SEDIMENT SOURCE ANALYSIS FOR THE MAINSTEM TRINITY RIVER, TRINITY COUNTY, CA

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INTRODUCTION

The Trinity River watershed in Trinity County (Figure 1) has been listed as a sediment impaired waterbody in California's 1995 CWA 303(d) list, adopted by the State of California North Coast Regional Water Quality Control Board (NCRWQCB). This sediment impairment has resulted in non-attainment of designated beneficial uses, primarily salmonid habitat.

In October 1999, Graham Matthews & Associates was requested by the U.S. Environmental Protection Agency (EPA) and Tetra Tech, Inc., to prepare a sediment source analysis and preliminary sediment budget for the mainstem Trinity River watershed. The purpose of the sediment source analysis and preliminary sediment budget is to assist the EPA in establishing a Total Maximum Daily Load (TMDL) for sediment in the mainstem Trinity River watershed. The largest tributary of the Trinity River, the South Fork Trinity River, had a separate TMDL prepared in 1998 (USEPA 1998).

The mainstem Trinity River watershed has been divided into four planning areas (Figure 1) with a total of 70 sub-watersheds (Figure 2a-d) for general planning purposes for this TMDL. For each of these sub-watersheds, past sediment production and delivery, by erosional process, will be evaluated.

The purpose of this report is to compile, summarize, and analyze sediment production data for the Trinity River watershed that could be used for TMDL development. The sediment production data is then integrated with other geomorphic information to develop a preliminary sediment budget for portions of the Trinity River watershed. This study combines office-based analyses of aerial photographs and GIS coverages with extensive field data collection and inventories, including considerable streamflow and sediment transport data collection.

Watershed Overview

The Trinity River is the largest tributary to the Klamath River, and has historically been recognized as a major producer of chinook and coho salmon and steelhead trout. The mainstem Trinity River originates in the Scott Mountains, Eddy Mountains, and Salmon-Trinity Alps of Northern California, approximately 20 miles southwest of Mount Shasta. From its headwaters, the mainstem and East Fork Trinity Rivers flow approximately 60 river miles (RM) before discharging into Clair Engle Reservoir, and then into Lewiston Reservoir. From Lewiston Dam, the regulated mainstem Trinity River flows approximately 112 RM to its confluence with the Klamath River at Weitchpec, picking up the North and South Fork Trinity Rivers and numerous tributaries along the way. The Trinity flows mostly through Trinity County, entering Humboldt County about 28 miles before its confluence with Klamath River at Weitchpec. From the confluence, the Klamath flows approximately 43 miles before discharging into the Pacific Ocean.

BENEFICIAL USES

Fisheries

Historically, the Trinity River was recognized as a major producer of chinook and coho salmon and steelhead trout, with total spawning escapements often over 100,000 fish. Anadromous fish species include chinook and coho salmon, steelhead trout, and Pacific lamprey. Other resident fish species include rainbow trout, three-spined stickleback, speckled dace, and Klamath small-scale sucker (Moffett and Smith 1950). Both eastern brook trout and brown trout have been introduced as sport fish. A dramatic decline in numbers of anadromous fish was observed shortly after construction of the Trinity River Division consisting of Trinity and Lewiston Dams. The dams blocked access to 109 miles of suitable productive habitat. Sedimentation from downstream tributaries could no longer be transported by the greatly reduced flows and was deposited, filling pools and spawning gravels. The degraded habitat limits the productive capacity of the river. The recreational, commercial, and Native American uses of the fishery resource have suffered as a result of the population reduction.

Other Wildlife Resources

Numerous terrestrial species inhabit the Trinity River watershed, including a number of species with special status. The wildlife species represent a high degree of diversity, reflecting the influences of elevation, climate, topography, and vegetation. Characteristic species of forested areas of the Pacific Northwest are relatively abundant. The northern spotted owl, the Pacific fisher, ring-tailed cats, northern flying squirrels are examples of special status species found in the watershed. Species associated with riparian habitats are also diverse, with 127 species sighted during recent surveys (Wilson 1991). Special status avian species found include the willow flycatcher, yellow-breasted chat, yellow warbler, and black-capped chickadee. Rare raptors, such as the bald eagle, peregrine, and merlin, are also found in the watershed. Native herpetofauna include the western pond turtle and yellow-legged frogs.

Natural Resources

The Trinity River watershed has produced natural resources (mining and timber) that have been critical to the economic and social well-being of local residents. Available resources have been actively developed and utilized, providing important economic benefits to the community.

Recreational uses

The Trinity River and watershed offer a wide variety of recreational opportunities, which have become increasingly popular in the last two decades. Fishing, river and reservoir water sports, hunting, hiking, backpacking and camping draw large numbers of visitors to the area. The recreation-based tourism industry has become one of the most important in the watershed. Excess sediment loading reduces fishing opportunities and enjoyment of river-based water sports.

Water supply

The Trinity River and tributaries provide the water supply for residences/businesses from the upper watershed above Clair Engle Reservoir to the Hoopa Valley Indian Reservation near the confluence with the Klamath River. Although the population of Trinity County is quite small, the majority derive their water supply from the river or its tributaries. Excessive turbidity, such as has occurred following the 1997 floods, may have impacts on local water supplies.

RECENT ASSESSMENT, PLANNING AND RESTORATION EFFORTS

The Trinity River Division was authorized by the Trinity River Act of 1955 (PL 84-386) to store water for regulated diversion into the Sacramento Valley for agricultural uses. Construction of Trinity and Lewiston Dams/Reservoirs was completed in 1963, although flows and sediment transport were affected by the projects as early as 1961. The dams blocked access to the upper 720 square miles of the Trinity River watershed, trapped all sediment from the upper watershed, and almost completely regulated flows. Approximately 90% of the annual streamflow at Lewiston was diverted into the Sacramento Basin following construction. Fish and wildlife mitigations were addressed by providing for a minimum flow of 150 cfs, and construction of a hatchery below the Lewiston Dam. In just a few years, a significant decline in the anadromous fish resource was detected. Sediment delivered from tributaries was not transported by these low flows, and large deltas built up at their confluences with the mainstem. Without higher flows to scour young seedlings, riparian vegetation rapidly encroached on the channel, developing a dense stand on the edge of the 150 cfs waterline, which greatly reduced the amount of fisheries rearing habitat. With almost complete flow regulation, residential and commercial development began to encroach on the historic floodplain.

Within a few years after construction, a statewide Task Force was established to evaluate and develop a program for addressing the problems associated with the dams. Funding for the Task Force to implement restoration projects was provided in 1974. Early efforts included construction of spawning riffles and excavation of holding pools in the reach immediately below Lewiston Dam. In 1976, an eight-year appropriation greatly increased the scope of the restoration activities. An EIS assessing the problems of the river and the potential benefits of increasing flow releases was completed in 1980. A decision by the Secretary of the Interior in 1981 increased the flows to a maximum of 340,000 acre-feet in wet years. The decision also ordered a 12-year study by USFWS to assess the effectiveness of the increased flows and other restoration measures. In this time period, pools were periodically dredged at the mouth and downstream of Grass Valley Creek, and the first side channel was constructed.

A major recommendation of the 1980 EIS was the development of a sediment storage dam on Grass Valley Creek (GVC). Although the original preferred solution was a dam at the “Sawmill” site near the mouth of Grass Valley, due to land ownership problems, habitat blockage, and public opposition, the “Buckhorn” site in the upper portion of the GVC watershed was instead eventually selected. This alternative was combined with sediment ponds at the mouth of the creek. The three ponds were completed in 1984, 1988, and 1989, and have been dredged periodically since then. The dam was completed in 1990.

The Trinity River Restoration Act (PL 98-541) of 1984 recognized that the Trinity River Division of the Central Valley Project “substantially reduced the streamflow in the Trinity River Basin thereby contributing to the damage to pools, spawning gravels, and rearing areas and to a drastic reduction in the anadromous fish populations and a decline in the scenic and recreational qualities of such river system”. The act directed the Secretary of the Interior to formulate and implement a fish and wildlife management program to restore the populations to levels approximating those prior to dam construction. The Trinity River Task Force was authorized to include 14 agencies, and a ten year Trinity River Restoration Program (TRRP) was funded. The TRRP has funded a wide variety of restoration activities, including land purchase, watershed restoration, instream restoration, fish population monitoring, and numerous watershed inventories, habitat typing and assessments, and other studies such as evaluation of flushing and/or channel maintenance flows.

Between 1988 and 1992, a program of instream restoration projects was undertaken including dredging of 5 pools, construction of 12 side channels between Lewiston and Junction City, and construction of 9 "feather edge" projects. The feather edge projects were designed to restore rearing habitat (shallow, low velocity gravel bars) for juvenile salmon which has been greatly reduced due to vegetation encroachment and loss of channel complexity. During construction of these projects, however, significant public controversy arose regarding construction turbidity impacts and project visual impacts. This ultimately led to the cessation of the projects in 1993 and the development of the Mainstem Trinity River Watershed Analysis (BLM 1995), the Trinity River Flow Evaluation (USFWS and HVT 1999), and the recently completed Trinity River Mainstem EIS/EIR (USFWS, et. al. 2000). A Record of Decision was adopted by the Secretary of the Interior in December 2000 to begin implementation of the preferred alternative. Litigation in early 2001 has prevented implementation of increased streamflow pending additional environmental analyses, although other project components are moving forward.

At the same time in the late 1980s and early 1990s, the Task Force had become convinced that commercial timber harvesting on highly erosive decomposed granite soils, such as those in GVC, was incompatible with the goals of the restoration program. As a result, some 17,000 acres overlying this erosive formation in the GVC watershed was purchased in 1993 from Champion International. The Bureau of Land Management is now managing the land for purposes other than timber harvest. Since the land purchase, NRCS and the Trinity County Resource Conservation District (TCRCD) have implemented a major watershed restoration effort. Between 1992 and 1996, the program has treated 10,838 acres, including 858 sites inventoried by SCS (1992), decommissioned 45 miles of old roads, landings, and skid trails, improved 19 miles of permanent roads, installed sediment basins, and revegetated extensive areas using 562,000 trees, shrubs, and plugs (TCRCD, in preparation).

Although most restoration effort has focused in watershed areas underlain by the highly erosive decomposed granite, most of the significant tributaries downstream of Lewiston Dam have had either fish habitat typing, watershed inventories for sediment sources, or watershed analyses performed. In 1988, a comprehensive inventory of all road crossings in the watershed was conducted and recommendations made for improvements. The TRRP is considering redoing this inventory and analysis to determine how much progress has been made since then.

In summary, a complex restoration program has been implemented on the Mainstem Trinity River and tributaries since the late 1970s. There is little doubt, based on anecdotal descriptions of the river in that time period, that the restoration program has had a beneficial effect on habitat in the river through a combination of watershed restoration, sediment detention, flushing flows, and mainstem habitat enhancement through pool dredging, side channel construction, and feather edge construction. Many of these actions have only been implemented in the early 1990s, and the full benefits have likely not yet been seen.

PREVIOUS WORK

Although there is an incredibly extensive amount of information available regarding the Trinity River, in most cases, this information was not particularly useful in terms of developing a sediment source analysis. For example, although DWR has mapped landslides throughout the watershed in 1979, there was no information attached to these slides in terms of type, associated cause, or delivery. The landslide inventory had not been updated since 1979 except in portions of the Six Rivers National Forest and in Grass Valley Creek. No comprehensive road inventory or even GIS road coverage for the entire watershed was available at the start of this study. No timber harvest records were available digitally at the start of this study. No long-term monitoring of cross-sections or channel substrate is available for the mainstem, despite thirty years of restoration activities.

The most useful previous information is that related to streamflow and sediment transport gaging, much of which has only been collected since 1997, although much longer-term records are available for Grass Valley Creek. The following sections list previous work regarding sediment and geomorphic parameters for the mainstem Trinity River and tributaries. This collection has been updated from that developed by Matthews and Anderson (1997). Similar sediment source analyses have been completed for other streams and rivers in the vicinity, including the South Fork Trinity River (Raines 1998), Van Duzen River (PWA 1999), and Redwood Creek.

SEDIMENT

Sediment, particularly sand-sized grains (0.0625-2 mm), has been repeatedly identified as a primary factor in the reduction in salmonid habitat in the Trinity River basin, which has been listed as "sediment impaired" by the NCRWQCB per Section 303(d) of the Clean Water Act. Significantly reduced streamflow, combined with accelerated erosion in various sub-watersheds primarily related to land use changes, resulted in sediment accumulation in the mainstem channel, as the river was no longer capable of transporting sediment downstream. These accumulations filled pools, covered spawning riffles and over-wintering areas, and impacted rearing areas, thereby greatly reducing salmonid habitat.

Even before completion of Trinity Dam in 1960, a number of individuals and agencies were concerned regarding the potential for sediment accumulations at tributary confluences once mainstem floods were eliminated by reservoir operation. Initial data collection regarding sediment problems was focused on sediment delivery from eight tributaries between Lewiston Dam and North Fork Trinity River confluence (Ritter 1968).

Grass Valley Creek

Grass Valley Creek watershed, which contains an extensive outcropping of the Shasta Bally Formation - which weathers to sand-sized grains, has been identified as the primary producer of fine sediment between Lewiston Dam and the North Fork confluence. Poor timber harvest practices in portions of this watershed created very high erosion rates and significant volumes of eroded material were transported into the Trinity mainstem.

Numerous studies (CDFG 1963, Coots 1967, Ritter 1968, USGS 1970, CA Resources Agency 1970, DWR 1978, DWR 1980, SCS 1980, SCS 1986, SCS 1992) have described and evaluated sediment sources in and delivery from the Grass Valley Creek watershed. The TRRP addressed this problem in a multi-pronged approach: (1) the Buckhorn Debris Dam was built in 1990 to trap sediments from about 25% of the watershed, (2) sediment control ponds were constructed near the confluence of Grass Valley Creek and the Trinity River, first one in 1984 and two additional in 1988-89, combined known as "Hamilton Ponds", (3) purchase and transfer of 17,000 acres in the watershed from Champion Company to the Bureau of Land Management in 1993 for restoration purposes, (4) extensive watershed restoration at over 550 sites identified as sediment producers by SCS (1992) by the TCRCD in 1993-1996, and (5) sediment control structures at almost every draw draining a cut slope along Highway 299.

Monitoring since 1995 has shown a decreasing sediment yield at the Ponds, which is attributed to the implementation of watershed restoration efforts (TCRCD, in preparation).

Flow and sediment monitoring in Grass Valley Creek is conducted by the USGS at one site, Grass Valley Creek at Fawn Lodge, near Lewiston, CA (gage # 1152560, period of record: 1975-present; drainage area

30.8 mi^2). Additional sediment transport data have been collected by the USGS at another site, Little Grass Valley Creek near Lewiston, CA (gage # 11525580, 1985-1998; drainage area 10.7 mi^2), but little has been done with these data, and as no flow records were developed concurrently, computations of actual loads could not occur.

Sediment Data from other Tributaries and Trinity Mainstem

In contrast to the relatively abundant data for Grass Valley Creek, there is only limited data available for the balance of the watershed, and much of that has been undertaken since 1990 for which there is no historical (pre-dam) comparison.

Mainstem Sediment Transport

Sediment transport data on the Mainstem Trinity River consists of USGS measurements at various locations for different periods of record. At the present, there are no active sediment stations on the Trinity River mainstem operated by the USGS. Historic sediment stations included: (1) Trinity River at Lewiston (gage # 11525500, 1955-1961), (2) Trinity River below Limekiln Gulch, near Douglas City (gage # 11525655, 1981-1991, including both suspended load and bedload), and (3) Trinity River at Hoopa (gage # 11530000, 1960-1979).

USBR measured turbidity of the Trinity River below Lewiston Dam between January and October 1978. DWR collected turbidity data on up to six storms at various sites along the Mainstem Trinity River in WY1978.

Strand (1981) collected sediment transport data (suspended sediment and bed material) at 10 cross sections between Grass Valley Creek and Steelbridge at flows of 300 and 600 cfs. At 2,200 cfs, similar samples were collected at two of these sections.

Johns Hopkins University/University of California Berkeley (JHU/UCB) collected measurements of bedload transport using Helley-Smith samplers in 1991-1993 at two study sites (Poker Bar and Steelbridge) during a flushing flow investigation. Sediment data were also collected using in situ bedload traps in 1993.

McBain & Trush collected bedload transport data at the Steiner Flat feather edge in WY1996. They also collected limited bedload data at Lewiston, and at the former USGS gage location below Limekiln Gulch in WY1997. These measurements consist of only a few data points at 2 or 3 different flows.

Tributary Sediment Transport

The USGS collected suspended sediment data on the following tributaries: (1) Weaver Creek (Gage # 11525800, 1962-1969), (2) North Fork Trinity River (Gage #11526500, 1962-1970), and (3) Supply Creek at Hoopa (gage # 11530020, 1982-1985).

