Cr	770	2,200	1,430
McCarthy Reach Scott	9,059	11,622	2,563
Middle Kidder Creek	350	6,000	5,650
Mill Creek [Quartz Valley]	1,624	6,000	4,376
Snow Reach Scott Riv	19	4,234	4,215
Ten Mile Creek	7,720	10,088	2,368
Upper Kidder Creek	5,512	6,383	871
Upper South Fork Indian	4,579	7,647	3,068
			35,148

Summary amounts - flood-altered channnel [entire Klamath westside]:

Miles of "new" [unmapped] channel:	120.21
Miles of "old" [mapped] channel:	389.74
Total miles of altered channel:	509.95

TABLE 13

FLOOD EFFECTS BY WATERSHED Watershed Name [field]	SLIDES acres [photo area]	# of slides	slides/ sqmi	ERFO SITES acres [watershed]	road miles	rd mi/ sqmi	# of sites	sites/ sqmi	sites/ rd mi	ALTERED CHANNEL altered [mi]	unaltered [mi]	total [mi]	density [altered mi /sqmi]	% altered
Cow Creek	8,151	13	1.02	8,151	27.3	2.14	12	0.94	0.44	5.32	19.91	25.23	0.42	21.1%
Bumblebee Reach Beaver	10,087	7	0.44	10,087	12.1	0.77	9	0.57	0.75	0.29	5.84	6.13	0.02	4.7%
Jaynes Canyon	7,007		0.00	7,007	45.1	4.12	9	0.82	0.20	4.58	23.52	28.10	0.42	16.3%
Upper West Fork Beaver	4,817	9	1.20	4,817	32.7	4.35	15	1.99	0.46	2.98	12.15	15.13	0.40	19.7%
Lower West Fork Beaver	8,263	5	0.39	8,274	56.2	4.35	19	1.47	0.34	6.99	31.47	38.46	0.54	18.2%
Buckhorn Reach Beaver	10,062	4	0.25	12,095	61.5	3.25	3	0.16	0.05	0.45	48.92	49.37	0.03	0.9%
Beaver Creek [5th]	**48,387**	**38**	**0.50**	**50,431**	**234.9**	**2.98**	**67**	**0.85**	**0.29**	**20.61**	**141.81**	**162.42**	**0.27**	**12.7%**
Upper Horse Creek	11,382	5	0.28	11,393	61.1	3.43	7	0.39	0.11	3.03	28.61	31.64	0.17	9.6%
Middle Horse Creek	9,221	9	0.62	9,221	53.6	3.72	12	0.83	0.22	2.93	27.15	30.08	0.20	9.7%
Middle Creek [Horse Cr]	8,037	5	0.40	8,037	61.9	4.93	4	0.32	0.06	0.15	13.20	13.35	0.01	1.1%
Buckhorn Reach Horse	10,306	1	0.06	10,306	54.3	3.37	4	0.25	0.07	2.26	27.38	29.64	0.14	7.6%
Horse Creek [6th]	**38,946**	**20**	**0.33**	**38,957**	**231.0**	**3.79**	**27**	**0.44**	**0.12**	**8.37**	**96.34**	**104.71**	**0.14**	**8.0%**
Upper Grider Creek	8,486	11	0.83	8,486	7.7	0.58	2	0.15	0.26	11.96	16.14	28.10	0.90	42.6%
Cliff Valley Reach Grider	5,033	5	0.64	5,033	16.2	2.05		0.00	0.00	3.44	16.52	19.96	0.44	17.2%
Rancheria Creek	4,398	37	5.38	4,398	9.6	1.39	6	0.87	0.63	12.63	4.95	17.58	1.84	71.8%
Lower Grider Creek	9,613	28	1.86	9,613	21.1	1.40	9	0.60	0.43	13.26	12.93	26.19	0.88	50.6%
Grider Creek [6th]	**27,530**	**81**	**1.88**	**27,530**	**54.5**	**1.27**	**17**	**0.40**	**0.31**	**41.29**	**50.54**	**91.83**	**0.96**	**45.0%**
Upper Seiad Creek	6,895	10	0.93	6,895	18.4	1.71	14	1.30	0.76	12.71	10.82	23.53	1.18	54.0%
Panther Reach Seiad Cr	3,734		0.00	3,734	18.3	3.13	2	0.34	0.11		7.15	7.15	0.00	0.0%
Lower Seiad Creek	7,829	2	0.16	7,829	5.6	0.46		0.00	0.00	3.20	22.68	25.88	0.26	12.4%
Seiad Creek [6th]	**18,458**	**12**	**0.42**	**18,458**	**42.3**	**1.47**	**16**	**0.55**	**0.38**	**15.91**	**40.65**	**56.56**	**0.55**	**28.1%**
Main Kelsey	899	9	6.41	899	2.9	2.06	1	0.71	0.35	2.81	0.52	3.33	2.00	84.4%
North Fork Kelsey Cr	5,160	22	2.73	5,160	1.3	0.16	1	0.12	0.79	9.57	13.45	23.02	1.19	41.6%
South Fork Kelsey	5,364	19	2.27	5,364	12.6	1.50	14	1.67	1.11	9.39	12.38	21.77	1.12	43.1%
Kelsey Creek [7th]	**11,423**	**50**	**2.80**	**11,423**	**16.7**	**0.94**	**16**	**0.90**	**0.96**	**21.77**	**26.35**	**48.12**	**1.22**	**45.2%**
Upper Thompson Creek	7,830	5	0.41	8,409	5.5	0.42	7	0.53	1.27	6.24	17.42	23.66	0.51	26.4%
Cedar Reach Thompson	9,213	17	1.18	9,213	18.4	1.28	20	1.39	1.09	13.16	10.96	24.12	0.91	54.6%
Fourmile Reach Thompson	5,585	2	0.23	5,585	30.6	3.50	4	0.46	0.13	1.75	12.70	14.45	0.20	12.1%
Thompson Creek [6th]	**22,628**	**24**	**0.68**	**23,207**	**54.5**	**1.50**	**31**	**0.85**	**0.57**	**21.15**	**41.08**	**62.23**	**0.60**	**34.0%**

TABLE 14

FLOOD EFFECTS BY WATERSHED	SLIDES			ERFO SITES						ALTERED CHANNEL				
Watershed Name [field]	acres [photo area]	# of slides	slides/ sqmi	acres [watershed]	road miles	rd mi/ sqmi	# of sites	sites/ sqmi	sites/ rd mi	altered [mi]	unaltered [mi]	total [mi]	density [altered mi /sqmi]	% altered
Headwaters Indian Cr	7,797	2	0.16	8,575	44.0	3.28	16	1.19	0.36	3.12	20.49	23.61	0.26	13.2%
West Branch Indian Cr	5,399	1	0.12	5,399	20.5	2.43	5	0.59	0.24	0.54	16.29	16.83	0.06	3.2%
Mill Creek [Indian Cr]	6,271	5	0.51	6,271	29.4	3.00	18	1.84	0.61	3.74	15.16	18.90	0.38	19.8%
Coon Reach Indian Cr	6,624	1	0.10	6,624	28.2	2.73	11	1.06	0.39	4.08	16.21	20.29	0.39	20.1%
Upper South Fork Indian	7,647	4	0.33	7,647	12.8	1.07	2	0.17	0.16		20.24	20.24	0.00	0.0%
Twin Valley Creek	4,255		0.00	8,744		0.00		0.00		1.74	14.52	16.26	0.26	10.7%
Little South Fork Indian	6,103		0.00	6,103	25.0	2.62	5	0.52	0.20		21.42	21.42	0.00	0.0%
Clauson Rch So Fk Indian	9,299		0.00	9,299	35.3	2.43	6	0.41	0.17	5.68	29.48	35.16	0.39	16.2%
East Fork Indian Cr	10,324	10	0.62	11,729	39.3	2.14	18	0.98	0.46	8.94	21.92	30.86	0.55	29.0%
Luther Reach Indian	7,797	2	0.16	7,797	44.1	3.62	5	0.41	0.11	3.94	25.23	29.17	0.32	13.5%
Doolittle Reach Indian	8,068		0.00	8,068	55.7	4.42	6	0.48	0.11	1.12	27.26	28.38	0.09	3.9%
Indian Creek [5th]	**79,584**	**25**	**0.20**	**86,256**	**334.2**	**2.48**	**92**	**0.68**	**0.28**	**32.90**	**228.22**	**261.12**	**0.26**	**12.6%**
Headwaters Elk Cr	5,854		0.00	5,854		0.00		0.00		5.00	14.18	19.18	0.55	26.1%
Hummingbird Reach Elk	7,067	24	2.17	7,067	0.0	0.00		0.00	0.00	16.14	14.92	31.06	1.46	52.0%
Granite Creek	7,525	9	0.77	7,525		0.00		0.00		11.50	18.57	30.07	0.98	38.2%
Bear Creek	6,740	16	1.52	6,740	11.0	1.04	34	3.23	3.10	8.86	13.70	22.56	0.84	39.3%
Stanza Reach Elk Creek	9,259	29	2.00	9,259	36.0	2.49	40	2.76	1.11	13.03	32.93	45.96	0.90	28.4%
Doolittle Reach Elk	10,966	5	0.29	10,966	48.5	2.83	28	1.63	0.58	6.48	38.85	45.33	0.38	14.3%
East Fork Elk Creek	10,291	11	0.68	10,291	47.4	2.95	32	1.99	0.68	3.21	34.63	37.84	0.20	8.5%
Hoop&Devil Reach Elk	3,074	1	0.21	3,074	15.5	3.22	1	0.21	0.06	4.37	9.86	14.23	0.91	30.7%
Elk Creek [5th]	**60,776**	**95**	**1.00**	**60,776**	**158.3**	**1.67**	**135**	**1.42**	**0.85**	**68.59**	**177.64**	**246.23**	**0.72**	**27.9%**
Upper Ukonom Creek	5,743	15	1.67	5,743	0.0	0.00		0.00		9.47	7.71	17.18	1.06	55.1%
McCash/Cub Reach Ukonom	8,395	18	1.37	8,395	18.5	1.41	5	0.38	0.27	8.02	19.93	27.95	0.61	28.7%
Lower Ukonom Creek	6,815	3	0.28	6,815	11.8	1.11		0.00	0.00	5.37	16.69	22.06	0.50	24.3%
Ukonom Creek [6th]	**20,953**	**36**	**1.10**	**20,953**	**30.3**	**0.93**	**5**	**0.15**	**0.16**	**22.86**	**44.33**	**67.19**	**0.70**	**34.0%**

TABLE 14

II. SLOPE AND CHANNEL PROCESSES AND FEATURES (TERMINOLOGY)

Hillslope Processes

During the flood of 1997, a full range of hillslope and channel processes played a role in mobilizing, transporting, and depositing sediment throughout the Klamath National Forest. In this report, the terms "flood processes" are used to include all of the processes which interacted to produce the effects visible across the landscape following the flood. This includes hillslope landsliding, debris flows down channels, and flooding. The landslide and flow terminology in this report describing those processes is modified from Pierson and Costa (1987), Bates and Jackson (1987), and Cruden and Varnes (1996).

Terminology

(1). **Slumps and Earthflows-** Deep, slow moving landslides which, move by slide processes (slump and translation), and to a lesser degree, flow processes, as in earthflows. Depths typically ranged from 20-100 feet, and the material involved in failure usually consisted of colluvium and landslide deposits, but some included bedrock. Velocities, (movement scale from Cruden &Varnes 1996) typically range from extremely slow (16 mm/yr) to very rapid (3 m/min). Flood-related slumps and During the earthflows ranged from small fractions of a acre to about 40 acres in area. Typically, the vegetation growing on these landslides survives the movement, though it may be damaged. In most cases, these landslides were observed to have formed on older landslide deposits, sometimes involving reactivation of the entire ancient landslide. Several of the reactivated slumps and earthflows had particularly important effects on channels downstream, in Walker, Tompkins, Kelsey, Grider, and Thompson Creek watersheds. Some of the reactivations occurred in areas where landslide features were prominent and little-eroded, whereas others occurred where original landslide features were very subtle due to post-sliding erosion.

At higher elevation, landslide deposits typically form gentle slopes near ridgecrests, with very steep channels below them. Reactivation of slumps and earthflows in this setting generated large debris slides. These debris slides typically formed at the toes of dormant landslide deposits. They were very fluid, and immediately evolved into debris flows, making them capable of traversing long stretches of gentle terrain to reach steep streamcourses (Morgan Creek). Once they reached channels, they mobilized additional bed and bank material. In bedrock channels, there was little debris available, but in alluvial reaches or areas where channels traversed landslide deposits, large volumes of material were mobilized. This mobilized bed material often greatly exceeds the volume of the initiating landslide. For example, in Walker Creek, one debris slide, 90 feet wide x 150 feet long x 8 feet deep = 4,000 cubic yards (landslide #---) mobilized about 280,000 cubic yards of material (triangular cross section 100 feet wide and 50 feet deep and 3000

feet long) as traveled down a faint draw. This debris flow created a 50 foot deep gully which triggered a large slump on the left bank (landslide # ---). A large slump in lower Kelsey Creek (Landslide # ------) has mobilized several hundred thousand cubic yards of material, most of which still remains on the hillslope.
At lower elevations, these features tended to move on the order of inches or feet, and in some cases the toe enchroached on streams and rivers, such as in the case of the Benjamin Creek Landslide along the Klamath River.

Road cut failures were a common type of slump which occurred, but were usually small, and deposited material on the road bed.

(2). **Debris Slides-** Shallow, rapidly-moving landslides which exhibit a continuum of slope processes, ranging from sliding (slump and translation) to flow and avalanche processes. Many evolve into debris flows as they travel down slope. They are most often much shallower than slumps and earthflows, and are limited to the soil or colluvium, but some were observed to involve bedrock. Depth usually ranged from 5-30 feet, but some were deeper. They move much more rapidly than slumps and earthflows, with velocities ranging from very rapid (3 m/min) to extremely rapid (>5 m/sec). Most of the debris slides were much smaller than the slumps and earthflows, and average about less than ½ acre in area, with the largest occupying about 2 acres. In most cases, all vegetation is stripped from the landslide site, leaving a barren scar on the landscape. One of the most common settings for the 1997 debris slides was on toe zones of dormant slump and earthflow deposits, as well as the toe zones of slumps and earthflows which were reactivated in 1997. As previously mentioned, several of these debris slides generated particularly large debris flows with channel-altering effects. Other common settings were on steep (>65%) swales in areas of sandy soil with little cohesion, and also on artificial embankments (road fills). Debris slides originating in road fills generated some very large debris flows, such as in the headwaters of McCash Creek. Some of these debris slides originated in subtle swales with slope gradients of only 60%. Overflow from Ukonom Lake also generated a large debris slide. Debris slides in shallow soil were observed in Deep Creek, Walker Creek, South Russian, Tompkins, and Rancheria Creeks. A large propoportion of these were within harvested or burned areas. Road fill failures are a special case of debris slides where the failing material is primarily artificial embankment. They range from a few cubic yards in volume with little watershed effects to large features which formed debris flows. Some failures of small fills were observed on plantation terraces in Rancheria Creek. Debris slides were activated along many of the larger channels which experienced debris flows, due in part to the undercutting effect of the debris flows.

In actuality, most landslides investigated in the field are actually complexes and exhibit all types of landslide processes. One of the most common types includes slump/debris slide processes.

(3). **Debris Flows-** Plastic flows of sediment/water slurries which usually travel through channels, but may also traverse hillslopes away from channels. They move at rates which range from very rapid (3 m/min) to extremely rapid (>5 m/sec). Most of the 1997 debris flows were generated by debris slides. Some debris flows appear to have been initiated by mobilization of channel bed sediment alone, and lack discrete initiation sites. An important characteristic of debris flows is the high density of the slurry which provides a buoyant force capable of floating large boulders. This greatly increases the transport and erosion power of the event. Debris flows typically removed or damaged most of the riparian vegetation adjacent to steam courses, and in several instances, cut deep gullies on hillslopes.

(4). **Hyperconcentrated Stream Flow-** Flow in which sediment concentration has reached a level (20-60 percent by volume) which causes it to be slightly plastic, but still appears to flow like a fluid. The onset of yield strength has important implications to sediment transport. To the observer, the only difference from stream flow would be a marked dampening of turbulence.

(5). **Stream Flow-** Flow of water or water/sediment mixture which behaves like a liquid to the observer.

(6). **Surface Erosion and Gullying-** The mobilization and transport of soil, usually less than few feet deep by raindrop impact, sheet wash, rilling, and gullying.

(7) **Cumulative Watershed Effects-** The accumulation and interaction of multiple events in a watershed over time and space, in particular, hydrologic interactions.

III. MAJOR LANDSLIDES

A. KELSEY CREEK

1. Kelsey Slump Outplant Site
2. Kelsey Slump Old
3. Cayenne Ridge Slump
4. North Fork Kelsey Slurry at Road

B. DEEP CREEK

1. Deep Creek Slump.

C. TOMPKINS CREEK

1. Tompkins Slurry.

D. WALKER CREEK

1. Walker Headwall Slump.
2. Walker Big Slump.
3. Walker Gully.

D. GRIDER CREEK

1. Rancheria Debris Slide on slump toe zone.

E. THOMPSON CREEK

1.Morgan Creek Forked Debris Flow (slump, debris slide, debris flow).
2. Thompson Timbered Slumps

F. UKONOM CREEK

1. McCash Debris flow
2. Ukonom Lake Debris Flow
3. Flems ? Fork

G. ELK CREEK

1. *Granite Creek Debris Slide (Tichner Peak)*

IV. PERFORMANCE OF ENGINEERED SLOPE STABILIZATION STRUCTURES

Observations by Ed Rose- The following list is based on cursory site visits while doing other field work and word of mouth descriptions from Forest personnel.

1) Cellular Earth Wall (corrugated aluminum can wall) on Beaver Ck. Road just before W. Fork of Beaver Creek. Structually intact. Corrugated aluminum face of wall was punctured with holes (max. hole size approx. 1.5' dia.) from logs and debris banging into it during high flows. Some material was lost out of holes but doesn't appear to have affected wall. Holes will be patched by placing corrugated aluminum over holes. Further investigation needed at this site.

2) Hilfiker welded wire retaining wall on W. Fork Beaver Creek. Structually intact. No damage from "97 storm".

3) Fabric reinforced fill (1:1 face) on W. Fork of Beaver Creek. Constructed in 1991. Failure of appoximately 1/3 of face of wall in "95 storm". This face was patched by Fruit Growers in summer of 96. They put rocky material on the face to prevent further failure and erosion. The rocky material was washed away by the "97 storm and small amount more of failure occured on the face. The road hasn't been affected yet. Failure may be a combination of things; 1) slope was a bit steeper than 1:1 in failed section, 2) The material (Condrey mtn. schist) the fill was made of has extremely poor shear strength and is not very suitable for use as structural fill even if reinforced, 3) The reinforced fill is near the toe of a very large earth flow that may have had some localized movement in the fill area. Not sure yet how to affect a repair to this site.

4) Fabric reinforced fill (1:1 face) on the "Sidewinder road". Constructed in 1995. Structually intact. Casual observation has shown no damage from "97 storm".

5) Fabric reinforced fill (1.25:1 face) on the South Fork Indian Creek road. Constructed in 1996. Small amount of settlement of road on upper end of fill and small failure of material approximately 10 feet below foundation of fill otherwise structully intact.

6) Rock fill just above reinforced fill on South Fork Indian Creek road. Constructed in 1996. Complete failure of rock fill and road during "97 storm".
Rock fill was temp. measure to get road width and it was not founded below active slide plane. Road again was opened recently in similar manner to access ground above site. Final fix will have to be found on stable material below slide plane or fix by reducing load at what appears to be head of slide (road prism).

7) Drained rock fill on Hungry Creek road. Constructed 1996. Haven't seen site but George Hahn said it weathered the storm.

8) Rock fill on Beaver Ck. road. Constructed 1992? Structurally intact.

9) Hilfiker welded wire retaining wall on 44N45 Boulder Ck. road. Constructed 1995. Structurally intact. The scarp of a small landslide has its head just at the foundation of the upper end of the wall in an approximately 10' location. No effect on the wall. Will keep an eye on it.

10) Two fabric faced retaining walls in Stanza Creek area. Talked to Harold Buma and he said they held up fine. There was some road drainage that threatened to erode one edge of the wall but he corrected it.

11) Hilfiker welded wire retaining wall on Elk Creek road. Structurally intact.

12) Geogrid reinforced fill (1.25:1 face) and fabric reinforced buttress fill (1:1 face) on Beaver Ck. road. Constructed 1996. Structually intact. Minor failures on face.

13) Hilfiker welded wire wall on S. Russian road, 40n54. Structurally intact. Minor erosion of top of fill on about a 2 foot section.

14) Rip Rap Channel Bank Protection on Upper South Fork Salmon River at Big Flat Campground.

V. ABSTRACTS

A. AGU DECEMBER 1997

Filed: flshpc/E:JUAN/Abstracts/agu97

EOS, Transactions, American Geophysical Union, 1997 Fall Meeting, Volume 78, Number 46, November 18, 1997 Supplement

Effects of the 1997 Flood on the Klamath National Forest: Influences of Physical Factors and Recent Disturbances - Fire, Timber Harvest, and Roads

Juan de la Fuente and Don Elder (Klamath National Forest, 1312 Fairlane Rd, Yreka CA 96097; 916-842-6131; delder/r5_klamath@fs.fed.us)

Physical attributes of the landscape and pre-flood disturbances to vegetation and soil played important roles in the distribution and effects of landslides. Landslide density averaged 0.23 landslides/sq km across the landscape. Concentrations occurred on slump and earthflow deposits (0.31 slides/sq km), as well as on slopes greater than 65% in plutons (0.29 slides/sq km), and at elevations from 1,200 - 1,830 m (.42 slides/sq km). Landslide densities in disturbed areas were as follows: timber harvest = 1.16 slides/sq km; fire = 0.77 slides/sq km; within 60 m of a road = 0.42 slides/sq km.

The storm of 12-26-96 through 1-3-97 delivered up to 43 cm of precipitation to parts of the study area. At the onset of the storm, the snowpack was slightly above average and extended down to about 1,000 m in elevation. The warm storm produced rain up to 2,400 m in elevation. One station recorded 13 cm in the last 18 hours of December 31. Total precipitation for December ranged from 1.7 to 4.2 times the norm for that month. Estimates of recurrence intervals for 1997 peak stream flows range from 9 to 37 years, e.g., Scott River = 14 yr; Salmon River = 37 yr; Klamath River at Orleans = 18 yr. Peak flows ranged from 51-84% of the 1964 flood (largest on record).

Landslides, debris flows, and channel modifications, were concentrated in a SW-NE trending band, which was about 32 km wide by 64 km long. To date, infrastructure damage exceeds $ 22 million. Effects were greatest in the Walker, Grider, Elk, Tompkins, Kelsey, Deep, and Ukonom watersheds. Debris flows were typically initiated by landslides at elevations in excess of 1,200 m. These flows scoured upper channel reaches, removed riparian vegetation, and deposited sediment and large logs in lower reaches. Field-based investigations are being conducted to assess possible cause/effect relationships and to develop road management guidelines.

B. AGU APRIL, 1998

Filed: fishpc/E:97Flood/AGU/abstract98
EOS Transactions, American Geophysical Union, 1998 Spring Meeting, Volume 79, Number 17, April 28, 1998 Supplement

ABSTRACT

AGU SPRING MEETING: MAY, 1998

The Debris Flows of August 20, 1997 in Whitney and Bolam Creeks, Glacially-fed Streams on the Northwest Flank of Mount Shasta Volcano, Northern California.

Juan de la Fuente, Don Elder, Polly Haessig, Abel Jasso, Peter Van Susteren, Bill Bachmann, John Chatoian

On August 20, 1997, debris flows occurred in Whitney and Bolam Creeks. They coalesced, and deposited debris on the alluvial fan to a maximum distance of 20 km to the NW of the summit of Mt. Shasta. The debris flows were preceded by several days of warm weather followed by a storm which produced heavy rain to the mountain summit on the evening of August 19, triggering the event. During the storm, Weed, CA, located 13 km west of Whitney Glacier, received 4.4 cm of rain on August 19-20. The debris flow buried a 600 m section of CA Highway 97 to a depth of about 1.5 m, flooded houses and agricultural lands, and introduced sediment into a water ditch.

TheWhitney Creek debris flow originated in three channels along the terminus of Whitney Glacier. Deep new channel scour occurred below Whitney Falls, and formed a vertically-walled chasm up to 15 m wide and 10 m deep. A single sample taken from the moving debris flow yielded a density of 2.0 grams/cu. cm. The Bolam Creek debris flow originated at two locations along the terminus of Bolam Glacier, and traveled down two separate channels. Below Coquette Falls, Bolam Creek cut deep new channels in its floodplain, but also deposited debris where channels overflowed. Boulders up to 5 m in diameter were moved, and the Bolam Creek trailhead was buried to a depth of 1.5 m.

During this century, debris flows in Whitney Creek have been documented in 1919, '35,'52,'60,'77,'85,'94, and '97, and at Bolam Creek in 1935, '55, and '73. The 1935 event was probably the largest this century. Most have been associated with glacial melting, and some, such as the 1935 event, with melting plus summer rain. Field observations of debris deposits, and mud marks on confined channel walls above Whitney Falls and at the Highway 97 crossing indicate that the 1997 event was similar in magnitude to the 1985 event, and larger than the 1994 event. Debris flow processes were recorded on video tape, documenting in-filling, and re-incision of channels. Resulting deposits usually exhibit a convex transverse profile, with channels often located at the crest of the deposit as posed by Blodgett and others in 1996. Debris flow activity was limited to areas previously identified as high hazard for this process. In two cases, the debris flow followed old roads on the fan. Despite the sparse population in this area, summer debris flows constitute a persistent hazard in the long term.

C. AGU DECEMBER 1998

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American Geophysical Union, 1998 San Francisco

The Debris Flows of 1997 on the Klamath National Forest, Central Klamath Mountains, CA: Older Landslide Deposits as a Major Source

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Following the flood of January 1, 1997, more than 900 landslides were mapped in a 356,000 hectare study area. Abundant debris flows modified stream channels and damaged roads. Most debris flows were initiated by landslides situated in two geomorphic settings: (a) toes of older landslide deposits; (b) steep colluvium-filled hollows. Published accounts of the 1997 flood in northern California, indicate that most debris flows originated in colluvium-filled hollows. In contrast, the majority of the large debris flows in the study area developed on landslide toes. Quaternary landslides (slumps, earthflows, block glides) form thick deposits occupying about 25\% of the study area. They are concentrated in the schists of the Rattlesnake Creek and Condrey Mountain geologic terranes, and are also abundant in serpentinite areas, but are rare in plutons. Along the distal margins, these deposits typically retain original morphological features such as the toe as described by Varnes (1978). In longitudinal profile, most are benched, due to the presence of multiple nested landslides. The steep slopes separating benches consist of toes or head scarps of smaller internal landslides. The term "toe zone" is applied here collectively to the steep (45-100\ %) slopes along the distal margin of landslide deposits, as well as to the steep internal toes and scarps. This landform is unstable due to the fact that it is formed of weak, unconsolidated landslide debris, is steep, and is frequently the site of emerging springs. The toe zones which produced the most destructive debris flows were in headwaters at elevations of 1370-1680 meters. Most of these debris flows were initiated by reactivated slumps. Some were able to traverse gentle benches then continue down steep channels. The incidence of 1997 landslides on roaded and de-vegetated toe zones is much higher than on those which are undisturbed. Due to its sensitivity to soil and vegetative disturbances, accurate mapping of this landform is essential to sound forest management. This is being accomplished with field work, air photos, 30 meter digital elevation models (DEM's), and high resolution laser-generated DEM's

D. AGU DECEMBER 1997: ENGLISH AND METRIC UNITS

Effects of the 1997 Flood on the Klamath National Forest: Influences of physical Factors and Recent Disturbances - Fire, Timber Harvest, And Roads
By: Juan de la Fuente and Don Elder

The storm of 12-26-96 through 1-3-97 delivered up to 17 inches (43 cm) of precipitation to parts of the Klamath National Forest. At the onset of the storm, the snowpack was slightly above average and extended down to about 3500 feet (1100) m in elevation. The warm storm produced rain up to 7200 feet (2,400 m) in elevation. One station recorded 5 inches (13 cm) in the last 18 hours of December 31. Total precipitation for December ranged from 1.7 to 4.2 times the norm for that month. Estimates of recurrence intervals for 1997 peak stream flows range from 9 to 37 years, and peak flows ranged from 51-84% of those measured for the 1964 flood (largest on record).

Physical attributes of the landscape and pre-flood disturbances to vegetation and soil (roads, timber harvest, wildfire) played important roles in the distribution and effects of landslides. Landslide density averaged 0.59 slides/ sq. mi. (0.23 slides/sq km) within the air photo boundary shown on Map 2, and 0.26 slides/sq. ~~mi. (~~0.10 slides/sq. km.) on undisturbed land. Concentrations occurred on slump and earthflow deposits 0.80 slides/sq. mi. (0.31 slides/sq km), as well as on slopes greater than 65% in plutons 0.75 slides/sq. mi. (0.29 slides/sq km), and 1.09 slides/sq. mi. (.42 slides/sq km). at elevations from 4,000-6,000 feet (1,220 - 1,830 m). Highest densities on landslide deposits considering elevation were at 4,000-6000 feet, where there were 1.70 slides/sq.mi.. Landslide densities in disturbed areas were as follows: timber harvest = 1.86 slides/sq. mi. (0.72 slides/sq km; fire = 2.03 slides/sq. mi. 0.78 slides/sq km; within 50 feet (15 m) of a road = 7.34 slides/sq. mi. (2.83 slides/sq km). Considering geomorphology, elevation, and disturbances, slide density was highest on dormant slide deposits at elevations 4,000-6,000 feet, and burned in wildfire (7.4 slides/sq.mi. For road corridors on landslide deposits at 4,000-6,000 feet, the rate was 11.51 slides/sq.mi. In the Walker Creek watershed, this rate was 91.87 slides/sq.mi.

Landslides, debris flows, and channel modifications, were concentrated in a SW-NE trending band across the Forest, which was about 20 miles (32 km) wide by 40 miles (64 km) long. This pattern cannot be projected beyond the boundaries of the forest at this time due to lack of comparable information in adjoining areas. To date, infrastructure damage exceeds $ 22 million. Effects on the Klamath National Forest were greatest in the Walker, Grider, Elk, Tompkins, Kelsey, Deep, and Ukonom watersheds. Debris flows were typically initiated by landslides at elevations in excess of 3600 feet (1200 m). These flows scoured upper channel reaches, removed riparian vegetation, and deposited sediment and large logs in lower reaches. Field-based investigations are being conducted to assess possible cause/effect relationships and to develop road management guidelines.

VI. DISCUSSION

A. RATIONALE FOR CONCLUSIONS

Precipitation and Stream Flow

1. Magnitude of Flood Effects- The 1997 flood was a large event, producing landslides and channel alterations similar to that of the most recent major storm (1974). However, effects were considerably smaller than those associated with the 1964 flood, the largest on record for this area. In 1997, only a few watersheds, such as Walker, Elk, Ukonom, Deep, Grider and Tompkins Creeks experienced the same level of effects produced by the 1964 Flood across most of the west side of the Forest. The 1964 flood had considerable effects on the Salmon River watershed, whereas, the 1997 flood had very localized effects, primarily in the Upper South Fork.
2. Cells of Intense Precipitation- Though not apparent in precipitation or streamflow records, it appears that local cells of exceptionally high precipitation developed on the west side of the Forest during the storm. This conclusion is supported by the observation that: (a) Landslides, ERFO sites, and altered channels were concentrated in discrete areas on the west side of the Forest; (b) Watersheds experiencing the greatest effects shared physical characteristics (bedrock, geomorphology, topography etc.) and disturbances (roads, harvest, fire) with comparable adjacent watersheds which experienced only minor flood effects. (c) Localized intense cells were documented to the SE of the Klamath Forest by precipitation gages in the Sacramento River (Pit River Tributary) watershed. However, it remains possible that other factors, as yet unidentified, may have influenced the localization of effects. It is very important to determine if intense cells developed, since this has serious implications to interpreting how other factors such as geomorphology or roads and timber harvest affected flood effects.
3. Predicting Future Flood Effects- Future floods are likely to produce landslides and channel effects in similar combinations of geomorphic setting and soil/vegetation disturbances (roads, harvest, fire) as did the 1997 flood. However, the elevation zones experiencing the most severe landsliding can be expected to vary by storm. For example, this flood assessment demonstrated that the 1997 storm exhibited the most severe landslide effects at higher elevations (>4000 feet) on the west side of the Klamath National Forest. However, this same event produced severe landsliding at lower elevations in the Ashland Creek Watershed (Rogue River watershed) to the NE, and in tributaries to the Sacramento River immediately east of Shasta Lake to the SE. Further, a recent landslide study on the Salmon River Watershed (Klamath River tributary), was able to establish that landslides associated with the 1964 flood were concentrated at elevations above 5,000, whereas landslides associated with storms from 1965-1975 were concentrated at elevations from 2,000 to 3,000 feet (de la Fuente and Haessig, 1993). Thus, variations in landsliding by elevation can be expected for future storms. These storms may be also produce similar variations in effects by bedrock and geomorphic terranes.

Roads, Landings, Rock Pits and Waste Areas

5. Interactions Between Roads and Flood Processes- Field observations revealed that roads had an important effect on flood processes in terms of changing local **hydrology**, **soil properties**, and **mass balance**. Some fairly obvious conclusions emerged regarding roads:

(a) Roads by streams are particularly susceptible to damage (60% of ERFO sites), and such roads altered flood processes by trapping sediment, diverting streams, and contributing sediment;
(b) Roads on landslide deposits initiated landsliding by undercutting toe zones or placing fill on the heads of slumps;
(c) Numerous road fills on steep mountain slopes failed catastrophically and generated debris flows.
(d) Roads concentrated on the same hillslope produced cumulative effects where where they were linked hydrologically.

Timber Harvest and Fire

8. The Effect of Timber Harvest and Fire on Landslide Rates- Landslides in de-vegetated areas occurred at a much higher rate (landslides per square mile) than in undisturbed areas. In fact, areas burned in the 1987 fire or harvested in 1977 or more recently occurred at a rate 6 times the undisturbed rate (excluding landslides in road corridors). Though we have a reasonable understanding of how vegetation affects slope hydrology and soil properties, we cannot automatically attribute landslides in de-vegetated areas to the loss of vegetation, since landslides also occurred on undisturbed lands, albeit at a much lower frequency. However, the pronounced concentration of landslides in de-vegetated areas strongly suggests that an underlying cause/effect relationship exists, but cannot be isolated at this level of analysis.

Physical Factors & Interactions Influencing the Flood

15. Flood Effects and Interactions- There is a strong correlation between the distribution of flood effects (landsliding and road damage sites) and physical attributes of the landscape.

a. Bedrock Terranes- Landslide frequencies were very high in certain terranes (Rattlesnake Creek and Plutons).
b. Geomorphic Terranes- Previously active landslides, inner gorges, and landslide deposits exhibited a high density of 1997 landslides. Debris slides from landslide toe zones generated debris flows and delivered large volumes of sediment to streams.
c. Elevation- There was a pronounced concentration of landslides between 4,500 and 5,500 feet in elevation suggesting the influence of melting snow. The pattern of lower elevation landsliding on the Rogue River National Forest near mount Ashland was (Hicks, 1997) very different. Similarly, there were concentrations of landslides and debris flows in the Squaw and Winnibully Creek watersheds on the Shasta Trinity National Forest lower than 3,000 feet in elevation (Steve

Bachmann, and Abel Jasso, personal communication, 1998).
d. Slope Gradient- Landslides were concentrated at slopes steeper than 40%.
e. Aspect- North and east aspects had considerably higher landslide concentrations than south and west, suggesting that snowmelt may have played a role and/or soil differences on north aspects may have influenced this.

16. Combinations of Factors- Multiple factors influenced the damage patterns observed following the flood, but geomorphology (older landslide deposits), elevation, and disturbance (fire, harvest, road) appear to have exerted the greatest influence. These associations can be supported on the basis of process. New landslides commonly develop within older landslide deposits, since these are subject to reactivation. Elevation is directly linked to snow accumulation and melt, and also influences soil and geomorphic factors, as well as the potential for orographic effects on the storm. Disturbances such as roads are known to increase landslide rates through changes in slope hydrology, mass balance, and construction of unstable fills. De-vegetation by timber harvest or fire affects slope processes by changing infiltration, evapotranspiration, root support, wind loading, etc. In many cases, entire watershed catchments of dormant landslides were de-vegetated prior to the flood. Field observations in several watersheds revealed that large slumps and earthflows were mobilized within older landslide deposits, and generated debris flows. These landslides occurred high in the watersheds, most often above 4000 feet in elevation (see the Walker Creek example). Most of these landslides occurred in roaded areas which were either harvested or burned at high or moderate intensity since 1987. There was a high debris flow incidence where granitic lands were burned or logged.

General

18. Limitations of This Assessment- This is a preliminary reconnaissance level assessment which relies primarily on air photo interpretations and field sampling. It determines landslide densities (landslides per square mile) in road corridors, logged areas, and burned areas, and compares them to densities in undisturbed areas. This information allows preliminary conclusions to be drawn regarding the effect of roads, harvest and fire on landslide susceptibility. However, it does not establish the magnitude of the effect (total volume of sediment or miles of stream altered) produced by landslides originating on roads, logged areas or burned areas. Neither does it prove that the roads, harvest or fire actually caused the landslides with which it is associated. It is important to consider that landslides are more visible on air photos within the de-vegetated road corridor and in logged or burned areas than on timber-covered hillslopes. This tends to inflate the density of landslides in open areas. Lack of air photo coverage on the SE side of the Forest, thus, some channel alteration such as on the south Fork of the Scott River were not identified.
19. Extrapolation of Findings- Findings regarding the effects of roads on landslide and erosion processes have widespread application to the Pacific Northwest. However, associations between geologic and physical factors and landsliding may have more limited application due to the possibility that variations in storm intensity had a strong influence on patterns of flood effects.

Flood effects patterns reported on adjacent National Forests indicate similar road effects, but considerable difference in elevation zones displaying the most severe effects. This points out the need for a Klamath Province level assessment utilizing similar data sets. It is clear that very different conclusions can be supported for the 1997 flood if different watersheds or river basins are included in the assessment.

21. Data Sources- Small scale air photos (1:40,000) taken after the flood provided quick, high resolution remote reconnaissance to be conducted across a large portion of the Forest. Similarly, Damage Site Reports completed by Forest Engineers provided extremely useful information for all the road damage sites (more than 900 sites). These reports allowed us to stratify sites and identify key problems, costs, and effects. Standardization of the data which are collected on Damage Site Reports and terminology across Forest boundaries would be extremely useful on future floods.

B. ROADS: THEIR EFFECTS ON FLOOD PROCESSES

Road Effects

Of the common human activities in forested lands, roads undoubtedly have the greatest effects on slope stability (Sidle and others, 1985). The primary effects are:

(a) Effect on Hydrology- Roads affect hillslope hydrology by intercepting, concentrating, and rerouting surface and subsurface runoff with road cuts and ditches. They affect channel hydrology by modifying channel configuration such as when fills at stream crossings create artificial dams which modify debris flow behavior, trap sediment and logs, and cause stream diversions.

(b) Effect on Soil Properties- Roads affect the **density** of the soil and regolith by making some areas more dense than the natural soil (compacting road surfaces) and others less dense (sidecast road fills). Changes in compaction and density in turn affect permeability, with the road surfaces being less permeable than the natural soil, and sidecast fills generally more permeable. This decrease in density and increase in **permeability** of sidecast fills makes them prone to catastrophic failure on steep hillslopes. Roads modify **slope gradients** and steepen parts of the landscape (cuts and some fills), and make other parts more gentle (road surfaces and some fills).

(c) Effect on Mass Balance- Roads affect mass balance by placing cuts and fills on hillslopes. The cuts remove weight, and fills add weight. This change in the distribution of mass on the hillslope can initiate landsliding.

Road Fills, Cuts, Surface Drainage

Road fills, cuts, surface drainage were found to have had critical effects on flood processes irrespective of the local geologic or geomorphic setting. These effects are described below:

(1) Road Fills- Road fills had three key effect on flood process: (1) By disrupting channel configuration at stream crossings, thereby creating dams when pipes clogged. In some cases, this caused deposition upstream, and in others, diverted flows to the road prism downstream. It also provided sediment to the stream when the fill failed or was eroded; (2) By placing fills on steep hillslopes, particularly in swales underlain by sandy soils. Such fills are less stable than the surrounding landscape and groundwater is concentrated there, plus road surface runoff is often delivered there causing many fill failures, and generating debris flows. (3) Fills placed on the head of slumps added driving force, and caused them to reactivate. Good mitigation technology exists to reduce the risk of fill failures. These include: controlled compaction during construction; subsurface drainage; fill reinforcement, and armoring where it is likely to be overtopped by future debris flows.

