STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
NORTHERN DISTRICT

WATERSHED MANAGEMENT FOR UNSTABLE AND ERODIBLE AREAS IN NORTH COASTAL CALIFORNIA

Prepared for the U.S. Environmental Protection Agency
and the State Water Resources Control Board
October 1982

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The preparation of this report was financed in part, through an Areawide Waste Treatment Management Continuing Planning Program grant from the U. S. Environmental Protection Agency, Region IX, under the provisions of Section 208 of the Federal Water Pollution Control Act, as amended.

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and the State Water Resources Control Board
October 1982

LIST OF WATERSHED MAPS

r Creek

e	$7\frac{1}{2}$-minute Quadrangle
Mountain	$7\frac{1}{2}$-minute Quadrangle
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FOREWORD

The north coastal area of California is one of the most unstable geologic areas in the country. It also supports a major timber industry. Soil erosion and landsliding are major land-forming processes. One characteristic that must be considered in making land-use decisions is once a landslide has occurred the slope is permanently weaker. Such activities as logging, road building, and grazing may be enough to reactivate landslides and cause significant losses in timber production capacity, fishery, and water quality.

Even though California has some of the best timber harvest rules in the nation, present timber harvest planning (THP) lacks information on which to make wise land-use decisions. The purpose of the 208 Phase II project is to gather the needed information and make specific recommendations concerning "best management practices" (BMPs) in these areas. Many of the observations and conclusions can be applied to other watersheds in the north coastal region.

Three watersheds were selected for the study. They are the Grouse, Blue, and Turwar Creek basins. These three basins are in unstable terrain where timber is now being harvested and where fishery and water quality considerations are important.

Watershed data were compiled and plotted on 7½-minute topographic quadrangles. Four types of maps were produced. They show geology, landslides, soil and vegetation, and timber harvests--for a total of 36 quadrangles.

The California Department of Water Resources, Northern District Geology Section, prepared this report under contract with the U. S. Environmental Protection Agency and the State Water Resources Control Board.

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Wayne S. Gentry
Acting Chief
Northern District

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CONVERSION FACTORS

Quantity	To Convert from Metric Unit	To Customary Unit	Multiply Metric Unit By	To Convert to Metric Unit Multiply Customary Unit By
Length	millimetres (mm)	inches (in)	0.03937	25.4
	centimetres (cm) for snow depth	inches (in)	0.3937	2.54
	metres (m)	feet (ft)	3.2808	0.3048
	kilometres (km)	miles (mi)	0.62139	1.6093
Area	square millimetres (mm^2)	square inches (in^2)	0.00155	645.16
	square metres (m^2)	square feet (ft^2)	10.764	0.092903
	hectares (ha)	acres (ac)	2.4710	0.40469
	square kilometres (km^2)	square miles (mi^2)	0.3861	2.590
Volume	litres (L)	gallons (gal)	0.26417	3.7854
	megalitres	million gallons (10^6 gal)	0.26417	3.7854
	cubic metres (m^3)	cubic feet (ft^3)	35.315	0.028317
	cubic metres (m^3)	cubic yards (yd^3)	1.308	0.76456
	cubic dekametres (dam^3)	acre-feet (ac-ft)	0.8107	1.2335
Flow	cubic metres per second (m^3/s)	cubic feet per second (ft^3/s)	35.315	0.028317
	litres per minute (L/min)	gallons per minute (gal/min)	0.26417	3.7854
	litres per day (L/day)	gallons per day (gal/day)	0.26417	3.7854
	megalitres per day (ML/day)	million gallons per day (mgd)	0.26417	3.7854
	cubic dekametres per day (dam^3/day)	acre-feet per day (ac-ft/day)	0.8107	1.2335
Mass	kilograms (kg)	pounds (lb)	2.2046	0.45359
	megagrams (Mg)	tons (short, 2,000 lb)	1.1023	0.90718
Velocity	metres per second (m/s)	feet per second (ft/s)	3.2808	0.3048
Power	kilowatts (kW)	horsepower (hp)	1.3405	0.746
Pressure	kilopascals (kPa)	pounds per square inch (psi)	0.14505	6.8948
	kilopascals (kPa)	feet head of water	0.33456	2.989
Specific Capacity	litres per minute per metre drawdown	gallons per minute per foot drawdown	0.08052	12.419
Concentration	milligrams per litre (mg/L)	parts per million (ppm)	1.0	1.0
Electrical Conductivity	microsiemens per centimetre (uS/cm)	micromhos per centimetre	1.0	1.0
Temperature	degrees Celsius (°C)	degrees Fahrenheit (°F)	(1.8 × °C)+32	(°F−32)/1.8

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INTRODUCTION

The purpose of the Phase II 208 watershed mapping project is to integrate watershed data and land-use considerations into the State timber harvest plan process. Among the tasks involved in accomplishing this are:

- Identify geologic hazards, such as landslides and high soil erosion areas.
- Prepare maps showing watershed characteristics, such as geology, soil and vegetation, land use, landslides, instability and erosion hazards, and precipitation.
- Incorporate these maps into the land-use planning process by providing these maps to land managers and the THP review committee.
- Recommend best management practices (BMPs) to the Board of Forestry for integration into the regulatory process.

This project is one of several studies funded and supported by the Federal Environmental Protection Agency (EPA), the State Water Resources Control Board (SWRCB), and the California Department of Forestry (CDF). The long-range goals of these projects are to conserve and protect forest soils, improve water quality, reduce stream sedimentation, and protect fish and wildlife habitat.

Background

The EPA has contracted with SWRCB to oversee federal funding under Public Law 92-500, Section 208, for water quality projects in California. Two similar pilot projects were funded: one conducted by CDWR (Phase II) and the other by CDF (Phase III). Both projects involve geologic hazard mapping of sensitive areas of the North Coast.

The Phase II 208 project began in 1981. The pilot watersheds chosen were Blue and Turwar Creeks, tributaries to the Klamath River, and Grouse Creek, tributary to the South Fork Trinity. Resource maps produced include geology, landslides, soil-vegetation, instability and erosion hazard, and timber harvesting. These maps are included as Appendix A in this report.

The CDF Phase III project is similar in scope, but will be an ongoing project to map unstable areas in the North Coast. The hazard mapping was subcontracted to CDMG and the Center for Natural Resources Studies of the John Muir Institute. Part of the Phase III project was to organize a Watershed Mapping Steering Committee. Members include representatives from private industry, CDWR, CDF, CDMG, EPA, SWRCB, and the U. S. Forest Service (USFS). The committee is advising both Phase II and Phase III.

Federal Water Pollution Control Act of 1972

The goal of Section 208 of the Federal Water Pollution Control Act Amendments of 1972 (Public Law 92-500, the Clean Water Act) is to insure "fishable and swimmable" water by 1983 (Coats and Miller, 1981). [redacted] Section 208 sets the guidelines for developing area-wide pollution controls from such sources as agriculture, silviculture, mining, and construction.

The EPA is charged with implementing the provisions of the Act and overseeing State programs (Weatherford, et al, 1979). The SWRCB and the regional boards are responsible for 208 planning in non-designated areas (areas where no regional planning agencies exist).

Non-point pollutants associated with silviculture include sediment, organic debris, water temperature increases, nutrients, pesticides, grease, and oil. The most extensive and serious pollutant is sediment. The most logical and least expensive method of reducing sediment in streams is to modify land-use practices.

Z'berg-Nejedly Forest Practice Act of 1973

California's timber industry is regulated by the provisions of the Z'berg-Nejedly Forest Practice Act (Division 4, Chapter 8, of the Public Resources Code). The Act ushered in a new era of regulation to protect environmental quality and downstream beneficial uses of water.

Some of the more important aspects of the Act are summarized below:

"We think it a settled principle..that every holder of property, however absolute and unqualified may be his title, holds it under the implied liability that his use of it may be so regulated that it shall not be injurious to the equal enjoyment of others having an equal right to the enjoyment of their property nor injurious to the rights of the community."

Supreme Court of Maine, 1908

"The social lesson of soil waste is that no man has the right to destroy soil even if he does own it in fee simple."

Henry A. Wallace
ex-Secretary of Agriculture, 1938

"We have long recognized that the police power--the power of government to implement its concern for the general welfare--may severely curtail the use to which real property may be put."

Supreme Court of Wisconsin, 1974

"A great unwritten compact exists between the dead, the living, and the unborn. We leave to the unborn a colossal financial debt, perhaps inescapable, but incurred, nonetheless, in our time and for our immediate benefit. Such an unwritten compact requires that we leave to the unborn something more than debts and depleted natural resources. Surely, where natural resources can be utilized and at the same time perpetuated for future generations, what has been called constitutional morality requires that we do so."

Edmond Burke

"Without adequate, competent personnel to administer it and without the desire of the governing body to enforce it, a soil loss regulation will be ineffective. An extensive education and information program also is essential for an effective program."

James L. Arts

Adapted from: James L. Arts, Jour. Soil Cons., V 36, N. 6. 1981

SECTION I

INTRODUCTION

Background
Consultant Tasks
Location, Climate and Vegetation

FISHERY

PROPOSED BEST MANAGEMENT PRACTICES

Watershed Planning
Resource and Hazard Mapping
Enforcement of Rules

- The intent of the Act is to "encourage, where feasible, the restoration and maintenance of the productivity of timberlands and which achieves the goal of maximum sustained production of high-quality timber products, while giving consideration to values relating to recreation, watershed wildlife, range and forage, fisheries and aesthetic enjoyment".

- The Act created a nine-member Board of Forestry responsible for dividing the State into forest districts, appointing technical advisory committees for each district, adopting district forest practice rules, and, in general, overseeing that the intent of the Act is carried out.

- The Act requires a Registered Professional Forester (RPF) to submit a Timber Harvest Plan (THP) to CDF for review and approval before logging on private land. The RPF is required to conduct a "feasibility analysis" which includes consideration of alternative silvicultural systems to lessen adverse environmental impacts. Plans are reviewed and field-inspected by a multi-disciplinary team consisting of representatives from CDF, California Department of Fish and Game, regional water quality control boards, and, in certain areas, a geologist from CDMG and an archaeologist from the Department of Parks and Recreation.

- The Act requires the Director of CDF to review the THP and disapprove all plans which "Do not reflect the results of a feasibility analysis as described in CAC 898 by incorporating feasible silvicultural systems, operating methods and procedures that will substantially lessen significant adverse impacts on the environment". A special condition requiring disapproval is if "implementation of the plan would cause damage to soil and water resources that would violate standards provided for in state and federal law".

Consultant Tasks

Work to be performed for the Phase II study was outlined in the SWRCB Interagency Agreement 0-046-118-0 with CDWR. One of the following watersheds was to be selected in consultation with CDF and SWRCB:

1. South Fork Smith River
2. South Fork Trinity River
3. All forks of Blue Creek, tributary to the Klamath River
4. Grouse Creek, tributary to the South Fork Trinity River
5. Turwar Creek, tributary to the Klamath River
6. Major streams in the Bureau of Land Management-USFS Big Butte-Shinbone Ridge study area
7. Major tributaries of the South Fork Smith River

One serious problem arose early in the study. Simpson Timber Company and Arcata Redwood Company, major landowners in the area and both represented on the steering committee, refused access to their lands. This prevented field-checking landslides on private land and preparing maps showing stream channel quality and fishery habitat. Instability and erosion hazard maps could not be made on Blue or Turwar Creeks. An informal decision was then made to continue, but increase the size of the study area. Instead of one, three watersheds (Blue, Turwar, and Grouse Creeks) were selected for study.

Four major tasks were specified in the contract between SWRCB and CDWR:

> Task 1. The Agency shall compile and evaluate all available basic data for the study area, including logging history, vegetative type and distribution, geology, soils, landslides, precipitation, hydrology, and water quality. This information shall be submitted to the State Board's contract manager.

Four types of watershed maps were prepared on 7½-minute topographic and planimetric quadrangles (scale 1:24,000). These showed landslide, soil-vegetation, geology, and timber harvest maps. Precipitation, hydrology, and water quality are discussed in the text.

Task 2. The Agency shall conduct on-site field investigations which examine and record those parameters set forth in Task 1.

Field investigations for verifying landslide maps were done on public land. Access was refused on private timber company lands.

Task 3. The Agency shall develop slope stability hazard zone maps which use information developed in Tasks 1 and 2. The scale and size of the maps shall be determined after consultation with CDF staff and the State Board's contract manager.

Lack of access to private land and resulting lack of specific on-site investigations made hazard zoning in the Blue and Turwar Creek watersheds impossible. A preliminary instability and erosion hazard map was prepared for Grouse Creek.

Task 4. CDWR shall prepare a report that includes the findings and recommendations of the study.

The findings and recommendations are in the "Recommended Best Management Practices" part of this report.

Task 5. CDWR shall assist CDF in the integration of these recommendations into rules, regulations, and procedures of the California State Board of Forestry.

Location, Climate, and Vegetation

The Blue, Turwar, and Grouse Creek watersheds are in northern California in the Klamath Mountains and Coast Ranges geologic provinces. Blue and Turwar are adjacent drainages tributary to the Klamath River only a few miles from the Pacific Ocean. Blue Creek has a basin area of 127 mi^2 and Turwar Creek has 33 mi^2. Grouse Creek, with an area of 59 mi^2, is a tributary to the South Fork Trinity River, and is about 60 miles inland. The watersheds are shown in Figure 1.