The California Department of Water Resources (DWR 1980) sampled turbidity at 73 sites on the mainstem and tributaries for up to six storms during WY1978.

In WY1997, McBain & Trush collected both suspended sediment and bedload measurements on Rush, Deadwood, and Indian Creeks. Although these data have not yet been reported, they are intended for use in a sediment budget for the Trinity River between Lewiston and Indian Creek. Data collection at these stations has continued to the present by the Hoopa Valley Tribe.

GEOMORPHOLOGY

Changes to the flow and sediment transport regimes of the Trinity River downstream of Trinity and Lewiston Dams have led to significant changes in channel form, primarily in the 40 mile reach from Lewiston Dam to the confluence of the North Fork. These changes to channel form have been identified as one of the primary factors in the decline of salmonids in the mainstem. A number of investigations have either qualitatively or quantitatively described the channel changes including:

Mainstem Data

Cross Sections

Over the years, numerous cross sections have been surveyed for a variety of purposes and by different organizations. Unfortunately, no comprehensive program has yet been initiated that incorporates historic data and provides for long-term trend monitoring.

The cross sections surveyed by the USGS (Ritter 1968) at the 8 tributary confluences in 1961-1965 (a total of 22 were across the mainstem) and apparently resurveyed in 1970, are the first post-dam sections located in this investigation. Cross sections were surveyed by DWR between Lewiston and Douglas City in 1973, 1974, and 1975, but at different locations than the USGS sections (FKA 1980). These DWR sections were referred to in the FKA (1980) report, but it is unknown if the data and locations are currently known.

Evans (1979) surveyed 25 cross sections below Lewiston Dam in 1970 and 1975-76 to investigate changes in stream width and the encroachment of riparian vegetation. It is unknown if the cross sections can be replicated.

The U.S. Army Corps of Engineers surveyed numerous cross sections along the Trinity River between Lewiston and Junction City in order to prepare a floodplain evaluation (USACE 1974). The profile sheets show only 23 section locations, but the thalweg and water surface profiles have much more detail, indicating that many more sections were used in the analysis.

An instream flow study by U.S. Fish & Wildlife Service (USFWS 1978) established 6 study areas (Bucktail, Poker Bar, Steelbridge, Douglas City, Oregon Gulch, and Coopers Bar) with 53 transects measured at several different flows. The study report did not contain sufficient information with which to relocate these sections, and it is not known whether such information is available.

Strand (1981) developed a hydraulic model to compute sediment transport rates between Grass Valley Creek and Steelbridge. This study used 23 cross sections with observed water surface elevations at low flows (300 and 600 cfs). The study report did not contain sufficient information with which to relocate these sections, and it is not known whether such information is available.

The Trinity River Flow Evaluation conducted by USFWS began in January 1985 (USFWS 1986). 14 study sites for implementation of the USFWS Instream Flow Incremental Methodology were established in 1985 between Lewiston Dam and Hoopa Valley Indian Reservation. In 1985, depth, velocity, substrate and cover measurements were collected at 127 transects at flows of 350 and 450 cfs. Cross sections were marked with rebar, the locations of the sections documented, and survey benchmarks were established (USFWS 1985). In 1986, the most upstream site immediately below the Lewiston Fish Hatchery was abandoned due to bulldozer modifications. Other sites have been resurveyed periodically since then, primarily to evaluate habitat conditions at a range of flows. Since the Flow Evaluation Report has not yet been completed, there remain a series of unknowns regarding the complete data set available through the Flow Evaluation Program.

JHU/UCB flushing flow study established two detailed study sites at Poker Bar and Steelbridge, which were superimposed on existing USFWS study reaches. This study established 11 cross sections at Poker Bar, and 10 at Steelbridge. These cross sections were resurveyed after flushing flow releases in 1991, 1992, and 1993. In addition, the study mapped pool volumes at 5 locations for pre and post flow releases. Cross sections and/or digital terrain model development for use in computing volume changes occurred at each site. The maps and cross sections provide a history of changes at these locations between 1991 and 1993. These pools are being resurveyed by McBain & Trush in 1997 for evaluating the effects of the 1995 and 1997 high flows.

A series of cross sections (8 total) were established between Poker Bar and Steelbridge in 1992 for the purposes of evaluating the effects of overbank flow in a regulated river system (Pitlick 1992). These cross sections were surveyed before and after the 1992 flow release of 6,000 cfs. The sections were surveyed into a common datum. The sections were monumented and accurately located on enlarged aerial photographs.

Trinity Restoration Associates performed a channel maintenance flow evaluation between 1991 and 1993 using 11 sites between Lewiston and the North Fork Trinity River, which were selected after stratifying the river into 10 geomorphic channel types based on valley confinement, slope, distance below dam, and potential for restoration. The study sites consist of monumented cross sections, minimum of 5 per site, and topographic maps produced from total station surveys.

McBain & Trush have produced detailed mapping of the feather edge sites since 1995 to evaluate the physical channel response of mechanical channel restoration.

McBain and Trush surveyed a series of 16 cross sections between Lewiston Dam and Weaver Creek for bedload modeling in 1995. These have not yet been resurveyed.

USFWS has also monitored biological parameters at the feather edge sites since 1990, which has involved establishment and resurveys of numerous transects. Some of these transects are duplicates of McBain & Trush cross sections.

DWR (1997) developed a hydraulic model of developed areas along the Trinity River between Lewiston Dam and Junction City. The modeling was focused at 6 sites where low lying bridges or homes could be inundated of damaged during higher flow releases or unusual flood events. The Lewiston site contained 8 cross sections, Salt Flat site 10 cross sections, Bucktail site 17 cross sections, Poker Bar site 17 cross sections, Steelbridge site 12 cross sections, and the Douglas City/Indian Creek site 12 cross sections. The study included the surveyed thalweg profile and nine computed water surface profiles ranging from flows of 400 to 71,600 cfs.

McBain & Trush and the Hoopa Valley Tribe surveyed many cross sections between Lewiston Dam and below Rush Creek in 2001 for development of a sediment transport model.

Bed Composition

Bed composition or the size distribution of the channel substrate has been a continuing concern along the Trinity River since extensive sedimentation was observed at and downstream of tributary confluences following flow regulation from dam construction. Although numerous qualitative descriptions of these impacts are found in the Trinity River literature, few quantitative data exist.

FKA (1980) collected 61 samples of bed material at sites between Lewiston Dam and Manzanita Creek, including the tributaries. 34 samples were collected at natural riffles on the mainstem, and 10 were collected at "restored" riffles. There is no description of the methods used in collecting the bed samples other than to say that the method has been used for years by the Washington Department of Fish and Game. Size distributions for all samples are reported in Appendix B of the 1980 document.

Strand (1981) collected bed material samples at 10 cross sections between Grass Valley Creek and Steelbridge, but the data are only presented in terms of reach-averaged size distributions.

The USGS collected size distribution data for channel substrate at the Limekiln gage between 1981-1991. Generally, these data are collected with a clam-shell sampler at higher flows, and by wading at low-flows.

Trinity Restoration Associates (1993) measured surface and subsurface size distributions at their 11 study sites using a combination of surface and subsurface bulk samples collected with McNeil samplers, and surface pebble counts.

Trinity Restoration Associates collected 15 permeability and freeze core samples at a pilot suction dredging operation by the Trinity River Restoration Program near Poker Bar in 1993. These data have not been published, but are available from Keith Barnard (K. Barnard, pers. comm., 1997).

JHU/UCB collected detailed information on size distribution of bed material for pre and post flow releases in 1991-1993 at their detailed study sites. 36 pebble counts were made at the Steelbridge site, and 53 at the Poker Bar site during the study period. 28 bulk samples were collected at Steelbridge and 23 at Poker Bar.

McBain & Trush compiled facies maps at 16 cross sections between Lewiston and Weaver Creek. The substrate determination was based on 1-4 pebble counts per section as necessary to adequately characterize the bed.

McBain & Trush and the Hoopa Valley Tribe have continued substrate sampling at the feather edge sites through bulk samples and pebble counts.

Effects of Flushing and/or Channel Maintenance Flows on Channel Form and Substrate

There have been two detailed studies conducted on the effects of flow releases on the channel bed: (1) JHU/UCB (1995) evaluated flows for the purpose of prescribing the most effective flow release to remove fine sediments from spawning riffles, and (2) Trinity Restoration Associates (1993) for the purposes of evaluating potential channel maintenance flows.

Both studies used a variety of techniques to evaluate changes for pre and post flow releases including cross section and/or total station surveys of study sites, use of painted rocks for tracers to evaluate sediment movement, scour chains or pockets of painted rocks to evaluate depth of scour during the flow releases, McNeil samples for surface and subsurface grain size distributions, pebble counts for surface size distributions, and bedload traps for evaluation of sediment transport rates.

Other studies prior to these field sampling based investigations, include FKA (1980), Strand (1981) and Nelson et. al. (1987), and more recently, Milhous (1994). These studies were all based on limited field data collection and application of various sediment transport formulae to predict the magnitude and duration of flushing flows necessary to both clean the Trinity River downstream of Grass Valley Creek of fine sediments (one-time flushing release), and maintain it in this condition (annual maintenance flow).

Effects of Floods/Reservoirs on Turbidity after large Flood Events

The hydrology of the pre-dam period, as reflected by USGS suspended sediment records at the Lewiston Gage from 1956-1960, showed that turbidity and/or suspended sediment loads responded very quickly to flow increases during storms. The duration of these flows and the elevated turbidity were generally short-lived during winter storms, and of longer duration during spring snowmelt periods. The effects of hysteresis on turbidity/suspended sediment during storm and snowmelt hydrographs were also documented.

In most years, turbidity values from reservoir releases are expected to be quite low, as documented by USBR (1979), compared to other downstream reaches and tributaries (DWR 1980). However in unusual flood years, such as WY1965, 1974, and 1997, large volumes of fine sediment are eroded from the watershed upstream of Trinity Dam and are subsequently trapped in the reservoir. As flows are released from the reservoir, the turbidity may remain substantially elevated for many months. A California Department of Public Health investigation following the December 1964 flood event indicated that it took nine months for river flows to approximate pre-storm clarity. Similar observations were made by residents following the January 1974 (Herb Burton, pers. comm., 1997), and following the January 1997 flood.

Riparian Vegetation Encroachment

Several studies have been undertaken to evaluate the extent of riparian vegetation encroachment on the Trinity River between Lewiston Dam and the North Fork Trinity River. Pelzman (1973) reviewed causes and possible prevention of riparian plant encroachment on fisheries habitat along the Trinity River. Evans (1975, 1979 and 1980) evaluated riparian encroachment along the Trinity River in this area. Wilson (1993) mapped the extent of riparian vegetation in 1960 and 1989 for the Mainstem Trinity River Watershed Analysis.

Trinity Restoration Associates (1993) mapped the location of riparian communities in relation to different flows at their 10 study sites. Each study site also included two monitoring sites for riparian germination and seedling survival. Alluvial features in the study reaches were monitored for seedling scour and survival during the flow releases.

McBain & Trush began detailed riparian vegetation evaluations at 3-5 cross sections at the Bucktail, Steiner, and Sheridan feather edge sites in 1995. Statistical analysis showed that trends could be described using data from one cross section (S. McBain, pers. com. 1997), and in 1997 only one cross section at each

of the nine feather edge sites was monitored. Monitoring included species, survival, growth rates, soil moisture conditions using piezometers and gypsum blocks, and surveys to determine scour/fill at the cross sections. This monitoring has been continued by McBain & Trush and the Hoopa Valley Tribe.

Pool Volumes

Filling of pools with fine sediment has been often cited as an important factor in the decline of fisheries on the Trinity River, however virtually no data exist to quantitatively describe the areal extent and volumetric magnitude of such infilling.

The Trinity River Flow Evaluation (USFWS 1989, 1990) mapped four pools (Upper Cemetery, Cemetery, Bucktail, and Poker Bar (also known as Society Pool) before and after dredging by the Trinity River Restoration Program primarily to evaluate habitat gains as a result of the sediment removal. The study also prepared an inventory of holding pools in 1989 between Lewiston Dam and Junction City using a selection criteria of a maximum depth of at least 10 feet. Pool width, length, area, maximum depth and volume were computed.

Trinity Restoration Associates mapped pool volumes in their 11 study sites in 1992-1993 to determine net changes in scour and fill.

As noted previously, JHU/UCB (1995) mapped five pools between Grass Valley Creek before and after flushing flows in 1991-1993. The same pools were re-surveyed by McBain & Trush in 1997.

McBain & Trush have mapped certain pools as part of their tributary delta surveys, including pools at Deadwood, Rush, and Indian Creeks.

Surficial Sediment by Visual Estimate

In order to provide a qualitative estimate of fine sediment (< 8 mm) storage over the entire 5.8-mile study reach between Grass Valley Creek and Steelbridge, the JHU/UCB (1995) study mapped the channel bed by independent visual estimates of the fine sediment percentage on the bed. Areas of uniform fine sediment content were mapped onto enlarged aerial photographs (scale 1:1,200). The observations were made prior to the 1992 flow release and immediately following the 1993 release. For computation of sediment storage in between the pools, discrete sub-reaches were defined. The major pools typically separated the study reaches. For each of these discrete sub-reaches, a weighted average fine sediment percentage was computed. The fine sediment estimates were used to evaluate a sand routing algorithm.

Tributary Data

Data are relatively scarce on the physical characteristics of the tributary channels, with the exception of Grass Valley Creek, although even in this case there is little quantitative historic data with which to evaluate long-term trends.

Numerous watershed assessments and sediment source inventories have been conducted on tributary basins in the mainstem Trinity watershed. These include the following basins: New River, Big French Creek, North Fork Trinity River, Canyon Creek, Soldier Creek, Dutch Creek, Conner Creek, Dutch Creek, Maple

Creek, Four Creeks (Soldier Bar, Big Bar, Price, and Eagle Creeks), Grass Valley Creek, Rush Creek, Deadwood Creek, Hoadley Gulch, Indian Creek, Browns Creek, Reading Creek, and Weaver Creek. Most of these documents focused on sediment sources, primarily related to roads, which were inventoried, prioritized, and recommendations for treatment generally made.

Fish habitat typing and habitat assessments have also been completed on many tributary basins. These reports generally sub-divide the channel into various habitat units and provide the relative abundance of each unit, including pool depth, ocular estimates of substrate, embeddedness, cover, etc. Such habitat assessments have been completed on Weaver Creek and tributaries, Deadwood Creek, Reading Creek, Dutch Creek, Connor Creek, Browns Creek, Indian Creek, Canyon Creek, and the New River.

Cross Sections

Selected cross sections on various tributaries are available from County and Caltrans surveys, either at bridges or due to road improvement/repair projects. Known cross section data are available from bridges on Highway 299 over Indian Creek, Weaver Creek, Grass Valley Creek, Canyon Creek, and the North Fork Trinity River.

Pacific Watershed Associates (PWA 2001) monitored channel conditions at four sites in Grass Valley Creek since 1991 (1991, 1993, and 1995 surveys), following the construction of Buckhorn Debris Dam. One monitoring reach is located upstream of the reservoir, the second immediately below the spillway, the third just upstream of the confluence with Little Grass Valley Creek, and the fourth is in lower Little Grass Valley Creek. This trend monitoring program includes detailed long profiles, numerous cross sections (approximately 80), and numerous monumented photo points. Selected portions of the PWA monitoring sites have been re-occupied by NRCS staff in 1997 after the large winter storms as part of their monitoring efforts in the Grass Valley Creek watershed.

Redwood Sciences Lab surveyed cross sections and a longitudinal profile in lower Grass Valley Creek near the USGS Fawn Lodge gage in 1996 for the purpose of comparing various monitoring methods for assessing the relative impacts of sediment. Unfortunately, these section locations were not monumented (T. Lisle, per. comm. 1997).

McBain & Trush have surveyed three cross sections each in 1997 on Rush and Indian Creeks for slope-area computations at their gaging stations. Three other cross sections on lower Rush Creek were surveyed in 1995 and resurveyed in 1997. One cross section was also surveyed on Deadwood Creek.

NRCS staff completed detailed topographic surveys, which included about 20 cross sections along a one-mile reach of Indian Creek for the design and construction of a channel restoration project. The project was constructed in 1996, but suffered significant damage in the high flows of WY1997. NRCS staff intends to re-survey the project reach this season in order to assess channel changes. A second reach also about one mile in length was surveyed downstream of the County road bridge. This survey also included about 20 cross sections.

NRCS staff are monitoring 6 large restoration sites along channels in the Grass Valley Creek watershed.

These sites typically contained large landings that were removed with heavy equipment and the estimated original channel configuration restored.

Bed Composition

FKA (1980) collected channel substrate samples on eight tributaries (4 on Rush Creek, 1 on Indian Creek, and 2 each on Grass Valley, Weaver, Browns, Reading, and Canyon Creeks, and 2 on the North Fork Trinity River.

Pacific Watershed Associates (PWA 2001) has monitored channel conditions at four sites in Grass Valley Creek. Substrate monitoring included McNeil samples, scour chains (which were all washed out in the 1995 high flows), and photo points.