(2) Road Cuts- Road cuts affected flood processes by intercepting subsurface flow, undermining slopes, and removing weight, thereby changing mass balance. Removal of weight from the toe zone of a slump can reduce forces which are buttressing the slope above, and cause it to fail. There are not many mitigation measures to reduce the risk of cut slope failure in steep terrain, so the most effective measure is avoidance. Buttressing with a retaining wall can be applied in special cases instances, but the measure is too expensive to apply to an entire road. Similarly, horizontal drains can reduce the risk of failure on some sites.. The best mitigation measure to address the issue of intercepted subsurface flow is to make sure that the intercepted water continues down the slope it would follow naturally, and not divert it from the site in a ditch. However, there may be special cases where water should be carried elsewhere.

(3) Road Surface Drainage- The road surface, inside ditch, and cross drains alter slope hydrology by conveying the water intercepted by road stream crossings, road cuts, and the road surface itself, and delivering it to new sites on the landscape. In-sloped roads with ditches in many cases intercepted and concentrated water, then delivered it to unstable sites, both on the surface, and by subsurface infiltration. In other cases, in-sloped roads received water from diverted stream crossings, and transported it to other sites, causing damage there. The road drainage system serves to extend the stream system, and make it more efficient in delivering water to the larger channels. In this way, it can influence peak flows and associated channel damage. Again, good mitigation technology exists to reduce the risk of water diversions caused by road drainage. These include positive dips in the road surface or rises (driveable water bars) were observed to be effective at preventing this problem.

These three primary road components (fills, cuts, surface drainage) play different roles in different geomorphic settings as described below.

Geomorphic Setting

It was found that roads had their largest effects on flood processes and also experienced the most damage in three geomorphic settings: (1) The stream channel environment where roads crossed or closely paralleled streams; (2) On older landslide deposits where roads undercut toe zones or loaded the heads of slumps; (3) on steep mountain slopes, where sidecast fills were placed in swales or large cuts made into hillslopes.

(1) **Stream Channel Environment-** The high density of road damage sites (ERFO sites) in the vicinity of streams is due to the dynamic nature of the stream environment. Roads built there have to withstand peak stream flows and periodic debris flows which alternately scour the channel, erode the banks, and deposit sediment. Canyon walls are usually steep (inner gorge), and groundwater is naturally concentrated there during wet periods, making them prone to debris slides. Some stream channels coincide with active earthflows. All these factors tend to make the streamside environment dynamic and unstable. Road fills placed in stream channels obstruct the passage of sediment and logs, but are also susceptible to erosion themselves. When culverts become clogged, road fills often divert streamflow out of the channel and down the road. In very steep stream crossings, road fills failed catastrophically by debris slide processes, and generated debris flows. Road cuts into inner gorge slopes approaching stream crossings initiate cut bank failures and debris flows. Roads paralleling streams constrict the channel, and can be undercut by high stream flows and debris flows, and those on gentle floodplains were affected by flooding and deposition of sediment.

(2) **Landslide Deposit Environment-** Ancient landslide deposits on the Klamath Forest have demonstrated a pattern of local reactivations during wet years such as in 1964, 1972-1974, 1983, and 1997. Reactivations move by slump and earthflow processes, and may range from 0.5 to 200 acres in size. If the reactivated slump has a prominent toe zone, it commonly sheds debris slides which in turn generated debris flows. They are sensitive to changes in the distribution of mass on a hillslope, and to diversion and concentration of surface and subsurface runoff. Drainage divides in dormant landslide terrane are typically very low, and as a result, streams can often be rerouted by a road prism. Some reactivations were initiated by placement of road fills on the head of dormant slumps. In others, road cuts into toe zones of slump and earthflow deposits failed as debris slides. The presence of road ditches along msny of the reactivated slumps suggests that the ditch contributed to reactivation by allowing water to infiltrate into the head of the landslide. In some cases, movement of the landslides dropped roads inches or feet, but in others, completely obliterated the road. About --% of landslide ERFO sites away from streams are on landslide deposits, and about --% of Stream crossing ERFO sites which involve landsliding are on landslide deposits. The geologic data layer does not identify all the landslide deposits, particularly those < 5 acres in size.

(3) **Steep Mountain Slope Environment-** Swales in steep mountainous terrain are often places which have experienced debris sliding in the past, and have been subsequently re-filled with soil and colluvium. Groundwater is commonly concentrated in these features. In dissected granitic terrane, these swales exhibit slope gradients of 60-90% and are unstable. Road fills placed there invite catastrophic failure by debris slide processes if not adequately compacted, strengthened, and drained. Also, the high road cuts necessary to build roads in steep terrain experience slumps and debris slides. Further, these high cuts intercept a large amount of subsurface water, and if the road is in-sloped, this water is then concentrated and diverted away from its natural flow path.

Cumulative Effects

Two primary types of cumulative effects relative to roads are addressed:

(a) Dense Road System- This situation is where multiple roads, one above the other, cross the same hillslope, resulting in complex interactions between the roads and geomorphic processes. In this setting, a simple debris slide on a hillslope can block a culvert, cause the road fill to fail, and generate a large debris flow which is capable of taking out any additional road crossings downslope. Another example is where a clogged cross drain diverts road drainage on to a landslide, activating it and sending it down to the next road down the hill.

(b) Long In-sloped Road Segments Without Drainage Safety Valves- Long road segments with inside ditches function basically as artificial stream networks. Even though flow is interrupted by cross drains and small drainages, unusually high discharges or cut bank failures can cause multiple cross drains to fail, and even allow water to bypass small stream crossings. In this situation, an entire stream can flow hundreds of feet down the ditch, and exit on a hillslope or in a totally different drainage. The term "cascade" was used on the Siskiyou National Forest as follows: "An initial cause can affect another site, which in turn causes an effect at one or several additional sites, which become causes of effects at further sites. This type of chain reaction is referred to as "cascading effects", or "cascades". The characteristics of sites that experienced a complex sequence of causes and effects:". This describes many of the effects observed on the Klamath Forest.

C. EFFECTS OF TIMBER HARVEST, FIRE, AND SITE PREPARATION

Effects of Vegetation Removal

Vegetation removal in itself affects slope and channel hydrology as well as soil characteristics, and to a minor degree, mass balance. Most of these effects increase landslide potential, but some reduce it. In the following section (modified from Greenway, 1987), adverse effects on slope stability and soil erosion are indicated with a minus sign (-), and beneficial effects with a plus sign (+). Greenway focused exclusively on slope stability per se, while this list also addresses surface erosion and large vegetation which could affect debris flow behavior (presence or absence of large logs on a hillslope or in a channel). This assessment tracks regeneration harvest only (clearcut and shelterwood), and considers partially logged areas such as thinned areas as undisturbed. Removing vegetation has the following effects:

Effects on Hydrology: a. Reducing evapotranspiration rates (-); (b) Changing snow accumulation and melt rates (-); (c) Modifying peak stream flows in snow zones (-); (d) Reducing the number of standing and down trees on hillslopes which in turn can modify the behavior of debris flows traveling down channels or across hillslopes. (-).

Effects on Soil Properties: a. Reducing the reinforcement and anchoring to rock or subsoil provided by tree roots (-); b. Reducing soil buttressing and arching (-); (c) Reducing the wedging and loosening of soil by roots (+); e. Reducing wind stresses (+); (f) Increasing soil cover (timber harvest produces organic material (slash) which provides soil cover). (+).

Effects on Mass Balance: Reducing surcharge applied to hillslopes by standing and down vegetation. These effects are relatively small (+,-).

Effects of Yarding, Mechanical Site Preparation, and Burning

Timber yarding involves the transport of timber from hillslopes with tractors, cables, or helicopters to truck landing sites. Tractor yarding on steeper ground sometimes requires constructed skid trails which are essentially small roads. Cable yarding is usually less disturbing to the soil, but can created gouges when logs are not suspended above the ground. Site preparation involves preparing a site for planting by removing logging slash and brush. On gentler ground is done mechanically, that is, it is piled with tractors. In some cases terraces are constructed on hillslopes to facilitate conifer regeneration, and these also are essentially small roads. On steeper slopes, site preparation is usually accomplished by burning. These practices affect slope and channel hydrology as well as soil characteristics.

Effects on Slope Hydrology-

Yarding and mechanical site preparation affect slope hydrology as follows: (1) Intercepting, concentrating, and rerouting surface and subsurface runoff with cuts or cable yarding corridors (-); (2) Creating water repellant or hydrophobic conditions with site preparation burning (-,+); Altering subsurface hydrology by providing subsurface water conduits when root systems of dead trees are burned. (-,+).

Effects on Soil Properties-

Yarding and mechanical site preparation affect soil properties as folows: (1) Yarding and mechanical site preparation affect the **density of the soil** and regolith by making some areas more dense than the natural soil (compacting skid trail surfaces) (+); and others less dense (sidecast along skid trails) (-); (2) Changes in compaction and density in turn affect **permeability**, with the skid trail surfaces being less permeable (+,-) than the natural soil, and sidecast fills generally more permeable (-). This decrease in density and increase in permeability of sidecast fills makes them prone to catastrophic failure on steep hillslopes; (3) Full bench skid trails and terraces **steepen** parts of the landscape (cuts and some fills) (-), and make other parts more **gentle** (skid trail surfaces and some fills) (+); (4) Site preparation removes logging slash, and thereby reduces **soil cover** (-).

Mass Balance-

Excavated skid trails, terracing, and extreme mechanical site prep can affect mass balance similar to roads (-,+), but effects are usually much smaller.

APPENDIX C
ROAD GUIDELINES

DEVELOPED IN RESPONSE TO THE 1997 FLOOD KLAMATH NATIONAL FOREST

*****FINAL: NOVEMBER 24, 1998*****

INTRODUCTION

The following guidelines apply specifically to repair of flood-damaged roads, but are also intended to guide future new construction, decommissioning, and maintenance. They are a product of what was learned during this investigation, and through discussions with Forest engineers, earth scientists, and biologists. This replaces the fall 1997 version of this document, which has been updated to incorporate comment received from Klamath Forest employees.

The guidelines provide a means of meeting Aquatic Conservation Strategy (ACS) Objectives, and specifically address standards for roads in the Northwest Forest Plan (NFP). Relevant ACS objectives and NFP standards are attached at the end of **Appendix C**. The term "ERFO" used below stands for Emergency Relief, Federally Owned, and refers to flood damaged sites identified by Forest Engineering personnel after the 1997 flood which qualify for emergency federal funds.

Guidelines are presented in four categories:

(1) **Administrative Process Guidelines-** These are recommendations on the administrative process used in ERFO repair, new roads, decommissioning, and maintenance.
(2) **Road Repair Guidelines: Forest-wide-** Guidelines which are intended to apply Forest-wide.
(3) **Road Repair Guidelines: By Geomorphic Setting-** Guidelines directed specifically to three geomorphic settings where most of the flood damage to roads occurred, **stream crossings, landslide terrane**, and **steep mountain slopes**.
(4) **Repair and Construction Guidelines for Waste Areas and Rock Pits**

Most of these guidelines are already being applied to repair of flood-damaged roads. Uniform application across the Forest is strongly recommended on ERFO sites yet to be completed.

I. ADMINISTRATIVE PROCESS GUIDELINES

1. **Meet Current Direction-** Assure that ERFO site repairs are consistent with the Klamath Forest Land and Resource Management Plan, and the Northwest Forest Plan (NFP) Standards and Guidelines, and associated Aquatic Conservation Strategy Objectives (ACS).
2. **Use Interdisciplinary Teams-** Assure that relevant disciplines are involved in all ERFO site assessments and repair design. For landslide repairs, compare the landslide potential associated with no action to that of the proposed action.
3. Use **Multiple Funding Sources-** While designing repairs for ERFO sites take the opportunity to upgrade problem areas or decommission roads utilizing additional funds (non-ERFO) as available. Upgrading includes designing stream crossings to accommodate debris flows or 100 year recurrence interval stream flows, improving fish passage, etc. Implement betterment as part of the ERFO program. Where possible, do the environmental assessment for the upgrade concurrent with the ERFO assessment and design. Focus on repairing, relocating, or removing roads posing the greatest risk for adverse effect on Riparian Reserve values.
4. **Identify High Risk Road Segments-** Initiate a systematic forest-wide inventory of high priority roads and identify stream crossing and landslide sites which pose a high risk of failure with high consequences to the watershed. A good example of such an inventory is a contract proposal submitted by the Klamath Forest to the California Department of Fish and Game on 11-5-98 **(Road/Stream Crossing Inventory & Risk Assessment Klamath National forest - Westside)**. Consider these roads for upgrading and/or decommissioning. High priority roads are those in high value watersheds where aquatic habitat conditions are good, and where sedimentation and cumulative watershed effects are often issues. In areas with many stream crossing failures, evaluate those which survived the flood, but exhibit a high risk of failure in the future. Seek funds to repair, upgrade, or decommission these crossings.
5. **Apply Proposed Road Guidelines-** Apply practices recommended in Appendix C as well as in the Klamath Forest Decommissioning white paper to road maintenance, upgrade, new construction and decommissioning.
6. **Develop a New Damage Site Report-** In preparation for future floods, develop a new Damage Site Report form to standardize terminology, and to add some information on watershed effects and to be able to classify sites into categories of causes, and effects. This will require close coordination between watershed/fish and engineering, and considerably more field involvement on the part of watershed personnel in collecting the data.

II. ROAD REPAIR GUIDELINES: GENERAL

These guidelines apply to ERFO repairs Forest-wide.

1. **Consider Relocating Roads in Riparian Reserves-** Where road damage is within Riparian Reserves, consider relocating or decommissioning the road. Avoidance of unstable lands and Riparian Reserves is often the best policy.
2. **Identify all Causes of Failure-** Assure that site assessments identify all factors which contributed significantly to the road failures at ERFO sites, and that repairs address these factors. For example, if diverted surface water contributed to saturation and failure of a fill, the repair must correct the surface diversion in addition to repairing the fill.
3. **Maintain or Improve Post-Flood Slope Stability-** Assure that repairs of ERFO sites, both temporary and permanent, do not result in a situation which is more unstable than the pre-repair condition, nor increase the risk of watershed degradation above the pre-repair situation. Avoid emergency, short-term road openings which would destabilize landslides, or jeopardize the permanent repair of any ERFO sites. Perform emergency road openings only where we can assure that the site will at be returned to post-flood (or more stable conditions) prior to the ensuing winter.
4. **Road Fills:** (a) Design and construct stable fills utilizing appropriate compaction, reinforcement, and drainage. (b) For stream crossings and steep fills on hillslopes or in swales, minimize the size of fills, and apply road repair guidelines described below for the stream channel environment and steep mountain slopes.
5. **Sidecast-** Limit or prevent sidecast, particularly where sedimentation of landsliding is possible. Use excavators in doing earthwork where appropriate.
6. **Road Cuts:** Design and construct stable cuts, using buttressing and drainage as appropriate. Avoid large cuts into wet, unconsolidated debris and toes of landslides. Apply guidelines described for cuts in steep mountain slope terrane.
7. **Road Surface Drainage:** Outslope roads and install rolling dips so as to eliminate inside ditches wherever possible. Emphasize those with the potential to have greatest adverse watershed effects. Minimize the length of road segment capable of diverting water away from its natural course. This can be accomplished by lowering the fill at a stream crossing, or with prominent dips designed to handle deposition which commonly accompanies debris flows. Long stretches of inside ditch with cross drains are prime candidates.

III. ROAD REPAIR GUIDELINES BY GEOMORPHIC SETTING

Three geomorphic settings are addressed: (A) Near **streams**; (B) On **landslide deposits**; (C) On **steep mountain slopes**. Refer to Photos 5-8, and 97-27-6A for examples of each setting. The following information is presented for each setting:

(1) Types of failure- The types of failure common to each setting are described.
(2) Assessment Needs- Assessment needs are outlined for each setting, indicating which disciplines should be involved, and what critical assessments should be performed;
(3) Objectives- Objectives (desired conditions for roads) are stated for each setting;
(4) Guidelines- Guidelines for attaining desired conditions in each geomorphic setting are provided.

This same information is also provided for rock pits and waste areas (Item IV below).

A. NEAR STREAM CHANNELS

Roads in the vicinity of streams experienced damage at **crossings**, where they **paralleled** the stream, and where they were on the **100-year floodplain**.

Types of Failure

Road Stream Crossings- Stream Crossing Failures were by far the most common type of flood damage to roads, and comprise about 51% of all ERFO sites. In the Klamath Province, where debris flows are common processes in streams, it should be assumed that most culvert crossings will experience debris flows during their design life, and fail. As a result, repairs of damaged crossings should be designed to survive such events without failing catastrophically. In many situations, simply replacing the damaged culvert with a larger one may not be the optimum solution. Good technology exists to address most of stream crossing problems.
Roads Paralleling Streams- Undercutting of roads paralleling and located near streams comprised about 8% of all ERFO sites, and were found to be important problems with high repair costs. Good technology exists (though it may be costly) to mitigate this problem.
Roads on Floodplains- Flooding and inundation damage occurred where roads or facilities were located on the 100 year floodplain. Damages included water saturation, sedimentation, and scour. Less than 1% of ERFO sites are of this type.

Assessment Needs

Disciplines typically needed for assessments in the stream channel environment are, Engineering, Hydrology, Fisheries, Geology, Geotechnical Engineering, and Biology. Floodplain situations frequently contain cultural resources, requiring Archaeological assessment. (1) For **stream crossing failures**, assess the potential magnitude and frequency of debris flows. As a minimum, utilize existing data and reports on past debris flows (GIS layer developed for the Salmon River Sub-basins Sediment Analysis) and historical air photos. Assess the stability of the foundation. For culvert replacement compute the 100 year flow using the standard USGS or other accepted technique. (2) For **roads paralleling streams** or **on the 100 year floodplain**, analyze the potential for future undercutting of the road, and flooding, and how the proposed repair will affect the stream flow regime. Where these damage sites are on major travelways, landscape architecture assessment may be needed, as well as soils and botany if revegetation of the site is appropriate.

Management Objectives (Desired Conditions) and Guidelines

Objective #1: At **road stream crossings**, maintain natural channel configurations and processes, including floodplain inundation, within the constraints of road design standards. Provide for passage of debris and logs during flood flows and debris flows. Provide low flow channel conditions which do not impede migration of aquatic species, and allow maintenance of water quality.

Guideline #1: At **road stream crossings**, consider relocation, if not possible, minimize the change in the longitudinal and transverse profile along the stream (within road design constraints) which is caused by road fills. This can be done by designing a vertical dip in the grade at the crossing, and similarly, a horizontal inflection up into the stream (both within the constraints of road alignment standards). Design should include aggregate surfacing on steep grades necessary to dip into crossings. Suitable structures for meeting objective #1 include concrete fords, rock fills, or reinforced fills with hardened faces. At some sites, objectives can be best met with a bridge, in which case sharp vertical and horizontal kinks in the alignment are not needed. Large through-fills should be avoided, and rock and soil waste should not be deposited in channels or on floodplains. Where appropriate, prevent vehicles from driving through water during low flows by use of culverts, removable grates, etc. Designs optimizing debris passage can be detrimental to fish passage, so these two conflicting objectives need to be worked out by engineering and fisheries specialists. If the objective can't be met, consider relocation or decommissioning of the road.

Objective # 2: Prevent drainage diversions at **road stream crossings**.

Guideline #2: Design road **stream crossing** repairs so that when a culvert fails, water will continue to flow down the natural channel, and will not be diverted elsewhere by the road. Some streams have several channels which can transport a debris flow. Assure that this is addressed in the design. Lower the fill the maximum possible. Place dips in the road as appropriate near drainage crossings, or design a positive road grade leaving the crossing. Assure that designs account for debris flow deposition which may occur at the site, in some cases raising the stream be by more than 10 feet.

Objective #3: Assure that repaired road **stream crossings** are designed and constructed to accommodate debris flows and 100 year recurrence interval flood flows without failing catastrophically. Minimize the fine sediment contribution from fills at crossings to streams.

Guideline #3: At road **stream crossings**: (1) Design and construct stable fills by applying appropriate techniques, such as controlled compaction, geotextile reinforcement, and subsurface drainage. Design criteria must include constructing fills so that they will survive 100 year flows, overtopping and debris flow impact. Armor the surface as appropriate, and minimize the height to facilitate the passage of debris over the top. Use wing walls where appropriate to facilitate passage of small debris; (2) Minimize the volume of fills (particularly the amount of fine material). The design details should be commensurate with the debris flow hazard (frequency and size) at the site.

Objective #4: For **roads paralleling streams** and **located near streams on floodplains,** maintain natural high flow channels and floodplain inundation and bank erosion patterns. Minimize future fine sediment contribution from stream undercuts and further damage to road and structures while preventing damage to facilities in floodplains.

Guideline #4: Minimize the size of fills and align them to be compatible with flow patterns. Armor road segments threatened by undercut with measures such as rip rap or hard-faced retaining walls, and revegetate where soil conditions permit. Avoid constricting the channel or diverting flows to unstable banks. Where use of rip rap would unduly constrict the channel, a steep hard-faced retaining wall may be a preferable alternative design, since it encroaches less on the channel. If the objectives can't be met, consider decommissioning or road relocation where this can be done without destabilizing other slopes.

B. IN LANDSLIDE TERRANE

Roads in landslide terrane typically experienced failures associated with: (1) Road fills placed on the heads of slumps or earthflows; (2) Road cuts placed on toe zones; (3) Diverted surface or subsurface water; (4) Natural reactivation of large slumps and earthflows.

Types of Failure

Landslides on road alignments away from streams made up about 18 % of all ERFO sites, and landsliding was a prominent slope process involved in about 50% of ERFO sites. Some were obviously triggered by the road, but others were probably little affected by the road. Types of failure included the following: (1) **Road Fills on Head of Landslides-** Fills on the heads of landslides initiated slumping at many sites; (2) **Road Cuts into Toe Zones-** Shallow debris slides and larger slump/reactivation occurred in some areas where roads undercut toe zones; (3) **Road**

Diversions of Surface or Subsurface Water- Changes in slope hydrology (diverted or concentrated surface and subsurface water) appear to have played an important triggering role in numerous landslides; (4) **Landslides Not Related to the Road-** Many large landslides appear to have been little affected by the road and would have reactivated even if the road were not present.

If not carefully planned, repair of ERFO sites can have a destabilizing effect, even on the natural landslides. Good technology exists to address many of the road-related landslide problems. However, most of the larger slumps and earthflows cannot be truly stabilized. There are numerous situations where a large active landslide affects a road, and ERFO funds will only pay to fix the portion which currently blocks road access. In these settings, future movement of the slide will likely remove the road, and decommissioning should be considered.

Assessment Needs

Site level geologic/geotechnical assessment is needed on all road repairs involving landslides and those in landslide terrane, since road work there may affect presently dormant landslides. In this way, the need for subsurface investigation can be determined, and specific designs can be tailored to individual sites. Engineering is also needed at all these sites, and in some cases Hydrologic, and Biologic skills are also necessary for assessment and design. The risk of continued slope failure under post-flood conditions should be assessed, and this risk compared to that associated with the proposed repair. In some cases, this will require factor quantitative factor of safety analysis. For large, complex landslides, it is essential to assess the likelihood that the landslide can be effectively stabilized. Relevant debris flow hazard should also be assessed.

Management Objectives (Desired Conditions) and Guidelines

Objective #1: Maintain or improve the stability of landslides affected by road repair work.

Guideline #1: (1) Conduct a geologic assessment prior to developing a repair design, and prior to any emergency earthwork. This includes as a minimum, review of existing GIS data layers (geology, active landslides, etc.), review of post-flood air photos, review of previous geologic investigations, and lastly, a review of maintenance history (engineering personnel); (2) Jointly develop the repair design (engineer, geologist, geotechnical engineer) to assure that proposed actions either maintain or improve the factor of safety and potential for adverse watershed effects. Incorporate buttresses, under-drains etc. as appropriate; (3) Evaluate the long term feasibility of maintaining long term road access across large complex landslides. Where objectives cannot be met or feasibility of keeping the road open is low, consider decommissioning, particularly where environmental and road maintenance costs are expected to be high.

Objective #2: Maintain **favorable (stable) mass balance** configurations on hillslopes during road repair design.

Guideline #2: Do not place fills on the heads of slumps and earthflows! Avoid routine filling of sags in the road caused by slumps and earthflows. Rather, consider reducing the size of the fill, or lightweight fill material. Similarly, avoid cuts into landslide deposits, particularly toe zones, unless it can be demonstrated through analysis that this action does not destabilize the slope. Where appropriate, place buttressing material at the toes of slumps and earthflows. Often the failed material can be incorporated into a buttress. If objectives cannot be met, consider relocation or decommissioning.

Objective #3:. Maintain favorable (promoting slope stability) surface and subsurface **hydrologic conditions** during road repair designs in landslide terrane. In most cases, this involves maintaining natural drainage patterns.

Guideline #3: Use sub-drains and horizontal drains as appropriate. Avoid diverting water to unstable sites. Eliminate ditches which convey off-site spring or surface flow to the heads of landslides or unstable areas. Where springs intersect roads, convey water directly across the road prism with appropriate subsurface drainage within its natural path of flow. Relocate surface and subsurface water only where this is part of a designed de-watering plan which will result in a more stable hillslope condition than that which currently exists.

C. IN STEEP MOUNTAIN SLOPE TERRANE

The most common types of road problems in this terrane are: (1) Failure of **steep side-hill fills**; (2) Failure of **road cuts**; (3) Failure of road **surface drainage** causing gullies and rills. The guidelines provided below emphasize the steep mountain slope environment, but also apply across the rest of the landscape.

Types of Failures

Road Fill Failures Away From Stream Crossings: Failure of road fills away from stream crossings constitute about 14% of all ERFO sites. They usually occur where un-reinforced, poorly compacted fills are placed on steep mountain slopes, particularly in swales underlain by sandy soil. This type of failure is confined primarily to the artificial embankment, but they commonly generate debris flows as they travel down steep mountain slopes. Sound technology exists for mitigating this problem.

Road Cut Failures- Small failures of road cuts not associated with landslides comprise about 6% of all ERFO sites. They usually occur where cuts are high (>10 feet) and into unconsolidated material or bedrock with structural weaknesses, and groundwater is present. These can be important where failure occurs adjacent to a stream, or on in-sloped roads where failures of the cut can divert surface runoff. Technology exists to stabilize road cuts (buttressing, biotechnical), but can be expensive if applied on entire roads.

Gullies; Rills, Sheet Wash Linked to Water Concentration and Diversion- This type includes problems associated with cross drains, ditches, outslopes, road dips, and some stream crossings. Gullies make up about 1% of all ERFO sites. However this small percentage may actually understate the importance of surface water diversions, since they are a factor in a large proportion of ERFO sites, including stream crossing failures which divert stream flow, cut bank failures on insloped roads, landslides which are triggered by diverted surface flow, etc. Technology exists to mitigate this problem.

Assessment Needs

For **fill failures**, assessment is needed by engineering, geology, geotechnical engineering, and in some cases hydrology, biology, botany and soils (where re-vegetation is needed or surface erosion is a problem). For fill failures, the geologist's role is to characterize relevant physical factors (debris flow potential, foundation material, weakness planes, subsurface water etc.), the geotechnical engineer to develop a conceptual design, and the engineer to finalize the design, and implement it. As part of the ERFO process, conduct field assessments on road segments which experienced many fill failures in 1997, and identify fills which survived the flood, but exhibit incipient failure, or physical characteristics similar to those which did fail. In areas experiencing many fill failures, conduct an evaluation of other fills in the vicinity and identify those with a high likelihood of failure. Seek funding to repair these or move the alignment. For **road cut failures**, the primary assessment to be made is whether the failed material is acting as a buttress, and implications to road surface drainage. For **gully and rill areas**, Soils and Engineering personnel should lay out the optimum road drainage plan, and consult with, hydrology, soils, and geology. The role of the road in altering surface and subsurface drainage patterns should be assessed

Management Objectives (Desired Conditions) and Guidelines

Objective #1: Repair and construct fills to stable configurations. Minimize the potential for catastrophic fill failures.

Guideline #1: (1) Construct stable fills by utilizing appropriate compaction, underdrains, and mechanical reinforcement as appropriate. Minimize fill size, yet making sure that this does not result in an unreasonably high cut. (2) Never fill in the hole left by a failed fill with loose soil and rock. (3) Consider alternatives to in-kind replacement of the fill such as retaining walls and rock fills which are appropriate in some settings. (4) If objectives cannot be met, consider relocating or decommissioning the road.

Objective #2: Repair and construct cuts to stable configurations. Prevent cut failures which can deliver sediment to streams or obstruct road drainage.

Guideline #2: (1) Prior to removing cut failure debris from road surfaces, determine if the debris is buttressing the area upslope. If it is serving an important buttressing role, repair options include: (a) Ramping over the debris; (b) Removing the debris and then placing it back on the site, with appropriate compaction, geotextile reinforcement and drainage as needed; (c) Removing debris to a waste area and replacing with other buttressing material such are rip rap. (2)Establish deep-rooted native species on the site where soil conditions permit. In areas with multiple cut failures, conduct a field assessment of the need to buttress cuts which did not fail in 1997. Areas where cut slope failures threaten road ditches are good candidates, and outsloping of the road surface should be considered in these areas. If objectives cannot be met, consider relocating or decommissioning the road.

Objective #3: Maintain natural hillslope drainage patterns to minimize the potential for rills and gullies. Prevent concentration or diversion of surface/subsurface water which accelerates erosion.

Guideline #3: (1) Outslope roads unless there is a specific need for in-sloping, and avoid placing dips where they deliver water to erodible or unstable areas. Armor dips as needed. (2) Where the road must be in-sloped: (a) Armor cross drain outlets as appropriate, use downspouts and or energy dissipators as appropriate, and design inlets to local conditions; (b) Assess the location and spacing of cross drains to prevent delivering water to sensitive areas. Design rolling dips to meet site conditions; (c) Where multiple cross drains occur, anticipate the failure of individual drains, and provide safety valves, such as armored dips in the road to prevent snowball effects; (d) Near streams, place dips to prevent the ditch from capturing stream flow; (e) Near switchbacks, avoid excessive water being carried through the feature, and if possible, provide water outlets before entering and upon leaving the switchback; (f) Maintain stable road cuts, particularly where road cut failures can divert surface runoff such as in road ditches. (g) Re-vegetate road cuts and fills as appropriate; (h) If objectives cannot be met, consider relocating or decommissioning the road.

IV. WASTE AREAS AND ROCK PITS

Development of waste areas and rock pits to repair flood damaged roads can result in slope destabilization, erosion, and sedimentation if not properly planned.

Types of Failure

Common types of failure include reactivated slumps where waste was placed on the head of the landslide. Undercutting of the toe of landslide deposits, as well as problems associated with disrupted drainage patterns can also cause landsliding and sedimentation..

Assessment Needs

Depending on the location, assessments should be made by engineering, geology, hydrology, soils, biology, archaeology, and botany. Assess site stability, mass balance, slope hydrology, surface erosion potential, and delivery to stream potential.

Objective #1: Maintain and construct stable cuts and fills associated with waste areas and rock pits. Maintain stable mass balance, cuts, and hillslope hydrologic conditions.

Guideline #1: (1) Conduct a field-based geologic assessment prior to developing waste areas or rock pits (see guidelines for roads in landslide terrane, objective #1). Due to the size of many rock pits and waste areas, subsurface investigations are likely to be needed on some of them. (2) Engineering, geology, and biology should jointly locate potential sites with review by archaeology and botany. (3) Avoid placing destabilizing fill on landslide benches. (4) Avoid removing rock and talus from landslide deposits unless a geologic investigation shows that this can be done without destabilizing the slope. (5) Complete rock pit development plans if needed (as directed in the Klamath National Forest Land and Resource Management Plan), and prepare reclamation plans for large rock pits and waste areas as appropriate.

V. ACS OBJECTIVES AND NFP STANDARDS AND GUIDELINES

The road guidelines in Appendix C are consistent with the Aquatic Conservation Strategy objectives as described in the Northwest Forest Plan (NFP). They are also consistent with the road standards and guidelines in the Record of Decision (ROD) for the Northwest Forest Plan. Relevant objectives and standards and guidelines from the NFP are listed below. Refer to to the Northwest Forest Plan Record of Decision (page B11) for the complete ACS Objectives, and pages C-32 to C-33 for the complete road standards and guidelines.

Aquatic Conservation Strategy Objectives: #2 (connectivity); #3 (physical integrity of aquatic system); #4 (water quality); #5 (sediment regime); #6 (stream flows); #7 (floodplain inundation); #8 (plant diversity); #9 (species populations)
Northwest Forest Plan Standards: RF-1a (minimize roads in Riparian Reserve); RF-1e (maintain hydrologic flow path); RF-1f (sidecast); RF-3a (reconstruct risky roads); RF-3b (reconstruct by risk priority); RF-3c (close, repair or reconstruct by risk level); RF-4 (design for 100 year event, avoid water diversions) RF-5 (minimize road sediment, route away from unstable areas); RF-6 (fish passage); RF-7c (routinely correct road drainage problems in road management).

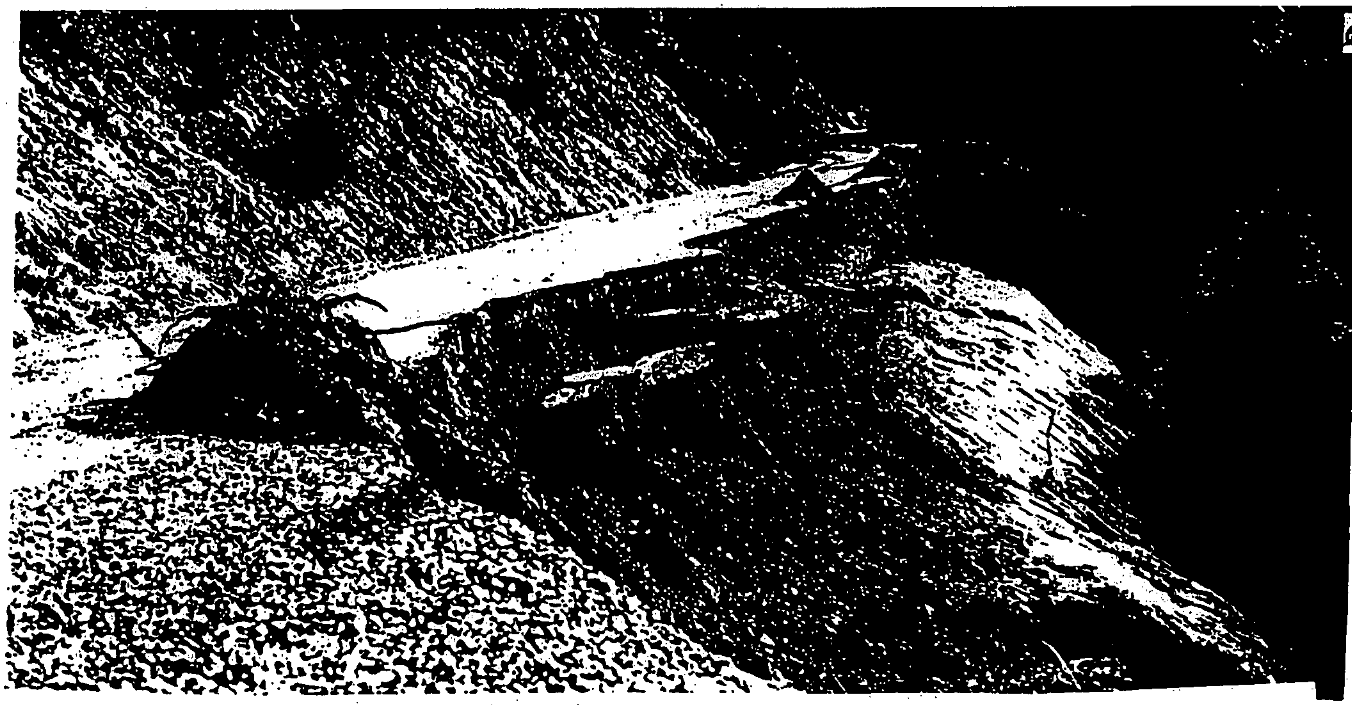


Photo #5: Fill Failure- This fill failure is on Road 44N45 in the Canyon Creek Watershed, Scott River Ranger District. Failure was a result of fill saturation with some additional water contributed to the site by the inside road ditch. Photograph by Ed Rose, spring, 1997. This site was subsequently repaired with a retaining wall.

Photo #6: Landslide- This slump/earthflow closed road 46N64 in the Walker Creek watershed. Happy Camp Ranger District. A cellular retaining wall (note corrugated metal) had been installed at this site several years before the 1997 flood. The entire area consists of the toe of a large old landslide deposit. Photo by J.d.l.F., February, 1997.

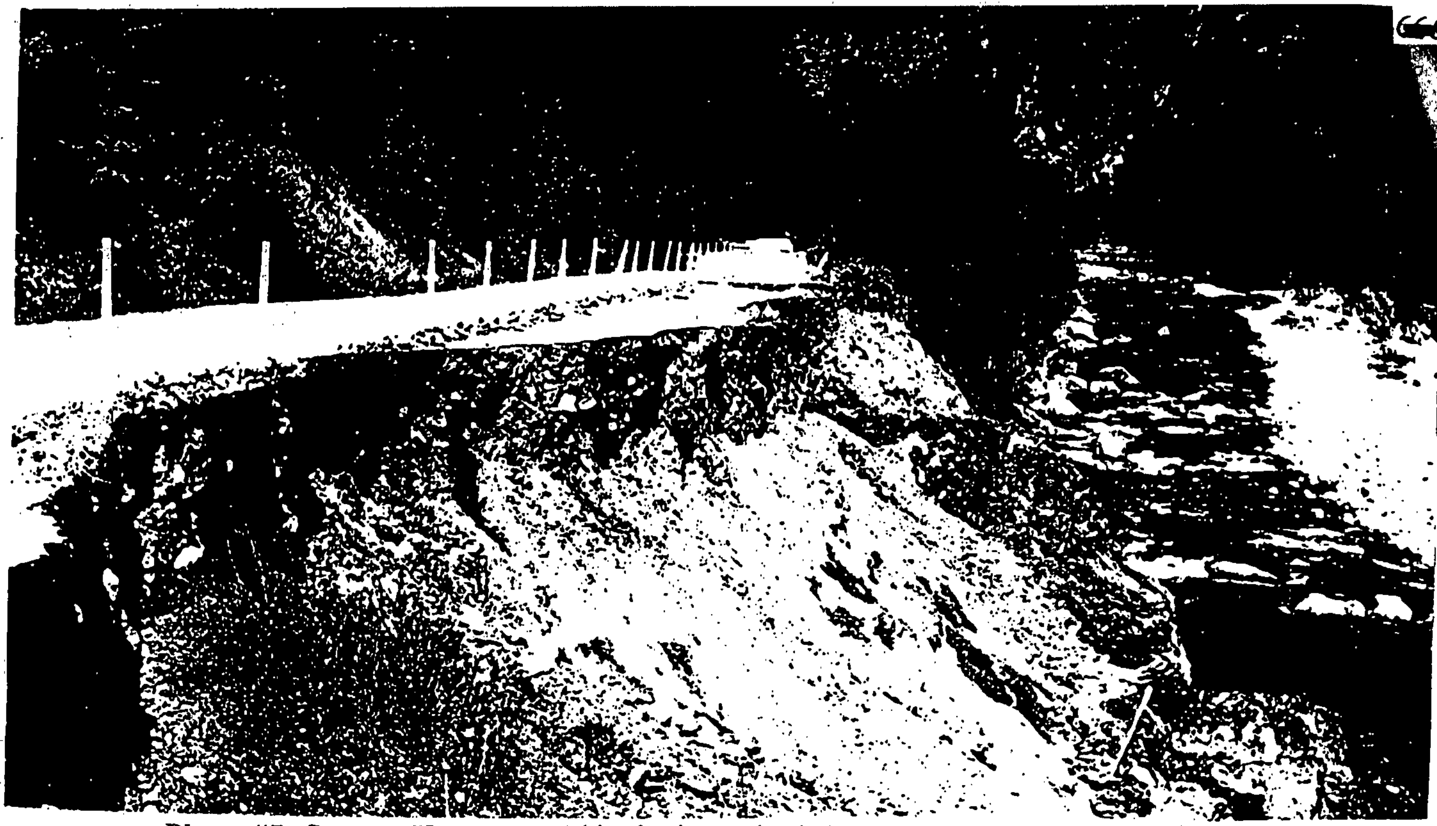


Photo #7: Stream Undercut- This site is on the Salmon River Ranger District, on the South Fork of the Salmon River, where the river undercut the county road. Photo by J.d.l.F, spring, 1998.