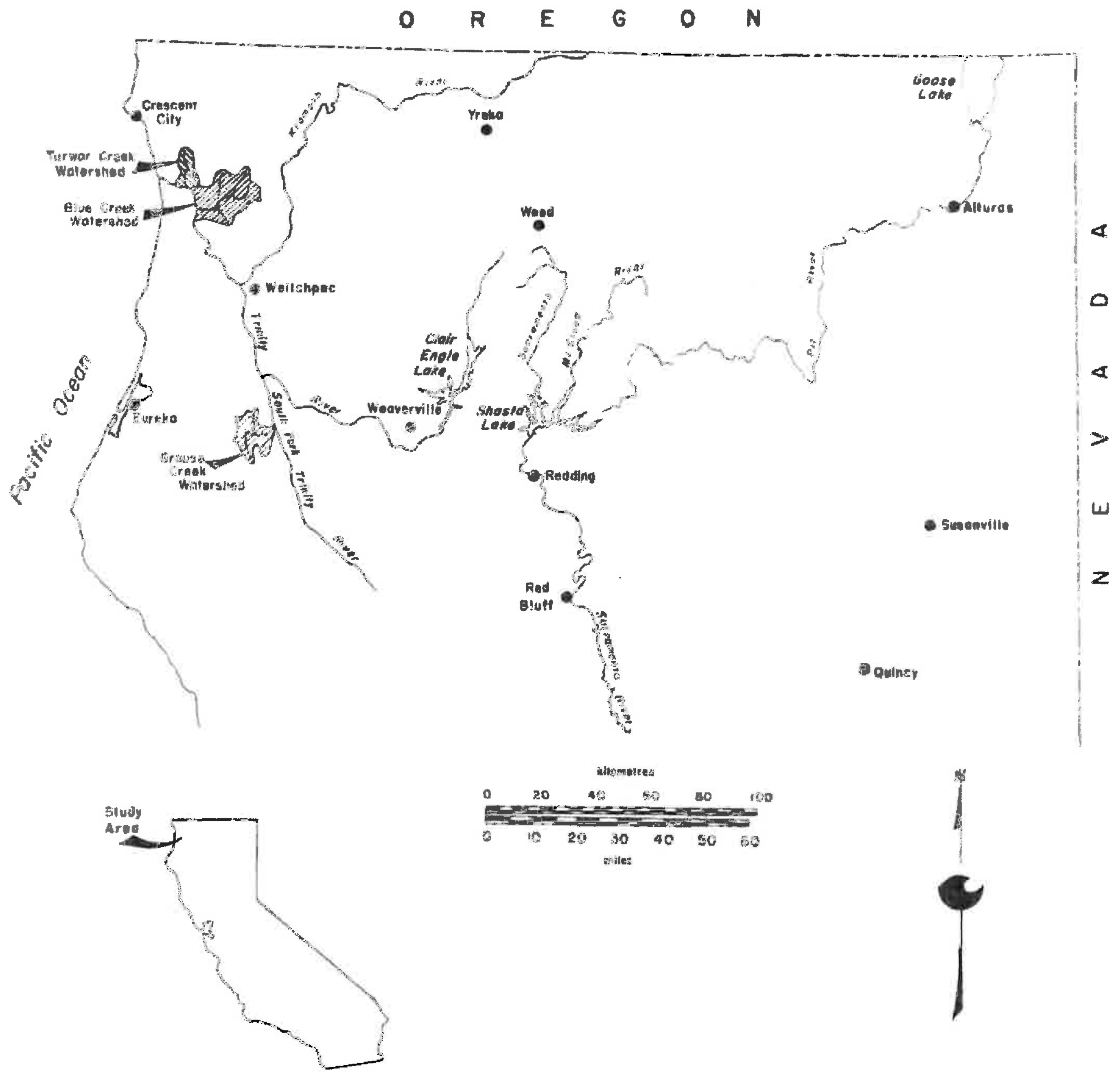
The climate of Blue and Turwar Creeks is influenced strongly by the Pacific Ocean. Winters are wet and mild and summers are fairly dry and cool. About 90 percent of the precipitation in these two basins falls between October and April. The average annual precipitation in the Blue Creek basin is about 100 inches (USFS, 1977) and about the same in Turwar Creek (Figure 2). Winter snowfall in the higher peaks of the Siskiyous is common. Summer temperatures are influenced by ocean breezes with highs generally less than 90°F and lows in the 30s.

The Grouse Creek basin is further inland, with a more distinctly Mediterranean climate of hot, dry summers and cold, wet winters. In summer, mountain temperatures around 100°F warm the ocean breezes and increase their capacity to hold moisture, so very little rain falls in the summer. Most of it falls in the winter, when westerly winds from the Pacific Ocean are cooled by the Coast Ranges. Yearly precipitation averages 80 inches in the basin. Winter temperatures go below freezing and snow is common on ridges through mid-June.

Vegetation within Blue and Turwar basins is complex in pattern and diversity. A number of vegetation types are common, but may intergrade extensively, creating a vegetational mosaic (USFS, 1977). Along the seaward slopes of the northern Coast Ranges are the redwood-Douglas fir forests. These are typically dense, with very tall evergreen trees and thick undergrowth. Soils are deep and rich and because of winter rains and summer fog drip remain moist year-round.

Further inland are the Douglas fir forests, generally at low elevations with reduced exposure. Soils are well developed with high organic content. Associated species include sugar pine and some incense cedar, white fir, Pacific dogwood, and Port-Orford cedar.

Figure 1



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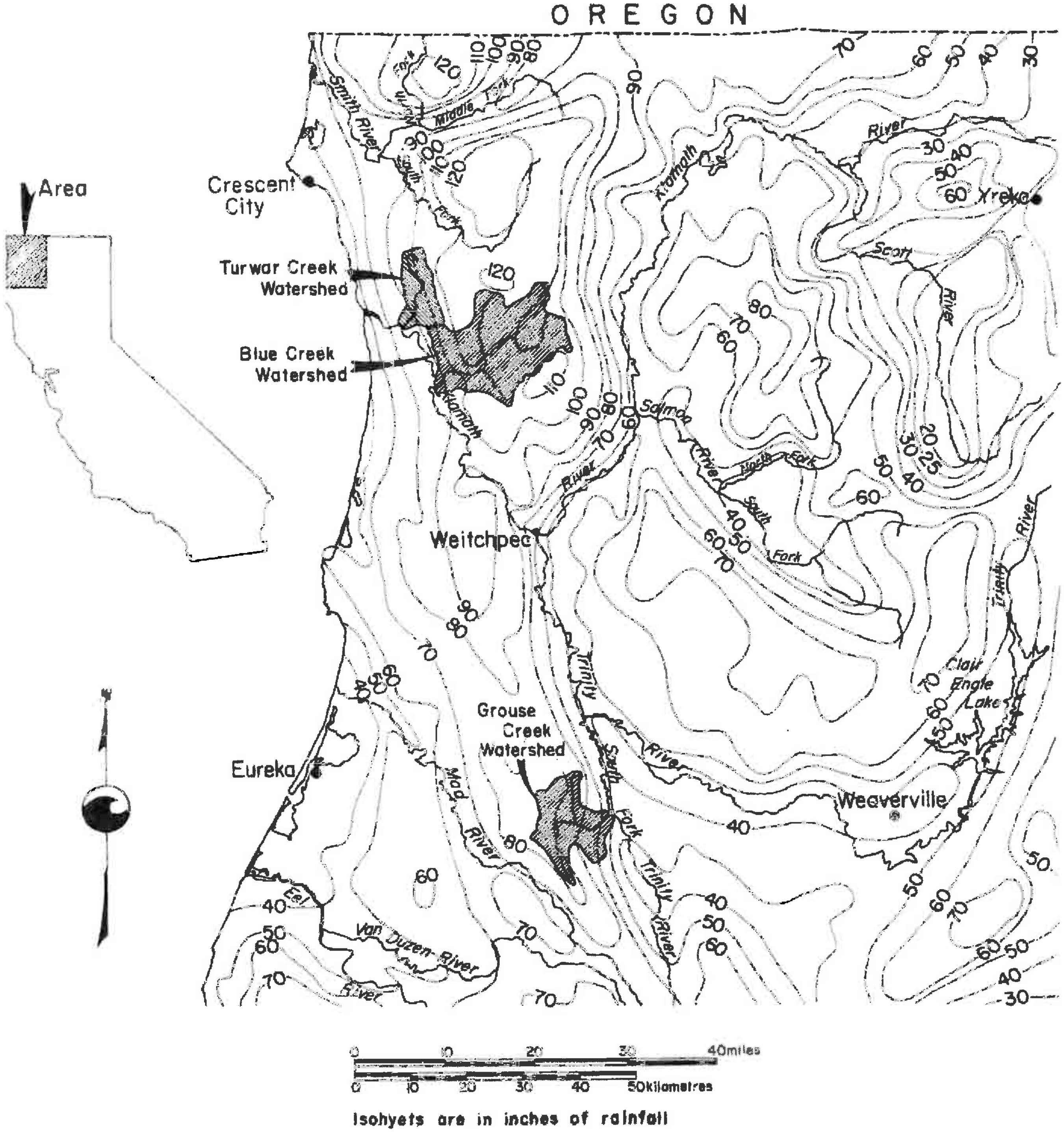
Location Map

Figure 2



Isohyetal Map
North Coastal California

On sites with poor soils, more exposure, higher elevations, and steeper slopes are the mixed conifer-fir forests. White fir, Jeffrey pine, and sugar pine dominate. Also present are western white pine, incense cedar, and Douglas fir. The brush layer is dense. Pine-mat manzanita, huckleberry oak, greenleaf manzanita, Sadler oak, dwarf silk-tassel, and serviceberry are some of the dominant shrubs.

At higher elevations, generally above 5,000 feet, the red fir forests predominate. The more common species are red fir, Shasta fir, western white pine, Jeffrey pine, and some weeping spruce in localized stands. The stands are dense, with closure as high as 95 percent (USFS, 1977).

Other land cover associations include serpentinite barrens, mixed shrubs, and meadows. The barrens occur on serpentinite where thin soils with high magnesium to low calcium ratio and low water-holding capacity limit vegetation. Trees are rare and stunted. The mixed shrub association occurs in timber harvest areas, burns, and areas of slope instability. Main species include coyote brush, blue blossom, salal, rhododendron, as well as species mentioned above.

Meadows occur along streams, springs, seeps, and landslides. Grass and herbaceous plants are dominant.

In Grouse Creek, the mixed conifer-fir forest type predominates. The most common natural vegetation is Douglas fir, intermixed with ponderosa pine, sugar pine, incense cedar, and, with higher elevations, white fir. Scattered digger pines grow where there are ultramafic rocks near the mouth of Grouse Creek.

Brush and hardwoods rapidly invade openings in the forest cover caused by fire and timber harvest. Common brush species are white thorn, deer brush, bush chinquapin, bigleaf maple, and red alder. Brush and grass prairies also occur near the ridge tops of Grouse, Board Camp, South Fork, and Sims Mountains.

FISHERY

Blue, Turwar, and Grouse Creeks are in the Klamath River system. This system drains about 15,600 mi^2 in Northern California. Most of this land is forested and the mainstay of the north coastal economy is timber harvesting.

The anadromous sport and commercial fisheries are second only to timber harvesting in economic importance to the region. Tributaries to the Klamath, including the Shasta, Scott, Salmon, and Trinity Rivers, and Blue Creek historically have supported large runs of anadromous salmonids.

The Klamath River system supports mainly three species of anadromous salmonids (Photograph 1): chinook, or king salmon (Oncorhynchus tshawytcha); coho, or silver salmon (Oncorhynchus kisutch); and steelhead trout (Salmo gairdnerii gairdnerii). Chinooks are by far the most important commercially and steelhead provide the largest portion of instream sport fishery.

Photograph 1. Nearly 200,000 chinooks, 50,000 coho, and 500,000 steelhead migrate through the Klamath River estuary to spawn in the river and its tributaries. Blue Creek is the most important spawning tributary in the lower Klamath River.

Salmon and steelhead spend most of their adult life in the ocean and migrate to fresh water to spawn. Adult chinooks enter the Klamath River estuary from the ocean in two well-defined spawning runs--one in the spring and one in late summer or early fall. The spring-run chinook begin in late March, reach a peak in late May, and end in July. They spawn in the upper Klamath tributaries. Before this century, spring-run chinook were by far the largest run in the Klamath River basin. The fall run usually enters the Klamath River estuary in July, peaks in August, and declines through September. The fall run generally spawns in the upper Klamath and in lower Klamath tributaries.

Coho salmon enter the Klamath estuary about one month after the fall-run chinook and spawn a short time after the chinook. Steelhead spawn from February through April.

Salmonids ascend rivers and streams to find suitable spawning gravel and water temperatures that are cool to cold.

Chinooks spawn mainly in the larger streams; coho and steelhead generally use the smaller tributaries. The female digs a shallow nest, or redd, and deposits her eggs in the gravel. Chinook salmon select suitable spawning gravel generally 2 to 6 inches in diameter. Coho and steelhead prefer finer gravel, typically 0.5 to 4 inches. The eggs are then fertilized by the male. The fertilized eggs are covered with gravel and the adult salmon die. Steelhead do not necessarily die after spawning and may return in subsequent years to spawn.

Eggs hatch in 50 to 60 days, depending on water temperature, and the young take 3 to 4 weeks to emerge from the gravel. In the spring and early summer, most chinook salmon migrate to the ocean, although some may remain until fall; the spring-run chinook and coho generally remain in fresh water about a year and emigrate in the spring. Steelhead spend between one and three years in the stream before migrating to the ocean.