Redwood Sciences Lab (T. Lisle, pers. comm. 1997) measured channel substrate using pebble counts in their study reach on Grass Valley Creek near the USGS Fawn Lodge gage. They had previously collected 4-6 bulk samples per residual pool volume reach (see next section).

Douglas Parkinson & Associates sampled bed material in the Indian Creek watershed in 1991. 11 samples were collected from the bed at various points along the mainstem of Indian Creek and in significant tributaries. Size, shape, and lithologic analyses indicated a high potential for bed compaction, explaining the observed abandonment of redd construction by salmonids due to the cemented substrate.

McBain & Trush have collected bed samples of fresh tributary deposits in their deltas for Rush, Deadwood, and Indian Creeks.

The USGS has collected bed material samples at their two sediment gages in the Grass Valley Creek watershed since 1975 for the Fawn Lodge gage, and since 1985 for Little Grass Valley Creek.

Pool Volumes

Lisle and Hilton (1992) measured residual pool volumes in the Big French, Horse Linto, Three Creeks, and Grass Valley Creek watersheds. The study reach in each creek consisted of between 13 and 21 pools. The watersheds were selected to represent a variety of land uses and thus sediment yields. Big French Creek had a reach averaged V* value of 0.04, indicative of very low sediment yields, while Grass Valley Creek had an average V* of 0.50. Fine sediments contained in the pools were sampled and analyzed for size distribution.

STUDY AREA

The Trinity River drains a 2,036 mi^2 watershed (excluding the South Fork Trinity) located in the northern California Coast Range in Humboldt and Trinity Counties (Figures 1 and 2), joining the Klamath River at Weitchpec, some 43 miles above the Klamath's entry into the Pacific Ocean. Despite such a large watershed, the population is quite small, only 13,300 in all of Trinity County according to the 2000 census, with perhaps an additional 7,000 in the Humboldt County and Hoopa Reservation portions of the lower watershed.

Sub-Watershed Areas

The Trinity River watershed has been subdivided into 4 planning watersheds (PW): Upper Trinity River, Upper Middle Trinity River, Lower Middle Trinity River, and the Lower Trinity River. These planning watersheds encompass drainage areas of 691.6, 321.2, 719.6, and 303.2 square miles (mi^2), respectively. The four planning watersheds have been divided again into a total of 70 Sub-Watersheds (SW). The four planning watersheds follow the CALWAA divisions, although the sub-watersheds do not. Many small sub-watersheds were delineated to coincide with drainages where streamflow and sediment transport data were collected. Table 1 presents the Planning Watersheds and Sub-Watersheds along with their drainage areas, while these areas are shown graphically in Figures 1 and 2.

History

The history of the Trinity River and its watershed is dominated by resource development, whether by mining, timber harvest, or water resources storage and diversion. Given the generally steep, mountainous terrain, relatively little flat land exists, and thus agriculture has played only a minor role in the economic development of the watershed. Logging, mining, fisheries, and recreation are the predominant uses.

Timber harvest began in the mid 1850's in response to the large population increase during the mining era and in conjunction with mining activities. Only the largest and most accessible trees were harvested in this time period. Following World War II, with much higher demands, significant volumes of timber were harvested and the number of mills increased sharply. Production averaged over 200 million board feet between 1950 and 1990. Industry changes and natural resource concerns have led to a significant reduction in harvest volumes (primarily on federal lands) in recent years, and Trinity County has only one mill currently operating, compared to 28 in 1961 (BLM 1995).

After 1940, tractor yarding and the construction of roads, skid trails and landings were the primary types of logging practices. Until the Forest Practices Act was passed in 1973, logging practices were unregulated. This Act required road construction and timber harvesting practices intended to protect aquatic habitat and watershed resources. During the past twenty years the use of cable yarding on steeper slopes has increased substantially, and tractor logging is generally restricted to gentler slopes. These most recent changes in practice create far less ground disturbance than tractor yarding, although tractor yarding is still responsible for a significant amount of the harvest, depending upon ownership.

Gold mining began in 1848 with the discovery of gold at Reading Bar near Douglas City. The gold rush brought a large influx of miners and settlers to the area. Relatively small mining operations gave way to huge hydraulic operations moving millions of cubic yards of hillslope and floodplain materials. The hydraulic mining era continued until the 1930s, much later than in most of California. Today, mining is mostly limited to small suction dredging operations which are predominately recreational, though there are over 7,000 mining claims across Trinity County (BLM 1995).

Ownership

Detailed ownership maps for the watershed were obtained from a variety of sources including Trinity County and the USFS in a GIS-based format. The majority of the basin is under some form of public ownership, including the Trinity Alps Wilderness area, the Shasta-Trinity National Forest, Six Rivers National Forest, Bureau of Land Management, Bureau of Reclamation, and various state and county entities. Ownership patterns in the basin, particularly upstream of Junction City, are often a checkerboard pattern of public and private lands as a result of railroad grants, mining laws, and homestead laws.

Figure 3 shows overall ownership patterns in the study area, while Table 2 quantifies the distribution both for the entire watershed and on a Planning Watershed level. More detailed figures and tables for each Planning Watershed and their associated sub-watersheds may be found in Appendix A. In the basin, 31.8% of the area is contained in the Trinity Alps Wilderness, while another 34.5% is managed by the U.S. Forest Service mostly in Shasta-Trinity NF, with a much smaller amount in Six Rivers NF. The Bureau of Land Management (4.3%) and the Hoopa Valley Indian Reservation (5.6%) are other significant public/tribal ownerships. 23.2% is privately held, with 15.6% owned by industrial timberland (dominated by the 13.4% of Sierra-Pacific Industries, Inc. Smaller private ownerships are limited to 7.7% of the watershed.

Topography

The Trinity River Basin is predominately mountainous and forested, with steep V-shaped valleys formed by tributaries (Figure 4). Much of the basin is remote, and moderately to extremely rugged. Most of the available farmland, approximately 5 percent of the basin, occurs in the Hayfork Valley, which is part of the South Fork Trinity River sub-basin. Elevations in the basin range from greater than 9,000 feet in the Trinity Alps, to less than 300 feet at the confluence of the Trinity and Klamath Rivers.

Slope Analysis

A slope analysis of the watershed was conducted using 10-meter DEM GIS data provided by the U.S. Forest Service. Figure 5 graphically presents the results of this analysis by color-coded slope class. Table 3 summarizes the areas of the entire watershed and the planning watersheds by slope class. The differences between the Lower Middle Trinity, and to a lesser extent, the Lower Trinity, which both contain a higher percentage of area with steeper slopes, and the two other planning watersheds are readily apparent. Over 50% of the Lower Middle Trinity has slopes in excess of 50%, while the Upper and Upper Middle Trinity have only 31-33%. A significant proportion of this steep land lies either within the wilderness areas or in the National Forests.

Geology

North Coastal California contains two parallel geologic provinces that differ in age, lithology, structure, and metamorphism: the Coast Range Province and the inland Klamath Mountains Province. The Coast Range Province, containing the well-known Franciscan Assemblage that is composed of unstable sedimentary and volcanic rocks, occupies a very small area in far western portion of the study area. East of the coast ranges are the older Klamath Mountains, underlain by metamorphic and plutonic rocks. The two provinces are separated by the South Fork Mountain Schist, a formation found to be quite unstable after disturbance in the SF Trinity watershed (Raines 1998).

The majority of the mainstem Trinity River Basin lies within the Klamath Mountains Geomorphic Province (Figure 6), which has primarily resulted from stream erosion of an elevated plateau resulting in a basin dissected by drainage channels. Soils in the basin are generally thin and well-drained, on moderate to steep slopes over sedimentary, granitic, and metamorphic rocks. The Klamath's were divided into the Eastern Klamath, Central Metamorphic, Western Paleozoic and Triassic, and Western Jurassic sub-provinces (Irwin 1960). Rock units generally dip to the east, with the older eastern unit overlying the younger western unit. Plutonic rocks are found intruding the metamorphic rocks throughout the watershed.

Eastern Klamath Sub-province

This sub-province occupies the eastern one-third of the watershed and includes the Trinity ultramafic sheet, Copley greenstone, and Bragdon Formation. These units are generally considered to be stable and erosion-resistant, with the exception of serpentinites contained in the ultramafic rocks that are characterized as readily susceptible to mass movement.

Central Metamorphic Sub-province

West of the Eastern Klamath sub-province is the Central Metamorphic sub-province. Two medium-grade to high-grade metamorphic rock units comprise this group: the Salmon Hornblende Schist and Abrams Mica Schist. Both of these units are considered moderately erodible.

Jurassic to Permian Sub-province

This sub-province is subdivided into three terranes: the North Fork, Hayfork, and Rattlesnake Creek (Irwin 1972).

The Northfork Terrane consists of serpentinite, gabbro, and diabase along the western side while rocks further east include silicious tuff, chert, mafic volcanic rock, minor lenses of limestone, phyllite, and locally, pebble conglomerate. The igneous rocks and the sediments produce moderately stable slopes, while the serpentinites produce unstable slopes.

The Hayfork Terrane consists of metamorphic and meta-volcanic rocks that form the steep, stable slopes of the Lower Middle Trinity. Landslides are a relatively minor feature in this terrane.

The Rattlesnake Creek terrane is composed of a mixture of metamorphic rocks including ultramafics, gabbro, volcanics, phyllite, limestone, and locally sandstone and pebble conglomerate. This unit is highly deformed and is considered unstable, with numerous landslide features.

Western Jurassic Sub-province

The western Jurassic sub-province consists of the Galice and Rogue Formations, which consist of interbedded graywacke, mudstone, conglomerate, and some volcanic rocks. Although many debris slides occur in the Galice along the South Fork Trinity, where the river parallels the structure and dip-slopes are formed, while the mainstem Trinity crosses the structure, and the Galice has moderately stable slopes.

Intrusives

North and southeast of Weaverville are light-colored, coarse-grained diorites of the Shasta Bally Batholith and associated Weaver Bally Batholith. Hill slopes underlain by these granitic rocks are deeply weathered. Slopes are erodible and produce large volumes of sediment when protective vegetation is removed.

The Canyon Creek pluton in the north central part and Ironside Mountain Batholith in the western half of the watershed are light-to medium-colored hornblende quartz diorites. They form steep slopes and are not considered serious erosion problems.

Weaverville Formation

The formation consists of weakly consolidated mudstone, sandstone, and conglomerate with an impervious dark green clay matrix, and sparse interbeds of light-colored tuffs (Irwin 1974). The Weaverville Formation tends to be unstable, particularly along roadcuts and streambanks where slopes are oversteepened.

Glacial, Terrace, and Surficial Deposits

Glacial deposits are found in the northern part of the watershed including the Canyon Creek, Stuarts Fork, Swift Creek, and Coffee Creek valleys. Terraces composed of sand and gravel from glacial erosion flank much of the Trinity River upstream from the North Fork and also from Salyer to Hoopa.

Climate

Climate in the Trinity River Basin can be described as "Mediterranean" in terms of precipitation, with most precipitation occurring in late fall, winter, and spring. Nearly all precipitation occurs from storms originating over the Pacific Ocean. The amount, distribution, and form (rain, snow, hail, etc.) of this precipitation are generally determined by topographic features of the basin. Average annual rainfall varies form 35 to 75 inches (Figure 7) with a range of variation, dependent upon location, of 15 to over 100 inches in extreme years (BLM 1995).

Large temperature fluctuations occur over the basin depending on location, topography, and season. Due to the moderating effects of the Pacific Ocean, temperatures are generally warmer and colder in summer and winter, respectively, west to east across the basin. Summer temperatures range between 90 to 110 degrees Fahrenheit at the lower elevations, and are generally cooler by 3 to 4 degrees Fahrenheit per 1,000 feet increase in elevation (BLM 1995). At lower elevations, freezing temperatures can be experienced any time during fall, winter, and spring, and any time at higher elevations.

Snow levels vary greatly over the basin from storm to storm, with lower levels typically on the east side of the basin. At higher elevations (7,000 feet and above) most precipitation falls as snow; conversely, only the lowest river canyon elevations on the west side of the basin (1,000 to 2,000 feet) receive most precipitation as rain (BLM 1995). The transient rain/snow zone geography can significantly influence precipitation and run-off events. Large precipitation quantities from warm storms subsequently falling on deep snow packs can produce extreme runoff events over much of the basin: most large flood events occur during this scenario. According to BLM (1995), occasional summer thunderstorms can cause more erosion and channel instability than the more common moderate winter storms.

Time Period of Analysis

The time period for the sediment source analysis includes a 76-year period extending from 1924 to 2000.

The period was dictated by available aerial photography coverage in the years 1944, 1979, and 2000. We assumed that features observed in the 1944 photographs covered a +/- 20-year period generally similar to the length of the subsequent 1980-2000 study period. Therefore, we assigned 1924 as the beginning of the sediment budget period.

Sediment source data have been developed for these time intervals and others, depending on location in the watershed as explained in the following section on stratification of the watershed. These intervals capture different periods of sediment-producing events, including both large storms (the 1938, 1956, 1965, 1974, and 1997 water years contained notable high flows) and changes in timber harvest practices. Thus, a combination of changing harvest and road building techniques, together with most of the largest storms this century, provide the framework for evaluating changes in sediment production and delivery within the watershed.

METHODS

Development of sediment TMDL standards for a watershed with highly divergent sediment sources, due to differing bedrock geology and land management, requires much more detailed information compared to less complex watersheds. Without specific information developed at a sub-watershed level, load allocations and reduction levels to meet specified targets are only crude estimates. Although the Trinity River has superior information in many areas compared to many watersheds, a number of areas lack any appreciable data, and existing information does not allow refinement of source areas and allocations beyond a main sub-watershed level. Furthermore, the size of the Trinity watershed requires an approach that stratifies, sub-samples, and perhaps even eliminates areas from more detailed study.

STRATIFICATION OF THE WATERSHED

Given the size of the watershed (approximately 2,000 mi^2), a sub-sampling approach was developed using a stratified random approach based primarily on geology and sub-watershed priority as developed by the Trinity River Restoration Program. The basin has been sub-divided into four Planning Watersheds: (1) the Upper Trinity Watershed, consisting of watershed areas upstream of Trinity Dam, (2) the Middle Trinity Watershed, extending from Lewiston Dam to Junction City, (3) the Lower Middle Trinity from Junction City to the confluence with the South Fork Trinity River, and (4) the Lower Trinity which extends from the SF Trinity confluence downstream to the confluence with the Klamath River.

Priority 1 Area: Upper Middle Trinity

The Middle Trinity Watershed has been given the highest priority simply because it provides the most critical spawning and rearing habitat for anadromous salmonids. All major tributary watersheds in the high priority area (Lewiston Dam to Junction City) will be mapped.

Priority 2 Area: Lower Middle Trinity

Selected tributaries will be mapped in this Planning Watershed, with representation of the various geologic formations in this area. At least one large and one small north side tributary draining the Trinity Alps will be mapped. Several smaller watersheds on the south side of the mainstem will be mapped.

Priority 3 Area: Lower Trinity

A considerable portion of the Lower Trinity is within the Hoopa Valley Tribal Reservation and the tribe has developed a water quality plan for their lands and has established a number of streamflow and sediment transport monitoring stations. Several significant streams outside of the Reservation will be monitored including Horse Linto and Cedar Creek, Willow Creek and some of its tributaries. All watersheds in which streamflow and sediment discharge data are collected will also be mapped from aerial photography, providing such photography can be located.

Priority 4 Area: Upper Trinity

In the past, the upper watershed has been mostly ignored in terms of producing sediment that would impact salmonids downstream of the dams. However, with three events in the past 30 years (Dec 1964, Jan 1974, and Jan 1997) where turbidity releases from the reservoirs have had a potentially significant impact on downstream habitat, this area can no longer be dismissed, nor can the potential impact to beneficial uses from management-related sediment delivery within the Planning Watershed. Although there are considerable portions of the upper watershed in wilderness, the balance of the area is a checkerboard of public and private ownerships.

With this stratification in terms of prioritizing study effort, much of the work was focused on the Upper Middle Trinity. For example, all significant tributaries in this Planning Watershed have continuous streamflow monitoring stations. The majority of our road inventories, sample plot sites, substrate quality samples, and bank erosion inventories were conducted within this Planning Watershed.

COMPILATION OF AVAILABLE DATA

The Trinity River watershed has an extensive collection of available data covering many aspects of natural resource management over the past 50 years. Existing data were compiled from a number of sources, including a variety of federal, tribal, state, and local agencies. Surprisingly though, much of the available information is only of limited use in developing a sediment source analysis that must cover the entire watershed. We focused our efforts on collecting data pertinent to sediment TMDL elements, such as problem characterization, background information, indicators of impairment, and source identification. This included streamflow and sediment transport data, historical survey data, and previous efforts at source analysis.