Photo #8: Stream Crossing Failure- This road stream crossing is on Road 15N75 in the Elk Creek Watershed (Doolittle tributary), Happy Camp Ranger District. Failure of the fill was caused by a debris flow which originated by a small fill failure on the same road where it crossed the head of the debris flow channel. Photo summer of 1997 by J.d.l.F.

APPENDIX D

EFFECTS OF 1997 FLOOD ON ADJACENT FORESTS AND 1996 FLOODS IN OREGON AND IDAHO

This section describes effects of the 1997 flood on forests adjacent to the Klamath National Forest. The Siskiyou National Forest issued a flood assessment on 1-9-98, but this assessment was not available for inclusion here. It also summarizes some of the effects of the floods of 1995-1996 in Idaho and Oregon.

Southern Oregon

Umpqua National Forest (Paul Uncapher, Geologist)

1. **Number of ERFO Sites ------; Dollar Cost-----**.
2. **Geographic Extent of Damage-** Damage was concentrated in the northern part of the Forest in November, and in the south and eastern parts in January.
3. **Predominant Flood Effects-** Inventory of ERFO sites indicates that most of the flood damage was associated with landslides (about 75%). There were at least 12 examples of cascading effects where a landslide high in the headwaters of a watershed traveled down a stream, initiating more landslides and triggering road fill failures downslope. Roughly 30-40% of the landslides inventoried as ERFO sites initiated movement in November, and then moved catastrophically in January. There were many dam-break floods caused by the temporary damming of streams by logs and debris. There were also many examples of stream undercutting of roads.
4. **Effects of Forest Management and Fire-** ~~Links between~~ flood-effects and land management (roads, harvest) and wildfire were as follows. Forest-wide inventories of landslides are not available, so the proportion of landslides which are road-related is not known quantitatively, but it estimated that 50-75% are road related, 20-25% harvest-related, and the rest on undisturbed ground. Most culvert failures were associated with debris flows. A large wildfire which burned in 1995 did not experience much in the way of landslides. There was a concentration of earthflows in harvest units.
5. **Influence of Physical Factors-** Physical characters of the landscape such as, bedrock, geomorphology, slope, elevation, and aspect appear to have influenced the flood effects as follows. The majority of landslides occurred below 3500 feet in elevation. There may have been some concentration of landslides on steeper slopes, particularly in clearcuts. South aspects seemed to have a higher slide frequency than other aspects. As far as bedrock, pyroclastic rock of the Western Cascades had the highest frequency of landslides, and low frequencies in areas

underlain by basalt flows and granitic rock.

6. Flood Recurrence Intervals- The flood of 1996-1997 consisted of two distinct episodes on the Umpqua National Forest, one in November 1996, and one in January 1997. The November episode hit hardest in the north part of the forest, and exhibited some 100 year return interval flows. The January episode hit harder in the south and east parts of the Forest, with maximum return intervals of about 25 years. This is different from California Forests where January flows were much higher than November flows.

Rogue River National Forest (Dan Sitton, Geologist)-

1. Number of ERFO Sites 270; **Dollar Cost** $6.0 million. There were another $8 million in N)N-ERFO damages.

2. Geographic Extent of Damage- The largest amount of damages were to the Klamath Mtns. (western) portion of the forest in the granitics and metamorphic rock types. However, there was also some damages in the western cascades side of the forest as well. We hd both Debris torrents and earthflows slides. The Ashland watershed, immediately north of the Klamath National Forest, experienced large numbers of low elevation landslides which severely damaged the Ashland water treatment plant (Hicks, 1997).

3. Predominant Flood Effects- Most damage from landslides, but also had some damages from high flows and meandering stream channels.

4. Effects of Forest Management and Fire- We had a lot of road related damages across the forest, clear cut harvesting related landslides in the Ashland and Applegate Districts (the west side of forest).

5. Influence of Physical Factors- Location of the damages were from 5,500 feet in elevation and down to about 2,000 feet. Most of the slides were in granitics, schist, serpentine, & metasediments in Klamath Mountains and also some in tuff, breccia and pumice on the eastern side of the forest. Slopes are mostly 60% and above, but the are some earthflow and slumps on 40% and above. Most of the slides are on concave slopes (draws, swales and near or in stream channels), but there are also some debris flows and slumps on smooth slopes.

6. Flood Recurrence Intervals- Highest recurrence interval near streams, draws and swales was experienced. This was likely a 50 year event in many areas and possibly a 30 year event in other portions of forest. I don't have river level information right now. Slides occurred lower in elevation slopes than they did in 1974. Grouted flood fords installed by Bill Hicks (former Rogue Forest Geologist) held up well and reduced the amount of sediment that entered into Reeder Reservoir.

Siskiyou National Forest (Cindy Ricks, Geologist. The Siskiyou National Forest has produced a report: PRELIMINARY ASSESSMENT REPORT, STORMS OF NOVEMBER & DECEMBER, 1996. Dated January 9, 1998. Prepared by the Forest Flood Team)-

1. Number of ERFO Sites ------; Dollar Cost-----.

2. Geographic Extent of Damage- Damages occurred in the northwest part of the Forest in November, and in the SE in December.

3. Predominant Flood Effects- There were many stream crossing failures on roads, and most of these involved some sort of culvert plugging. Landslides caused decrease in pool habitat area and or depth, increases in large wood in channels. Habitat improvement structures in channels were displaced. Channel aggradation occurred in pools in creeks such as Grayback, Left Fork Sucker, and Rock.

4. Effects of Forest Management and Fire- Stream diversions at road crossings were a common problem, and greatly increased adverse effects. Culvert clogging was common. Approximately 50,000 cubic meters of sediment were delivered to streams from road failures. The ratio of management related to natural landslides is unknown, since inventories to this point have focused on roads. **Previous decommissioning of roads** had positive benefits in that roads which had fills and pipes removed did not contribute much additional sediment do debris flows, and no stream diversions occurred at these sites. Pull-back of fills and outslope of roads also appeared to be an effective sediment-reducing measure. Placing of large rip rap at removed crossings was not effective at some crossings where the stream was able to meander around the rock and cut back into natural ground. Deep, well-placed water bars were effective, as were re-vegetation efforts. Some roads which had been decommissioned never were high sediment producers, such as those on gentle slopes near ridge tops. Many road failure sites showed signs of **previous failures**, and some new fixes did not address the key factors contributing to failure. Wide culvert inlets allowed debris to clog culverts more easily than narrow inlets which tend to direct long pieces of wood directly into the pipe. Landslides were involved in about 50% of all road failures.

5. Influence of Physical Factors- Rain on snow was described as a key factor in influencing flood effects. Also, it was felt that the storms had distinct cells with areas of concentrated precipitation. No data were cited as support to this idea. Landslides were common in areas of sandy soil developed from granitic rock and from sandstone. They were also common on steep slopes, in areas with thick colluvium adjacent to streams, and on old landslide deposits. Roads built up floodplains adjacent to streams were damaged by stream undercutting. Nearly 50% of all road failures were on the lower 1/3 of the hillslope.

6. Flood Recurrence Intervals- The Siskiyou Forest experienced two major storms in the winter of 1996-1997. The November storm was described as having high to moderate intensity, and short duration. Flows were greater than 50 year recurrence interval. Port Orford, OR received 15.5 inches of rain in two days, with 11.7 inches coming on November 19. The soil moisture content at the outset of the storm was low. The December storm was described as having a moderate intensity with long duration, and soils had s high moisture content at the outset of the storm. Flows were in the 25-50 year recurrence interval.

Northern California

Six Rivers National Forest (Mark Smith, Geologist)-

1. Number of ERFO Sites 81; **Dollar Cost** $0.85 million. About 81 damage sites identified, of which 60 were funded by ERFO at approx. $850,000 on NFS lands, plus about 4 other sites on county roads within Forest boundary or on Forest highways funded at approx. $800,000. Sites not funded by ERFO will be covered by other storm damage funding of about $350,000.

2. Geographic Extent of Damage- Major damage on Six Rivers was scattered and clumped, 40% Mad River RD, 25% Orleans RD, 25% Lower Trinity RD, and 10% Gasquet. Generally central and eastern parts of Forest and typically within a couple of miles of the main rivers.
3. Predominant Flood Effects- Probably the vast majority of damage was related directly or indirectly to landsliding. Roughly half the sites were slumped road prisms due to landsliding downslope. Typical size was probably 1/2 to 2 acres that affected from 100 to 300 ft of road. Roughly one-third of the sites were washouts where culverts were plugged; these appeared to be due in most cases to mass movements upstream, commonly with relatively fine organic debris loads. Downstream channel alteration from these sites was usually only moderate for several hundred feet. Drainage diversion occurred at many of these sites and appeared to greatly aggravate the overall resource damage due to additional sediment mobilization. The other roughly one-sixth of sites were extensive areas of landsliding in and above the cutslope; damage was generally restricted to the roadway with few offsite effects. Lastly, there was considerable direct damage from flooding along the Klamath main stem (access roads buried or washed out, facilities damaged or buried).
4. Effects of Forest Management and Fire- From air photo work done so far (most of Mad River), it appears that new and reactivated landsliding occurred most commonly within stream corridors (some inner gorge terrain) and not associated with roads or harvesting. Road slump areas noted in DSRs are generally hard to detect on the 1:40K photos, and not many other slide sites have been noted. A moderate fraction of new slides were found in cutblocks (probably 5-15 years old), generally less than 1 acre in size. Surprisingly little slide activity noted in the Blake or Travis fire areas of 1987, although there are field reports of some tribs in the Blake area being "sluiced out" of large organic debris and stored sediment (not generally visible on the airphotos).
5. Influence of Physical Factors- Flood damage was clearly concentrated at lower to middle elevations as well as lower to middle relative slope positions. It occurred predominantly in Galice metasediments and Rattlesnake Creek melange terrain, commonly where deeply weathered or in older landslide complexes. All Mad River damage is in Franciscan terrane, both moderately competent sandstones and less competent melange (probably more the former than the latter - not what we would expect). Apparently little damage on the limited areas of intrusive rocks on the Forest, but I haven't looked at all the areas yet (such as Trinity summit area). Scattered damage in ultramafic terrane, but relatively large scale (e.g., Devastation Slide moved considerably). New and reactivated slides on Mad River District are mostly on intermediate slopes and some steeper headwater areas; roughly one-third so far appear to be within older landslide terrain. I expect the proportion to be higher moving north into Klamath Mountains province, though. Most of the landsliding and damage seems to be restricted or localized in extent with few debris torrents or avalanches noted. Perhaps 5 percent of occurrences involved extended down-channel damage from mobilized landslide debris.
6. Flood Recurrence Intervals- Forest Hydrologist Mike Furniss estimates that the 1997 flood was probably a 15 to 25-year event on rivers within the Six Rivers. The few recorded discharges at gaged sites indicate flows of about 30-60 percent of the 100-year event (higher to the east?).

Klamath National Forest- (Juan de la Fuente, Geologist)

1. **Number of ERFO Sites;** approximately 800; **Dollar Cost**$33 million.
2. **Geographic Extent of Damage-** Damage was concentrated west of Interstate 5 in a band from the headwaters of Beaver Creek, through Horse Creek, Lower Scott River, Walker, Grider, Elk, Indian, and Ukonom Creeks. There was a separate area of considerable channel effects in the Upper South Fork Salmon River.
3. **Predominant Flood Effects-** Predominant effects were damages to roads, particularly at stream crossings, and damage to houses in the lower reaches of Walker and Grider Creeks. Landslides played a large role in damage to roads, and initiated debris flows. Many stream channels were significantly altered in that many streams experienced widening, shallowing, and increases in fine sediment in lower reaches, and loss of riparian vegetation.
4. **Effects of Forest Management and Fire-** Landslides were concentrated in road corridors, areas burned at high or moderate intensity, and recently logged areas (since 1977), relative to forested undisturbed lnads.
5. **Influence of Physical Factors-** Patterns of damage suggest that local cells of high intensity developed, but precipitation data do not support this idea. Landslides were concentrated at elevations from 4,000-6,000 feet, on previously active landslides, in dormant landslide deposits, and within the in inner gorge. They were also concentrated on steep slopes and on north and east aspects.
6. **Flood Recurrence Intervals-** Recurrence intervals varied from 15-37 years across the forest (preliminary values computed with the FEMA method).

Modoc National Forest (Randy Sharp, Geologist)-

1. **Number of ERFO Sites-** 0; **Dollar Cost-** $500,000.
2. **Geographic Extent of Damage-** East side of the forest (east of the Warner Mountains).
3. **Predominant Flood Effects-** Landslides which sent debris flows down stream channels.
4. **Effects of Forest Management and Fire-** Roads played a minor contribution, but there was not apparent link to timber harvest, fire, or grazing.
5. **Influence of Physical Factors-** The landslides occurred primarily at higher elevations on the steep slopes formed by fault scarps on the margins of fault-block valleys. Landslides were primarily in volcanic tuffs.
6. **Flood Recurrence Intervals-** Twenty to fifty years.

Shasta Trinity National Forest (Abel Jasso, Geologist, Steve Bachman, Hydrologist)-

1. **Number of ERFO Sites**: 85; **Dollar Cost**: $8.0 million.
2. **Geographic Extent of Damage-** Damage was concentrated west of Interstate 5, especially in the Scott Mountain area. It appears that there is a marked reduction in landslides and altered channels on the Klamath side of the divide north of Scott Mountain. Damage was severe on the South Fork of the Trinity River.
3. **Predominant Flood Effects-** Damages were across the board, including rotational landslides, debris flows, debris torrents, inner gorge mass wasting, and altered channels. Dominating damage

was road culvert blow-outs due to under-sizing and poor maintenance.
4. Effects of Forest Management and Fire- There were links between poor road location (on unstable slopes) and culvert under-sizing, and apparent links between harvest areas and landslides. Most situations could have been avoided if more understanding of stream process and mass wasting had been applied in design of management activities.
5. Influence of Physical Factors- The South Fork Mountain Schist and Trinity Ultramafic sheet had a large proportion of damage sites, but this may be due to the high elevation of these areas. Areas of high elevation experienced much damage. Rain on snow appears to have played an important role in flood effects.
6. Flood Recurrence Intervals- Pit River flows were nowhere near 100 year events, possibly due to less rain in the Alturas area. Sacramento River was a 25-100 year event. Recurrence interval of 21 years were recorded on the South Fork Trinity near Coffee Creek.
7. Description of Flood (Stephen Bachmann 2-12-97)- The January floods that caused widespread damage to roads, bridges and facilities on the Shasta-Trinity National Forest were caused by a series of tropical storms that brought unusually warm temperatures and heavy precipitation to the north state in late December and early January. The series of storms responsible for the flooding began to impact the Shasta-Trinity National Forest on December 26th. From December 26th through January 1st precipitation fell nearly continuously across the forest. In the Sacramento River Canyon between Lakeshore and Dunsmuir precipitation fell at a rate of nearly three inches per day for three straight days prior to the arrival of the largest storm system on December 30th.

The largest storm, accompanied by unusually warm temperatures, entered the north state on December 30th. Precipitation totals in the Sacramento River Canyon for the three day period of December 30th through January 1st exceeded 12 inches. On New Year's Eve streamflow levels rose rapidly in response to continually increasing runoff from the melting snowpack and saturated ground. Flooding occurred in most of the major tributaries to Shasta Lake including the Sacramento and McCloud Rivers, Squaw Creek, and tributaries to the Pit River above Shasta Lake. While all of these watersheds were were impacted by the flooding, the degree of flooding and the amounts of precipitation varied widely between and within the watersheds.

Rainfall totals for the Sacramento, McCloud and Pit River Arms of Shasta Lake were significantly larger than rainfall totals to the north of Shasta Lake in the vicinity of McCloud and Mount Shasta City. Over an eight day period from December 26th through January 2nd approximately 22 inches of rain fell in the lower reaches of the Sacramento River Canyon at Lakeshore. Precipitation totals were similar in the lower McCloud River Arm at Hirz Bay. Precipitation totals for the same eight day period exceeded 35 inches in localized areas along the lower Pit River above Shasta Lake. Considerably less rainfall occurred in the Mount Shasta area. Precipitation totals for Mount Shasta City and McCloud for the same period were ____ and 13.8 inches respectively. Large amounts of snowmelt occurring at elevations between 4,000-7,000 feet contributed additional runoff resulting in flooding in the normally dry channels draining Mount Shasta such as Panther, Big Canyon and Ash Creeks.

With the exception of the Pit River, all rivers approached and possibly exceeded record levels on New Year's Day. Streamflow data for 1996 and 1997 is preliminary in nature and may be adjusted following quality control checks, however the flow data permits relative comparisons between historical floods and the 1996-97 flood. On New Year's Day streamflow in the Sacramento River at Delta (above Shasta Lake) peaked at approximately 62,300 cubic feet per second. This flow was much larger than the high flows recorded in 1964 and 1995 but lower than the record peak of 69,800 cfs recorded during the 1974 flood. Due to the localized nature of the heavy rainfall streamflow in the Pit River did not approach the peak discharge of 73,000 cfs recorded in 1970 downstream of the Montgomery Creek confluence. The McCloud River above Shasta Lake peaked at about 50,000 cfs. During the 47 year period of record, the previous peak was 45,000 cfs recorded in 1974. Therefore, the 1997 peak may have been greater than a 100 year return interval event.

Mendocino National Forest (Bob Faust, Hydrologist)-

1. Number of ERFO Sites- 50; **Dollar Cost-** $1,622,000.
2. Geographic Extent of Damage- Dispersed across the Forest without any apparent concentration.
3. Predominant Flood Effects- Culvert failures (blocked and topped with debris or too much water), and landslides on road prisms.
4. Effects of Forest Management and Fire- Flood damage was not linked to harvest, fire, or roads. An area burned the previous year did not experience damage on roads, probably because of work done on drainage structures as part of the emergency fire rehabilitation effort.
5. Influence of Physical Factors- Damage was concentrated at 5,500-5,000 feet in elevation, in Franciscan rocks on slopes steeper than 40%. This was a rain-on-snow event which caused flooding and culvert failures.
6. Flood Recurrence Intervals- Not available yet

Sierra Nevada Mountains

El Dorado National Forest (Anne Boyd, Geologist, Chuck Mitchell, Soil Scientist)-

1. Number of ERFO Sites (projected)- 90; **Dollar Cost-** $5,000,000.
2. Geographic Extent of Damage- Along the main stems of the Middle and South Forks of the American, Cosumnes, Rubicon, Mokelumnes rivers.
3. Predominant Flood Effects- Landslides 37%, Altered Channels- 15%, Plugged Culverts 49%. Record runoff events and landslides in the inner gorges of the major rivers. Many road crossings on streams were plugged or washed out due to the amount of debris transported by streams. Large, catastrophic, deep-seated landslides were confined to the South Fork American River Canyon (Highway 50). Flooding was confined to existing flood plain along the major rivers. No catastrophic flooding occurred on the forest outside of these areas, but downstream areas outside of the forest experienced significant flooding and damage to homes and crop land (Sacrament

Valley). Alteration of channel courses was also not a major effect, though incision and deposition (debris flow areas) were commonplace.

4. Effects of Forest Management and Fire- Fire appears to have influenced flood effects on the South Fork American River (Highway 50). The Wright's Fire (1982), and Cleveland Fire (1992) experienced debris slides and flows. The highest level of landsliding occurred in burned areas, some of which have burned several times (1959 and 1992). Large old rotational slides were reactivated in Mill Creek. The location of Highway 50 in the river gorge facilitated severe damage. Homes and bridges there were also damaged. Most of the small debris flows were associated with failed road cuts, plugged culverts, or other man-made structures such as irrigation ditches, but there were also many on undisturbed hillslopes. Steep road cuts in volcanic material in the northern part of the Forest experienced much landsliding.

5. Influence of Physical Factors- Most of the landsliding occurred below 5,000 feet in elevation, with the exception that debris slides originated at 6,000-7,000 feet. Most of the landslides developed into debris flows, regardless of bedrock type or elevation. It is estimated that 300 landslides were activated, with the majority being small debris flows of less than 25 cubic yards. In the northern half of the Forest (Rubicon, Middle Fork American River), the canyons are deeply incised in metamorphic rock with volcanic cap rock. Many of these landslide initiated in andisitic mudflows and stream gravel deposits or the contact with metamorphic rocks. Foliation planes in metamorphic bedrock which daylighted influenced landsliding in road cuts and natural slopes alike. Rain-on-snow was the prime factor. Many types of landslides occurred in the 8 mile stretch between Riverton and Kyburz (debris flows, earthflows, rotational slides, debris slides). This area contains unique bedrock types and contacts contributed to failure. Older weathered granitic rock adjacent to meta-gabbros and schist and gniess developed many translational and other deep slides. Within the river channel and floodplain, toe inundation caused a significant number of failures, particularly to Highway 50 shoulders.

6. Flood Recurrence Intervals- Preliminary data indicate that all river basins had record flows, with the Cosumnes being over twice the previous peak, and the South Fork American being 150% of the previous 1964 high. This was the biggest event recorded on the El Dorado National Forest. Rainfall totals for the South Fork American River Canyon were 353% of average (32.59 inches recorded vs. 9.23 average) and 234% of average for January 24.3 inches redcored vs. 10.37 average). Much of the rainfall came in short time periods (3-5 day events) and as rain-on-snow below 7,000 feet (during New Year's Day storm).

Plumas National Forest (Gordon Keller, Geotechnical Engineer)-

1. **Number of ERFO Sites-** 350; **Dollar Cost-** $9 million. Some of these "sites" are roads with multiple damage sites. Additionally we have 3 approved EWP sites and 28 Non-EWP watershed damaged sites. For these we've received $300,000 approved funds. We asked for $800,000 to cover the damage. Many forest slides are not even on the list.

2. Geographic Extent of Damage- The damage was actually quite widespread across the Plumas and parts of the Lassen. The West side of the forest with steeper ground, deeper weathered soils has half the sites but 2/3 of the cost of damage since their sites are the larger ones, especially slides. The east side has many widely scattered sites, particularly culvert failures and drainage problems.

3. Predominant Flood Effects- We sustained a lot of all types of damage, landslides, altered channels, and flooding, as well as damage to several bridges and a major retaining wall. The west side has numerous slide failures, in road cuts, fill failures, and on many natural slopes. The intensity of the event caused debris torrents in many drainages, totally "gutting" and altering them, particularly on steeper terrain. Many culverts plugged and channels changed, causing local flooding in many areas. The drainage problems and flooding occurred on the east and west sides of the forest. Because of the large amount of debris accumulated in many drainages now, the systems will remain unstable and give us problems, particularly with culverts, for many years to come. A good time to shift to low-water fords where we can! Many of the drainages are only meta-stable now, with major amounts of stored material.

4. Effects of Forest Management and Fire- I suspect there is a good correlation between damage sites and roads since the ERFO program is for roads. Many small slumps are associated with roads. However many slides, particularly many large earthflows and debris slides, appear totally natural and began in undisturbed areas, roadless areas, rocky highlands, etc, including sites on the Lassen and Tahoe NF. Roads were only in the way. Many culverts failed along roads, some due to undersize. However many failed because of debris and bedload movement. The entire channel was damaged, including culverts in the way. Thus much of the drainage impact was natural but the culverts made the problem more severe and costly. This was a major landforming event in the northern Sierra Nevada. The dominantly natural event and large slides and channel debris torrents overwhelmed other factors such as manmade features and management practices. The volume of sediment moved due to roads, fires, or logging appears minor compared to the volume moved by this large event. Our practices only contributed to the overall problem.

5. Influence of Physical Factors- Most of the damage occurred in a zone between 3,000 and 7000 feet. The heavy warm rain impacted the front of the west side and mid forest at 3000 to 5,000. Higher areas 5000 to 7000 also had many debris slides and plugged culverts. Above 7000 feet there seemed to be enough snowpack to buffer and minimize the damage. The steeper west side slopes and peak areas had the most slides, but the flatter east side had a lot of channel movement also. Culvert failures and gully erosion were common on the east side. Bedrock areas experienced the least damage, but several large debris slides began in shallow, rocky swale areas on steep mountainsides and moved a long distance downslope. Deeper soil areas were scoured out deeper and wider.

6. Flood Recurrence Intervals- There appears to be a lot of local variation in small watersheds. Some had minor damage, suggesting a 15 to 25 year event, while other watersheds were severely damaged, suggesting a 50 to 100 year event. Locally flows were less than 1986 or 1995, but wide areas received heavy runoff producing flows in major tributaries suggesting an 80 to 100 year event. The North Fork of the Feather River at Pulga had the flow of record, with records back to 1906. 1986 was the last largest recorded flow at 90,000 CFS. 1997 was 118,000 CFS.

B. STUDIES OF THE FLOODS OF 1995-96 IN OREGON & IDAHO

Oregon Department of Forestry

Recent assessments of the floods of 1995-1996 in Oregon by the Oregon department of Forestry have mentioned:
1. There was a huge variability of flood effects across state; The study highlights the need for good precipitation intensity data
2. Robison studied the effects on small channels (change in stream geometry, wood, shading, and preliminary sediment budget); tallied large wood, using the 40% rule. Results: About 70% of channels were impacted; 18% = high impact, 9% landslide tracks. About 80% of sediment is channel-derived, 20% from landslides; much of the large wood was deposited outside the active channel.

Oregon Department of Forestry examined the area from Eugene to the Oregon border for flood, and selected 6 sample areas of 10 square miles each. Three were selected in highly disturbed areas, and three were stratified random samples. Physiographic areas included the Coast Ranges, Western Cascades, and Interior of Oregon. They posed a number of hypotheses at the outset, including: Road fills on steep slopes are prone to landsliding; variations in the intensity of the storm played a big role in observed flood effects; "high risk" lands would have high landslide frequencies, roads built prior to 1983 would have high landslide frequencies; landslides under a timber canopy cannot be effectively mapped from air photos.

Findings were:
1. Landslide densities in the sample areas varied from 0.46-12.24 slides/sq. mi.
2. Slope steepness was a prime determinant of landsliding.
3. Landslide density varied widely within study sites, eg. Slides were concentrated in the west edge of the Mapleton area.
4. Air photo inventories (1:6,000 scale) in areas under a timber canopy missed 50% of the landslides mapped by field inventories. Of the 50% which were seen, 20% were only partly visible, and only 30% were clearly visible.
5. Field inventories of 98 stream miles, 73% exhibited low impacts, 18% high impacts, and 9% experienced landslide runout. In the Tillamook sample, the distribution was 67% high impact or landslide runout.
6. Sediment delivered to channels was comprised of 20% landslide debris, and 80% channel derived sediment.

Clearwater National Forest

A recent study of the effects of the floods of 1995-1996 on the Clearwater Forest by the U.S. Forest Service (McClelland, et. al. 1997, McClelland, et. al. 1998) addressed the following objectives:
1. Describe the storm event and flows.
2. Compare landslide risk by land use and landscape characteristics.
3. Describe the effects of landslides and floods on streams.

4. Compare the 1996 flood to those in the early 1970's.
5. Evaluate current road standards.
6. Evaluate recent road obliteration, and prioritization criteria for mitigating landslides.
7. Provide options for reducing landslides on the Clearwater NF.
8. Share info with the public.

Findings:
1. About 400,000 cubic yards of landslide debris was mobilized, with about half of it reaching streams. These figures do not include two very large landslides which totaled another 250,000 cubic yards. Through a combination of air photo inventory (1:15,840) and field study, 905 landslides were identified. Of these, 58% were road-related, 29% on undisturbed slopes, and 12% on harvested lands. This distribution was very similar to the storms of the early 1970's there. They ascribe 5 factors as controlling landslide occurrence. They are Bedrock, elevation, aspect, slope, and landform. Highest landslide rates were in Border (0.89 slides per 1000 acres), Belt (0.36), and Batholith (0.51) rocks. Landslide density by elevation was highest at 2500-3000 feet (1.48 landslides per 1000 acres), and 3000-3500 (1.66 slides per 1000 acres). By slope gradient, landslide density was highest on slopes steeper than 56% (2.0 slides per 1000 acres). Southwest and west aspects had the highest landslide density (0.89 and 0.74 slides per 1000 acres).

ERFO sites totaled $8 million, compared to $4 million in 1974-76.
Stream effects were generalized as: increased channel width, shallowing of channel, higher cobble embeddedness, and fewer pieces of in-channel wood than before the flood. The greatest changes occurred in small streams. Landform seemed to influence the level of impact observed in streams.

Most road related slides were fill failures, and road design measures were offered.

EXECUTIVE SUMMARY

APPENDIX E

THE FLOOD OF 1997: KLAMATH NATIONAL FOREST

PHASE I: NOVEMBER 24, 1998

BY: JUAN DE LA FUENTE AND DON ELDER

Photo 97-82 #19- Granite Creek (Tributary to Elk Creek) Happy Camp Ranger District. Photo by J.d.l.F. 6-30-97. A large debris slide on the valley wall initiated a debris flow which deposited this log jam in Granite Creek.

A. BACKGROUND

This summary is intended to provide an overview of flood effects. Attached is a copy of Appendix C1, which is an abbreviated version of the road management guidelines developed during this assessment. Refer to the main report, The Flood Of 1997: Klamath National Forest (11-24-98), and Appendix C for details.

Assessment of the 1997 flood is being conducted in two parts, Phase I and Phase II.

Phase I Flood Assessment

Phase I is a reconnaissance level assessment commissioned by the Klamath National Forest Supervisor's Office. It is based on air photo interpretation (post-flood photos), data from damaged road sites collected by Forest Service Engineers, as well as field sampling. Phase I was completed in March of 1998, and final results are presented here. **Phase I objectives were to:**

1. Characterize the storm-related precipitation and stream flows of the 1997 flood.
2. Characterize the effects of the flood and where they occurred..
3. Identify the natural patterns of flood effects and influence of physical factors.
4. Identify possible influences of land management on flood effects.
5. Identify post-flood opportunities, and offer recommendations.
6. Evaluate the effectiveness of past mitigation measures addressing erosion and sedimentation.
7. Determine sedimentation rates and compare these to rates predicted by the Klamath Forest Land Management Plan.

Preliminary findings have been presented previously at meetings of the Klamath National Forest leadership team (10-23-97 and 11-18-98), the Klamath Province Advisory Committee (10-30-97), and the Scott River Coordinated Resource Management Plan (CRMP) on 2-17-98. The Phase I Executive Summary and Final Report of 11-24-98 replace the **Draft Flood Assessment of April 25, 1997.**

Phase II Flood Assessment

Phase II is a detailed field level assessment which was commissioned and funded by the Regional Office of the Forest Service Pacific Southwest Region, and is currently underway. It is being conducted jointly by the Klamath National Forest, and the Pacific Southwest Range and Experiment Station (Redwood Sciences Laboratory). Phase II carries on where Phase I left off, and involves detailed field investigations regarding the effects of roads and de-vegetation on landsliding, and the ways in which landslides affected stream channels. It will also quantify natural and management-related sediment in sample watersheds and examine the effects of the flood on stream channel conditions and fish assemblages. Some Phase II funding was used in completing the Phase I final report. An status report for Phase II will be completed in November, 1998, and the final report in 1999.

B. FINDINGS

Key findings are presented below. A summary is presented first, and then findings for objectives 1-7 of the Phase I Flood Assessment follow. Refer to the **Phase I Final Report of 11-24-98** and its Appendices for additional detail.

Summary

This assessment produced three principal findings, all of which have direct implications to future management of the Klamath National Forest. These findings are are: (1) **Sensitive Lands-** Certain land types are particularly sensitive and prone to landslides and debris flows under flood conditions; (2) **Roads-** Of the typical forest management practices, roads, have the largest effect on flood processes; (3) **Deforestation-** Widespread deforestation of some watersheds by a combination of wildfire and timber harvest appears to have had a destabilizing effect and increased landslide potential, particularly when it occured on certain land types. These three findings point toward changing some past management practices and keeping (reinforcing) others **(Adaptive Management)**. This report offers recommendation which will greatly reduce the cost of repairing roads in future floods, and also greatly reduce the adverse watershed effects caused by forest management. Many of these practices are already in effect, and full application is recommended.

1. Sensitive Lands- A disproportionate number of landslides and damaged road sites occurred on certain geomorphic terranes: previously active landslides; inner gorges, portions of older landslide deposits, particularly toe zones; and dissected granitic terrane. This pattern affirms the classification of much of this land as Riparian Reserve due to its instability. **Adaptive Management** practices which would address this issue include: (a) Identify and delineate these lands at the watershed (during Watershed Analysis) and site (when projects are done) levels. Utilize sound proven tools as well as newly developed ones such as laser generated DEM's; (b) Develop vegetative and soil objectives for these and other Riparian Reserve lands; (c) Manage these lands for riparian values, and toward the stated objectives as directed in the Klamath Forest Land and Resource Management Plan (LRMP).

2. Roads- Roads experienced a disproportionate number of landslides, particularly on older landslide deposits and on previously active landslides. About 60% of ERFO sites (those qualifying for Emergency Relief, Federally Owned funding) involved stream crossings or where the road was near a stream. Road-related landslides contributed to overall flood effects. Failure of road fills was a common problem. The technology exists to greatly reduce the adverse effects of roads in future floods. **Adaptive Management** practices to accomplish this include: (1) Fix ERFO sites in accordance with guidelines in Appendix C of this report; (2) Initiate a process for inventorying high risk road segments and sites; (3) Repair problem sites and upgrade roads on a priority basis as funds become available; (4) Decommission un-needed roads; (5) Focus road maintenance where most needed to prevent watershed damage, and with attention to repairing road drainage and diversion problems; (6) Avoid unstable lands when new roads are constructed, and utilize state of the art geotechnical techniques in landslide terrane and at stream crossings; (7) Place special attention on constructing stable fills, whether for ERFO repair, new roads, waste areas, landings, etc.

3. Deforested Areas- Harvested or burned areas experienced a high density of landslides, and were the sites of origin of many large debris slides and debris flows. **Adaptive Management** practices which would address this issue include would include maintaining vegetation on unstable lands according to direction in the Klamath Forest Land and Resource Management, and not logging these areas. Though we cannot prevent high intensity wildfire from burning unstable areas, we can reduce the potential for such fire on unstable lands and large areas of burn in hydrologic basins draining landslide deposits.

Objectives 1-7: Findings

The Phase I flood assessment identified seven objectives. Results for each of these objectives are presented below.

OBJECTIVE #1: CHARACTERIZE PRECIPITATION AND PEAK STREAM FLOWS

The flood-producing storm occurred from December 26, 1996 through January 3, 1997. It was a warm storm, involving rain above 7,000 feet in elevation on the Klamath Forest (Map 1). Total precipitation for the water year from October 1, 1996 through January 3, 1997 measured at recording stations across the Forest was about double the average for that time period. Amounts ranged from 1.5 to 2.2 times the average for the water year to that point in time. The precipitation for December at these stations was in most cases more than double the average. The range was 1.7 to 4.2 times the average. At the onset of the main storm (December 26), data from snow pillows and anecdotal accounts indicate that the snowpack was slightly greater than average. Air reconnaissance by Forest personnel after the storm revealed that the snowpack was considerably reduced, with some south slopes free of snow up to 6000 feet in elevation. The fact that heavy precipitation halted abruptly on January 3 probably slowed the movement of newly mobilized slumps and earthflows. Had heavy precipitation continued into the spring, many of these landslides would have likely have accelerated, resulting in more and larger debris flows. Precipitation data do not indicate cells of exceptionally high precipitation. Due to the broad spacing of recording stations (Map 4), and their location at river level, it is likely that such cells did develop, but were not detectable by the network.

Snow pack prior to the flood was slightly above average, and extended down to about 3500 feet on north slopes, and 4000 feet on south slopes (Map 3). After the flood, the snow level had risen to about 6000 feet on south slopes in the lower Scott River area.

Peak flows in rivers and streams on the Forest ranged from second to fifth highest on record. Estimated recurrence intervals for the 1997 Flood ranged from 14 years at Scott River to 37 years at Salmon River. The return interval was, 32 years on the Shasta River, 15 years at Indian Creek, 15 years on the Klamath River at Seiad, and 18 years on the Klamath at Orleans (Map 5). These intervals are preliminary, and were computed by the Federal Emergency Management Act (FEMA) method.

OBJECTIVE #2: CHARACTERIZE EFFECTS OF THE FLOOD AND WHERE THEY OCCURRED

Area Affected by the Flood

Major flood effects were concentrated on the west side of the Klamath National Forest, within the Klamath Mountains. Debris flows, channel alterations and damage to facilities were concentrated in an east/northeast trending band across the northern half of the Forest (Map 2). Watersheds most affected were: Walker, Deep, Tompkins, Middle, Kelsey, Grider, Portuguese, Thompson, Independence, Elk, Indian (Happy Camp), and Ukonom Creeks (Maps 10-12).

Effects on Roads and Facilities

As of March 1998, damage to Forest Service roads and other facilities has been assessed at about $27 million. This included 712 sites which qualified for Emergency Relief, Federally Owned (ERFO) funding. The total number of ERFO sites has grown continuously over time. The number used in computations for this assessment was 927. By November of 1998, the number has grown to around 1100 sites (including those which occurred in the winter of 1997-1998). Road damage was concentrated in the vicinity of streams (about 60% of sites). Failures at stream crossings were often the result of clogged culverts, and clogging was caused by debris flows, wood and sediment, and in a few cases excessive water. A bridge over the Klamath River was lost, and several smaller bridges damaged. Landsliding was a primary slope process on 34-61% of the damaged road sites. Road fill failures on steep slopes away from streams accounted for 15-18% of damage sites, and road cut failures 5-6%.

County and state roads were also damaged along the Klamath, Scott, and Salmon Rivers. Damage to County and State roads consisted mostly of stream undercutting where the roads paralleled rivers and streams. However, numerous large slumps and earthflows damaged State Highway 96 between Happy Camp and Orleans. One of these landslides near Ti Bar moved slightly in 1997, then failed catastrophically in February, 1998, closing the highway for a month. Houses and other buildings were damaged or destroyed at Walker, Grider, and Kelsey Creeks, as well as near the Happy Camp airport. Campgrounds and their access roads were damaged in many areas. Fish habitat improvement structures were damaged across the Forest.

Effects on Stream Channels and Fish Habitat

Air photo inventory revealed that about 446 miles of stream channel were altered by the flood. This constitutes about 16% of the mapped stream system within the study area. This figure does not include the main Rivers (Klamath, Scott, Salmon) which, if included, would add roughly 90 more miles. The average density of altered channel in the photo area was 0.37 miles per square mile. Most of the larger flood-altered channels (such as Elk Creek) exhibited a general shallowing of pools, widening of the channel, and decrease in particle size (finer material) in the substrate. Mobilization of the substrate during the flood likely removed all fish eggs present in stream gravels prior to the flood, and had adverse effects on invertebrates and on the larval stage of the Pacific Lamprey. Post-flood gravels are unstable, and subject to mobilization, thereby placing the 1997 crop of fish at risk. However, peak flows in the spring of 1997 were not very high, and steelhead eggs appear to have successfully incubated. Pool depth appears to have been reduced in the areas most affected by the flood.

Riparian vegetation was damaged or removed from some stream segments. Temperature increases in the summer of 1997 were documented at Elk Creek, and may have occurred in Walker, Indian, Tompkins, Portuguese, and Ukonom Creeks, as well as the South Fork of the Salmon River. Large logs were mobilized in many streams, and re-positioned within the channels. Many of the accumulations are above the bank-full channel. Additionally, channel widening undermined large trees in lower stream reaches, causing them to topple into the channel where many remain to the present time. They have not been systematically assessed, but a few observations can be made. Large boulder clusters and weirs in Elk and Indian Creeks as well as the South Fork Salmon appear to have weathered the high flows, though some were moved or buried. Cabled log structures were more often damaged, raised out of the channel, or removed. A small sample of log structures examined in middle Beaver Creek survived the high flows. These were oriented perpendicular to flow direction, and were embedded in both banks.

Preliminary assessment of summer 1997 water temperature data indicate increases in Elk Creek, and possibly other watersheds. Water temperature at Elk Creek showed an increase in 1997 relative to the period from 1990-1995. The largest differences were in the instantaneous maximum and in diurnal temperature. The fact that 31 day averages were only 0.5 degrees higher in 1997 than the 1990-1995 mean, and even cooler than in 1991 and 1994 is probably a result of higher diurnal variations in 1997 which would average out. The high diurnal variation was most likely due to the loss of shade and shallowing and widening of the channel which allows more efficient heating during the day, and rapid cooling in the evening.

