Stitz Creek
Sediment Source Assessment and Sediment Reduction Recommendations

Prepared for

The Pacific Lumber Company

Prepared by

Natural Resources Management Corporation

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STITZ CREEK SEDIMENT SOURCE ASSESSMENT AND SEDIMENT REDUCTION RECOMMENDATIONS

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Stitz Creek Sediment Source Assessment and Sediment Reduction Recommendations

INTRODUCTION

This report summarizes the methods and results of a sediment source investigation of the Stitz Creek watershed, northern California. This assessment was performed by Natural Resources Management Corporation, at the request of The Pacific Lumber Company. The report describes the effects of storms and erosional events that have occurred in the Stitz Creek watershed over the past 60 years.

Purpose

The purpose of this investigation was to:

1) Identify sources of erosion and sediment delivery in the Stitz Creek watershed,
2) Investigate the associations between land management activity and mass wasting, and
3) Inventory and identify sites with potential for future sediment production that may be amenable to prevention or control.

The Role of Mass Wasting in Watershed Dynamics

Mass wasting is defined as the downslope movement of soil or rock material under the influence of gravity and water without the direct aid of other media such as air or ice (Selby 1993). It is the most important process in developing the morphology of steep, mountainous terrain and provides the vital sediment link between hillslopes and stream channels. Mass wasting events are episodic in nature and deposit debris on hillslopes and stream channels. Mass wasting features that reach stream channels can alter stream environments. Changes may take the form of increased bed and suspended sediment loads, redistributed channel-bed sediments, introduced woody debris, changed channel geomorphology from accelerated bank erosion and undercutting, or in extreme cases, sediment dams and channel obstruction, and/or channel scour down to bedrock. Streams adjust to the alterations of individual mass wasting events in both the downstream and upstream directions. The magnitude of these geomorphic alterations are dependent on the intensity and frequency of mass wasting events, as well as the sediment processing capabilities of a particular stream. Larger streams and rivers adjust to mass wasting perturbations faster than smaller streams.

ENVIRONMENT

Study Area

Stitz Creek is located in Humboldt County on the north coast of California. The Stitz Creek watershed encompasses 4.0 square miles (2,587 acres) and is a third order tributary to the lower Eel River (see Figure 1). Its confluence with the Eel River is approximately 26 miles upstream from the mouth of the Eel River to the Pacific Ocean, and approximately five miles upstream of the town of Scotia. It is entirely owned by The Pacific Lumber Company (PALCO).

Geology

The Stitz Creek watershed is located in the North Coast Range geomorphic province and lies on the tectonically active plate margin of North America, approximately 17 miles east of the Mendocino Triple Junction at Cape Mendocino. The Mendocino Triple Junction is formed by the intersection of the North American, Gorda, and Pacific Plates. The geologic evolution of the plate margin from Late Jurassic to Paleogene time is dominated by subduction-related accretion of oceanic rocks of the Central and Coastal Belt Franciscan Formations, and Yager Formation (Manning and Ogle 1950, Ogle 1953, Irwin 1960, Bailey et al. 1964, Blake and Jones 1974 and 1981, McLaughlin et al. 1982, Blake et al. 1985). These rocks comprise the basement rocks of the region. Complex plate interactions associated with the northward migration of the Mendocino Triple Junction and continued subduction of the Gorda Plate (Jachens and Griscom 1983, Furlong 1993, and Furlong et al. 1998) throughout the late Cenozoic has resulted in coincident uplift, erosional stripping of basin deposits, and progressive northward migration of the locus of sedimentation (Nilsen and Clarke 1989).

Today, tectonism associated with the Mendocino Triple Junction region is dominated by north-west trending, north-east dipping thrust faults, and broad anticlinal folds (Carver et al. 1985, 1986; Carver 1987). Rapid uplift rates on these structures have continued throughout the late Quaternary (Kelsey and Carver 1988, Merritts and Bull 1989, Merritts 1996). One thrust system, the Little Salmon Fault Zone, has generated three large dip slip displacements, 3.6 to 4.5 meters per event, during the last 1700 years (Carver and Burke 1987, Clarke and Carver 1989). These rapid uplift rates result in ongoing erosional stripping of basin sediments and deposition and preservation of these sediments in local depocenters, including the Eel River Basin. Downcutting by streams in response to the uplift has resulted in steep V-shaped canyons and a high frequency of landslide occurrence.

The Stitz Creek watershed is underlain by Paleocene Yager Formation and Miocene-Pleistocene Wildcat Group sediments. The Wildcat Group is composed of a lower unit composed of deep marine mudstones and siltstones (Pullen Formation), marine mudstones, siltstones, and sandstones (Eel River Formation), marine massive mudstones with innerbedded thin sandstones, mudstones, and very fine sandstones (Rio Dell Formation); and an upper unit including shallow marine fossiliferous massive sandstones and pebbly conglomerates (Scotia Bluffs Sandstone), and non-marine conglomerates, sandstones, and claystones (Carlotta Formation) (Ogle 1953). Mudstone is the dominant rock type in the Wildcat sequence, but minor amounts of limestone, tuff, and lignite also exist. The Wildcat Group sediments were deposited unconformably on the underlying Yager and Franciscan basement rocks (Clarke 1992). The Yager formation consists of well-indurated marine mudstone, thin-bedded siltstone, lesser amounts of greywacke sandstone, and locally thick lenses of polymict conglomerate (Clarke 1992).

The Wildcat sediments in the watershed strike roughly east-west and have a moderate regional dip to the north. From geologic contacts identified on the Scotia Quadrangle by the California Department of Mines and Geology (DMG 1982), 54 percent of Stitz Creek watershed is characterized as Undifferentiated Wildcat, 30 percent as Scotia Bluffs Wildcat Formation, nine percent Carlotta Wildcat Formation, two percent Pullen Formation, and five percent Yager Formation. To more precisely characterize the Undifferentiated Wildcat Group in the Stitz Creek watershed, geologic contacts defined west of Stitz Creek were extrapolated along strike into the watershed. These contacts include the Rio Del Formation, Pullen Formation, and Eel River Formation. The resulting distribution of the underlying geology in the Stitz Creek watershed is

45 percent Rio Dell Formation, 30 percent Scotia Bluffs Formation, nine percent Carlotta Formation, seven percent Eel River Formation, four percent Pullen Formation, and five percent Yager Formation (see Figure 2).

Mass wasting processes acting on the Stitz Creek watershed are largely dependent on the underlying bedrock. The Rio Dell Formation (45% of watershed area) is the most extensive and erodable Wildcat unit in the Stitz Creek basin. Hillslopes underlain by the Rio Dell Formation characteristically have an intricate system of cross fracturing (Ogle 1953). The mudstones of the Rio Dell are generally softer than the mudstones of the Eel River and Pullen Formations, and thus have a higher incidence of shallow landslides. Landslides usually occur on dip plane surfaces where there is thin, rhythmic alternation of sandstone and mudstone bedding. Subsurface water accumulates above the less permeable mudstone layers that result in a decrease in effective normal stresses within the slide plane. A possible consequence of this subsurface water flux is slope instability. Often thin sandstone interbeds will fail as the rock glides on these slide planes. The occurrence of many thin rock glide failures led Ogle (1953) to describe the characteristic Rio Dell Formation hillside as "onion-skin" weathering.

Hillslopes underlain by the Scotia Bluffs Sandstone (30% of watershed area) and Carlotta Formation (9%) are characterized by rock fall; shallow landslides; steep, nearly vertical cliffs of 100 feet or greater; and thin, if any, colluvium. Scotia Bluffs Sandstone is able to form high relief cliffs due to its massive nature, compactness, and resistance to chemical decomposition of many of the grains (Ogle 1953). Cliff formation in the Carlotta Formation is the result of rapid weathering of claystone innerbeds which leads to undercutting and collapsing of masses of the loosely compacted conglomerate (Ogle 1953).

Hillslopes underlain by the Eel River Formation (7% of watershed area), Pullen Formation (4%), and Yager Formation (5%), found within the first mile or more of Stitz Creek, are generally not as steep as hillslopes further up in the watershed. Characteristic features of these formations include poorly exposed bedrock, frequent springs and seeps, and soft, plastic clayey materials. Large deep-seated slumps and earthflows commonly occur along watercourses where toe support is removed by fluvial erosion. Shallow landslides do occur in these formations, but are less frequent than in the Rio Dell, Scotia Bluffs, and Carlotta Formations.

A wide variety of geologic and hydrologic may influence the occurrence of mass wasting failures in the Stitz Creek watershed. Failure of a slope occurs when the driving forces are greater than the resisting forces. Driving force variables include cohesion, effective normal stress and the angle of internal friction. Resisting force variables include the weight of the landslide and the angle of the slope (Sidle 1995, Spittler 1998). Material strength is dependent on the composition of soil and bedrock materials, and depth and degree of weathering. At the soil and bedrock interface where subsurface water concentrates, slope failure may occur on dip slopes (where the bedding plane of the bedrock is parallel to the hillslope) due to changes in material hydraulic conductivities (Sidle 1985). Bedrock failures occur along discontinuities (e.g. bedding planes, fractures, faults, joints, etc.). Bedrock failure analysis includes an evaluation of several factors such as joint roughness coefficient (perturbation geometries of the discontinuity), strength values of the bedrock and discontinuity infilling, and geometry of the ground water regime (Hoek and Bray 1981, Goodman 1989). However, not all bedrock dip slopes are unstable nor all bedrock slopes dipping into the slope stable, and a licensed professional geologist may be needed to evaluate soil and bedrock stability.

Strong ground accelerations associated with earthquakes generated by the seismically active Mendocino Triple Junction can influence the occurrence of mass wasting. Seismic shaking has been documented to induce rock avalanches (Schuster et al. 1992) and lacustrine landslides (Jacoby et al. 1992) in the Puget Sound, Washington area. Liquefaction under a seismic load depends largely on the presence of groundwater in the soil, thus a well-drained soil has less exposure to seismically induced liquefaction and landslides (Hall et al. 1994). A summary of landslide data from 40 worldwide earthquakes indicates that the area affected by earthquake-induced landslides is directly proportional to earthquake magnitude (Keefer 1985).

Hydrologic factors that can influence the stability of hillslopes include intense and prolonged precipitation, the rate of water recharge into the soil mantle, the transmission rate of water within the soil mantle, and evapotranspiration (Sidle 1985). The relative rates of these processes determine the transient level of groundwater within hillslope soils. When infiltration rate of water is greater than the subsurface flow rate of water, increased pore water pressures, and thus landslide incidence, can result. Forest evapotranspiration rates, when compared to ground water recharge rates and ground water fluxes in pressure potentials, may be considered negligible to landslide occurrence. For example, typical evapotranspiration rates for coniferous forests are a few hundredths to a few tenths of an inch per day (Waring and Schlesinger 1985) whereas recharge and pressure potentials changes can be several inches per day (Kohler, personal communication).

Anthropogenic factors acting in conjunction with natural geologic and hydrologic factors can also influence the occurrence of landslides. Road, skid-trail, and landing construction can affect slope stability by mechanically steepening slopes, undercutting toe slopes, and concentrating runoff water onto the slope. Root decay (reduction in root strength) has been associated with a period of increased susceptibility to landsliding, which occurs approximately 3 to 10 years after clearcutting (Megahan et al. 1978).

Climate and Storm History

California's north coast region is subject to intense rainfall of long duration. The mean annual precipitation (1926 to 1997) at Scotia is 47 inches (DWR 1998), occurring predominately during the months of November through May (Appendix B). When high intensity precipitation events occur in the coastal mountains, localized and sometimes regional flooding is expected to follow. The amount of rainfall (magnitude) within a limited time (intensity) are critical factors that influence flooding and mass wasting on the landscape. For example, the 1964 storm is not associated with a high rainfall year, yet the intensity and magnitude of that rainfall event initiated mass wasting and flooding on a regional scale. From monthly rainfall data at Scotia, the largest monthly precipitation occurred in January 1995 (26.41 inches), December 1955 (22.88 inches), and December 1996 (22.58 inches). The respective December-January two-month totals for these years ('95, '55, '96) were equal to 32.73 inches, 37.31 inches, and 35.48 inches, respectively. The 1964 December-January two month total equaled 27.87 inches.

Daily precipitation records (1968 to 1998) for Casper Creek, Mendocino County, California, were analyzed in relation to the initiation of mass wasting features greater than 100 yd^3. Storm events capable of causing this mass wasting were called "stressing storms" and precipitation data were analyzed in 1-, 3-, 5-, and 10-day maximum rainfall totals. The analysis showed that landslide activity associated with high 3-day or 10-day precipitation totals in combination with moderately high 1-day amounts were more important than very high 1-day rainfall totals alone. In Caspar

Creek, stressing storms equated to a 1-day precipitation of 2.26 inches, a 3-day precipitation of 4.97 inches, a 5-day precipitation of 6.11 inches, or a 10-day precipitation of 8.32 inches (Cafferata and Spittler 1998). Preliminary rainfall data for the 1997 New Year's storm taken from the Bridgeville tipping gage (Appendix B), approximately 15 miles east of Stitz Creek, show a one day total on December 30, 1996 of 3.80 inches, a 3-day rainfall total of 10.60 inches, a 5-day total of 13.80 inches, and a 10-day total of 16.80 inches. An increase of landslide occurrence was noted throughout the region after this particular storm.

In the absence of site-specific rainfall data to evaluate rainfall intensities, the record of large flood events may be used as a guide for storm events that could potentially trigger landslide processes. Discharge records provide a good record for regional storms of significance, but they cannot take into account the variability and intensity of localized precipitation throughout a drainage area. Stitz Creek enters the Eel River approximately 5.5 miles above the USGS Gauging Station at Scotia (records from 1911-1995). The Scotia gage provides an indication of *regionally* intense storm events because its drainage area is over 3,000 square miles. The 1964 and 1955 storm events, which caused widespread regional flooding, hold the top discharge records for the Eel River drainage at Scotia. The discharges for these events were 752,000 cubic feet per second (cfs) and 541,000 cfs, respectively. The next 12 records are in the 300,000 to 387,000 cfs range, with the 1995 flood being the fourth largest discharge on record at 368,000 cfs.

However, due to rainfall variability that can occur over such a large area, the Eel River discharge is not completely representative of what occurs in Stitz Creek, a four square mile subset of that drainage area. The USGS gage at Bull Creek (drainage area of 28.1 sq. mi.), a tributary to the Eel River approximately 10 miles south (upstream) of Stitz Creek, is the nearest gage with a comparable drainage area to Stitz Creek. The Bull Creek gage (records from 1961-1995) recorded its highest discharge during the 1964 storm (6,520 cfs), followed closely by the 1995 storm (6,400 cfs) (Appendix B). The next highest discharges range between 4,280 cfs and 5,880 cfs for storms in 1966, 1970, 1974, 1982, and 1986. In comparison, the discharges for the water years between 1987 to 1994 rarely exceeded what would be considered as the average annual bankfull discharge (less than 1,500 cfs). Data are unavailable for the discharge peak of the 1997 storm at Bull Creek. However, judging by the rainfall records from Bridgeville, the discharge for January 1, 1997, would be of comparable magnitude to the top discharges on record for Bull Creek.

Land Use History

Initial land management in Stitz Creek occurred in the early 1900's. The old-growth in Stitz Creek was harvested at that time, primarily with steam donkey and oxen yarding techniques, apparently with the intent to convert it to pastureland. Historical rail tracks and ties were observed in the main channel of Stitz Creek. Review of the earliest available aerial photos (1947 and 1954) of Stitz Creek show no road network associated with the turn of the century timber harvesting. Stitz Creek was not re-entered for timber harvesting until the mid-1970's.

The role and influence of timber harvesting practices in the region have changed significantly over the last 30 years. Prior to the 1970's, there were virtually no regulations regarding management practices, silviculture, or size of timber harvest units. In the period between 1940 and 1973, road construction practices had few standards for proper compaction of fill materials. Side-casting of waste material was common. Roads commonly occurred on steep slopes, often adjacent to stream channels. Although Stitz Creek was not entered in this manner, many of the watersheds in northwestern California were heavily harvested utilizing tractor yarding and skidding, with little or no regard given to the watercourses. To compound matters, the 1964 flood event triggered tremendous amounts of mass wasting in the region due to a combination of natural landsliding and mass wasting exacerbated by the poor roading and yarding practices of the time. Channel aggradation resulting from that event can still be observed in northern California rivers today. In the Stitz Creek watershed, a debris flow (Slide #54, Figure 6) initiated during the 1964 storm deposited a terrace at the confluence of the tributary channel and the main stem of Stitz Creek. This terrace deposit was identified and published on a landslide map (DMG 1982), and was observable on the 1997 air photos and in the field.

Since the passage of the Z'berg-Nejedly Forest Practice Act of 1973, timber operations and road construction practices have improved. Among other measures, Watercourse and Lake Protection Zone (WLPZ) requirements add protection to watercourses and inner gorge locations. Roads are built further away from watercourses and avoid steep slopes, typically located on and near ridges to accommodate cable yarding practices. New roads are constructed to higher standards, minimizing side casting and installing culverts sized to withstand at least a 50-year flood event.

In the early 1970's approximately one mile of road was constructed from the Shively Road at the south end of the drainage. The first significant harvest to occur in Stitz Creek began in 1974 on 185 acres in the northern corner of the watershed in conjunction with the harvesting occurring in the Van Duzen River drainage. Between 1974 and 1981, approximately 12 miles of road were constructed and approximately 30 percent of the watershed had been re-entered for timber operations (see Figure 3). Road construction in Stitz Creek was located primarily on the ridges with several midslope spur roads. In some areas, skid trails were utilized for tractor yarding purposes. From 1981 to the present, an additional 7 miles of road were constructed. Approximately 1,250 acres (48% of the watershed) were re-entered for harvest operations by 1987. From 1988 to 1993, 360 acres were re-entered, and from 1994 to 1998, 344 acres had timber management with some acres overlapping the 1988 to 1993 areas for silvicultural steps (see Figure 4). By 1997, approximately 73 percent of the watershed had undergone timber management operations over the previous 23 years.

METHODS

Mass Wasting Inventory

Aerial photographs of Stitz Creek were obtained for the years of 1947, 1948, 1954, 1963, 1966, 1970, 1974, 1981, and 1997. However complete stereo coverage of the watershed were available only for the years of 1963, 1966, 1981, and 1997. All the photos were reviewed to provide an understanding of the spatial distribution, timing, and possible associations of mass wasting processes active in the Stitz Creek watershed, and the progression of land management occurring in the watershed. Mass wasting features from the Scotia Quadrangle map of Geology and Geomorphic Features Related to Landsliding (DMG 1982) and harvest history GIS maps provided by PALCO covering 1984 to the present were also incorporated in the analysis.

An initial tally was made of mass wasting features identified on the aerial photos in 1963, 1966, 1974, 1981, and 1997. Because the highest occurrence of mass wasting features occurred on the 1966 and 1997 photos, further analysis of the mass wasting features in those two years was conducted. Physical and geomorphic characteristics of the landslides were recorded including an identification number, type of landslide process, approximate failure date, approximate length, width, depth, area, volume, estimated sediment delivery range, geomorphic location (inner gorge, debris slide amphitheater, headwater swale, midslope, or ridge top), associated land use, slope form, aspect, and interpretation certainty (Appendix C). Landslide length and width were measured from the photo, and depths were determined from field measurements or estimated based on aerial photo interpretation and field calibration. Ocular estimates of sediment delivery were made in the field to validate estimates made from air photos. The percent of the landslide volume that reached a watercourse was estimated in four percentage volume ranges (1-25, 25-50, 50-75 and 75-100 percent), based on photo interpretation and field assessment. The minimum and maximum sediment delivery volumes were determined by multiplying the landslide volume by the low and high sediment delivery values in the percent range. The midpoint of the minimum and maximum sediment delivery range was reported in the following tables and text as the "estimated sediment delivery" in order to compare sediment delivery for different types of landslides and different time intervals.

Approximately 1.8 miles of the 4-mile main Stitz Creek channel were walked (from Shively Road bridge walking upstream) for a field reconnaissance of small inner gorge landslides. This was done to determine the significance of sediment delivered by inner gorge slides not observable on aerial photographs. Freshness of the scarp and the amount of revegetation on the scarp were the criteria used to determine approximate age of failure. Only slides considered to be less than 10 years old were included in the streamside analysis. Field measurements of landslide dimensions and sediment delivery were taken for the observed small inner gorge landslides. A sediment delivery index was determined by totaling the sediment volume and dividing by the miles walked (volume/river mile). This index was then extrapolated to the rest of Stitz Creek and to the larger Class II tributary streams from the USGS Scotia quadrangle.

Based on the assumption that landslide scars are visible on air photos for approximately 30 years, roughly two equivalent time intervals (1936-1966 and 1967-1997) were established in which to perform a detailed mass wasting inventory. Each interval ended with a significant storm event. The 1966 photos were the closest available photos following the 1964 storm event, and the 1997 photos were taken only eight months following the 1997 New Year's storm. To evaluate the effects of high intensity rainfall events on mass wasting in the Stitz Creek watershed, landslides associated with the 1964 and 1997 storm events were analyzed separately from the rest of the data set. Landslides that exhibit "fresh" scarp appearance on the 1966 and 1997 air photos were assumed to be a product of the aforementioned storms. Older landslides were dropped out of the storm event analysis. Sediment production determined for the 1964 and 1997 storm events were then compared to the overall sediment production for the time interval.

To assess the association of road construction with mass wasting occurrence, the landslides in Stitz Creek were divided into road related and non-road related categories. To assess the association of timber harvest with mass wasting occurrence, the landslides in Stitz Creek were classified by occurrence in areas harvested within the previous ten years, harvested prior to the previous ten years, or not harvested since the turn of the century. Landslides that were considered to be road related were excluded from the harvest association analysis.

Road Inventory

A detailed road inventory was used to evaluate the condition and erosion potential of the existing road network in Stitz Creek. The road inventory evaluated potential and present fluvial erosion and mass wasting erosion. An example of a road erosion data sheet is in Appendix D. The results obtained from the inventory provided field based data of sites that could contribute significant volumes of sediment to watercourses.

The primary haul and spur roads accessing the Stitz Creek watershed (H03 and H11 road networks) were inventoried for condition and potential sites or practices that could reduce future sediment production and delivery to the streams in the watershed. An aerial photo analysis provided a catalog of the road construction history in the watershed. The field based road inventory recorded the condition of roads, landings, and all the drainages crossed by the road. Potential future erosion, estimated future sediment delivery to watercourses, and approximate volume of past erosion were also quantified at drainage crossings, fill slopes, mass movement sites, and landings. General road maintenance sites, such as cutbank slumps, were not included in the survey if they were not likely to result in sediment delivery to a watercourse. Culvert condition and size were recorded and evaluated for storm discharge passage. The lengths and condition of inboard ditches were also evaluated and added to the drainage area of the stream culvert for flood risk, when relevant. Based on these data, road conditions were evaluated for opportunities to reduce future sediment inputs into a watercourse.

Road reaches and potential erosion sites were prioritized for repair as High, Moderate, and Low. Prioritization was based on potential volume of future erosion, potential sediment delivery to a watercourse, accessibility, and cost-effectiveness of the treatment to minimize the future sediment inputs. For example, if there was a single site that had a moderate to high sediment volume with a 50 percent sediment delivery probability, but was located at the end of an abandoned road reach that would require substantial road rebuilding to access, the priority of the site would drop to low as the cost in time and impact on the land would be greater than the potential sediment "saved". Likewise, the treatment of sediment source problems is limited to what is feasible.