HYDROLOGY

Existing precipitation data were collected from the USFS, DWR, and the National Weather Service. Streamflow records were obtained from the USGS, USBR, DWR, and the Trinity River Restoration Program.

Stream Flow and Sediment Transport

Streamflow records have been maintained in the Trinity River basin for various periods of record. The USGS, USBR, DWR, the Hoopa Valley Tribe, and private organizations have maintained gages on the Mainstem Trinity River, North Fork Trinity River, various tributaries, and Clair Engle Lake. The quality of streamflow records range from good to excellent. Most records are available from the various agencies and/or organizations in either digital or hardcopy formats.

Table 5 lists the active gaging stations for the Mainstem Trinity River, and Table 6 lists various discontinued gaging stations. Both tables include reach location, station number, station name, station type, agency and/or organization, period of record, and drainage area. All gaging stations are listed in downstream order.

Hoopa Valley Tribe and the Trinity River Restoration Program

Since 1996, the Hoopa Valley Tribe has been installing and operating a series of mainstem and tributary streamflow stations, mostly in the Upper Middle Trinity Planning Watershed. The purpose of these stations is to provide streamflow and sediment transport data with which to develop a sediment budget for the mainstem in this reach, as part of planning efforts for implementation of the Trinity River Restoration Program.

GMA WY2000 and WY2001 Data Collection

Phase 1 of data collection for this project, completed during WY2000, involved a reconnaissance assessment of relative tributary sediment yields based on collection of turbidity and suspended sediment data during storm events. Sample sites were established throughout the entire watershed on sub-watershed of all sizes and with a variety of upstream land uses. In WY2000, samples were collected at over 150 sites, with a total of 650 samples collected. Preliminary streamflow rating curves were established at over 60 sites, with a total of 230 discharge measurements made. Sample sites were stratified by geology and comparisons of sediment transport rates between basins and differing geologies were made.

In Phase 2, dataloggers were installed at 11 sites throughout the watershed. These records, combined with existing streamflow and sediment transport stations operated and maintained by the USGS or the Hoopa Valley Tribe, were used to compute continuous records of streamflow and sediment transport. In addition, many of the manual gage sites, established in Phase 1 were also operated in WY2001. Most of these sites were upgraded to contain crest stage gages and indirect peak discharge (e.g. slope-area peak) computation sites. Unfortunately, WY2001 turned out to be a critically dry year, with only a few small storms. Approximately 400 samples were collected in WY2001 in the Trinity Watershed.

Site Establishment

Monitoring stations were established at various sites throughout the watershed during this study based on access permission and access availability (all-weather roads) during storm events. Stage was generally measured by fenceposts driven into the streambed at most sites, although a few sites had standard staff plates installed at the gage location. During sampling, river stage was measured from the water surface to the top of the fence post using a pocket surveyor's tape. Stage was measured directly off the staff plate at these locations. Most stage locations were surveyed to a locally established benchmark using an auto level in the case that the sites are disturbed (by vandalism or high flows) and the stage measurement location needs to be reestablished. Flow measurements were taken at all sites using standard or modified USGS methods. All streamflow measurements collected by GMA at their sites were limited to wading measurements. Wading streamflow equipment included a 4ft top-set wading rod, JBS Instruments AquaCalc 5000-Advanced Stream Flow Computer, and either a Price AA or Pygmy current meter.

Due to the large number of study sites and short period of time for the study, it was necessary to modify some standard stream flow methods. The Price AA current meter was used where stream flow velocities were over 3.0 ft/s and at measurement locations where surging flow or poor hydraulics were encountered.

The Price AA meter typically performs better in sections with surging flows or poor hydraulics due to its added weight. Typically, the Price AA meter is not used in depths below 1.5 ft, but due to poor hydraulics and the steep gradient of many locations, the Price AA current meter was used in depths as shallow as 0.3 feet.

The maximum discharge per vertical was set as 10% instead of the more standard 5% in order to streamline the time required to complete flow measurements. Fewer verticals were also used in discharge measurements in order to reduce field time associated with a single measurement, thus allowing for more measurements per person-day of fieldwork, or to limit the measurement to a smaller portion of the often rapidly changing storm hydrograph. Most discharge measurements contained 15-25 verticals, and were typically collected on the falling limb of storm hydrographs due to lesser amounts of floating organic debris and less rapid changes in stage. Efforts were made to obtain at least one measurement near the peak of a large storm, although no major storms occurred during the study period. Typically 3-5 discharge measurements were obtained at each site over a range of flows.

Dataloggers

Only manual stations were operated by GMA in WY2000 with periodic measurements of stage-discharge at about 75 sites, while in WY2001 continuous dataloggers were installed at 11 sites (Big French Creek, Mill Creek, Manzanita Creek, Little Browns Creek, Little Grass Valley Creek, Upper Rush Creek, Upper Browns Creek, Swift Creek, Coffee Creek, East Fork Trinity River, and the Trinity River above Tangle Blue). All of these sites used Global WL-14 dataloggers. In addition, during WY2001, the California Department of Water Resources installed gauging stations on the NF Trinity near Helena site (a former USGS gage site) and on Weaver Creek. In addition, the Hoopa Valley Tribe installed dataloggers on Browns Creek and Reading Creek for the Trinity River Restoration Program.

Records from our dataloggers were periodically downloaded by laptop and then analyzed using Western Hydrologic Systems *Surface Water* computer program to compute discharge records. Continuous records of suspended sediment transport were computed by linking the 15-minute discharge values with the appropriate sediment rating curve. Hydrographs for stations monitored in WY2001 which did not have dataloggers installed were synthetically derived by scaling our other continuous records by watershed area and adjusting, as necessary, to match our observed gage heights during sampling periods.

Turbidity and Suspended Sediment Sampling

Depth-integrated turbidity and suspended sediment sampling was performed at most locations. Sampling was performed using a US DH-48 Depth-Integrating Suspended Sediment Sampler, with handles of different length depending on the flow depth, or when bridge access was available during high flows, using a rope-deployed US DH-59 sampler. Sampling locations were located at or near stage locations. Standard methods were used for sampling, although velocity criteria for DH-59 sampler were occasionally exceeded.

Due to the number of sites being sampled, a tag line was not always set during sampling; instead, the distance between verticals was estimated. For each sample, the location, time, stage, number of verticals, distance between verticals, and bottle # was recorded. At locations where it was not possible to get a true depth integrated sample, grab samples or modified depth integrated samples were taken, and this information was recorded. At sites within the Upper Middle Trinity where dataloggers were located, typically 3 samples (replicates) were collected.

Data Analysis

Stage/discharge relationships were developed for each site by plotting stage versus discharge. Generally, a power equation of the form $Q = a*(stage^b)$ was then fit to the rating points in order to determine the stage/discharge relationship. However, in some cases, the power equations poorly matched the stage-discharge data and the relationships were instead developed by eye-fitting curves to the observed data. From these relationships, rating tables were constructed.

Turbidity and suspended sediment data were analyzed in several ways. Turbidity versus Suspended Sediment Concentration (SSC), Turbidity versus discharge, SSC versus discharge, and Suspended Sediment Load (SSL) versus discharge relationships were developed for all sites. In addition, because lab sample analysis in WY2000 had used TSS (EPA 180.1 method), we collected either two or three samples (replicates) at many of the Trinity River sites and processed two for SSC (ASTM D-3977) and one for Total Suspended Solids (TSS) (EPA 180.1 method) in order to evaluate the relationship between these tests of sediment concentration. When more than one sample was collected and analyzed for a given parameter, the final result is the average of these replicates. All WY2001 samples were analyzed for turbidity and the values averaged.

Sediment discharge rating curves were developed for each station for both bedload (when available) and suspended sediment. Annual loads were computed by applying the sediment discharge rating curves to the continuous flow record.

<u>Develop Reference Sites</u>

Although it is difficult to find true reference (undisturbed) watersheds, we attempted to identify at least one watershed or portion of a watershed per major geologic terrane that has the lowest level of disturbance, which could act as a reference watershed for measurement of non-management related background sediment generation and yield. Similar data collection efforts were used as described in the following sections to collect sediment transport data and to compute annual loads.

<u>Analyze Data, Computing Annual Load</u>

For streamflow monitoring stations with continuous stage records, we computed flow based on 15-minute intervals of stage measurement. For those stations without continuous records, we developed hydrographs based on storm observations, crest gage peak records, and records from nearby continuous stations.

<u>Assess WY2001 in Historical Framework</u>

Since the detailed Phase 2 intensive data collection effort could only span one winter season, it is important to assess the relative magnitude of the winter in comparison to long-term historical records of storm intensity, duration, and frequency in order to develop a mechanism for translating data from WY 2001 into average yields (for example a 10-20 year period). We used two approaches to accomplish this: (1) by comparison to gages with longer-term sediment records in the area (Grass Valley Creek) and other gages with shorter records that extend from 1997 to present (Deadwood, Rush, and Indian Creeks), and (2) by computing sediment loads from a combination of synthetic and historic mean daily discharge values at each of the streamflow sites in the Upper Middle Trinity PW. This method is described more fully in the sediment budget section of this report.

GEOMORPHOLOGY

SUBSTRATE QUALITY

The purpose of substrate quality sampling undertaken as part of this study was to provide information useful for completing the TMDL by identifying current substrate quality in high priority portions of the Trinity River between Lewiston Dam and Junction City and selected tributaries. To achieve these goals, the following objectives were developed:

- Establish baseline substrate composition and permeability conditions for long-term trend monitoring in the Trinity River and tributaries.
- Assess the relationship between substrate composition (as measured by both pebble counts and bulk sampling) and permeability.
- Evaluate the longitudinal changes to gravel quality along the mainstem Trinity River to assess the influence of tributary derived sediments.

Methods

Establish Sampling Sites:

Sampling was conducted on both the Trinity River mainstem and significant tributaries, with almost all sites within the Upper Middle Trinity PW. Watersheds sampled included all of the major tributaries in the high priority area (Lewiston Dam to Browns Creek) including Deadwood Creek, Rush Creek, Grass Valley Creek, Indian Creek, Weaver Creek, Reading Creek, and Browns Creek. Additional samples were collected in Canyon Creek and the North Fork Trinity.

Mainstem sample sites were selected based on access, access permission, presence of WY2000 spawning evidence, ability to compare to historic data, and general location along the mainstem between Lewiston Dam and Junction City. We sampled 8 sites along the mainstem. Sites were selected after consultation with USFWS and McBain & Trush. All sites and methods conform to protocols under consideration by the Adaptive Management Program. Tributary sites were located near existing streamflow gages, near the mouths of the respective tributaries, and where access allowed.

Once a site was selected, a cross section was established using 5/8" rebar on each bank as endpins. These monuments will allow future recovery or re-occupation of the site. A measuring tape was strung between endpins with station 0 on the left bank pin and all further sampling at the site was referenced to the tape. The cross section for all sites was established over similar geomorphic features (i.e. pool tails).

Collect and Analyze Samples:

After establishment of the site cross section, 10 permeability measurements following procedures developed and recent technique improvements by Barnard and McBain (1994) and McBain & Trush (2000), were made to assess variability within the site including two measurements within the areas where bulk samples were collected. Five to ten replicate measurements of permeability were made at each sample point.

Bulk samples were collected using a 24-inch version of a McNeil Sampler to allow larger sample volumes to be collected. In general, we attempted to meet the 1% rule, by which the weight of the largest grain does not comprise more than 1% of the total sample weight. Often this requires very large sample volumes (200-400 kg). Two bulk samples were collected on each cross section at similar points (i.e. halfway between the channel thalweg and the channel midpoint). The exact stationing of each bulk sample was determined from a tape stretched between the cross section endpoints. Surface and sub-surface populations were collected and processed separately, thereby allowing for differing analyses and comparison to pebble counts which were also conducted at each site following standard procedures

(Wolman 1954).

The hole from which the bulk sample was excavated was backfilled with crushed quartz, (a landscape material), which provides useful tracer properties, being easily distinguished by color and shape. The final elevation of these scour cores was accurately surveyed.

When possible, the bulk samples were dried and sieved on-site using rocker sieves down to 8mm size fraction. At times, due to data collection during winter months, site drying was not feasible, and the larger fractions (>16mm) were weighed wet and a correction factor empirically determined. The weight of each size fraction was recorded. Before sieving, the total dry weight of the sample is determined to ensure that only a small sample loss during sample processing occurs. The fines smaller than 8mm are all weighed on site and a split was taken for size analysis in the laboratory for processing with smaller sieves and a mechanical shaker. At the lab, the entire sample was thoroughly oven-dried and sieved through 2mm using a Gilson TS-1 Testing Screen. This high-volume testing screen allows up to one cubic foot of sample to be sieved in 3-5 minutes. For materials finer than 2 mm, a total weight was first obtained, and then the sample was split into quarters. A random split was selected and run through 8” sieves with a Gilson SS-15 Sieve Shaker. For several samples, multiple splits were independently sieved to verify that each split was truly representative of the entire fine fraction of the sample.

SEDIMENT SOURCE ANALYSIS

LANDSLIDE MAPPING

Background and Purpose

The purpose of the landslide mapping is to develop an inventory for each planning or sub-watershed studied. The assessment evaluates the effects of past and present land management activities on landslide activity.

The program of air photo analysis and fieldwork included a historical inventory of landslides in the portions of the watershed along with field verification of a subset of the landslides mapped in the most recent analysis period. The landslide inventory included identification of both management (primarily timber harvesting and road building) and non-management natural practices that appear to be associated with landslide activity. Any non-forest practices (e.g., grazing or residential development) that appeared to be linked to landslide events were also documented.

A series of comparative analyses were carried out to identify and document relationships between forest practices and landslide activity. This work included documentation of the effects of landslides on streams, compared background landslide frequencies with those associated with timber harvest and road building, and outlined the landslide component of a watershed-wide sediment budget. Landslides are one of several sediment sources in a watershed. The relative importance and contribution of landslide-generated sediment is based on air photo and field estimates of volumes of sediment introduced into streams by landslides over the duration of the air photo record. Measurements made during the landslide inventory were used to estimate the sediment contribution from landslides.

Methods

The landslide assessment was built around the examination of air photos. Air photos were used for the period of 1944 to 2000. Scales were at 1:20,000 to 1:24,000.

Office Landslide Inventory:

The landslide inventory documented the location, timing, and relative size of landslides in the watershed. This information was used to estimate sediment input to streams and assess relationships between land use and landslide activity.

The methods used are as follows:

1. 1944 and 2000 sets of air photos for the various watershed areas to be mapped were obtained. Information developed from these photo sets was compared to mapping products developed by DWR in their 1979 Erosion Investigation for the Trinity River watershed, which used 1978 aerial photography. Thus we are looking at three periods, prior to 1944, 1945-1978 and 1979-2000. The DWR mapping was digitized and input into the project GIS.

2. A field survey of a representative sample of the observed landslides was undertaken to collect data on landslide dimensions and the percentage of sediment entering streams. This fieldwork included documentation, measurement and description of the smaller landslides that cannot be identified with certainty on air photos (sample plots). This information was used to calibrate air photo measurements and interpretations, and to document the size of landslides that can reasonably be identified on air photos. The field sampling also documented the type, size, frequency, and function (e.g., sediment input to streams) of smaller landslides that will not be identified on the air photos. Typically, only landslides with areas of 3000 to 5000 square feet can be reliably and consistently identified on 1:10,000 to 1:24,000 scale air photos in most terrains. The actual size of landslides that can reliably be identified varies with the scale and quality (black and white or color, age and resolution) of the air photos.

3. All landslides, larger than the minimum sizes, that were visible on the air photos were identified and the locations of these landslides were manually transferred to 1:24,000 scale acetate overlays either printed from GIS or traced from topographic base maps. When photo scale was the same as overlay, mapping was done directly from photo onto overlay. A unique identification number was assigned to each landslide. The overlays were then digitized into the GIS. The set of data for that landslide is then entered into a landslide database and the database is linked to the GIS.

4. For each landslide identified on the air photos, the following information was recorded in the landslide database:

   A. Landslide number.
   B. Year of the air photo on which the landslide first appears.
   C. Number and flight line of the air photo on which the landslide first occurs.
   D. Landslide classification (following Crudden and Varnes, 1996).
   E. Certainty of identification: d = definite, p = probable, q = questionable.
   F. Activity level using the following categories: active, inactive, or relict
   G. Sediment delivery to streams: No sediment delivered, Sediment delivered, or Indeterminate.

   H. Estimate of the percentage of landslide volume delivered to the stream course. Using four categories: 0-2%, 3-33%, 34-66%, 67-100%.
   I. Land use activity associated with the landslide. Information on activities at the point of initiation of the landslide, including harvest-related, road-related, and other non-forest

land use such as ranching, grazing, farming, residential, industrial.