Landslides and debris flows uprooted large trees in the headwaters of Walker, Tompkins, Granite (upper Elk), Walker, and Thompson Creeks, and transported them downstream to gentler reaches. Debris flows and flood flows in some channels undermined banks and toppled large trees into streams where they remained through the summer of 1998.

OBJECTIVE #3: IDENTIFY THE NATURAL PATTERNS OF FLOOD EFFECTS AND THE INFLUENCE OF GEOLOGIC AND PHYSIOGRAPHIC FACTORS

A total of 1100 landslides were identified, (712 from air photos, and the rest from field sampling and ERFO site inventory). The distribution of landslides, ERFO sites, and flood-altered channels show strong correlations with certain **geologic** and **physiographic** elements of the landscape (bedrock and geomorphic terranes, elevation, slope gradient, slope aspect). These correlations are described below.

Influence of Geologic and Physiographic Factors

Landslide Distribution: (1) Bedrock Terranes- Landslide concentrations were highest in the Rattlesnake Creek Terrane, and Plutons (granitic lands), and lowest in the Western Jurassic Terrane (Map 6); (2) Geomorphic Terranes- The highest landslide density was on landslides active prior to 1997, inner gorge, and older landslide deposits. Glacial deposits and debris basins expressed the lowest density (Map 7); (3) Elevation- The highest landslide density was at 4,500-5,500 feet, and the lowest density was below 2,000 feet (Map 8); (4) Slope Gradient- Gradients of 40-65% had highest density, and 0-20% the lowest; (5) Aspect- Landslide density was highest on north and east aspects, and lowest on south and west. See Tables 1 and 4, and Map 3.

Distribution of ERFO Sites- ERFO sites are areas where flood damages (primarily to roads) qualified for Emergency Relief Federally Owned Funding. (1) Bedrock Terranes- ERFO sites were most dense in the Condrey Mountain and Rattlesnake Creek bedrock Terranes, and lowest in Sawyers Bar, Stuart Fork, Central Metamorphic Terranes and Plutons; (2) Geomorphic Terranes- The geomorphic terranes with the highest and lowest ERFO site densities were the same as for landslides (Highest = landslides active prior to 1997; inner gorge; and older landslide deposits. Lowest = debris basins, steep mountain slopes, and glacial deposits); (3) Elevation- In contrast to landslides, ERFO sites were most dense in elevation zones from 2,000-4,000 feet, and least dense above 6,000 feet; (4) Slope Gradient- Also contrasting with landslides, ERFO sites were most dense at slope gradients of 0-20%, and least dense on slopes >65%; (5) Aspect- ERFO density by slope aspect was similar to that of landslides, with highest density on north and east aspects, and lowest on south and west. See Table 2.

Distribution of Altered Channels- (1) Bedrock Terranes- Stream channels modified by scour, deposition or damage to riparian vegetation (altered channels) were most dense in Plutons (granitic rock) and Rattlesnake Creek Terranes, and lowest in the Stuart Fork, Condrey Mountain, and Western Jurassic Terranes; (2) Geomorphic Terranes- Altered channels were most dense within the inner gorge geomorphic terrane (as expected) and active landslides, and lowest in undifferentiated mountain slopes; (3) Elevation- The highest density was at <2,000 feet, and 4,000-6,000 feet, and the lowest density was above 6,000 feet; (4) Slope Gradient- Slopes

0-20 % had highest density, and >65% the lowest; (5) Aspect- Density was highest on north aspect, and lowest on south aspect.

Natural Patterns of Flood Effects

Greatest effects were observed in streams radiating outward from the Marble Mountain Wilderness (Map 2). The Siskiyou Crest (separating the Klamath River from the Rogue River drainages) also experienced considerable flood effects, and these continued northward into the Rogue River and Siskiyou National Forests. To a lesser degree, the Upper South Fork of the Salmon River exhibited effects, and these effects were more pronounced immediately to the south in the headwaters of the South Fork Trinity River on the Shasta-Trinity National Forest (Steve Bachmann and Abel Jasso, personal communication, 1998). Typical patterns included concentrations of landslides and debris flows in the headwaters of watersheds, typically those in Rattlesnake Creek Terrane or Plutons (granitic lands). There is a marked absence of flood effects in the SE half of the west side of the Forest (Map 3). It should be noted that the inventory of this part of the Forest was limited to aerial reconnaissance and field checking of roads. Air photos were not available.

OBJECTIVE #4: IDENTIFY THE INFLUENCES OF LAND MANAGEMENT ACTIVITIES AND FIRE ON FLOOD PROCESSES

Roads

Field and air photo observations revealed that of all land management activities, roads had the largest effect on flood processes. A total of 182 landslides identified on the air photo inventory were within the road corridor, (25% of the total), and the density in the road corridor was 27 times higher than that of undisturbed land. The primary road effects were: (1) Roads changed **hillslope and channel hydrology**; (2) Road earthwork changed **soil properties** (density, permeability, and slope gradients); (3) Roads changed the **mass balance** on hillslopes (adding and subtracting weight). Road fills, cuts, and surface drainage influenced flood processes as follows:

Road Fills- (a) At stream crossings, road fills changed the configuration of channel beds, thereby causing diversions, and obstructing the passage of sediment and logs. These fills also contributed sediment to the stream; (b) On steep hillslopes, many fills became saturated and failed, initiating debris flows; (c) Fills placed on the heads of slumps and earthflows added weight and initiated landsliding.

Road Cuts- Road cuts intercepted subsurface flow, undermined slopes, and removed weight, (changing mass balance). Also, local failures of road cuts blocked drainage ditches and diverted water.

Road Surface Drainage- The road surface, inside ditch, and cross drains, altered slope hydrology by conveying the water intercepted by road stream crossings, road cuts, and the road surface itself, and delivering it to new sites on the landscape. In some cases, road ditches conveyed water to stream crossings, and in others, they received water from diverted streams at crossings, and carried it down the road.

It was found that, roads had the greatest effect on flood processes and also experienced the most damage in **three geomorphic settings**:

(1) **Stream Channel Environment-** About 60% of ERFO sites occurred in or adjacent to streams. At stream crossings, roads diverted flows to new parts of the landscape, and obstructed the passage of sediment and logs. In some cases, the road bed served as a repository for sediment which would otherwise have continued down the stream. Fills commonly shed sediment to the stream when culverts failed. Where the road paralleled the stream, the fill locally constricted the channel, and contributed sediment when it was undercut by flood flows;
(2) **Landslide Deposits-** On older landslide deposits ("landslide"geomorphic terrane) where roads undercut toe zones, loaded the heads of slumps, or intercepted water and delivered it to unstable portions of the landslide deposits.
(3) **Steep Mountain Slopes-** Here, many fills on steep slopes failed, particularly those placed in swales in sandy soil derived from granitic rock such as in the Elk Creek watershed.

Cumulative effects were evident where multiple roads traversed the same hillslope, particularly where landslides and debris flows interacted with road drainage. These areas experienced complex hydrologic interactions such as where a small fill failure on an upper road generated a debris flow which in turn caused multiple road stream crossing failures downslope. Similarly, long road segments with inside ditches uninterrupted by major drainage breaks, were prone to failure, (particularly when a stream was diverted down the ditch) unless well-defined relief dips or other breaks in drainage were present. Lastly, small fill failures on upper road segments commonly affected multiple crossings downstream.

Rock Pits, Waste Areas and Timber Landings

These features behave similar to roads and involve the same types of features on the landscape (fills, cuts, and surface drainage features). Numerous waste areas and landings initiated landslides. As a consequence of the flood, there is a critical need for a large volume of rock (rip rap in particular) as well as for waste areas, where soil, and rock removed from damaged roads can be deposited. Landslides along Highway 96 during the 1997 flood and the 1998 landslide at Ti Bar caused an emergency need for suitable waste areas between Happy Camp and Somes Bar. About 100,000 cubic yards of debris from the Ti Bar Lanslide were hauled to a waste area in Orleans. The recent EPA sponsored capping of mine tailings from the Gray Eagle Mine in Indian Creek north of Happy Camp, created an immediate demand for earth material. These periodic emergency demands for sources of earth and rock materials (borrow pits), and places to dispose of earth and rock materials (waste areas) highlight the opportunity for the Forest to develop a strategy for managing borrow pits and waste areas.

Timber Harvest and Fire

Harvested areas had higher densities of landslides, and ERFO sites, but a lower density of altered channels than did undisturbed sites (Map 9). Harvested areas contained 37% of all landslides identified on air photos. The landslide density on harvested land was 7 times the rate on undisturbed land. The rate for new harvest (1977 or younger) was 11 times the undisturbed rate. If landslides within road corridors are excluded, 13% of landslides inventoried on air photos were on harvested land, and the density on harvested land was 3 times the undisturbed rate, and the rate on young harvest was 6 times the undisturbed rate. A total of 227 ERFO sites were identified on harvested land (31% of a sample of 744 sites), and ERFO sites were about 2 times more dense in harvested areas than on timbered land. Altered channels were less dense in harvested areas than in unharvested areas (the rate in harvested land was 0.7 times the undisturbed rate).

Burned areas had higher densities of landslides, ERFO sites, and altered channels than did undisturbed areas. Areas burned at high and moderate intensity had about 8 times the density of landslides as undisturbed land, but if road corridor landslides are removed, the rate was 6 times the undisturbed rate. ERFO sites were about 2 times as dense on areas burned at high or moderate intensity in 1987. However, if all fires since 1977 are considered the rate is only 1.1 times the undisturbed rate. The density of altered channels within burned areas (all intensity classes) was 2.4 times that in unburned areas. However, the density in areas burned at high to moderate intensity was actually lower than in unburned areas (0.9 times that un unburned land).

Summary: Effects of Roads, Timber Harvest and Fire

Some of the most important conclusions which can be drawn with Phase I findings are that: (1) Road stream crossings on the Klamath Forest must be able to accommodate debris flows. Debris flows are common natural process in the Klamath Mountains, and most streams will experience them sooner or later. Only the largest of culverts are capable of passing debris flows, so it should be assumed that most pipes will become clogged and fail within their design life. (2) Many road fills on steep hillsides away from streams failed in 1997 causing considerable adverse watershed effects. We have the technology to make fills reasonably safe in most settings, and can greatly reduce the magnitude of adverse effects. (3) Road surface drainage caused landsliding, stream channel diversions and surface erosion in many areas. We have the technology to mitigate much of this problem; (4) Roads built across landslide toe zones had destabilizing effects on landslides. It is difficult to mitigate this effect, and in general, roads in this setting should be avoided. Similarly, fills on the heads of slumps activated some landslides. The mitigation for this effect is avoidance or minimizing fill size. (5) De-vegetated areas on landslide terrane produced large debris slides from toe zones with adverse effects. In such settings, the management objective can be to maintain vegetation on unstable slopes.

The Phase I flood assessment has identified roads as an important point of origin for landslides and debris flows, but does not establish cause/effect relationships, nor quantify the volume of sediment or miles of altered channels which can be attributed to roads. Phase II will address these questions for some sample watersheds. Some of the 1997 road-related landslides are obviously road-caused, such as where the landslide occurs entirely within a road fill, or where a large road cut undermines a slope and triggers a slump. For others, the link is more tenuous, such as when road cuts, fills, and drainage effects are small relative to the size of the landslide. In these situations, the road may be incidental to the landslide.

OBJECTIVE #5: IDENTIFY OPPORTUNITIES AND OFFER RECOMMENDATIONS

Opportunities

There is an opportunity to learn from the flood and apply **adaptive management** to the repair of ERFO sites as well as to future road management (including inventory of restoration needs and decommissioning). This will allow restoration to focus on highest priority watersheds, and will greatly reduce the damage to roads and adverse effects to aquatic values in future floods. Further, there is an opportunity to better analyze the role roads and de-vegetated areas played in the total sediment budget of the 1997 flood, and to monitor the movement of sediment through flood-altered channels. There is a similar opportunity to apply **adaptive management** to future vegetation manipulation, fire suppression, and prescribed burning.

Roads: Recommendations For Fills, Cuts, Drainage, and Spacial Distribution

During this assessment, some convincing patterns emerged regarding road stream crossings and road-related landslides which likely apply across the Klamath Mountains Province as a whole. Recommendations have been developed to address them. **It is strongly recommended that the guidelines in Appendix C be applied to all ERFO repairs**, and also to future road location, design, maintenance, decommissioning, and upgrading. This will greatly reduce the costs of repairing the damage of future storms, and will also reduce the adverse watershed effects associated with roads. A summary of Appendix C follows:

(1) **Road Fills-** For all fill repairs and new construction, assess foundation stability, and design and construct strong, stable fills, including reinforcement and drainage as appropriate; armor fills subject to overtopping. Minimize fill size, and also, the fine particle component of the fill which is susceptible to erosion. For situations where fills may be needed but are not in the design package, a provision similar to provision C6.602 of the Timber Sale Contract may be appropriate.
(2) **Road Cuts-** Stabilize road cuts which are prone to failure and consequences of failure are high (buttress or horizontal drains);
(3) **Road Surface Drainage-** Eliminate inside road ditches unless a site specific need for a ditch is identified. Install positive dips and water bars on long, uninterrupted road segments with multiple cross drains to prevent failure of road ditches along in-sloped roads.
(4) **Cumulative Effects-** Reduce road density (decommissioning) in areas where multiple roads cross hillslopes and interact hydrologically.

Roads: Recommendations For Specific Geomorphic Settings

Stream Environment- Minimize the number of road stream crossings (particularly multiple crossings on the same stream) and length of road on floodplains or paralleling streams. (1) At **road stream crossings**, maintain the natural channel geometry (horizontal and vertical) within road design constraints. Design crossings to accommodate 100 year flows and debris flows. In the event of debris flows, crossings should: (a) Survive overtopping without failing catastrophically; (b) Minimize the contribution of fine sediment to the stream; (c) Avoid causing stream diversions; (d) Minimize the volume of sediment which would be trapped upstream of the crossing if the culvert fails; (2) **Roads paralleling streams**, or on the **floodplain** should minimize constrictions to the channel and facilitate natural floodplain inundation. Areas susceptible to stream undercut should be armored.

Landslide Deposits- Minimize the length of roads in this environment, particularly on active portions and toe zones. Roads in landslide deposits should maintain favorable mass balance (fostering stability of the slope), avoid placing fills on heads of slumps, avoid cuts on toe zones. They should also maintain natural drainage patterns, and avoid diverting off-site water to unstable parts of the landslide.

Steep Mountain Slopes- Minimize the number and size of fills on steep mountain slopes particularly those on sandy soils in topographic swales with evidence of groundwater. Where avoidance is not possible, make the design responsive to site conditions, including the appropriate level of compaction, reinforcement, and subsurface drainage. Minimize high cuts into areas with unconsolidated deposits, evidence of shallow groundwater, or adverse structural features in bedrock. Where avoidance is not possible, cuts should be buttressed or drained as appropriate. This is particularly true where failures could deliver sediment to streams, or obstruct road surface drainage.

Roads: Recommendations for Management

Decommissioning- Use decommissioning as a tool to remove those roads with little utility to the transportation system and with the greatest potential for adverse watershed effects, both at the site specific level, and in terms of cumulative effects. Access and travel management plans in conjunction with NEPA assessments are essential in identifying and prioritizing roads for decommissioning.

Maintenance and Upgrading- In addition to focusing on arterial and other high-use roads, emphasis should also be placed on: (1) Roads with highest potential for drainage-related problems; (2) Fixing the most fixable things such as culvert collection basins, drainage diversion potential and long uninterrupted cross drain situations, and outsloping.

Inventory For Restoration Sites- Inventory should focus on priority watersheds, and identify problems which: (1) Have the Potential for large adverse effects; (2) Can be accurately identified; (3) Can be effectively repaired; (4) The repairs have a high cost/benefit ratio. Recent work on the Klamath National Forest (Ledwith and others, 1998) revealed that while it was not possible to predict which stream crossings were going to fail in 1997, it was possible to accurately predict consequences of such failures. This argues that we inventory fills and landings with the greatest potential for adverse effects (such as those which affect multiple road crossings downslope) and prioritize for repair or upgrading. A recently submitted (11-5-98) grant proposal, **Road/Stream Crossing Inventory & Risk Assessment Klamath National Forest - Westside** prepared by the Klamath National Forest is a good example.

Rock Pits, Waste Areas, and Landings: Recommendations

Develop a Forest inventory of rock pits in particular, identifying rip rap sources. Identify (Interdisciplinary Team) waste areas in the Happy Camp to Somes Bar corridor of the Klamath River, adjacent to Highway 96. A process is underway, but needs to be completed. Inventory landings with potential to generate landslides. In cases where contract specifications for construction of a waste area fill have not been prepared for the project, provision C6.602 of the Timber Sale Contract may be appropriate. Conduct geologic investigations, including stability analyses as needed for rock pits and waste areas, attaining favorable mass balance, and drainage configurations. For rock pits or waste areas over 5,000 cubic yards in size, a development plan is appropriate.

Vegetation Management: Recommendations

Develop and apply vegetation management guidelines for Riparian Reserves. Guidelines in the recent Eddy Late Successional Reserve (LSR) assessment provide a good foundation. In timber harvest planning (outside the Riparian Reserve), avoid de-vegetating landslide deposits and granitic terrane with timber harvest over large contiguous drainage areas. This can be accomplished by utilizing skilled earth scientists during layout. Avoid denuding steep swales in granitic terrane which are prone to debris slides. Maintain down logs to interact with future debris flows, in balance with desired fuel loading.

Fire Management: Recommendations

(1) During suppression of wildfire, take aggressive steps to prevent high and moderate intensity fire in landslide deposits, dissected granitic terrane, and other unstable land. Apply watershed skills in the Resource Advisor role during suppression. (2) During prescribed burns, prevent high and moderate intensity fire on landslide deposits and toe zones and dissected granitic lands (particularly the swales) by appropriate mitigation measures such as pre-burning or hand piling fuel accumulations in these areas. This requires some field delineation of unstable lands such as toe zones and dissected granitic lands where there is a high risk of intense prescribed fire.

Fish Habitat Improvement Structures: Recommendations

Systematically assess the response of habitat improvement structures to the flood of 1997, and develop recommendations for future placement, maintenance, and monitoring.

OBJECTIVE #6: EVALUATE THE EFFECTIVENESS OF PAST EROSION AND LANDSLIDE CONTROL MEASURES

Engineered structures survived the flood well, with only few catastrophic failures identified. In general, reinforced fills installed on sound foundations with subsurface drainage survived the event. However, many structures on large landslides were deformed and damaged by 1997 movement. This is a common occurrence where a road is taken out by a relatively small landslide which is actually part of a much larger feature. The small landslide may be fixable, but the larger landslide is beyond the scope of ERFO stabilization. In these cases, the long term potential for loss of the road are high, and this should be weighed heavily in considering decommissioning opportunities. A segment of the Steinacher Road in the Wooley Creek watershed was decommissioned immediately before the flood and emerged with only minor erosion. Bedrock in this area is granitic, and the sandy soils are highly erodible.

OBJECTIVE #7: DETERMINE FLOOD-RELATED SEDIMENTATION RATES & COMPARE TO PREDICTIONS IN THE FOREST LAND AND RESOURCES MANAGEMENT PLAN

Estimates of landslide sedimentation rates by geomorphic terrane were not made as part of this study due lack of time. This question will be addressed in Phase II of the flood assessment.

APPENDIX F

WEATHER FACTORS AND THE FLOOD

BY: DON ELDER

APRIL 25, 1997

Weather Factors & the Flood

The New Year's day flood of 1997 caused extensive damage to roads and other facilities. Debris flows and high stream discharges altered channels, some dramatically. Motion of deep-seated slides was initiated. Although effects of the flood were widespread, certain watersheds seemed especially hard-hit. To explain the pattern of damage and to assess causes, it is necessary to define processes involved and to understand the role played by each. Weather played a central role.

This section of the assessment will present climatological data and interpretations that are consistent with the information. For discussion purposes, precipitation data will be presented in three chronological (& functional) section, followed by ~~sections on~~ stream flow, data sources & uses, and conclusions. The "functional" part of the precipitation sections establishes conditions described in a model for "abundant debris avalanches" as presented in a paper by Cannon and Ellen [1985: California Geology, v. 38, no. 12, p 267-272]. Most of data collected is shown in the accompanying tables and plots (Figures 1- 6). We apoligize for the lack of Figure captions. Abbreviations used on the plots are (sometimes) found in accompanying tables.

Antecedent Rainfall [Nov 1 to Dec 25, 1996]:

Fall rainfall amounts were moderately to substantially above normal. November precipitation amounts (Fig. 1A) ranged from 92% to 173% of normal. Most of the pre-Christmas December precipitation accumulated during a significant storm from Dec 5 - Dec 10. Moderate amounts of precipitation came in a cold storm from Dec 21 - Dec 23. Snow was recorded on the ground at elevations as low as 1,800' (Seiad & Horse Creeks). Pre-Christmas December measured precipitation totals are shown in Figure 2A, for westside stations, ranging from ~6-8" (Yreka & Ft. Jones) to >20" (Happy Camp & Seiad Cr..). Amounts are typically 200% of normal for the entire month of December (Fig. 1A).

California Dept of Water Resources operated remote snow sensors ("snow pillows") recorded the steady build up of the mountain snowpack, from almost none on Dec 1 to 7.4" SWC at Big Flat (at 5,100' ele) to 14.6" & 15.6" SWC at Bonanza King and Peterson Flat (6,450 ' & 7,150' ele). [SWC = snow water content; at density of 33% (typical for "settled" snow) implies snow depths of ~ 2' to 4' or more with densities <33%]. "Snow pillow" sites are located in the upper Trinity River basin, north of Trinity Lake. There are stations along the Trinity-Scott divide, including ones at Scott Mtn (near Hwy 3), Middle Boulder Lake, Peterson Flat, Big Flat (near the FS campground on the upper South Fork of the Salmon River). Snowpack depths recorded around Dec 25 are moderately above normal for this time of the year.

This above-normal antecedent precipitation played an important role in the flood event to follow. The sub-soil (sub-surface) was recharged with moisture to the point that subsequent water could not be absorbed at high levels. The full thickness of the soil mantle was brought to field capacity.

The Storm Event [Dec 26 to Jan 2 or 3]:

Beginning after Christmas a series of wet & warm storms hit California & the Pacific Northwest (nicknamed the "pineapple" express, because their origin in the central Pacific, around Hawaii). Daily rainfall amounts (and event totals) are shown in Fig. 2A and plotted in Fig. 2B. Temperatures were consistently warm and remarkably did not vary much by elevation or time of day. Recorded highs and lows for Dec 28 through Jan 1 ranged from daily lows of 34° (Dec 30) to 38° F (Jan 1) and highs of 39° to 48° F recorded at "snow pillow" sites that ranged in elevation from 5100' to 7150'.

Despite the warm temperatures and heavy amounts of rainfall, snow runoff appears not to have played a significant role in the flooding. According to the Corp of Engineers' *Snow Hydrology* manual, it would take about **10"** of rain to melt **1"** of snow at 48° F air temperature. Rain water is simply absorbed and frozen into the snow mass, increasing its density, but leading to NO runoff. Not until a density of ~55 % is reached does snow becomes 'water-saturated' and melt/runoff can occur. Almost 7" of rain would have to fall on 10" SWC at 33% density to increase the snowpack to 55% density and saturation/melt/runoff. Rain totals approached this amount, suggesting that some runoff might have occurred, but not in significant quantities. "Snow pillow" readings of 'snow water content' at several stations confirm this, showing only modest snowpack losses.

The Flood Event [Dec 30 to Jan 2]:

Beginning Dec 30, rainfall intensified. "Snow pillow" gauges recorded intensities of between .38" and .42" per hour at four station over the last six hours of 1996 (6:00 PM - Midnight, Jan 1; Fig. 2C), producing 6 hr totals of over 2". During the last 18 hrs of Dec 31, totals of 4" to > 5" were recorded. Daily totals from Siskiyou County stations record lesser amounts (Fig. 2A & 2B) over the same time periods. However, these readings were from low elevation "valley" stations, and may not reflect conditions "up slope."

Although the heavy precipitation may not have caused significant snow melt/runoff, the rainfall intensity & duration may have caused a perched ground-water table of sufficient thickness to have caused slope failures.

This period of intense rainfall activity caused flood stage discharges in all streams. Peak flows were measured at different gauging stations at different times, but all coincided with this peak in rainfall. Five stations recorded peak discharges the evening of Jan 1 (5:50 PM to 10:30 PM; Fig. 3). For reasons unknown, the Trinity River station showed peak flows the evening of Dec 31 (10:30 PM), and the Indian Creek station, the evening of Dec 30 (8:45 PM)!!!

Stream Gauge Data:

Peak discharges were recorded at seven gauging station in the area. A summary is shown in Figure 3. Historic annual peak flow data was collected for these same gauging stations. This information is presented in tabular form (Fig. 4) and plotted as histograms (Figures 5A, 5B, 5C, 5D, 5E, 5F, 5G). Included in Figure 4 is the computed recurrence interval associated with each annual peak flow. This value ("T") is simply the years of recorded data (+1), divided by the ranking of that particular discharge (against other recorded annual peak flows). For example, the 1997 (estimated) peak flow of 91,000 cfs for the Salmon River ranks 2nd (behind the 1964 peak) and there exists 73 years of data for that station; therefore, T = (73+1)÷2 = 37. This implies a recurrence interval of 37 years, which means (by FEMA rules), the probability of a peak annual flow of this magnitude or larger occurring in **any** given year is 1÷37, or prob = .027. (See bottom of Fig. 4, for more details).

This methodology for assessing probability and recurrence interval associated with flood stage discharges was driven by administrative needs of FEMA to assign (insurance) risks to property adjacent to streams. It may or may not make hydrological sense. The maximum recurrence interval that can be assigned to any event depends on the number of years of data available. The popular practice of comparing high flows to the so-called "100-year flood" events technically can not happen until 99 years of flow measurements are made. With this in mind, calculated recurrence intervals for the 1997 flood at each station are shown in Figure 3. 'Recurrence intervals' vs. 'peak annual flows' is plotted for each station and shown in Figures 6A, 6B, 6C, 6D, 6E, 6F, 6G.

Along with kurtosis, 'skewness' measures how values are distributed about their mean. In a "well-behaved" data set, values are evenly distributed about their mean and when plotted, create a symmetrical "bell-shaped" curve. In this case, 'skewness' = 0. *Summary Statistics* section of Figure 4 show skewness values the peak annual flow data for each gauging station. Indian, Scott, Klamath (at Seiad), and Salmon Rivers have very similar values, ranging from 2.26 to 2.65, while Trinity and Klamath River (at Orleans) cluster at 1.6. Indian Creek's peak annual flow data have a 'skewness' value of 4.01. This 'skewness' is reflected in the upwards-bending curves on the "T" vs "Q" plots of Figures 6A,..,6G. Plotting Klamath data would produce an asymmetric, lop-sided "bell" (?) curve. Skewness values of less than one (<|1|) generally mean that the data set approximates a "normal" or "binomial" distribution. The Klamath discharge data is skewed toward the high flow end of the data set.

Implications of this are as follows:

(I) Widely used 'yearly probability & recurrence interval' models are built on the assumption that annual peak discharges fit a binomial distribution, with (absolute) 'skewness' values < 1. Klamath data do not meet the basic criteria of the model, which suggests that probability/recurrence interval predictions should be accepted with healthy skepticism.

(ii) High positive skewness values suggest that the Klamath pattern of flood discharges is characterized by relatively low mean annual flows, punctuated by very high flood events.

Mean peak annual flows are poor predictors of the magnitude of large flood event discharges.

The New Year's day flood of 1997's place in history:

While not matching up to the flood stage discharges recorded of 1964, this year's flood does represent a significant "hydrological" event. In general, peak discharges for the 1997 flood are on a level with flood stages recorded in 1955 and 1974 (Fig. 4, 5, 5A,...,5G, 6A,..., 6G). Typically, 1997 flood peaks rank between 2 & 5 (Fig. 4), but when peak volume numbers [cfs] are compared, they are not significantly different from those of 1955 and 1974. For example, Klamath River at Seiad station recorded peaks as follows: 1974 = 126,000; 1955 = 122,000; 1997 = 117,000. And for the Scott River station: 1955 = 38,500; 1974 = 36,700; 1997 = 34,300.

The Data:

Precipitation information was collected from numerous sources. These sources are shown on Figures 1A & 2A. This information was plotted on Figures 1B & 2B. Snow condition, hourly temperature, hourly and daily precipitation data for stations in the Trinity River basin (see note Fig. 2A) was downloaded from the Snow Survey WEB site. Historic peak annual river discharge data (Figures 3 & 4, & plotted on Figures 5 & 5A, ..., 5G and Figures 6A, ..., 6G) from stream gauges operated by the USGS (US Geological Survey) were downloaded from their WEB site. 1997 flood peak discharges were obtained via telephone conversations with USGS personnel in their Redding Field Office.

Rainfall information for areas most affected by the storm/flood event on the westside of the Klamath National Forest was obtained from relatively low-elevation "valley" stations. Remote weather stations at higher elevations do not operate properly in the winter due to freezing. The only (detailed) data that might reflect conditions in higher elevation "upland" settings was provided by the remote snow sensor stations ("snow pillows") mentioned above. Extrapolation of this data to our areas involves some uncertainty. Certain evidence, however, supports this extrapolation with some degree of confidence:

[1] Rainfall patterns for the storm event (Dec 26 - Jan 2) appear regional consistent, showing no evidence of major local variations in intensity or duration (i.e., normally high precipitation areas received more than areas of normally low precipitation) [Fig. 1A & 1B; Fig. 2A & 2B].

[2] Temperature readings are consistent with those from KNF-operated RAWS [remote operated weather station] on Collins Baldy, and in agreement with local weather reports of "high snow lines" during the storm.

[3] Peak rainfall intensities and amounts over the evening of Dec 31/Jan 1 are consistent with peak discharges recorded at stream gauging stations, and seem to coincide with timing of destructive debris flow/landslide events Fig 2B & 2C).

Conclusions:

While severe weather triggered and exacerbated mass-wasting events, and intense precipitation caused flooding in most streams, no evidence was found to suggest local variations played a major role in the damage pattern. Data did not show that areas more heavily damaged by flooding received substantially more precipitation. Since weather information was limited to low elevation "valley" sites, with wide and patchy distribution, and not set up to provide hourly readings, we can not categorically rule out the possibility that rainfall intensity &/or duration played a larger role.

As mentioned in the introduction, Cannon and Allen (1985) present a model in which certain rainfall conditions must be met in order for "abundant" debris flows to result. The necessary conditions of their model were defined as a result of a study of six major storm events that hit the San Francisco bay area between 1955 and 1982. Certain storms that hit the area with high intensity (inches rain per hour) and long duration (typically > 24-30 hrs), yet lacked antecedent rainfall, failed to produce abundant debris flows; likewise, for storms with antecedent rainfall, but lacking in either high intensity or long duration rainfall.

Plotting rainfall conditions on an 'Intensity' vs 'Duration' graph led to the creation of thresholds across which storm events must cross in order to produce abundant debris flows. Those thresholds are shown in Figure 8, along with hourly rainfall data from the "snow pillow" stations mentioned above. Both thresholds are crossed during the 5 or 6 hours before midnight on Dec 31 and into the morning hours of New Year's day 1997. Although caution must be exercised in applying parameters generated elsewhere to local conditions, the data of Figure 8 is suggestive.

MONTHLY & EVENT Precipitation Amounts from Local & Regional Sites

Local Flooding in a Larger Climatological Context

Station	Storm				December			November & Water Year				Annual		
	Dec. 20 - Dec. 25	Dec. 26 - Jan. 3	Dec. 20 - Jan. 3	12/20 -1/3 % of Dec Tot	Total	Dec Norm	% Norm	Nov Total	10/1 - 1/3 Water year	totals Water yr Norm	% Norm	Annual Norm	97 Dec % of Norm	12/20-1/3 storm, % Norm
Oak Knoll [OK]	1.56	8.65	10.21	82%	12.5	4.77	262%	4.82	26.69	14.57	183%	24.79	50%	41%
Horse Creek [HC]	3.19	12.78	15.97	69%	23.04									
Seiad Creek [SC]	3.3	17.12	20.42	65%	31.51	9.16	344%					45.37	69%	45%
Happy Camp [HA]	2.08	10.72	12.80	45%	28.56	10.35	276%	7.4	51.92	31.86	163%	54.65	52%	23%
Slater Butte [SB]	0.88	12.26	13.14	55%	23.72			6.01	42.53					
Somes Bar [SO]	4.21	13.93	18.14	77%	23.64	10.51	225%	9.52	51.13	34.69	147%	62.23	38%	29%
Orleans					26.17	10.18	257%							
Sawyers Bar [SA]	2.82	10.17	12.99	58%	22.54	8.03	281%	6.84	43.54	25.20	173%	45.08	50%	29%
Fort Jones [FJ]	1.02	7.24	8.26	72%	11.46	4.17	275%	3.83	22.55	12.44	181%	21.47	53%	38%
French Creek [FC]	0.8	9.72	10.52	68%	15.45	3.66	422%							
Callahan					9.05	3.66	247%					20.73	44%	
Goosenest [GN]	0.36	2.54	2.90	88%	3.31	1.74	190%	1.5	8.72	5.76	151%	11.63	28%	25%
Yreka [YR]	0.7	7.80	8.50	88%	9.67	3.50	276%	4.29	22.15	9.93	223%	17.85	54%	48%
Hornbrook	0.62	5.77	6.39	72%	8.92	5.23	171%	3.58	19.79	13.18	150%			
Weed	0.25	9.44	9.69	62%	15.57	7.40	210%	9.54	33.08	19.42	170%			
			Average:	69%		Average:	264%							

Misc Area Sites							
Big Bar RS			12.80	75%	17.14	6.88	249%
Coffee Cr RS			21.28		30.74	9.46	325%
Dunsmuir			26.51		38.29	9.43	406%
Eureka			10.33	49%	21.26	6.40	332%
Gasquet			30.40		43.43	16.32	266%
Redding			7.04		10.05	5.51	182%
Shasta Dam			19.47		27.82	10.87	256%
Weaverville			14.73		21.04	6.85	307%
McCloud RS			14.83				
Mt. Shasta			10.06				
Klamath Falls			3.66				
Medford			6.60		9.94	3.32	299%

Bold = KNF station
Italics = private station
Underlined = from NCDC Tech. Rpt [TR 97-01]
9.72 = missing Jan 1, 2, 3, data, extraplolated using Ft. Jones & Callahan data
21.28 '= extrapolated using average % of 'storm' total [12/20 - 1/3] to Dec tota; = 69%, see above

DAILY Precipitation Amounts from Local Sites

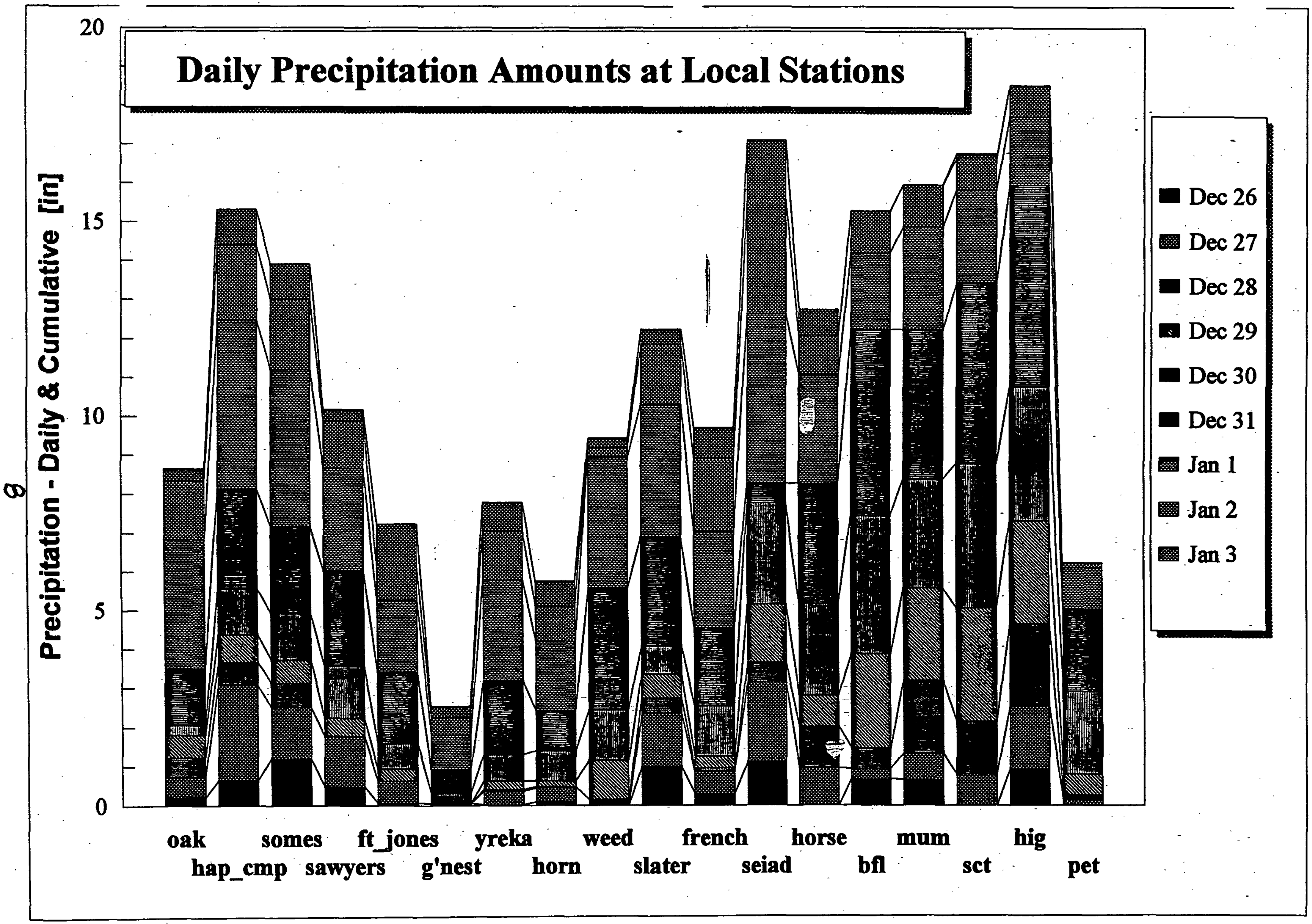
Focusing on time period of Storm & Flood Events: Dec 26 to Jan 3

Time	Local Sites													"Snow-pillow" Data*				
	Oak Knoll	Happy Camp	Somes Bar	Sawyers Bar	Fort Jones	Goosenest RS	Yreka CDF	Horn-brook	Weed	Slater Butte	French Creek	Seiad Creek	Horse Creek	Big Flat	Mumbo Basin	Scott Mtn	Highland Lake	Peterson Flat
Pre-Christmas:																		
[Dec 1 - Dec 25]	8.98	20.44	16.47	16.51	8.07	2.39	6.48	6.50	9.97	16.83	11.65	23.24	14.75	14.41	12.40	12.67	18.12	4.14
Storm Event: [daily amounts]																		
Dec 26	0.22	0.65	1.20	0.49	0.07	0.06	0.02	0.09	---	0.99	0.30	1.10	---	0.67	0.66	---	0.93	---
Dec 27	0.51	2.42	1.32	1.30	0.56	---	0.34	0.35	---	1.36	0.55	2.05	0.95	0.26	0.67	0.80	1.60	0.13
Dec 28	0.50	0.60	0.61	---	---	---	0.05	0.04	0.15	0.40	0.10	0.51	1.07	0.54	1.87	1.34	2.14	0.13
Dec 29	0.58	0.71	0.60	0.45	0.30	---	0.22	0.15	1.00	0.60	0.30	1.50	0.80	2.40	2.39	2.93	2.66	0.54
Dec 30	0.26	1.20	1.21	1.34	0.66	0.26	0.68	0.77	1.30	0.74	1.30	2.63	2.38	3.59	2.80	3.73	3.47	2.13
Dec 31	1.45	2.54	2.23	2.45	1.80	0.60	1.88	1.02	3.15	2.80	2.00	0.48	3.09	4.80	3.87	4.67	5.20	2.13
Jan 1	3.32	4.35	4.03	2.65	1.89	0.90	2.61	1.78	3.35	3.43	2.50	4.40	2.80	2.00	2.67	2.40	1.73	1.07
Jan 2	1.49	1.95	1.81	1.19	0.90	0.44	1.27	0.92	0.25	1.54	1.87	2.95	1.00	1.07	1.06	0.80	0.80	0.13
Jan 3	0.32	0.90	0.92	0.30	1.06	0.28	0.73	0.65	0.24	0.40	0.80	1.50	0.69	---		0.13	---	---
Flood Event:																		
3-day totals:	**6.26**	**8.84**	**8.07**	**6.29**	**4.59**	**1.94**	**5.76**	**3.72**	**6.75**	**7.77**	**6.37**	**7.83**	**6.89**	**10.39**	**9.34**	**10.80**	**10.40**	**5.33**
Event Totals:																		
[Dec 26 - Jan 3]	8.65	15.32	13.93	10.17	7.24	2.54	7.80	5.77	9.44	12.26	9.72	17.12	12.78	15.33	15.99	16.80	18.53	6.26

* Snow survey sites operated by CA Dept of Water Resources. These stations contain electronic equipment that measures snow water content, precipitation, and air temperature. Most transmit this data on an hourly basis.