All priority sites were divided into three categories for prevention and control of future road related erosion. Those categories were 1) hydrologic road decommissioning, 2) individual erosion sites, and 3) road upgrading. Hydrologic road decommissioning and treatment of individual erosion sites reduces future potential sediment production by utilizing heavy equipment to minimize volume of mass wasting sites and excavate stream crossings. Road upgrading work reduces fluvial erosion risk and minimizes chronic surface erosion source inputs, by eliminating diversion potentials, installing culverts sized for larger return interval discharge, and installing additional inboard ditch relief drains. Design criteria by PALCO for such work utilizes the standards described in the *Forest and Ranch Roads Handbook* (Weaver and Hagans 1994), unless otherwise specified and approved.

MASS WASTING BACKGROUND

Mass Wasting Types

The terminology used to describe individual landslides in this report closely follows the definitions of Varnes (1958, 1978), Cruden and Varnes (1996), and DMG (1997). Landslides were differentiated into three types: shallow landslides, debris flows, and deep-seated landslides.

Shallow Landslides: Shallow landslides, rock falls, and debris avalanches are the three kinds of mass wasting processes represented in this type. Shallow landslides are characterized as any mass-movement process involving sliding over a discrete failure surface that transports soil and rock downslope under gravitational stress. These landslides often occur on steep slopes (>65%), and areas with over-steepened road fill. Rock falls are characterized by rapid downslope movement of disaggregated rock and soil fragments by falling, rolling, and bounding. Debris avalanches are produced by the failure of the soil mantle, colluvium, and weathered bedrock, with a depth of failure less than 15 feet.

Shallow landslide headscarp widths range from about 5 feet to up to 500 feet in length. Shallow landslide debris moves rapidly downslope and sometimes transforms into debris flows upon entering confined steep-gradient channels. Often two or more shallow landslide features can coalesce into one larger complex feature. Deposits of shallow landslides can be recognized by the accumulation of an apron or fan of debris at the base of slopes and hummocky, irregular toe surfaces on hillslopes. The initial failure is usually followed by a few years of secondary erosion in the form of steep headscarp failures and rilling and gullying of the hummocky toe deposit and exposed slide face.

Movement or activation of shallow landslides is typically in response to elevated ground water conditions resulting from high intensity and/or long duration rainfall. Among the major factors influencing landslide incidence and susceptibility are soil mechanics properties, soil hydrologic properties (Hall et al. 1994), slope gradient, precipitation, rock type, faults, joints and bedding planes, soil type, and degree of weathering (Satterlund 1992). Additional naturally occurring factors that can contribute to the occurrence of landslides include removal of lateral support by stream erosion and undercutting, and changes in lateral stress, structure, cohesion, and pore water capacity due to seismic shaking in large earthquakes (Bishop and Stevens 1964, Alley and Thomson 1978). Land management practices that can increase the potential for shallow landslide activation include road construction or maintenance, which may remove lateral support as a result of road cuts, and/or add additional mass to the slope with fill material. Root decay following timber harvest can potentially weaken the soil cohesion as both the numbers of roots and the tensile strength of the remaining individual roots decrease with time (O'Loughlin 1974, Burroughs and Thomas 1977, O'Loughlin and Ziemer 1982, Greenway 1987). This can contribute to landslide incidence in unstable areas (Ziemer and Swanston 1977).

<u>Debris Flows</u>: Debris flows are characterized by a highly mobile slurry of soil, rock, vegetation, and water that can travel many miles down steep confined mountain channels (Benda and Cundy 1990). Debris flows are initiated in deep colluvial hollows along first order streams where ground and surface waters tend to concentrate. Debris flows can also initiate when oversaturated road fill material fails. Failure usually begins as a shallow landslide and becomes a debris flow as the moisture content of the material increases. Debris flows contain 70 to 80 percent solids and only 20 to 30 percent water (Selby 1993). Entrainment of additional sediment and organic debris can increase the volume of the original landslide by 100 percent or more (Swanston and Swanson 1976). Debris flows become more destructive as their volume increases with distance traveled. Large debris flows can travel down tributaries, scour a channel down to bedrock, and continue downslope to their confluence. Debris flow deposits are massive (not layered or stratified), coarse-grained, poorly sorted (large range in debris size), and are often preserved as in-channel debris fans. Once a colluvium-filled hollow (headwater swale) has been evacuated by a debris flow, it may take thousands of years of creep deposition to sufficiently load the resulting hollow for another debris flow (Dietrich et al. 1982, Reneau 1988).

Deep-Seated Landslides: Deep-seated landslides are generally large scale features that include translational/rotational landslides and earthflows. They are characterized by coherent movement (back rotation) of a blocky mass along a concave failure surface. Earthflows are deep-seated failures that move through a combination of slumping and plastic flow (Cruden and Varnes 1996). Deep-seated landslides typically include a steep, arcuate, poorly-vegetated headscarp, a back-tilted bench below the scarp, a lobate, hummocky body (which may be bounded on either side by a stream), and an oversteepened toe. However, one or more of these features may be absent or poorly expressed. Steep slopes at the toe of a deep-seated landslide commonly produce shallow landslides and earthflows. Deep-seated landslides can exceed five acres in area and are often associated with a failure surface that extends into bedrock.

Deep-seated landslides are natural features of the landscape that are characterized by intermittent periods of movement and dormancy. The movement or activation of deep-seated landslides is typically triggered by the build up of pore-water pressure in mechanically weak materials such as deep soils or clay rich rocks. Elevated pore-water pressures are usually caused by several consecutive extremely wet rain years followed by a high intensity rainfall event. Movement of deep-seated landslides may also be activated by stream incision of the landslide toe and strong ground shaking generated by large magnitude earthquakes. Land management activities and harvest operations generally are considered to have limited, if any, influence on deep-seated features. Deep-seated landslide features can be difficult to identify in aerial photographs due to the subdued attributes of the slide morphology and thick forest canopy.

Mass Wasting Geomorphic Zones

To evaluate landslide potential in the watershed, it is useful to describe the geomorphic zones where they are most prevalent. The geomorphic zones can be considered by land managers in making land use decisions that will minimize future mass wasting sediment input to watercourses. The physiographic and topographic features of each geomorphic zone in which landslides commonly occur in the Stitz Creek watershed have been modified from definitions outlined by DMG (1997) and are as follows:

Inner Gorge: An inner gorge is a geomorphic feature formed by fluvial downcutting and coalescing landslide scars. The most common mechanism of failure in this geomorphic zone is loss of toe support by active stream erosion and undercutting. The feature is identified as that area of the stream bank situated immediately adjacent to the stream channel, having smooth planar side slopes generally greater than 65 percent. The zone is situated below the first break in slope above the stream channel. Landslides initiating in this zone deliver between 75 to 100 percent of their mobilized material to the watercourse. This geomorphic zone applies to both perennial and ephemeral channels. The term ephemeral inner gorge was used to differentiate the inner gorge landslides occurring higher in the drainage network (i.e. Class II streams) from those occurring lower in the drainage. Ephemeral inner gorges are often located in or associated with debris slide amphitheaters.

Midslope: This geomorphic zone is characterized by moderate to steep side slopes with gradients generally 35 percent to more than 65 percent. This zone is commonly located upslope of the inner gorge and downslope of the ridge top geomorphic zones, and the slopes can exhibit planar, divergent, and locally convergent forms. Much of the debris generated from shallow landslides in this zone is deposited on the hillslope, but often up to 25 percent is deposited in watercourses. Midslope landslides often occur at a break in slope, a point where more gentle terrain drops quickly to a steeper gradient in a downslope direction within the midslope location. Surface and ground waters can concentrate at the break in slope resulting in localized saturated soil conditions.

Headwater Swale: The headwater swale area is the basin above a Class III watercourse, commonly referred to in geomorphic literature as the zero order basin, or bedrock hollow. This is an area where colluvial deposits tend to be thickest and ground and surface waters concentrate due to strongly convergent slope form. The most common mass wasting processes acting in this zone are debris flows. Debris flow slides often scour the channel to bedrock and deliver 75 to 100 percent of the mobilized material to a watercourse.

Ridgetop: This geomorphic zone is characterized as the uppermost portion of the slope that climbs steeply towards the ridge. The zone includes the headwalls above headwater swales and along steep ridges located between tributary streams and watersheds. Shallow landslides generated in this zone rarely reach watercourses, but can contribute significant amounts of sediment to the loading of midslope areas.

Debris Slide Amphitheater: Debris slide amphitheater slopes are geomorphic features in which slopes have been sculpted by numerous debris slide events. These features are the site of chronic failure and have been active far longer than human involvement in the watershed. The amphitheaters are characterized by an aggregate of scars (old and recent) left by the movement of predominately unconsolidated rock, colluvium, and soil along relatively shallow failure planes. Slopes in debris slide amphitheaters generally exceed 65 percent. Sediment delivery volumes from individual landslide events in these zones are difficult to quantify because landslides often overlap each other over time.

RESULTS AND DISCUSSION

From the initial analyses of the aerial photograph coverage of Stitz Creek, it was apparent that large storms influenced the magnitude of mass wasting processes in the watershed. In a simple tally of mass wasting features observed in the years 1963, 1966, 1981, and 1997 (Table 1), the greatest number of features occurred in years following significant storm events (i.e., 1964 and 1997). The 1966 photos were taken two years after the 1964 storm event and the 1997 photos were taken 8 months after the 1997 storm event.

Table 1. Number of Mass Wasting Features Identified on Aerial Photos by photo year.

Year	Total
1963	69
1966	107
1981	69
1997	172

One reason for observing a greater occurrence of mass wasting in 1966 and 1997 compared to the other photo years is that vegetation had not yet established on landslides caused by the 1964 and 1997 storm events. These fresh scars made landslides more apparent on the air photos. The lesser number of landslides recognized on the other photos may be a result of longer periods between stressing storm events that caused mass wasting, which allowed for revegetation to obscure slide scars.

Landslide Characteristics in Stitz Creek Watershed

A total of 279 landslides were tallied in the Stitz Creek watershed from the 1966 and 1997 photo analysis combined (see Figure 5). Individual landslide data are listed in Appendix C. Landslide studies that use aerial photos in "mature" or "undisturbed" forests have been documented to underestimate the amount of landslides (Dent et al. 1997). Based on this observation the total number of landslides tallied in the Stitz Creek watershed is recognized as a minimum.

The majority of the inventoried landslides occurring in the two time intervals originated in planar topography (47%), where sub-surface water is evenly distributed across the slope, or convergent topography (33%), where surface and sub-surface waters concentrate. Few landslides originated in divergent topography (16%), where sub-surface water is diverted to the sides of topographic noses. Four percent could not be categorized.

The dominant mass wasting process in the Stitz Creek watershed was shallow landsliding (Table 2). Shallow landslides accounted for 74 percent of all landslides recognized, whereas debris flows and deep-seated landslides accounted for 24 percent and 3 percent, respectively. This percentage distribution of landslide type is similar to the distribution determined by the California Department of Mines and Geology (DMG 1982) on the Scotia Quadrangle. In the Stitz Creek watershed they identified 36 shallow landslides (84%), four debris flow/torrent tracks (9%), and three earthflows (7%).

Table 2. Distribution of the landslide type for mass wasting features (entire data set).

Type of Slide	Number of Landslides	Percent of Total Landslides	Percentage of Estimated Sediment Delivery
Debris Flow (DF)	65	24%	70%
Shallow Landslide (SL)	203	74%	24%
Deep-seated Landslide (DS)	8	3%	6%

Although shallow landslides were the most common mass wasting process, they did not produce the greatest sediment delivery. The mass wasting process responsible for the greatest percent of estimated sediment delivery was debris flows. Debris flows accounted for 71 percent of the estimated sediment delivery, whereas shallow landslides and deep-seated landslides accounted for 24 percent and 5 percent, respectively.

The combined landslides for the two time periods were then analyzed for their distribution in each geomorphic location, percent of total landslides per location, and percent of estimated sediment delivery per location (Table 3).

Table 3. Distribution of the landslides for each geomorphic location (entire data set).

Geomorphic Location	Number of Slides	Percent of Total Landslides	Percentage of Estimated Sediment Delivery
Inner Gorge	115	42%	36%
Midslope	92	33%	20%
Ridgetop	46	17%	13%
Headwater Swale	23	8%	31%

The inner gorge landslides represent the greatest percent of total landslides (42%) and the greatest percentage of the estimated sediment delivery (36%). In contrast, headwater swale landslides represent the smallest percent of the total landslides (8%) and the second greatest percentage of the estimated sediment delivery (31%). This is due to two massive debris flows (Slides #53 and #54 on the 1966 photos) that originated in headwater swale locations. While the sediment volume from these two landslides cannot be discounted for this study, it is recognized that landslides of this magnitude are a rare occurrence. As a result, the estimated sediment delivery from headwater swales determined in this study may be misrepresentative of sediment delivery from headwater swales in other watersheds in the region.

Observations from similar terrain in the California Coast Ranges show that shallow landslides and debris flows can occur anywhere from the ridge top to the stream channel (Louisiana-Pacific Corp. 1998). Steep slopes, slope form, geomorphic location, condition of the weathered Wildcat bedrock units, and the occurrence of high intensity rainfall events appear to be the major factors influencing the distribution and occurrence of landslides in the Stitz Creek watershed. Shallow landslides and debris flows occur in each geomorphic location, but are most commonly initiated in inner gorge and midslope areas. Deep-seated landslides tend to be initiated in inner gorge areas by erosion and loss of support at the toe of the slide. Due to their large size and nature, deep-seated landslides, can extend great distances upslope and include debris slides originating in midslope areas. Rock falls commonly occur along ridgetop zones and steep rock inner gorges.

Significance of Small Inner Gorge Landslides Not Observable on Photos

Forty-five percent of the mainstem of Stitz Creek was walked to identify and measure the dimensions of small inner gorge slides not visible on the aerial photos that are estimated to have occurred in the last two years. From these data, a sediment delivery volume of 2,002 cubic yards was calculated on 1.8 miles of stream reach, yielding a sediment delivery index of 1,112 cubic yards per mile. An additional sediment delivery volume of 3,336 cubic yards was calculated when the sediment delivery index was extrapolated to the major USGS blue-line tributaries. Assuming 100 percent sediment delivery, the total sediment volume delivered to the Stitz Creek drainage from small inner gorge landslides not observable on air photos was 5,338 cubic yards (Appendix E). This represents a maximum of three percent of the 1997 mass wasting sediment delivery volume. In some watersheds these small inner gorge landslides can contribute significant sediment volumes within the watershed's sediment budget (Louisiana-Pacific Corp. 1998); however, due to the relatively minor contribution these slides have to the overall mass wasting sediment contribution in Stitz Creek, they were dismissed from further analysis.

Detailed Mass Wasting Analysis occurring over 30-Year Time Intervals

Total mass wasting sediment production, and minimum, maximum, and estimated sediment delivery produced by each landslide type for the time intervals 1936-1966 and 1967-1997 is presented in Table 4.

Table 4. Total mass wasting volume and sediment delivery volumes (yd^3) for 30-year time intervals.

Time Interval	Landslide Type*	Total Mass Wasting (TMW) Volume	Minimum Sediment Delivery	Maximum Sediment Delivery	Estimated Sediment Delivery
1936 to 1966	DF	197,125 (74%)	129,082 (80%)	178,363 (80%)	153,723 (80%)
	SL	58,141 (22%)	28,182 (18%)	40,809 (18%)	34,496 (18%)
	DS	10,913 (4%)	2,728 (2%)	5,456 (2%)	4,092 (2%)
	Total	266,179 (100%)	159,992 (100%) (60% of TMW)	224,627 (100%) (80% of TMW)	192,310 (100%) (72% of TMW)
1967 to 1997	DF	144,611 (43%)	95,598 (66%)	131,725 (58%)	113,662 (60%)
	SL	134,959 (41%)	43,025 (29%)	73,424 (32%)	58,225 (31%)
	DS	53,022 (16%)	10,419 (7%)	23,341 (10%)	16,680 (9%)
	Total	332,592 (100%)	147,906 (100%) (44% of TMW)	228,490 (100%) (69% of TMW)	188,567 (100%) (57% of TMW)

* DF, Debris Flow; SL, Shallow Landslide; DS, Deep-Seated Landslide.

This table indicates several facts: first, the total mass wasting (TMW) volume mobilized in the 1967-1997 time interval was greater than in the 1936-1966 time interval; second, the volume of the estimated sediment delivery was approximately the same for both time intervals; third, the percent of the total mass wasting volume delivered to watercourses during the 1967-1997 time interval (57%) was less than the percent delivered in the 1936-1966 time interval (72%); and fourth, the shallow landslide volume and sediment delivery increased from the time interval 1936-1966 to the time interval 1966-1997.

The majority of sediment delivery in both time intervals was the result of debris flows. Debris flows may begin as small features, but have the potential to incorporate large volumes of debris into the slurry by scouring channels and sideslopes. Although debris flows contributed the majority of sediment volume to watercourses for each time period, the debris flows occurring in the 1936-1966 interval represented a greater percentage of the total mass wasting volume. The total volume of material mobilized in the 1967-1997 time interval by shallow landslides was comparable to the total volume mobilized by debris flows for that interval, the sediment volume delivered by shallow landslides was significantly less than the sediment volume delivered by debris flows. This can be attributed to the fact that material derived from shallow landslides occurring on the hillslopes may settle out on the hillside or become retained in the vegetation, limiting the amount of sediment delivery to the drainage network.

Sediment Production and Delivery Rates

A sediment mobilization rate and delivery rate was assessed for the Stitz Creek watershed based on the data presented in Table 4. Sediment delivery and mobilization rates are calculated by the following equation:

Rate = cubic yards of sediment / square area of watershed / time (Table 5).

Table 5. Sediment mobilization rates (yd^3/sq.mi./yr) for each time interval.

Time Interval	Rate of Sediment Mobilization	Minimum Sediment Delivery Rate	Maximum Sediment Delivery Rate	Estimated Sediment Delivery Rate
1936 – 1966	2,218	1,333	1,872	1,603
1967 – 1997	2,714	1,270	1,942	1,606

The mass wasting sediment mobilization rate was greater for the time interval 1967-1997 than the time interval 1936-1966, although the estimated sediment delivery rate for each time interval was similar. Three factors that can influence these rates are magnitude and frequency of large storms, occurrence of rare, large volume mass wasting features, and the land management activities occurring in the watershed within the time interval. While the time intervals have similar rates, different factors have occurred in the watershed to influence those rates. The large magnitude storm of 1964 produced two exceptionally large debris flows (Slides #53 and #54) that resulted in high sediment mobilization and delivery rates for the 1936-1966 time interval. The latter time interval incorporates a period of timber harvesting, as well as a several large magnitude rainfall events in 1995 and 1997.

Comparison of 1964 and 1997 Storm-Generated Mass Wasting

For each photo year, the storm generated landslides were identified by their fresh scars, and the landslides identified as being approximately five to 30 years old were dropped from the storm analysis. The distribution of each type of landslide produced by the 1964 and 1997 storms is presented in Table 6. The locations of individual landslides generated by these storms are in Figures 6 and 7, respectively.

Table 6. Landslide type and distribution resulting from the 1964 and 1997 storm events.

Storm Event	Type of Slide	Number of Slides	Percent of Total
1964	Debris Flow (DF)	17	19
	Shallow Landslide (SL)	69	77
	Deep-seated Landslide (DS)	1	1
	Rock Fall (RF)	3	3
	Total	90	100
1997	Debris Flow (DF)	15	15
	Shallow Landslide (SL)	75	77
	Deep-seated Landslide (DS)	3	3
	Rock Fall (RF)	4	4
	Total	97	100

The total number of mass wasting features associated with the 1964 storm (90) was remarkably similar to the number of features of the 1997 storm (97). Shallow landslides represented 77 percent of the total mass wasting features produced by each storm. Debris flows represented up to 19 percent of the features produced in the storms, while deep-seated landslides and rock falls each represented less than five percent of the storm related mass wasting. The distribution of landslide types generated by the two storms closely resembled the distribution found in the time interval analysis.

The total volume of sediment produced by each type of landslide in each storm as well as the minimum, maximum, and estimated sediment delivery are presented in Table 7.

Table 7. Total mass wasting volume and sediment delivery volumes (yd^3) for each storm event.

Storm Event	Landslide Type	Total Mass Wasting Volume (TMW)	Minimum Sediment Delivery	Maximum Sediment Delivery	Estimated Sediment Delivery
1964	DF	155,114 (72%)	110,146 (80%)	148,925 (78%)	129,536 (78%)
	SL	49,871 (23%)	25,411 (18%)	36,157 (19%)	30,784 (19%)
	DS	10,913 (5%)	2,728 (2%)	5,456 (3%)	4,092 (3%)
	RF	435 (0%)	1 (0%)	24 (0%)	13 (0%)
	Total	216,333 (100%)	138,286 (100%) (64% of TMW)	190,562 (100%) (88% of TMW)	164,446 (100%) (76% of TMW)
1997	DF	80,003 (55%)	56,987 (72%)	76,981 (68%)	66,984 (69%)
	SL	60,615 (42%)	20,889 (25%)	33,733 (29%)	27,311 (28%)
	DS	4,059 (3%)	2,252 (3%)	3,267 (3%)	2,760 (3%)
	RF	130 (0%)	1 (0%)	15 (0%)	15 (0%)
	Total	144,807 (100%)	80,129 (100%) (56% of TMW)	113,995 (100%) (79% of TMW)	97,070 (100%) (67% of TMW)

As in the analysis for the 30-year time intervals, debris flows were the dominant sediment producing feature and delivered the most sediment to watercourses in the analysis of individual storms. Two exceptionally large debris flows initiated in the 1964 storm (Slide #53, producing 69,403 yd^3, and Slide #54 producing 55,229 yd^3) represent 58 percent of the total sediment produced by the 1964 storm. The combined volume of these two slides approaches the volume produced by the 1997 storm. These two slides are of much greater size than the largest debris flow in the 1997 storm (Slide #4, producing 19,900 yd^3). If the two large 1964 debris flows were dropped from the analysis, the data would suggest that the smaller magnitude 1997 storm produced more mass wasting volume than the 1964 storm. However, the occurrence of these two slides, led us to conclude that the 1964 storm generated more mass wasting by volume than the 1997 storm. This illustrates how the variability of one or two large landslide volumes can influence the interpretation of mass wasting results. There were no contemporary land management activities occurring in the Stitz Creek watershed during the 1964 storm event. This shows that large intensity storms do cause large-scale landsliding and debris flows, independent of road and harvest influences.

The two storms produced approximately the same number of shallow landslides, with the 1997 storm producing a greater mass wasting volume. The volume produced by the 1997 storm may be attributed to greater accuracy in measuring slide dimensions. Slide dimensions were more accurately measured in the 1997 storm because the short time interval between the storm event and the photographs, and the open canopy created by timber harvest made the landslides more visible. Additionally, field measurements on the 1997 landslides allowed for calibration of the analysis. The 1964 storm analysis, in contrast, was conducted on photos taken approximately 1.5 years after the storm with much greater canopy closure, resulting in less accurate landslide dimension measurement. However, that the 1997 storm mobilized a greater total shallow landslide volume and delivered less volume than the 1964 storm, may also embody the 23 years of land management in the watershed. The lesser sediment delivery ratio of the 1997 shallow landslides may be the effect of the shallow slides being influenced by roads and/or harvesting, with more deposition occurring on the hillslope instead of in direct relation to the watercourses.