The Klamath River fishery is faced with many problems, including dams, overfishing, environmental degradation due to land use, and natural predation. Earth Sciences Associates (1980) outlined the factors most likely to have adversely affected the fisheries of the lower Klamath River tributaries. These are, in descending order of importance: logging, the 1964 flood, the 1976 drought, and overfishing. The fisheries of many of these streams have been so severely damaged (Photograph 2) over time that even when fish habitat conditions improve and log jams are removed, the tributary remains under-used by the remaining limited stocks of fish. This problem has been discussed at length by many authors and will not be treated further here. For more information on the Klamath River fishery, please see the following authors: ESA (1980), Rankel (1980), U. S. Fish and Wildlife Service (USFWS) (1979), Buer (1981), Kesner (1977), Snyder (1931), and USFWS (1960).

Photograph 2. Numerous log jams and barriers prevent anadromous fish from using most of Grouse Creek and its tributaries. These streams support mostly a resident fishery.

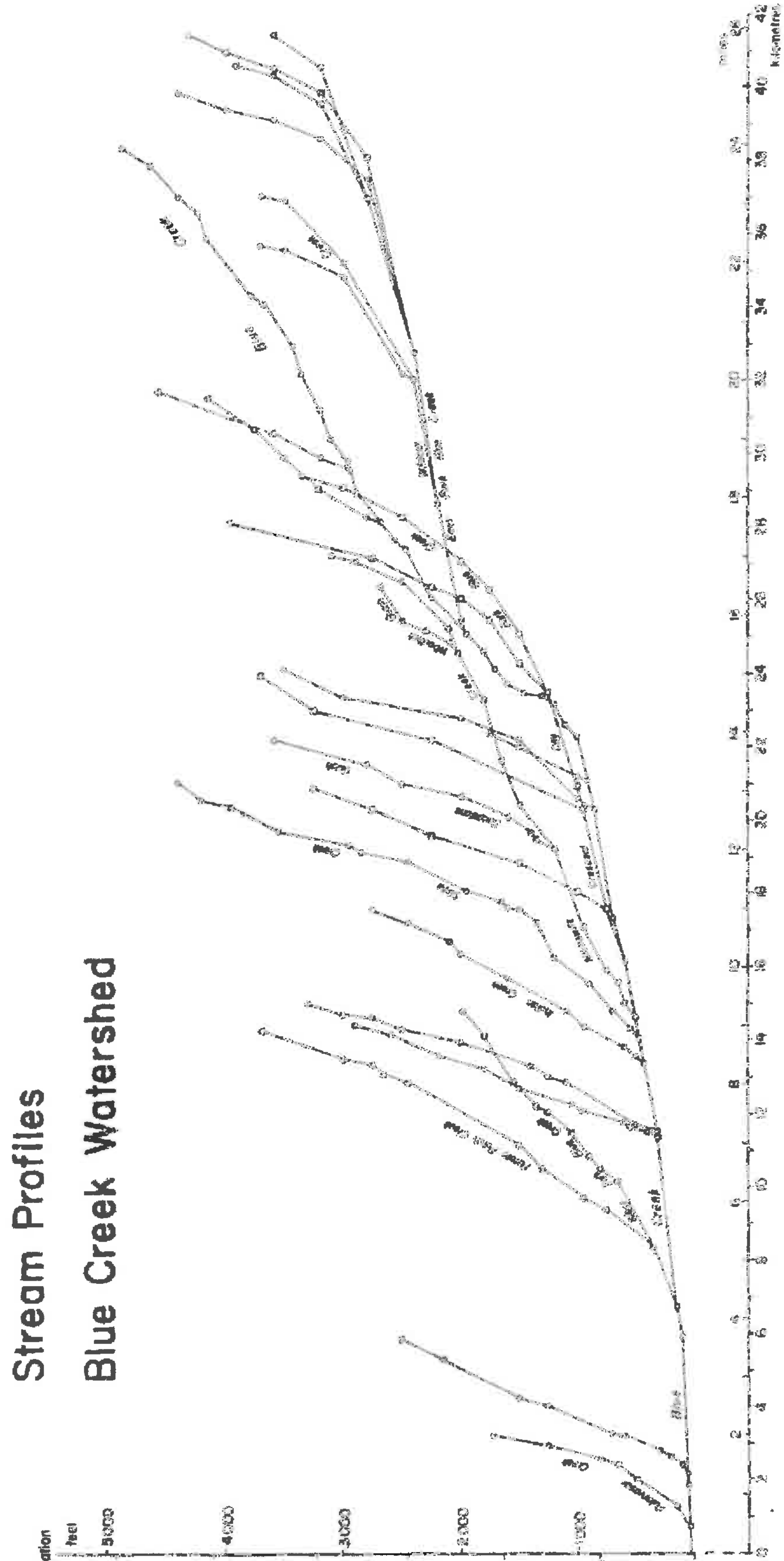
Blue Creek

Blue Creek is the largest, most important spawning tributary to the lower Klamath River for salmon and steelhead. The basin is 127 mi^2 in area and the main stem is about 23 miles long. The lower four miles (Figure 3) contain most of the anadromous habitat.

Historic fishery surveys are few and incomplete. Interpretation of 1936 aerial photos (ESA, 1980) indicates pristine watershed and stream channel conditions. In 1951, John W. DeWitt, head of the Humboldt State University Fisheries Department, noted that Blue Creek was "chock-full of small chinook salmon in the lower four miles I examined" and noted that long-time residents in the area report that every pool was swarming with salmon. He also estimated 5,000 to 10,000 fish spawning in Blue Creek, although DFG had estimated 500 as the annual run. A survey by DFG in 1961-62 noted that the habitat was "superb". In April 1964, about 100 steelhead were counted by USFS personnel on Blue Creek near the confluence with the West Fork. A number of surveys were completed between 1964 and 1977 but no estimate of the total population was available. In 1977, the USFWS (1979) inventoried the Hoopa Valley Indian Reservation waters, including Blue and Turwar Creeks. The following is quoted from this paper:

> "Blue Creek is the largest tributary flowing through the Hoopa Valley Reservation, draining 127.1 square miles and entering the Klamath River at river mile 16.4. The creek has long been known for its clean water and large numbers of spawning fish, but clearcutting and road building in the watershed are contributing to its rapid deterioration. Blue Creek was surveyed on October 12, 1977.
>
> "Most of lower Blue Creek is composed of gravel bars which shift with each high water and a few deep holes near rocky bluffs. High flows and a large amount of bedload transport have prevented any stable growth of brush or alders along the banks. There are no barriers or diversions in the lower 10 miles of the stream.
>
> "Numerous spawning ground surveys conducted on Blue Creek in 1977 and 1978 revealed the presence of considerable numbers of chinook salmon adults as well as steelhead adults and 'half-pounders'. The annual run of chinook salmon in Blue Creek may approximate 500 fish,which is probably considerably less than runs of former years but probably considerably more than runs existing in other tributary streams flowing through the reservation.
>
> "Electrofishing surveys conducted on Blue Creek on March 17, April 28, and May 24, 1978, turned up several chinook salmon and rainbow/steelhead juveniles. Two juvenile cutthroat trout were also captured.
>
> "Blue Creek has the greatest potential to support anadromous fish of any tributary on the reservation. Logging guidelines should be strictly followed to prevent any further degradation such as that which occurred on the West Fork of Blue Creek. The entire drainage should be surveyed for habitat suitability and existing or potential barriers."

Figure 3


Stream Profiles
Blue Creek Watershed
Elevation
metres
feet
1500
5000
1250
4000
1000
3000
750
2000
500
250
1000
0
miles
kilometres

There are several bedrock and boulder barriers in Blue Creek a few miles above its confluence with the Crescent City Fork, and salmon probably do not migrate above this point. The resident trout population above the barriers appeared to be healthy (USFS, 1978). The USFS also noted stream damage, including aggradation, landsliding, and torn-out riparian vegetation. They also noted that the stream seems to be in a state of recovery from past high flows. Four summer steelhead were observed near the mouth of the Crescent City Fork. An estimated seven acres of spawning gravel is available at present to the anadromous salmonids in the lower part of the watershed.

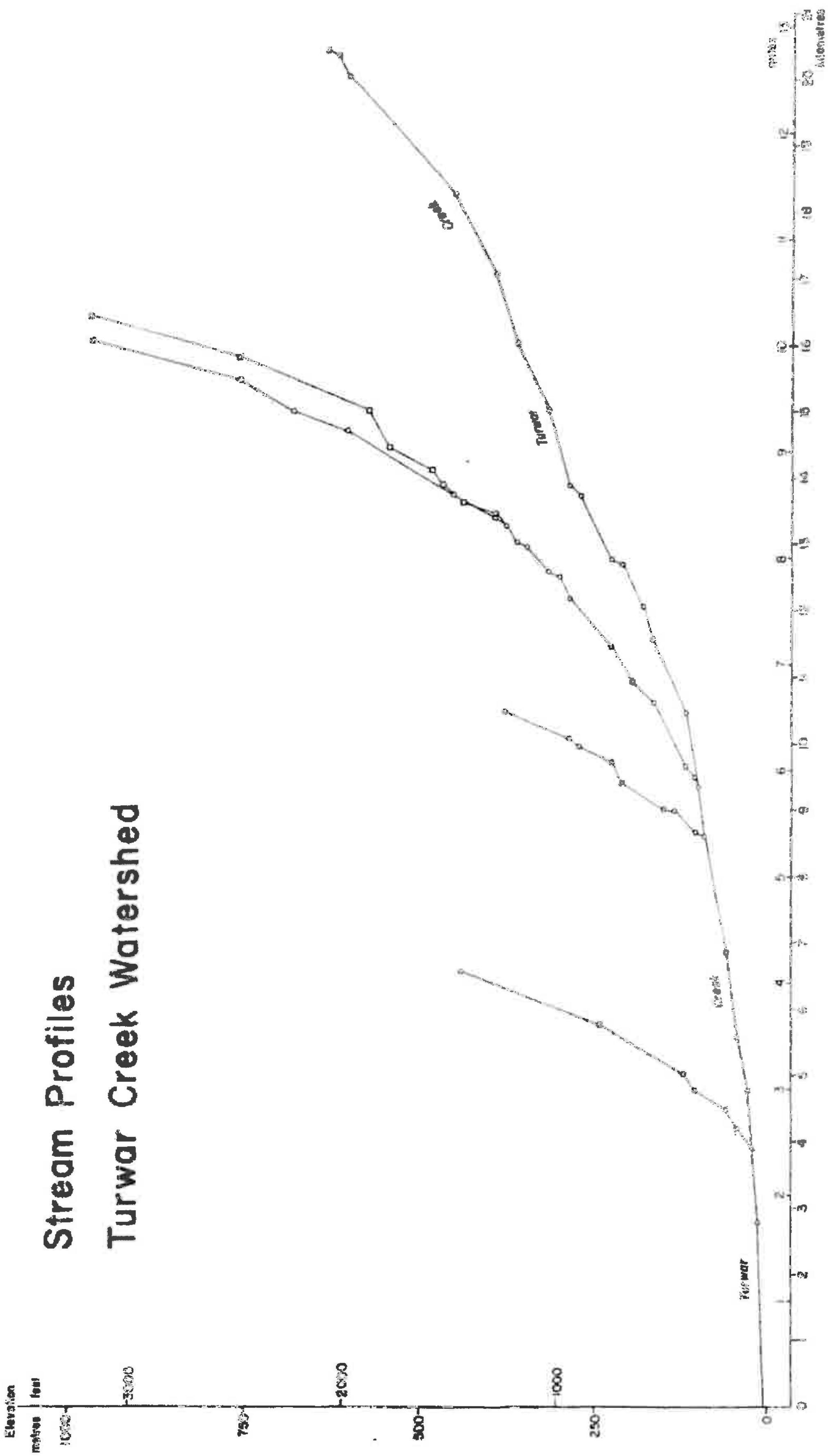
Turwar Creek

Less is known about the Turwar Creek fishery. A DFG survey in the fall of 1967 noted nine log jams. Two were barriers, but general stream conditions were classified as "good". In 1977 and 1978 the USFWS (1979) noted the following:

> "Spawning ground surveys conducted on November 29, 1977 and December 2, 1978 and spot surveys conducted on December 6, 1977 and November 30, 1978 resulted in the sighting of only one chinook salmon adult. Electrofishing surveys conducted on March 13, April 20, and May 11, 1978 resulted in the capture of numerous young-of-the-year chinook salmon. On one occasion, over 650 chinook salmon smolts were found in a backwater area which had been isolated from the stream. The smolts were electrofished and returned to the stream. Even though our spawning ground surveys resulted in the sighting of one adult, <u>it appears that chinook salmon utilize Turwar Creek to a considerable extent</u>. Coho salmon and rainbow/steelhead trout were also captured in the stream.
>
> "Turwar Creek appears to be one of the streams on the reservation least impacted by logging activities. However, the area has been involved in a land exchange for the Redwood National Park and can be expected to be clearcut in the near future. There are presently no barriers or significant water diversions in the lower 4.75 miles of the creek. There is not much debris in the creek and the gravel areas are not high in sand-silt content. Gravel removal operations and channelization activities should be more closely monitored. Turwar Creek has the potential of supporting a good chinook salmon run if habitat quality can be maintained (Photograph 3)."

Turwar Creek also has suitable coho habitat. Hatchery stock coho were introduced in the early 1970s. The present run of adult coho is estimated at 50 fish (ESA, 1980).

Figure 4


Stream Profiles
Turwar Creek Watershed
Elevation
metres
feet
1000
750
500
250
0
3000
2000
1000
Turwar
Creek
kilometres

Photograph 3. The lower five miles of Turwar Creek has most of the anadromous salmonid habitat in the watershed.