Landslides observed on the aerial photographs were plotted on acetate overlays placed on 7½ -minute topographic maps. They were classified as rotational/translational, earthflow, debris slide, or debris torrent. Rotational/translational and earthflow slides are characterized as relatively deep-seated, slow-moving or static slides, and it is generally assumed that such failures are contributing little sediment except that derived from sheetwash or gullying processes. Debris slides, however, are judged to be short-term active failures that contribute relatively modest to large volumes of sediment to the drainage. However, over time they revegetate and eventually heal so that, in many cases, sediment input is reduced to similar levels as adjacent undisturbed areas. Debris flows/torrents are fast moving and relatively shallow (in most, but not all) failures. For this study, cutslope and fillslope failures and rock avalanches were also included in this classification.

In an attempt to maintain uniformity in the size of failures mapped from photo set to photo set, only those failures with estimated dimensions of about 75 to 100 feet or more in width or length were mapped. This included almost all failures observed.

Large, deep-seated landslides were identified as either active, dormant, or relic. Those considered dormant are judged to be relatively stable but could be partially or wholly reactivated under current climatic environmental conditions. Relic means it was judged unlikely to become reactivated under current climatic/environmental conditions. Very few deep-seated landslides were identified as active.

Detailed Study Areas:

In addition to the 1944 and 2000 aerial photos mapped, in selected sub-watersheds in the Upper Middle Trinity (Rush Creek and Browns Creek) additional photo years were mapped in an effort to refine the occurrence of landslides and provide for improved trend analysis. Photosets from 1960, 1970, 1980, and 1989 were additionally mapped for these two watersheds.

Landslide Field Inventory:

We field verified about 15% of the landslides mapped, which was considered a representative sample of landslides in the watershed to evaluate air photo interpretation limitations and help resolve major uncertainties. The sample size was primarily a function of access (i.e. permission, distance from road access, etc.), with most emphasis on verification in the Upper Middle Trinity PW. The factors assessed during the field inventory included the following:

(1) Landslide area, volume, and surface erosion estimates as appropriate.
(2) Land use associated with landslide activity (e.g. forest harvesting, road fills and cuts).

(3) Factors contributing to the initiation or reactivation of landslides (e.g. overloading, saturation from redirected surface water, root strength deterioration).
(4) Delivery of landslide sediment to streams.

Data and techniques suitable for field assessments and measurements of landslides followed those outlined in Turner and Schuster (1996).

GIS Analysis:

The landslide database and landslide inventory maps were linked through the project GIS. Each slide mapped onto the overlays was digitized as a polygon and linked to the database. After this process was completed, GIS analysis of the slides occurred. Slides judged questionable and/or non-delivering were discarded from further analysis. The remaining dataset was queried by landslide type, year, number of slides and area, geology, and the locations were separated into sub-watershed areas for evaluation at that level. Summary tables for the Planning Watersheds and each sub-watershed were prepared for use in interpreting the data and performing volume calculations. The volume of delivering landslides in each accounting unit (watershed and/or sub-watershed) was computed based on delivery percentage multiplied by slide area times slide thickness. Selection of an average slide thickness by type was based on literature review and field verification. Slide volumes were converted from cubic yards to tons based on soil bulk density data. This allows comparison of sediment inputs to sediment transport values, which are usually computed in term of tons.

<u>Detailed Sediment Source Mapping (Sample Plots)</u>

Aerial photo mapping of landslides at 1:24,000 is limited by the minimum feature size that can be resolved at that scale. In order to assess the relative contribution of smaller slide features, detailed mapping in the watershed study area was also undertaken. Although it was originally intended that the number of detailed study sites per geologic type would be a function of the area covered by each geologic terrane, this became infeasible due to the access limitations on private property, particularly in the Upper Middle Trinity PW. Although we determined the geology of each sample plot, we ended up combining all sample plots into one dataset from which average values were computed. Due to the access constraints, some of the geologic terranes were represented by only a few plots, and thus there were insufficient data to produce reliable results. Within the Upper Middle Trinity PW, sites were randomly selected. Depending on access limitations, initially selected sites may have to be rejected and another site randomly chosen. The size of each site was be approximately 40 acres, which provided a manageable size and often has easily determined boundaries due to the subdivision of sections (40 acres being 1/16th of a square mile (640 acres per section)). A total of 40 detailed sample plots were mapped, with almost all of these sites in the Upper Middle Trinity PW. All of these sites were located on public land, thus the effects of management activities on private lands could not be ascertained by this method.

Once a sample plot was selected, field personnel mapped all erosional features within the boundaries of the plot by walking its entire area. Each feature had the following data recorded: (1) type of sediment source, (2) any apparent land use or management associations, (3) area, thickness and volume of erosion, (4) estimate of the percentage of sediment delivered to the stream, (5) estimate of the features age, and (6) specific location characteristics such as geomorphic form, hillslope steepness, dominant vegetation, and canopy cover. All data was entered on a data form that was then input into the project database.

Data analysis included evaluation of sediment delivery by process (slides, gullies, rill erosion, bank erosion) and by land use association (non-management, harvest-related, road related). Data collected allowed differentiation between system roads (currently in use) and abandoned or legacy roads. Volumes were computed and rates computed after selecting a typical time period for which the observed features were determined to be representative. These rates were then applied on a per square mile basis to all

watershed areas with the following exception: management-related yields were not computed for those areas in wilderness areas.

<u>SURFACE EROSION</u>

Road Surface Erosion

Unlike surface erosion from exposed hillslopes where revegetation usually occurs within a few years, road surfaces can continue to erode as long as the road is used. The road cutslopes and fillslopes tend to revegetate, reducing erosion from those sources over time. However, road-running surfaces continue to provide fine-grained sediments over the life of the road. The purpose of this part of the sediment source analysis was to identify portions of the road network that deliver sediment to streams and therefore affect aquatic habitat or water quality. This analysis developed an understanding of the overall effects of the road system on sediment yield by roughly quantifying the amount of sediment delivered to streams from roads in a sub-basin for use in comparing that amount to the estimated sediment input rates for background and other land management activities.

The approach for estimating sediment production was to examine road segments for characteristics of the road prism, drainage system, and traffic as they influence the delivery of sediment to the stream system, and calculate sediment yield based on them. Factors were applied for differing conditions of the road tread, cut- and fill-slopes, and traffic use that increase or decrease the estimated sediment yield of that segment. The result is an estimate of sediment yield for each road segment. The estimate was further modified according to the estimated delivery of sediment to streams along that segment.

Data were collected for the following factors and road attributes that influence the amount of sediment delivered to streams from roads in a watershed:

- The erodibility of the soil/geology the road is built upon
- Precipitation amount and intensity
- The age of the road
- Road drainage pattern (insloped/outsloped/crowned)
- Probability that sediment from road reaches stream (depends on distance and slope between road drain and stream, amount of obstructions to trap sediment, and road area that collects water and sediment)
- Length of road that delivers to stream
- Width, surfacing type and durability, traffic use, and slope of road tread
- Cutslope cover and height
- Fillslope cover and height
- Ditch width, slope, and armoring

Procedure

Road segment groups were analyzed to produce estimates of sediment delivery for each road segment type. That rate was applied to all of the segments of that type in each sub-basin, resulting in an estimate of sediment delivery from roads for each sub-basin. The amount of sediment delivered to the stream from each road segment type was estimated by apportioning the inherent erosion rate among the road prism components. Each component rate was modified by factors based on road prism characteristics and the percentage of the road delivering sediment into the steam system. The final product is the rate of sediment delivered to streams from road segment types. The rate multiplied by the length of each segment type in each sub-basin provides the total sediment from roads for each sub-basin.

Since it was not realistic to visit every road segment in every watershed, the road system was stratified to enable representative portions of the roads to be sampled. Each road "type" was characterized, and sediment yields determined and extrapolated to other roads of the same type. Road types consist of segments of similar hillslope location (riparian, mid-slope, and ridge), surfacing (paved, rocked, native), and geologic terrane.

Field Inventory was used to verify traffic and surfacing information, to verify segment types and grouping, to check average road attributes (tread, ditch, cutslope, fillslope) and prism dimensions, to collect information on cover percentage on cut- and fill-slopes, to review localized problem areas, and to determine potential delivery to streams. Prior to field inventory, we performed GIS analyses to identify those portions of the road network within the standard 200-foot buffer from a Class I, II, or III watercourse (i.e. riparian roads). Because of the much greater delivery from riparian roads, these areas were prioritized. During field surveys, information on road sediment delivery was also collected for each segment. At each drainage site, the potential for sediment delivery to the stream was determined.

Gully Erosion On Roads

Gully erosion on roads can occur when surface runoff is concentrated along the tread or ditch for long distances. The most common causes of gully erosion are plugged culverts, undersized culverts, or steep un-surfaced roads (over 10% grade). Gully erosion is not included in estimates of surface erosion using the WDNR method, and so must be analyzed separately. Because gully erosion is often episodic (e.g., in response to a blocked culvert that causes a stream to flow down or across the road tread) it is difficult to obtain a good quantitative estimate of gully erosion. Instead, a qualitative estimate of how severe the problem is in different areas of the basin or on different road slopes was made during road field-verification. When gullying was seen in the field, data were recorded including the location, cause, and approximate dimensions of the gully to help determine the relative amount of sediment produced by this mechanism. Separate rates for gullies were developed by road surface, hillslope position, and geology.

Field Inventories of Road Erosion

A total of 101.75 miles of roads in the Trinity River basin were surveyed between May and June 2001. Information from the surveys was entered into a database. The data were then analyzed based on identified sort parameters. Prior to inventorying roads, the basin was stratified by geology, road surface type, and hill-slope location. Roads were also chosen by the percentage of road in each hill-slope location, with the highest concentration of inventory in the riparian areas. All information was provided in a GIS database. Harvest history maps and aerial photo maps were used in order to produce a road history index. Once field surveys were complete and entered in the database, geology and road age where linked to each site. Total erosion was then calculated for each geology type. Total erosion was then calculated for each surface type and hillslope location within each of the geology types.

Road Surveys

Field surveys were conducted to gather data on sediment production from roads. All drainage features on a surveyed reach of road were considered a site and a site sheet was filled out for each drainage feature.

Drainage feature types include; ditch release culverts, rolling dips, and stream crossings. Road attributes affecting the amount of sediment produced from the road segment were recorded. A delivery percentage was then assigned to the site. Delivery was based on the road shape (insloped, outsloped, crowned), distance to stream, and geomorphic evidence of connectivity (gullies and rills). Other sources of erosion directly related to the drainage feature were also recorded on the site sheet. Other erosional features associated with the road prism include; cut bank failures, fill failures, crossing failures, and gullies. Site sheets were also filled out at every erosional feature not directly associated with a drainage feature. Erosional features less than 10 cubic yards were recorded.

Development of the Road Model

A formula was developed in order to estimate total sediment delivered for the entire Trinity River basin. The formula used was similar to the formula used in SEDMODL, which was used in the Sediment Source Analysis for the South Fork Trinity River (Raines, 1998). The formula developed does not, however, account for road use factors, precipitation factors, or road slope factors. Information of such was recorded and could be used in a more in-depth study.

Tread erosion was based on both measured attributes and erosion factors found in the Washington Department of Natural Resources Standard Methodology for Conducting Watershed Analysis, Surface Erosion Module (Washington Forest Practices Board, 1995), with modifications based on additional empirical road erosion research conducted in the Pacific Northwest (Raines, 1998). Field measured attributes for tread drainage included; segment length, road width, ditch width, and delivery percentage. Geological erosion rates based on geology were obtained from both the default geology coverage's supplied with SEDMODL (Bond and Wood 1978, Huntting et al. 1961, Walker and MacLoed 1991) and the modified geologic erosion rates used in the South Fork Trinity River Sediment Source Analysis (Raines, 1998). The maximum geologic erosion rates were used because the values seemed most applicable. Tread surfacing factors were based on the factors used by Raines in the South Fork Trinity River Sediment Source Analysis. Tread erosion was then calculated as the product of the above-mentioned attributes.

Tread Erosion = Geologic Erosion Rate x Tread Surfacing Factor x Segment Length x Road Width x Delivery Factor

Cutbank erosion was calculated based primarily on physically observed attributes. Cut bank erosion attributes included; cut bank height, an armoring factor (based on exposed bedrock and vegetation), the average depth of eroded material (based on exposed root and rock as well as rills and gullies), the length of cut bank, and a delivery percentage. Total cutbank erosion for each segment was calculated as the product of these attributes.

Cutbank Erosion = Cutbank Erosion (depth) x Cutslope Cover Factor x Segment Length x Cutslope Height x Delivery Factor

Other sources of erosion such as fill failures, cutbank failures, crossing failures, and gullies were recorded for each drainage segment. Volumes of sediment eroded were recorded as well as an estimate of the time period (by decade) of the erosion. Decade of erosion was based on indicators such as vegetation coverage and tree age. Delivery was based on field investigations of each erosional feature. Total erosion from other sources was calculated as the product of volume and delivery.

The total amount of erosion from each drainage segment is calculated as the sum of tread erosion, cutbank erosion, and other sources of erosion. Total erosion is then divided by the length of the segment and by the age of the road. The ratio of segment length to total length surveyed was then used to derive an adjusted total erosion amount recorded in tons per mile per year. Total erosion from each site was then summed for each of the geology types and then sorted by both surfacing type and hillslope location. These values were then used to develop surface erosion rates (tons/mi/year) which could then be applied to data extracted from the project GIS.

It was anticipated earlier in this project that data collected on 244 miles of road completed by Trinity County for the 5-County Road Erosion Inventory would also be useable as part of the surface erosion road sample. However, those data do not contain attributes needed to calculate surface erosion in the road model, and were more focused on potential erosion in order to prioritize future management actions.

Road Surface Erosion Calculations by Sub-Watershed

Surface erosion from roads within each sub-watershed and planning watershed was computed for existing conditions by stratifying by geology, stratifying by location (riparian, mid-slope, and ridge categories), and stratifying by road surface (paved, rocked, and native categories) and then applying the appropriate rate developed from the field inventories. Slope positions were assigned using the following methodology. To determine the location of Riparian roads, all Class I and Class II streams were buffered by 200 feet on either side. All roads segments within this buffer were considered Riparian. To determine the location of Ridge roads, ridgelines were identified by creating watershed boundaries from the 10-meter DEM with a minimum area of approximately 75 acres. Next all Class I streams were buffered by 500 feet to clip the watershed boundaries away from the riparian zone. The resulting ridgeline coverage was then buffered by 100 feet on either side. All roads segments within this buffer were considered Ridge roads. All the roads segments that didn't fall into the 200 foot riparian buffer or the 100 foot ridge buffer were considered to be Mid-Slope.

Surface Erosion from Harvest Areas

Surface erosion from harvested areas is most often related to various surface disturbance activities, primarily skid trails. Without access to verify rates for harvested areas (almost all recently harvested land in the watershed is privately owned), we were limited to application of a single sediment delivery rate that was obtained from the literature. 4 tons/ac/year was selected from a review of the literature and values used in the South Fork Trinity River Sediment Source Analysis (Raines 1998) for the post-1974 period reflecting development of Forest Practice Rules regulating harvesting methods. For pre-1974 harvesting, the rate was assumed to be 12 tons/ac/year or three times as great prior to regulation. These values were applied to all harvested areas, regardless of sivilculture method, by the appropriate period. Areas of harvest were determined in several ways, including: (1) maps of timber harvesting prepared by DWR (DWR 1980) were digitized and input into the project GIS thus providing information from 1940 to 1978, (2) maps contained in CDF THP's for the period 1979-2001 were digitized and combined with USFS compartment data to arrive at harvest acreages by sub-watershed for the current period.

The only modification to the calculation of surface erosion as described above occurred in those portions of the Upper Middle Trinity underlain by the extremely erodible Shasta Bally Formation, primarily in the Grass Valley Creek sub-watershed. This area has long been known to have produced enormous sediment yields following disturbance in the 1960s and 1970s. For those portions of the basin underlain by this geologic formation, a rate of 40/tons/ac/year was used.

LEGACY ROAD EROSION

Data from our sample plots allowed a distinction to be made between active, system roads and abandoned roads (termed legacy roads). Rates for sediment delivery from legacy roads were computed assuming that observed erosion occurred over a 30-year period. Sediment volumes from legacy roads for each sub-watershed were computed on a per square mile basis, since no data were available on the extent of these abandoned roads.

LEGACY MINING EROSION

The Trinity River Watershed has a long history of mining, starting with the Gold Rush in 1848. Hard rock, placer, and hydraulic mining were all extensive, with hundreds of mines operating at various times between 1948 and 1962 with an estimated production of $60,000,000-$70,000,000. One of the largest hydraulic mines in the world, the La Grange Mine near Junction City, operated for a number of years in the watershed. Although scars are still visible at a number of these historic mining sites, no acreage for these mines is available with which to compute a surface erosion rate. However, there is fairly detailed information on a mining-related feature, ditches, which have caused considerable erosion, and we developed data with which to estimate the magnitude of these impacts on sediment delivery. Ditches conveyed water from the point of diversion, often high up in a tributary watershed, to the hydraulic mine site, where with the considerable pressure obtained from the elevation difference, large hydraulic "giants" could be operated. These ditches were constructed over often steep and challenging terrain, and a number of large landslides have occurred in recent years caused by failure of some portion of the long-abandoned ditch system. We walked several miles of the most well-known of the ditches (the La Grange Ditch) and mapped all landslides and gullies found along the ditch. We converted the volume into a rate per mile of ditch assuming that an 80-year period had occurred since the ditch was last maintained. The miles of ditches by Planning Watershed were obtained from California Division of Mines and Geology 1965 Trinity County Mineral Resources Report.