Road Construction and Mass Wasting Association

Construction of a road network can lead to accelerated erosion rates in a watershed (Beschta 1978, Reid and Dunne 1984). Several studies in the western Cascade Range in Oregon show that mass wasting associated with roads are 30 to more than 300 times greater than in undisturbed forests (Sidle et al. 1985). Road failures that occurred during the storms in 1955 and 1964 in numerous other watersheds in the region did not occur in the Stitz Creek watershed because the watershed had not yet been re-entered from its historic logging period, and therefore had no associated road network. As the road network in Stitz Creek expanded during in the 1980's, storms capable of triggering landslides were mostly absent. Only the 1997 aerial photographs captured the immediate effects of a regional landslide-triggering storm on road related landslides. For this analysis, it was assumed that any slide that initiated along a road or identifiable skid trail was produced directly or indirectly by that feature.

Slide #4 (Figure 7) was the largest debris flow by volume that initiated during the 1997 New Year's storm. The landslide scarp evacuated a section of road H03-0642, torrented down its channel to the mainstem of Stitz Creek, and delivered 75-100% of its material to the watercourse. The sandstone bedrock at the scarp has slope-parallel fractures and easily crumbles when touched. The stand in which the slide occurred had been selectively harvested in 1993, and the 1997 aerial photos show a full canopy of mature trees. It is unlikely that significant loss of root strength of the stand occurred as a result of the harvest, as a mature second growth redwood stand existed at the site. An additional field analysis was undertaken to more accurately identify the cause of the slide and estimate its volume.

The field investigation of Slide #4 revealed two gullies in the road at the scarp of the slide. The first gully originated on the road northeast of the slide and had undermined the culvert at the outer edge of the road to a depth of five feet. This gully appeared to have supplied water to the base of the slide. The other gully originated where the culvert was plugged near the back edge of the road and diverted water directly onto the crown of the slide. Because the road gullies diverted water to the base and top of the slide, we concluded that Slide #4 was influenced by the road. However we recognize that, in conjunction with the road runoff, a variety of natural causes also contributed to slope failure. A summary of field observations compiled by John Coyle, Certified Engineering Geologist, is in Appendix F.

Along the entire torrent track of Slide #4 it was noted that very little scour of the channel occurred and some of the material was deposited along the channel in debris flow levee bars. The material deposited along the channel was included in the delivery volume because it can be remobilized by high flows. Detailed field measurements of the dimensions of Slide #4 were used to calculate a sediment delivery volume of 19,900 yd^3 (Appendix G). This volume total was included in the road related category. The number of road related and non-road related landslides and their associated sediment delivery volumes are presented in Table 8.

Table 8. Road related vs. non-road related landslides that occurred in the 1997 storm.

Road Related	No. of Slides	Percent of Total	Minimum Sediment Delivery (yd^3)	Maximum Sediment Delivery (yd^3)	Estimated Sediment Delivery (yd^3)
Road Related	25	26%	52,842 (66%)	74,348 (65%)	63,595 (66%)
Not Associated	72	74%	27,287 (34%)	39,647 (35%)	33,467 (34%)
Total	97	100%	80,129 (100%)	113,995 (100%)	97,062 (100%)

Landslides assumed to be road related represent 26 percent of the total number of landslides, and 66 percent of the total estimated sediment volume delivered by the 1997 storm. Non-road related landslides represented 74 percent of the total number of landslides and only 34 percent of the estimated sediment delivery to Stitz Creek. These results are consistent with a similar analysis completed for Elk River, approximately 15 miles north of Stitz Creek (PWA 1998), which identified 24 percent of the landslides as road related and 76 percent as "hillslope landslides."

It is apparent from this analysis that the lower number of road related landslides contribute far more sediment volume than the greater number of hillslope landslides. This illustrates the fact that although road related landslides are less frequent than hillslope related slides, they tend to be responsible for a greater percentage of sediment delivery to watercourses. Therefore, when an effort is made to reduce sediment to watercourses, minimizing potential sediment volume from identified road sites will have a greater return in sediment reduction efforts.

Timber Harvest and Mass Wasting Association

Research has indicated that there tends to be an increase in landslide incidence five to 10 years following harvesting due to the decay of tree root systems (O'Loughlin and Ziemer 1982, Sidle et al. 1984). The effect of clearcutting on mass wasting processes has also been documented (Rood 1984, Ice 1985, Howes 1987). The trees in the Stitz Creek watershed are predominately redwoods, which sprout from their stumps rapidly after harvest. Root strength may be retained as the effect of the mother tree root decay is compensated for by the root development of the sprouts. Because of this "stump sprouting" the effect of loss of root strength on landslide occurrence in Stitz Creek may be less than in drainages with other vegetation types.

The effect of timber harvest on landslides was evaluated for all landslides not related to roads. The estimated sediment delivery volume from landslides not related to roads in Stitz Creek was 33,467 cubic yards, or 34 percent of the total estimated sediment delivery from the 1997 storm (from Table 7). The number of landslides and associated sediment volume that occurred in harvested areas as a function of time since harvest, and in areas not harvested, are presented in Table 9.

Table 9. Harvest age and sediment delivery volumes (yd^3) for the 1997 non-road related landslides.

Harvest History	Acres	Percent of landbase	No. of landslides	Minimum Sediment Delivery	Maximum Sediment Delivery	Estimated Sediment Delivery
Greater than 10 years ago (1974 – 1987)	1,249	48	50	23,289 (85%)	33,309 (84%)	28,229 (85%)
Less than 10 years ago (1988 – 1997)	628	24	13	1,845 (7%)	3,020 (8%)	2,433 (7%)
Not Harvested	710	27	10	2,153 (8%)	3,318 (8%)	2,736 (8%)
Total				27,287	39,647	33,467

Table 9 indicates that majority of the sediment volume from hillside landslides occurred on the landbase harvested more than 10 years ago and that more landslides have occurred in areas with timber harvest operations than in areas without harvest operations.

This analysis ignores several factors that could contribute to landslide incidence and size. The natural physiographic features of landscape (particularly slope), type of silviculture and yarding, revegetation characteristics, and storm history could all affect landslide differences not related to time since harvest. The analysis also encompasses a relatively small sample size, and individual large landslides may have skewed the results. One factor that may have contributed to the observed pattern is that areas harvested more than 10 years ago in Stitz Creek included a large proportion of the debris slide amphitheater area in the watershed; these areas are naturally prone to sliding.

Given the numerous variables affecting landslide occurrence and the limited data collected in the Stitz Creek watershed, results of this analysis may not adequately identify the effect of harvesting on mass wasting. However, in general terms, landslides associated with roads had a greater sediment contribution in the watershed (66 percent of the estimated sediment delivery), than non-road related landslides.

Road Inventory

A road inventory was conducted to identify treatable sites of potential future erosion for the existing roads in Stitz Creek. Roads that were not maintained and were not provided with no-maintenance erosion control measures associated with modern road decommissioning were termed abandoned. Road decommissioning measures include removal of watercourse crossing fills, removal of unstable road and landing fills, and providing for erosion-resistant drainage.

Approximately 16 miles of the nearly 20 miles of road construction in the Stitz Creek watershed were inventoried (Figure 8). All these roads were accessed from the south on roads H03 and H11. Two miles of historical road in the northwest corner of the drainage, accessed by crossing the Van Duzen River during low water conditions, were inaccessible for this inventory. During the inventory of the roads, several of the road reaches that were abandoned approximately a decade ago were not inventoried. These reaches were the terminal 20 percent of road H03.1606 (approximately 3,000 feet) and the abandoned portion of road H11.33 beyond the first 2,000 feet. These sections of road would require major rebuilds to access; either the road prism is entirely gone and/or the future sediment savings were too low to ensure a cost-effective treatment considering the rebuild needed to access the area. However, if these sections of road were to be rebuilt in the future, a subsequent erosion investigation would be warranted.

The primary roads accessing the drainage (H03 and H11) are generally located along the ridges and high in the drainage. They are typically surfaced with approximately 8 to 12 inches of rock and/or have had deep waterbars installed. The spur roads branching off of these roads have had varying degrees of maintenance, with some road reaches being abandoned over a decade ago. Figure 8 shows the current 1998 road network in Stitz Creek, with road and site labels. Several sections of the road, particularly those located in identified debris slide amphitheaters were completely obliterated by slides, isolating the more stable segments of the road prism beyond.

Recommendations for Roads in Stitz Creek

The erosion problems identified in the Stitz Creek watershed involved roads on slopes of greater than 50 percent, and insufficient drainage of the roads. A general overview of needed improvements follows.

Often a timber harvesting plan (THP) presents an opportunity to upgrade or decommission roads in an area. Road construction and reconstruction for THPs must comply with the California Forest Practice Rules (FPRs). PALCO has incorporated additional requirements in their *Truck Road and Landing Specifications and Construction Standards*, many of which were adopted from the *Handbook for Forest and Ranch Roads* (Weaver and Hagans 1994). Overall, the FPRs state the minimum standards required for road construction and reconstruction, and the *Handbook for Forest and Ranch Roads* provides more descriptive design criteria recommendations to achieve those standards. New road construction will occur in conformance to specified construction standards, which address erosion concerns and thereby minimize future sediment production potential.

Improvement of Existing Roads

In Wildcat geology, the road surface is easily rutted by vehicular traffic, especially on roads that are not rocked. In many cases, road outsloping would prove ineffective in this geology when the surface becomes rutted. Road improvements in the Stitz Creek watershed should minimize the surface water on roads by outsloping where appropriate, and maintaining inboard ditches and installing additional ditch relief culverts. Frequent drainage of the road system by rolling dips and relief drains is an important component of the strategy to minimize road surface water accumulation. Ditch relief culverts may need spacing as frequent as the waterbar spacing requirements, particularly on steep slopes. All headwall swales should have at least one drainage structure to minimize and drain the concentration of water that naturally occurs in those areas. Culvert sizing for at least a 50-year flood event appears appropriate. Armoring the outlets of culverts may be recommended to lessen the erosion potential that occurs if the culvert is overtopped.

Maintenance Recommendations

Wildcat geology is erosive and waterbars should be deep and spaced at a high frequency. Waterbars should be inspected and repaired as needed after storm events capable of triggering mass wasting or replaced each fall if the road has had vehicular traffic. Closed roads should exclude vehicular traffic, except possibly for quadrunner/ ATV access. Road maintenance in Stitz Creek should minimize outboard berms, keep inboard ditches clear, endhaul fill material rather than incorporating it into the road prism, and eliminate sidecasting.

Priority Sites from Road Inventory

High Priority

Table 10. High Priority road maintenance sites (Site locations in Figure 9).

Hydrologic road decommissioning	Estimated Erosion Potential (yd³)
H11.67 (0.3 miles)	200
H11.33 (0.5 miles)	200
H11 (east) beyond H11.590 – X5 to terminal end (0.7 miles)	670
Individual erosion sites	
H11 – M1	1,800
H11.5974(W) – L3	500
H03.1606 – X4 and X5	445

3815

Road upgrading / preventative erosion measures	
H11	1,000+

Hydrologic road decommissioning: H11.67 is a spur road that has extensive diversions causing water concentration and fill failures. Hydrologically decommissioning road H11.33 would include removal of perched fill at the end landing as well as correcting the drainage problems exacerbated by an earthflow feature along the road. The end of road H11 (eastern end) is not actively maintained and the drainage crossings are eroding the fill prism, particularly crossings 1, 2, and 5.

Individual erosion sites: H11 – M1 is a site of deep-seated land movement and the material of the road and downslope of the road is at risk of large scale failure. As the feature is deep-seated, it is unlikely that all the potential future erosion can be eliminated from the site. Landing L3 on H11.5974(W) is actively failing, and concentrated water diverted from the road system feeds the site. H03.1606 – X4 and X5 are stream crossings that have failed or have no drainage structures and are eroding the road fill. However, to access these sites a temporary crossing would have to be installed in the channel that was "blown out" by a major debris torrent in the 1997 storm event. When these sites are repaired, there are several moderate priority sites further down the road that could also be treated (see below).

Road upgrading: H11 is the primary road accessing the watershed towards the east. It is well rocked, but needs inboard ditch clearing and additional ditch relief culverts. A high frequency spacing of relief culverts is necessary in this geology. Two headwall swales are chronic problem sites along this road and need additional drainage, and relief drains installed.

Moderate Priority

Table 11. Moderate priority sites for road maintenance (Site locations in Figure 10).

Hydrologic road decommissioning	Estimated Erosion Potential (yd³)
H11.55 (0.2 miles)	100
H11.5974 (W), first 800'	75
Individual erosion sites	
H11 (main) – X4, 6, 9, 11, 15, 18, 19, 20	420
H11.59 – S1	45
H11.8225 – X1	200
H03.1606 – X2, 3, 3a, M1	500
H03.06 – L1, X1	35
Road upgrading / Preventative erosion measures	
H03.06	300+

Hydrologic road decommissioning: H11.55 is a short spur road with perched fill at the end landing and outboard edge of the road. H11.5974(W) needs re-constructed waterbars/drainage and is the approach to a high priority site, L3.

Individual erosion sites: The crossings on H11 need clearing, elimination of diversion potential, upgrading, and/or additional ditch relief drains. H11.59 – S1 contains perched fill along the outboard edge of the road prism in an area prone to failures. H03.1606 X2, 3, 3a, and M1 are sites of fill susceptible to fluvial or mass wasting erosion (attending to both the high and moderate sites along this road would result in hydrologic decommissioning of this road reach). H03.06 – L1 has perched fill, and X1 is a headwall swale which needs relief drainage.

Road upgrading: Road H03.06 climbs a ridgeline, has steep road grades, and is rocked for the initial mile. However, the road needs upgrading with additional rock and improved waterbars and/or relief drains. Currently several of the waterbars have been eroded and need re-installation.

Low Priority:

Several low priority sites are worthy of mention in this section. These sites would become a higher priority only if work was to be completed in the area in which the roads to these sites were to be rebuilt. By themselves, the access limitation and minor future sediment delivery are not significant enough to warrant a higher rating.

Low priority sites: H03.0642 – X1. This crossing is on the opposite side of the debris torrent slide. If access were achieved, then this crossing should be excavated or upgraded because the culvert is plugged and there is also a road diversion feeding the erosion of the fill. The landing located at the end of H11.3317 has perched fill remaining, but would require a significant road rebuild to access. The long abandoned portion of H11.5974(W) has minor sediment potential existing at the crossings along the road. If this road were to be re-opened, crossing improvements would be required.

CONCLUSIONS AND MANAGEMENT RECOMENDATIONS

Mass Wasting Conclusions

Mass wasting naturally occurs in the Stitz Creek watershed due to the steep, uplifted terrain and the weathered, inherently weak structure of the bedrock. Shallow landslides represented 74 percent of the identified features. The mudstone dominated Rio Dell member of the Wildcat Formation was particularly susceptible to shallow landsliding. Shallow landslide features identified as debris flows produced the majority of the sediment volume in the watershed. The landslides typically initiated on steep slopes, most being associated with debris slide amphitheaters, inner gorges, and mid slope areas. Several deep-seated features were identified in Stitz Creek, but sediment production from these features was significantly less than the contribution from shallow landslides.

Higher numbers of landslides were observed in the 1966 and 1997 air photos compared to other photo years, which was attributed to the large storms of 1964 and 1997. The total mass wasting volume was higher in the time interval 1967-1997 than the volume determined for the 1936-1966 time interval. However sediment deliveries for the two time intervals are similar. In both the photo years, large debris flow features were the predominate source of sediment in our analysis of the mass wasting volume totals. From an analysis of the landslides generated by the 1997 storm event, 26 percent of the landslides were associated directly or indirectly to roads or skid trails and delivered up to 66 percent of the total sediment volume. Harvested areas, particularly those areas harvested over 10 years ago, tended to be associated with an increased incidence of landslides, although other contributing factors such as slope, geology, and location were not controlled for, and the variability of that data set was high.

Interim Aquatic Strategy

The Interim Aquatic Strategy (Appendix H) targets two of the most significant components of sediment yield in the watershed: 1) road and harvest activities on steep slopes, and 2) stream side buffers. As identified in this assessment, shallow landslides have the greatest occurrence on steep slopes, inner gorges, and midslope areas. Under the *Mass Wasting Avoidance Strategy*, a geologist's report and recommendations are required prior to harvesting or road construction in inner gorges, headwall swales, and unstable areas. Under the *Interim Aquatic Strategy*, restricted harvest requirements are set along the watercourses, which add protection to inner gorge slopes and headwalls, and create sediment buffers, which limit sediment delivery. In addition, under the *Interim Aquatic Strategy* new roads are constructed to a higher standard, and a goal of at least 500 miles per decade of restoration and storm-proofing of existing road is targeted.

Erosion Control and Sediment Reduction

Approximately 1.8 miles of road have high or moderate priority for hydrologic decommissioning. Twenty individual crossings, landings, and/or fill sites were identified as having a high or moderate priority need for erosion control work (fill excavation and/or elimination of diversion potential). General road upgrades, primarily the installation of additional relief culverts, are also needed on the two main system roads. Some sites may require a Certified Engineering Geologist (CEG) for final treatment prescriptions.