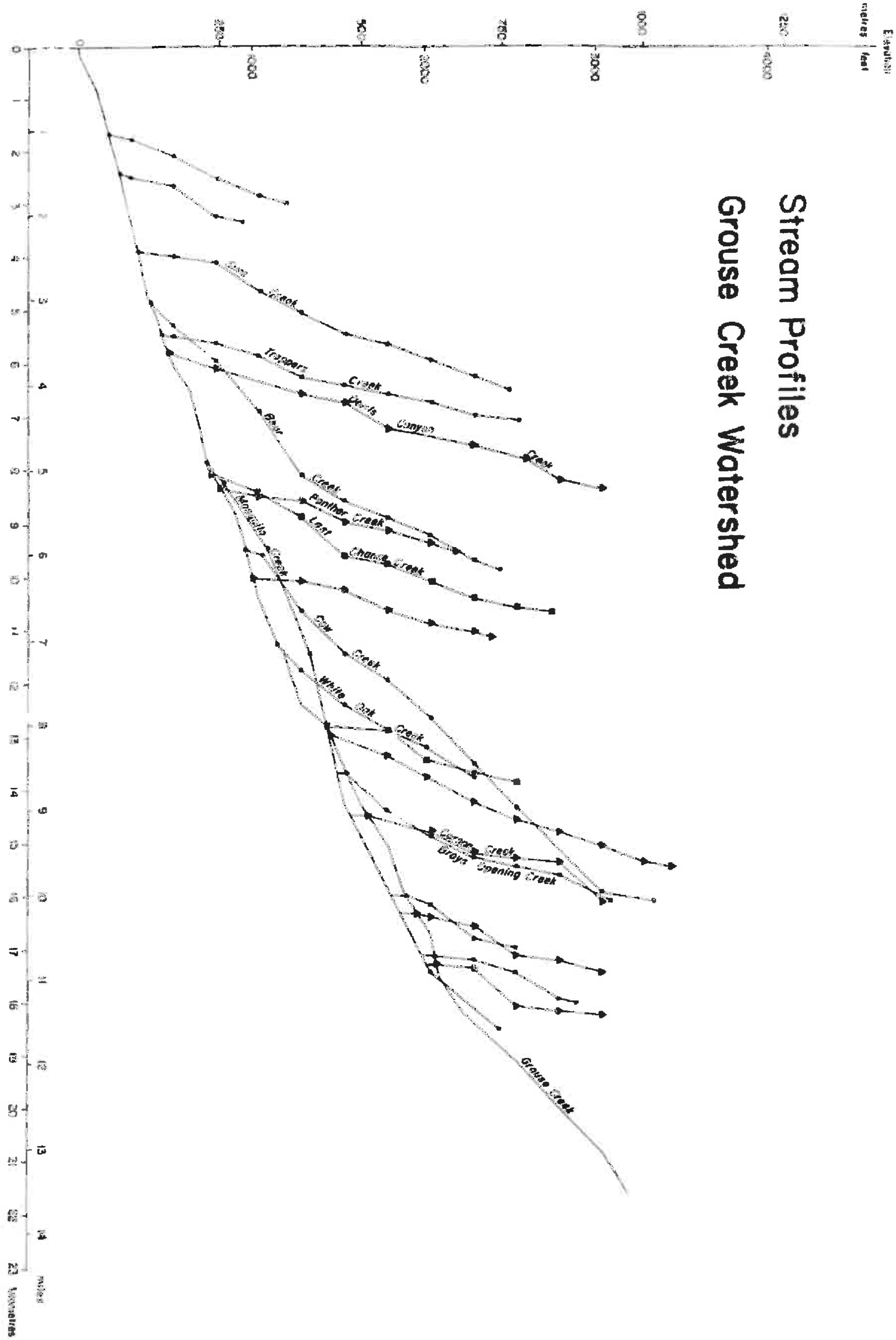
Grouse Creek

Grouse Creek and its tributaries mostly support a resident trout fishery. The watershed was severely damaged during the December 1964 flood and many post-storm log and debris dams occurred along the main channel and tributaries. DFG (1951) records indicate that steelhead may have used the lower part of Grouse Creek in the past. Steelhead have also been seen recently as high up as Mosquito Creek (Forrest Reynolds, DFG, personal communication), although no data are available as to the number of spawners.

Two major problems facing the Grouse Creek fishery are the slow recovery of the watershed and the stream channel since the flood (Photograph 4) and continued clearcutting of large areas on geologically sensitive terrain. Stream profiles for Grouse Creek are shown in Figure 5.

Photograph 4. Large amounts of sand, gravel, and debris were deposited in Grouse Creek and its tributaries during the 1964 flood.

Figure 5


Stream Profiles
Grouse Creek Watershed
Elevation
metres
feet
Trappers Creek
Devils Canyon Creek
Panther Creek
Lost Chance Creek
Cow Creek
White Oak Creek
Brays Opening Creek
Grouse Creek
miles
kilometres

PROPOSED BEST MANAGEMENT PRACTICES

The Federal Water Pollution Control Act of 1972, Public Law 92-500, requires that each state develop an area-wide planning process for waste treatment management. Section 208 of the law specifies that water quality management include procedures that (1) identify sources of non-point pollution, including those associated with silviculture and related runoff; and (2) develop methods and procedures (including land-use requirements) to control to the extent feasible such sources. These procedures and methods are referred to as "best management practices" or BMPs.

BMPs are defined by EPA as "a practice, or combination of practices, that is determined by a state (or designated area-wide planning agency) after public assessment, examination of alternative practices, and appropriate public participation to be the most effective, practicable (including technological, economic, and institutional considerations) means of preventing or reducing the amount of pollution generated by non-point sources to a level compatible with water quality goals" (40 CFR 130.2q).

Non-point source pollution includes sediment, organic debris, changes in water temperature, nutrients, pesticides and herbicides, grease and oil. These pollutants are often associated with land uses such as timber harvesting, road construction, stock grazing, urbanization, and agriculture. Timber harvesting has been identified by the SWRCB as being one of the largest causes of non-point source pollution in California, reducing important beneficial uses of rivers and streams throughout the timbered areas of the State.

The implementation of BMPs in forestry is probably best done through necessary revisions and additions to the Z'berg-Nejedly Forest Practices Act (FPA) of 1973. The present rules are among the most comprehensive and thorough in the nation. However, California's North Coast has some of the highest erosion rates and sediment yields in the world (Judson and Ritter, 1964). Present rates have been estimated to be between two and twenty times the long-term natural rates (Coats and Miller, 1981). This area also has a combination of factors conducive to the severest geologic impacts of logging and the keenest public sensitivity to these impacts (Huffman, 1977). These factors include: (1) a large lumber industry--

a large part of the timber from private land in the State is logged here; (2) many stands of old growth which are being actively logged; (3) use of the clear-cutting method over large areas; (4) high recreational use; (5) extremely unstable and erodible soils; (6) seasonally high, intense precipitation; and (7) thousands of miles of streams that are, or were, important spawning grounds for steelhead and salmon. Before proposing BMPs, improvements, and changes in the Act, it is well worthwhile to consider what provisions to reduce erosion are already present. Reference for the following is the California Administrative Code (CAC), Title 14, Division 1.5, Subchapter 2.

Section 14CAC 912 defines a "Stream and Lake Protection Zone" which means a strip of soil and vegetation defined as 100 feet (30.48 m) as measured along the surface of the ground from the stream and lake transition line of any stream or lake which supports and is used by trout or anadromous fish at any time of the year, and downstream therefrom" and 50 feet from any other "stream" (as defined in the Act).

Section 912 also provides for a procedure for estimating surface soil erosion hazard. The hazard rating is then used to determine the number of water bars required on skid trails and to limit tractor logging in certain areas.

Section 14CAC 913 of the Act limits the size of timber harvest areas logged by the clear-cutting method: "Except as otherwise provided in this section, clearcut areas shall not exceed 80 acres (32.37 ha) in size and shall be limited to 40 acres (16.19 ha) if all or a portion of the clear-cut area has an Extreme Erosion Hazard Rating." The act also provides that all parts of a clear-cut area shall be at least 300 feet (91.44 m) from any other clear-cut area within the same land ownership that do not meet stocking standards defined in 14CAC 912.7 and where less than 3 years have elapsed regardless of stocking." Another restriction is that clear-cutting in old growth on slopes over 70 percent where the erosion hazard rating is extreme shall be by cable, helicopter, skyline or balloon systems. The width of a cut block may not exceed 1,000 feet (304 m) measured along the surface of the ground.

This section also provides for restocking standards. Although this has no immediate effect on erosion reduction, it will have significant long-term effect. The width restrictions are apparently being removed by new silvicultural rules that will become effective in 1983. Section 14CAC 914 calls for logging practices "to prevent unreasonable damage to residual trees, seedlings, streamside vegetation, and water quality. Specifically, (1) trees shall be felled away from roads, streams and lakes; (2) where skid trails are constructed, these only shall be used for skidding logs and on return trips; (3) "skid trails shall not be so steep as to require the use of bulldozer blade for braking"; (4) use old skid trails whenever possible; and, finally, (5) "Tractor yarding equipment shall not be operated on known potential or active slide areas unless satisfactory protective measures to be taken are specified in the plan."

Section 14CAC 915 specifies erosion control measures on logging roads and landings. Measures in general include flagging road locations prior to construction, minimum widths, avoiding erodible and landslide-prone areas where possible, seeding of certain sidecast areas, and stabilization of road surface when necessary. After use of roads without permanent drainage facilities, waterbreaks shall be constructed each year before November 15. The distance between waterbreaks is determined by the erosion hazard rating.

Stream and lake protection zones are specified in 14CAC 916. All streams and lakes shall be kept substantially free of slash and debris. Tractor operations shall be prohibited within 50 feet (15.24 m) of the zone, except for stream crossings. Seeding of exposed soil is required in areas of high or extreme erosion hazard within 150 feet (45.72 m) of a stream or lake. Permanent stream crossings shall be designed to the 25-year storm, and temporary structures shall be removed before November 15.

From this short discussion of present forest practices, it is clear that erosion is considered in the Act. However, a number of problems with the present rules need to be considered. Proposed additions and changes to the Act are presented broadly as "Best Management Practices". They are not written in "rules language". BMPs are proposed for Blue, Turwar, and the Grouse Creek basins. The BMPs however, have broad applicability to other forested, sensitive, landslide-prone areas in the north coastal area, primarily in the Coast Forest District. In no way are these proposed changes meant to be applicable to geologically stable, nonerodible areas of California.

The following concerns with present forest practice rules on private land will be considered:

1. Need for planning and watershed management to spread timber harvest impacts in time and space.
2. Need for data in sensitive areas from which to make wise land-use decisions.
3. Need for enforceable rules, and funds to immediately begin clean-up and abatement in problem areas.

Watershed Planning

Planning is one of the most important steps in timber harvesting and watershed management. The planning process is complex and requires consideration of geologic hazards, water quality, fisheries, past and future harvesting, regeneration, economics, etc. BMPs require that not only the timber but all watershed values are considered.

The following are proposed BMPs dealing with watershed planning. They are not presented in "rules language", nor are they all inclusive. We have avoided as much as possible to repeat BMPs already in, or in the process of being incorporated into, the FPA.

1-1. Feasibility Analysis Shall be Written. THPs shall include all the considerations as outlined in 14CAC 898. Additional factors to be considered in the feasibility analysis shall include cumulative effects and significant adverse changes to the values as listed in 14CAC 898 (a) (1) (c) that have occurred within or adjacent to the proposed harvest.

Discussion: The feasibility analysis is an extremely important part of the planning process. Requiring it to be written makes it a formal part of the planning process and allows the Director (of CDF) and other reviewers to more clearly determine if the THP reflects the results of the feasibility analysis.

1-2. Plan Maps. THPs having part or all of the area with High to Extreme EHR shall include a topographic map at a scale of 1" = 500' (or larger) showing the location and size of features relevant to the proposed harvest. Features to be plotted, when present, include:

(A) Location of proposed harvest areas (and silvicultural method) and previous harvested areas (showing year harvested) within and adjacent to the proposed THP area.

(B) The present road system and proposed additions.

(C) Landslides, soil erosion hazard ratings, slopes over 50 percent, slopes over 70 percent.

(D) Stream and fishery data including spawning and holding areas, fish barriers, log jams, stream course protection zones, etc.

(E) Distance to downstream users affected by water quality.

Discussion: Maps are an important planning tool. In order to evaluate the various effects of a THP, it is necessary to present all relevant data on one map. The topology of impacts, the location of landslides and erodible areas with respect to proposed roads and harvest units are important considerations in the planning process. A 1" = 500' scale may not be appropriate in all cases, but is large enough to plot most important features with accuracy. Maps included with THPs under present rules are typically 1" = 1 mile or 1" = 2,000" and are too small to plot important data. Maps may be made at 1" = 500' scale by photographic enlargements or tracing 4x or 10x projections of USGS 7½-minute and 15-minute quadrangles, respectively.

1-3. Spreading the Effects of Timber Harvesting Operations Over Time and Space. The spacing of harvesting units shall be dependent on the erosion hazard rating (Board of Forestry, Technical Rule Addendum #1) or preferably, where available, the "Instability and Erosion Hazard Maps" such as produced by this project. The required spacing, if found to be inappropriate in the feasibility analysis, may be changed as agreed upon by the Director and the RPF.

(A) Clear-cutting method:

(1) Extreme Instability and erosion hazard - no clear cutting allowed.

(2) Very High. Maximum size of cut block shall be 20 acres, with 600-foot buffer and leave strips between harvest units. Leave-strips between units may be harvested when the harvested units:

   (a) retain 50 percent of the pre-harvest root support, to bind unstable soils, and develop a full protective vegetative cover to prevent rain splash on bare soils, or

   (b) are adequately stocked with crop trees at least 4½ feet high before another regeneration unit may be cut immediately adjacent, or

   (c) ten years, whichever comes first.

(3) High. Maximum size of cut blocks shall be 40 acres, with a minimum of 600-foot buffer strips between harvest units. Buffer strips may be harvested same as 2a, 2b and 2c above.