CHANNEL EROSION

Bank erosion is a component of the sediment budget that must be evaluated based on considerable fieldwork. Most bank erosion, except large-scale changes in alluvial reaches, cannot be mapped from aerial photography. Likewise, gullies, which have been found to be a significant sediment source in some other north coastal watersheds (Best, et. al., Garrett Creek watershed). Road-related drainage issues most often cause gully erosion, either from stream diversion at drainage structures or the effects of new drainage structures.

The channel network in each watershed was analyzed to compute stream order. The number of segments of each type was computed, and a field sampling undertaken. The main channel of each significant tributary watershed was walked where access was available.

In order to quantify the amount of sediment contributed to stream channels, selected reaches of channels were selected and inventoried for past erosion. All erosion from hillslopes and inner channel banks was summed and divided by total length of the stream reach. Stream length and site location were identified using a range finder and aerial photography mapping. Erosional features less than ten cubic yards were not recorded. Sources of erosion were from natural bank erosion from channel changes, road related features, and hillslope debris slides. Features were given a volume, delivery percentage, and an age. The

data set was limited by the amount of private land surrounding the stream channels in the priority watershed, however, 27 miles of channel, all in the Upper Middle Trinity PW, were field inventoried.

ALLUVIAL CHANNEL STORAGE

Sediment generated from upslope processes are transported through downstream reaches and frequently stored in landforms of various ages and often behind woody debris jams. In order to develop a sediment budget, an evaluation of changes in alluvial channel storage must be made.

This effort was intended to involve two phases: (1) an office phase that identified alluvial reaches from aerial photo analysis, and (2) a field phase which involves walking or floating the alluvial "response" reaches and making qualitatively evaluations of storage change. Due to access constraints on many of the tributary channels, many of the most important response reaches were inaccessible. As a result, except for a few qualitative observations of alluvial storage in selected tributary channels, no data exist for this category.

DEVELOPMENT OF A SEDIMENT BUDGET

Purpose

A detailed sediment budget for the various planning areas was developed from the various data sources previously described in this document.

Following the analysis of sediment generated by inventoried sources in the study area, a sediment budget was constructed (Swanson et al. 1982, Reid and Dunne 1996). An analysis of the relative contributions of sediment from different sources is valuable in understanding the interactions between natural conditions, land use activities, and resource conditions.

To compile sediment input estimates, we prepared series of tables breaking estimates into the following categories:

- Erosion process (e.g., landslides, surface erosion, stream erosion)
- Land management activity (e.g., roads, timber harvest, grazing)
- Air photo period
- Grain size categories (<8 mm, >8 mm) and lithology
- Estimate rates of erosion, sediment transport, and storage in stream systems in the watershed. Compare estimates of background or natural rates to managed areas for the period of air photo record.

Separating Erosion Estimates into Grain Size Components:

In order to determine the effects of sediment introduction on aquatic and water quality resources, it is helpful to separate the total contribution into different grain size components. Separating bedload sediment into two size classes will allow differentiation of grain sizes that directly effect aquatic habitat: particles less than 8mm, typically sand [0.1-2 mm] (transported relatively rapidly by intermittent suspension, size fraction associated with infilling of spawning gravel) and fine gravel, (0.08-0.3 inches [2-8 mm], transported relatively rapidly by intermittent suspension); and coarse sediment greater than 8mm which provides essential instream habitat.

Develop Sediment Budget

In this budget, we have input and output terms. Change in storage is not available for a sufficient portion of the watershed to have meaningful results. Inputs are from landsliding, road surface erosion, harvest area surface erosion, bank erosion, fluvial hillslope erosion (gullies), legacy roads and mining, and creep. Output values are based on measurements of sediment transport at the gaging stations near the confluence of each tributary with the mainstem.

HYDROLOGY

The hydrology of the Trinity River, particularly in relation to the effect of the TRD on streamflow, has been thoroughly described in the Trinity River Flow Evaluation (1999) and the Trinity River Mainstem Fishery Restoration EIS/EIR (2000) and will not be discussed in detail in this report. Other analyses developed in the course of this study are included.

Precipitation

Precipitation in the Trinity Watershed, as is typical of California, is highly seasonal, with 90 percent falling between October and April. Depending on location in the watershed, snowmelt or rainfall runoff dominates the hydrologic budget. The only long-term annual precipitation records in the watershed are in Weaverville, which has a mean annual precipitation of 36.29 inches, for 1906-2001, excluding 1981-983 for which records are incomplete. Mean annual precipitation for the watershed is about 55 inches, based on an areal weighting of mean annual precipitation that had been obtained as GIS coverages for the entire watershed from USFS. The isohyetal maps for the watershed indicate that annual precipitation generally increases as one moves from the valley floors towards the higher elevations along the northern and eastern parts of the watershed. In addition, annual precipitation is actually highest along the far western edge of the study area, reflecting the orographic effects of the Coast Ranges. Surprisingly, there are only small differences between the Planning Watersheds in terms of mean annual precipitation.

Figure 9 shows the annual precipitation at Weaverville for the 1906-2001 period (missing 1981-1983) along with the computed cumulative departure from the mean. For Weaverville, the wettest year contained in this record is 1974, when precipitation totals reached 63.58 inches, only slightly wetter than 1998, the next highest, when 63.27 inches were recorded. The driest year at Weaverville was 1977, when only 12.57 inches of precipitation were recorded. The mean for the 96-year record is 36.29 inches. Furthermore, most of the watershed averages higher precipitation than Weaverville, and the accuracy of the available isohyetal maps is unknown.

Cumulative departure from the mean is a measure of the consecutive and cumulative relationship of each year’s rainfall to the long-term mean. When the cumulative departure line is descending (left to right), there is a dryer than normal period, while an ascending line denotes wetter then normal. In reviewing the record at Weaverville, we see a slightly wetter than normal wet period extending from 1906 through 1915, followed by a prolonged drought period from 1916-1937. 1928-1935 was the worst multi-year drought in the 96-year record, with 8 consecutive years below the long-term average. 1938-1943 was a wet period, followed by a 7-year dry period between 1944 and 1950. 1951 through 1958 was a very wet period, as was 1968-1975. The 1976-1977 drought was intense, but short-lived. The 1987-1992 drought was quite severe. 1995 through 1998 was the wettest period on record (i.e. has the steepest rise). Four years stand out from the perspective of total annual precipitation and thus runoff: 1958, 1974, 1995, and 1998

Streamflow

Numerous streamflow records are available in the Trinity River watershed, although many of them have been only recently installed and thus have short records.

USGS Gages

The USGS has historically operated 18 continuous recording gaging stations in the mainstem Trinity River watershed, including 7 on the mainstem and 11 on tributaries. 5 of these are currently in operation, four on the mainstem (Trinity River above Coffee Creek, Lewiston, Burnt Ranch, and Hoopa) and 1 tributary station, Grass Valley Creek.

USBR Gages
USBR operates three gages in the watershed all related to TRD, including lake level at Trinity and Lewiston lakes, and the diversion flow at the Carr Powerplant near French Gulch.

DWR Gages
DWR currently operates three gages in the watershed, lake level for Buckhorn Dam, and Weaver Creek and North Fork Trinity River, both started in WY2001.

Hoopa Valley Tribe
The Hoopa Valley Tribe operates three gages on the mainstem (Limekiln, Douglas City, and Junction City) and six tributary stations (Deadwood, Rush, Indian, Reading, Browns, and Canyon Creeks). Reading and Browns were installed in WY2001, while Canyon Creek was installed for WY2002.

The Tribe also operates a number of gages within the Hoopa Valley Indian Reservation, although this area is not included in the sediment source analysis.

US Forest Service
USFS operated a gage on Horse Linto Creek in WY2000 and 2001, but the results were not obtained in time for use in this report.

Graham Matthews & Associates
GMA operated twelve continuous streamflow stations in the watershed as part of this study in WY2001, including one on the mainstem (Trinity River at Parks Creek Road) and eleven on tributaries.

Peak Discharge

Annual maximum peak discharge records are available from four mainstem Trinity River sites with over 40 years of record, with one site, Trinity River at Lewiston, having 89 years of record, and one, Trinity River at Hoopa having 74 years of record.

The largest flood in the upper watershed, as measured at the USGS Trinity River above Coffee Creek, occurred in January 1974, when discharge reached 26,500 cfs. This was almost certainly the largest flood event in the upper watershed this century and perhaps since 1862. December 1964 (WY1965), January 1997, January 1982, and January 1970 round out the top 5.

At Lewiston, the largest flood prior to the construction of Trinity Dam in 1963 occurred in December 1955 (WY1956). Flow peaked at 71,000 cfs. Based on the relationship between the Trinity River above Coffee Creek for this same event (peak discharge of 11,400 cfs) and the flow at Lewiston, it is likely that, had the dam not been constructed, peak instantaneous flows at Lewiston would have exceeded 100,000 cfs in the 1965, 1974, and 1997 floods.

Further downstream at the Trinity River near Burnt Ranch gage, 1956 was also by far the largest flood recorded, although the three very large events since then (1965, 1974, and 1997) would all have had discharges at that site greater than 172,000 cfs except for the flood control provided by the dam.

Interestingly, by far the largest event at the Hoopa gage occurred in 1965, when flows reached 231,000 cfs, about 20% greater than the 1956 event. It is apparent that the peak in 1956 was driven by runoff from the upper and middle portions of the watershed, as only 18,000 cfs additional inflow occurred between Burnt Ranch and Hoopa (the New River and South Fork Trinity being the large tributaries). In contrast, in WY1965, the increase between Burnt ranch and Hoopa was over 150,000 cfs, demonstrating that runoff from that flood event was dominated by lower watershed runoff. Release from Trinity Dam in the WY1965 flood was only 392 cfs, instead of 80-120,000 cfs.

Table 7 lists the annual peaks for these mainstem gages, while Table 8 adds annual peaks for tributary gages (excluding the SF Trinity). Figure 9 plots the peak discharges at Lewiston for its period of record (1912-2000). The effect of the dam on peak discharges is readily apparent.

<u>Flood Frequency</u>

Flood frequency analysis is a method used to predict the magnitude of a flood that would be expected to occur, on average, in a given number of years (recurrence interval) or to have a specific probability of occurrence in any one year (1% chance event, for example). Typically, the observed annual maximum peak discharges are fitted to the distribution using a generalized or station skew coefficient, although numerous other distributions may also used. When long records are available, the station skew is generally used exclusively. The Trinity River Flow Evaluation Report, hereafter TRFE, (USFWS and Hoopa Valley Tribe 1999) included flood frequency of the Lewiston gage records using the Log-Pearson Type III distribution for both pre- and post-dam flow regimes. The $Q_{1.5}$ event (flood event that would occur on average once every 1.5 years) was reduced by the dam from 10,700 to 1,070 cfs, while the Q10 was reduced from 36,700 to 7,500 cfs.

<u>Historic Floods</u>

The extensive period of streamflow records for the Trinity River provides considerable insight into the geomorphic significance of the various storm events, particularly when combined with other regional and historic data. Known large flood events in the region, many of which would also have occurred in the watershed, have occurred in Water Years 1862, 1890, 1956, 1965, 1974, 1986, and 1997. The largest of these were likely to have been the 1862 and 1965 events, followed by the 1974, 1997, 1956 and 1890 events (not necessarily in that order by magnitude). The relative significance of these individual flood events would have varied throughout the watershed, even without construction of the dam.

<u>Flow Duration</u>

The TRFE report included a flow duration analysis on mean daily discharges for both the pre- and post-dam flow regimes. Pre-dam a discharge of 1,000 cfs was exceeded almost 42% of the time, while post-dam this occurs only about 5.7% of the time. At low flows, the current minimum flows of 300 cfs are well in excess of the historic pre-dam flows, when 300 cfs was exceeded only about 65% of the time, and 5% of the time flows got lower than 100 cfs.

<u>Annual Runoff</u>

Annual runoff data has been compiled in the Trinity River watershed at the various USGS, DWR, and HVT streamflow gages for variable periods of record.

Unimpaired mean annual runoff for the Trinity watershed at Lewiston, for the 1912-2000 period is

1,246,000 acre-feet. The annual unimpaired runoff data are plotted in Figure 10. Interestingly, only one of the four largest volumes of runoff (WY1941, 1958, 1974, and 1983) is associated with a large flood year. The other years had very high annual precipitation, but it was spread out enough that no unusually large flows were generated. The extended dry period from 1917-1937 really stands out in the cumulative departure analysis, showing that over the 20-year period, cumulatively runoff fell below the mean by over 6,000,000 acre-feet, or almost 5 years worth of average flows.

SEDIMENT TRANSPORT

Historic sediment transport data on the Mainstem Trinity River consists of USGS measurements at various locations for different periods of record. At the present, there are no active sediment stations on the Trinity River mainstem operated by the USGS. Historic sediment stations included: (1) Trinity River at Lewiston (gage # 11525500, 1955-1961), (2) Trinity River below Limekiln Gulch, near Douglas City (gage # 11525655, 1981-1991, including both suspended load and bedload), and (3) Trinity River at Hoopa (gage # 11530000, 1960-1979). Since 1996, limited mainstem sediment transport data have been collected at the Lewiston and Limekiln gages by the Hoopa Valley Tribe for the Trinity River Restoration Program.

The USGS collected suspended sediment data on the following tributaries: (1) Grass Valley Creek at Fawn Lodge (gage #11525600, 1975-2001), (2) Little Grass Valley Creek (gage #11525580, 1985-1997), (3) Weaver Creek (Gage # 11525800, 1962-1969), (4) North Fork Trinity River (Gage #11526500, 1962-1970), and (5) Supply Creek at Hoopa (gage # 11530020, 1982-1985). Bedload data have been collected by the USGS at Grass Valley Creek at Fawn Lodge for the 1975-present period, and Little Grass Valley Creek for 1985-1997. In recent years, the amount of tributary sediment data collection has increased substantially. Since 1997, sediment data (both suspended load and bedload) have been collected for Deadwood, Rush, and Indian Creeks by the Hoopa Valley Tribe. In WY2000, sediment data also began to be collected on Reading, Browns, Weaver, and Canyon Creeks.

In 2000 and 2001, GMA (this study) collected turbidity and suspended sediment data on numerous sites throughout the watershed. Samples were collected from about 142 sites in WY2000, while additional samples were collected at 50 of those sites in WY2001.

GMA General Approach for Sediment Transport Data Analysis

Sediment transport data collected in this study may be used in several ways:

(1) WY2001 sediment loads have been computed for 27 sites in various parts of the watershed, with most data concentrated in the Upper Middle Trinity PW. The relative loading rates provide quantitative data with which to evaluate the effects of different disturbance regimes. Additional sites in the Upper Trinity or Lower Middle Trinity PW were generally collected to define reference watershed rates.

(2) Several watersheds had multiple gages, allowing upstream/downstream loading rate comparisons. The upstream sites generally had much lower amounts of disturbance upstream.

(3) WY2000 samples collected from multiple sites within various Upper Middle Trinity watersheds allow a snapshot comparison of the relative loading rates of fairly small portions of these watersheds, including areas with lower amounts of disturbance.

(4) WY2000 and 2001 data were used as the basis to compute tributary sediment loads for a 20-year period, 1981-2000. This period was used to allow comparison of the WY2001 data, collected in a critically dry year, to a longer and more hydrologically diverse period of record. These data were also used to provide tributary inputs for the mainstem and tributary sediment budgets developed.

(5) The computed sediment transport data for a given tributary may be compared to sediment inputs from the various upslope sources as a means of verifying the data sets.

(6) Computed sediment transport for the tributaries and the mainstem can be compiled to evaluate the effect of tributary loading on the mainstem both under existing (i.e. historic) and proposed (ROD flow prescription) conditions.

(7) Computation of sediment transport rates by grain size (i.e. >8mm, <8mm) assists in evaluating the relative amounts of coarse (generally beneficial to instream habitat) and fine (generally detrimental).

WY2000 Sediment Transport Data

The objective of this data collection effort was to provide reconnaissance level information on the relative current contributions of sediment from major sub-watershed areas in the Trinity River. The work consisted of collecting field data and developing the following work products for each sampling site:

1. Develop a stage/discharge relationship,
2. Collect turbidity and suspended sediment data
3. Develop a SSC/discharge relationship,
4. Develop a suspended sediment load (SSL)/discharge relationship
5. Compare rates at different planning and sub-watershed areas to identify areas for focused WY2001 data collection.
6. Compare transport rates from different geologies to evaluate whether the DWR (1981) relative erosion risk categories were appropriate.