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Appendix A

Figures

Figure 1. Location of Stitz Creek Watershed, Humboldt Co., CA

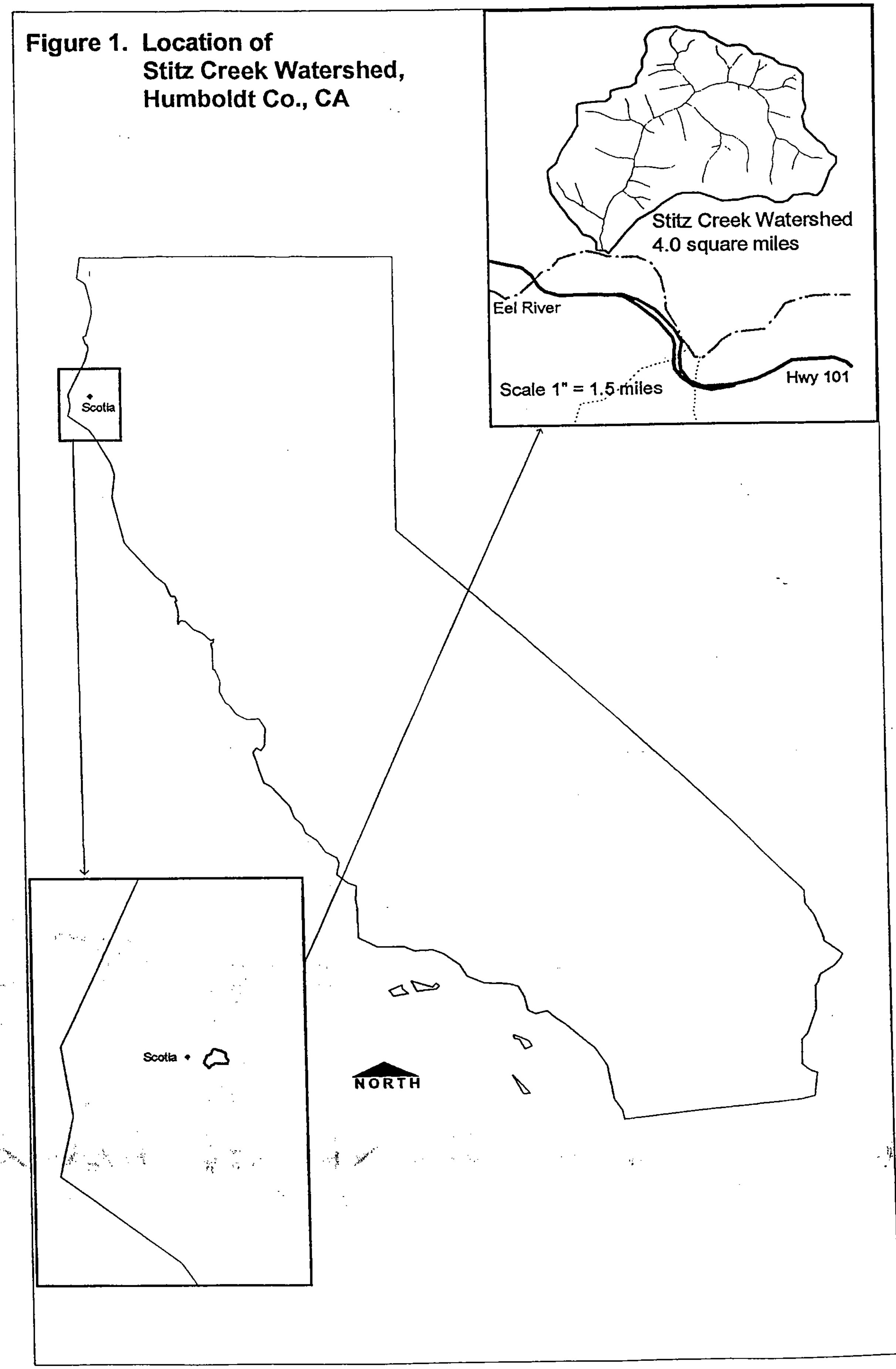


Figure 2. Stitz Creek Geologic Contact and Geomorphic Features Map

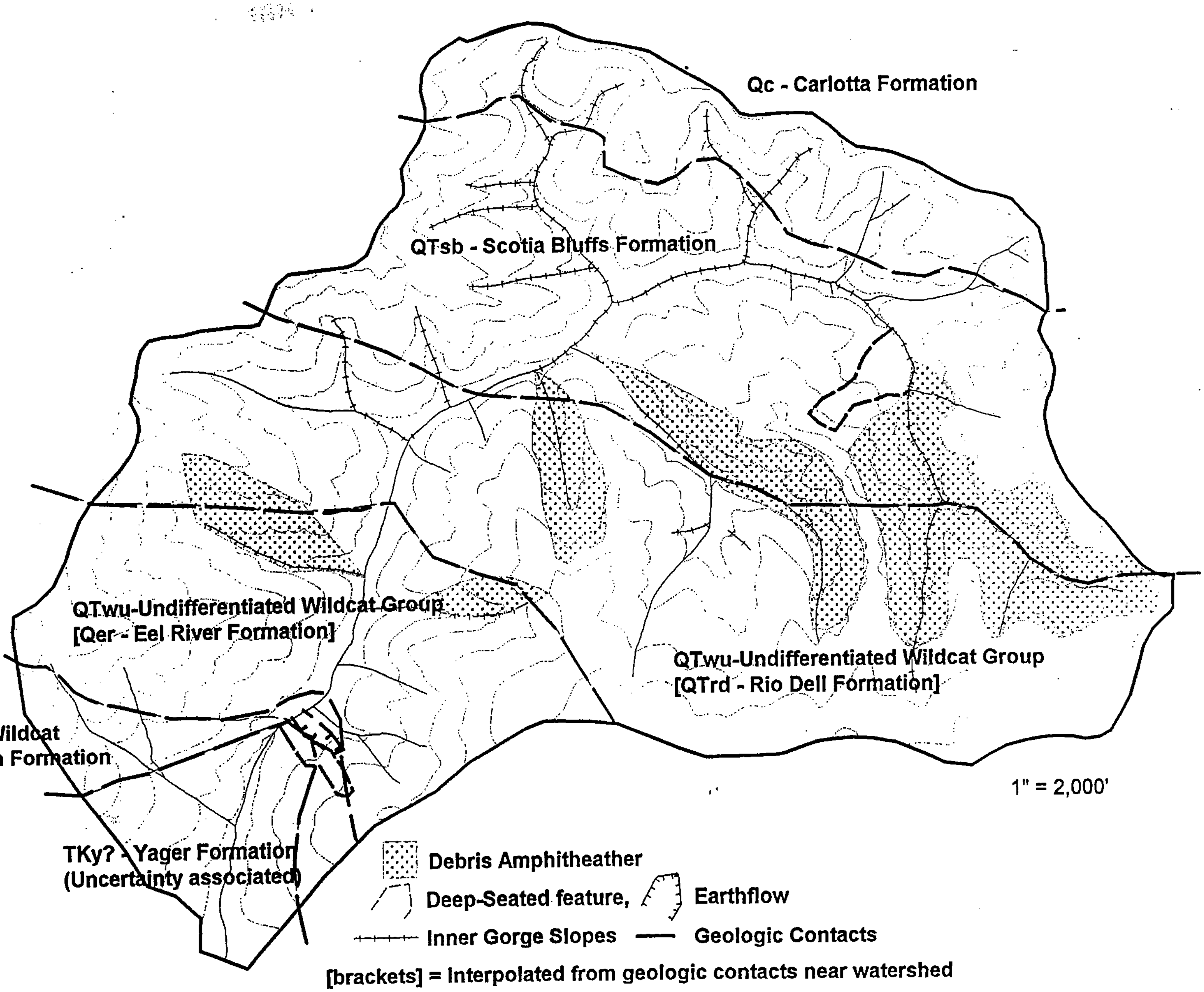


Figure 3. Land Use History from 1974 and 1981 aerial photographs

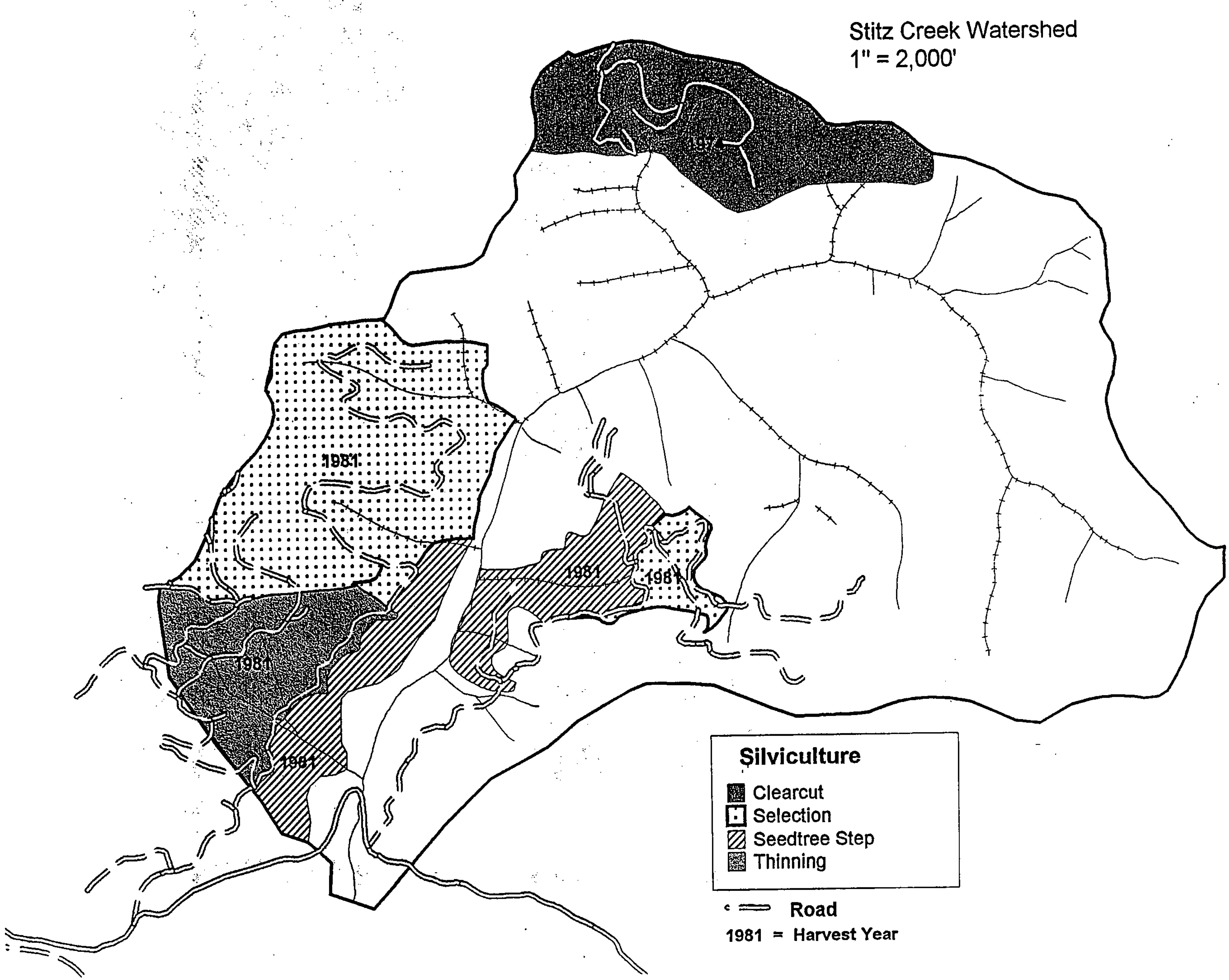
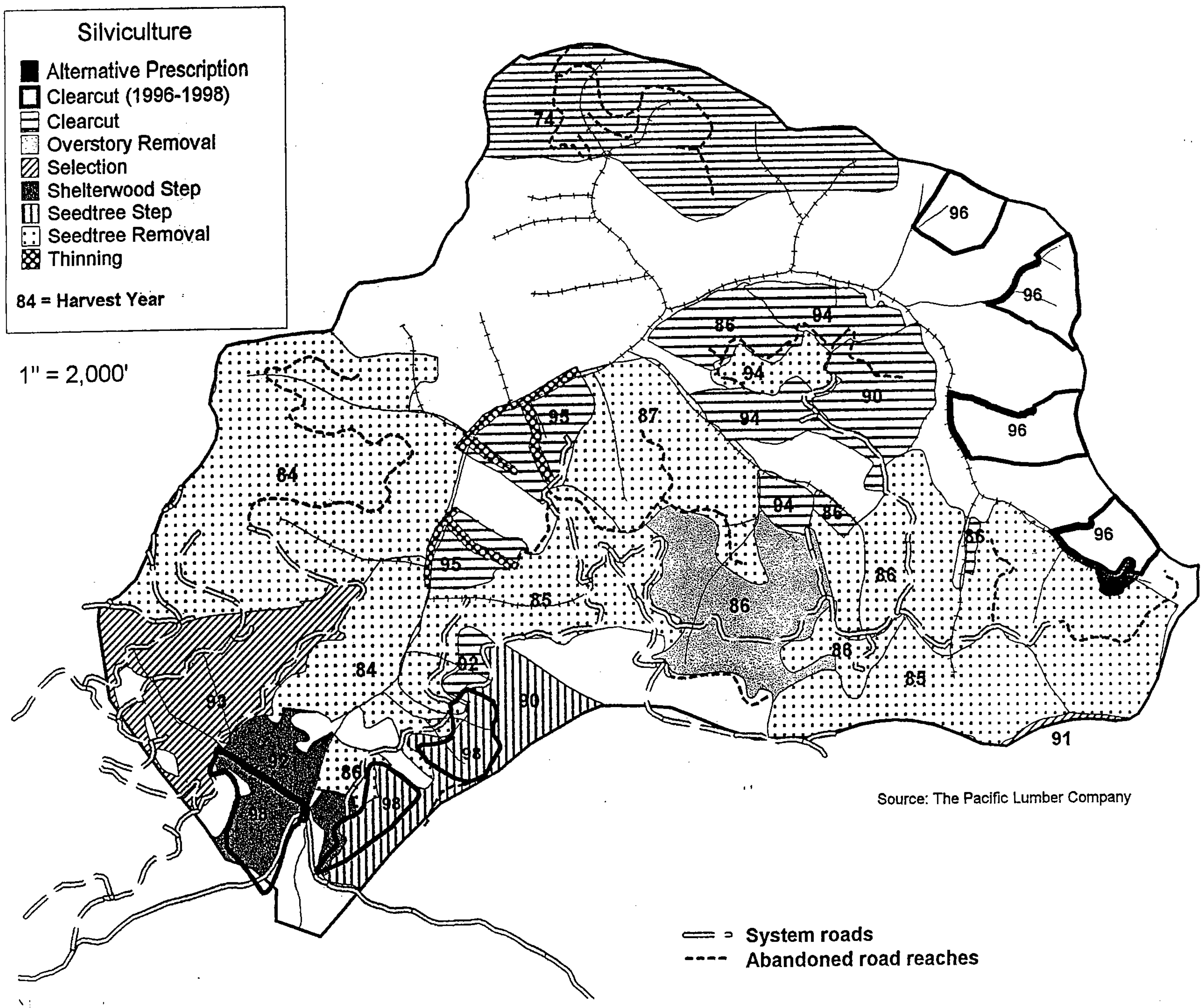


Figure 4. Land-Use History in Stitz Creek Watershed



Source: The Pacific Lumber Company

Figure 5. Locations of all landslides identified on the 1966 and 1997 photos

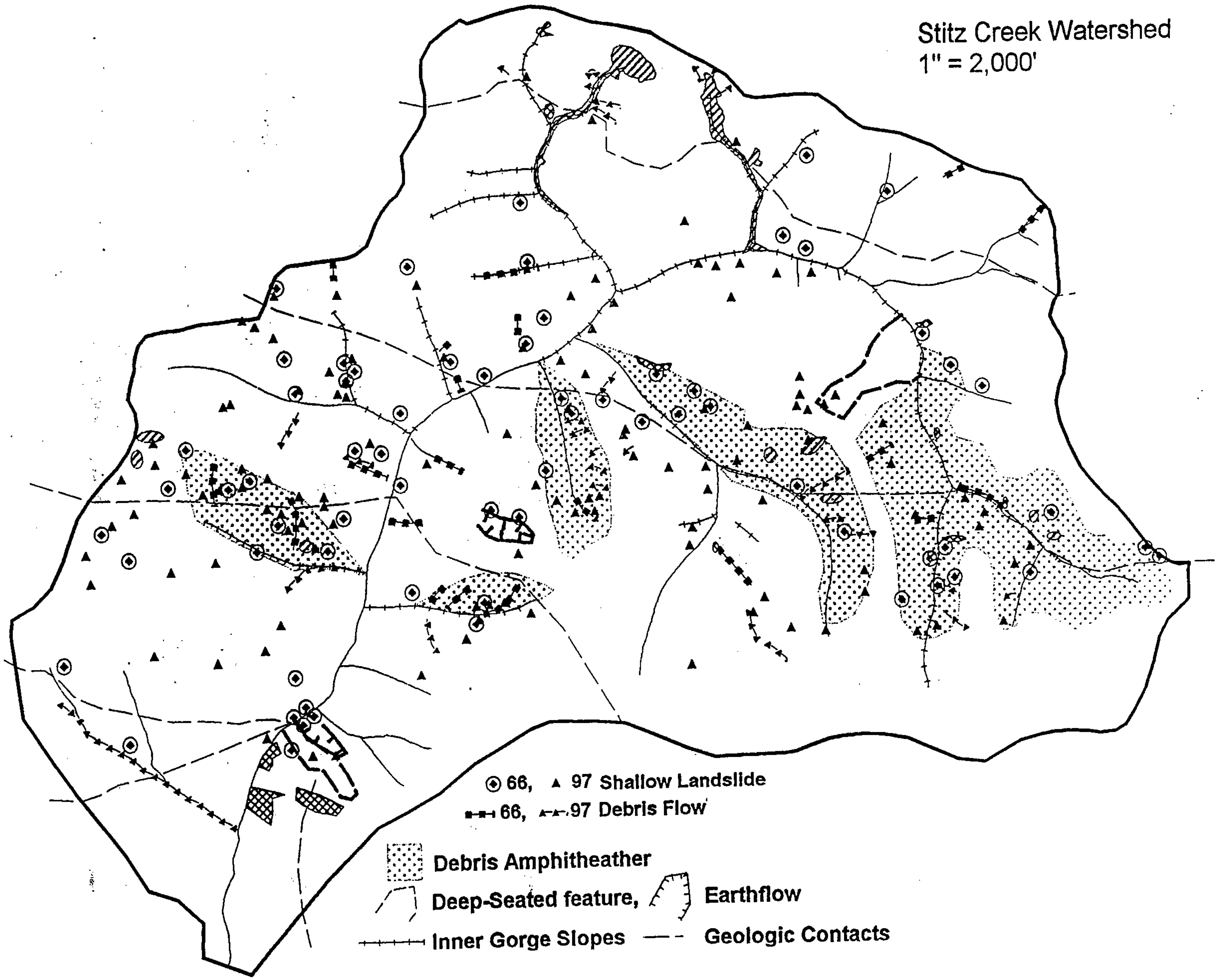


Figure 6. Locations of landslides generated by the 1964 storm event.

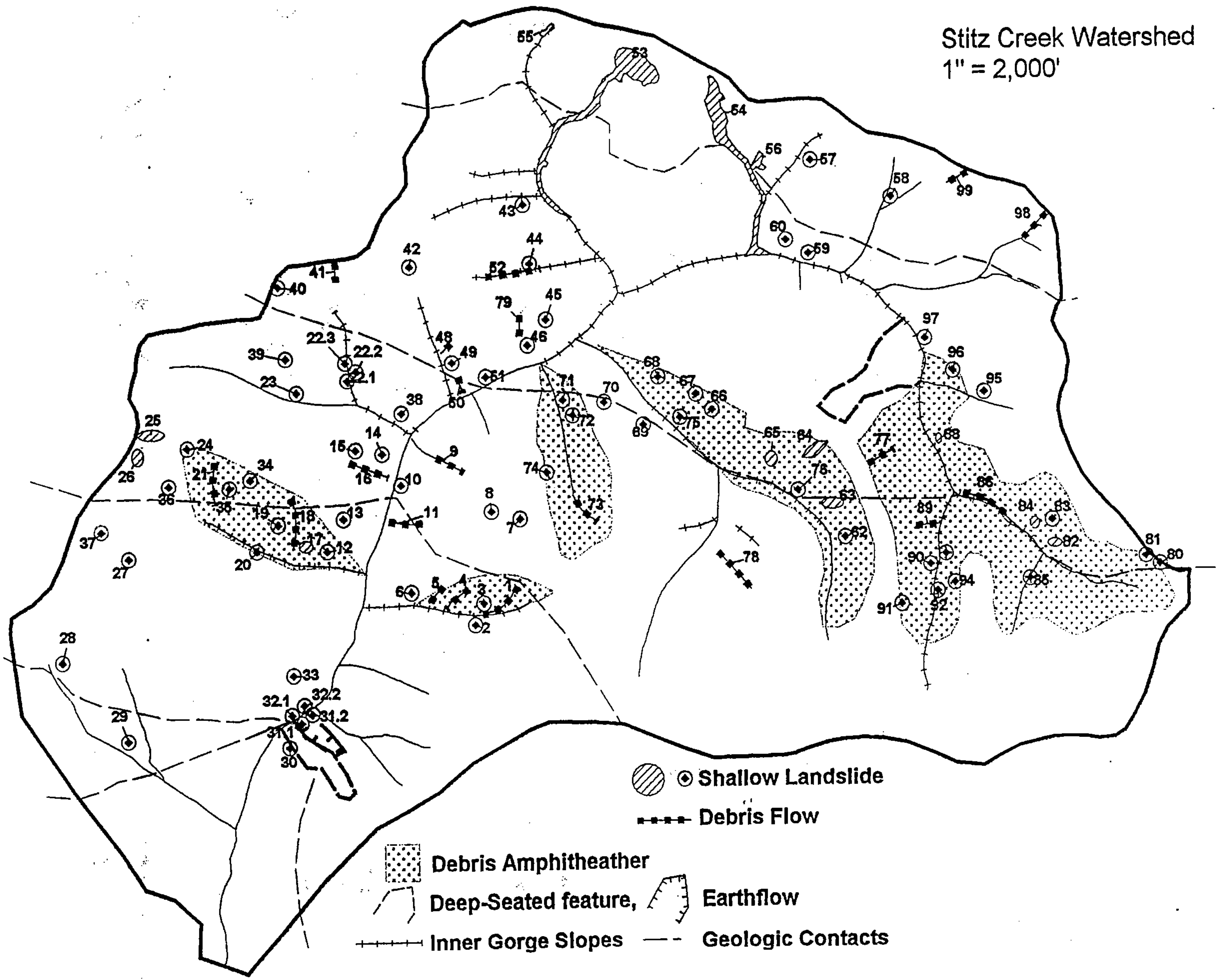


Figure 7. Locations of landslides generated by the 1997 storm event

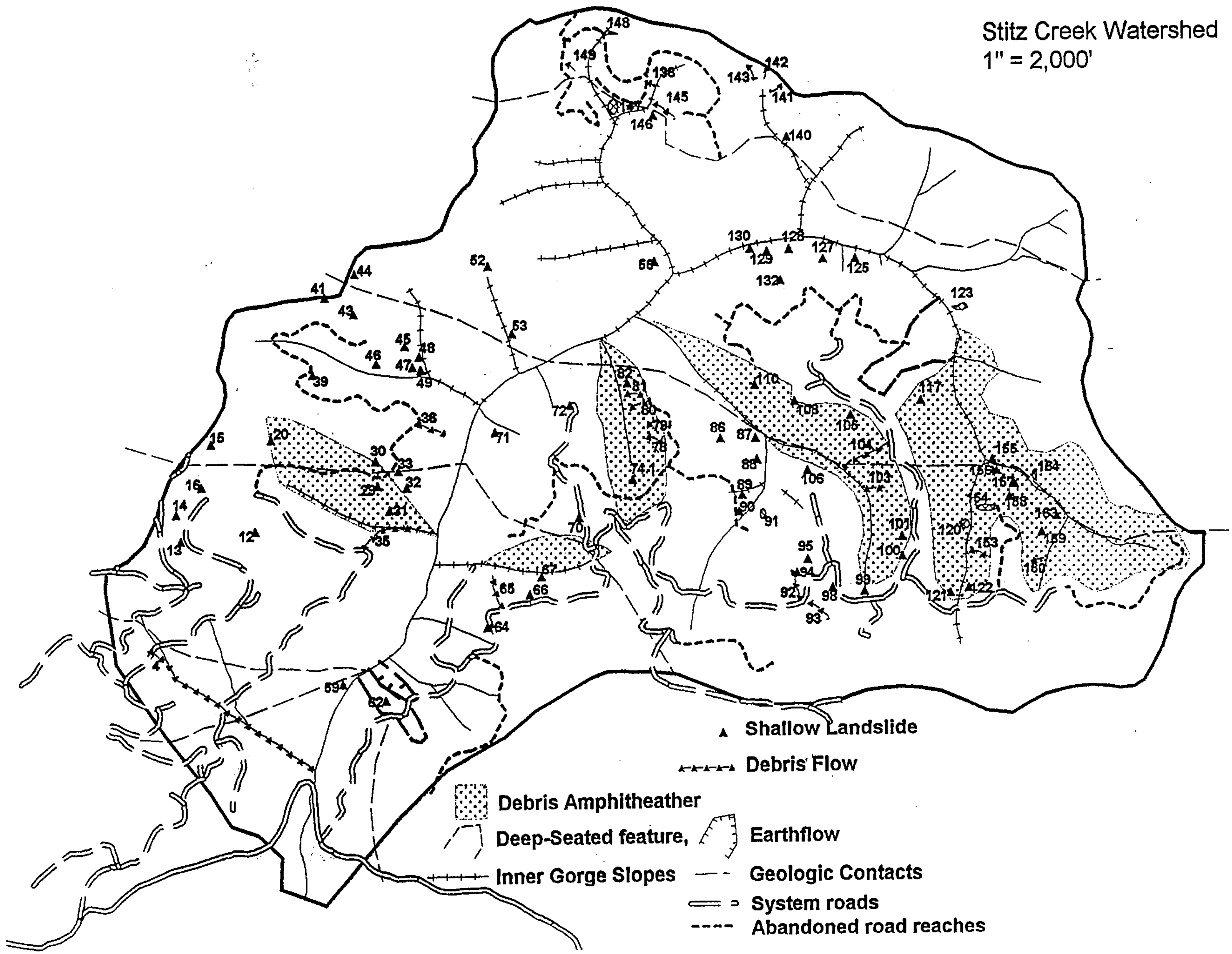


Figure 8. Road network in 1998.