(4) Moderate. Same as the FPA 14 CAC 913.5.

(B) Seed Tree Method. It shall be demonstrated that this method is effective in restocking harvest units prior to approval of the THP by the Director. Restrictions shall be the same as with the clear-cutting method.

(C) Selection Method - High to Extreme. No size limits shall apply if 50 percent of the pre-harvest (virgin) basal d.b.h. area remains after harvest. If less than 50 percent is to be left, then 40-acre-limits with 600-foot buffer strips between harvest units shall apply. Re-entry into harvest areas shall be on 10-year or more cycles, unless shorter time periods are approved by the Director.

Discussion: Probably the most serious problem with the present FPA is that few harvest size limits apply. For example, let us assume that a large timber company wants to maximize production from a one square mile (640-acre) watershed, consisting of virgin fir in an area of extreme erosion hazard and with slopes less than 70 percent. The company's options include the following:

- Using the clear cutting method (Ref. 14 CAC 913.5), the company may harvest about nine 40-acre cut blocks, with 300-foot buffer strips. In the first year, 50 to 60 percent of the watershed may be tractor yarded. If the clearcuts were restocked that fall, the remainder of the watershed may be harvested in three years, with the exception of 50 percent of the shade canopy along stream protection zones. The result is that practically the entire watershed may be clearcut in three years.
- Using the selection method (Ref. 14 CAC 913.2), the company may legally tractor yard the entire watershed, but leave six trees/acre, 24 d.b.h. or more, and cable out 50 percent of the trees from any stream protection zones. In two years, the company may remove the remaining trees and restock by artificial means. The net result in two years is a one square mile clearcut.
- Using the seed tree method (Ref. 14 CAC 913.4), the entire watershed may be tractor yarded with the exception of stream protection zones and four seed trees/acre, 24 inches d.b.h. or more. Two years later the seed trees may be removed and the watershed restocked by planting. The net result is a one square mile clearcut.

In the previous discussion, the one square mile watershed could easily have been 10, or even 100 square miles, and the results under the law would have been the same.

The U. S. Forest Service (1982) generally classify extremely unstable land as "unsuited to timber management because existing technology is not adequate to manage these areas and maintain slope stability". The USFS also maintains that "generally no more than an average of 15 percent of a second or third order watershed should be in Equivalent Road Acreage (ERA) in any one decade. Generally watersheds in poor condition should not exceed 11 percent and watersheds in good condition should not exceed 18 percent in ERA." The USFS uses ERA as a measure of land disturbance equivalent to one acre of road. Using USFS estimates of ERA, our hypothetical one square mile watershed would have in excess of 30 percent ERA, or about three times that recommended by the USFS (1982) for lands in poor condition.

Finally, the USFS requires that "regeneration units must be adequately stocked with crop trees at least 4½ feet high before another regeneration unit may be cut immediately adjacent."

It should be evident that the present FPA dealing with allowable harvests are not BMP's. The proposed revisions would lead to considerable improvement in that no clearcutting would be allowed in extreme instability and erosion hazard areas. In areas of very high erosion hazard, 20-acre cut blocks with 600-foot buffer strips means that no more than about 30 percent of a watershed may be cut in one pass before the basin is allowed to recover for ten years.

In areas of high instability and erosion hazard, about 40 percent of the basin may be cut in one pass, versus the 55 percent allowed under present rules. Ten-year reentry cycles would allow the watershed to partially recover before further cutting occurs.

Resource and Hazard Mapping

Detailed watershed mapping has not been available for sensitive areas in the north coastal area. The Phase II and III watershed mapping programs were designed to rectify this.

Phase II Watershed Mapping program includes mapping geology, landslides, soil-vegetation and timber harvests on 7½-minute quadrangles. Precipitation, stream gradient, fishery, and other parameters are discussed on a watershed basis elsewhere in the report.

The watershed maps can be used in the planning process by the Registered Professional Forester (RPF) to locate and design the road networks, to determine the type, size, and location of timber harvesting units, and to select the best yarding systems and landing locations. The landslide maps can assist foresters and other land-use planners to prevent water quality problems from originating on unstable areas, and to determine when the services of an engineering geologist would be advisable.

State, federal and county planners can use these maps to evaluate proposed developments and road construction. Geology, soil-vegetation, and landslide maps are particularly useful.

The THP review team can use the maps in a number of ways. Careful inspection of the hazard maps will help to establish THP priorities. The SWRCB and the Regional Water Quality Control Board staff can estimate the potential for water quality degradation from the proposed harvest. DFG may use the maps in much the same way to evaluate the potential impact of the THP on the stream channel and on the fishery. CDF and CDMG can evaluate the proposed logging in terms of regeneration, soil retention, and other environmental considerations.

Land Use in Unstable Areas

Where available, the landslide map shall be used to determine the number, type and location of slide features in the proposed THP.

2-1. The THP map shall delineate the landslides in relation to proposed roads, landings, harvest areas, stream protection zones, etc. Landslide features such as bogs, seeps, scarps, flat areas, jackstrawed trees, bare soils and gullies shall also be shown.

2-2. Landslides shall be classified into the following categories:

(A) Active slides having shallow failure planes (debris torrent tracks, debris slides, debris slide amphitheaters).

(B) Dormant slides having shallow failure planes (debris slides, colluvial mantles and inner gorges).

(C) Active slides having deep failure planes (earthflows, translational-rotational slides).

(D) Dormant slides having deep failure planes (earthflows, translational-rotational slides).

Shallow slides are easier to activate by road construction because cuts may intersect the failure plane and remove support for the upslope part of the slide mass. On shallow slides, tree roots bind the soil and often penetrate into underlying bedrock, thus acting as anchors. Timber harvesting reduces this stabilizing influence as the root mass decomposes.

Deep slides are not as readily reactivated by surface disturbance and tree removal. Failure planes and slide-bedrock contacts are generally too deep for roots to penetrate. Surface disturbance may cause small debris slides, soil slips and increased erosion. Tree removal may affect slide stability by reducing evapotranspiration and increasing the amount of water in the slide.

2-3. The following are recommended Best Management Practices for active landslides having shallow failure planes. Variances to the following BMPs shall be explained by the RPF and meet the approval of the Director.

(A) An engineering geology report signed by a certified engineering geologist will be required prior to road construction or the operation of heavy equipment.

(B) No timber harvests except to salvage dead or dying timber.

(C) Road crossings shall be avoided when other routes are feasible. Road crossings shall be arched over landslides to allow inboard ditches to carry water off the slide, or the road outsloped to prevent concentration of water on the slide.

(D) Road surface and inboard ditches shall be protected from erosion with gravel, crushed rock, chip-and-seal or pavement.

(E) End-haul cut material to safe depository. Buttress unstable road cuts.

2-4. The following are BMPs for dormant landslides having shallow failure planes.

(A) An engineering geology report is recommended.

(B) Retain a minimum of 50 percent of the pre-harvest (virgin) root support.

(C) Road crossings shall be avoided when other routes are feasible. Road crossings shall be arched over landslides to allow inboard ditches to carry water off the slide, or the road outsloped to prevent concentration of water on the slide.

(D) Road surface and inboard ditches shall be protected from erosion with gravel, crushed rock, chip-and-seal or pavement.

(E) End-haul cut material to safe depository. Buttress unstable road cuts.

2-5. The following are BMPs for active slides with deep-seated failure planes.

(A) Roads with cuts in the toe region require the inclusion of an engineering geology report.

(B) Clear cuts shall be limited to a maximum of one-half of the slide mass and shall not be larger than 10 acres. Remainder of landslide may be cut after ten years, or when regeneration height of conifers in clearcut area is 4½ feet or more.

(C) Road crossings shall be avoided when other routes are feasible. Road crossings shall be arched over landslides to allow inboard ditches to carry water off the slide, or the road outsloped to prevent concentration of water on the slide.

(D) Road surface and inboard ditches shall be protected from erosion with gravel, crushed rock, chip-and-seal or pavement.

(E) End-haul cut material to safe depository. Buttress unstable road cuts.

(F) All drainage structures shall be temporary and removed in the fall.

2-6. The following are BMPs for dormant slides with deep-seated failure planes.

(A) Road crossings shall be avoided when other routes are feasible. Road crossings shall be arched over landslides to allow inboard ditches to carry water off the slide, or the road outsloped to prevent concentration of water on the slide.

(B) Road surface and inboard ditches shall be protected from erosion with gravel, crushed rock, chip-and-seal or pavement.

(C) End-haul cut material to safe depository. Buttress unstable road cuts.

Enforcement of Rules

The majority of forest practice violations are now resolved through corrective actions and misdemeanor complaints. In aggravated cases, CDF has used temporary restraining orders. Recent legislation authorizes the use of stop orders, which will make possible more prompt action to stop operations causing, or threatening to cause, serious environmental damage (Jim Denny, personal communication).

DWR and the Regional Board believe that much of the potential damage caused by timber harvest activity can be mitigated by cleanup and repair before winter storms. This requires prompt action on the part of regulatory agencies and timber companies. We believe that performance bonds should be required in these cases to rehabilitate damaged areas. If timber companies fail to clean up potential problems, then the bonds could be used to do prompt cleanup.

SECTION II: WATERSHED MAPPING

GEOLOGY MAPS

LANDSLIDE MAPS

SOIL-VEGETATION MAPS

TIMBER HARVEST MAPS

INSTABILITY AND EROSION HAZARD MAPS

Performance bonds should be required of timber operators that are proposing to log in Zones 1 and 2 (extreme, very high instability, and erosion hazard, respectively) if the Director determines that resource damage may result.

Management Guidelines Versus Enforceable Rules

There are several ways in which rules, regulations, and BMPs may be implemented to mitigate potential mass movement or seriously accelerated surface erosion.

CDF favors use of a checklist of measures likely to be effective to one degree or another in maintaining site stability when timber harvesting or other forestry-related activities are proposed. Using the checklist (or "Management Guidelines"), mitigation measures would be selected and included in a THP, or, when necessary, an engineering geologist would assist the RPF in determining needed measures. If the THP Review Team determined the measures proposed were inadequate, CDF and the RPF could negotiate an amended THP to include those measures deemed essential. If the RPF was unwilling to incorporate such measures, he or she could either withdraw the THP or the CDF could withhold approval (Loyd Forrest, personal communication).

DWR agrees that site-specific management guidelines should be selected from a checklist and included in the THP. DWR also agrees that an engineering geologist should assist the RPF in determining needed measures. DWR, however, also believes that those measures proven effective in most cases should be incorporated as enforceable rules into the Forest Practices Act. Exceptions to rules may be granted by the Director when it can be demonstrated by the RPF that these measures are not required at a particular site to prevent failures, protect water quality, and the fishery. The advantages of specific enforceable rules are obvious. First, it will be easier on CDF since the burden of proof will be shifted from CDF to the timber company. Instead of CDF having to prove that certain management guidelines are required at a particular site, the timber company will have to prove that they are not required. A second advantage is the shifting of liability. If failure and damage to downstream resources do occur after the timber company has requested and been granted a BMP exception, then it would be clear that the timber company, and not CDF, is liable for damages.

GEOLOGY MAPS

Geologic data for this report came from numerous sources. Many areas within the Blue and Turwar Creek watersheds have been recently mapped as part of a project to update the Weed sheet of the State geologic map (Dave Wagner, CDMG, personal communication). Large parts of USFS land have also been mapped at a scale of 1:24,000. Areas not recently mapped were compiled from the CDF Title II geologic mapping project.

The geology was plotted on 7½-minute topographic quadrangles. Bedding planes, foliation, and other geologic features were plotted where available. Adjacent areas, mapped by different authors, were matched as closely as possible. Land stability characteristics of geologic units are described elsewhere in this report.

The geologic units mapped in all three watersheds are remarkably similar. All three lie along the border between the Coast Ranges and the Klamath Mountains geologic provinces. The Coast Ranges province borders the Pacific Ocean and tapers toward the north. In contrast, the Klamath Mountains province expands northward into Oregon. The two provinces are separated by the South Fork fault (Irwin, 1974).

The Coast Ranges province is composed mainly of rocks of the Franciscan complex, a suite of sedimentary and volcanic rocks deposited in a deep marine environment. These rocks have been highly deformed and uplifted in a complex tectonic environment, but in general they are only slightly metamorphosed. The Klamath Mountains are formed of higher grade metamorphosed volcanic and marine sedimentary rocks and mafic and ultramafic igneous rocks. They are older than the Coast Ranges but were formed in a similar tectonic environment.

Blue Creek originates in the Klamath Mountains province and generally flows across the northwest-trending structural grain towards the west. Most of its watershed is in this province. Shortly after crossing into the Coast Ranges province, Blue Creek joins the Klamath River. Conversely, Turwar Creek is mostly in the Coast Ranges province. It generally flows southeastward, parallel to the Franciscan structural grain, and joins the Klamath River about 10 miles downstream from the confluence of Blue Creek. Grouse Creek heads in the Coast Ranges, then flows north and east into the Klamath Mountains before joining the South Fork Trinity.

Klamath Mountains Geologic Province

The Klamath Mountains province comprises the eastern part of each watershed. These rocks were included in Irwin's (1960) "western Paleozoic and Triassic belt" and the "western Jurassic belt", so named for their ages and narrow elongate outcrop patterns. The former belt has been subdivided (Irwin, 1972) into three terranes. One, named the Rattlesnake Creek terrane, underlies the eastern portion of Blue and Grouse Creeks. Originally, the rocks of the "western Paleozoic and Triassic belt" were believed to be Triassic age or older, based on blocks of fossiliferous limestone. However, recent age dating (Irwin, Jones, and Passagno, 1977) has yielded dates as young as Middle Jurassic for some sedimentary rocks within this unit. This belt is thus composed of sedimentary rocks having a wide variation in age that was emplaced at a much later date than previously thought. To the west is the western Jurassic belt, represented by the Galice Formation and the Josephine ophiolite complex. This belt underlies a major portion of the Blue and Grouse Creek watersheds and the eastern part of Turwar.