Some 650 samples from 142 stations were collected and analyzed for turbidity and/or total suspended solids (TSS) in WY2001. Figures 11a-d show the sample sites by Planning Watershed. Table 9 lists the measurements per site for WY2000.

WY2001 Sediment Transport Data

Some 299 samples were collected at 50 sites in WY2001. Sampling practices were changed in WY2001, such that most reported sample values consist of an average of at least 2 replicates collected sequentially at each site. In the case of turbidity, commonly 3 samples were analyzed. The replicate samples provide increased confidence that the results are accurate.

As noted previously, continuous dataloggers were installed at 12 sites in WY2001. Discharge rating curves were established at all sites based on 3-5 streamflow measurements, and where available,

historical data or data from the Trinity River Restoration Program or other agencies (USGS and DWR).

Figure 12 shows portions of selected WY2001 hydrographs developed for 5 study sites in the Upper Middle PW. Table 10 lists the measurements per site for WY2001.

Sediment Transport Data Analyses:

Maximum NTU Observed by Station

Table 12 shows the maximum turbidity values observed during the course of this study at selected sites throughout the watershed. Values in NTU's are separated into groups of various ranges of turbidities for ease of comparison. General notes are included for each site identifying watershed issues or possible causes of the observed values. No sites that are considered to have little disturbance upstream were found to have NTU values exceeding 100, and most were lower than 50 during the storms in WY2000 and 2001 when data were collected. In contrast, in watersheds with high disturbance, values were typically in excess of 100 NTU, and sometimes higher. The highest turbidity value observed was 911 NTU at a small creek draining the Diener Mine, southwest of Trinity Center. Values in excess of 500 NTU were also found in Indian, Reading, and Browns Creeks, all watersheds with substantial recent management activities.

WY2000 Synoptic Sampling

Detailed synoptic sediment sampling was conducted in three sub-watersheds within the Upper Middle Trinity in WY2000. Synoptic sampling involves the collection of samples from numerous sites within a watershed in as short a period of time as possible so that samples generally reflect similar hydrograph positions. For the synoptic sampling, most of the samples were only analyzed for turbidity, since many of these sites were not complete gaging sites, but were rather measurements collected to compare the relative sediment loading from as many sites as possible. Rush Creek (Table 13 and Figure 13), Weaver Creek (Table 14 and Figure 14), and Browns Creek (Table 15 and Figure 15) were the Upper Middle Trinity PW sub-watersheds monitored using this technique.

In Rush Creek, samples were collected from 6 mainstem sites, starting at the upstream end of the USFS campground near the wilderness boundary and proceeding downstream to the HVT gaging site near the confluence with the Trinity River. 11 tributary streams were sampled that provide inflow at different reaches between the mainstem sites, as listed in Table 13. Figure 13 shows the locations of the sample sites. Values ranged from 6.0 to 743 NTU during the 2/14/2000 storm. All measurements were collected in a 40-minute period and so represent relatively comparable positions on the storm hydrograph. The mainstem Rush Creek samples progressively increase from a value of 6 NTU seen at the campground to 149 NTU near the confluence with the Trinity. Most of the sampled tributaries join Rush Creek downstream of Highway 3 and were sampled along Rush Creek Road. A number of tributaries, and in particular Baxter Gulch (known to be a large source of sediment in recent years), also enter from the east side, but no access for sampling could be obtained. Tributary values ranged from 24 to 743 NTU, with the highest values coming from a small tributary that torrented in 1997 and is still bleeding, and Snow Gulch, a tributary draining the Browns Mountain Fire area, which includes salvage logging and road effects.

In the Weaver Creek watershed, samples were collected at 24 sites, including the four larger tributaries (West Weaver, Sidney Gulch, East Weaver, and Little Browns Creeks) and numerous smaller streams. Table 14 lists the sites, turbidity values, and a general source description, while Figure 14 shows the location of the sample sites. All samples were collected in a 65-minute period on 2/14/2000. West

Weaver Creek had a low to moderate turbidity value of 27 at Highway 299 which increased sharply to

103 at Mill Street. Sources between these two sites include roads and development up Oregon Street, Highway 299 runoff, and possible bank erosion and effects from historic mining (now mostly land owned by BLM). Sidney Gulch values were 53 NTU at Memorial Drive (near the Caltrans yard) and decreased to 37 NTU at Mill Street. Relatively clear runoff from impermeable urban areas probably helps dilute the higher values observed upstream. The drainage area above Memorial Drive includes road runoff, timber harvest, a small amount of development, and effects from historic mining. Sampling in the East Weaver sub-basin showed very low turbidity values (5 NTU) near the National Forest boundary, increasing to 31.5 NTU at Highway 3, and to 53 NTU at Mill Street. Little Browns Creek samples began at Roundy Road (27 NTU), increased to 48 NTU at Highway 3, and then to 75 NTU at Browns Mountain Road near the confluence with mainstem Weaver Creek. The highest value in the entire watershed in this storm was 192 NTU at the Weaver Creek near Douglas City site, the most downstream of the sites.

In the Browns Creek watershed, 9 samples were collected on 2/14/2000 in a 65-minute period (Figure 15). Four of these sites were on the mainstem, and 5 on tributaries (Table 15). A number of significant tributaries were not available for sampling either due to location (being across the mainstem from any road access, and thus not reachable during higher flows, such as East Fork Browns Creek) or access (no permission on private property, such as Horsemane Creek). Values ranged from 48 to 407 NTU. No sample was obtained at the Browns Creek near Douglas City site, the most downstream in the watershed, as that gage was not installed until March 2000. Moderate turbidity values were observed on the mainstem above the East Fork (48 NTU), which had increased to 76 NTU at a site below Hazel Gulch, to 407 NTU at Deerlick Springs Road, and then decreased to 168 NTU at Highway 3. High turbidity values (149-347) were found on Spring Gulch and Middleton Gulch, both draining land with extensive recent timber harvest, and in Little Creek (at Highway 3 and on the West Fork) draining Highway 3 and areas of recent timber harvest.

Analysis of Sediment Load Values by Geologic Terrane

Figure 16 shows the WY2000 sample sites overlain on a simplified geology map of the watershed. WY2000 data were stratified by geology to evaluate possible differences between sediment generation and transport rates in the various geologic terranes. Figure 17 plots turbidity values versus discharge for 5 geologic terranes. Although there is considerable scatter, the data suggest that the Hayfork Terrane produces lower turbidity values. The North Fork Terrane and Galice Formation best-fit lines are very similar, though the data for the Galice Formation exhibit the greatest scatter of all the terranes, and thus there is little statistical relationship between discharge and turbidity. The Eastern Klamath and Central Metamorphic terranes plot well above the other terranes at most discharges, indicating greater sediment loads from those areas. Figure 18 is a similar analysis, but uses suspended sediment load instead of turbidity. Since computation of suspended sediment load requires discharge information that was unavailable for many downriver sites, there were considerably fewer data available for this analysis, and no data for the Hayfork Terrane were available. The North Fork Terrane still plots below the other geologic terranes. Given the scatter observed in these analyses, it is apparent that geology by itself does not explain much of the variability between watersheds in terms of observed sediment loads or turbidity. The extent of management activities appears to play a more significant role that geology in determining sediment yields.

Figure 19 plots suspended sediment load versus unit discharge (cfs/mi^2) for five sites all in the Weaver Creek sub-watershed and all in the Central Metamorphic Terrane. The data for the individual sites show much better relationships (less scatter) and also highlight significant differences throughout the watershed. Sediment load per unit discharge are highest at the downstream most site, Weaver Creek near

Douglas City. Loads at this site are up to an order of magnitude higher for the same unit discharge than the four major tributaries, suggesting that a considerable amount of the load may be coming from between Mill Street and the Highway 299 bridge from instream sources (slides, bank erosion) and other unmeasured tributaries. Sidney Gulch produces notably lesser sediment per unit discharge than the other sites.

Historic Suspended Sediment Data

Several datasets are available from USGS records with which to evaluate historic suspended sediment discharge and annual loads. On the mainstem, records are available for 1957-1967 for the South Fork Trinity near Salyer, and 1957-1970 for the Trinity River at Hoopa, while discrete samples at Lewiston during this same period allow suspended sediment transport to be computed (Table 16). For the period 1957-1960, annual suspended sediment discharge for the Trinity River at Lewiston gage averaged only 5.2% of the load at Hoopa, despite having 25% of the drainage area. In contrast, the South Fork Trinity delivered 25% of the load at Hoopa for the same period of 4 years. The data suggest that roughly 70% of the load at Hoopa was generated in areas mainstem areas downstream of Lewiston, or as shown in the table below, at a rate 6 times the upper watershed and more than 1.5 times the SF. This implies a considerable amount of instability and sediment yield in the Upper, Lower Middle, and portions of the Lower Trinity areas even before the December 1964 storm.

COMPARISON OF MAINSTEM SUSPENDED SEDIMENT LOADS

WATER YEAR	TRINITY RIVER AT LEWISTON (tons)	SF TRINITY RIVER NEAR SALYER (tons)	TRINITY RIVER AT HOOPA (tons)	HOOPA - LEW + SFT (tons)
1957	109,727	425,000	1,688,000	1,153,273
1958	554,807	2,501,000	7,423,000	4,367,193
1959	71,624	349,600	2,193,000	1,771,776
1960	62,498	408,900	1,682,000	1,210,602
TOTAL	798,656	3,684,500	12,986,000	8,502,844
Drainage	719	898	2,853	1,236
Yield ($tons/mi^2/yr$)	278	1,026	1,138	1,720

The measured sediment yield at Hoopa during the 1964 flood was enormous: some 33 million tons of suspended sediment, which amounts to 15 times the average pre-flood load based on 8 years of pre-flood data. 31% of that sediment was estimated to have been delivered by the South Fork Trinity, while the remaining 23 million tons would have come from the mainstem watershed below the recently completed Trinity Dam, or at a rate of almost 19,000 $tons/mi^2$, and these values do not include bedload. Sediment loads remained elevated for a number of years after the 1964 flood, particularly in the SF Trinity, which is still recovering today, almost 40 years later. Data from Knott (1974) show that by 1970 some of the sub-watersheds were nearly recovered to per-1964 conditions, such as the North Fork Trinity, while loads remained elevated at Hoopa and on the SF Trinity.

Eight years of suspended sediment data were also collected on Weaver Creek, from 1962-1969. Based on these data, Knott (1974) estimated the average suspended sediment load of Weaver Creek would be 34,600 tons/year or 715 tons/mi^2/yr. Interestingly, the 1964 flood did not, according to Knott, cause a change in the sediment transport rates for Weaver Creek, implying that the event was not that geomorphically significant in the Weaverville area. Figure 20 compares historic suspended sediment data for Weaver Creek with data collected in WY1999-2001. A shift in the best-fit line for the datasets indicates that suspended sediment loads have been reduced in the watershed since the 1960s.

Grass Valley Creek and Trinity River below Limekiln Gulch Total Sediment Load

Extensive sediment data are available from the USGS for Grass Valley Creek at Fawn Lodge covering the period 1976-1999, and for the Trinity River below Limekiln Gulch from 1982-1991. Since 1999, the USGS gage on the mainstem below Limekiln Gulch has been re-occupied by the Hoopa Valley Tribe (HVT) for the Trinity River Restoration Program. Available data are summarized in Table 17. For Grass Valley Creek, sediment discharge has totaled some 843,000 tons over the 25-year period of record, a rate of 1,095 tons/mi^2/yr. Of this total, 78.5% was suspended sediment and 21.5% was bedload. It should be remembered that the Fawn Lodge gage only measures 30.8 mi^2 of the 36.8 mi^2 entire watershed, and thus the sediment load reaching the Hamilton Ponds at the mouth of the creek is considerably larger. Figure 21 shows suspended sediment rating curves for Grass Valley Creek for 1976-2001. In water years 1997-1999, it appeared that the sediment discharge rating curve had shifted to the right, implying lower suspended sediment loads for the same discharge, perhaps indicating the success of watershed restoration efforts in reducing sediment yield. However, in this study, data was collected at the Fawn Lodge site in WY2000 and 2001, and these data show that any shift in the rating curve did not appear to continue in the most recent period. A substantial portion of the coarse load is now trapped by the Hamilton Ponds and prevented from entering the mainstem.

At the Limekiln Gage, 10 years of sediment data were collected by the USGS and 2 years by HVT. The total sediment load measured for these 12 years is 796,000 tons, or 714 tons/mi^2/yr for the 93 mi^2 basin downstream of Lewiston Dam. Of this amount, 66.2% has been suspended sediment and 33.8% has been bedload.

Comparing the two datasets, it is apparent that Grass Valley Creek produces almost as much sediment as the mainstem can transport by itself, without taking into account any of the other tributaries, sediment generated in-channel from the mainstem, or any other sources.

Trinity River Restoration Program Sediment Rating Curves

Since 1997, the Trinity River Restoration Program has been collecting sediment transport data on major tributaries in Upper Middle Trinity Planning Watershed. The focus initially was on the tributaries between the dam and Indian Creek in order to provide estimates of fine and coarse sediment delivery to the mainstem in the reach that the river was least able to transport it. In WY2000 and 2001, additional sediment transport data were collected on the remaining large tributaries in this area (Weaver, Reading, and Browns).

Suspended sediment rating curves are shown for Deadwood, Rush, and Indian Creeks for available years in Figures 22-24. The most important observation to make form these curves is that substantial shifts in these curves have been observed in recent years as sediment supply changes in response to storm events. In most of these watersheds, the large 1997 flood event generated substantial sediment inputs that caused a shift in the rating curves. These shifts continued into WY1998, but by late in the season at most

sites, the curves had shifted back to their pre-1997 storm rates, indicating that much of the readily transportable material has been flushed through the system. On Indian Creek, this process has occurred twice, first in response to the 1997 flood and then as a result of the April 2000 high flows.

Figure 25 shows suspended sediment rating curves for the mainstem Trinity River below Limekiln Gulch sub-divided by the nature of the high flow event. Winter storms typically transport much higher suspended sediment loads than do dam release flows, due to the suspended sediment contributions of the tributaries

during the winter. Dam releases typically occur in the spring when tributary inflows are decreasing, and even safety of dams releases in the winter months typically transport much less sediment due to reduced tributary contributions on the falling limb of whatever significant storm event filled the reservoir to the point that storage was encroaching on the flood control pool, and releases to the river has to be increased. It is important to be aware of the flow timing-related difference between the transport rates when evaluating sediment transport along the mainstem. In general, suspended sediment transport operates in a supply-limited framework, in that a given flow in the mainstem typically has the ability to transport as much suspended sediment as is delivered to it. However, deposition may also occur in various reaches of the river simply due to local hydraulics.

Figures 26-29 are bedload rating curves for the same sites. Similar, but even more distinctive shifts in the bedload discharge rating curves have occurred at these sites in response to large flood events. At Deadwood Creek (Figure 26), the transport rates do not appear to have recovered from the 1997 and 1998 high flows, in contrast to the other sites. At Rush Creek (Figure 27), bedload transport rates after recovery from the 1997 flood are roughly one-half an order of magnitude less than those affected by the storm generated sediment pulse. The rate change is even greater at Indian Creek (Figure 28), where there is more than an order of magnitude difference in the transport rates. Two cycles of storm-generated bedload sediment pulses are evident in Indian Creek after both the Jan 1997 and April 2000 events.

Bedload transport rating curves at the mainstem Limekiln site are shown in Figure 29, including data from the USGS. It was apparent that there were two distinct populations of bedload transport in the 1982-1991 period of USGS operation: rates were much higher in the early and mid 1980s. We interpret this change after 1986 to perhaps reflect improved conditions in the mainstem, with lesser amounts of sand-sized material available for transport. However, data collected in WY2000 by HVT indicate a modest shift back towards higher rates. This may be in response to sediment delivery in 1997 and 1997 when the Hamilton Ponds filled and spilled considerable sediment into the mainstem. Future monitoring should be able to detect if this is a short-term phenomenon.

Unit Discharge vs. Suspended Sediment Load

To examine sediment source relationships between the various tributary sites in the Upper Middle Trinity PW, the individual site data and relationships were combined and plotted on one graph. In Figure 30, the discharge was normalized by dividing by the contributing watershed area and plotted against suspended sediment discharge for the various sampling sites. This analysis shows that for a similar unit discharge (cfs/mi^2), there appear to be three general groupings of sediment transport rates. Indian, Reading, and Browns Creek all transport similar amounts of suspended sediment, while Weaver Creek occupies an intermediate position, and Rush and Deadwood Creeks transport an order of magnitude less sediment than do the highest producers. These findings support the relative disturbance levels found in these watersheds as described in later sections of this report.