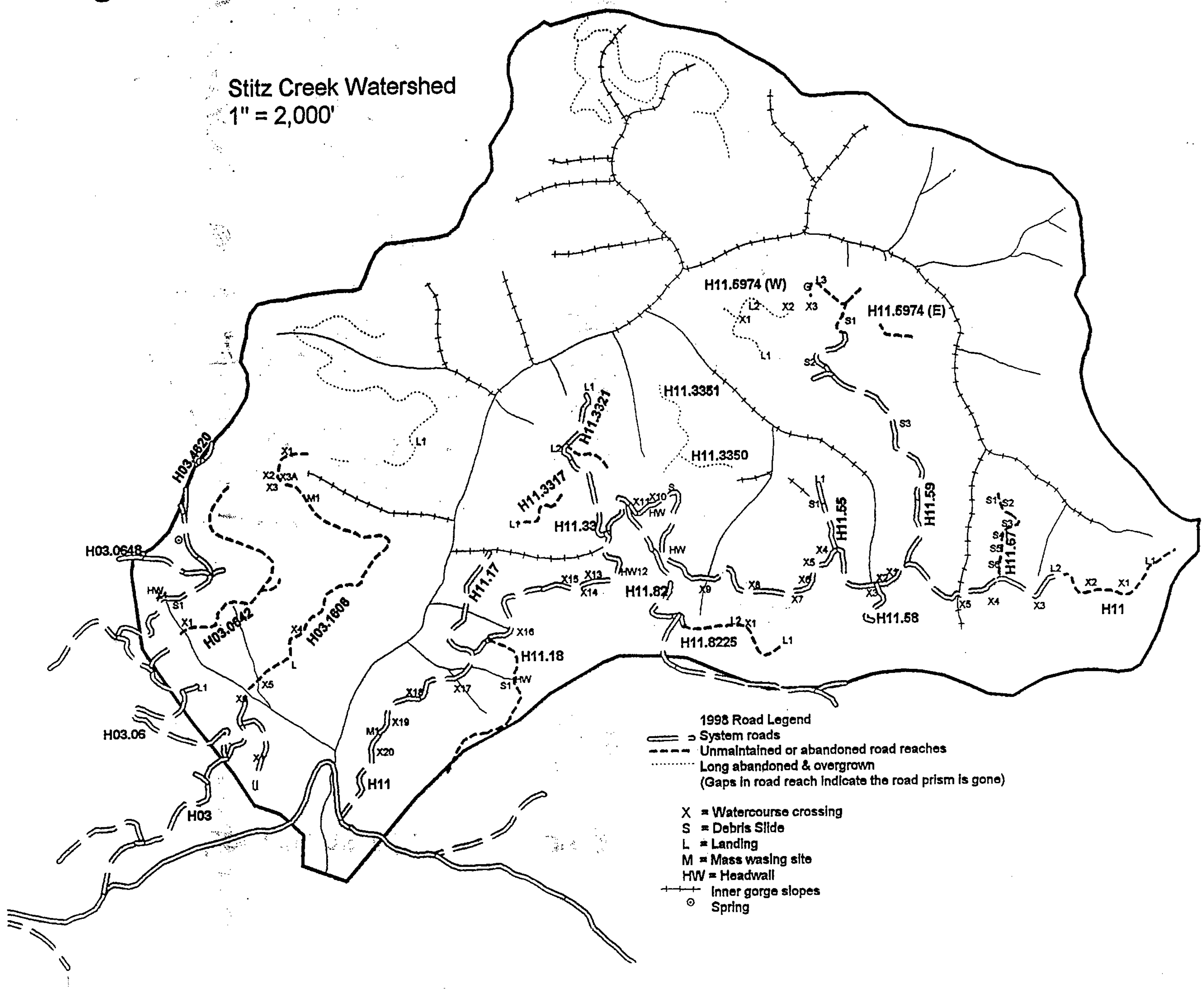


Figure 9. High priority sites identified in Stitz Creek road inventory

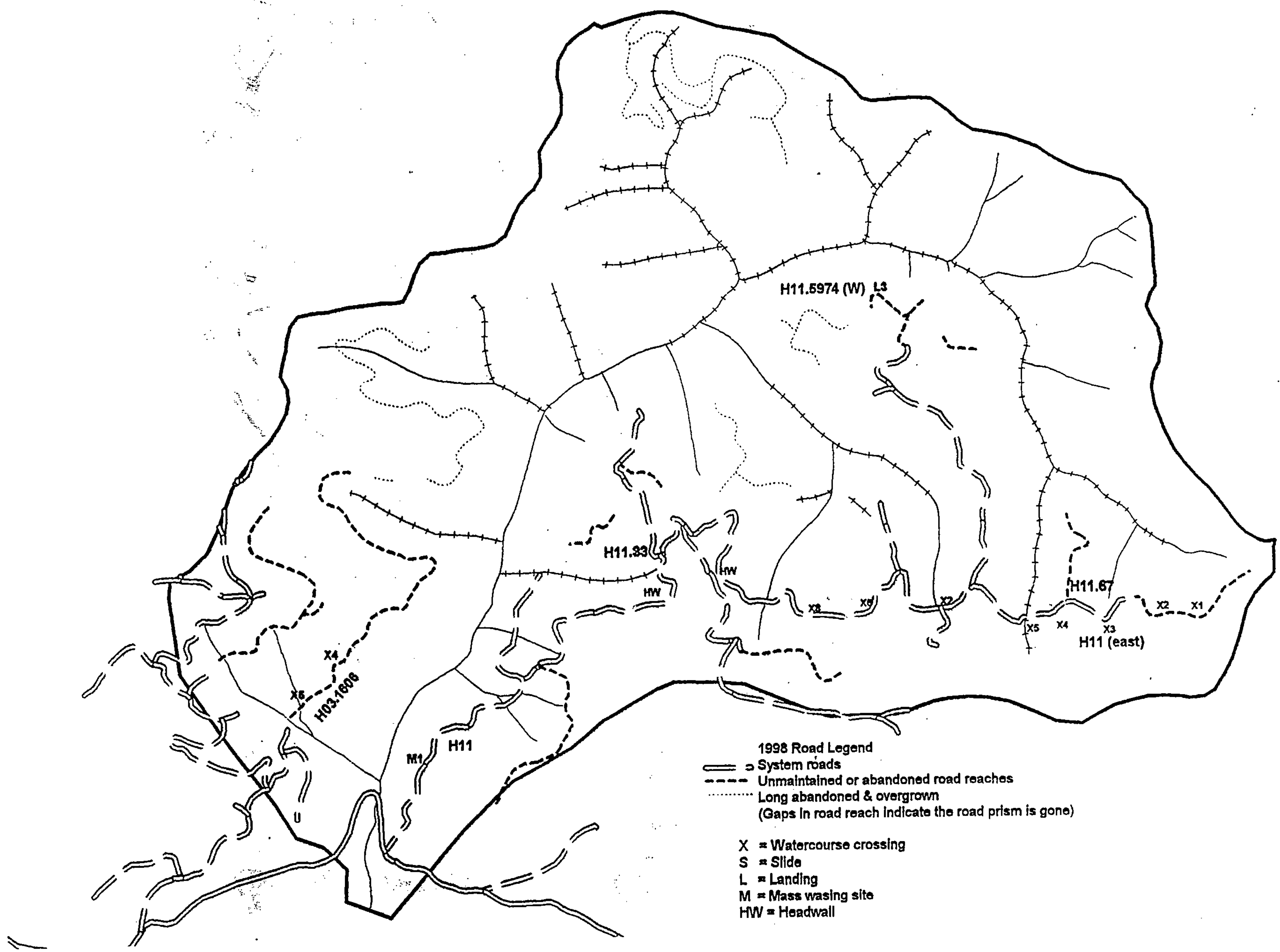
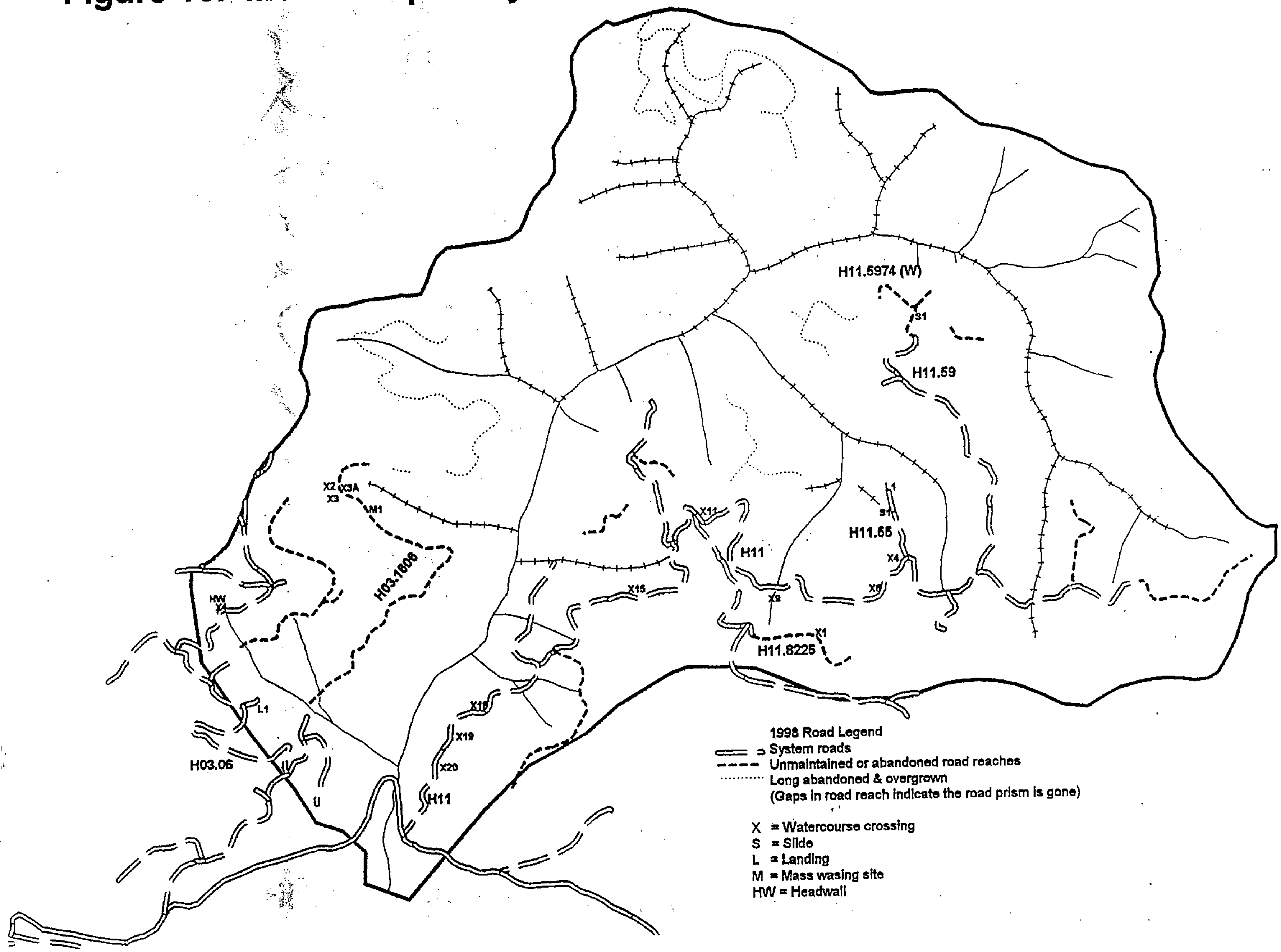


Figure 10. Moderate priority sites identified in Stitz Creek road inventory



Appendix B

Bull Creek Annual Maximum Discharges 1961-1995 and Bridgeville and Scotia Rainfall Data

US GEOLOGICAL SURVEY PEAK FLOW DATA
Peak flow data were retrieved from the National Water Data Storage and Retrieval System (WATSTORE).
Station name : Bull C Nr Weott Ca Station number: 11476600
drainage area (square miles).................. 28.1
base discharge (cubic ft/sec)................. 1700

Water Years Retrieved 1961-1995

Water Year	Date	Discharge (cfs)
1965	22-Dec-64	6520
1995	9-Jan-95	6400
1983	16-Dec-82	5880
1974	16-Jan-74	5830
1966	4-Jan-66	5000
1967	5-Dec-66	4800
1986	17-Feb-86	4780
1970	26-Jan-70	4280
1978	14-Dec-77	4260
1963	31-Jan-63	4120
1972	22-Jan-72	4000
1982	16-Nov-81	3840
1969	24-Dec-68	3550
1985	12-Nov-84	3500
1961	10-Feb-61	3400
1993	20-Jan-93	3300
1975	18-Mar-75	3290
1971	3-Dec-70	2970
1984	10-Nov-83	2810
1968	14-Jan-68	2710
1980	14-Jan-80	2540
1988	6-Dec-87	2310
1991	4-Mar-91	2040
1964	20-Jan-64	1930
1981	27-Jan-81	1770
1976	26-Feb-76	1590
1987	5-Mar-87	1460
1962	9-Feb-62	1380
1973	16-Jan-73	1370
1989	22-Nov-88	1150
1994	23-Jan-94	1110
1979	11-Jan-79	878
1990	8-Jan-90	806
1992	16-Feb-92	635
1977	19-Sep-77	173

BRIDGEVILLE *(BGV)*

Elevation: 646' · VAN DUZEN R basin · Operator: CA Dept of Water Resources

INCREMENTAL PRECIP (6524)

12/23/1996 00:00	0.08 inches
12/24/1996 00:00	0.00 inches
12/25/1996 00:00	0.28 inches
12/26/1996 00:00	1.16 inches
12/27/1996 00:00	0.88 inches
12/28/1996 00:00	0.52 inches
12/29/1996 00:00	3.04 inches
12/30/1996 00:00	3.80 inches
12/31/1996 00:00	3.76 inches
01/01/1997 00:00	1.96 inches
01/02/1997 00:00	1.24 inches
01/03/1997 00:00	0.16 inches
01/04/1997 00:00	0.00 inches
01/05/1997 00:00	0.00 inches

These data have not been reviewed for accuracy.

Highest Monthly Rainfall Totals at Scotia

Raw html Data		Date	Inches	2 month total over the new year		
01/01/1995	26.41 inches	1995	26.41	(12/01/1994	6.32 inches)	32.73
12/01/1955	22.88 inches	1955	22.88	(01/01/1956	14.43 inches)	37.31
12/01/1996	22.58 inches	1996	22.58	(01/01/1997	12.90 inches)	35.48
02/01/1958	21.54 inches	1958	21.54			
11/01/1973	21.53 inches	1973	21.53			
01/01/1959	19.75 inches	1959	19.75			
02/01/1938	19.39 inches	1938	19.39			
12/01/1941	18.94 inches	1941	18.94			
11/01/1984	18.70 inches	1984	18.70			
12/01/1952	18.66 inches	1952	18.66			
11/01/1926	18.65 inches	1926	18.65			
12/01/1964	18.37 inches	1964	18.37	(01/01/1965	9.50 inches)	27.87
12/01/1945	18.31 inches	1945	18.31			
12/01/1987	18.02 inches	1987	18.02			
12/01/1968	17.37 inches	1968	17.37			
01/01/1970	17.32 inches	1970	17.32			
12/01/1983	17.31 inches	1983	17.31			
01/01/1978	17.20 inches	1978	17.20			
12/01/1940	17.11 inches	1940	17.11			
03/01/1938	16.54 inches	1938	16.54			
01/01/1969	16.19 inches	1969	16.19			
02/01/1986	16.10 inches	1986	16.10			
01/01/1954	16.08 inches	1954	16.08			
03/01/1995	16.07 inches	1995	16.07			
11/01/1983	16.01 inches	1983	16.01			
02/01/1959	15.52 inches	1959	15.52			
12/01/1982	15.51 inches	1982	15.51			
01/01/1941	15.32 inches	1941	15.32			
01/01/1952	15.22 inches	1952	15.22			
11/01/1937	15.15 inches	1937	15.15			
12/01/1925	15.11 inches	1925	15.11			
12/01/1995	14.82 inches	1995	14.82			
03/01/1975	14.78 inches	1975	14.78			
12/01/1939	14.65 inches	1939	14.65			
02/01/1940	14.60 inches	1940	14.60			
10/01/1950	14.55 inches	1950	14.55			
12/01/1969	14.45 inches	1969	14.45			
01/01/1956	14.43 inches	1956	14.43			
01/01/1966	14.24 inches	1966	14.24			
01/01/1936	14.11 inches	1936	14.11			
03/01/1949	14.05 inches	1949	14.05			
12/01/1931	13.81 inches	1931	13.81			
02/01/1983	13.76 inches	1983	13.76			
02/01/1969	13.52 inches	1969	13.52			
12/01/1933	13.49 inches	1933	13.49			
01/01/1983	13.34 inches	1983	13.34			
03/01/1991	13.33 inches	1991	13.33			
12/01/1970	13.32 inches	1970	13.32			
12/01/1992	13.27 inches	1992	13.27			
01/01/1953	13.23 inches	1953	13.23			

Scotia Monthly Preciptation Data from CA Dept. of Water Resources
Elevation 139' Eel River Basin - Operator: National Weather Service

Raw html Data

Date	Inches
1997 Total	41.13
1996 Total	64.87
1995 Total	70.57
1994 Total	39.01
1993 Total	46.33
1992 Total	44.95
1991 Total	33.24
1990 Total	33.03
1989 Total	31.11
1988 Total	36.40
1987 Total	50.34
1986 Total	48.13
1985 Total	24.33
1984 Total	44.16
1983 Total	73.23
1982 Total	30.45
1981 Total	0.00
1980 Total	33.82
1979 Total	52.56
1978 Total	47.70
1977 Total	36.58
1976 Total	24.97
1975 Total	55.11
1974 Total	52.23
1973 Total	66.82
1972 Total	43.62
1971 Total	49.30
1970 Total	56.34
1969 Total	56.69
1968 Total	49.65
1967 Total	45.35
1966 Total	49.85
1965 Total	40.29
1964 Total	51.89
1963 Total	52.08
1962 Total	47.83
1961 Total	41.03
1960 Total	47.97
1959 Total	46.23
1958 Total	59.39
1957 Total	54.81
1956 Total	42.99
1955 Total	52.25
1954 Total	56.42
1953 Total	53.34
1952 Total	55.90
1951 Total	52.47
1950 Total	58.60

Scotia Monthly Preciptation Data from CA Dept. of Water Resources
Elevation 139' Eel River Basin - Operator: National Weather Service

Raw html Data

Date	Inches
1949 Total	34.16
1948 Total	49.60
1947 Total	33.34
1946 Total	29.70
1945 Total	62.85
1944 Total	43.54
1943 Total	39.35
1942 Total	49.76
1941 Total	67.49
1940 Total	56.86
1939 Total	36.88
1938 Total	66.65
1937 Total	60.69
1936 Total	36.79
1935 Total	42.15
1934 Total	40.56
1933 Total	47.62
1932 Total	35.09
1931 Total	41.43
1930 Total	30.09
1929 Total	23.15
1928 Total	38.10
1927 Total	46.58
1926 Total	53.04
1925 Total	15.11
Grand Total	3325.94

Average Annual Rainfall = 46.84 inches
(no rainfall data for 1981)

Appendix C

Landslide Data Form Descriptions and Individual Landslide Data

Description of the Parameters used to describe mass wasting in the mass wasting inventory

I.D. Number: Each landslide is numbered in the order invertoried.

Slide Type: The landslide type is recorded at each site by SL, shallow landslide; DS, deep-seated landslide; DF, debris flow; SL/DF, shallow landslide and debris flow; RF, rock fall.

Certainty: The certainty of identification is recorded at each site by D, definite; P, probable; Q, questionable.

Age/approximate failure date: Minimum failure date is assumed to be the photo year that the slide first appears on. Degree of revegetation, scarp morphology, and review of older air photos were used to better constrain the age.

Slope Form: The shape of the slope in which each slide originates is recorded by P, planar; C, convergent; D, divergent.

Aspect: The direction that each slide failed is recorded by E, east; W, west; N, north; S, south

Location: The geomorphic location where each slide occurs is recorded by IG, inner gorge; EIG, ephemeral inner gorge; MS, mid slope; HW, headwater swale; RT, ridge top.

Physical Characteristics: Include length, width, depth, area, and volume

Sediment Delivery: A range of sediment delivery (0-25, 25-50, 50-75, 75-100) was applied to each slide to determine minimum and maximum sediment delivery.

All Slides Identified on the 1966 Aerial Photos

ID	TYPE	LENGTH	WIDTH	AREA	DEPTH	CY_VOLUME	SED_DEL	MIN_DEL	MAX_DEL	SLOPE_FORM	ASPECT	AGE	LOCATION	ROAD	CERTAINTY
1	SL/DF	182	109	19,838	8	5,878	75-100	4,408	5,878	C	SW	< 66	IG	0	D
1.1	DF	218	36	7,848	4	1,163	75-100	872	1,163	C	SW	< 66	IG	0	D
2	SL	55	36	1,980	4	293	25-50	73	147	C	W	< 66	IG	0	D
3	SL	10	36	360	4	53	50-75	27	40	P	S	< 66	MS	0	P
4	SL/DF	109	109	11,881	4	1,760	25-50	440	880	P	S	< 66	MS	0	D
5	SL/DF	255	55	14,025	4	2,078	75-100	1,558	2,078	P	S	< 66	IG	0	D
6	SL	72	36	2,592	4	384	50-75	192	288	P	W	< 66	IG	0	D
7	SL	72	36	2,592	3	288	0	0	0	C	W	< 66	MS	0	Q
8	SL	72	72	5,184	3	576	0	0	0	P	W	< 66	MS	0	Q
9	SL/DF	328	50	16,400	6	3,644	25-50	911	1,822	C	W	< 66	MS	0	D
10	SL	72	90	6,480	4	960	50-75	480	720	P	W	< 66	IG	0	D
11	SL/DF	72	109	7,848	8	2,325	50-75	1,163	1,744	P	W	< 66	IG	0	D
11.1	DF	182	55	10,010	4	1,483	50-75	741	1,112	P	W	< 66	IG	0	D
12	SL	90	72	6,480	4	960	25-50	240	480	D	S	< 66	IG	0	D
13	SL	72	36	2,592	3	288	1-25	3	72	D	E	< 66	MS	0	D
14	SL	36	36	1,296	3	144	0	0	0	P	E	< 66	MS	0	D
15	SL	145	36	5,220	4	773	0	0	0	P	E	< 66	MS	0	D
16	SL/DF	360	20	7,200	3	800	25-50	200	400	P	E	10+	MS	0	D
16.1	DF	36	72	2,592	6	576	25-50	144	288	P	E	10+	MS	0	D
17	SL	146	72	10,512	4	1,557	50-75	779	1,168	P	S	< 66	IG	0	D
18	SL/DF	360	54	19,440	4	2,880	50-75	1,440	2,160	D	S	< 66	MS	0	D
19	SL/DF	145	40	5,800	4	859	50-75	430	644	P	S	5+	MS	0	D
20	SL	54	36	1,944	4	288	75-100	216	288	P	N	< 66	IG	0	D
21	SL/DF	182	72	13,104	8	3,883	75-100	2,912	3,883	P	S	1966	MS	0	D
21.1	DF	291	18	5,238	3	582	75-100	437	582	P	S	1966	MS	0	D
22.1	SL	30	30	900	3	100	50-75	50	75	C	S	1966	IG	0	D
22.2	SL	72	27	1,944	4	288	75-100	216	288	P	E	1966	IG	0	D
22.3	SL	18	18	324	3	36	75-100	27	36	P	E	1966	IG	0	D
23	SL	182	40	7,280	4	1,079	75-100	809	1,079	P	S	< 66	IG	0	D
24	SL	36	18	648	3	72	0	0	0	C	SE	< 66	HW	0	P
25	SL	72	36	2,592	3	288	0	0	0	C	S	< 66	RT	0	Q
26	SL	36	182	6,552	3	728	1-25	7	182	P	S	< 66	MS	0	Q

All Slides Identified on the 1966 Aerial Photos

ID	TYPE	LENGTH	WIDTH	AREA	DEPTH	CY_VOLUME	SED_DEL	MIN_DEL	MAX_DEL	SLOPE_FORM	ASPECT	AGE	LOCATION	ROAD	CERTAINTY
27	SL	54	25	1,350	3	150	0	0	0	P	SE	< 66	MS	0	D
28	SL	72	36	2,592	4	384	1-25	4	96	C	SW	< 66	HW	0	D
29	SL	36	18	648	3	72	1-25	1	18	P	S	< 66	IG	0	D
30	DS	254	145	36,830	8	10,913	25-50	2,728	5,456		NW	< 66	IG	0	D
31.1	SL	145	36	5,220	4	773	75-100	580	773	P	NW	< 66	IG	0	D
31.2	SL	145	72	10,440	4	1,547	50-75	773	1,160	P	NW	< 66	IG	0	D
32.1	SL	145	36	5,220	4	773	75-100	580	773	P	SE	< 66	IG	0	D
32.2	SL	54	36	1,944	4	288	75-100	216	288	P	SE	< 66	IG	0	D
33	SL	72	18	1,296	3	144	0	0	0	D	SE	< 66	MS	0	D
34	SL/DF	436	109	47,524	6	10,561	25-50	2,640	5,280	P	S	20+	RT	0	Q
35	SL/DF	290	72	20,880	6	4,640	25-50	1,160	2,320	P	S	20+	MS	0	Q
36	SL	70	36	2,520	3	280	1-25	3	70	P	S	< 66	EIG	0	D
37	SL	36	18	648	3	72	0	0	0	D	SE	< 66	MS	0	D
38	SL/RF	36	36	1,296	2	96	1-25	1	24	D	S	< 66	IG	0	D
39	SL	32	18	576	3	64	0	0	0	P	S	< 66	MS	0	P
40	RF	36	18	648	2	48	0	0	0	P	S	< 66	RT	0	D
41	RF	109	36	3,924	2	291	0	0	0	C	S	1966	RT	0	D
42	SL	36	36	1,296	3	144	1-25	1	36	C	SE	< 66	HW	0	D
43	SL/DF	182	54	9,828	4	1,456	25-50	364	728	D	NE	20+	IG	0	P
44	SL	36	253	9,108	3	1,012	25-50	253	506	P	SE	< 66	IG	0	D
45	SL	46	36	1,656	3	184	0	0	0	P	S	< 66	MS	0	D
46	SL	55	27	1,485	4	220	1-25	2	55	P	S	< 66	IG	0	D
48	SL	182	36	6,552	4	971	75-100	728	971	P	SW	5-10	MS	0	P
49	SL	54	36	1,944	4	288	50-75	144	216	P	SW	< 66	IG	0	D
50	SL	182	18	3,276	4	485	75-100	364	485	D	SE	< 66	IG	0	D
51	SL	18	18	324	3	36	75-100	27	36	P	SE	< 66	IG	0	P
52	SL/DF	473	72	34,056	8	10,091	75-100	7,568	10,091	C	E	20+	MS	0	P
53	SL/DF	546	200	109,200	15	60,667	75-100	45,500	60,667	C	SW	< 66	HW	0	D
53.1	DF	1092	36	39,312	6	8,736	75-100	6,552	8,736	C	SW	< 66	HW	0	D
54	SL/DF	546	182	99,372	12	44,165	75-100	33,124	44,165	C	S	< 66	HW	0	D
54.1	DF	1383	36	49,788	6	11,064	75-100	8,298	11,064	C	S	< 66	HW	0	D
55	SL	290	54	15,660	12	6,960	75-100	5,220	6,960	C	SW	< 66	MS	0	D