These sites are located in the Trinity River upper basin, generally north of Trinity Lake.

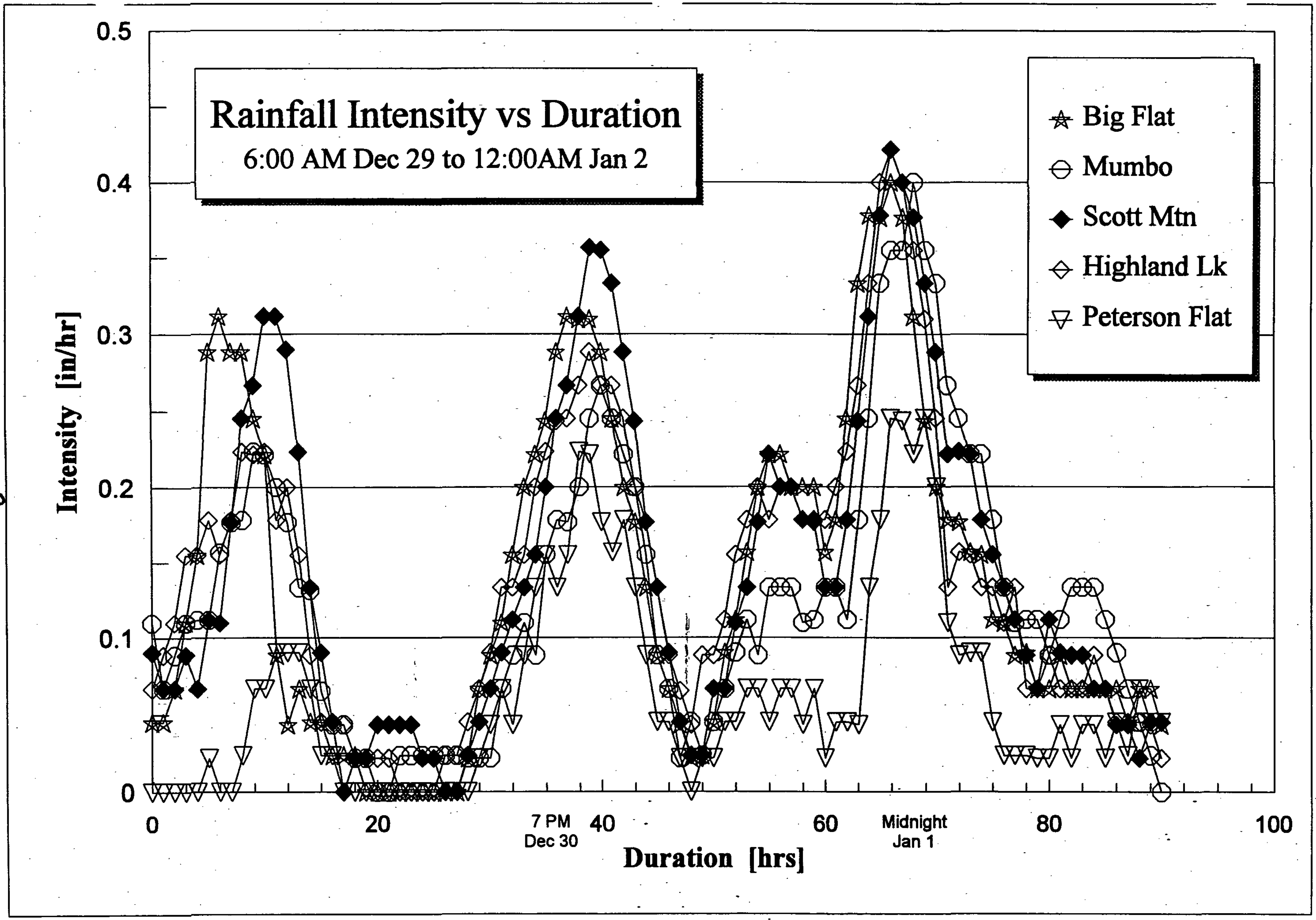
Although set up to monitor snow conditons in the Trinity Basin, the Big Flat, Scott Mtn, Peterson Flat, and Middle Boulder sites lie along the Trinity - Scott divide.



DAI_PLOT.WK4

Figure 2B

04/23/97



6

4_HR.WK4 Figure 2C 04/24/97

Peak Flows from Gauging Stations: 22-Jan-98

Station Name:	Klamath River below Irongate	Shasta River near Yreka	Scott River below Ft Jones	Klamath River at Seiad Valley	Indian Creek nr Happy Camp	Salmon River nr Somes Bar	Klamath River at Orleans	Trinity River abv Coffee Creek
General:								
USGS Station #:	11516530	11517500	11519500	11520500	11521500	11522500	11523000	11523200
Drainage area [sm]:	4,630	793	653	6,940	120	751	8,475	149
Gage datum [ele, ft]:	2,162.44	2,000.00	2,623.80	1,320.00	1,198.37	482.97	353.98	2,536.93
Base discharge [cfs]:		630	2,700	10,000	3,100	10,000	40,000	2,300
Years of recorded data:	38	62	56	60	46	73	70	41
Average annual peak	8,347	2,255	10,228	29,990	8,136	25,388	83,814	7,080
Median annual peak	7,235	1,380	7,095	19,650	7,135	21,000	65,600	5,580
1997 Flood Event:								
Event peak flows [cfs]:	**20,500**	**11,400**	**34,000**	**117,000**	**21,200**	**91,000**	**272,000**	**20,400**
Date:	Jan 1	Jan 1	Jan 1	Jan 1	Jan 1	Jan 1	Jan 1	Jan 1
Time:	07:00 PM	06:30 PM	05:50 PM	10:30 PM	08:45 PM		04:45 PM	10:30 PM
Max recorded Q [1964*]:	29,400	21,500	54,600	165,000	39,000	133,000	307,000	26,500
1997 as % of Max [1964*]:	70%	53%	62%	71%	54%	68%	89%	77%
Ranking of 1997 flows:	2	2	4	4	3	2	4	3
Est. Recurrence Interval	19.5 yr	31.5 yr	14.4 yr	15.3 yr	15.7 yr	37.0 yr	17.8 yr	21.0 yr

* = except Trinity Rv station, where max was recorded in 1974

Peak Discharges for each Water Year at Gauging Station - with Recurrence Intervals

Rank	Indian Date	Indian Q [cfs]	Indian T [yrs]	Salmon Date	Salmon Q [cfs]	Salmon T [yrs]	Scott Date	Scott Q [cfs]	Scott T [yrs]	Klam Rv at Seiad Date	Klam Rv at Seiad Q [cfs]	Klam Rv at Seiad T [yrs]
01	12/22/64	39,000	47.00	12/22/64	133,000	74.00	12/22/64	54,600	57.00	12/23/64	165,000	61.00
02	12/21/55	23,000	23.50	01/01/97	91,000	37.00	12/22/55	38,500	28.50	01/16/74	126,000	30.50
03	01/15/74	17,200	15.67	12/22/55	84,000	24.67	01/16/74	36,700	19.00	12/22/55	122,000	20.33
04	03/02/72	15,000	11.75	01/16/74	63,500	18.50	01/01/97	34,300	14.25	01/01/97	117,000	15.25
05	12/30/96	14,900	9.40	03/02/72	56,900	14.80	12/20/81	25,500	11.40	12/20/81	71,500	12.20
06	01/12/59	14,400	7.83	01/18/71	51,700	12.33	01/24/70	20,700	9.50	01/01/26	65,000	10.17
07	12/19/81	11,100	6.71	01/02/27	49,000	10.57	01/18/71	16,300	8.14	01/24/70	56,000	8.71
08	01/17/71	11,100	6.71	01/18/53	45,900	9.25	01/19/53	16,000	7.13	03/03/72	55,800	7.63
09	01/26/70	10,800	5.22	01/22/70	42,600	8.22	02/18/86	15,800	6.33	01/19/53	55,200	6.78
10	01/12/80	10,800	5.22	12/19/81	41,300	7.40	03/03/72	14,800	5.70	01/17/71	51,800	6.10
11	95-00-00	10,200	4.27	02/18/86	39,100	6.73	02/25/58	14,000	5.18	02/18/86	43,100	5.55
12	02/26/57	10,200	4.27	12/02/62	37,100	6.17	12/03/62	13,500	4.75	01/14/80	41,400	5.08
13	01/26/83	9,970	3.62	01/29/58	34,400	5.69	12/14/77	13,300	4.38	95-00-00	38,870	4.69
14	12/02/62	9,570	3.36	95-00-00	33,000	5.29	95-00-00	13,300	4.38	02/25/58	38,800	4.36
15	02/18/86	9,420	3.13	12/28/45	33,000	5.29	01/13/80	13,100	3.80	12/02/62	35,100	4.07
16	01/08/90	8,830	2.94	01/07/48	32,500	4.63	02/23/68	12,800	3.56	12/15/77	29,300	3.81
17	02/23/68	8,600	2.76	02/23/68	32,100	4.35	02/02/52	10,600	3.35	12/17/82	29,000	3.59
18	02/17/12	8,430	2.61	12/14/77	31,700	4.11	02/05/51	10,400	3.17	03/19/75	26,900	3.39
19	11/25/77	8,390	2.47	01/12/80	30,600	3.89	01/27/83	9,460	3.00	12/31/13	26,500	3.21
20	01/29/58	8,100	2.35	12/11/37	27,000	3.70	01/22/43	8,870	2.85	02/02/52	25,400	3.05
21	02/08/60	8,100	2.35	02/08/60	25,900	3.52	01/08/48	8,800	2.71	02/26/57	25,000	2.90
22	11/22/88	7,390	2.14	12/16/82	25,700	3.36	12/29/45	8,410	2.59	12/14/83	24,500	2.77
23	01/28/67	7,250	2.04	02/05/51	25,500	3.22	03/19/75	8,400	2.48	02/04/25	23,700	2.65
24	01/06/66	7,020	1.96	11/22/88	24,400	3.08	02/08/60	8,220	2.38	02/23/68	23,400	2.54
25	02/10/61	6,540	1.88	02/17/12	23,800	2.96	02/11/61	7,560	2.28	02/21/21	21,800	2.44
26	1996[e]	5,800	1.81	01/06/66	23,600	2.85	03/17/93	7,430	2.19	96-00-00	20,930	2.35
27	11/12/84	5,780	1.74	12/31/13	23,500	2.74	02/26/57	7,210	2.11	02/13/54	20,900	2.26
28	12/02/80	5,780	1.74	02/26/57	22,700	2.64	96-00-00	7,150	2.04	03/18/93	20,900	2.26
29	01/11/79	5,700	1.62	02/02/52	22,500	2.55	01/21/69	6,980	1.97	01/20/64	20,100	2.10
30	12/10/87	5,510	1.57	12/27/42	22,400	2.47	01/29/67	6,880	1.90	03/10/89	19,700	2.03

Figure 4

Peak Discharges for each Water Year at Gauging Station - with Recurrence Intervals

	Indian			Salmon			Scott			Klam Rv at Seiad		
Rank	**Date**	**Q [cfs]**	**T [yrs]**	**Date**	**Q [cfs]**	**T [yrs]**	**Date**	**Q [cfs]**	**T [yrs]**	**Date**	**Q [cfs]**	**T [yrs]**
31	02/01/15	5,180	1.52	01/21/69	21,700	2.39	03/10/89	6,430	1.84	01/29/67	19,600	1.97
32	03/17/93	4,860	1.47	01/14/36	21,600	2.31	01/20/64	5,860	1.78	02/08/60	19,600	1.97
33	02/13/84	4,380	1.42	02/28/40	21,200	2.24	03/10/54	5,650	1.73	02/11/61	17,000	1.85
34	02/02/87	4,010	1.38	03/26/28	21,200	2.24	12/17/41	5,500	1.68	02/10/16	16,600	1.79
35	12/19/61	3,390	1.34	12/02/41	21,100	2.11	01/12/59	5,470	1.63	01/21/69	16,000	1.74
36	12/10/68	3,180	1.31	01/29/67	21,000	2.06	01/08/90	5,170	1.58	02/09/19	15,300	1.69
37	11/15/75	3,180	1.31	01/12/59	21,000	2.06	12/15/83	4,700	1.54	01/06/66	15,000	1.65
38	01/02/14	3,150	1.24	03/17/93	20,800	1.95	12/10/87	4,610	1.50	02/03/15	14,600	1.61
39	11/09/12	2,830	1.21	01/08/90	20,600	1.90	01/06/66	4,580	1.46	11/12/84	13,800	1.56
40	01/20/64	2,810	1.18	03/18/75	20,400	1.85	01/11/79	3,940	1.43	01/08/90	12,900	1.53
41	03/25/75	2,790	1.15	12/10/87	20,200	1.80	03/05/87	3,920	1.39	01/12/59	11,000	1.49
42	03/04/91	2,770	1.12	11/24/53	19,500	1.76	02/17/81	3,450	1.36	01/16/73	10,300	1.45
43	12/18/72	2,690	1.09	04/13/37	19,400	1.72	11/12/84	3,420	1.33	12/06/75	10,300	1.45
44	02/21/92	2,460	1.07	03/19/32	19,300	1.68	02/14/45	3,240	1.30	05/14/17	9,760	1.39
45	12/08/93	1,850	1.04	01/20/64	19,300	1.68	11/15/75	3,120	1.27	05/18/22	9,760	1.39
46	09/28/77	848	1.02	96-00-00	17,770	1.61	12/22/72	2,930	1.24	01/11/79	9,310	1.33
47				12/14/83	17,600	1.57	02/12/47	2,740	1.21	04/26/13	9,190	1.30
48				02/01/15	17,400	1.54	04/17/92	2,600	1.19	12/10/87	8,720	1.27
49				02/11/61	16,700	1.51	12/20/61	2,540	1.16	12/21/61	7,910	1.24
50				02/13/45	15,700	1.48	03/19/50	2,520	1.14	12/28/22	7,250	1.22
51				01/11/79	14,700	1.45	05/13/49	2,470	1.12	02/14/81	7,250	1.22
52				11/12/84	14,600	1.42	03/05/91	1,830	1.10	03/06/87	6,820	1.17
53				12/19/61	13,100	1.40	05/21/55	1,480	1.08	12/01/17	6,380	1.15
54				12/02/80	12,900	1.37	05/07/44	1,350	1.06	02/09/24	6,170	1.13
55				03/17/50	12,300	1.35	05/08/94	861	1.04	05/21/55	5,990	1.11
56				01/13/73	10,900	1.32	06/10/77	290	1.02	03/05/91	4,950	1.09
57				03/28/34	10,600	1.30				04/17/92	4,600	1.07
58				11/15/75	10,500	1.28				12/22/19	3,650	1.05
59				04/17/92	8,660	1.25				11/15/76	3,630	1.03
60				11/19/46	8,120	1.23				12/08/93	2,970	1.02

Figure 4

Peak Discharges for each Water Year at Gauging Station - with Recurrence Intervals

	Indian			Salmon			Scott			Klam Rv at Seiad		
Rank	**Date**	**Q [cfs]**	**T [yrs]**	**Date**	**Q [cfs]**	**T [yrs]**	**Date**	**Q [cfs]**	**T [yrs]**	**Date**	**Q [cfs]**	**T [yrs]**
61				12/21/40	8,100	1.21						
62				06/10/33	7,750	1.19						
63				03/13/39	7,660	1.17						
64				03/12/87	7,560	1.16						
65				12/31/54	7,500	1.14						
66				03/18/31	7,250	1.12						
67				02/22/49	6,730	1.10						
68				04/29/35	5,880	1.09						
69				03/04/91	5,830	1.07						
70				03/10/44	4,420	1.06						
71				05/21/29	3,770	1.04						
72				12/08/93	3,210	1.03						
73				09/29/77	1,810	1.01						

Summary Statistics:

		Indian		Salmon		Scott		Klam Rv at Seiad	
		Q [cfs]	**T [yrs]**	**Q [cfs]**	**T [yrs]**	**Q [cfs]**	**T [yrs]**	**Q [cfs]**	**T [yrs]**
count		46	46	73	73	56	56	60	60
max		39,000	47	133,000	74	54,600	57	165,000	61
min		848	1.02	1,810	1.01	290	1.02	2,970	1.02
mean	**[m]**	8,136	4.55	25,388	4.94	10,228	4.69	29,990	4.76
median		7,135	2.00	21,000	2.00	7,095	2.00	19,650	2.00
variance		41,911,543	58.92	459,826,250	99.30	108,813,448	73.69	1,086,113,419	79.66
std dev	**[sd]**	6,474	7.68	21,444	9.97	10,431	8.58	32,956	8.93
stand err		955	1.13	2,510	1.17	1,394	1.15	4,255	1.15
skewness		2.6583	4.1909	2.5058	5.2603	2.2570	4.6320	2.2704	4.7892

Figure 4

Peak Discharges for each Water Year at Gauging Station - with Recurrence Intervals

Rank	Date	Indian Q [cfs]	Indian T [yrs]	Date	Salmon Q [cfs]	Salmon T [yrs]	Date	Scott Q [cfs]	Scott T [yrs]	Date	Klam Rv at Seiad Q [cfs]	Klam Rv at Seiad T [yrs]
kurtosis		9.6977	19.2206		8.4463	31.2766		5.5951	23.8050		5.1977	25.5812
correlation w/ Qmax			0.9457			0.9074			0.9071			0.8912
covariance w/ Qmax			45,973			191,247			79,775			257,775
coef of var		79.57	168.53		84.46	201.59		101.98	182.89		109.89	187.43
[100*sd/m]												
regression f Q & T			Q = [7,721] ln (T)		Q = [24,571] ln (T)			Q = [10,942] ln (T)			Q = [33,068] ln (T)	
COD*			0.8735		0.9398			0.9495			0.9495	
corrlelatio *			0.9468		0.9697			0.9756			0.9756	
stand dev o para*			259.5		500.3			238.8			238.8	

* = 'goodness' of fit parameters

Note:

Q = maximum peak flow for a given water year [Oct 1 to Oct 1]

T = Predicted Recurrence Interval, calculated using the equation $T = (n + 1) / r$,

where n = years of data [i.e., # of yearsrecorded annual peak flow measurements]

r = rank of associated peak flow [Q] [e.g., the largest recorded peak flow is ranked 1, etc.]

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Peak Discharges for each Water Year at Gauging Station - with Recurrence Intervals

Rank	Shasta			Trinity			Klam Rv at Orleans			Klam Rv at Irongate		
	Date	Q [cfs]	T [yrs]	Date	Q [cfs]	T [yrs]	Date	Q [cfs]	T [yrs]	Date	Q [cfs]	T [yrs]
01	12/22/64	21,500	63.00	01/16/74	26,500	63.00	64-12-22	307,000	71.00	64-12-22	29,400	39.00
02	01/01/97	10,900	31.50	12/22/64	20,800	31.50	74-01-16	279,000	35.50	01/01/97	20,500	19.50
03	01/16/74	7,260	21.00	12/31/96	20,400	21.00	86-02-18	278,000	23.67	82-02-21	18,700	13.00
04	12/22/55	6,090	15.75	11/16/81	14,500	15.75	01/01/97	258,000	17.75	74-01-16	18,700	13.00
05	01/27/70	5,570	12.60	12/21/69	13,600	12.60	55-12-22	202,000	14.20	72-03-03	17,000	7.80
06	12/20/81	5,460	10.50	02/24/58	12,800	10.50	81-12-20	201,000	11.83	70-01-26	14,900	6.50
07	01/29/58	3,780	9.00	12/22/55	12,800	10.50	82-12-17	198,000	10.14	86-02- 01	13,900	5.57
08	01/20/64	3,720	7.88	05/31/93	11,300	7.88	72-03-03	191,000	8.88	93-03-24	11,100	4.88
09	01/21/69	3,170	7.00	01/12/59	10,800	7.00	71-01-17	190,000	7.89	83-12-17	10,900	4.33
10	01/13/80	3,070	6.30	03/09/89	10,100	6.30	70-01-24	175,000	7.10	83-03-15	10,800	3.90
11	95-00-00	2,930	5.73	95-00-00	9,204	5.73	27-02-21	141,000	6.45	71-03-28	10,800	3.90
12	02/19/86	2,840	5.25	10/12/62	8,990	5.25	53-01-18	137,000	5.92	01/01/95	10,609	3.25
13	03/02/83	2,840	5.25	01/14/78	8,250	4.85	80-01-12	121,000	5.46	62-12-02	10,600	3.00
14	03/03/72	2,700	4.50	02/14/86	8,150	4.50	77-12-14	111,000	5.07	89-03-11	10,200	2.79
15	03/18/75	2,630	4.20	01/26/83	6,380	4.20	01/01/95	110,000	4.73	69-04-04	9,090	2.60
16	01/18/53	2,520	3.94	05/27/90	6,330	3.94	68-02-23	109,000	4.44	80-01-13	8,580	2.44
17	02/29/40	2,440	3.71	02/11/61	6,270	3.71	67-01-29	98,600	4.18	75-03-18	8,260	2.29
18	12/02/62	2,410	3.50	03/05/87	5,850	3.50	45-12-28	97,000	3.94	85-04-11	7,970	2.17
19	01/17/78	2,140	3.32	11/19/66	5,720	3.32	58-01-29	96,800	3.74	77-12-14	7,580	2.05
20	03/01/41	2,100	3.15	01/22/81	5,590	3.15	66-01-06	96,200	3.55	67-05-14	6,890	1.95
21	03/12/57	2,000	3.00	02/18/80	5,580	3.00	48-01-07	92,200	3.38	93-11-01	6,558	1.86
22	01/28/54	1,980	2.86	96-00-00	4,960	2.86	62-12-02	85,300	3.23	60-12-01	6,030	1.77
23	02/02/52	1,940	2.74	05/12/69	4,640	2.74	57-02-26	79,200	3.09	75-12-05	5,900	1.70
24	03/23/38	1,930	2.63	11/14/63	4,520	2.63	69-01-21	77,800	2.96	01/01/96	5,594	1.63
25	02/09/60	1,740	2.52	01/22/72	3,920	2.52	83-12-15	76,800	2.84	65-11-16	4,940	1.56
26	12/30/83	1,710	2.42	12/06/87	3,890	2.42	75-03-18	74,800	2.73	64-01-20	4,850	1.50
27	02/05/51	1,700	2.33	05/14/75	3,770	2.33	50-10-29	74,400	2.63	72-12-24	4,790	1.44
28	01/20/93	1,610	2.25	02/08/60	3,750	2.25	59-01-12	73,700	2.54	62-04-07	3,710	1.39
29	96-00-00	1,580	2.17	02/23/68	3,650	2.17	37-12-11	73,700	2.54	68-02-23	3,470	1.34
30	03/26/71	1,450	2.10	04/17/92	3,630	2.10	60-02-08	70,700	2.37	90-01-09	3,360	1.30

Figure 4

Peak Discharges for each Water Year at Gauging Station - with Recurrence Intervals

Rank	Shasta			Trinity			Klam Rv at Orleans			Klam Rv at Irongate		
	Date	Q [cfs]	T [yrs]	Date	Q [cfs]	T [yrs]	Date	Q [cfs]	T [yrs]	Date	Q [cfs]	T [yrs]
31	12/05/66	1,390	2.03	05/08/71	3,270	2.03	40-02-28	70,300	2.29	87-03-18	3,350	1.26
32	12/01/60	1,370	1.97	12/22/72	2,840	1.97	43-01-21	68,400	2.22	79-01-02	3,320	1.22
33	01/05/66	1,310	1.91	11/10/83	2,840	1.97	01/01/93	68,000	2.15	76-11-14	3,120	1.18
34	12/18/41	1,270	1.85	04/01/66	2,780	1.85	52-02-02	67,600	2.09	81-03-31	3,120	1.18
35	01/07/48	1,060	1.80	05/05/79	2,740	1.80	88-11-22	66,800	2.03	88-02-28	2,890	1.11
36	01/15/36	1,000	1.75	11/12/84	2,630	1.75	84-11-12	64,400	1.97	90-12-28	2,430	1.08
37	01/19/50	924	1.70	04/14/62	2,400	1.70	28-03-26	60,300	1.92	01/01/94	1,833	1.05
38	02/14/45	847	1.66	05/08/76	1,730	1.66	36-01-15	60,000	1.87	91-12-02	1,000	1.03
39	01/04/46	823	1.62	03/04/91	1,650	1.62	64-01-20	59,900	1.82			
40	12/21/61	784	1.58	12/10/93	1,480	1.58	37-04-14	59,500	1.78			
41	11/22/88	745	1.54	09/28/77	555	1.54	87-12-10	58,800	1.73			
42	11/28/84	728	1.50				01/01/96	58,000	1.69			
43	01/08/90	725	1.47				41-12-02	58,000	1.69			
44	02/23/68	705	1.43				61-02-11	57,600	1.61			
45	02/10/49	568	1.40				53-11-23	57,500	1.58			
46	02/26/76	552	1.37				90-01-08	56,700	1.54			
47	04/15/37	500	1.34				32-03-19	51,600	1.51			
48	02/22/59	492	1.31				45-03-13	48,400	1.48			
49	09/06/91	440	1.29				79-01-11	48,200	1.45			
50	01/11/79	436	1.26				50-03-17	41,900	1.42			
51	12/03/80	428	1.24				80-12-02	40,300	1.39			
52	02/13/47	403	1.21				72-12-22	38,400	1.37			
53	01/16/88	352	1.19				61-12-19	38,300	1.34			
54	12/19/72	344	1.17				40-12-21	36,500	1.31			
55	01/07/35	331	1.15				75-11-15	35,100	1.29			
56	01/02/87	312	1.13				87-03-12	32,600	1.27			
57	03/27/39	303	1.11				49-02-22	30,200	1.25			
58	11/15/76	240	1.09				54-12-31	26,900	1.22			
59	02/16/92	233	1.07				46-11-19	26,700	1.20			
60	11/13/54	228	1.05				38-12-03	26,500	1.18			

Figure 4

Peak Discharges for each Water Year at Gauging Station - with Recurrence Intervals

	Shasta			Trinity			Klam Rv at Orleans			Klam Rv at Irongate		
Rank	**Date**	**Q [cfs]**	**T [yrs]**	**Date**	**Q [cfs]**	**T [yrs]**	**Date**	**Q [cfs]**	**T [yrs]**	**Date**	**Q [cfs]**	**T [yrs]**
61	05/07/94	218	1.03				91-03-04	25,400	1.16			
62	01/03/34	166	1.02				92-04-17	22,200	1.15			
63							34-03-28	21,300	1.13			
64							33-06-09	19,900	1.11			
65							01/01/94	19,000	1.09			
66							35-04-16	18,000	1.08			
67							31-03-18	17,600	1.06			
68							28-12-29	13,700	1.04			
69							44-03-10	13,500	1.03			
70							77-09-29	7,800	1.01			
71												
72												
73												

17

Summary Statistics:

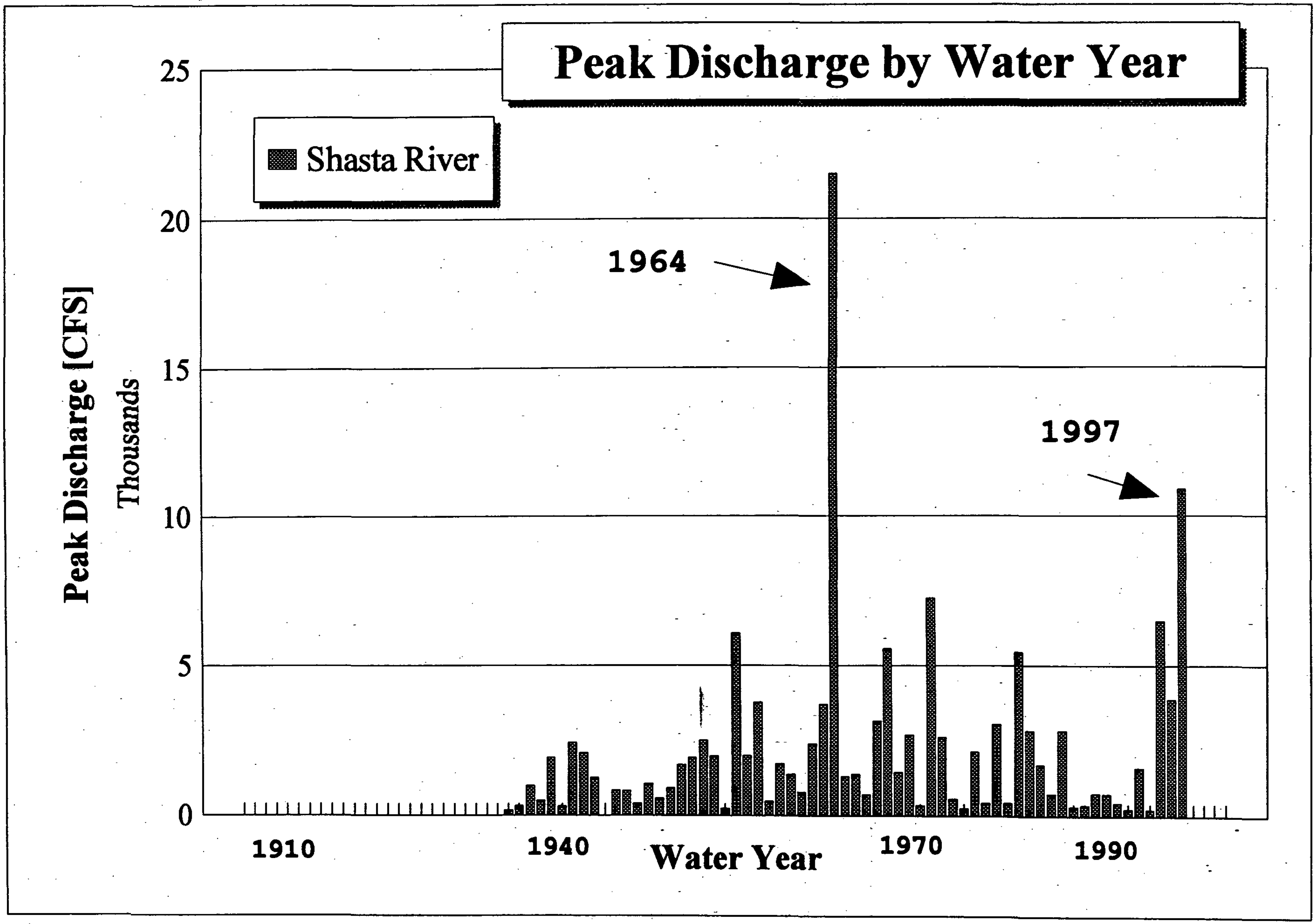
	Shasta		Trinity		Klam Rv at Orleans		Klam Rv at Irongate	
	Q [cfs]	**T [yrs]**	**Q [cfs]**	**T [yrs]**	**Q [cfs]**	**T [yrs]**	**Q [cfs]**	**T [yrs]**
count	62	62	41	41	70	70		
max	21,500	63	26,500	42	307,000	70		
min	166	1.02	555	1.02	7,800	1.00		
mean [m]	2,255	4.79	7,080	4.43	83,814	5		
median	1,380	2.00	5,580	2.00	65,600	2		
variance	10,240,174	82.68	32,745,900	51.66	***********	95		
std dev [sd]	3,200	9.09	5,722	7.19	68,282	10		
stand err	406	1.15	894	1.12	8,161	1		
skewness	4.0132	4.8625	1.6061	3.9608	1.6003	5		

Peak Discharges for each Water Year at Gauging Station - with Recurrence Intervals

Rank	Shasta Date	Shasta Q [cfs]	Shasta T [yrs]	Trinity Date	Trinity Q [cfs]	Trinity T [yrs]	Klam Rv at Orleans Date	Klam Rv at Orleans Q [cfs]	Klam Rv at Orleans T [yrs]	Klam Rv at Irongate Date	Klam Rv at Irongate Q [cfs]	Klam Rv at Irongate T [yrs]
kurtosis		19.9521	26.4432		2.3646	16.9611		2.0433	30			
correlation			0.9811			0.8814		0.7899				
covariance			28,086			35,367		517,528				
coef of var		141.89	189.67		80.82	162.13						
[100*sd/m]												

regression	Q = [2,720] ln (T)			Q = [6,962] ln (T)			Q = [???] ln (T)	
COD*	0.7748			0.9745				
corrlelatio	0.8978			0.9925				
stand dev o	146.1			110.3				

Figure 4



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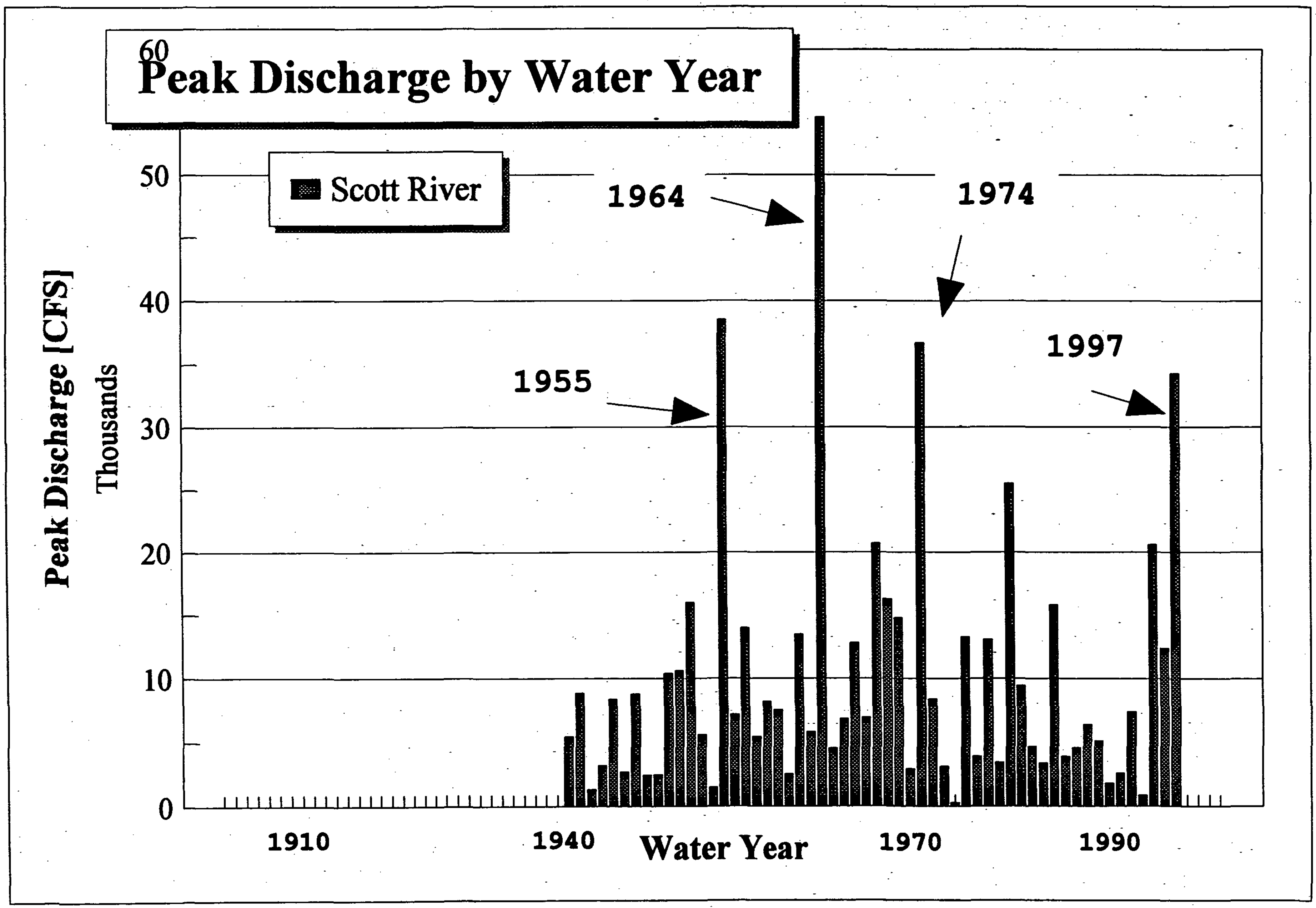
FLOWHIST.WK4