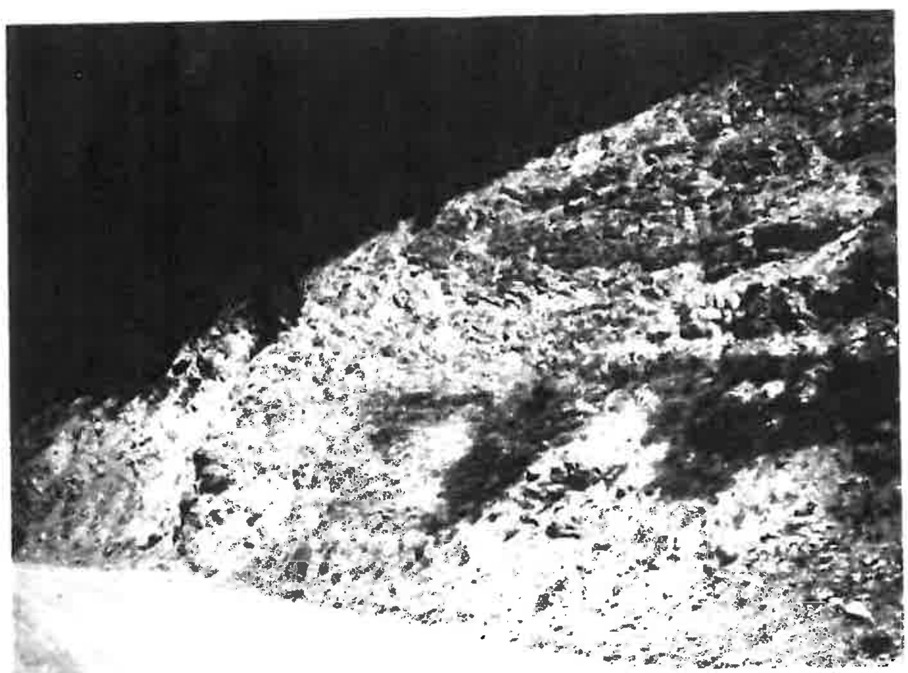
Rattlesnake Creek Terrane (JPzr)

The Rattlesnake Creek terrane is now thought to be a melange formed of ophiolite (oceanic crust and upper mantle rock) together with once overlying marine sediments (Irwin, 1972). The more common igneous rock types include serpentinized ultramafic rocks, gabbro, diabase, quartz diorite, pillow lava, and greenstone (Photograph 5). These rocks are intermixed with fine- to medium-grained phyllitic graywacke and slate. There are also lenticular bodies of thinly bedded chert, recrystallized limestone, siliceous argillite, and conglomerate. The terrane is generally separated from the Galice Formation to the west by an east-dipping thrust fault.

Galice Formation (Jg)

The Galice Formation is composed mainly of clastic metasedimentary rocks intercalated with mafic metavolcanic rocks. The unit is probably Upper Jurassic in age. It includes phyllitic metagraywacke, (Photograph 6), slate, and metaconglomerate. Coarser-grained layers display a semi-schistose fabric. Minor chert and massive-to-foliated

Photograph 5. "Serpentinite barrens" in the Rattlesnake Creek terrane. Rocks in the foreground are highly sheared serpentinite and greenstone. The peak in the background is Chimney Rock, a massive monolith of greenstone.



Photograph 6. Galice Formation metagraywackes in the upper Blue Creek watershed. The unit is highly fractured but relatively unweathered in most road cuts.

greenstone are also present. The Galice is generally in fault, or depositional contact, with mafic volcanic rocks of the Josephine ophiolite complex.

Josephine Ophiolite Complex (Jo)

This complex is the largest exposure of ultramafic rocks and related mafic rocks in the western Klamath Mountains. It is exposed continuously for more than 100 miles along the western boundary of the province. The complex has been identified as an ophiolite (oceanic crust and mantle) by Vail and Dasch (1977) and Harper (1980). The complex is sheared and faulted.

Rocks in this unit occur in Blue and Turwar Creeks but not in Grouse Creek. The most abundant rock types are peridotites and sheared serpentinites. East of these rocks one finds cumulate ultramafic rocks, grading into gabbros and sheeted dikes, and finally, mafic pillow basalts and breccias on top. The Galice Formation is thought to have been deposited on top of the ophiolite sequence (Harper, 1980). The South Fork fault separates the ophiolite from the Coast Ranges to the west.

On the geologic quadrangle maps, several authors used in the compilation mapped individual units of the ophiolite. These are shown. however, a number of authors did not recognize these rocks as parts of an ophiolite, and mapped them as mafic, ultramafic and Jurassic intrusive rocks. These units are now shown as undifferentiated ophiolite (Jo) on the maps in the Appendix.

Intrusive and/or Ultramafic Rocks (Ji and Um)

Plutonic rocks associated with the Klamath terrane are regarded as Jurassic or older. Undivided Jurassic intrusive rocks are generally coarse-grained quartz diorite, diorite, and gabbro.

Ultramafic rocks can be present as large, continuous bodies or sheared, sporadic lenses generally found along major fault zones. Larger bodies are generally coarse-grained peridotite that grades into sheared serpentinite near the margins. Also included are some greenish quartz keratophyre and basic pegmatite, and lenses of serpentinite. Some blocks of metasomatized gabbro, diorite, and greenstone are included. Many of these ultramafic rocks in Blue and Turwar Creeks are probably related to the Josephine ophiolite.

Coast Ranges Geologic Province

The Coast Ranges are separated from the Klamath Mountains to the east by an east-dipping thrust fault named the South Fork fault by Irwin (1974) (Photograph 7). The most common geologic unit in the Coast Ranges is the Franciscan complex. These sedimentary, metamorphic, and volcanic rocks were formed in a deep marine environment. In general, the degree of metamorphism and age of the Franciscan decreases towards the west. The degree of metamorphism is most easily recognized by the degree of schistosity and deformation. The rock subunits are separated on this basis into textural zones that are generally bounded by east-dipping thrust faults.

Photograph 7. Looking north along the eastern edge of the Turwar Creek basin. The South Fork fault parallels the edge of Red Mountain, approximately at the break in slope. Numerous landslides have occurred along the fault, such as the one in the foreground.

The eastern unit is the South Fork Mountain Schist. It is structurally underlain by other members of the Franciscan complex to the west. On the whole, the rocks are present as both melange, broken or coherent (unbroken) units. In many places these units are undifferentiated (symbol KJfu). The age ranges from Jurassic to Cretaceous.

South Fork Mountain Schist (KJsf)

The South Fork Mountain Schist is largely composed of well-foliated and intensely crumpled, fine- to coarse-grained quartz-albite-muscovite-chlorite-schist. Well-developed segregation banding has produced gneissic textures in some cases. Lawsonite-grade blueschist and greenschist knockers are present locally. The unit is regarded as the highest and oldest structural unit in the Coast Range geologic province. Blake (1965) mapped the schist as textural zone III near Grouse Creek, but in Blue and Turwar, the schist also includes the less metamorphosed rocks of textural zone II.

Franciscan Complex Melange (KJfm)

The melange unit consists of graywacke sandstone, siltstone, mudstone, and conglomerate blocks in a sheared shale matrix. It is highly disrupted and mixed. Exotic blocks include chert, greenstone, serpentinite, gabbro, and rare blueschist. The melange is slightly metamorphosed, with the quartz-albite-muscovite-pumpellyite mineral assemblage represented. The unit lies west of the South Fork Mountain Schist and east of Franciscan broken formation.

Franciscan Complex Broken Formation (KJfbf)

The broken formation is highly faulted and disrupted, but not intermixed with exotic blocks from other units, as is the melange. The main rock types are massive graywacke sandstone and interbedded sandstone and mudstone, in a shaley matrix (Aalto et al, 1981).

Other lithologies that occur along fault zones in the unit include greenstones and bedded chert.

Quaternary Units (Q)

This unit includes various surficial deposits as well as some near-shore marine silts and sands (Aalto et al, 1981). Surficial deposits include Recent fluvial sand, silt, and gravel, present in stream channels, and older terrace deposits above the present stream channel.

Evidence for past glaciation occurs in the upper part of Blue Creek above 5,000 feet. Glacial deposits include moraines, boulder erratics, and outwash.

Landslide deposits are abundant. They are discussed in the next section of the report and are plotted on a separate map.

Geologic History

The geology of the Coast Ranges and the Klamath Mountains reveals an extremely active margin between the North American continent and ocean lithosphere. Most of the older rocks in the study area were derived from ocean rocks and emplaced along the continental margin in a subduction zone (Figure 6).

The geologic history as it affects the study area began in the Jurassic Period. At this time, a marginal sea apparently existed along the edge of the continent. Subduction of sea floor both westward under an island arch and eastward under the continent probably occurred (Schweickert and Cowan, 1975). When all of the basin was subducted, the island arc was accreted to the continental margin during what is called the Nevadan Orogeny.

Using this scenario, the Josephine ophiolite is probably a remnant of the subducted marginal basin (Harper, 1980) or the basement of the island arc (Snoke et al, 1977).

The Rattlesnake Creek terrane, found in the eastern parts of the Blue and Grouse Creek watersheds, is apparently a dismembered ophiolite suite representing oceanic crust involved in this collision. The Galice Formation probably represents intercalated clastic detritus and intrusive and extrusive igneous rocks derived from both the continent and the island arc.

After the Nevadan orogeny, subduction moved west of the accreted arc. This marked the beginning of a new accretionary prism and volcanic arc. Today, these are represented by the Franciscan complex of the Coast Ranges and the Tertiary volcanism in the Cascade Ranges.

The Franciscan complex is in part melange, and in part composed of a series of east-dipping, thrust-bounded structural slabs. Overall, the unit displays progressively greater age and degree of metamorphism to the east. The uppermost structural unit is the South Fork Mountain Schist, which is most likely the sole of the South Fork fault along which the Franciscan underthrust the Klamath Mountains (Blake, 1965).

Subduction continues today north of Cape Mendocino. South of the Cape, subduction was replaced by a strike slip movement along the San Andreas fault. Today, the San Andreas joins the Mendocino Fracture Zone at Cape Mendocino. Late Tertiary and Quaternary uplift in the Coast Ranges occurred after the subduction stopped. This is evidenced by narrow, deeply incised stream valleys, elevated fluvial and coastal terraces, and actively eroding headwater reaches of most coastal streams.

Present landforms in the three basins are affected by a number of factors. Rapid geologic uplift has resulted in steep, rocky, dissected topography. The underlying northwest-trending geology is responsible for the rectangular drainage patterns seen in Turwar Creek, the lower end of Blue Creek, and parts of Grouse Creek.

Pleistocene glaciation has sculptured the headwaters of Blue Creek at elevations above about 5,000 feet (Maxon, 1933). Landsliding is a dominant land-forming process at lower elevations. Active landslides, mostly debris slides along stream channels, have increased significantly in the past four decades. These are largely attributable to recently initiated land-use activities in the area (ESA, 1980).

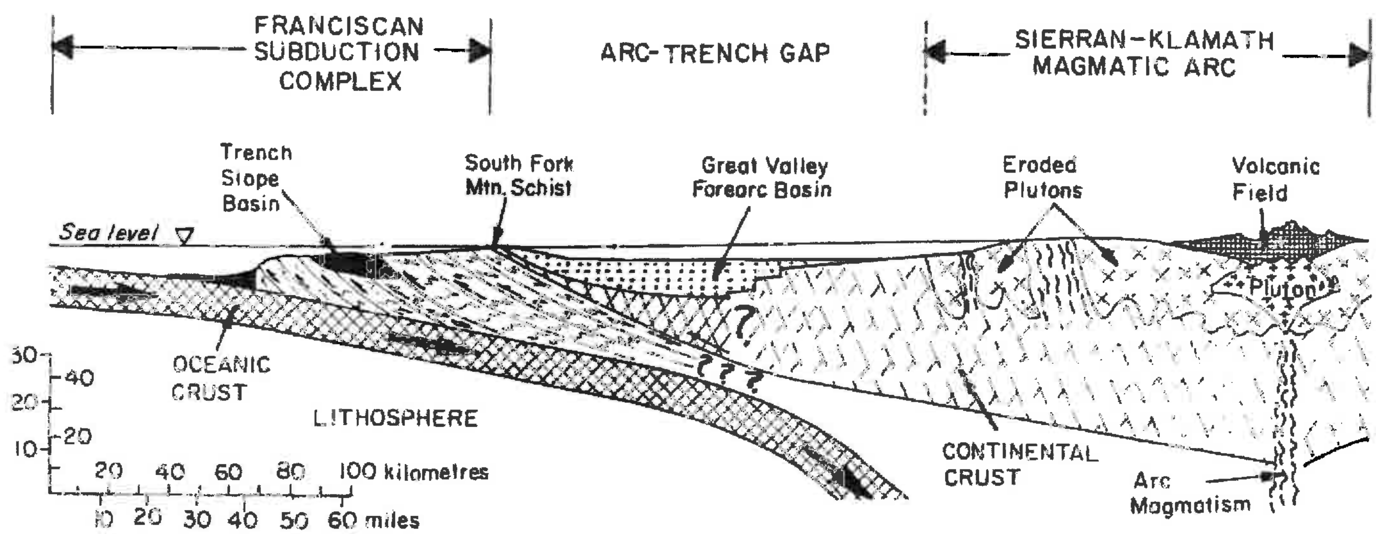


Figure 6. Schematic profile of a typical transect across Northern California during the late Cretaceous. From west to east are the California Coast Ranges, Great Valley, and the Sierra-Klamath Mountain Ranges (modified from Dickinson and others, 1982).