All Slides identified on the 1966 Aerial Photos

ID	TYPE	LENGTH	WIDTH	AREA	DEPTH	CY_VOLUME	SED_DEL	MIN_DEL	MAX_DEL	SLOPE_FORM	ASPECT	AGE	LOCATION	ROAD	CERTAINTY
56	SL/DF	76	54	4,104	4	608	50-75	304	456	C	W	< 66	IG	0	D
56.1	DF	54	218	11,772	4	1,744	50-75	872	1,308	C	W	< 66	IG	0	D
57	SL	109	73	7,957	4	1,179	75-100	884	1,179	C	W	< 66	HW	0	D
58	SL	127	36	4,572	4	677	75-100	508	677	C	SW	< 66	HW	0	D
59	SL	145	76	11,020	4	1,633	50-75	816	1,224	P	S	< 66	IG	0	D
60	SL	145	36	5,220	4	773	50-75	387	580	P	S	1966	IG	0	D
62	SL	182	36	6,552	4	971	50-75	485	728	P	W	< 66	IG	0	D
63	SL	182	36	6,552	4	971	50-75	485	728	P	W	1966	IG	0	D
64	SL/DF	145	76	11,020	4	1,633	50-75	816	1,224	C	S	10-20	MS	0	P
65	SL/DF	182	109	19,838	4	2,939	75-100	2,204	2,939	P	S	5-10	IG	0	D
66	SL	18	18	324	3	36	0	0	0	C	S	< 66	MS	0	D
67	SL	91	36	3,276	4	485	0	0	0	P	W	< 66	MS	0	D
68	SL	76	27	2,052	3	228	1-25	2	57	P	SW	1966	MS	0	D
69	SL	182	36	6,552	4	971	50-75	485	728	P	E	< 66	IG	0	D
70	SL	218	109	23,762	6	5,280	25-50	1,320	2,640	P	NE	10-20	RT	0	D
71	SL	109	20	2,180	4	323	25-50	81	161	P	W	5-10	IG	0	P
72	SL	109	54	5,886	4	872	50-75	436	654	P	W	< 66	IG	0	D
73	SL/DF	290	54	15,660	4	2,320	50-75	1,160	1,740	C	W	5-10	HW	0	D
74	SL	76	36	2,736	4	405	0	0	0	P	E	< 66	RT	0	D
75	SL	76	40	3,040	4	450	25-50	113	225	P	SW	< 66	IG	0	D
76	SL	54	54	2,916	4	432	75-100	324	432	P	SW	< 66	IG	0	D
77	SL	218	18	3,924	4	581	0	0	0	P	NE	< 66	MS	0	D
78	SL/DF	291	76	22,116	4	3,276	25-50	819	1,638	P	NW	10-20	MS	0	P
79	SL	109	36	3,924	4	581	50-75	436	436	P	S	1966	IG	0	D
80	SL	25	25	625	3	69	0	0	0	P	W	< 66	RT	0	D
81	SL	36	25	900	3	100	0	0	0	P	W	< 66	RT	0	D
82	SL	146	146	21,316	4	3,158	50-75	1,579	2,368	P	SW	< 66	IG	0	D
83	SL	36	54	1,944	4	288	1-25	3	72	C	SW	< 66	IG	0	D
84	SL	109	109	11,881	4	1,760	75-100	1,320	1,760	D	SW	< 66	IG	0	D
85	SL	76	36	2,736	4	405	75-100	304	405	P	NW	< 66	IG	0	D
86	SL	76	509	38,684	4	5,731	75-100	4,298	5,731	D	SW	< 66	IG	0	D
88	SL	109	109	11,881	4	1,760	50-75	880	1,320	P	W	< 66	IG	0	D

All Slides Identified on the 1966 Aerial Photos

ID	TYPE	LENGTH	WIDTH	AREA	DEPTH	CY_VOLUME	SED_DEL	MIN_DEL	MAX_DEL	SLOPE_FORM	ASPECT	AGE	LOCATION	ROAD	CERTAINTY
89	SL/DF	254	76	19,304	4	2,860	50-75	1,430	2,145	P	E	5-10	IG	0	D
90	SL	76	76	5,776	4	856	75-100	642	856	P	E	5-10	IG	0	D
91	SL	76	36	2,736	4	405	0	0	0	P	E	20+	MS	0	Q
92	SL	25	25	625	3	69	75-100	52	69	P	W	< 66	IG	0	D
93	SL	65	20	1,300	3	144	50-75	72	108	P	W	1966	IG	0	D
94	SL	36	36	1,296	3	144	0	0	0	P	W	< 66	MS	0	D
95	SL	30	30	900	3	100	0	0	0	C	W	1966	MS	0	D
96	SL	25	25	625	3	69	0	0	0	P	W	1966	MS	0	D
97	SL	30	76	2,280	4	338	75-100	253	338	P	W	1966	IG	0	D
98	SL/DF	218	76	16,568	4	2,455	25-50	614	1,227	C	SW	< 66	HW	SKID	D
99	SL	182	54	9,828	4	1,456	0	0	0	D	SW	< 66	RT	SKID	D

All Slides Identified on the 1997 Aerial Photos

ID	TYPE	LENGTH	WIDTH	AREA	DEPTH	CY_VOLUME	SED_DEL	MIN_DEL	MAX_DEL	SLOPE_FORM	ASPECT	AGE	LOCATION	ROAD	CERTAINTY
4	SL/DF	from field measurements				19,900	75-100	14,925	19,900	C		1997	IG	1	D
7	SL	40	30	1,200	4	178	0	0	0	D	E	5-10	MS	1	Q
8	SL	40	20	800	0	0	0	0	0	D	SE	5-10	MS	2	D
9	SL	0	0	0	0	0	0	0	0	C	SE	5-10	MS	1	Q
10	DS	360	250	90,000	10	33,333	1-25	333	8,333	C	E	5-20	MS	3	D
11	SL/DF	120	100	12,000	5	2,222	50-75	1,111	1,667	C	N	5	MS	1	D
12	SL	30	120	3,600	4	533	1-25	5	133	C	N	1997	MS	0	D
13	SL	100	30	3,000	3	333	0	0	0	C	NE	1997	HW	0	P
14	SL	60	30	1,800	3	200	0	0	0	D	NE	1997	HW	0	D
15	SL	140	40	5,600	4	830	0	0	0	C	E	1997	HW	0	D
16	SL	80	80	6,400	3	711	0	0	0	D	E	1997	MS	0	D
17	SL	320	60	19,200	8	5,689	25-50	1,422	2,844	D	E	5-20	MS	2	D
18	SL	240	60	14,400	4	2,133	75-100	1,600	2,133	D	E	5-20	IG	0	D
18	SL	80	40	3,200	4	474	75-100	356	474	D	E	5-20	IG	0	D
19	SL	80	40	3,200	3	356	50-75	178	267	C	E	5-20	HW	0	D
20	SL	80	40	3,200	4	474	25-50	119	237	D	S	1997	MS	0	D
21	SL	20	20	400	3	44	0	0	0	D	S	5-20	MS	2	Q
22	SL	100	20	2,000	3	222	0	0	0	P	S	5-20	MS	2	Q
23	SL	120	40	4,800	3	533	0	0	0	P	S	5-20	RT	0	P
24	SL	240	40	9,600	4	1,422	1-25	14	356	C	S	5-20	RT	0	D
25	SL	240	80	19,200	4	2,844	1-25	28	711	C	S	5-20	RT	0	D
26	SL	240	70	16,800	4	2,489	50-75	1,244	1,867	P	S	5-20	IG	1	P
27	SL/DF	280	70	19,600	4	2,904	50-75	1,452	2,178	P	S	5-20	IG	1	D
28	SL/DF	320	50	16,000	5	2,963	25-50	741	1,481	P	S	5-20	IG	1	D
29	SL/DF	160	50	8,000	4	1,185	50-75	593	889	P	S	1997	IG	1	D
30	SL	80	80	6,400	4	948	0	0	0	P	S	1997	MS	2	D
31	SL	280	40	11,200	5	2,074	75-100	1,556	2,074	D	S	1997	IG	3	P
32	SL	150	20	3,000	4	444	1-25	4	111	D	S	1997	IG	3	P
33	SL	120	20	2,400	4	356	1-25	4	89	D	SE	1997	MS	1	D
34	SL/DF	360	120	43,200	5	8,000	25-50	2,000	4,000	C	SE	5-20	MS	1	D
35	SL/DF	480	140	67,200	8	19,911	75-100	14,933	19,911	D	N	1997	IG	1	D
36	SL	60	20	1,200	3	133	0	0	0	D	SE	1997	MS	1	Q
37	SL	160	60	9,600	4	1,422	1-25	14	356	D	NE	5-20	MS	0	D
38	SL/DF	400	100	40,000	8	11,852	75-100	8,889	11,852	C	N	5-20	MS	2	D
39	SL	20	20	400	3	44	25-50	11	22	P	S	1997	EIG	1	D
40	SL	80	40	3,200	3	356	50-75	178	267	P	S	5-20	EIG	1	P
41	SL	80	300	24,000	8	7,111	1-25	71	1,778	C	S	1997	RT	3	D

All Slides Identified on the 1997 Aerial Photos

ID	TYPE	LENGTH	WIDTH	AREA	DEPTH	CY_VOLUME	SED_DEL	MIN_DEL	MAX_DEL	SLOPE_FORM	ASPECT	AGE	LOCATION	ROAD	CERTAINTY
42	SL	80	60	4,800	3	533	0	0	0	C	S	5-20	RT	0	Q
43	SL	160	40	6,400	4	948	25-50	237	474	D	S	1997	MS	0	D
44	SL	240	40	9,600	4	1,422	0	0	0	D	SE	1997	RT	0	D
45	SL	30	30	900	4	133	1-25	1	33	P	E	1997	IG	0	D
46	SL	120	40	4,800	4	711	25-50	178	356	P	S	1997	IG	0	D
47	SL	80	40	3,200	4	474	75-100	356	474	C	S	1997	IG	0	D
48	SL	20	20	400	3	44	75-100	33	44	P	E	1997	IG	0	D
49	SL	30	40	1,200	3	133	75-100	100	133	D	S	1997	IG	0	D
50	SL	40	30	1,200	3	133	1-25	1	33	C	S	5-20	IG	0	Q
52	SL	30	30	900	3	100	1-25	1	25	C	S	1997	EIG	0	P
53	SL	20	20	400	3	44	1-25	0	11	P	SW	1997	IG	0	Q
54	SL	20	30	600	3	67	1-25	1	17	P	S	5-20	IG	0	Q
55	SL	120	20	2,400	4	356	1-25	4	89	C	S	5-20	MS	3	P
56	SL	20	10	200	3	22	0	0	0	P	S	1997	MS	0	Q
57	DS	350	120	42,000	10	15,556	50-75	7,778	11,667	C	W	20+	IG	0	D
57	SL	60	35	2,100	1	78	75-100	58	78	C	W	1997	IG	0	D
58	DS	200	280	56,000	0	0	75-100	0	0	P	NW	20+	IG	0	D
58	SL/DS	80	75	6,000	4	889	75-100	667	889	P	NW	1997	IG	0	D
58	SL/DS	40	50	2,000	1	74	75-100	56	74	P	NW	5-10	IG	0	D
58	SL/DS	100	200	20,000	3	2,222	50-75	1,111	1,667	P	NW	1997	IG	0	D
59	SL	80	60	4,800	8	1,422	75-100	1,067	1,422	P	SE	1997	IG	0	D
61	SL	80	50	4,000	5	741	75-100	556	741	P	N	5-10	IG	1	D
62	SL	20	20	400	4	59	0	0	0	C	N	1997	IG	1	Q
63	SL	400	120	48,000	8	14,222	1-25	142	3,556		W	20+	MS	0	P
64	SL	80	60	4,800	5	889	1-25	9	222	C	N	1997	MS	1	D
65	SL/DF	200	100	20,000	7	5,185	75-100	3,889	5,185	D	N	1997	MS	1	D
66	SL	15	10	150	3	17	0	0	0	P	N	1997	MS	0	Q
67	SL	80	10	800	4	119	1-25	0	0	P	N	1997	IG	0	D
68	SL	80	10	800	4	119	75-100	89	119	D	SW	5-20	IG	1	P
69	SL/DF	240	40	9,600	4	1,422	75-100	1,067	1,422	P	S	20+	IG	0	D
69	SL/DF	200	30	6,000	4	889	75-100	667	889	P	S	20+	IG	0	D
69	SL/DF	240	40	9,600	8	2,844	75-100	2,133	2,844	P	S	20+	IG	0	D
70	SL	80	95	7,600	8	2,252	1-25	23	563	D	W	1997	MS	1	D
71	SL	40	40	1,600	3	178	0	0	0	P	SW	1997	MS	0	Q
72	SL	240	30	7,200	4	1,067	50-75	533	800	P	W	1997	RT	1	D
73	SL/DF	320	80	25,600	8	7,585	75-100	5,689	7,585	P	NE	5-20	MS	0	D
74	SL/DF	100	120	12,000	10	4,444	75-100	3,333	4,444	P	NE	5-20	RT	0	D

All Slides Identified on the 1997 Aerial Photos

ID	TYPE	LENGTH	WIDTH	AREA	DEPTH	CY_VOLUME	SED_DEL	MIN_DEL	MAX_DEL	SLOPE_FORM	ASPECT	AGE	LOCATION	ROAD	CERTAINTY
74	DF	220	60	13,200	6	2,933	75-100	2,200	2,933	P	NE	1997	HW	0	D
75	SL	600	120	72,000	8	21,333	50-75	10,667	16,000	C	N	5-20	RT	1	D
75	SL/DF	200	50	10,000	4	1,481	25-50	370	741	P	W	5-20	MS	0	D
76	SL	80	80	6,400	1	237	0	0	0				MS-	0	D
77	SL	160	20	3,200	1	119	50-75	59	89	P	W	5-20	MS	0	D
78	SL/DF	300	60	18,000	4	2,667	50-75	1,333	2,000	P	W	1997	RT	0	D
79	SL	80	10	800	3	89	1-25	1	22	P	W	1997	RT	0	D
80	SL/DF	400	40	16,000	8	4,741	75-100	3,556	4,741	P	W	1997	RT	0	D
81	SL/DF	200	20	4,000	4	593	50-75	296	444	P	W	1997	RT	0	D
82	SL/DF	180	20	3,600	4	533	50-75	267	400	P	W	1997	RT	0	D
83	SL	150	50	7,500	4	1,111	75-100	556	833	C	N	5-10	IG	0	D
84	SL	80	80	6,400	4	948	1-25	9	237	P	E	5-20	RT	0	P
85	SL/DF	120	40	4,800	8	1,422	75-100	1,067	1,422	P	E	5-20	RT	0	D
86	SL	60	20	1,200	3	133	0	0	0	D	NW	1997	MS	0	D
87	SL	20	20	400	3	44	1-25	0	11	P	E	1997	IG	0	Q
88	SL	20	20	400	3	44	1-25	0	11	D	E	1997	IG	0	Q
89	SL	60	60	3,600	2	267	1-25	3	67	P	E	1997	MS	0	D
90	SL	200	80	16,000	4	2,370	50-75	1,185	1,778	D	E	1997	MS	1	D
91	SL	320	80	25,600	4	3,793	75-100	2,844	3,793	P	NW	1997	IG	0	D
92	SL/DF	80	120	9,600	10	3,556	75-100	2,667	3,556	D	N	1997	IG	3	D
92	DF	600	40	24,000	6	5,333	75-100	4,000	5,333	D	N	1997	IG	3	D
93	SL/DF	240	40	9,600	4	1,422	75-100	1,067	1,422	C	N	1997	IG	2	D
93	DF	200	20	4,000	6	889	75-100	667	889	C	N	1997	IG	2	D
94	SL/DF	80	120	9,600	10	3,556	50-75	1,778	2,667	P	W	1997	IG	0	D
94	DF	160	40	6,400	6	1,422	50-75	711	1,067	P	W	1997	IG	0	D
95	SL	50	30	1,500	3	167	0	0	0	D	W	1997	MS	0	Q
96	SL	120	75	9,000	7	2,333	50-75	1,167	1,750	P	W	1997	RT	3	D
97	SL	40	60	2,400	3	267	0	0	0	C	N	5-20	MS	0	D
98	SL	30	30	900	3	100	0	0	0	P	NW	1997	MS	0	P
99	SL	40	30	1,200	3	133	75-100	100	133	C	N	1997	HW	3	D
100	SL	80	42	3,360	6	747	1-25	7	187	D	W	1997	RT	3	D
101	SL	100	40	4,000	4	593	0	0	0	C	W	1997	MS	0	D
102	SL/DF	0	0	0	0	0	75-100	0	0	P	W	5-20	RT	1	D
103	SL	200	40	8,000	4	1,185	75-100	889	1,185	P	W	1997	IG	0	D
104	SL/DF	120	90	10,800	3	1,200	75-100	900	1,200	C	W	1997	RT	3	D
104	DF	200	40	8,000	3	889	75-100	667	889	C	W	1997	RT	3	D
105	SL	60	40	2,400	4	356	0	0	0	C	W	1997	RT	0	D

All Slides Identified on the 1997 Aerial Photos

ID	TYPE	LENGTH	WIDTH	AREA	DEPTH	CY_VOLUME	SED_DEL	MIN_DEL	MAX_DEL	SLOPE_FORM	ASPECT	AGE	LOCATION	ROAD	CERTAINTY
106	SL	50	40	2,000	2	148	1-25	1	37	C	N	1997	MS	0	D
107	SL	160	120	19,200	3	2,133	25-50	533	1,067	C	SW	5-20	MS	0	P
108	SL	30	20	600	3	67	1-25	1	17	P	NW	1997	MS	0	P
109	SL	80	30	2,400	4	356	25-50	89	178	C	W	1997	HW	0	D
110	SL	30	30	900	3	100	0	0	0	C	S	1997	RT	0	Q
111	RF	40	40	1,600	1	59	0	0	0	C	NE	5-20	RT	0	D
112	RF	40	40	1,600	1	59	0	0	0	C	E	5-20	RT	0	P
113	SL/DF	70	40	2,800	4	415	1-25	4	104	C	N	5-20	RT	3	D
113	DF	110	90	9,900	4	1,467	1-25	15	367	C	N	5-20	RT	3	D
114	SL	120	80	9,600	4	1,422	1-25	14	356	P	N	5-20	RT	0	P
115	SL	50	40	2,000	4	296	0	0	0	P	N	5-20	MS	0	P
116	SL	60	40	2,400	4	356	0	0	0	C	N	5-20	MS	0	P
117	SL	120	80	9,600	6	2,133	25-50	533	1,067	C	E	1997	MS	0	D
118	SL	160	40	6,400	4	948	25-50	237	474	C	NE	5-20	RT	0	D
119	SL	160	20	3,200	3	356	25-50	89	178	C	E	5-20	MS	0	P
120	SL	120	120	14,400	2	1,067	75-100	800	1,067	C	N	1997	HW	0	D
121	SL	20	10	200	3	22	1-25	0	6	P	N	1997	HW	0	P
122	SL	30	30	900	3	100	25-50	25	50	P	N	1997	HW	0	P
123	SL	200	60	12,000	4	1,778	50-75	889	1,333	P	SW	1997	IG	0	D
125	SL	60	40	2,400	4	356	25-50	89	178	P	SE	1997	RT	4	D
127	SL	200	40	8,000	6	1,778	1-25	18	444	C	N	1997	MS	3	D
128	SL	60	30	1,800	4	267	0	0	0	D	W	1997	MS	0	D
129	SL	30	20	600	4	89	25-50	22	44	C	N	1997	IG	0	D
130	SL/DS	160	40	6,400	4	948	50-75	474	711	C	N	1997	IG	0	D
131	SL	120	20	2,400	4	356	1-25	4	89	C	SW	5-10	EIG	0	P
132	SL	40	60	2,400	4	356	0	0	0	P	W	1997	MS	0	D
134	SL	20	20	400	3	44		0	0	P	SW	5-10	RT	0	Q
135	SL	40	40	1,600	4	237	0	0	0	P	SW	5-10	RT	0	Q
136	SL	240	60	14,400	6	3,200	75-100	2,400	3,200	C	SE	1997	MS	1	D
137	SL	120	40	4,800	4	711	1-25	7	178	P	NE	5-10	MS	0	D
137	SL	60	40	2,400	3	267	25-50	67	133	C	NE	5-10	MS	0	D
138	SL	50	40	2,000	4	296	1-25	3	74	P	E	5-10	MS	0	D
138	SL	40	60	2,400	3	267	1-25	3	67	C	E	5-10	MS	0	D
139	SL/DF	160	80	12,800	4	1,896	25-50	474	948	C	N	5-10	IG	0	D
140	RF	80	10	800	2	59	1-25	1	15	C	S	1997	IG	0	D
141	RF	30	10	300	1	11	0	0	0	P	S	1997	RT	0	D
142	RF	80	10	800	1	30	0	0	0	P	S	1997	RT	0	D