Figure 5A

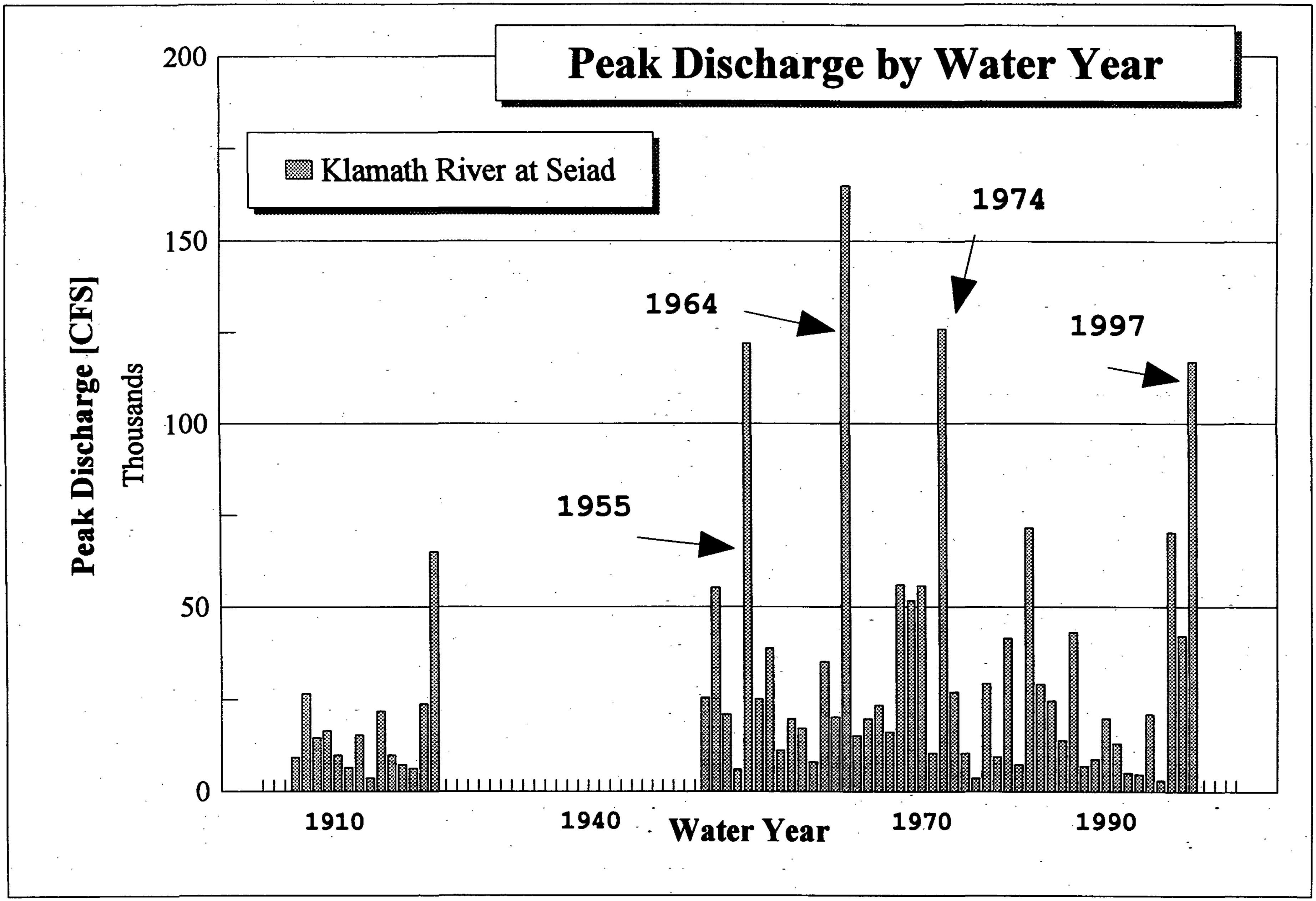
04/23/97



FLOWHIST.WK4

Figure 5B

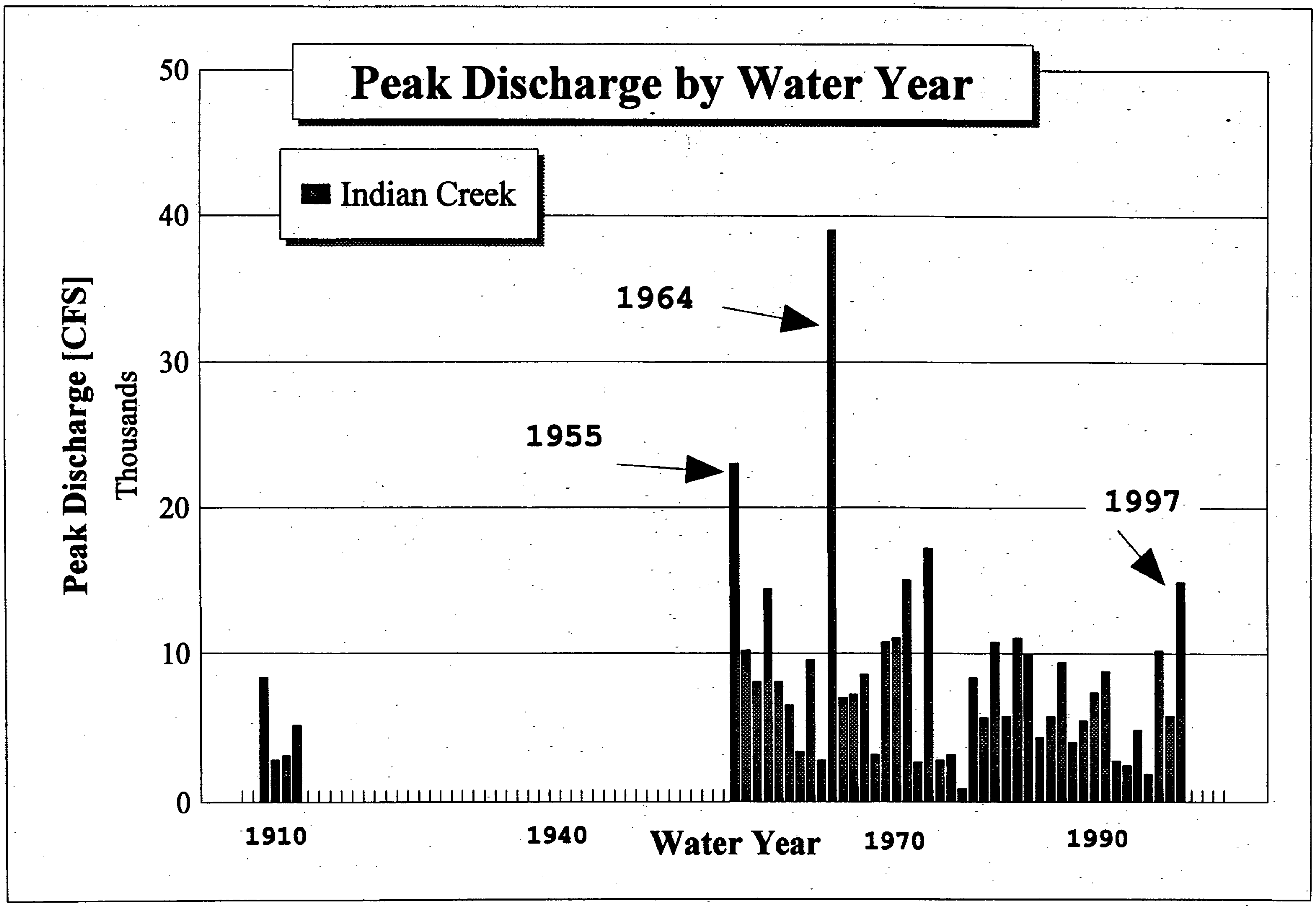
04/23/97



FLOWHIST.WK4

Figure 5C

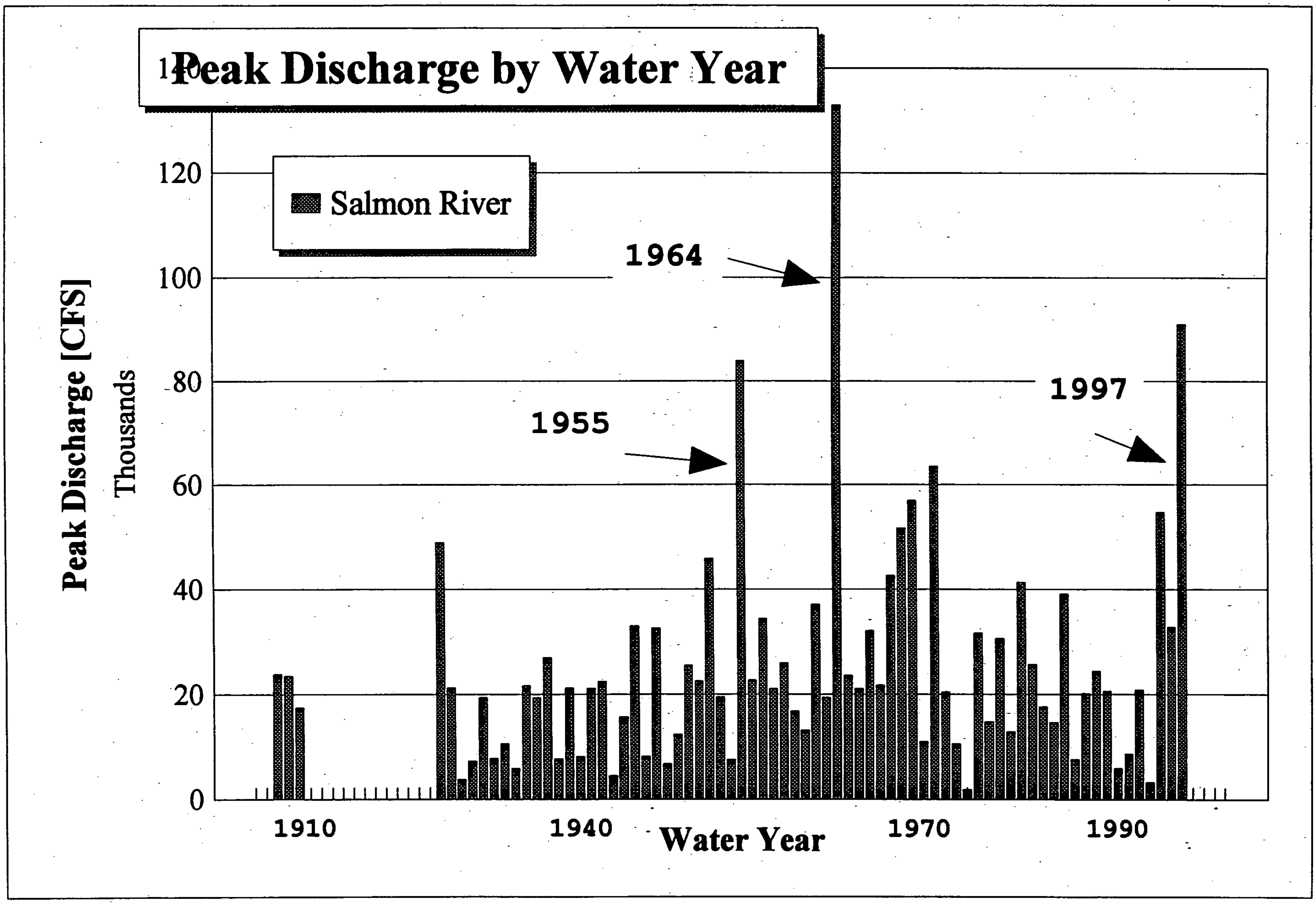
04/23/97



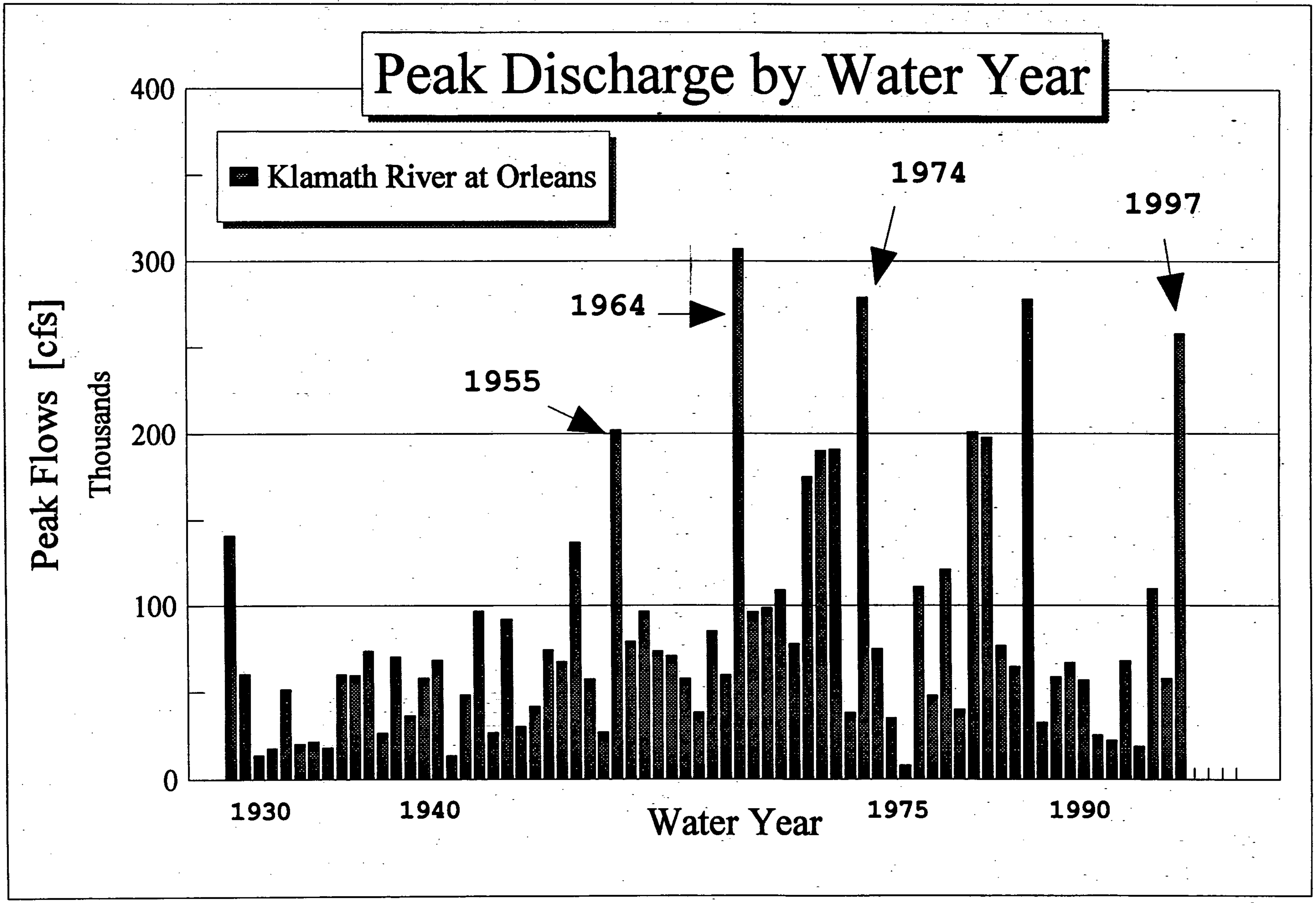
FLOWHIST.WK4

Figure 5D

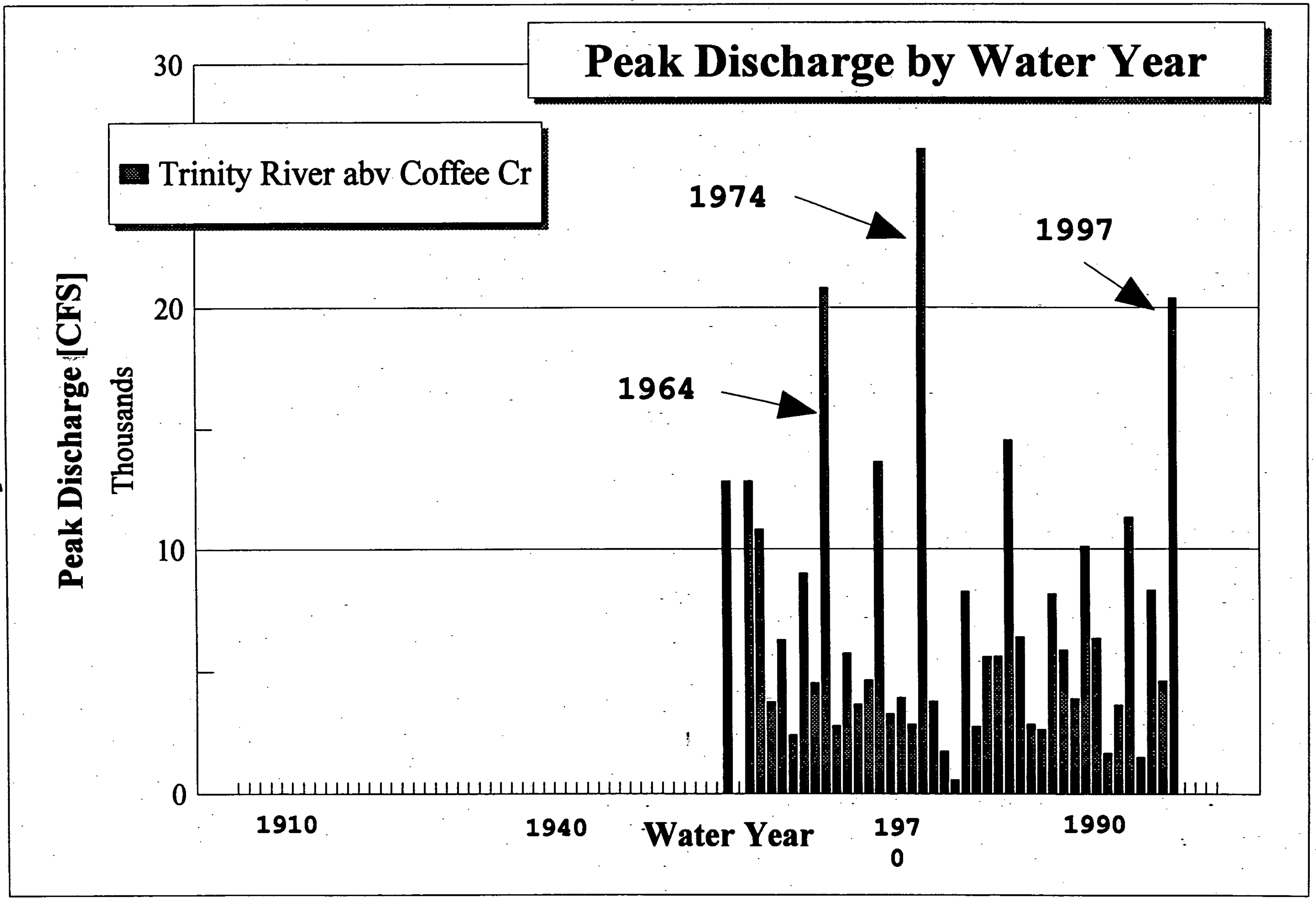
04/23/97



FLOWHIST.WK4 Figure 5E 04/23/97



FLOWHIST.WK4 Figure 5F 04/23/97



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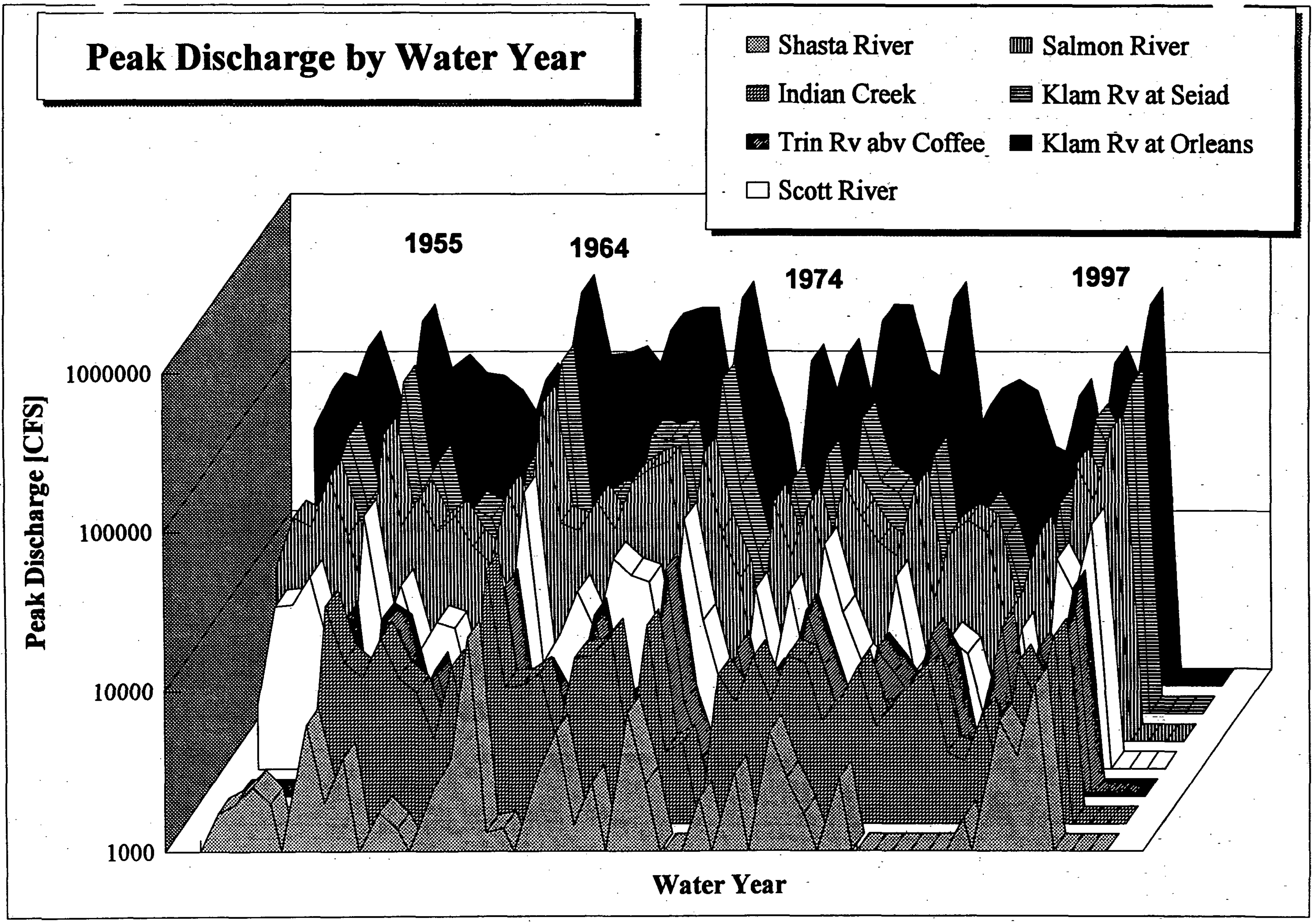
FLOWHIST.WK4

Figure 5G

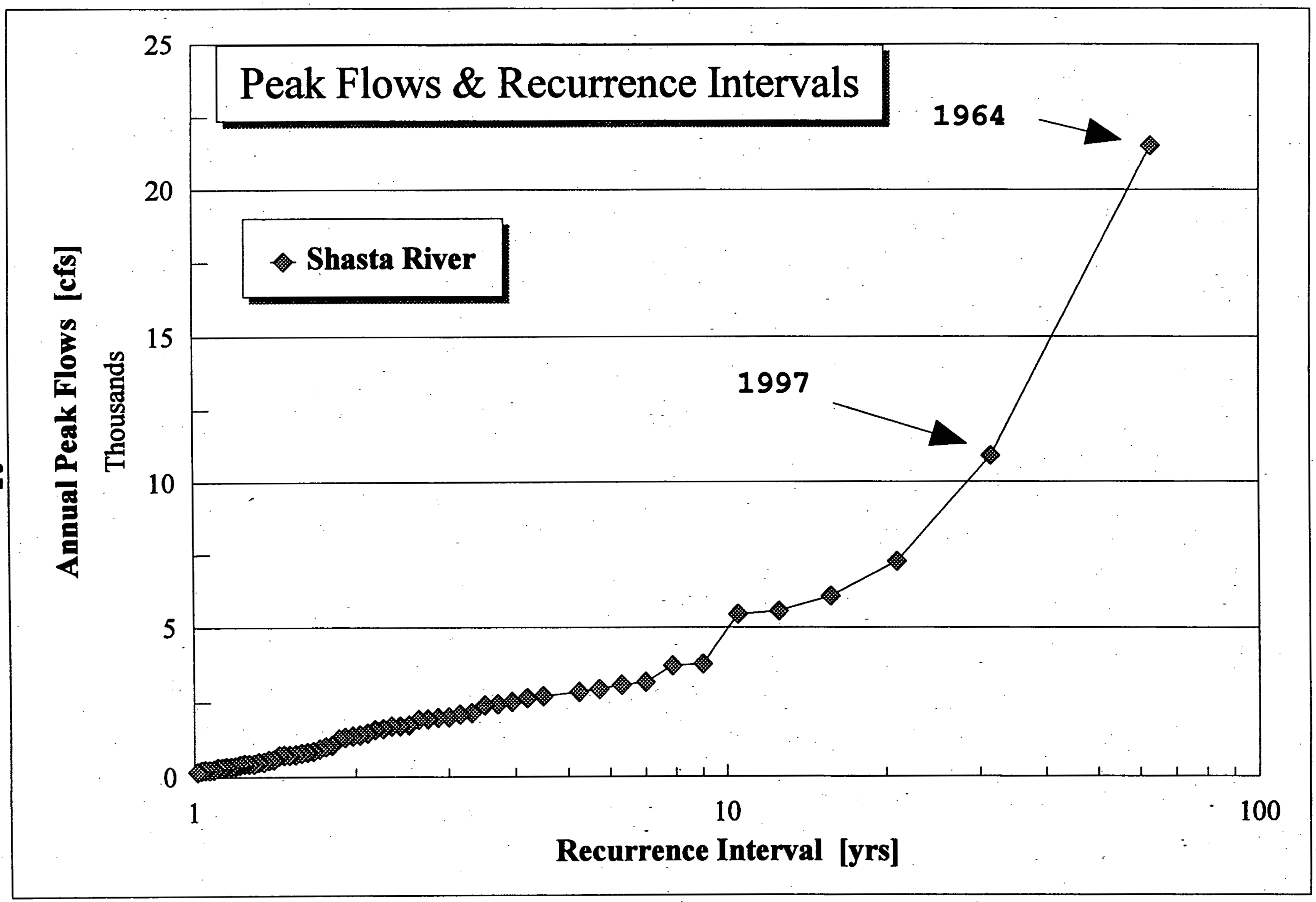
04/23/97



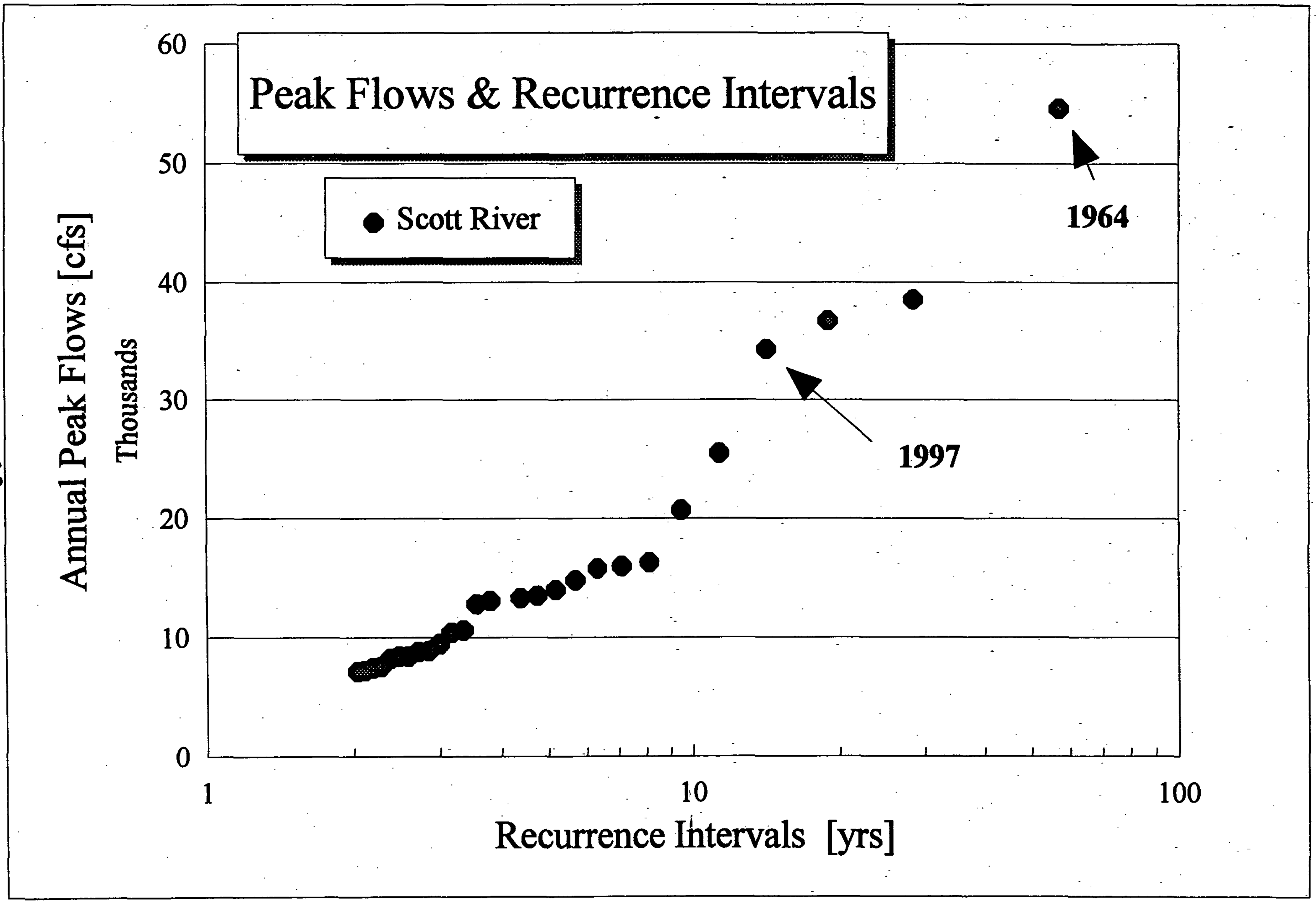
FLOWHIST.WK4

Figure 5

04/23/97



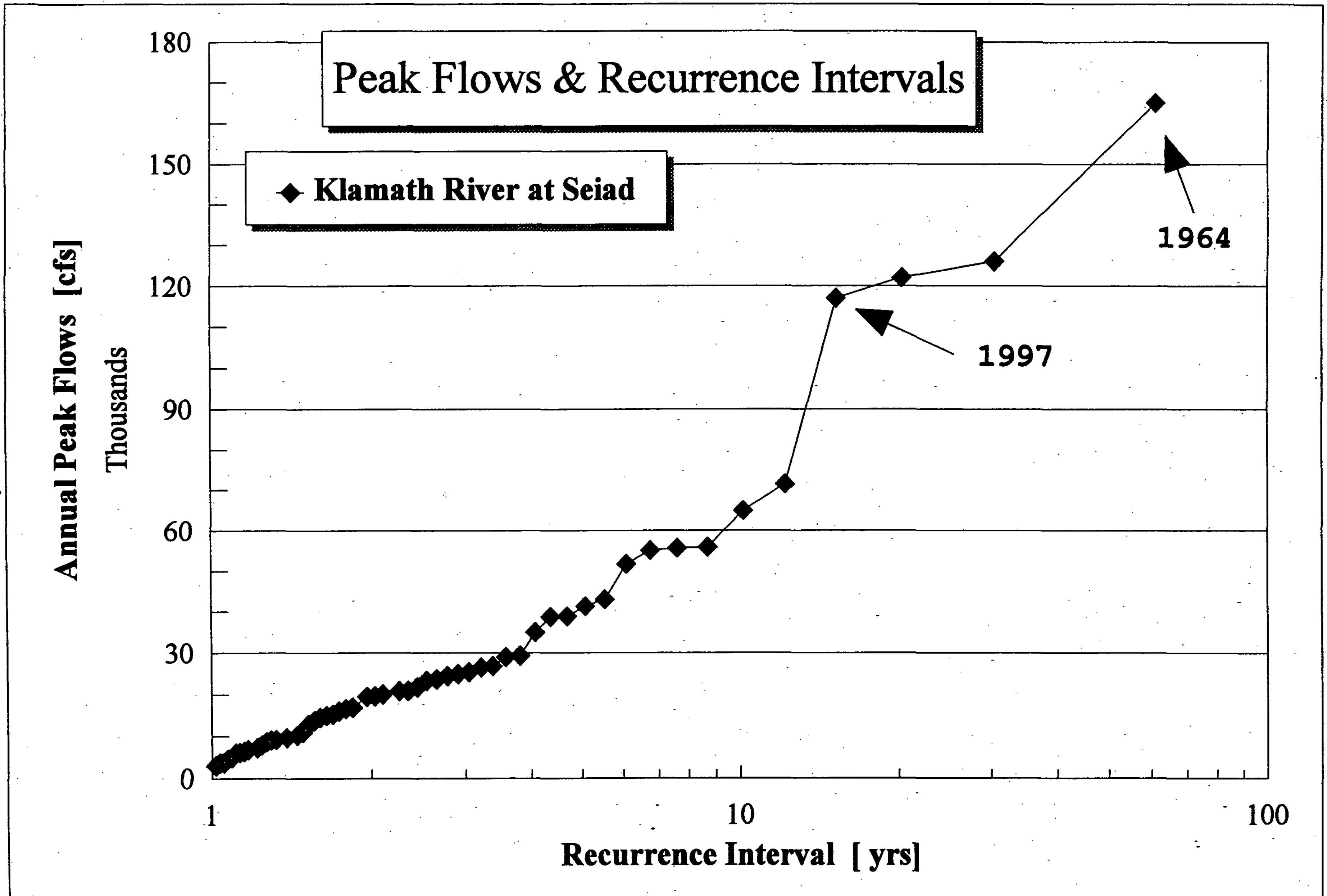
RECURREN.WK4 Figure 6A 04/23/97



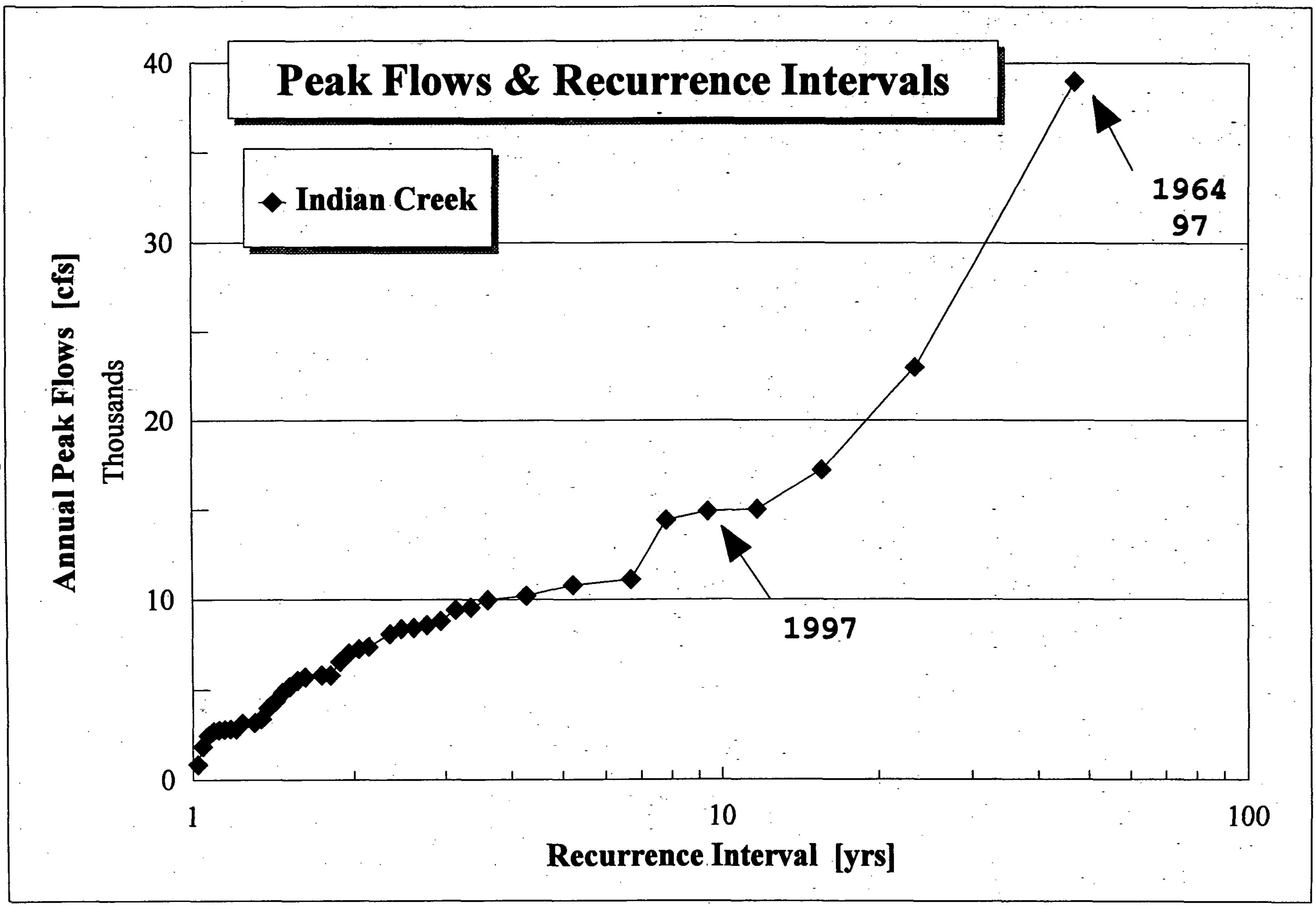
RECURREN.WK4

Figure 6B

04/23/97



RECURREN.WK4 Figure 6C 04/23/97


Peak Flows & Recurrence Intervals
Indian Creek
1964
97
1997
Annual Peak Flows [cfs]
Thousands
40
30
20
10
0
1
10
100
Recurrence Interval [yrs]

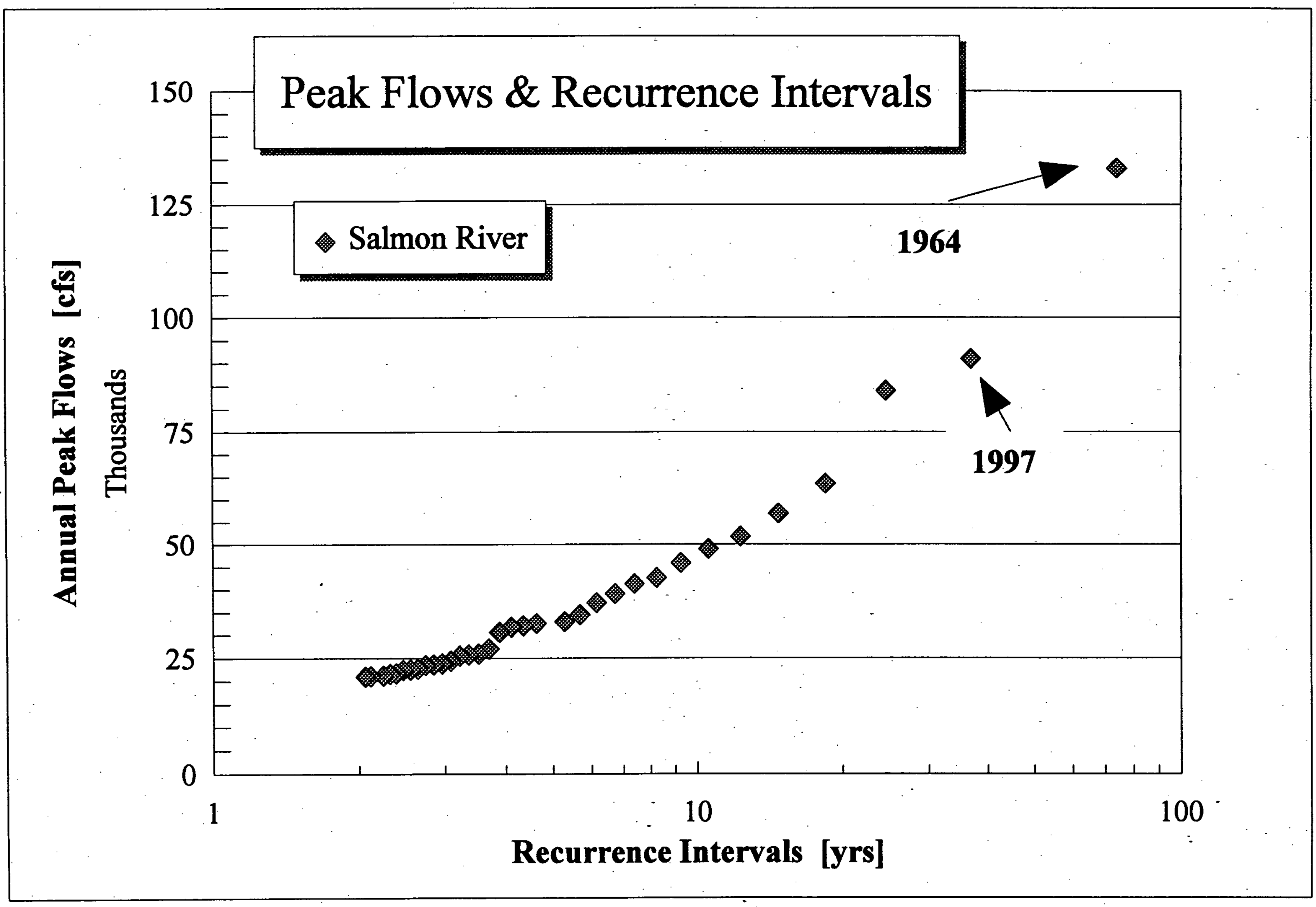
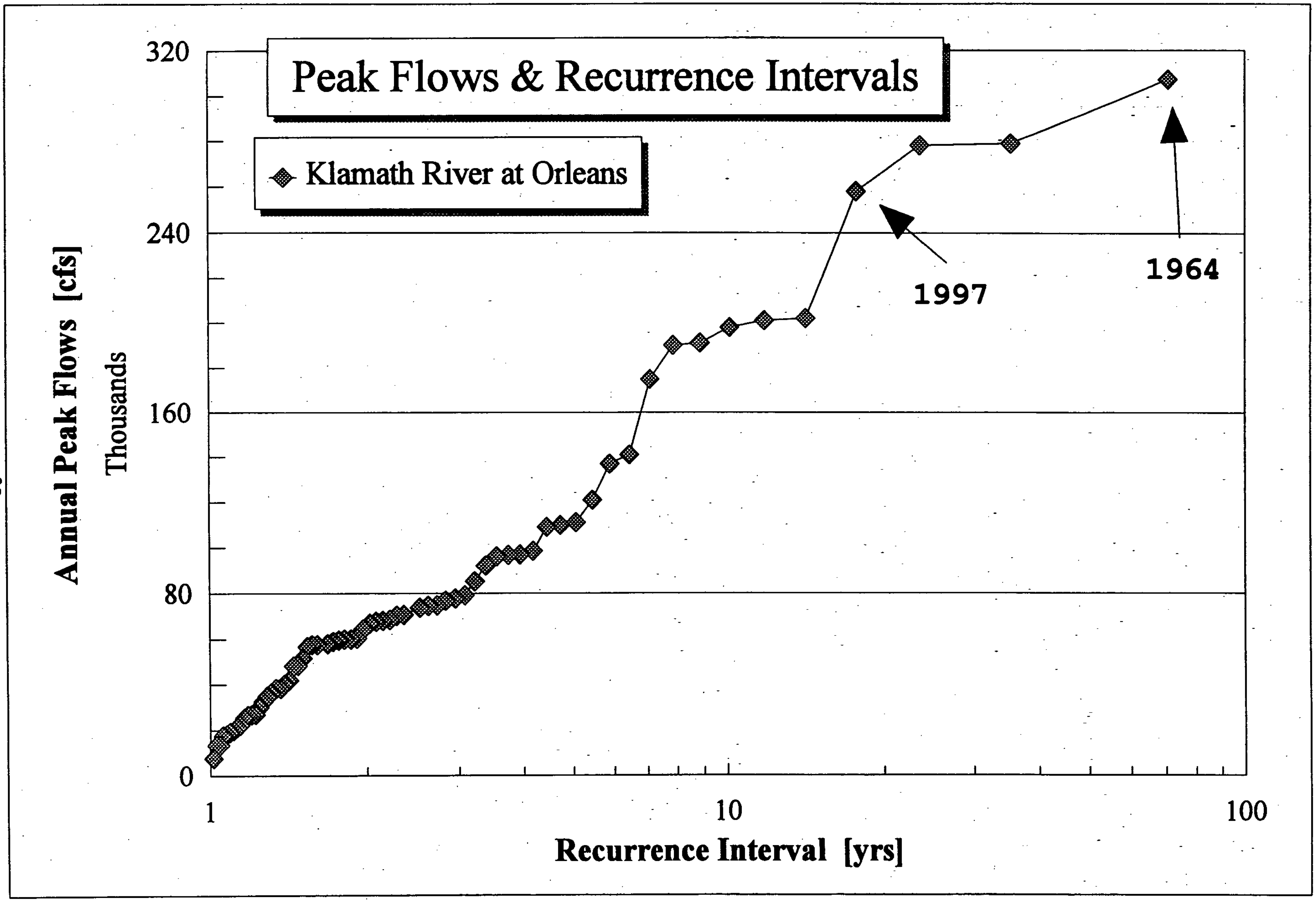
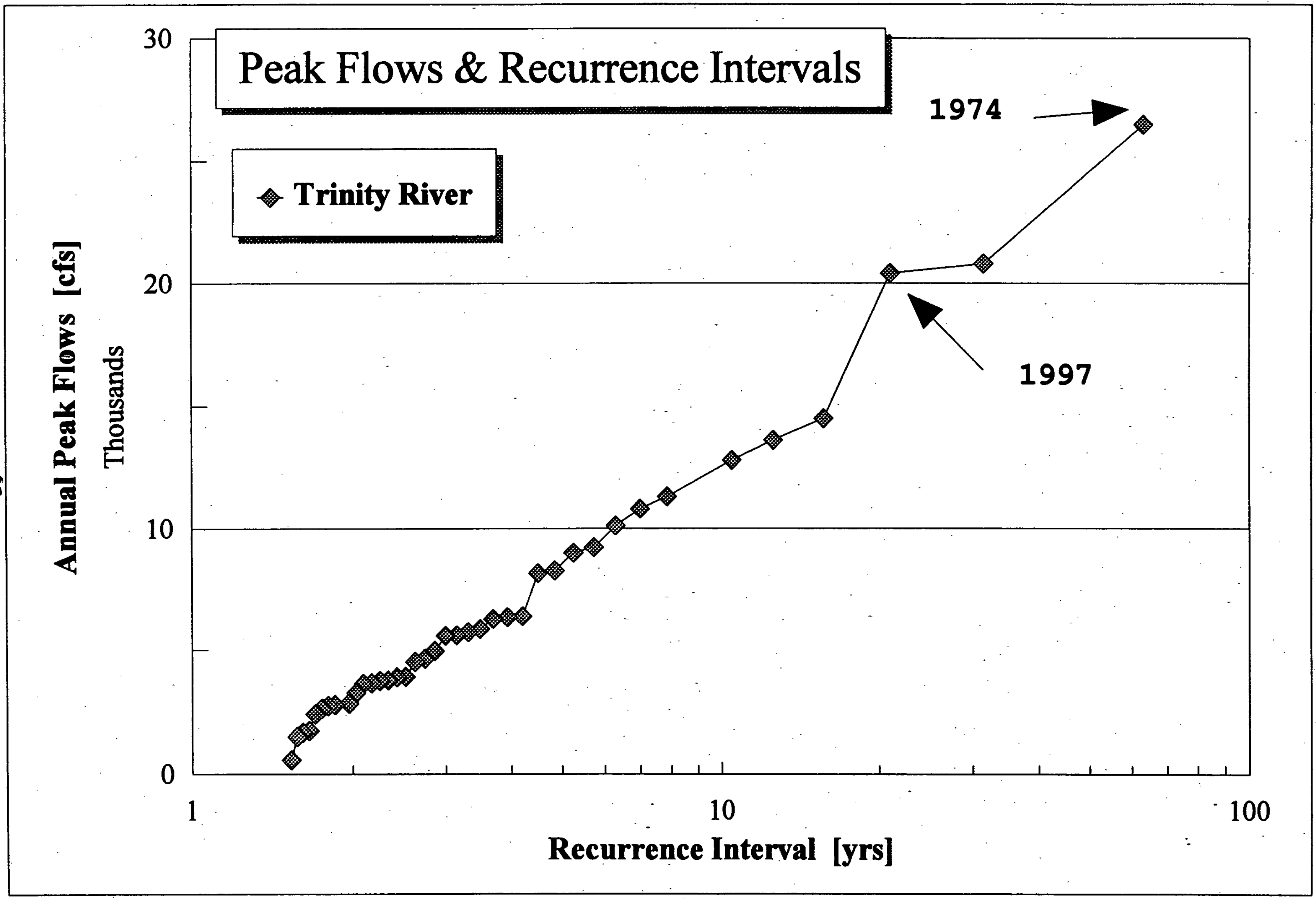