LANDSLIDE MAPS

A landslide is a general term covering a wide variety of mass movement land forms and processes involving the downslope transport of soil and rock material enmasse. The landslide maps show areas of active and dormant mass movements. Landsliding is a major natural land-forming process in the North Coast. One landslide characteristic that must be considered in making land-use decisions is that once failure has occurred, the slope involved is permanently changed to a weaker state. Such activities as logging, road building, and grazing may be enough to reactivate these features if they are not identified and precautions taken.

Types of Movement

There are many landslide classification systems. Most are based on types of movement. The system used for this study was developed by the 208 Watershed Mapping Steering Committee, Technical Subcommittee, and is based on the types of movements common in the north coast. A brief description of each landslide is given here. Plate 1 (in pocket inside back cover) describes landslide features and factors affecting landslide potential. Figure 4 shows the parts of a landslide. This report and accompanying maps describe seven types of landslides, as follows:

1) Translational-Rotational Slide (Photograph 8). A combination slide that is characterized by a rotational, or slump-type failure in the head region and translational movement in the main slide mass. The failure plane is generally deep and the slide mass is generally cohesive when compared to a debris slide of similar size.
2) Debris Slide. Slow-to-rapid downslope movement of predominantly unconsolidated and incoherent debris (a combination of earth, soil, rock, and organic matter), in which the mass slides and rolls forward along a relatively shallow failure plane. These slides occur most often along streams (Photograph 9) and typically form steep, unvegetated scarps in the head region and irregular, hummocky deposits (when present) in the toe region.
3) Debris Flow/Torrent Tracks. These are formed by extremely rapid movement of debris-ladened water. They are commonly caused by a

Photograph 8. The head scarp region of a translational-rotational slide. The slide occurred in deeply weathered ultramafic rocks on Red Mountain in Blue Creek.

Photograph 9. A large debris slide along Grouse Creek. The scar continues to ravel and erode long after initial failure.

debris slide or a road streamcrossing failure in the upper part of a low-order drainage during a high-intensity storm. The debris torrent scours and erodes streambanks below the initial failure, which in turn causes further failures downstream. Long, bare, exposed slopes along drainages and lack of streamside vegetation identify debris torrent tracks.

4) Debris Slide Amphitheater. This is a large, bowl-shaped feature in which the slopes have been sculptured by numerous debris slides over time. Active debris slides may be present.

5) Earthflow. This is a mass movement involving initial slow-to-rapid flowage like a viscous fluid of usually saturated earth and/or debris (Photograph 10). After initial failure, the flow may move, or creep, seasonally in response to destabilizing forces. Bogs and seeps are common. The failure surface is generally deep seated.

6) Inner Gorge. The gorge is a geomorphic feature formed by coalescing scars originating from mass wasting and erosional processes caused by stream erosion. The feature is identified as that area of streambank immediately adjacent to the stream, having a slope of over 65 percent and being situated below the first break in slope.

7) Colluvial Mantle. The mantle consists of relatively shallow, irregularly moving slide material on a generally large, uniform slope with indistinct boundaries and subdued features. Movements are generally slow and seasonal. It also includes areas of numerous small coalescing slides and flows.

All these features occur in the three studied watersheds, but translational-rotational and debris slides predominate. Inner gorges are not common in the two coastal watersheds; there is no distinct break in slope in most places and the hill remains steep from creek to ridge top.

Using aerial photo interpretations, landslides are divided into active and dormant categories.

Active landslides display evidence of recent movement, such as fresh barren scarps, jackstrawed trees, displaced roads and stream channels, and clusters of large rocks in the stream channels. The active classification includes streams and gullies with extensive or accelerated bank erosion. Many of the active landslides originate during and after a major flood.

Photograph 10. Toe region of a large earthflow in the Grouse Creek basin. Note the hummocky ground, uprooted vegetation, and the general lack of revegetation 15 years after the last major movement.

Vegetation on active landslides is sparse, with willows, grass, and brush predominating. Dormant landslides exhibit slide topography, such as bowl- or spoon-shaped depressed areas bounded by steep crown and flanking slopes. Flat lobes and irregular hummocky topography are generally well defined. Depressed sags and ponds, water seeps, and water-loving vegetation may occur. Vegetation is generally a well-established, mature forest stand but may very in type and density from surrounding stable areas. Old growth conifers with bowed trunks occur within portions of these slides. This feature may indicate that deep-seated movement is occurring at slow rates. Dormant landslides define areas of past instability and indicate sensitivity to erosion and mass wasting.

Causes of Landslides

Landslides have many causes, both natural and man-made. Some causes are: (1) a naturally steep slope is increased by stream or road undercutting; (2) high ground water conditions that contribute to high pore-pressure, seepage, and uplift forces; (3) movement occurs at natural planes of weakness, including joints, fractures, faults, bedding, foliation, or ancient landslide failure planes; (4) localized weight is increased by road fills or soil saturation during storms; and (5) vegetation is removed, causing eventual loss of root support and increased ground water storage through reduced transpiration.

Landslides that occur near the bottom of a hill remove support from uphill slopes and may cause progressive upslope failure. In this situation, areas of complex landsliding are created where slope stability is sensitive to any manipulation. Smaller slides often occur within the weakened material of larger slides.

Active landslide movement commonly occurs in winter and spring when heavy rains have thoroughly saturated the regolith and streamflows are high. Increased moisture in soils increases the unit weight of soil, pore-water pressure, and plasticity, and decreases capillary forces and cohesive properties. Movement of ground water increases with infiltration of runoff, and creates seepage and uplift forces that act normal to the slip surface (Zaruba and Mencl, 1969). All of these factors adversely affect the slope stability of the regolith and contribute to landsliding.

Tectonic mountain-building processes affect slope stability in several ways. Regional tilting and uplift of tectonic blocks increase overall slopes, leading to rejuvenation of stream channel erosion and unstable slopes. Earthquakes associated with tectonic processes promote movement of landslides through ground vibrations.

SOIL-VEGETATION MAPS

Soil-vegetation surveys are designed to produce maps useful to the resource manager. The maps show location, extent, and interrelations of various soil and vegetation types. Soil erosion hazard, soil depth, and slope are important data available in a soil-vegetation map.

The California State Cooperative Soil-Vegetation Survey Project mapped private lands, and the USFS mapped National Forest lands. These maps were combined and replotted at a scale of 1:24,000. USFS symbology was changed to conform with mapping on private land, although in most places public land was not mapped in as much detail.

Map Symbols

Explanation of map symbols appears in the legend. A more detailed explanation follows. The descriptions are condensed from Colwell (1974). Original legends are available from the USFS, 630 Sansome Street, San Francisco, California 94111.

Soils are mapped by soil series and phases (depth class, slope class, and certain other soil phases). Soil information is coded in the form of a numerical fraction, e.g.:

$$\frac{815m}{4SE\text{-}1} = \frac{\text{Soil Series/soil series modifier}}{\text{depth class/other phases/-slope class}}$$

Soil series can be coded in three categories, as follows:

Soil series names are designated by numbers of three or four digits in the numerator of the fraction.

Soil series variants are soils of limited extent which are distinctly different, but similar and closely related to a known soil series. They are designated by the symbol "V" following the soil series symbol, e.g. 815V.

Soils of limited extent which are distinctly different from and unrelated to a known soil series are indicated by an "X", "Y", or "Z", instead of the final numeral in the soil series symbol, e.g. 84X.

Soil series modifiers give additional information about the soil series or indicates a variation from the normal characteristic of the series. They have special symbols and examples as shown below:

Parent rock or parent material phases are designated by a lower case letter following the soil series number, e.g. 815m.

Variations from normal are shown by upper case letters (different from any given above) following the soil series number, e.g. a landslide phase, 815L, or a tax adjunct, 815A, etc.

If there is more than one variant or tax adjunct of a given soil series designated by the same letter, each is numbered in succession, e.g.:

Soil series variants:	815V1, 815V2
Tax adjuncts:	815A1, 815A2

Other soil phases are designated by letters and numbers in the denominator of the fraction. Soil depth class is designated by the first digit. Rockiness, stoniness, and/or erosion are designated by letters and numbers immediately following the depth class symbol. The slope class in the delineated area is represented by a letter or number symbol which is separated by a hyphen from the other phase symbols.

In some areas, an association of two soils occurs in too intricate a pattern to be separated at that map-scale. Such a soil complex is designated by two fractional symbols separated by a vertical line, e.g.:

$$\frac{847}{2\text{-}2}\Big|\frac{752}{3\text{-}2} \qquad \frac{847\,|\,752}{3\text{-}2}$$

The dominant soil unit (51 to 80 percent of a delineated area) appears on the left.

Unclassified soil areas are usually agricultural or potentially agricultural lands for which, in many cases, soil surveys have already been made by other agencies, such as the SCS. Symbols for unclassified soils are "100", "200", or "400", but are not in fraction form; sometimes a letter follows the number indicating further breakdown of the general definition of the symbols, e.g., 200W.

Some land types have little or no soil, or soil that cannot feaibly be classified. They are distinguished as a group by the symbol "700", also not in fraction form. Subdivision within the groups is shown by letter symbols in parentheses following the "700" symbol, e.g. 700(CK).

Vegetation Symbols

Plant species are represented by letter symbols, such as Af for chamise (Adenostoma fasiculatum) and D for Douglas fir (Pseudotsuga menziesii). Dominant species in a delineated area (excluding individual grass species and most associated herbs) are indicated by one or more symbols which may be grouped. Each group of symbols represents an element which may be either a broad kind of vegetation (commercial conifers, minor conifers, hardwoods, shrubs, bushy herbs, grass, marsh) or some other landscape unit (nonvegetated and rock, cultivated, urban industrial). Each delineated area may have one or more elements occupying from 5 to 100 percent of the ground area. Elements can be determined on the map by grouping the appropriate symbols. For example, an area has the symbols Y D I B W Cpo Ci Ba. They represent four elements, respectively: commercial conifers (YDI), hardwoods (BW), shrubs (CpoCi), and nonvegetated (Ba).

Elements are listed in order of abundance with the one listed first making up the greatest proportion of the cover. Likewise, the order of symbols within an element indicates the relative abundance of the species within that element. Symbols of vegetation elements not classified as to species (grass, marsh, and bushy herbs) and the non-vegetation element (barren) are included among plant symbols in proper order of abundance of elements or may stand alone, as the case may be.

In the above example, there is a greater proportion of commercial conifers than hardwoods, shrubs, or grass, and there is more Y than D, more D than I. But the proportion of I is not necessarily greater than B or Ba. If five or more species symbols appear in one group, the relative abundance of the species is variable within the delineated area.

A species must occupy 20 percent or more of the crown space of the element to which it belongs to be mapped in a delineated area. The individual element also must comprise the following minimum parts of a delineated area: crowns of commercial conifers--5 percent or more of the ground space; hardwoods and minor conifers--each at least 5 percent, or 20 percent when in combination with 20 percent or more of commercial conifers; shrubs--at least 5 percent, or 20 percent when in combination with 20 percent or more of a tree element; and all other elements--at least 20 percent if they appear on the map.

In some areas, logging, burning, or clearing may have eliminated one or more (or all) species of commercial conifer trees. In such areas, symbols of conifers eliminated or reduced to less than 5 percent cover are shown in parentheses. The Timber Harvest Map should be checked to see if an area has been logged since the area was mapped.

The approximate percent of the ground covered by woody vegetation (i.e., canopy of all trees and shrubs combined) is shown as a cover class symbol which appears as a number above or to the left of the vegetation species symbols and separated from them by a line, e.g., 2/YDIBWCpoCiBa. The cover class symbols and explanation are:

Cover Symbol	Cover Class	Ground Cover (Percent)
1	Dense	> 80
2	Semidense	50 - 80
3	Open	20 - 50
4	Very Open	5 - 20
5	Extremely Open	< 5

In areas with climate and soil unsuitable for growing commercial conifer crops, the symbol "N" precedes the cover class symbol in numerator portion of the fraction. "N" is not used in cultivated and urban industrial areas.

In some areas, distinct vegetation units cannot be shown separately at the scale of mapping. In such cases, two groups of cover class and species symbols are shown with a vertical line separating them, e.g.:

1	2
D	T
R	M
T	Ba

Timber Site Symbols

Site quality (capacity of the land for growing commercial conifer timber) is indicated on the maps by single-number symbols (Arabic or Roman) such as 4 and II. For each delineated commercial timber cropland area, a predominant site quality class is designated, based on the age-height relationship of trees. The site classification system used depends on the species type and location of the survey area.

The pine, fir, pine-Douglas fir, and pine-Douglas fir-fir types are graded using site class curves based on the total height that average dominant trees reach at 300 years of age, by 25-foot class intervals.

Site class symbols are designated by numbers 1 through 7:

Class Symbol	Height in Feet At 100 Years	Height in Feet At 300 Years
1	52	75
2	67	100
3	82	125
4	102	150
5	122	175
6	140	200
7	160 (est)	225

Douglas fir and redwood types are graded in terms of the total height that average dominant and codominant Douglas fir trees reach at 100 years of age, by 30-foot classes. Site class symbols are designated by Roman numbers I through V.

Class Symbol	Height at 100 Years (feet)
I	200
II	170
III	140
IV	110
V	80

The site curves used have been adjusted to the average height of dominant Douglas fir trees.

Soil and Vegetation Boundaries

Soil or vegetation boundaries or both are normally shown on the map by dashed lines. In some places, however, it is necessary to show a soil boundary distinct from a vegetation boundary. Where this is done, a dotted line indicates a soil boundary. When needed, a double-headed arrow is used to show the appropriate adjacent soil.