All Slides Identified on the 1997 Aerial Photos

ID	TYPE	LENGTH	WIDTH	AREA	DEPTH	CY_VOLUME	SED_DEL	MIN_DEL	MAX_DEL	SLOPE_FORM	ASPECT	AGE	LOCATION	ROAD	CERTAINTY
143	RF	40	20	800	1	30	0	0	0	P	S	1997	RT	0	D
144	SL/DF	240	160	38,400	6	8,533	75-100	6,400	8,533	C	NW	5-10	RT	0	D
145	SL/DF	60	40	2,400	6	533	75-100	400	533	C	NW	1997	MS	0	D
145	DF	240	80	19,200	4	2,844	75-100	2,133	2,844	C	NW	1997	MS	0	D
146	SL	60	60	3,600	4	533	0	0	0	P	SW	1997	EIG	0	D
147	SL	240	160	38,400	4	5,689	75-100	4,267	5,689	D	SW	1997	IG	4	D
148	SL	160	40	6,400	3	711	0	0	0	D	SW	1997	RT	0	D
149	SL/DF	120	30	3,600	4	533	1-25	5	133		S	1997	IG	1	D
149	DF	80	20	1,600	3	178	1-25	2	44		S	1997	IG	1	D
150	SL/DF	320	60	19,200	6	4,267	75-100	3,200	4,267	C	E	5-10	HW	1	D
151	SL	40	80	3,200	4	474	75-100	356	474	D	W	5-10	IG	0	D
152	SL	100	100	10,000	20	7,407	50-75	3,704	5,556	C	W	5-10	RT-	1	D
153	SL	240	40	9,600	4	1,422	25-50	356	711	C	NW	1997	MS	0	D
154	SL	80	120	9,600	4	1,422	1-25	14	356	D	W	1997	RT	1	D
155	SL	20	20	400	3	44	75-100	33	44	C	S	1997	IG	0	D
156	SL	40	20	800	3	89	1-25	1	22	C	N	1997	IG	0	D
157	SL	70	30	2,100	3	233	1-25	2	58	C	NE	1997	IG	0	D
158	SL	40	40	1,600	3	178	0	0	0	C	E	1997	MS	4	D
159	SL	30	30	900	3	100	0	0	0	C	W	1997	MS	4	P
160	SL	120	30	3,600	4	533	25-50	133	267	C	W	1997	IG	0	D
161	SL	40	40	1,600	3	178	1-25	2	44		NW	5-10	IG	3	P
163	SL	60	80	4,800	4	711	75-100	533	711			1997	IG	0	D
164	SL	80	40	3,200	4	474	25-50	119	237			1997	MS	0	D

Appendix D

Example Road Erosion Data Form

Road Name ____________________

Potential Sed. Yield: H M L

Road Inventory Form

NRM 4/20/98

Date____________ Surveyors_______________ Creek_______________ Watershed_______________ Air Photo#, date___________

Quads________________________________ Township / Range / Sections T__________ R__________ S__________

ROAD INFORMATION / SUMMARY

Abandoned per CDF Standards? T F Drivable? T F Maintained? T F Major Rebuild? T F Has ≥1000' over 12% T F

Year Built:_____ **Condition**: Stable__ Maintenance problems__ Upgrades needed__ Failures__ **Cross Drains**: Adequate Inadequate

Summary / Comments

Road: Addnl. Ditch relief sites/lengths:____; Outslope ___ Inslope ____

Remove Berm___ Rock Rd___ Tx.immed: H M L Complexity: H M L ; Hrs for: b/hoe___; grader___; excavator___; dozer___; dump tr.___; loader___

Est. Volume moved__________ yds^3: stockpiled_____% incorporated_____% endhauled_____% Production Rate (yds^3/hr)_____

DRAINAGE CROSSING RECORD

- Tx #s: (0) none; (1) add rolling/ critical dip; (2) install /upgrade CMP; (3) repair/clean CMP; (4) add IBD relief drains; (5) clean/ cut ditch; (6) add downspout; (7) reconst. fill; (8) remove berm; (9) rock road; (10) outslope rd; (11) inslope rd; (12) add trash rack; (13) pull fill / excavate

Site #	Ford, None Humboldt or ?	Xing Obsvs.– %plug, +IBD, o/l erosion...	CMP Dia. (in.)	Head-wall ht (inches)	Drainage Area (ac)	DP/ DV	Future EP L x (ch.)W x D ft or yd	Est. Vol. (cy)	Past Erosion (cy)	% Fut. Delivery	Tx. #s	Immed H M L
							x x			%		
							x x			%		
							x x			%		
							x x			%		
							x x			%		
							x x			%		
							x x			%		
							x x			%		
							x x			%		
							x x			%		
							x x			%		
							x x			%		
							x x			%		
							x x			%		
							x x			%		
							x x			%		
							x x			%		
							x x			%		

MASS MOVEMENT SITES -- Tx.#s: (0) none; excavate: (1) soil, (2) logs/debris; (3) rock armor/ buttress; (4) protect base of slope w/ logs; (5) reveg; (6) other:

Feature & ID (Landing, rd.fill, rd.cutbank, swale, inner gorge, Hillslope)	Process (Debis slide, fill failure, channelTorrent)	Origination (Rd, IBD, Skid tr., Cut, Spring, Natural)	Erosion (Future, Past, Both)	Existing Volume L x W x D (ft or yd)	Active Perched, Undercut	Failure into Class I, II or III	Distance (ft)	% Slope	% Sed Yld.	Tx. #s
1.___				__x__x__						
2.___				__x__x__						
3.___				__x__x__						
4.___				__x__x__						
5.___				__x__x__						

Tx.immed. Site 1: H M L Complexity: H M L Access: G M P ; Hrs for: excavator___; dozer___; dump tr.___; labor___; b/hoe___

Tx.immed. Site 2: H M L Complexity: H M L Access: G M P ; Hrs for: excavator___; dozer___; dump tr.___; labor___; b/hoe___

Tx.immed. Site 3: H M L Complexity: H M L Access: G M P ; Hrs for: excavator___; dozer___; dump tr.___; labor___; b/hoe___

Tx.immed. Site 4: H M L Complexity: H M L Access: G M P ; Hrs for: excavator___; dozer___; dump tr.___; labor___; b/hoe___

Tx.immed. Site 5: H M L Complexity: H M L Access: G M P ; Hrs for: excavator___; dozer___; dump tr.___; labor___; b/hoe___

PAST EROSION VOLUMES

Site # or ID	Type: Mass Mvmt, Fillslope, Gully, Torrent, etc.	Past Erosion Volume LxWxD	Age -recent/old	% Delivery to Channel

ROAD DECOMMISSIONING: EXCAVATION VOLUME MEASUREMENTS

Site #	CMP Dia. (in.)	(PROFILE MEASUREMENTS) inlet slope % or °	inlet fill length	Road length	outlet slope % or °	outlet length	(X-SEC MEASUREMENTS) Inlet valley Width	Outlet valley Wid.	Ch. Wid.	DP / DV	Future EP L x (ch.)W x D ft or yd	Est. Vol. (cy)	Past Eros. (cy)	RNP (cy)
											__x__x__			
											__x__x__			
											__x__x__			
											__x__x__			
											__x__x__			
											__x__x__			
											__x__x__			

Site___________ Volume Caluculation from RNP Program _________cubic yards

Profile Notes:

% ANGLE arctan (%/100) = °	ANGLE (degrees)	LENGTH (ft)	FLAGS
	_	___	(optl.) Abv Inlet
	_	___	TOP UES
	0	0	TRN XS1 IBR
(ROAD)	0	___	TRN XS2 OBR
	_	___	BOT

Cross Section Notes:

ANGLE (degrees)	Inlet WIDTH (XS1)	FLAGS	ANGLE (degrees)	Outlet WIDTH (XS2)	FLAGS
0	_	LRP (ref pt)	0	_	LRP
0	_	LEC (edge cut)	0	_	LEC
0		TRN CLP	0		TRN CLP
0		REC	0		REC
0		RRP	0		RRP

Appendix E.

Sample Distances and Volume of Sediment Delivered by Small Inner Gorge Landslides not Observable on Air Photos

Sample distances (miles) and volume of sediment delivered by small inner gorge landslides that were not observable on air photos.

Location	Distance (miles)	Delivery Rate (cubic yards/mile)	Volume (cubic yards)
Stitz Creek (field)	1.8	1,112	2,002
Stitz Creek extrapolation	1.4	1,112	1,557
Blue-line tributary extrapolation	1.6	1,112	1,779
Total	4.8		5,338

Appendix F

Site Observations and Preliminary Conclusions on Slide #4 by John Coyle, CEG

JOHN COYLE &
ASSOCIATES, INC
Engineering Geologists

November 30, 1998

DEC 0 3

TO: Tom Koler
Staff Geologist
Scotia Pacific Company LLC

SUBJECT: STITZ CREEK DEBRIS SLIDE
Site Observations and Preliminary Conclusions

Dear Mr. Koler:

We have completed a preliminary field review of the Stitz Creek slide. The purpose of our field review was to attempt to form an opinion as to whether the slide was a road related failure or an "in unit" failure that migrated up slope to include the road now at the crown of the failure. The scope of work included review of portions of a report prepared by Oscar Huber (CEG) specifically addressing the slide and portions of the watershed analysis for Stitz Creek prepared by Natural Resources Management (NRM) Corporation that specifically address the Stitz Creek slide. Rick Koehler of NRM accompanied us in the field.

The slide is located on a southeast-facing slope characterized by slopes up to 65%. A southeast-trending ridge through which the road was cut creating some high, steep cut slopes opposite the slide scar. A drainage swale delivers run off to the road from the hillside area just to the east of the ridge noted above. A road further up the hillside crosses this swale. The site is underlain by rocks of the Wildcat Group. Geologic mapping by CDMG for the Scotia Quadrangle suggests that a general east-west strike and a moderately steep dip to the north characterize bedrock in the area of the slide. The rocks exposed in the scarp are generally highly fractured sandstone. Soils exposed in the slide scar are locally thick. A logging road crosses the crown of the slide. Another road about mid-way down slope between the scar and Stitz Creek was crossed by the torrent tract related to the failure. The head of the slide is at an elevation of about 1250 feet; the scar extends down slope about 250 to 300 feet (slope distance).

Color aerial photographs taken in 1994, before the failure, and 1997, after the failure, were reviewed. On the 1994 photographs the road (now at the crown of the slide) exhibits a light grayish-white color, probably do to the rocked surface. However, in the area of the failure light yellow-brown colors (similar to the color of the bedrock) are observed along the inside and outside margins of the road. We interpret the different color to be due to rock debris that has fallen on to the road from the adjacent cut slope, some of which was cleared and placed on the out side margin of the road.

334 State Street, Suite 106
Los Altos, California 94022
650-948-4279

SITE OBSERVATIONS

The following briefly summarizes our site observations:

- The slide involved both the overlying soil cover and the underlying bedrock.
- Prior to undertaking our field review, it was explained to us that the road was built as a full-bench road. Our field review the northeastern margin of the scarp showed about 4 feet of fill at the outside edge of the road.
- The remnants of the road form the crown of the scarp.
- At the crown of the slide (along the road) the scarp is about 150 feet wide and the scarp is about 70 to 80 feet high.
- There was slide debris due to cut slope failures on the remnants of the road surface.
- The remaining road section that extends to the northeast of the slide scarp slopes toward the slide scar.
- Drainage from the swale just east of the ridge delivers water to the road and to the eastern margin of the slide scarp.
- There is a culvert just to the east of the slide scarp; the inlet is plugged.
- Just east of the slide scarp, a gully has been eroded across the road down to the top of the culvert; locally to a depth of about 5 feet.
- Weak and highly fractured and jointed rocks are exposed in the slide scarp.
- A set of moderately steep to steep southward-dipping joints was observed. This system appears to control the general orientation and development of the scarp.
- Thick soils are locally exposed.
- Weak soils are probably present, but this has not been confirmed.
- Steep hillside slopes are present, especially down slope of the road adjacent to lateral margins of the slide.
- It appears that relatively smaller parts of the scarp have continued to fail subsequent to the initial failure.

- Though it is thought that the road was built using full-bench methods; based on our review of aerial photographs and field observations it appears that some fill may have been present along the out-side margin of the road, placed either during construction or side cast during times of cleanup of cut-slope failures, or both.

DISCUSSION

The exact location and cause or origin of the slide is difficult to ascertain. It is possible that the slide initially began as an "in unit" failure that migrated up slope to include the road. Such a failure could have been initiated by erosion and down-cutting along the drainage that borders the northeastern margin of the slide scar. It could also have begun on the slope below the road due to weak soils and bedrock and high pore pressures (maybe influenced by the road) in the soils and rock fractures. However, the topography, the generally the planar nature of the slope prior to failure (as seen on 1994 aerial photographs) and the ridge through which the road was cut, argue somewhat against concentration of subsurface water.

It could be possible that the presence of the road was the causative factor. Though it appears the road was built using full-bench methods, it is likely that some fill was present along the outer margin of the road. The fill could have been place during initial construction or later maintenance that resulted in placement of side-cast fill, particularly from clean up of nearby cut-slope failures, or both. Other factors that might have influenced failure could have been related to the possibility that the culvert was plugged, directing run off from the road, along with runoff from the small drainage just to the northeast of the failure, on to the road toward the area of the slide scar. From there run off could have either flowed over the edge of the road and on to the slopes below the road, or it might have been ponded, to some extent, on the road, due to the presence of the side cast fill from maintenance and cut slope clean up, or both. In any event, the water would have added to the saturation of the slope and the already weak rocks and soil, leading subsequently to failure of the slope. Failure of the adjacent cut slope and redirection of run off just prior to the catastrophic failure of the slope might also have influenced failure of the slope and road.

Placement of fill, even a small amount, on already weak and steep slopes and later saturated soils and bedrock could have finally, over time, resulted in failure of the road and slope. Also sudden placement of slide debris from the nearby cut slope on the road could have surcharged the weak earth materials that underlie the road section enough to cause or at least influence failure.

PRELIMINARY CONCLUSIONS

In short, the specific cause of failure of the slope and whether the failure was road-related or "in unit" is difficult to pin down definitively. Based on our observations several failure scenarios are possible, some somewhat more plausible that others. Because of the presence of the road and some observations related to the road, the influence of the road can not be ruled out and it maybe likely it did have some influence; however, that the road was the primary cause can not be positively demonstrated. It is possible that the slide was an "in unit" failure but, with the information available, this can not be determined for certain either.

If you have any questions, please call.

Sincerely,
JOHN COYLE & ASSOCIATES, INC.

John M. Coyle

John M. Coyle
Chief Engineering Geologist
CEG 1263

Appendix G

Volume Calculations and Assumptions for Slide #4

Slide #4 is broken up into five pieces (B, C, D, E, and debris torrent) in order to calculate volume.

The volume of piece A (not part of the slide) is used with geometric relations to calculate the volume of B. The pieces A, B, and C are treated as pyramids and the pieces D and E are treated as trapezoids. We assume that the debris torrent only scoured for the first 500 ft below the slide with a depth of 3 ft and a width of 10 ft. The volume of the debris torrent is treated as a rectangle.

Volume of landslide = vol. B + vol. C + vol. D + vol. E + vol. of debris torrent.

Volume of B = vol. (A + B) – vol. A = (1/2)*66*75*140 – (1/2)*26*75*140

= 346,500 – 136,500 = 210,000 ft^3

Volume of C = (1/2)*20*17*120 = 20,400 ft^3

Volume of D = (1/2)*(120 + 80)*20*92 = 184,000 ft^3

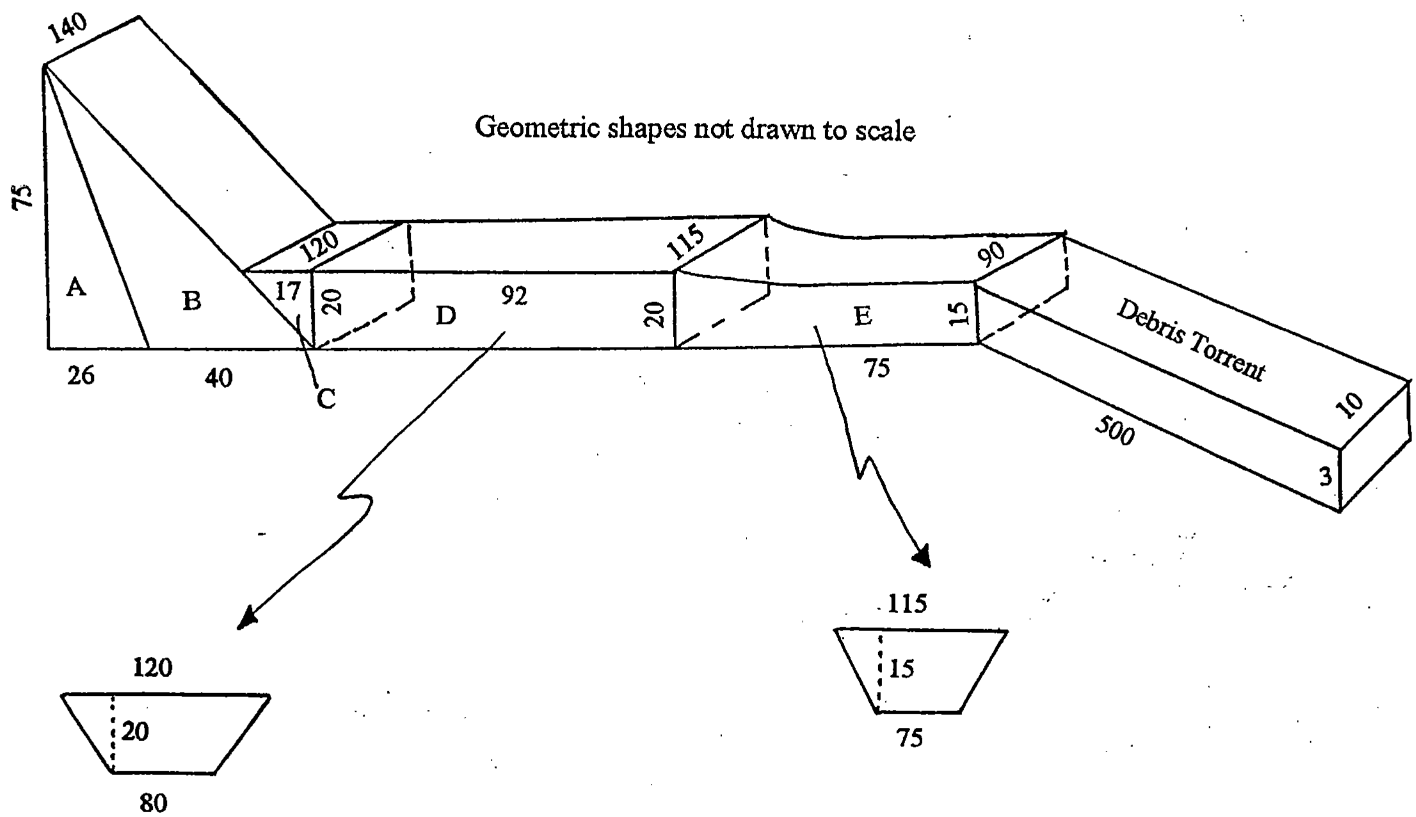
Volume of E = (1/2)*(115 +75)*15*75 = 106,875 ft^3

Volume of debris torrent = 500*10*3 = 15,000 ft^3

Volume of landslide = 210,000 ft^3 + 20,400 ft^3 + 184,000 ft^3 + 106,875 ft^3 + 15,000 ft^3

= 536,275 ft^3 / 27ft^3/yd^3

= 19,900 yd^3



Appendix H

Interim Aquatic Strategy and Mass Wasting Avoidance Strategy

INTERIM
(July 24, 1998)
AQUATIC STRATEGY
for Timber Harvest & Roads
for the
PACIFIC LUMBER CO. HCP

Management Zone	Prescription	Related Function/Indicator
Channel Migration Zone [CMZ] evaluations will be conducted as part of the DNR Watershed Assessments that are planned for each basin on the ownership. All segments of Class I and Class II streams that have a Rosgen type C, D or E channel morphology will be examined to identify the current boundaries of the bankfull channel and the remaining portion of the floodplain that is likely to become part of the active channel during the 50 years covered by the Incidental Take Permit (ITP) as evidenced by past channel migration and other field indicators. Areas not evaluated in a watershed analysis must be analyzed separately by PL using a qualified fluvial geomorphologist before any THP that includes CMZ areas can be approved. Additionally NMFS, CDF&G, USFWS, and EPA or NCRWQCB will be consulted regarding any such mapping.	The following measures will apply to Channel Migration Zones: • Management within the CMZ will be allowed under two cases. The first case will be to enhance and facilitate riparian functions based upon a completed Watershed Analysis, and Riparian Management Plan as agreed upon by the permitting agencies. The second will be in cases of emergencies which could result in the loss of life or property, and in cases of emergencies as per agreement with NMFS, USFWS, and CDF&G. Loss of property is defined as a demonstrated high risk of loss of capital improvements such as bridges, roads, culverts, and houses, however it does not include loss of vegetation. • No herbicides or pesticides will be used in the CMZ. Fertilizers can be used, ground application only, for erosion control purposes. Aerial application of fertilizers is not allowed. • No sanitation salvage or exemption harvest, including emergency exemption harvest, (as defined and allowed in the California Forest Practice Rules (CFPRs)) will be allowed in the RMZ, except as per agreement with NMFS, FWS, and CDF&G in accordance with the approved HCP.	Bank Stability, LWD protection, Off-channel habitat protection, Channel migration protection, microclimate protection, pools, etc.