Peak Flows & Recurrence Intervals
Salmon River
Annual Peak Flows [cfs]
Thousands
150
125
100
75
50
25
0
1
10
100
Recurrence Intervals [yrs]
1964
1997

Figure 6E



RECURREN.WK4 Figure 6F 04/23/97



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RECURREN.WK4 Figure 6G 04/23/97

Summary Characterization of ERFO Sites

[by Terrane, by Unstable Terranes, by Riparian Reserve Component, by Geo 13 , by Fire,& by Plantation]

Terrane	ERFOs		
Surficial	2		
Sawyers Bar	10		
Condrey	102		
Eastern Hayfork	22		
Stuart Fork	13		
Sbt?/sf?	1		
Western Jurassic	42		
Central Meta	9		
North Fork	10		
Plutons	174		
Rattlesnake Cr	266		
		mv	12
		mvs	6
		mvt	17
		qd	1
		sch	20
		um	77
		gb	17
		ms	116
Salmon Rv	16		
['um' = 4]			
Trinity	9		
['um' = 6]			
Western Hayfork	78		
Yreka	6		
Total:	**760**		

Unstable/high Sediment Producing Terranes

Terrane	# of ERFOs	% of Tot ERFOs	Terrane Acres	% of Tot Acres	ERFO % / acre %
Condrey	102	13.4%	92,524	5.6%	**2.4**
Western Jurassic	42	5.5%	14,835	0.9%	**6.1**
Plutons	174	22.9%	409,363	24.9%	0.9
Rattlesnake Cr	266	35.0%	509,778	31.0%	**1.1**
Totals:	**584**		1,026,502		
Percent of total:		**76.8%**		**62.5%**	**1.2**
Other terranes	180	23.6%	616,410	37.5%	0.6

Riparian Reserve:	**ERFOs**	**%**	**"Westside" acres**	**%**	**% ERFO / % acres**
Dorm. Qls	253	33.3%	345,058	16.5%	**2.0**
Inner gorge	217	28.6%	216,986	10.4%	**2.8**
Toe zones	51	6.7%	30,472	1.5%	**4.6**
Act Qls	21	2.8%	12,325	0.6%	**4.7**
Stream buffer	308	40.5%	384,769	18.4%	**2.2**
Granitc lands	174	22.9%	451,429	21.6%	1.1

Geo 13	ERFOs	%	Acres	%	% ERFOs / % acres	Geo 13 #
No designation			110,597	6.1%	0.0	0
Active slides	20	2.6%	12,118	0.7%	**4.0**	1
Toe Zones	9	1.2%	8,429	0.5%	**2.6**	2
Dormant slides	177	23.3%	262,253	14.4%	**1.6**	3
Granitic lands [>65%]	6	0.8%	49,392	2.7%	0.3	4
Granitic lands [<65%]	90	11.8%	208,678	11.5%	1.0	5
Non-granitc [>65%]	24	3.2%	166,230	9.1%	0.3	6
Goosenest	0	0.0%	405	0.0%	0.0	7
Non-granitc [<65%]	189	24.9%	620,215	34.1%	0.7	8
Inner gorge in uncon.	56	7.4%	43,896	2.4%	**3.1**	9
Inner gorge in gran.	61	8.0%	44,709	2.5%	**3.3**	10
Inner gorge in non-gr.	98	12.9%	121,343	6.7%	**1.9**	11
Debris basins	0	0.0%	19,235	1.1%	0.0	12
Qg, Qt, Q, etc.	30	3.9%	152,259	8.4%	0.5	13
Totals:	760		1,819,759			

Other Special ["sensitive"] Lands

Fire [burn intensity]:	
Hog [high]	3
Specimen	0
Dillon [4@cls 1, 1@class 2]	5
87 Fires	213
high [16]	
mod [89]	
low [108]	
fire_perim [>1977]	211
Y1 = 211	
Y1+Y2 = 19	
Plantations:	147
< 1977 [75]	
> 1977 [72]	

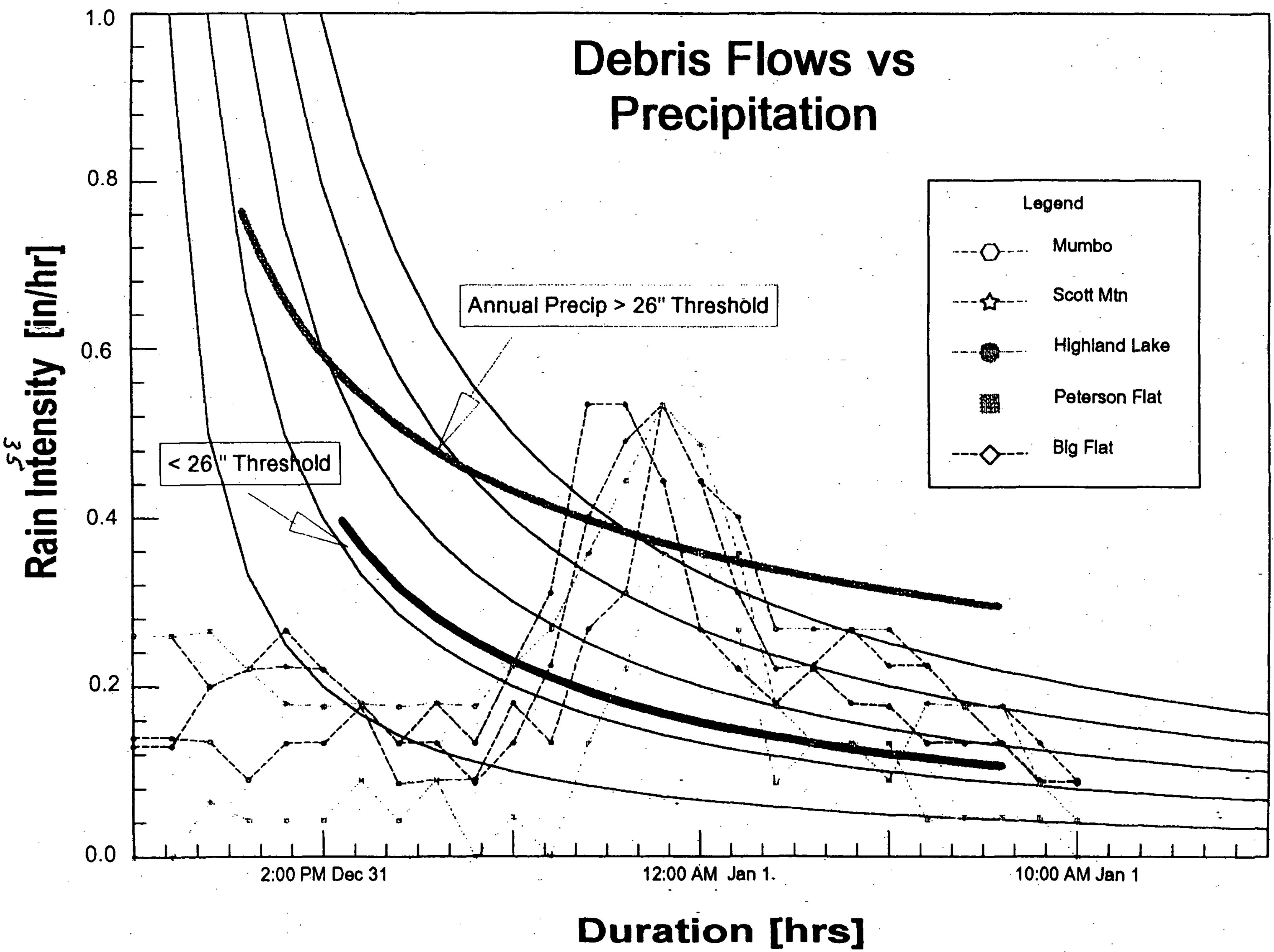
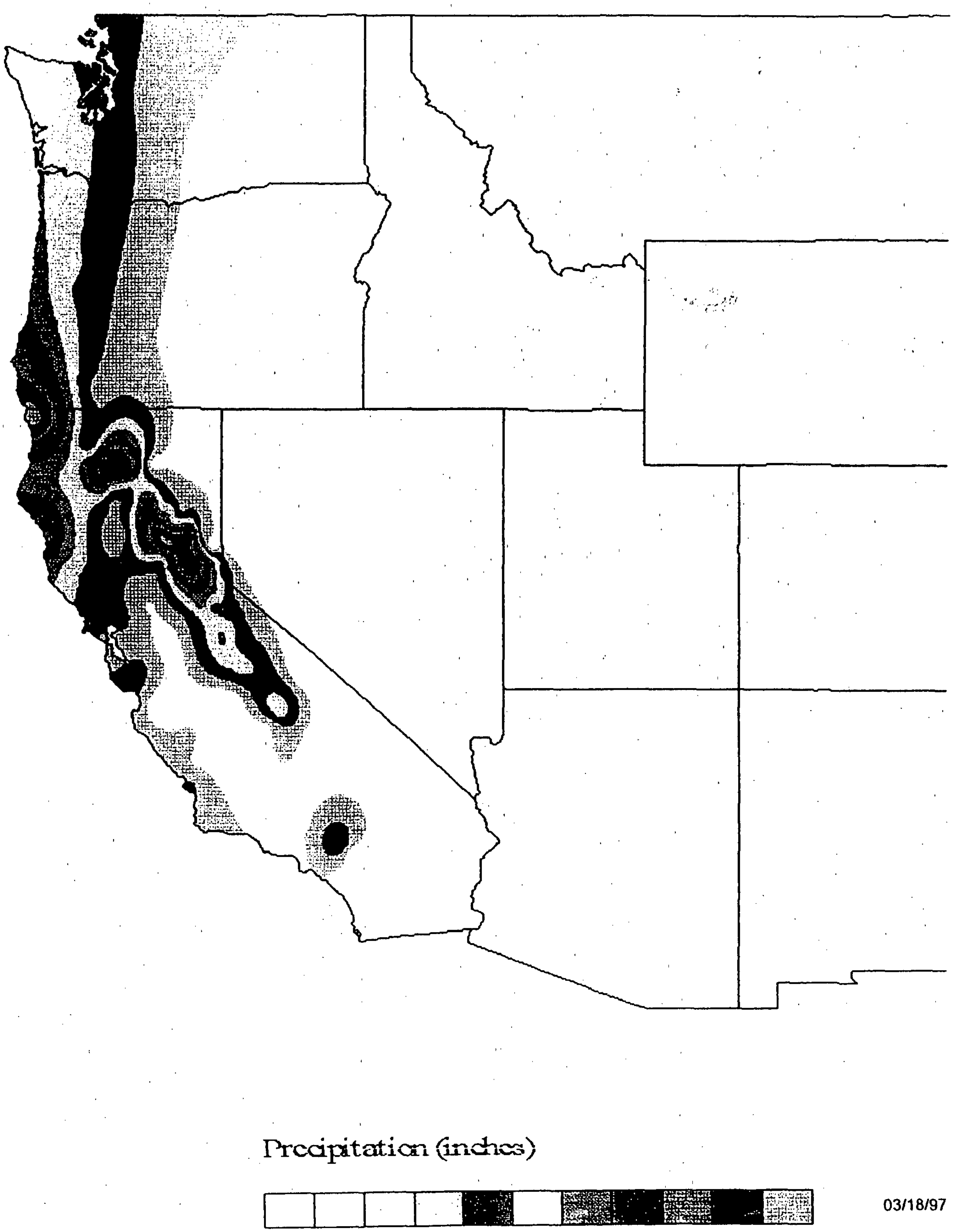

Debris Flows vs
Precipitation
Rain Intensity [in/hr]
1.0
0.8
0.6
0.4
0.2
0.0
Duration [hrs]
2:00 PM Dec 31
12:00 AM Jan 1.
10:00 AM Jan 1
Annual Precip > 26" Threshold
< 26" Threshold
Legend
Mumbo
Scott Mtn
Highland Lake
Peterson Flat
Big Flat

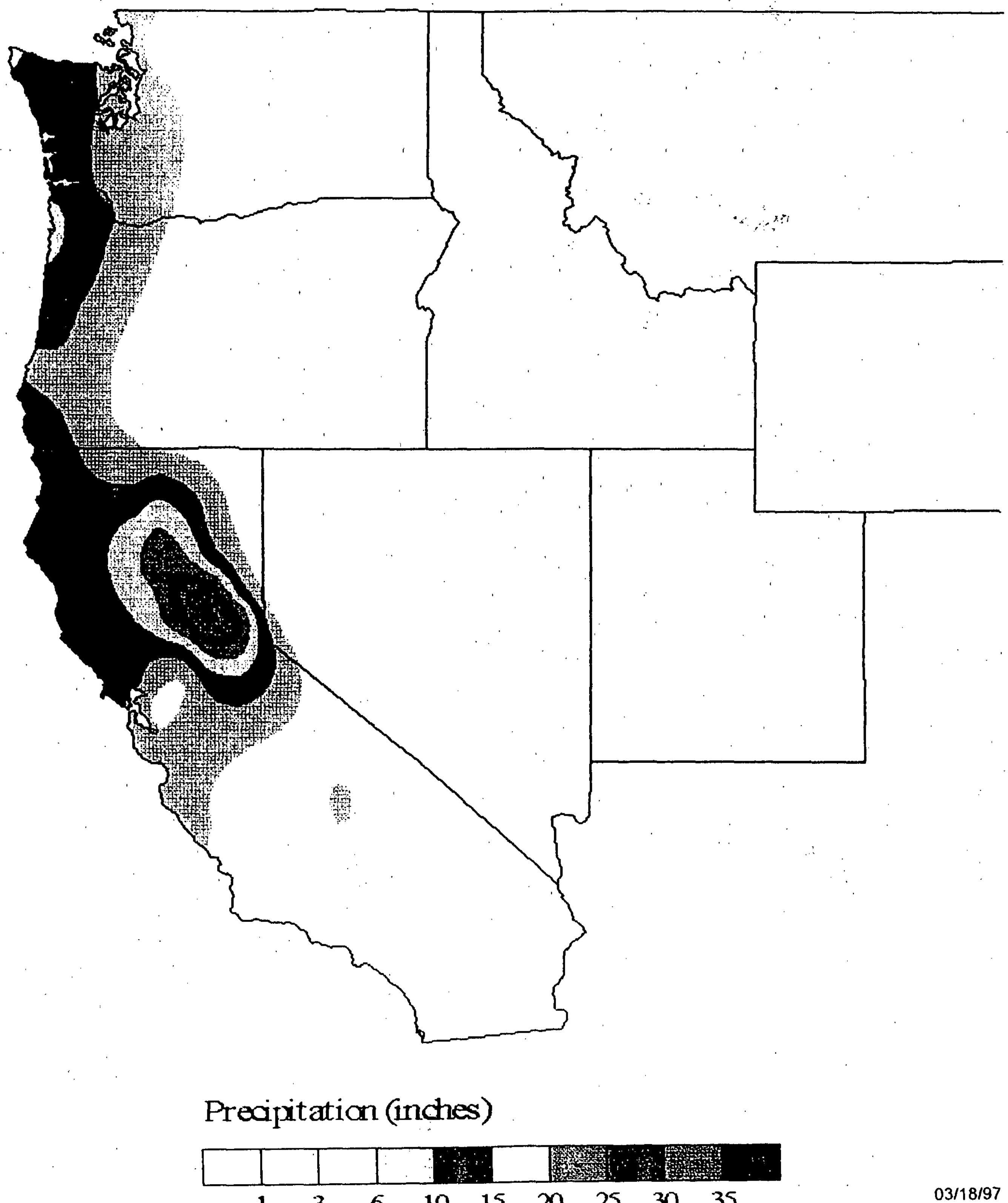
Figure 8

Total Precipitation (inches), December,

Total Precipitation (inches), December,



Total Precipitation (inches), December 20, 1996 - January 3, 1997



Percent of Normal Precipitation, December

APPENDIX G

EFFECTS OF THE FLOOD ON FISH HABITAT

APRIL 25, 1997

BY: Jon Grunbaum, Dave Payne, Bill Bemis, Orion Dix, Roberta Van de Water, Polly Haessig, Cal Conklin, Bill Snavely, Ken Baldwin, Sharon Koorda, Jim Kilgore, Allen Tanner, Al Olson, Tom Reed, Nels Brownell, Mark Maghini, Juan de la Fuente

\>>Message from Juan de la Fuente:R05F05A; to j.delafuente:r05; autoforwarded
\>>on 11/25/98 at 11:12:34.

CEO document contents:

SECTION III: EFFECTS OF THE FLOOD ON FISH HABITAT
DRAFT REPORT ON KLAMATH FLOOD DAMAGE ASSESSMENT
DRAFT 4-25-97

CONTENTS

III. EFFECTS OF THE FLOOD ON FISH HABITAT

By: Juan de la Fuente, Sharon Koorda, Nels Brownell, Jim Kilgore, Polly Haessig, Cal Conklin, Jon Grunbaum, Bill Bemis, Orion Dix, Robbi Van de Water, Bill Snavely, Ken Baldwin, Allen Tanner, Dave Payne, Al Olson, Tom Reed, Mark Maghini..

INTRODUCTION

The following preliminary findings are based on our field observations, and prior aerial and raft reconnaissance of some areas. Field trips included the following:

3-19-97	Beaver Creek, Klamath River, Scott River, Tompkins Creek
3-27-97	Grider, Walker, Indian, Elk, Clear, Dillon, Wooley, Main Stem Salmon River.
3-31-97	North and South Russian, North Fork Salmon, South Fork Salmon, Methodist Creek, Knownothing Creek, Hotelling Gulch, Upper South Fork Salmon River.

1. Ranking of Channel Disturbance- There was a broad range of channel disturbance exhibited by the streams we visited. They are listed below in order of decreasing disturbance (loss of riparian vegetation, scour, deposition: Some of the streams were visited at times other than the dates listed above.

1. Walker and Deep Creeks.
2. Grider, Portuguese, Tompkins, Middle, Kelsey, Oneil, Ukonom Creeks, Upper South Fork Salmon, upper Beaver, Horse Creek.
3. South Fork Salmon from East Fork to Forks of Salmon, Canyon Creek, Lower Beaver.
4. South and North Russian, East Fork Salmon, North Fork From South Russian to Forks, Main Stem Salmon Below Forks, middle Beaver.
5. Dillon, Clear, North Fork Salmon above Idlewild.

2. Effects of Bed Mobilization- Mobilization of bed material likely destroyed most of the 1996 crop of fish eggs in gravels in most channels. This widespread mobilization is also likely to have had a large adverse effect on the larval stages of the Pacific Lamprey which spends 6 years of its life cycle in the channel substrate. Substrate mobilization is likely to have a widespread adverse effect on the aquatic community. Most aquatic organisms are closely associated with the substrate during winter and its associated cold water temperatures. Fish species (particularly salmonids, and lamprey), aquatic invertebrates (including crayfish, and insects), utilize the substrate, and were likely impacted. While macroinvertebrates will recolonize the system quickly, fish species will take longer.

3. Stability of New Gravels- The post-flood gravels in Elk, Indian, Grider, Walker and similarly altered channels are unstable, and susceptible to mobilization should high flows occur later this year, particularly if the landslides in the headwaters shed more sediment to the stream system. Thus, the survival of eggs in these new gravels is questionable.

4. Pools- There appeared to be considerable reduction in size and depth of pools, particularly in alluvial reaches, in Elk, Indian, Grider, Walker, Tompkin, and lower Beaver Creeks. Similarly, pools in South Fork Salmon from Summerville to the East Fork appear to be smaller and shallower. The impact appears to decrease farther downstream in the South Fork below the East Fork.

5. Shade- Most of the alder shade, and locally, large conifers were removed from the main stem of Walker and Deep Creeks and several tributaries. Roughly 40% of the riparian vegetation (20-35 year old alders) was removed from alluvial reaches of Elk, Indian, Tompkins, Middle, and Grider Creeks. The greatest potential for increased water temperatures exists in in Walker and Indian Creeks, as well as Elk, Grider Upper South Fork, particulary where loss of vegetation was accompanied by widening and shallowing of the channel. A

considerable amount of the alder shade was removed from the middle and upper reaches of the South Fork Salmon. The implications to stream temperature are likely increased summer water temperatures. There will likely be a cummulative effect downstream on the entire Salmon River basin. Tributaries to the South Fork, while not capable of delivering enough cold water to reduce overall temperatures, will be critical for providing cold water refuge to salmonid fishes late in the summer. There may well be fish die-offs this season based on past temperature data in the South Fork. In previous years, sublethal temperatures have been reached.

6. Fish Habitat Improvement Structures- Large boulder clusters and wiers in Elk and Indian Creeks appear to have weathered the high flows, but cabled log structures were more often damaged or removed. Large rock structures were also observed to have survived though somewhat altered in the South Fork Salmon. More than 50% of the fish structures placed in the upper South Fork over the past 15 years have been impacted. The river obliterated rock and boulder structures designed to narrow and deepen the channel for summer low flows. Boulder clusters and a surprising number of woody structures in the South Fork remain in the system. At Elk and Indian Creeks, may log structures were washed away or floated up and deposited well above the active channel. In Middle Beaver Creek, several log structures perpendicular to flow direction and anchored in both banks survived with minor damage to abutments. Boulder structures there generally survived, with local deposition.

7. Aggradation at Stream Mouths- Aggradation at the mouths of Grider and Walker Creeks could pose a problem to fish migration, but we did not examine the mouths of these creeks. Grider was being reworked by the irrigation ditch intake. Walker Creek has been channelized in its lower reaches, as was Thompson Creek.

8. Substrate Composition- There was a general increase in fine sediment in alluvial reaches of the more altered channels, particularly in areas where sedimentation made the channel wider and shallower. This included the presence of finer gravel in the tailout pools.

OPPORTUNITIES

The following opportunities have been identified:

1. Monitoring of Channel Conditions- We have the opportunity to monitor the evolution of aggraded channels. This should focus on important stream segments across the forest, and the entire Forest watershed and fish group should work toward answering questions. We need to consolidate Forest monitoring into a few creeks, so that better integrated data can be collected and used for regional interpretations. Monitoring of channel conditions should include changes in stream temperature as channels revegetate, and the rate and character of natural revegetation. We have an opportunity to see change since the spring of 1988 when riparian vegetation was mappped on major bars on the lower North Fork and Lower South Fork Salmon (Powell's report). We need to re-run the earlier profiles in Indian and Beaver Creeks and the Salmon River, as well as V* pools and pool depth measurements. We have residual pool depth and volume measurements in the Salmon River dating to 1987.

2. Channel Restoration- While natural revegetation is likely to occur at a rapid rate in most areas, there may be special cases where artificial revegetation should be considered. Channel manipulation may be warranted in cases where highly disturbed channels have lost fish access at their junctions with the Klamath River (such as Grider, Walker, and Thompson Creeks) due to aggradation, or where channelization has created a situation adverse to fish passage. Access to tributaries along the North and South Forks Salmon River does not appear to be an issue. Channel manipulation may be warranted in some areas, preceded by a rigorous analysis of the biologic, hydrologic, and geomorphic processes at play.

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DESCRIPTIONS OF CHANNEL CONDITIONS

BEAVER CREEK

1. Beaver Creek Above the Campground- Above the Beaver Creek Campground, flood effects consisted primarily of bed mobilization, local bank undercuts, road undermining, and very minor abrasion of 20-30 year old alder stands in the floodplain. In this area, the channel gradient is 1-2%, the creek about 30 feet wide, and the affected floodplain about 40-100 feet wide. Peak flows at the sites we visited ranged from 4-6 feet above water levels of 3-19-97. Aggradation occurred in at least two of the sites visited where V* data had been recorded in the past. Similarly, about 3 feet of aggradation and a few feet of bank erosion occurred at site where the District has pre-flood cross section data immediately above the bridge over Beaver Creek at the junction with Hungry Creek. One bedrock channel area appeared little modified by the flood. Most of the mobilized woody debris was smaller than 20?? inches in diameter and 20??? feet long. Two log wiers Hungry Creek survived the flood intact, with minor erosion of one abutment. The logs were installed perpendicular to the channel. Similarly, many logs cabled to the banks survived. Since the alders are little damaged in this reach, shade will not change appreciably.
Opportunities for monitoring??? Rerun profiles, and V*, fish habitat surveys, establish new cross sections to measure sediment movement, survey structures to see if they survived and are still functional (what worked/survived and what did not).

We visited a log wier above Hungry Creek, with the log about 36 inches in diameter, and spanned the creek for about 30 feet in width. There were also many single trees cabled to the banks in the vicinity. Channel gradient was about 2% in this area, and peak flows got to about 5 vertical feet above the current water level. Another log wier about 100 feet upstream had survived the flood, but channel had scoured benind some boulders placed to protect the end of the log on the west bank.

We visited one of the District's V* Pools (#4). This pool lies at location --------, and is a natural pool which developed downstream of some large (4? feet diamater) boulders in the channel. Much of the pool was filled in, and it was estimated that some of the lower parts of the pool which had been about 3 feet deep were now about 1 1/2 feet deep. A profile was run here in the past. Peak water levels got to a height about 6 feet higher than current levels. Downstream of the pool, the channel had scoured the west bank an area about 20 feet wide and 18 inches deep.

Hungry Creek V* Pool- This pool where V* measurements had been taken was almost filled with sand and gravel. The gradient on Beaver creek here is about 1/2%. Most of the 4-8 inch alders on the floodplain survived with minor battering. Sand derived from granitic rock was evident in both the Hungry creek channel and the Beaver creek channel.

Hungry Creek Cross Section Site- A District cross section site is located about 100 feet upstream of the bridge over Beaver Creek. It revealed about 3 feet of aggradation near the west bank, and the east bank steel pin had been eroded away indicating a widening of about 4 feet. In sum, the channel widened here and got shallower. The cross section was last measured in 1995. This is a straight channel segment, with alders and 20 year old pines growing on the floodplain which received some water (about 5 vertical feet above current water level). We observed an alder stump which was 20-25 years old, giving an idea of the last time the floodplain was stripped of vegetation. There was also a large cottonwood (about 24 inch diameter) on the floodplain which was probably more than 60 years old.

2. Beaver Creek From the Mouth to Beaver Creek Campground- (Observations of Allen Tanner, Nels Brownell and Sharon Koorda)
In this area, the channel has been significantly altered. The spawning habitat has increased to cover the majority of the reach as the transported bedload

began dropping out in this generally lower gradient, less constricted portion of the stream channel. However the channel also underwent widening and braiding with creation of mid channel gravel bars and in some areas created side channels in the flood plain leaving "islands" of riparian areas. The widening also took out banks and riparian vegetation so the channel flow, as well as being spread out and more shallow, is also receiving more solar exposure so a decrease in water quality (higher temperatures) can be expected. There has also been a loss in the complexity of habitat, most of the pools are gone as well as woody debris in the channel. The majority of the wood transported in the flood is caught up on the banks lying within the high water zone. There does not appear to be a problem with embeddedness of the spawning gravels as most of the deposition of fines has occurred along the banks creating sandy beaches and point bars. To recap the initial observations:

a. Spawning gravels/habitat has been greatly increased.
b. Complexity of habitats has been decreased.
c. Decrease in water quality (higher temperatures) is expected.

At its mouth, Beaver Creek created a new channel where it enters the Klamath River, a short distance (50 feet) downstream. The old channel was filled with sand and gravel. There was about ---- feet of aggradation under the bridge under Highway 96 at Beaver Creek, and upstream from the bridge, there was ------- feet of aggradation across the broad floodplain (200?? feet wide). The channel was extensively braided. It appeared that most of pre-flood alders 4-12 inches in diameter survived the flows, and served to catch woody debris, and locally deflect the channel.

TOMPKINS CREEK

Observations of Jim Kilgore- The sites we visited on Tompkins revealed that the majority (70-90%) of the 20-30 year old alder cover along the creek survived, though there was considerable abrasion on trunks, and local areas where small stands had been removed. In general, the debris torrents' inability to remove all vegetation, created numerous new "meanders" in the stream that were absent in the channel created as a result of the '64/'74 event. This may translate into increased habitat complexity, such as more numerous pools. (Data to be collected this year on Tompkins Creek could be compared with fish habitat data gathered in the latter 80's to test this assumption). From the low water crossing down, the channel bed was stair-stepped, and consisted mostly of unsorted large rock with only very small pockets of sorted gravels. With the exception of the lowest reaches of the east fork, gravels appeared to be much scarcer than before the flood. Many trees along the streambanks have been toppled but most are still suspended above the bankfull zone. In the future this wood should add to habitat complexity. Presently, shade is expected to be reduced and this reduction is likely to have a measurable effect on stream temperatures. This effect may be large enough in the short term to negatively affect summer rearing. (Some sections of the stream will not develop suitable "shade" canopies for several years). Over-wintering fish populations, such as steelhead (& possibly coho) were probably negatively affected by the debris torrent. (Planned summer observations on Tompkins Creek may also be able to partially address this assumption). Presently, most stream substrates, including spawning gravels, are only crudely sorted as to size. Gravels contain high levels of "fine" material (sand size and smaller). The reduction in gravel (amount and quality) is very likely to limit spawning opportunities, especially in the short term, until future increased flows begin to re-sort substrate material. Spawning and rearing opportunities should be increased in the long term as spawning gravels and riparian vegetation "recover" and as presently suspended wood more directly influences channel processes and creates more complex habitat. Fish passage is not thought to be a concern due to small & local falls created by woody debris.
At present, the district desires to install a permanent Stream Condition Inventory (SCI) on the anadromous reach extending from the "Potatoe Patch" area upstream to the old low-water crossing site, a distance of about 1.1 stream miles. (This monitoring protocol would measure pool frequency and quality, large wood concentrations, average substrate size, shade, streambank stability, establish several x-section sites, etc.). If funding allows, a long-term longitudinal profile could be installed on a distance of 20-30 bankfull units to track elevation changes and channel recovery of banks, pools, stream widths,

etc. Also desireable, would be 1) the creation of several electroshocking reaches to track population "recovery" of salmonids and other aquatic species and 2) initiate and continue aquatic macroinvertebrate sampling over a several year period according to established protocols to track changes in insect populations as stream conditions change.

KLAMATH RIVER AT LITTLE HUMBUG AND BARKHOUSE CREEK

1. Mouth of Little Humbug Creek- (Observations of Sharon Koorda) During the flood, Little Humbug Creek abandoned its channel on the fan immediately above the Klamath River, and flowed through an old channel which enters the Klamath River about 500??? feet upriver of its original junction. Much of the Klamath River baseball field was covered with large cobbles, and this field lies about 30???? vertical feet above current water level on the river.

2. Mouth of Barkhouse Creek- (Observations of Sharon Koorda) The main flow in the Klamath River now flows in an old overflow channel which is immediately below Highway 96. Previously, the main river channel was to the south where it is joined by Barkhouse Creek.

3. Klamath River From Irongate to Orleans- This section needs to be assessed and written up.

SCOTT RIVER

1. Mouth of Scott River- Flows at the mouth of the Scott River had gotten up near the bottom of the bridge, and we noted fine sand deposits about 23 vertical feet above current water level immediately downstream of the bridge on the east bank. It appeared the main channel had deepened itself below the bridge. Above the bridge, two channels of the Scott River converge, and the eastern channel, which was an overflow channel appeared to have deepened. Between these two channels, there appeared to be considerable aggradation, as evidenced by a bar about 10?? feet thick. An old debris slide on the west bank about 600?? feet upstream of the bridge experienced a small reactivation in its lower part. There was a large bar on the Klamath River immediately downstream of the confluence with the Scott which appeared to have aggraded a few feet. This used to be a driveable river access. In summary, the main channel appeared deeper on the Scott, but there was evidence of aggradation also, so we couldn't say whether the Scott River bottom was higher or lower than before the flood. The bridge would be an easy place to monitor such changes.

2. Lower Scott River- The lower several miles on the Scott River experienced considerable bed mobilization in alluvial reaches, in places up to 300??? feet wide. There were new, clean gravel bars as well as accumulations of woody debris. These accumulations occurred at a frequency of ------ per 1000 feet of channel, and the average wood size was ------ feet in diameter, and ------- feet long, with the largest ------ feet long and ------ feet in diameter. Alder in the size class of 4-12 inches generally survived/was taken out??? by the peak flows. In non alluvial reaches, little modification of the channel was evident, and riparian vegetation was bent over and scarred but usually not removed.

3. South Fork Scott River and Valley Segment of Scott River- This section needs to be assessed and documented. The South Fork Scott River appears to have experienced considerable alteration.

GRIDER CREEK

1. Grider Creek Campground- Much of the campground had been flooded and was covered by fine sand and woody debris. The creek had undercut the margin of the campground, leaving a vertical bank 3-4 feet in height. This portion of Grider Creek appears to have experienced considerable aggradation, patches of alders had been removed, but perhaps 70%? had survived the flood, and the only damage the survivors recieived was abrasion on the trunks. The alders were probably vintage 1964. There appeared to be considerable aggradation, and the bed material had been mobilized across much of the floodplain. Mobilized bed

material varied from fine gravel to 3 foot diameter boulders. Above the campground, the channel appeared to be a little steeper and contained mostly large boulders (>3 feet in diameter). Large logs were locally caught up in the alders.' We discussed the liklihood of increased summer water temperatures due to loss of riparian vegetation, but since we did not have a good idea of proportion of the alders removed by the flood, could not estimate the level of the problem. We talked about the instability of the spawning gravels and how high flows later this spring could remove any eggs layed by steelhead or salmon. The foot bridge was taken out.

2. Upper Bridge Over Grider Creek- There was aggradation in a bedrock swimming hole upstream from the bridge. Downstream, there were large accumulations of logs, and the alders had been stripped from much of the riparian area.

3. Summary Observations- Limited data available (air recon) indicates that from Rancheria Creek to the mouth, Grider Creek experienced much aggradation, patches of alders were removed, and channel shifts and meanders developed in lower reaches. Abundant large logs were transported and deposited on the floodplain and along the channel, often caught against alder stands. Numerous debris flows entered Grider Creek from Grider Ridge.

WALKER CREEK

We visited the lower bridge crossing of Walker to view channel changes in this creek. The entire channel bed was mobilized and carried large logs. This was the most disturbed of the channels we visited. Large amounts of deposition had occurred, and the channel had later incised 2-3 feet back into the debris. We discussed the possibility of a channel obstruction upstream of the bridge over Walker Creek playing a role in the surge of debris which traveled through the creek and overrode Highway 96 downstream. The water was slightly turbid, due to the movement of bed material.

ELK AND INDIAN CREEKS

Observations by Jon Grunbaum- Effects of the flood on channel characteristics, riparian vegetation, and fish habitat were similar in Elk and Indian Creeks. Observations of effects in these creeks will be described together. The character and magnitude of some of the flood effects appeared to depend on degree of channel constraint and valley morphology, while other effects were consistently observed throughout the stream segments that were reconnoitered. Flood effects in Elk and Indian Creeks is described for: 1) effects observed throughout all stream segments; 2) effects observed in alluvial reaches; and 3) effects observed in transport reaches. For this discussion, alluvial reaches are defined as depositional stream segments that occur where the valley floor is wide and stream channel is unconstrained by high banks or adjacent hillslopes. Sediment is often deposited in alluvial reaches and may remain there for long periods of time before being transported downstream again by subsequent flows. Transport reaches occur in places where the stream channel is narrow because it is constrained by high channel banks or because the hillslopes of narrow valleys impinge upon one or both sides of the stream channel. Much of the sediment entering transport reaches passes through quickly without being deposited for long. The overall proportion of alluvial versus transport reaches is given for the surveyed segments of each creek so that the extent of flood-related disturbance can be fully assessed.