TIMBER HARVEST MAPS

Timber production is a large part of the north coastal economy. Timber is milled and made into lumber, plywood and paper products in Eureka, Crescent City, and many smaller towns. Much timber is shipped to foreign countries.

The upper watersheds of Turwar and Blue Creeks, predominantly USFS land, were virgin until recently. The lower part of the two watersheds are private, and most of this has been logged. Public land in the upper Turwar basin was recently traded to Simpson Timber Company to compensate for land incorporated into Redwood National Park (ESA, 1980). This area is now being harvested. Cutting in the Blue Creek Planning Unit (USFS) is also in progress.

About 45 percent (5 percent clearcut) of the Grouse Creek basin had been harvested by 1977. More than three-fourths of this was cut after 1965. A substantial amount of virgin forest remains in the headwaters of Grouse Creek.

Timber harvesting is plotted on 7½-minute USGS topographic quadrangles. Sources of data include USFS and CDF records, 1980 aerial photos, and 1975-77 orthophoto quadrangles.

The timber harvest maps show clearcut and selective cut areas (Photographs 11 and 12). They differentiate between tractor and cable (highlead-skyline) yarding methods. The maps are current to about June 1980 in all three watersheds. In multiple-entry areas, generally only the last date is recorded; in some places two dates are shown, i.e. 1955-65. This means it was first cut in 1955, and then recut in 1965.

Timber harvest data in Grouse Creek were compiled in several parts. USFS harvests were compiled from individual timber sale maps, available in district offices. Data on logging for private land were obtained from the county tax assessor. If 70 percent of the timber 16" dbh or larger was removed the timber value was removed from assessment for 40 years or more. Land with less than 70 percent of the timber removed prior to 1975 is therefore not recorded as having been harvested. Most of the land in Grouse Creek was harvested by the seed-tree method. Harvesting records after 1975 were obtained from CDF.

INSTABILITY AND EROSION HAZARD MAPS

An Instability and Erosion Hazard Map (in back pocket) combines erosion and landslide susceptibility. The map outlines areas of relative potential sediment yield and sensitivity to land use and road construction. The map is interpretive in that it is developed by subjective, empirical data that represents the cumulative knowledge and observations of engineering geologists familiar with an area. All boundaries should be considered approximate and gradational.

The maps should be used as a planning tool in the timber harvest review process. The maps aid in identifying areas requiring a more comprehensive pre-harvest inspection and review. They may also be used to determine areas where cumulative effects should be considered. The maps, however, are not to be substituted for site-specific investigations.

Grouse Creek Watershed

Grouse Creek was selected for the pilot hazard mapping study area for a number of reasons:

- o California Department of Water Resources has conducted previous studies (1979, 1982) and are familiar with the physical characteristics of the watershed;
- o extensive ground reconnaissance has been conducted;
- o geotechnical investigations on South Fork Mountain by the U. S. Forest Service provide insight into the causative mechanisms.

In addition, ground access to both Blue and Turwar Creeks was denied by timber companies owning the land; and no maps could be prepared for those watersheds.

The Instability and Erosion Hazard Maps are made using all available data, including:

- o Field observations of virgin terrain, roads, timber harvests, and stream channels;
- o aerial photo interpretation of erosion and landsliding;
- o rainfall, topography and proximity to streams;

TABLE 1

INSTABILITY AND EROSION HAZARD CLASSIFICATION
GROUSE CREEK WATERSHED

Zone 1 - Extremely unstable and/or erodible areas. Numerous active landslides and/or gullies present. This category generally mapped where a combination of steep, unstable slopes, high rainfall, erodible soils, unfavorable geologic conditions, and proximity to streams combine to create a condition where additional destabilizing forces practically guarantee further failures.

Zone 2 - Very high instability and erosion hazard. Numerous landslides, some active or probably active. Soils are highly erodible, but slopes are generally more subdued, further from streams or in a less unstable geologic unit than Zone 1. Probability of reactivating landslides with poorly conceived timber harvesting or improperly constructed roads is very high.

Zone 3 - High instability and erosion hazard. Landsliding is a major geomorphic process but few slides are considered active. Soils are erodible and slopes may be steep. Probability of reactivating landslides with timber harvesting and improperly constructed and engineered roads is moderate to high.

Zone 4 - Moderate instability and erosion hazard. Few landslides are present, and erosion is the major geomorphic process. Includes steep slopes in stable terrain and gentler slopes and ridgetops in unstable areas. Soil slips and gullying in harvested areas and below roads are expected if proper erosion control measures are not followed.

Zone 5 - Low instability and erosion hazard. Slopes are gentle. No landslides but minor erosion problems are to be expected after road construction and timber harvesting. Areas in this category in the Grouse Creek watershed are too small to map and are incorporated into Zone 4.

o relative sensitivity of geologic units, and the presence of geologic structures such as faults and dip slopes that adversely affect erosion and landsliding.

Each hazard zone is determined by a combination of factors and do not necessarily follow geologic contacts or geomorphic features such as inner gorges and rock units. A five-part hazard classification (Table 2) was adapted. Zone 1 is the most, and Zone 5 is the least sensitive. Zone 5 only occurs in places too small to map in the Grouse Creek basin and is incorporated into Zone 4.

The concept of hazard zonation in Grouse Creek has been aided by studies done by Kojan (1976) and CDWR (1979; 1982) and Haskins, et al (1980). Kojan conducted a study on "Mass Erosion Sensitivity Analysis, Hitchcock Creek Zone, South Fork Mountain, Shasta-Trinity National Forest" in an area similar to the southern half of Grouse Creek. He divided the terrain into three geomorphic zones. These are: (1) the inner gorges, (2) secondary peripheral zones of instability, and (3) interfluvial divides.

Haskins et al (1980) divided the interfluvial zone into the interdivide zone, the swale zone, and the bog zone. CDWR (1979; 1982) conducted landslide investigations and generalized sensitivity analyses.

In highly unstable terrain, a combination of the inner gorge and the peripheral zone is included in Hazard Zone 1 (extreme hazard). The interfluvial zone is included in Hazard Zone 2. In more stable geologic terrain the inner gorge and peripheral zone are included in Hazard Zone 2 and the interfluvial area in Zone 3.

Use of Maps

Because of the interpretive and empirical nature of hazard maps, they are not to replace site-specific geotechnical investigations. They are extremely useful for land-use planning in that they indicate what areas within a watershed are sensitive, where cumulative effects may be expected, and where landslide and erosion problems occur. The maps show areas where detailed pre-harvest inspections and geologic investigations are necessary to prevent accelerated erosion and damage to streams.

The maps should be consulted early on in the planning process by the landowners and the THP review committee.

Cumulative Effects

Cumulative effects are on- or off-site changes in the forest and hydrologic ecosystems, which tend to accumulate over time and space and affect the productivity of the natural environment (Teeguarden, 1981). Watershed damages from cumulative effects include: (1) destruction of fish habitat, (2) deterioration of water quality, (3) loss of forest products, (4) increased bank erosion and landsliding, (5) loss of productive soil, (6) altered stream channels, and (7) destruction of roads, bridges, and other structures. The amount and severity of cumulative effects damage depends on slope, aspect, geology, soil, climate, the quality of the human activity, the rate of regrowth for vegetation, the size of area disturbed within the basin, and the amount of soil compaction.

Changes in the land surface affect hydrology and sediment yields and landsliding rates. Human alteration of the amount and type of vegetation, road construction, and soil disturbance changes the infiltration rate of precipitation into the soil and the lag time of runoff (Leopold, 1981). When bare soils are exposed, raindrop impact detaches sediment, and overland flow, which accumulates quickly, carries the detached sediment to streams. Sediment increases the volume of flow in streams and adds to the abrasive power of water.

The amount of additional sediment and runoff that a stream channel can carry before damages begin to occur varies for each site. At each, there is a threshold of stability. When the load exceeds the threshold, landslides, channel aggradation or degradation, and bank erosion occur.

One of the most important principles of cumulative effects is that the effects of land use gather and reinforce each other exponentially in a downstream direction. For example, natural sediments and runoff rates can increase exponentially in areas disturbed by land-use activity. That is, any increase in streamflow may be accompanied by a massive increase in sediment load, where sediment is available (Leopold, 1981).

This sediment then deposits in channel and causes widening. This results in bank undercutting with subsequent bank or landslide failure (Fredriksen, 1970). These slides further increase the amount of sediment in the channel and impose more hazard to the stability of channels and slopes downstream (Dodge, 1976).

The percent of soil compacted by land use appears to correlate with the increased size of peak flows (Harr, Fredriksen, and Rothacher, 1979). In some watersheds, a peak floodflow with a natural return period of 100 years could be expected to occur every 35 years after 12 to 13 percent areal surface compaction by logging (Harr et al, 1979).

The non-linear aspect is also characteristic of landslides resulting from timber harvesting on steep, sensitive hillslopes. Figure 7 is a plot showing the number of active landslides compared to the percentage of a basin that is logged. The data were derived from "The Lower Klamath River Basin Investigation" (ESA, 1980) and plotted by Leopold (1981). Creeks within the Blue and Turwar basins are shown with thicker lines. All show an increase in landslide frequency and all but two show that this increase is non-linear but approaches a geometric increase. In this respect the curves are similar in character to those relating peak discharge increases with increases in percentage area affected by surface disturbance, but each increment has a larger effect than the preceding one.

For determining the magnitude of potential downslope damages from land use activities the sensitivity of the terrain is an important consideration. According to Farrington and Savina (1977), the location of the disturbance with respect to marginally stable slopes is probably the primary controlling factor. The Instability and Erosion Hazard Maps are therefore particularly useful for determining if cumulative effects are likely to occur.

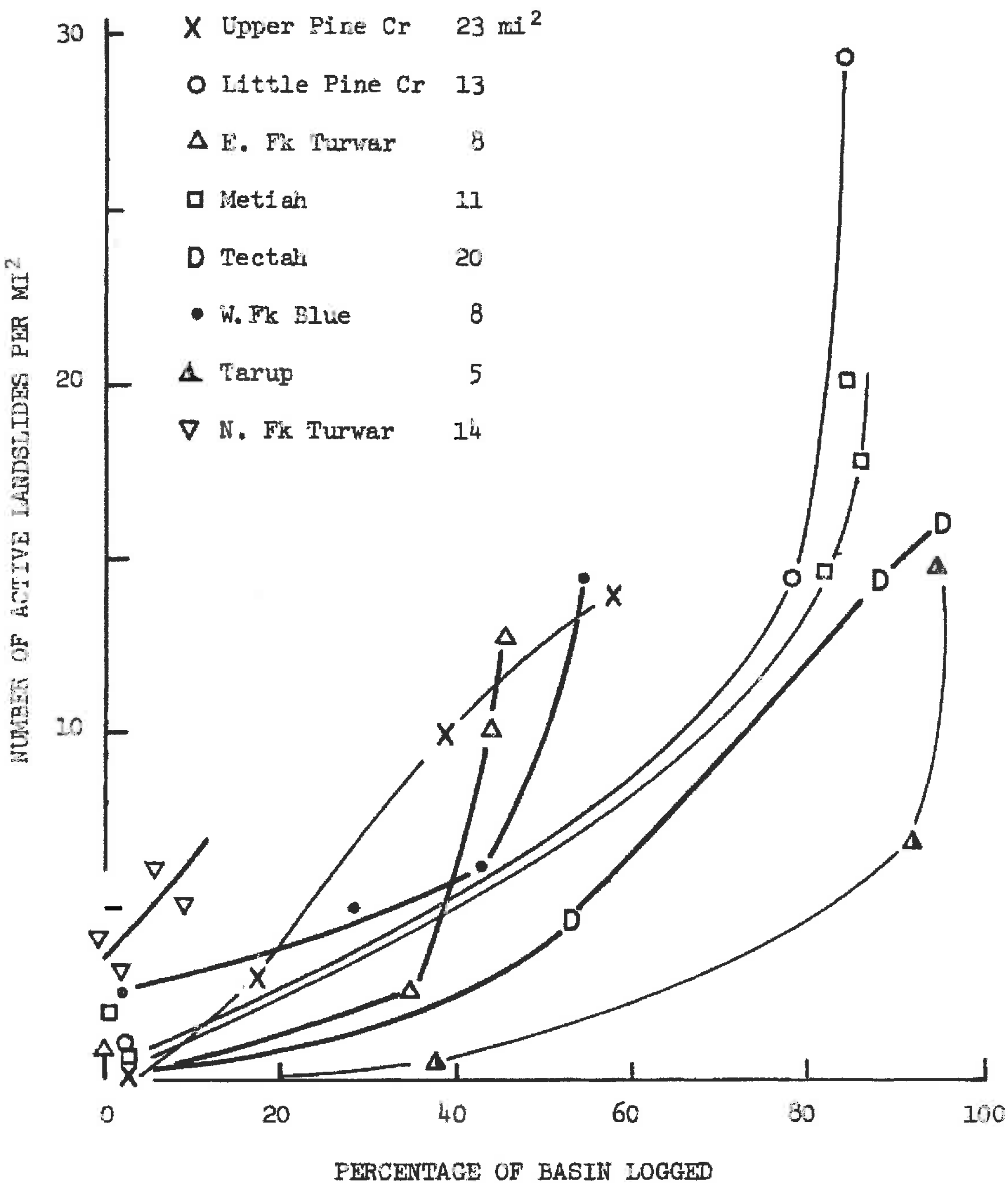


Figure 7 . Effect of various percentages of basin logged for timber harvest on number of landslides per square mile, Lower Klamath Basin, California. Adapted from Leopold, 1981.

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