CLASS I All fish bearing (or restorable) Class I watercourses as defined in the CFPRs will have a Riparian Management Zone (RMZ). The RMZ will measure 170 ft (slope distance) from the watercourse transition line as defined in the CFPRs or CMZ edge (if a CMZ is present), on each side of the watercourse. Willows will not be considered permanent vegetation for the purposes of determining the location of the watercourse transition line. The RMZ for Class I watercourses is divided into three management bands, the Restricted Harvest Band (RHB), the Limited Entry Band (LEB) and the Outer Band (OB). The bands are	Prescriptions that apply to the entire Class I RMZ	• After each entry, PALCO will retain an additional 10 trees greater than 40 inches DBH per acre on each side of the watercourse. The trees can be counted entirely or partially within the RHB. If trees of this size are not available, the 10 largest trees in the RMZ will be retained. • No sanitation salvage or exemption harvest, including emergency exemption harvest, (as defined and allowed in the California Forest Practice Rules (CFPRs)) will be allowed in the RMZ, except as per agreement with NMFS, FWS, and CDF&G in accordance with the approved HCP. • All portions of down wood (i.e., LWD) except as defined as slash in the FPA, or within Class I outer bands as specified below will be retained. • Trees felled during current harvesting operations and THP approved roads construction are not considered down wood for purposes of retention. • Felled hazard trees or snags not associated with a THP are considered down wood and are to be retained in the general vicinity. • Trees that fall naturally onto roads, landings, or harvest units within the RMZ are considered down wood and are to be retained in the general vicinity. • All non-hazard snags will be retained, as per the snag policy in Volume II Part M. • The RMZ is an equipment exclusion zone (EEZ) for timber operations, except for roads and permitted equipment crossings. • No herbicides or pesticides will be used within the RMZ. Fertilizers will be used for ground application for erosion control only. Aerially-applied fertilizers will not be directly applied to Class I RMZs. • Full suspension yarding will be used when feasible. Full suspension is not feasible on flat ground, in other sites with limited deflection, where an adjacent landowner will not provide permission to secure a cable, or where a full suspension yarding system would jeopardize the safety of field personnel. For these conditions, yarding will be conducted in a manner that avoids ground disturbance that may deliver sediment to a watercourse to the maximum extent practicable. Where ground disturbance occurs PALCO will treat (e.g., through seeding, mulching, etc.) all sites with exposed mineral soil that can reasonably be expected to deliver sediment to a watercourse (e.g., gullies, ruts). • Trees may be felled within RMZs to provide clearance for cable yarding corridors. Such felling will be done only as needed to ensure worker safety. In such cases, to the extent feasible given site conditions and the CFPRs, trees will be felled toward the watercourses to provide LWD. Regardless, trees felled within the WLPZ for safety purposes will be retained as down wood. • Trees not marked for harvest which are damaged in the	Bank Stability, LWD protection and recruitment, temperature, sediment filtration, microclimate, soil compaction

measured 0 ft to 30 ft, 30 ft to 100 ft, and 100 ft to 170 ft from the watercourse transition line as defined in the CFPRs or CMZ edge (if a CMZ is present), respectively.		cable yarding corridors must be retained in place, either standing or as down wood. • There will be a maximum of 1 entry every 20 years.	
<u>CLASS I</u>	Prescriptions that apply to Class I Restricted Harvest Band (Edge of watercourse transition line or CMZ if present to 30')	• Harvest to enhance and facilitate riparian functions such as canopy or LWD levels, may be allowed within the RHB based upon a completed watershed analysis and Riparian Management Plan as agreed upon (both processes) by the permitting agencies. • Watershed analysis and/or PWA protocol (see section on watershed analysis) will be used to determine the priorities and road storm proofing standards to be used on all existing haul roads and stream crossings. • Road segments within the RHB must be mitigated by extending the RHB on the opposite side of the watercourse from the existing road an equivalent distance of that portion of the road prism within the RHB. In the case of RMZ road crossings, the first 50 ft of road extending inland from the watercourse transition line as defined in the CFPRs (14 CCR 895.1) is exempt from this mitigation.	Bank Stability, LWD protection and recruitment, temperature, sediment filtration, microclimate, soil compaction
<u>CLASS I</u>	Prescriptions that apply to Class I Restricted Limited Entry Band [LEB] (30' to 100' from the watercourse transition line or channel migration zone if present) PL's Late Seral Prescriptions	• Only single tree selection harvest will occur within the LEB. Harvest will only occur if there is a preharvest conifer basal area of 345 sq ft per acre or greater within the LEB. • A minimum 300 sq ft post harvest conifer basal area per acre will be retained within the LEB. • Basal area measurements will be made for conformance every 200 ft lineal segment of RMZ. • No more than 40 percent of the conifer basal area may be harvested in a single entry. • Tree sizes and quantity distribution will be retained as per Table 4. If replacement size classes must be used to obtain the stated size distributions, the replacement size class must come from higher size classes if such trees are available; provided, however, that the largest trees in the stand must be left and harvesting conducted in a manner that facilitates and expedites development of stand conditions stated in Table 4. • Watershed analysis and/or the PWA road storm-proofing protocol will be used to determine the priorities and road storm proofing standards to be used on all roads inside the LEB. Surface area covered in roads will be included in all calculations of basal area.	Bank Stability, LWD protection and recruitment, temperature, sediment filtration, microclimate, soil compaction

CLASS I	PL's Late Seral Prescriptions will apply to Class I Outer Band [OB] (100' to 170' from the channel migration zone [CMZ])	• Only single tree selection harvest will occur within the OB. • Harvest will only occur in the OB if there is a preharvest conifer basal area of 276 sq ft per acre or greater within the OB on each side of the watercourse. • A minimum 240 sq ft post harvest conifer basal area per acre of OB will be retained. • No more than 40 percent of the conifer basal area may be harvested in a single entry. • Tree sizes and quantity distribution will be retained as per Table 4. If replacement size classes must be used to obtain the stated size distributions, the replacement size class must come from higher size classes if such trees are available; provided, however, that the largest trees in the stand must be left and harvesting conducted in a manner that facilitates and expedites development of stand conditions stated in Table 4. • Basal area measurements will be made for conformance no less than every 200 ft lineal segment of RMZ. • In areas with slopes <50 percent portions of downed wood (i.e., LWD) can be removed from the OB. That is, if a tree originating in any of the 3 Bands falls, portions in the RHB and LEB must be retained onsite in place, but the portions in the OB can be removed for slopes <50%. • In areas with slopes 50 percent or greater, all down wood (i.e., LWD) except as defined as slash in the FPA must be retained.	Bank Stability, LWD protection and recruitment, temperature, sediment filtration, microclimate, soil compaction
CLASS II Non-fish bearing streams (Class II watercourses as defined in the CFPRs) will have a Riparian Management Zone (RMZ). The RMZ of Class II streams will measure 100 ft (slope distance) from the watercourse transition line as defined in the CFPRs or CMZ edge (if	Prescriptions that apply to the entire Class II RMZ are as follows:	• No sanitation salvage or exemption harvest, including emergency exemption harvest, (as defined and allowed in the CFPRs) will be allowed in the RMZ, except as per agreement with NMFS, FWS, and CDF&G in accordance with the approved HCP. • All portions of down wood (i.e., LWD) will be retained, except as defined as slash in the CFPRs. • Full suspension yarding will be used when feasible. Full suspension is not feasible on flat ground, in other sites with limited deflection, where an adjacent landowner will not provide permission to secure a cable, or where a full suspension yarding system would jeopardize the safety of field personnel. For these conditions, yarding will be conducted in a manner that avoids ground disturbance that may deliver sediment to a watercourse to the maximum extent practicable. Where ground disturbance occurs PALCO will treat (e.g., through seeding, mulching, etc.) all sites with exposed mineral soil that can reasonably be expected to deliver sediment to a watercourse (e.g., gullies, ruts). • Trees felled during current harvesting and approved THP roads construction are not considered down wood for purposes of retention. • Felled hazard trees not associated with a THP are	Bank Stability, LWD protection and recruitment, temperature, sediment filtration, microclimate, soil compaction

a CMZ is present), on each side of the watercourse. Willows will not be considered permanent vegetation for the purpose of determining the location of the watercourse transition line. The RMZ is divided into two management bands, the Restricted Harvest Band (RHB), and the Selective Entry Band (SEB), which are measured from the watercourse transition line as defined in the CFPRs or CMZ (if a CMZ is present), 0 ft to 10 ft, and 10 ft to 100 ft, respectively.		considered down wood and are to be retained in the general vicinity. • Trees that fall naturally onto roads, landings or harvest units are considered down wood and are to be retained in the general vicinity. • Trees not marked for harvest may be felled within WLPZs to provide clearance for cable yarding corridors. Such felling will be done only as needed to ensure worker safety. In such cases, to the extent feasible given site conditions and the CFPRs, trees will be felled toward the watercourses to provide LWD. Regardless, trees felled within the WLPZ for safety purposes will be retained as down wood. • Trees damaged in the cable yarding corridors must be retained in place. • The RMZ is an EEZ for timber operations, except for roads and permitted equipment crossings. • No herbicides or pesticides will be used within the RMZ. Fertilizers will be used for ground application for erosion control only. Aerial fertization will be excluded from Class II RMZs.	
<u>CLASS II</u>	Prescriptions that will apply to the Class II Restricted Harvest Band [RHB] (Edge of watercourse transition line or CMZ if present to10')	• Management to enhance and facilitate riparian functions such as canopy or LWD levels may be allowed within the RHB based upon a completed watershed analysis and Riparian Management Plan as agreed upon (both processes) by the permitting agencies. • If the 10 ft line falls anywhere on a tree bole, the tree is to be retained as part of the Restricted Harvest Band. • Watershed analysis and/or the PWA road storm-proofing protocol will determine the priorities and road storm proofing standards to be used on all existing haul roads and stream crossings. • Road segments within the RHB, must be mitigated by extending the RHB on the opposite side of the watercourse as the existing road an equivalent distance of	LWD protection and recruitment, temperature, sediment filtration, microclimate, soil compaction

		that portion of the road prism within the RHB. In the case of RMZ road crossings, the first 15 ft of road extending inland from the watercourse transaction line as defined in the CFPRs (14 CCR 895.1) is exempt from this mitigation.	
<u>CLASS II</u>	Prescriptions that will apply to the Class II Selective Entry Band [SEB] (10-100' from the watercourse transition line or CMZ if present) PL's Late Seral Prescriptions	• Only single tree selection harvest will occur within the SEB. • Harvest will only occur in the SEB if there is a preharvest conifer basal area of 276 sq ft per acre or greater within the SEB. • A minimum 240 sq ft post harvest conifer basal area per acre of SEB will be retained. • No more than 40 percent of the conifer basal area may be harvested in a single entry. • Tree sizes and quantity distribution will be retained as per Table 4. If replacement size classes must be used to obtain the stated size distributions, the replacement size class must come from higher size classes if such trees are available; provided, however, that the largest trees in the stand must be left and harvesting conducted in a manner that facilitates and expedites development of stand conditions stated in Table 4. • Basal area measurements will be made for conformance every 200 ft lineal segment of RMZ. • There will be a maximum of 1 entry every 20 years. • Watershed analysis and/or PWA protocol will be used to determine the priorities and road storm proofing standards to be used on all roads inside the LEB. Surface area covered in roads will be included in all calculations of basal area.	Sediment Metering, LWD delivery to Class I and II watercourses.
<u>CLASS III</u>	Prescriptions that apply to all Class III watercourses: Class III streams will have three management categories based on percent slope, <30%, 30% - 50%, and >50%.	• There will be no removal of any portion of down wood within the Equipment Limitation Zone/Equipment Exclusion Zone (ELZ/EEZ) except for emergencies as per agreement with NMFS, USFWS and CDFG in accordance with the approved HCP. • Trees felled during current harvesting and approved THP road construction are not considered down wood for purposes of retention. • Felled hazard trees not associated with a harvesting operation or road construction are considered down wood and are to be retained in the general vicinity. • Trees that fall naturally onto roads, landings, or harvest units are considered down wood and are to be retained in the general vicinity. • No fire will be ignited within the equipment limitation zones (ELZs) or EEZs.	
<u>CLASS III</u>	Prescriptions that apply to Class III streams with	• Equipment Limitation Zone (ELZ) extending 25 ft from the stream edge, or to the drainage divide, or ridgeline of the Class III stream whichever is less. • Stabilize skid trails as per the CFPRs (Section 916.7) or	

	slopes <30 percent:	as per an approved THP. • Ground based equipment in the ELZ is acceptable if less resource damage will occur by operating in the ELZ, as per an approved THP. Where the above measure applies, all tractor road watercourse crossings must be flagged on the ground prior to the preharvest inspection and shown on the THP map in order to be adequately evaluated for the potential to generate sediment.	
<u>CLASS III</u>	Prescriptions that apply to Class III streams with slopes of 30 - 50 percent:	• ELZ extending 50 ft from the stream edge, or to the drainage divide, or ridgeline of the Class III stream whichever is less. • Stabilize skid trails as per the CFPRs (Section 916.7) or as per an approved THP. • Ground based equipment in the ELZ is acceptable if less resource damage will occur by operating in the ELZ, as per an approved THP. • Where the above measure applies, all tractor road watercourse crossings must be flagged on the ground prior to preharvest inspection and shown on the THP map in order to be adequately evaluated for the potential to generate sediment.	
<u>CLASS III</u>	Prescriptions that apply to Class III streams with slopes >50 percent:	• EEZ (Equipment Exclusion Zone) extending 100 ft from the stream edge, or to the drainage divide, or ridgeline of the Class III stream whichever is less. • Ground based equipment in the EEZ is acceptable if less resource damage will occur by operating in the EEZ, as per an approved THP. • Where the above measure applies, all tractor road watercourse crossings must be flagged on the ground prior to preharvest inspection and shown on the THP map in order to be adequately evaluated for the potential to generate sediment.	

<u>ROAD NETWORK</u>	Assessment of existing road network and sediment sources	PALCO will assess the road network and associated sediment sources on its lands either as part of the watershed assessment or the road storm-proofing program protocols (see below). Given the accelerated schedule being proposed for watershed analysis, most of this assessment is likely to occur within the first few years after issuance of the ITPs. However, at a minimum, the assessments must be completed as follows: • Elk River, Freshwater Creek, Lawrence Creek, and Yager Creek will be evaluated within the first decade of Plan implementation; • Van Duzen and Middle Eel rivers will be evaluated during the second decade; and • Larabee Creek, Salmon Creek, and Mattole and Bear rivers will be evaluated during the third decade. It is anticipated that all sites assigned a high or medium priority rating based on the audit of potential sediment sources will be storm-proofed over the first 30 years of Plan	Sediment Control

		implementation.	
	Restoration of sediment delivery sites for non-THP related roads	<u>Prior to issuance of the ITP:</u> - Based on PWA analysis, complete recommended road storm proofing on high and medium risk sites, on at least 50 miles per year. <u>After issuance of the ITP:</u> - Based on watershed analysis, complete recommended work on high and medium risk sites, on a planning watershed basis, within the prioritized hydrologic units and schedule listed above. Variations from this schedule will be conducted only upon approval of the agencies.	
	Storm-proofing or upgrading THP related roads	- All THP related roads and landings shall comply with specifications described in Handbook for Forest and Ranch Roads (Weaver 1994) • For purposes of this Plan, a road will be considered upgraded when it is well drained and shows no signs of imminent failure (e.g., as evidenced by slumping, scarps or cracks in the road fill) which would deliver sediment to a watercourse. Actions necessary to upgrade a road include the installation of ditch relief culverts and/or rolling dips where significant downcutting of the ditch is noted and removal or stabilization of unstable fill material at sites showing signs of imminent failure which could impact a watercourse. An upgraded road, as described above meets the definition used in the Plan of "complying with the specifications described in the Handbook for Forest and Ranch Roads (Weaver and Hagans 1994.)" • In each decade of HCP implementation, or until all active roads have been storm-proofed, at least 500 miles of existing roads will be improved to meet the storm-proofing standards identified in the PWA guidelines (Volume II Part N). PL will work closely with agencies to identify priority areas for this work. Additionally, unless otherwise agreed to by the agencies pursuant to prioritization discussions, storm-proofing will proceed according to the schedule by decade for hydrologic units provided in the January 7, 1998 Interagency Aquatic Strategy on page 10 thereof (see Section 3). Storm-proofing conducted as part of THPs will count towards the per-decade objective. When used in this Plan, the term storm-proofing describes a process which involves the following elements: 1. An audit of potential sediment sources along a road is conducted. A trained observer walks the road segment looking for actual or potential occurrences of erosion, slippage, mass wasting, blocked or perched culverts, or other potential sediment sources. The audits document instances of Humboldt crossings, unstable fill slopes for roads and landings, stream crossings that have high	

		potential for culvert blockage and diversion of stream flows onto the road bed, sufficient drainage and diversion of road drainage directly into watercourses. 2. The likelihood that each identified feature will deliver sediment to watercourses is also evaluated as part of the road audit, as is the total volume of sediment that could be prevented from delivery if remedial action is taken. 3. Based on the volume of sediment saved and likelihood of delivery, sediment sites are assigned a rating of high, medium or low priority. 4. All high and medium priority sites are then scheduled for corrective action. Corrective action typically requires an excavator, bulldozer, and one or more dump trucks to dig up and replace stream crossings, install drainage structures, remove unstable fill, alter the road bed to reduce the potential for diversion of flows onto the road surface, and the installation of rolling dips and/or water bars to route water and sediment. 5. Storm-proofing is considered complete when the specified corrective actions are complete, and the roads database and GIS system are updated to show that the subject road has been storm-proofed.	
	Construction of new roads	• All new roads will be built to site-specific storm-proof specifications. (See previous storm proofing discussion.) • New roads will not be constructed in RMZs except for crossings or when feasible alternatives that would have less environmental impact are clearly not available as determined through consultation with the appropriate agencies, and will be designed to minimize the number of stream crossings and avoid mass wasting risk areas. Road layout will attempt to follow natural grades to help limit sedimentation, will be constructed on slopes primarily under 50%, and will be single lane (between 12 to 14 feet wide). In addition, bridges, culverts, or fords at stream crossings will provide for adequate passage of water during storm events. • Structures over fish-bearing streams and restorable fish-bearing streams for all new roads will be designed to provide for unimpeded fish passage. This could involve use of bottomless or baffled culverts, bridges, or other such structures. Where culverts are used they will be installed at an appropriate gradient, be sized to permit passage of a 100 year recurrence interval flood, and will contain downstream storm proofing of the stream bed to ensure that they are passable, and to prevent culvert "perching." Fish passage will be ensured by adhering to guidelines for culvert installation by NMFS, or by agency review of alternate installation measures. • Road or landing construction or reconstruction shall comply with applicable state and federal laws and shall not occur during periods of measurable precipitation (excluding fog drizzle or drip) and shall not resume	

		thereafter until and unless soil moisture conditions are not in excess of that which occurs from normal road watering or light rainfall such that the construction or reconstruction activities will result in the loss of soil materials in amounts that will cause a visible increase in the turbidity in a Class I, II, or III watercourse, or in any drainage facility or road surface that drains directly to a Class I, II, or III watercourse (not applicable to standing water that is not draining directly to a watercourse). During each winter period (which for these purposes shall be between November first of each year and April first of the following year) no more than 2.5 miles of new road construction and 5 miles of reconstruction or storm-proofing shall occur on the Plan Area unless such additional work is approved after consultation with NMFS, USFWS, and CDFG. PALCO and the agencies shall reevaluate these winter mileage limitations during the first three years of plan implementation to determine their effectiveness. If modifications are deemed appropriate, PALCO and the agencies shall meet and agree on any necessary changes.	
	Maintenance and Use of existing roads	Truck hauling, road grading, road rocking, or other non-emergency road use activities shall comply with applicable federal and state laws and shall cease when the activities result in a visible increase in the turbidity in a Class I, II, or III watercourse, or in any drainage facility or road surface that drains directly to a Class I, II, or III watercourse (not applicable to standing water that is not draining directly to a watercourse). Once these activities have ceased due to the foregoing conditions, these activities shall not resume until and unless soil moisture conditions are not in excess of that which occurs from normal road watering or light rainfall such that use will result in the loss of surface materials from the road in amounts that will cause a visible increase in the turbidity in a Class I, II, or III watercourse, or in any drainage facility or road surface that drains directly to a Class I, II, or III watercourse (not applicable to standing water that is not draining directly to a watercourse).	
	Monitoring Road Network	1. All open (i.e., non-abandoned) roads will be inspected at least yearly. 2. Roads will be inspected during the winter period incidental to normal operations and note all occurrences of road slippage, erosion or impending mass failure, blocked culverts, and failures or erosion control measures. 3. Any maintenance needs identified by inspections will be performed by the end of the field season following the inspection.	

<u>HILLSLOPE MANAGE-MENT</u>	Mass Wasting Extreme, Very High and High Mass Wasting Potential Zones (including Inner Gorges, Headwall Swales & Unstable Areas)	The Hillslope Management-Mass Wasting process applies to all portions of PL's ownership, including inside the RMZs. The prescriptions in the RMZs for mass wasting will not be less restrictive than the riparian prescriptions developed as part of the interim or default strategies or through watershed analysis as appropriate and applicable to this Plan. PL will not harvest or construct new roads in portions of its ownership with an "extreme" mass wasting potential, in inner gorges, headwall swales, or unstable areas without a geologist's report recommending alternative prescriptions that are approved by CDF. The professional registered PL geologist shall assess the influence of the proposed operation on the risk of hillslope failure. In areas where the potential for mass wasting is rated as "very high" or "high," PL will not operate heavy equipment off of existing roads or construct new roads, without a geologist's report recommending alternative prescriptions that are approved by CDF. The geologist's written report must accompany the THP when submitted for review. For portions of the ownership lacking geology and soils maps necessary to make a determination of risk, PL is responsible for providing site specific risk ratings based on review by a geologist. In most cases such determinations will be done as part of the THP approval process. NMFS, CDFG and EPA or Regional Water Quality Control Board shall be notified of all THPs that are being submitted on areas of extreme, very high and high mass wasting potential in addition to inner gorges, headwall swales, and unstable areas, if the proposed operation goes beyond the default prescriptions. A registered geologist shall assess the influence of the proposed operation on the risk of hillslope failure and prepare a written report. If required (i.e., if prescriptions other than the defaults are being proposed), the geologist's report along with the THP will be sent to NMFS, CDF&G and either EPA, or the Regional Water Control Quality Board upon THP submission. If the notified agencies have concerns regarding the harvest proposal related to the risk of mass wasting, they may communicate such concerns to the RPF and CDF within 30 days of receipt of materials from PALCO or until the close of the public comment period, whichever is longer. As mandated under the FPA, CDF, as lead agency for THP review, will consider all input and determine whether the mass wasting mitigation measures contained in the THP will avoid significant impacts.	
	Surface Erosion	PL will treat all sites of exposed mineral soils, resulting from forestry activities within watercourses protection zones that are equal to or greater than 100 sq ft, or areas less than 100 sq ft which are on slopes greater than 30 percent if the site can deliver fine sediment to watercourses. Exposed mineral soil treatments can include revegetation or other erosion control measures including, but not limited to, seeding and mulching. Watercourse crossings will also be treated to avoid or minimize sediment delivery, using watershed analysis and/or road storm proofing protocols and road armoring standards to	

		be used on all such crossings. Cable corridors (cable roads) that divert or carry water away from natural drainage patterns or channelize run-off that reaches watercourses will have waterbreaks installed at intervals as per the CFPRs (14 CCR 914.6).	

<u>BURNING</u>		PL will continue to manage prescribed burns (including brush piling, fire breaks, ignition techniques, prescriptions for environmental conditions permitting ignition, etc.) to minimize adverse effects. Mitigation may be required for fire management, including suppression and rehabilitation efforts, if PL or its agents are found in violation of, or out of compliance with, their burning permit. Additional prescribed burning practices may be identified during the watershed assessment process.	Sediment Control and slope stability

Attachment #1

Table 4. Tree size and quantity necessary to meet two different residual basal area requirements.

Residual Basal Area Requirement	DBH Class	Basal Area Percent	# of Trees Per Acre*
300 sq ft/acre	6 to 12"	5%	34
	12 to 18"	10%	24
	18 to 24"	15%	19
	24 to 30"	15%	11
	30 to 36"	15%	8
	36 to 42"	20%	7
	42 to 48"	20%	5
	Over 48"	0%	0
240 sq ft/acre	4 to 8"	3%	37
	8 to 12"	4%	18
	12 to 16"	8%	18
	18 to 20"	10%	14
	20 to 24"	12%	11
	24 to 28"	12%	9
	28 to 32"	15%	7
	32 to 36"	18%	7
	36 to 40"	18%	5
	Over 40"	0%	0

* Retention requirements are based on basal area not tree number. Number of trees/acre provided for information purposes only.

Inner gorge, as used here, is defined as that area of the watercourse bank situated immediately adjacent to the watercourse channel, having a sideslope of 65% or greater, and extending from the edge of the channel upslope until the slope becomes less than 65% or for a distance of 400 ft., (slope distance) whichever is less.

Headwall swale is defined here as a concave depression, with convergent slopes > 65%;–that is connected to a watercourse via a continuous linear depression (a linear depression interrupted by a landslide deposit is considered continuous for this definition).

Unstable areas are characterized by slide areas or by some or all of the following: hummocky topography consisting of rolling bumpy ground, frequent benches, and depressions; short, irregular surface drainages which begin and end on the slope; tension cracks and head wall scarps; slopes are irregular and may be slightly concave in upper half and convex in lower half from previous slope failure; evidence of impaired ground water movement resulting in local zones of saturation within the soil mass which is indicated at the surface by sag ponds with standing water, springs, or patches of wet ground. Some or all of the following may be present: hydrophytic vegetation prevalent; leaning, jackstrawed or split trees are common; pistol butted trees with excessive sweep may occur in areas of hummocky topography (leaning and pistol butted trees should be used as indicators of unstable areas only in the presence of other indicators