Surveyed Stream Sections

In Elk Creek, flood effects were observed in the mainstem from the 11 Mile Bridge to the mouth - excluding the 'whooping devil' gorge (RM 4.7 to 5.0). River Mile 4.5 to mouth was surveyed on March 17. RM 11.0 to 5.0 was surveyed on March 29. Access for surveys was via inflatable kayaks.

In Indian Creek, flood effects were observed in the mainstem from the confuence of Mill Creek (RM 12??) downstream to confluence with the Klamath River. The lower 4.5 miles (starting from the area commonly known as Buchannan Falls and moving downstream to the mouth) was surveyed in its' entirety on March 20. Access was via inflatable kayaks. Mainstem Indian Creek reaches between Mill Creek confluence and Buchannan Falls were spot checked by hiking in to various sites or by viewing the creek from Indian Creek Road.

Flood effects observed throughout surveyed stream segments

During the flood, much more sediment was delivered to the mainstems of Elk and Indian Creek than these streams were capable of transporting downstream. Excessive sediment recruitment into the surveyed reaches was evidenced by the in-filling of former depressions in the streambed by silt, sand, gravels and other mobile substrate particles. Sedimentation of the mainstem reaches has serious implications for anadromous fish populations because much of the spawning and rearing habitat in the Elk and Indian watersheds occurs in the mainstem reaches.

The effects of excessive sediment loads was particularly apparent in pool habitat. Pools that are critically important for habitat diversity and refugia for salmon, steelhead, and resident trout were completely filled in or greatly diminished is size and depth. Almost all pools were filled in to some degree and most were 50% or more filled in. Bars composed of sand and small gravel were commonly observed in pool tail-outs and in places that were formerly deep areas of pools. Pools in narrow bedrock gorges were least affected but it was still obvious that even these pools had lost some volume and depth due to in-filling.

Substrate composition in pool tail-outs and other prime salmon and steelhead spawning areas changed as a result of the flood. The average diameter of substrate particles in spawning areas appeared to be much smaller post-flood. This could have implications for spawning success and survival rate of incubating eggs. In many spawning areas the gravel size may be too small to entice spawning by chinook salmon. Excessive fines may increase mortality rate of incubating eggs by restricting the interstitial flow of water necessary for delivery of oxygen and flushing of metabolites. Excessive fines can also entrap newly hatched fish within the gravel thereby reducing rate of successful emergence.

Perhaps the biggest threat to successful repoduction by salmon and steelhead that has resulted from the flood is instability of the streambed, particularly areas of the streambed that are typically used by salmon and steelhead for spawning. At high flows, the depth and area of scour is much greater in channels in which streambed instabilty is increased as a result of excessive sedimentation and increased fractions of smaller-sized sediment particles. Increased depth and area of scour results in decreased reproductive success because more individual eggs, or entire redds, are dislodged during high-flow events. Degree of egg washout from unstable spawning beds will be largely dependent upon magnitude of peak flows. Egg mortality will increase rapidly with increases in size of peak flows - at least in the next few years. Excessive gravels and fine sediments delivered during the flood will take many years to be moved out of these stream systems. It may take up to 10 years or longer for these streambeds to regain a level of meta-stability so that non-flood peak flows will not result in high egg mortality. This estimate assumes that another large runoff event will not deliver another large slug of sediment before streambed stability is neared.

Excessive streambed scour will occur in conjuntion with large pulses of sediment being transported and redeposited in other locations. In contrast to reproductive failure due to loss of eggs because of scour, egg incubation and hatching success could also decrease because of excessive deposition over redds, which could suffocate eggs and entrap hatchlings.

The flood caused widening and shallowing of the active stream channel and loss of riparian vegetation. This was observed along the entire length of surveyed segments, although much more pronounced in alluvial reaches. Increased heating of the stream in summer is likely because there is less vegetative canopy to shade the streams and because water flowing in wider and shallower stream channels is more prone to heating from solar radiation and increased surface area in contact with warm air.

Aquatic invertebrate populations, the primary food source of rearing salmonids, were drastically reduced by scour and deposition during the flood. These populations are expected to rebound quickly, probably within a year or two, and should not present any serious prey shortages for rearing fish. In the short-term a food shortage could occur this spring and summer if there was a strong run of coho and steelhead post-flood and hatching rate was high due to low flow conditions that have persisted since the flood.

Most fish enhancement structures that were constucted of logs were washed out of the creeks or pushed up on the channel margins and no longer contacting the wetted channel. Boulder structures placed to increase habitat diversity fared better by staying in place or at least not being moved far. However, many of the placed boulders were buried or partially buried in thick deposits of sediment during the flood.

Flood effects observed in alluvial stream segments

Largescale changes in channel characteristics and riparian vegetation were observed in alluvial stream segments, while transport reaches appeared less disturbed. Alluvial channels comprise approximately 10% of the stream sections surveyed on Elk Creek and approximately 15% of the surveyed portions of Indian Creek.

In alluvial stream sections thick deposits of sediment were deposited over most of the stream channel and adjacent floodplains, although in some instances large tracts of floodplain were eroded away. Heavy sediment loads carried with the flood water raised the level of the stream channel bottom during the height of the flood causing the streamflow to spread out and increase erosion of low terraces and distant streambanks. As the flood peaked a thick lens of sediment was deposited over large areas of the former channel and on adjacent floodplains. The fact that the streambed was elevated during the flood was evidenced in many areas where old stream channels were re-established or new stream channels were formed within days after the flood, as decreasing flows with lower sediment loads quickly cut through through the lens of sediment that composed the top of the streambed during the flood.

Because of the massive aggradation occuring on these alluvial flats during the flood there was quite a bit of channel instability occurring. Channel instability was manifested by radical channel re-alignments and channel braiding. This channel instability contributed to loss of riparian and floodplain vegetation as new channels were constantly being scoured through adjacent floodplains and revegetated remnant or overflow channels.

Excessive deposition buried riparian vegetation in places and filled in most depressions in the former stream channel. Approximately 30% to 60% of the riparian vegetation (mostly alder and willow) growing on these alluvial flats was buried or removed by the flood. Scour, physical impact by a floating objects, and deposition appear to be the primary factors resulting in loss of riparian vegetation. As noted earlier, loss of riparian vegetation coupled with widening and shallowing of stream channels may allow excessive heating of water during the summer months, which in turn could reduce growth and survival of rearing salmonids.

In addition to the loss by washout or exceesive sediment deposition that occurred throughout the surveyed stream segments, incubating salmon eggs in alluvial reaches may have been left stranded in 'dry' streambeds in sections where channel realigments occurred. As excess sediment from this large storm event is moved out of these creeks new channel migrations are likely as the channel repositions into some stable configuration. Washouts, burial, and stranding of incubating eggs are possible during such channel reconfigurations.

Flood effects observed in transport stream segments

In transport stream segments there was less channel widening and mortality of streamside vegetation was not as great - probabaly averaging about 20%. Much of the alder immediately adjacent to the stream was removed by scour or impact during the flood and the channel banks were scoured clean of moss and other vegetation in many places. Loss of this streamside cover in these segments has minor implications for direct solar heating of Indian Creek because canopy cover and shading will still be provided by trees that are near the wetted channel but that survived because they were slightly higher up the steep stream banks and/or hillslope. Topographic shading also provides some protection from direct solar heating in the channel types. Widening and shallowing of stream channels in these sements has occurred which has increased the air/water surface area, but channel widening was limited by channel constraint. Spawning is less common in transport reaches but does occur. Spawning areas in transport reaches are also likely to be unstable because large pulses of sediment will pass through these reaches as excess sediment is moved out of these stream systems.

East Fork Elk Creek- (Observations of Ken Baldwin) While East Fork Elk creek exhibited little evidence of alteration at out site visit, there was a good debris flow and wash-out of a road fill on the west side of upper East Fork of Elk Creek. Also, there is a general pattern of flood effects in Elk and Indian Creeks. Areas of deposition (middle Indian and middle Elk) in 1997, coincided with areas of deposition and "damage" during earlier floods in the 1960's and 1970's. This is part of the distinction between East fork and Main Elk Creek. It's too early to access the amount of landsliding in these areas. The East Fork of Elk seems to me to be cleaner, less sediment in storage than before the flood.

Observations by Dave Payne- On Saturday March 29th, Jon Grunbaum and myself floated ElK Creek. We started at the bridge at the eleven mile marker and floated to the five mile bridge. We noticed right away that former deep pools had substantially filled in. A mini gorge starts the trip. At the end of this gorge is where the road bed was substantially damaged ($240,000 +). It was hard to recognize the creek as large granite cobble were piled high replacing alder trees that had been uprooted and washed downstream.

The creek has changed character. Last season this section was a more defined pool-drop type of float. The flood seems to have transformed the run into a more continuous gradient type float with non-stop easy whitewater. The creek seems really shallow. Former deep pools were shallow to non-existent. Earth slides moved large boulders into the creek creating exciting new rapids in a couple of spots.

Near Cougar Creek falls large deposits of granite boulders have dramatically changed the look of the creek. On the private lands the creek bed seems to have raised as floating along one can now view four structures that were never visible before. Much of the riparian alders have been knocked down. Huge deposits of woody debris and granite cobble have been laid down, and the creek channel seems to have straighten out. What was once a closed alder canopy is now a wide open swath creating distant views to the surrounding ridges. It is warm and sunny, with sandy beaches. It is still beautiful, although it is quite different looking from one season ago.

Downstream of the private lands the creek re-enters another mini-gorgewith a tight canopy section that did not receive as much flood damage. The alders are still intact. It seems that the deposition of tremendous amounts of woody debris upstream saved this area from excessive change. Changes did occur in two spots were earth slides moved huge boulders into the active stream channel. These created really fun rapids.

On one unnamed tributary, a blowout down to bedrock occurred. This has created a small waterfall that is visible from the creek.

We saw the remnants of log fish structures scattered throughout the run. Individual logs with wires were deposited in scattered places. I do not remember seeing any log fish structure remaining intact. Boulder clusters placed as fish structures were still in place. We saw portions of six highway culverts in flood deposits along the creek. These look as if they could be removed with float tubes. The remnants of a '20's vehicle were uncovered and are in a place were they can be removed without having to float. We saw little other human trash.

The flood transformed this six mile creek run into a really fun continuous whitewater gem that is worth visiting.

CLEAR CREEK:

Observations by Jon Grunbaum- The mainstem of Clear Creek was observed from Slippery Creek to the mouth on March 19th via inflatable kayaks. Much new spawning gravel had been recruited into this stream segment by the flood but sediment deposition was not excessive. Pools appeared to be as approximately as deep as before the flood and residual pool volume appeared to be just slightly lower than before. Some braiding was noted on one especially wide tail-out/riffle area, indicating that at some point during the flood sediment recruitment rate was nearing the transport capacity of the streamflow. No remnant elevated flood streambeds were observed as in Elk and Indian Creeks except at the Klamath River confluence.

Although there was a distinct line high on the channel banks indicating that very high flows had occurred, much of the moss and other vegetation on the banks was intact. Overall alder mortality was 5% or less.

From a fish habitat perspective the surveyed segment of Clear Creek was actually improved by the scouring action of the flood and the deposition of new spawning gravels.

Observations by Dave Payne- I floated Clear Creek yesterday with Jon Grunbaum. We were checking flood related damage to creek, reconning cleanup debris, and checking scenery on Clearview Unit near mouth of Clear Creek. The river canyon survived with very little disturbance. Flowers are blooming below the high water mark! Possibly 5-10% of the riparian alders were uprooted or broken off. The umbrella plant root clusters are still in place on the canyon walls. A high water line is noticeable in a few spots in the lower canyon. One active earth flow had knocked down large trees. This is an enlargement of a slide that has been active in the recent past and is noticeable from the Clear Creek road. A new rapid had formed where a second slide deposited large boulders in mid channel. Jon noticed positive differences in spawning gravels on some pools. It seems some excellent spawning habitat was laid down in many areas. Management of the snags outside of unit lines on the Clearview unit has left downed trees and a few stumps visible from the water. The evidence of the clearcut is more apparent now. Should flush cut stumps We noticed a small logjam in South Fork Clear Creek, didn't have time to check site of former huge logjam. Also noticed lots of silt in South Fork Clear Creek. Saw 1 logging cable to remove from canyon.

DILLON CREEK

Observations by Jon Grunbaum- The lower 0.3 mile of Dillon Creek was oberved on March 27th and 28th. Observations were made at the mouth from the Highway 96 Bridge and from the Dillon Creek campground, and upstream from the campground via the trail that follows the creek for several hundred meters.

As in Clear Creek, fish habitat in Dillon Creek appeared to benefit from the flood in terms of scour and recruitment of new spawning gravels. Alder mortality was very low (many alder as small as 3 inches in diameter growing on cobble bars next to the creek survived).

SALMON RIVER

1. Lower Salmon River Below Steinacher Creek- Observations by Jon Grunbaum- The lower Salmon River from Butler Creek to the Mouth was observed from the road on many occasions between January and April. The passage of high water through this reach was readily apparent. The primary effect of the flood on this segment of the Salmon River was transport and removal of much material off of the high cobble and gravel bars that characterize this stretch. On most bars it appeared that from one to three feet of stored sediment was transported downstream. It did not appear that much of this sediment was re-depositied in the river because the pools appeared to have retained much of their depth and volume. Many of the willows growing on the margins of the cobble bars were scoured out in the flood but these plants did not provide much cover or shade pre-flood. Substrate composition in the wetted area of the river did not appear to be substantially altered.

Removal of material off of the high cobble/gravel bars may represent an increment of recovery for the lower Salmon River. These bars have been so high that plants and trees cannot get established in the dry desert-like conditions where roots cannot reach the water table before succumbing to dessication. Lowering of the level of the top of these bars might allow establishment of riparian and floodplain vegetation which could provide shading, stabilze banks, and produce large wood for recruitment into the river.

2. Knownothing Creek- (Observations by Robbi Van de Water and Orion Dix) We examined the creek about 1/2 mile above the mouth where a small road accessing an active mining operation reached the stream. The channel is about 35 feet wide here, and downcutting in the channel bed had moved upstream about 60 feet according to District personnel. Pre flood photographs and pebble counts are available for this site in District Files (Dix). A few alders had been knocked down on a bar located near the west bank of the creek. Above us, the channel appeared of uniform width, was a riffle?? situation, and had no bars in it. There was only minor abrasion of alder trunks above us.

> ...uniform width riffle habitat. The site was monitored after the 1987 fire and recovery process. Orion Dix noted the riffle upstream appears much as it has over the last twelve years. Downstream, the channel appears to be downcutting. Alders on the right bank (looking downstream) are one to two feet above the current channel indicating the degree of down cutting occurring there.

2. Hotelling Creek Debris Basins- (Observations by Robbi Van de Water and Orion Dix) We visited debris basins constructed immediately above and below the County road on Hotelling Gulch which were built after the 1987 fires. The one above the road had completely filled in with gravel and cobbles up to 4 inches in diameter. It had been excavated back out, leaving a hole about 70 feet long and 30 feet wide, and the material was piled on the west bank in a berm about 7 feet high. After blockage of the pipes, the water and sediment from Hotelling Gulch had flowed westward along the road and buried it to a depth of about a foot, and then exited to the north about 150 feet to the west. Of the two 36?? inch culverts under the county road, the western culvert was still plugged. The channel of Hotelling Gulch above the county road did not show evidence of a debris flow having passed through. The riparian vegetation was primarily intact. It appears that the pipe was clogged by gravel and cobbles which filled the debris basin. Most of the water and debris and water appears to have then run down the road to the west, and only a small amount appears to have continued below the county road to the lower debris basin (however we did not go down and verify this). The fact that these basins filled is notable in that they had never accumulated debris during the years following the 1987 fires til now.

3. Debris Settling Basins in Methodist Creek- We visited three small debris basins built after the 1987 fires on a tributary to Methodist Creek (un-named) about a mile upstream from the mouth of Methodist Creek. Two basins were located below the road by a 20 foot high boulder. The lower one was about 30 feet long and 25 feet wide, the upper one about 40 feet wide and 20 feet long. Both were about 5 feet deep, and were built by installing boulder dams without fabric in the channel. The third was of similar construction, but smaller, and was situated above the road. All three were filled with gravel and cobbles and it appeared that the channel upstream had not passed a debris flow (we did not walk the channel to verify this), since riparian vegetation looked intact. Thus the event on the creek was probably similar to that on Hotelling Gulch, a large sediment load, but ordinary stream flow. There is no name for the tributary to Methodist Creek where the debris basins are located. The basin are located just below the Hensher place.

4. Upper South Fork Salmon at Boy Scout Bar Above the Confluence With Ray's Gulch- (Observations by Robbi Van de Water and Orion Dix) The river removed a very large wedge of gravel bar about 10 feet thick, over about 4? acres, and channel shifted from north edge of floodplain to south edge. Lots of alders removed, likely consequernces to temperature. The channel changes here are typical of those present down the South Fork to a distance below Petersburg, and also, reportedly up into the wilderness. Approximately 2.5 acres of the bar has been removed. The entire bar was just 4 acres when it was planted recently.

5. Log Jam Above Boy Scout Bar- (Observations by Robbi Van de Water and Orion Dix) A large (about 60 feet in diameter) log jam with max logs about 36 inches diameter? and 40? feet long consisting of about ?? logs.

UKONOM CREEK

Observations by Dave Payne- The January 1, 1997 flood event caused some remarkable changes within the Ukonom Creek drainage. I surveyed by foot the remnants of the hiking path used by floaters to access Ukonom Falls on March 24th 1997.

The flood rearranged the mouth of Ukonom Creek. A slide two winters ago ('95) blocked the creek and forced a channel change that scoured out a 40' deep channel where there was once a shaded glen. This past winter that channel was covered by the flooding Klamath River. Ukonom Creek straightened its path to the river carrying huge granite boulders that were deposited upon meeting the Klamath flow. Mature alders were shattered and laid down like broken match sticks. The channel that had formed one year before was blocked by a logjam and swallowed by a huge Klamath River eddy. The result produced a magnificent drop of sand where only days before was the active Ukonom Creek channel.

The Ukonom Creek flow scoured the creek of most of the large woody debris that was deposited in the active channel. One log that was deposited during the receding flood waters acts as a bridge across Ukonom Creek linking the new sand deposit with the downstream cobble deposit.

The slide that caused much of this change remained reasonably stable. The creek flow scoured much of the loose rock away as Ukonom Creek reclaimed its pre-slide channel back. The trail that is annually built across the bottom of this slide will be pretty easy to replace. Throwing and placing a few strategic rocks should produce a usable path.

Much of the trail along the creek was at the highest water level of the flood. Parts were scoured away, other parts recieved deposits of wood, bark, etc. Re-establishing the trail through this zone should be very easy. At the point where the trail climbs bedrock and crosses a talus zone two slips occurred. These slips erased approximately 200' of trail tread that had been in place for approximately 16 years. Re-routing of the trail through this area will require the most work. Once the trail clears this talus slope it drops back down to the creek level. The trail is usable to the shallow water crossing, parts are under water, other sections have been washed and are easily traversed.

The trail upstream of the shallow water crossing has been washed but suffered little damage. Some areas recieved deposits of sand, other spots accumulated woody debris. A one point there is a 10' deep logjam that must be crossed. A tunnel along the edge of the bedrock exists for "slim" folks, others will have to climb over the pile or swim around a large boulder to get around it.

The trail across the bluffs was unchanged by the flood. The trail beyond the bluffs to the falls was also undamaged by the flood. The alders lining the creek immediately below the falls were swept away. This has left open views to the falls from about 300' away.

The most stunning change occurred at the falls themselves. A second invisible falls about 10' high had always existed above the 18' high twin falls. It was separated by a narrow pool enclosed by verticle bedrock walls and not visible to folks enjoying the plunge pool at the twin falls.

A logjam created by the flood has filled the narrow gorge above the twin falls. This logjam is maybe 35' in height!! This logjam has dammed the channel and changed the invisible 10' falls into a visible 18' verticle falls that sits atop of the 18' twin falls! The top falls plunges into a small pool then forms a rooster tail and plunges mostly over the Happy Camp side of the twin falls. In viewing Ukonom Falls from any distance it appears that the falls have doubled in height!! It is simply awesome.

The plunge pool at the bottom of the falls has changed a bit. A deeper, fast channel now scours the area the you enter the "viewing bowl" of the falls. Large granite cobble have accumulated on the Ukonom side of the bowl. The wind and spray from the falls immediately soaks you when you enter the "viewing bowl". Photography is difficult as water builds up rapidly on camera lens, glasses, clothing, etc. It is a fitting monument to the power of moving water and the flood flow of 1997.

1996 / 1997 NEW YEAR FLOOD

EFFECTS ON ANADROMOUS FISH HABITAT IN:

ELK, INDIAN, & DILLON CREEKS & LOWER SALMON RIVER

By: Jon Grunbaum 1997

ELK AND INDIAN CREEKS

Effects of the 1996/97 New Years flood on channel characteristics, riparian vegetation, and fish habitat were surveyed in mainstem sections of Elk and Indian Creeks. An analysis of habitat conditions and water temperature of Elk Creek was then performed to gain some understanding of the type of changes that occurred in Elk Creek and other nearby streams that also appeared to be greatly changed by the flood (Indian, Grider, Walker).

The character and magnitude of some flood effects appeared to depend on degree of channel constraint and valley morphology, while other effects were consistently observed throughout the stream segments that were reconnoitered. Flood effects in Elk and Indian Creeks is described for: 1) effects observed throughout all stream segments; 2) effects observed in alluvial reaches; and 3) effects observed in transport reaches. For this discussion, **alluvial reaches** are defined as depositional stream segments that occur where the valley floor is wide and stream channel is unconstrained by high banks or adjacent hillslopes. Sediment is often deposited in alluvial reaches and may remain there for relatively long periods of time before being transported downstream again by subsequent flows. **Transport reaches** occur in places where the stream channel is narrow because it is constrained by high channel banks or because the hillslopes of narrow valleys impinge upon one or both sides of the stream channel. Much of the sediment entering transport reaches passes through quickly without being deposited for long. The overall proportion of alluvial versus transport reaches is given for the surveyed segments of each creek so that the extent of flood-related disturbance can be more accurately described.

Surveyed Stream Sections

In **Elk Creek**, flood effects were observed in the mainstem from the 11 Mile Bridge to the mouth - excluding the 'whooping devil' gorge (RM 4.7 to 5.0). River Mile 4.5 to mouth was surveyed on March 17. RM 11.0 to 5.0 was surveyed on March 29. Access for these surveys was via inflatable kayaks. Later in the summer, post-flood habitat conditions were quantified and compared to pre-flood conditions recorded in a similar survey conducted in 1989 (Table 1). Water temperature was recorded in the summer of 1997 and compared to water temperature data recorded during the summers of 1990 to 1995 (Table 2). Detailed analysis of the sediment composition of spawning gravels in Elk Creek was performed by the California Department of Fish and Game in the summer following the flood.

In **Indian Creek**, flood effects were observed in the mainstem from the confluence of Mill Creek (RM 12) downstream to confluence with the Klamath River. The lower 4.5 miles (starting from the area commonly known as Buchannan Falls and moving downstream to the mouth) was surveyed in its' entirety on March 20. Access was via inflatable kayaks. Mainstem Indian Creek reaches between Mill Creek confluence and Buchannan Falls were spot checked by hiking in to various sites or by viewing the creek from Indian Creek Road. Habitat conditions in Indian Creek were quantified post-flood but comparisons to pre-flood conditions have not yet been made. Detailed analysis of the sediment composition of spawning gravels in Indian Creek was performed by the California Department of Fish and Game in the summer following the flood (Appendix ??).

Flood effects observed throughout surveyed stream segments

During the flood, much more sediment was delivered to the mainstems of Elk and Indian Creeks than these streams were capable of transporting downstream. Excessive sediment recruitment into the surveyed reaches was evidenced by the in-filling of former depressions in the streambed by silt, sand, gravels cobbles, and even larger sized particles (boulders) that were mobilized during the flood. Sedimentation of the mainstem reaches has serious implications for anadromous fish populations because much of the holding, spawning, and rearing habitat of salmon and steelhead in the Elk and Indian watersheds occurs in the these areas.

The effects of excessive sediment loads was particularly apparent in pool habitat. Pools that are critically important for habitat diversity, rearing, and refugia for salmon, steelhead, and resident trout were completely filled in or greatly diminished is depth and volume. Almost all pools appeared to be filled in to some degree and many were 50% or more filled in. Bars composed of sand, gravel, and even cobbles were commonly observed in pool tail-outs and other places that were formerly deep areas of pools. Pools in narrow bedrock gorges were least affected but it still appeared that even these pools had lost some depth and volume due to in-filling.

Substrate composition in pool tail-outs and other prime salmon and steelhead spawning areas changed as a result of the flood. Large quantities of sediment was imported to the mainstem reaches during the flood. This greatly increased the total area of gravel that is of suitable size for spawning salmon and steelhead. Although the flood deposited large quantities of gravels of suitable spawning size, these spawning areas may not be of high quality due to a high percentage of fines that now makes up the bedload. The average diameter of substrate particles in spawning areas appeared to be much smaller post-flood and the streambeds of the two creeks appeared more embedded with fines. This could affect the spawning success of fish and survival rate of incubating eggs. Excessive fines may increase mortality rate of incubating eggs by restricting the interstitial flow of water necessary for delivery of oxygen and flushing of metabolites. Excessive fines can also entrap newly hatched fish within the gravel thereby reducing rate of successful emergence.

Another threat to successful reproduction by salmon and steelhead that has resulted from the flood is instability of the streambed, particularly areas of the streambed that are typically used by salmon and steelhead for spawning. At high flows, the depth and area of scour is much greater in channels in which streambed instability is increased as a result of excessive sedimentation and increased fractions of smaller-sized sediment particles. Increased depth and area of scour results in decreased reproductive success because more individual eggs, or entire redds, are dislodged during any given peak flow. Egg mortality will increase rapidly with increases in size of peak flows, at least until excessive gravels and fine sediments delivered during the flood are transported out of these stream systems. It may take up to 10 years or longer for these stream beds to regain a level of meta-stability so that non-flood peak flows will not result in high egg mortality. This estimate assumes that another large runoff event will not deliver another large slug of sediment before streambed stability is neared.

Excessive streambed scour will occur in conjunction with large pulses of sediment being transported and redepositing in other locations. In contrast to reproductive failure due to loss of eggs because of scour, egg incubation and hatching success could also decrease because of excessive deposition over redds, which could suffocate eggs and entrap hatchlings.

The flood appeared to cause widening and shallowing of the stream channels and loss of riparian vegetation. This was observed along the entire length of surveyed segments, although much more pronounced in alluvial reaches. Increased rates of heating and cooling of the streams is likely because there is less vegetative canopy to shade or blanket the streams and because water flowing in wider and shallower stream channels is more prone to heating from solar radiation and increased water surface area in contact with air.

Aquatic invertebrate populations, the primary food source of rearing salmonids, were drastically reduced by scour and deposition during the flood. These populations are expected to rebound quickly, probably within a year or two, and should not present any serious prey shortages for rearing fish.

Most fish enhancement structures that were constructed of logs were washed out of the creeks or pushed up on the channel margins and are no longer contacting the wetted channel. Boulder structures placed to increase habitat diversity fared better by staying in place or at least not being moved far. Many of the placed boulders were buried or partially buried in thick deposits of sediment during the flood.

Flood effects observed in alluvial stream segments

Large scale changes in channel characteristics and riparian vegetation were observed in alluvial stream segments, while transport reaches appeared less disturbed. Alluvial channels comprise approximately 15% of the stream sections surveyed on Elk Creek and approximately 20% of the surveyed portions of Indian Creek.

In alluvial stream sections thick deposits of sediment was deposited over most of the stream channel and adjacent floodplains, although in some instances large tracts of floodplain were eroded away. Heavy sediment loads carried with the flood water raised the level of the stream channel bottom during the height of the flood causing the streamflow to spread out and increase erosion of low terraces and distant streambanks, and undercut sections of roadway. As the flood peaked and receded a thick lens of sediment was deposited over large areas of the former channel and on adjacent floodplains. The fact that the streambed was elevated during the flood was evidenced in many areas where old stream channels were re-established or new stream channels were formed within days after the flood, as decreasing flows with lower sediment loads quickly cut down through the lens of loose sediment that composed the top layers of the streambed during the flood.

Because of the massive aggradation occurring on these alluvial flats during the flood there was quite a bit of channel instability. Channel instability was manifested by radical channel re-alignments and channel braiding. This channel instability contributed to loss of riparian and floodplain vegetation as new channels were constantly being scoured through adjacent floodplains and re-vegetated remnant or overflow channels.

Excessive deposition buried riparian vegetation in places and filled in most depressions in the former stream channel. Approximately 30% to 60% of the riparian vegetation (mostly alder and willow) growing on these alluvial flats was buried or removed by the flood. Scour, physical impact by a floating objects, and deposition appear to be the primary factors resulting in loss of riparian vegetation. As noted earlier, loss of riparian vegetation coupled with widening and shallowing of stream channels may allow excessive heating of water during the summer months, which in turn could reduce growth and survival of rearing salmonids.

In addition to the loss by washout or excessive sediment deposition that occurred throughout the surveyed stream segments, incubating salmon eggs in alluvial reaches may have been left stranded in `dry' streambeds in sections where channel realignments occurred. As excess sediment from this large storm event is moved out of these creeks new channel migrations are likely as the channel repositions into more stable configurations. Washouts, burial, and stranding of incubating eggs are possible during such channel re-configurations that are likely to take place during peak flows over the next few years.

Flood effects observed in transport stream segments

In transport stream segments there was less channel widening and mortality of streamside vegetation was not as great - probably averaging about 20%. Much of the alder less than 30 years old immediately adjacent to the stream was removed by scour or impact during the flood and the channel banks were scoured clean of moss and other vegetation in many places. Loss of this streamside cover in these segments has minor implications for direct solar heating of Indian Creek because canopy cover and shading will still be provided by trees that are near the wetted channel but that survived because they were slightly higher up the steep stream banks and/or hillslope. Topographic shading also provides some protection from direct solar heating in these channel types. Widening and shallowing of stream channels in these segments has occurred which has increased the air/water surface area, but channel widening in transport reaches is limited by channel constraint. Spawning is less common in transport reaches but does occur. Spawning areas in transport reaches are also likely to be unstable because large pulses of sediment will pass through these reaches as excess sediment is moved out of the stream systems.

Pre- and post-flood comparison of habitat conditions in Elk Creek

Physical attributes of the Elk Creek mainstem that are important in determining the quantity and quality of fish habitat were assessed pre-flood in 1989 and post-flood in 1997. The effects of the flood on fish habitat from the creeks' mouth upstream to the confluence of Lick Creek (approximately 12 valley miles) was then analyzed by comparing the characteristics of the 1989 stream channel to the characteristics of the stream channel post-flood in 1997 (Table 1). Although other processes have undoubtedly changed Elk Creek since the last survey in 1989, the New Years flood is by far the overriding event accounting for the present configuration of the stream channel and floodplain. This analysis serves to illustrate some of the changes that occurred in Elk Creek fish habitat condition because of the flood. Similar changes can reasonably be assumed to have occurred in the mainstems of other nearby streams which were also drastically altered during the flood (Indian, Grider, and Walker Creeks).

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Table 1. Comparison of fish habitat and stream channel condition of pre- and post-flood Elk Creek (mouth to confluence of Lick Creek).

	Notes	ELK CREEK 1989 May 30-June 22	ELK CREEK 1997 July 17-Aug 26	% Change 1989 to 1997
Overall				
No. of Units	a	612	356	-42%
Primary channel (mi)	a	14.3	12.5	-13%
Side Channel (mi)	a	1.6	0.3	-81%
Total Length	a	15.9	12.8	-19%
Fast Water (Riffles and Glides)	b			
No. Fast Water units	c	401	234	-42%
Length Fast (ft)	c	59334	52568	-11%
Avg Fast Length	c	148	225	52%
Avg Fast Width	d	41	33	-20%
Avg Depth	d	1.8	1.0	-44%
Embeddedness		22	34	55%
Slow Water (Pools)	b			
No. Slow Water	c	211	122	-42%
Length Slow (ft)	c	24555	14793	-40%
Avg Slow Length	c	116	121	4%
Avg Slow Width	d	39.6	33.2	-16%
Avg Depth	d	3.5	2.0	-43%
Avg Max Depth	d	6.4	5.2	-19%
Avg Resid Pool Depth	c	4.5	3.7	-18%
Avg Resid Pool Vol	c	16544	8014	-52%
Embeddedness		28.8	34.3	19%
Fast/Slow Water				
No. Fast / No. Slow		1.9:1	1.9:1	0%
% Fast by No.		65.5	65.7	0%
Length Fast/Slow		2.4:1	3.6:1	50%
% Fast by Length		70.7	78.0	10%

Notes:
a = Habitat units in primary and secondary channels were combined.
b = Habitat types were condensed into "Fast" and "Slow" types.
c = These metrics can be directly compared - do not depend on flow
d = These metrics cannot be directly compared because of possible differences in streamflow during the 1989 and 1997 surveys.

Table 1 shows that between 1989 and 1997 there was a loss of 3.1 miles of stream habitat. Some of this decrease is associated with the loss of 1.3 miles of side channels as stream reaches that had multiple channels before the flood became consolidated into one channel after the flood. Another important process that contributed to loss of stream length within the surveyed reach was meander cutoff - the stream straitened as a result of the flood. Amount of error associated with length measurement is unknown but assumed to be small.

The stream channel became less diverse and more uniform as a result of the flood. There was a 42% reduction in the number of individual habitat units identified by surveyors. This reduction in numbers was evenly split between fast water (riffles and glides) and slow water habitat types (pools), however, the total percentage of length of slow water habitat decrease (-40%) was much greater than the total percentage of fast water habitat (-11%) decrease. The average length of pools remaining after the flood was slightly greater (4%) than pre-flood but the average length of fast water habitats increased 52%. The ratio of length of fast to slow water increased 50% (from 2.4:1 to 3.6:1).

In addition to the large decrease in the total length and number of pools following the flood, there was also a large decreases in the average volume of the pools that remained. Average residual pool depth and average residual pool volume are good metrics for comparing pool characteristics because these metrics can be measured regardless of streamflow volume. Average residual pool depth decreased 18%, post-flood vs pre-flood. Average residual pool volume decreased 52%.

Embeddedness was estimated in fast water and slow water habitat types in both 1989 and 1997 surveys. Average embeddedness post-flood was greater than pre-flood in both fast water (55%) and slow water (19%) habitat types.

<u>Pre- and post-flood comparison of water temperature in Elk Creek</u>

Water temperature of Elk Creek has been monitored since 1990. The recording instrument was faulty in the 1996 deployment which resulted in useless data. A comparison of pre- and post-flood water temperatures was prepared to assess the effects of physical changes in the channel and riparian vegetation on summer water temperatures. The warmest water temperatures in consecutive 31 day periods in the summer of each year was used in comparisons (Table 2). The average temperature over the entire 31 day period, the instantaneous maximum recorded temperature, the seven day maximum average, the 31 day maximum average, and the average diurnal variation were calculated. These calculations were made for each individual year pre- and post-flood. A mean for all years pre-flood (1990-1995) was also calculated for use in comparing to the one post-flood year (1997). The low flow rate and average air temperature during the water temperature recording period for each year is included in Table 2 to provide context for the water temperature data.

The instantaneous maximum water temperature and the seven day maximum average water temperature were markedly higher in post-flood summer of 1997 than either the mean of the pre-flood years or in any one of the individual pre-flood years. The 31-day maximun average in post-flood 1997 was also higher than the mean for pre-flood years but not much higher than in some of the individual pre-flood years alone. The average 31-day temperature for post-flood 1997 was about equal to the mean for pre-flood years. The average diurnal temperature variation over warmest 31 day period was much greater in post-flood 1997 than the mean for the pre-flood years as well as much greater than for any individual pre-flood year. This explains why the post-flood average maximums can be greatly higher than the pre-flood mean average maximums while the average 31 day average temperature in 1997 was about equal to pre-flood years. Apparently stream heating was greater after the flood but the stream was also more susceptable to cooling at night as well. This also supports the reasoning that the higher than mean instantaneous and maximum average temperatures post-flood versus pre-flood is not an artifact of differences in ambient air temperature or flow rates.

Table 2. Elk Creek water temperatures: Comparison of 1990 - 1995 with 1997.

Creek	Year	Begin Hottest 31 Days	Ave.	Inst. Max.	7 Day Max Avg	31 Day Max Avg	Diurnal Var.	Low Flow	Average Air Temp
Elk	1990	July 22	63.9	72.3	71.2	69.1	8.1	a	74.1
Elk	1991	July 11	65.5	71.4	70.3	69.1	8.3	28	73.8
ELK	1992	Aug 1	64.8	72.7	71.2	68.0	7.4	17.4	69.4
Elk	1993	July 18	59.9	67.3	65.7	62.8	7.0	44.0	69.6
ELK	1994	July 5	65.8	72.3	71.2	69.1	8.1	16.1	76.0
ELK	1995	July 16	60.9	68.2	66.4	63.9	7.0	a	71.4
Elk	**Mean**	**1990-95**	**63.5**	**70.7**	**69.4**	**67.0**	**7.6**	**26.4**	**72.4**
ELK	1997	Aug 2	64.0	74.5	73.0	69.6	12.5	49.3	74.6

a = no data

Analysis of substrate composition of post-flood Elk and Indian Creeks

Potential salmon and steelhead spawning habitat quality was assessed in Elk and Indian Creeks by Natural Stocks Assessment Program personnel of the California Department of Fish and Game (CDF&G) in post-flood 1997 (Appendix ??). Assessment was made by detailed analysis of substrate composition. Mean percent fines in sampling stations of Elk and Indian Creeks were found to be at the limit or exceed levels associated with egg mortality. Sand-sized sediments were at or above levels associated with decreased salmonid sac fry emergence rates at all sampling stations. Similarly, small sediment fractions measured at all stations exceeded levels associated with entombing and decreasing sac fry emergence rates. CDF&G concluded that these impacts are likely to lead to the reduction of juvenile salmonids from these two streams.

CLEAR CREEK:

The mainstem of Clear Creek was observed from Slippery Creek to the mouth on March 19th via inflatable kayaks. Much new spawning gravel had been recruited into this stream segment by the flood but sediment deposition was not excessive. Pools appeared to be as approximately as deep as before the flood and residual pool volume appeared to be just slightly lower than before. Some braiding was noted on one especially wide tail-out/riffle area, indicating that at some point during the flood sediment recruitment rate was nearing the transport capacity of the streamflow. No remnant elevated flood streambeds were observed as in Elk and Indian Creeks except at the Klamath River confluence.

Although there was a distinct high water line on the channel banks indicating that very high flows had occurred, much of the moss and other vegetation on the banks was intact. Overall alder mortality was 5% or less.

From a fish habitat perspective the surveyed segment of Clear Creek was actually improved by the scouring action of the flood and the deposition of new spawning gravels.

DILLON CREEK:

The lower 0.3 mile of Dillon Creek was observed on March 27th and 28th and another 2.7 miles were observed in August. As in Clear Creek, fish habitat in Dillon Creek appeared to benefit from the flood in terms of scour and recruitment of new spawning gravels. Alder mortality was very low (many alder as small as 3 inches in diameter growing on cobble bars next to the creek survived). In-filling of pools appeared minor. Evidence of extreme flows were apparent as water lines on the moss, debris line in trees, and the movement of a very large boulder as captured on photos taken at a reference station in 1996 and again in 1997.

LOWER SALMON RIVER:

The lower Salmon River from Butler Creek to the Mouth was observed from the road on many occasions between January and April. The passage of high water through this reach was readily apparent. The primary effect of the flood on this segment of the Salmon River was transport and removal of much material off of the high cobble and gravel bars that characterize this stretch. On most bars it appeared that from one to three feet of stored sediment was transported downstream. It did not appear that much of this sediment was re-deposited in the river because the pools appeared to have retained much of their depth and volume. Many of the willows growing on the margins of the cobble bars were scoured out in the flood but these plants did not provide much cover or shade pre-flood. Substrate composition in the wetted area of the river did not appear to be substantially altered.

Removal of material off of the high cobble/gravel bars may represent an increment of recovery for the lower Salmon River. These bars have been so high that plants and trees cannot get established in the dry desert-like conditions where roots cannot reach the water table before succumbing to dessication. Lowering of the level of the top of these bars might allow establishment of riparian and floodplain vegetation which could provide shading, stabilize banks, and produce large wood for recruitment into the river.