Total Load Sediment Transport, 1997-2001

Total sediment loads have been computed for the four tributary sites (Deadwood, Rush, Grass Valley, and Indian) since 1997, based on the transport relationships presented in the previous sections. Table 18 summarizes these total load results and computed averages and yields for the available data. Yields for Weaver, Reading, and Browns Creek, with only one year of record (and a very dry year at that), are obviously not representative of their longer-term average rates.

WY 2001 Sediment Transport Data

Table 19 presents the sediment transport data collected in WY2001 as part of this study combined with unpublished, provisional data from the HVT gages. Total sediment load computations are presented for 27 sites, of which 3 are located in the Upper Trinity PW, 5 are located in the Lower Middle Trinity PW, and 19 are located in the Upper Middle Trinity PW. 6 of the 27 sites did not have continuous stage records and synthetic hydrographs were developed by correlation with the nearest stream with a continuous flow record adjusted by the ratio of drainage areas. In addition, all sites without continuous stage records have crest stage gages, so that the maximum stage for each significant storm is known. The synthetic hydrographs were adjusted to match the crest stage records as well as discrete gage height observations collected during storm sampling. Not all of the sites had bedload data, and bedload rates were estimated based on a percentage of suspended sediment load from the nearest similar watershed with such data. Bedload rates were typically in the range of 10-40% of suspended sediment loads.

The results of this detailed sediment transport evaluation provide quantitative insights into the relative loading of various sub-watersheds with different levels of disturbance. WY2001 was an extremely dry year and it is not known whether the relationships seen in this “snapshot” would remain valid in other water year types or over a longer-term period.

Stratification of the data provides three general groupings: (1) highly disturbed watersheds with WY2001 loads over 100 tons/mi^2 (Indian Creek and Grass Valley Creek), (2) moderately disturbed watersheds with WY2001 loads in the range of 15-100 tons/mi^2 (most of remaining stations), and (3) reference watersheds with 0-12 tons/mi^2. These groups are not precise, and some watersheds would likely shift into higher categories if more data were available, as a result of having “average” runoff conditions. In our estimation this would include the Trinity River at Parks Creek Rd, East Fork Trinity River, and Little Browns Creek at Browns Mountain Road. In addition, values seem low for Little Creek at Hwy 3 and Oregon Gulch, both of which appear to have extensive disturbance from a combination of highway, harvest, and other roads sources.

The data also allow evaluation of upstream/downstream relationships in watersheds that have less disturbance in their upper watersheds. Such comparisons are possible for Rush, Grass Valley, Weaver, and Browns Creeks. In Rush Creek, loads at the USFS campground upstream of Highway 3, near the wilderness boundary, were very low at 2 tons/mi^2. Loads near the confluence of Rush Creek with the Trinity River had increased to 15 tons/mi^2, a seven-fold increase in the rate per unit area. Considerable sediment loading comes from the lower, more disturbed portions of this watershed, and these load values confirm the general relationships observed in the synoptic sediment sampling discussed in earlier sections.

Subdivision of the Grass Valley Creek watershed provides insights in current locations of sediment generation. With Buckhorn Dam operating on the mainstem of the creek in the upper watershed, Little Grass Valley Creek becomes the most important sediment source, with a rate of 210 tons/mi^2, and 63% of the load measured at Fawn Lodge. A gaging station operated for this study at Lewiston Road, just upstream of the Hamilton Ponds, indicates that considerable sediment is generated between Fawn Lodge and Lewiston Road in the lower 6 mi2 of the watershed. WY2001 data estimate that about 31% of the total sediment originated downstream of Fawn Lodge, either from highway, other roads, harvest, bank erosion, or other disturbance. About 10% of the load measured at Lewiston Road was bedload, all of which would have been trapped in Hamilton Ponds. Much of the remaining suspended sediment load would have passed through the ponds into the Trinity River.

Sediment loads in Weaver Creek also generally follow the results of synoptic turbidity sampling, with low values at West Weaver at Highway 299, and undoubtedly there would have been low values on East Weaver near the Forest Boundary, but there were insufficient data to compute reliable records. Values increased substantially by the time these major tributaries reached Mill Street, though values were still quite low in this dry year. Flows did not reach anywhere near the levels seen in WY2000 at these sites, though WY2000 really only had about "average" precipitation, compared with about 60% of average in WY2001. Little Browns Creek produced less sediment than either of the Weaver Creek branches. Unit area loads had doubled at the downstream most sampling station, at the Highway 299 bridge near Douglas City, indicating substantial inputs from smaller tributaries, bank erosion, and other instream sources.

In the Browns Creek watershed, similar results were found. At the upper station just upstream of the East Fork, loads were measured at 23 tons/mi2, indicating a low to moderate level of disturbance upstream. Middleton Gulch, a small but intensively managed tributary, yielded 44 tons/mi^2. Little Creek, a larger tributary watershed that has substantial highway, road, and harvest impacts, contributed lesser amounts at 17 tons/mi^2. Total load at the downstream station had increased to 65 tons/mi^2, roughly a three-fold increase.

In conclusion, detailed sediment transport measurements provide quantitative data on the effects of disturbance regimes on the sediment yields. WY2001 data support what many persons familiar with the watershed have observed in recent times: Grass Valley and Indian Creeks are the main sediment sources downstream of Lewiston Dam, and due to the level of disturbance, provide significant loads even in critically dry years. Combined loads of these two tributaries in WY2001 were over three times larger than the combined loads of all of the remaining tributaries between the Dam and Browns Creek. If just the watershed from Indian Creek upstream to the dam is considered, these two tributaries produced 36 times the combined load of Deadwood, Rush, and Hoadley. With the most deleterious portion (sand-sized particles) trapped in Hamilton Ponds, Grass Valley does not present the enormous problem that it once did. Currently, emphasis on sediment control should be transferred to the Indian Creek watershed, as it produced over three times the sediment that mainstem could transport, based on comparison of WY2001 transport rates of Indian Creek and the mainstem Limekiln Gage. With this type of loading, the deposits in the mainstem will continue to grow downstream at a significant rate, as has been observed by local residents. This has, and will continue to, increase flood risks for those properties, as well as contribute to habitat degradation downstream. Such efforts could well involve a combination of sediment traps and upper watershed stabilization.

Mainstem Trinity River Sediment Budget for Upper Middle Trinity PW

<u>Introduction</u>

The purpose of this section of the report is to develop a preliminary sediment budget, based entirely on empirical sediment transport rates, between Lewiston Dam and Douglas City. The sediment budget will be computed for two scenarios: (1) existing historic flows, and (2) flow prescriptions assuming implementation of the U.S. Department of the Interior Record of Decision (hereafter ROD), based on the

Trinity River Flow Evaluation and the EIS/EIR completed in 2000. The sediment budget presented here is really an estimate of what would occur if the same series of flows that historically occurred in the 1981-2000 period, occurred in the future, and sediment transport rates developed in 1997-2001 remained consistent for that entire period. Then, the scenario is repeated with the identical flows and transport relationships with the exception of providing the recommended flow prescription from the ROD for each year based on the water year classification scheme (TRFE 1999).

Methods

The evaluation period uses flow information for 1981-2000, a 20-year period. All calculations are based on mean daily flows. On the mainstem, mean daily flows were available for the entire period at Lewiston, for 1982-1991 and 1999-2000 for Limekiln, and 1996-2000 for Douglas City. Synthetic flows for the missing periods at Limekiln were developed by taking the Lewiston measured flows, adding tributary flow inputs (Deadwood, Rush, and Grass Valley) and an adjustment factor (for smaller unmeasured tributaries) based on analysis of the relationship between measured tributary flows and measured mainstem flows in WY1999 and 2000. Once flows had been obtained at Limekiln, a similar process was used to develop flows at Douglas City, using tributary inflows from Indian, Weaver, and Reading Creeks and an adjustment factor based on WY1999 and 2000 data analysis. Tributary flows were developed, as previously described, from measured Grass Valley Creek flows using adjustment factors based on drainage area ratios. Where measured data existed (some tributaries 1997-2000) these values were used.

To adjust Lewiston flows per the ROD flow prescriptions, the water year type was determined. This had been completed through 1995 in the TRFE, but needed to be updated for years since. Once the water year type had been determined (see table below), the ROD flow prescription and timing was determined and these values were pasted into the Lewiston flows. Appropriate smoothing was made when necessary for the flow record to make sense.

WY	Reservoir Inflow Inflow (AF)	Type
1981	884,000	Dry
1982	2,002,000	Ex Wet
1983	2,893,000	Ex Wet
1984	1,535,000	Wet
1985	861,000	Dry
1986	1,597,000	Wet
1987	899,000	Dry
1988	977,000	Dry
1989	1,074,000	Normal
1990	732,000	Dry
1991	504,000	Crit Dry
1992	936,000	Dry
1993	1,766,000	Wet
1994	568,000	Crit Dry
1995	2,221,000	Ex Wet
1996	1,492,000	Wet
1997	1,512,000	Wet
1998	2,701,000	Ex Wet
1999	1,426,000	Wet
2000	1,669,000	Wet

# of Years	Type
4	Ex Wet
7	Wet
1	Normal
6	Dry
2	Crit Dry

Downstream of Lewiston, the net inflows from all tributary sources were obtained by subtraction of the Lewiston flows from the Limekiln flows. These net inflow values were then added to the ROD flow prescriptions to simulate the incremental tributary accretion, in order to arrive at the ROD flows at Limekiln. A similar process was completed between Limekiln and Douglas City.

Sediment transport relationships were based on a power function linear regression of available bedload and suspended load data for WY1998-2001. Mainstem bedload transport values were sub-divided into >8mm and <8mm categories similar to McBain & Trush (1997) and TRFE (1999). Data were not readily available to apply a similar process to tributary data. Daily sediment transport values were then summed by water year and pasted into summary tables.

WY1981-2001 Tributary Sediment Loading Estimates

Development of a sediment budget for the mainstem requires computation of tributary sediment loading. Estimates of tributary loading for the 1981-2001 period were developed as described above and are shown in Table 20. Under the scenario of existing transport rates, Indian Creek delivers about twice as much sediment over the period, compared to the next largest tributary. Grass Valley and Browns Creek are computed to deliver about the same overall amount, followed by Reading Creek, Weaver Creek, Rush Creek, and finally Deadwood Creek. Computed average sediment yield from Indian Creek is 3,649 tons/mi^2/yr. Rush Creek had the lowest rate of 266 tons/mi^2/yr.

Mainstem Sediment Transport, Historic and ROD Flow Prescriptions

Table 21 shows computed sediment loads for the three mainstem stations, Lewiston, Limekiln, and Douglas City based on the combined historic and synthetic flow records. The results at each site are divided into the >8mm and <8mm size fractions. Only bedload is computed from Lewiston, since there is very little source of fine grained materials that comprise suspended sediment in the short reach downstream of the dam. Furthermore, no data have been collected with which to estimate any loading rate for suspended sediment. The sediment transported at Lewiston is predominately coarse sediment, as that is all that is available for transport. This volume of coarse load is also the minimum addition of gravels that would be necessary to prevent channel incision and armoring in the reach downstream of the dam. Roughly an average of 6,000 tons per year would be the minimum necessary, with much larger volumes in wet or extremely wet years, and essentially none in critically dry, dry, and normal years. By Limekiln, the amount of bedload capable of being transported has almost doubled due to tributary flow accretion, and it is about equally divided between the >8 and <8mm size classes. Since there are essentially no sediment transport data for Douglas City, we simply used the relationship for Limekiln as a first approximation. As the tributary accretion is significantly larger in this reach, sediment loads, particularly of bedload increase substantially, with the volume of bedload more than doubling again.

Table 22 shows the same stations for the same period, but the flows now include the ROD prescriptions for spring high flow releases. At Lewiston, the sediment transport is computed to increase about 5-fold with the high flow releases, requiring almost 30,000 tons of coarse sediment per year on average to be added, although Deadwood Creek contributes a small portion of this coarse load. The bedload transport capacity at Limekiln triples, but is computed to be actually lower than Lewiston. It should be realized that this discrepancy is a function of the sediment transport curves used in the analysis, for which there is limited data, and none above 6,000 cfs. However, the analysis suggests that the river at Limekiln might not be able to transport all of the sediment needed to be input at Lewiston. A possible explanation for this is that tributary inflows during the release are relatively small, so flows do not increase by a sufficient amount to compensate for a hypothesized decrease in channel gradient and a change in channel geometry. Sediment transport capacity increases by almost 50% between Limekiln and Douglas City.

Combined Mainstem and Tributary Sediment Transport, Historic and ROD Flow Prescriptions

Table 23 combines the mainstem stations of Lewiston and Limekiln with the tributary inputs between them for the historic and synthetic flow record. The data show that the combined bedload sediment deliveries from the tributaries were about 1.7 times what the mainstem could transport at Limekiln, suggesting that under these conditions (1981-2000) sediment has been accumulating in the channel. However, since the data for Grass Valley Creek do not take into account the trapping and removal of sediment in the ponds since the early 1990s, the deficit is probably not nearly as large. The data do suggest that if all of the bedload were removed at the Hamilton Ponds, by efficient O&M during the winters to prevent any fill and spill situations, then the mainstem would be able to transport upstream tributary loads without long-term aggradation.

Table 24 includes the ROD flow prescriptions, with the identical tributary sediment loads. The mainstem transport capacity upstream of Limekiln sharply increases due to the increased transport of the higher flows at Lewiston. The deficit at Limekiln between the combined Lewiston and tributary loads and the Limekiln transport capacity actually increases with the ROD flows. This implies a net accumulation of coarse sediment in the reach between Lewiston and Limekiln.

Tables 25 and 26 are a similar analysis between Limekiln and Douglas City for the historic flows (Table 25) and the ROD flow prescriptions (Table 26). Browns Creek has been omitted since it joins the Trinity well downstream of Douglas City. Under historic flow conditions, a large accumulation of bedload occurs in this reach, on the order of 540,000 tons over the 20-year period. This would amount to about 400,000 cubic yards or enough to raise the streambed by an average of 5 feet for 4 miles of channel 100 feet wide. This volume seems a little large given what has been observed by local residents, but certainly within a factor of 2 or 3. The important observation here is that the major problem area in the river is not the reach between Grass Valley and Limekiln, but rather the reach between Indian Creek and Douglas City. The data show that the worst problem would occur immediately downstream of Indian Creek, since it is the large sediment source, while further downstream with additional tributary flow accretion from Weaver and Reading Creeks, the situation improves somewhat.

Table 26 shows the results with the ROD flow prescriptions. Surprisingly, these flows do not significantly change the results seen in Table 25. The explanation lies in the increased transport rates occurring upstream of Limekiln due to the high flow releases. The amount of bedload transported at Limekiln shows a three-fold increase, but because there is more sediment being transported there and with the small flow contributions from the tributaries, the river is not capable of transporting significantly greater amounts. This suggests that if transport of tributary-derived sediment was the primary objective, then a "piggyback" release schedule would be much more effective.

Tables 27 and 28 simply summarize the results of Tables 23-26 for easier review, and include a calculation for the increased sediment transport potential from the ROD flow prescriptions.

GEOMORPHOLOGY

Channel Geometry

Trend monitoring of channel geometry can provide insight into changes to the river channel due to specific events (typically large floods) and to longer-term adjustments and recovery from these flood events. Channel geometry is most often monitored through cross section and profile surveys, both of which are two-dimensional representations of channel shape, with the cross section perpendicular to the flow direction, and the longitudinal profile parallel.

Streambed elevations generally reflect the overall balance of sediment transport at their location. If sediment delivered to the channel is greater than the transport capacity of the channel (which is a combination of flow and channel geometry), then the channel will aggrade or rise in elevation. When sediment loads are less than transport capacity, the channel will degrade or scour as long as suitably sized (i.e. capable of being mobilized) alluvial deposits are present on the channel bed. Dramatic channel adjustments have been observed to occur in watersheds with very high sediment production and delivery, particularly when delivered catastrophically, such as in the December 1964 flood in SF Trinity, Willow Creek, and to a lesser degree the New River (Hickey 1969, Lisle 1981)

Channel Planform Changes

Alluvial valley reaches in river systems often act as "response reaches," since they are areas of temporary (in a time frame of 10s to 100s of years) sediment storage that adjust their storage and the stream channel geometry traversing these areas in response to changes in streamflow and sediment discharge. Thus, episodic events such as large floods may cause the channel location to change, sometimes dramatically, in response to the energy of high flows that exceed the resisting forces of the stream channel banks and riparian vegetation. In a similar manner, large influxes of sediment, whether derived in a single large storm event or delivered chronically over a longer time period, may cause changes in channel form in these response reaches as sediment deposition locally overwhelms the capacity of the channel to transport it. Braided and rapidly laterally migrating channels are often the result. This has occurred in the Upper Trinity watershed on the mainstem and in several tributaries during the 1997 flood. Large debris torrents partially blocked the mainstem Trinity River, causing significant channel change.

Below the dam, the pre-dam channel has become "fossilized" due to a lack of high flows and the subsequent encroachment of riparian vegetation. These factors have prevented virtually any channel adjustments until the Junction City area, some 30 miles downstream of the dam. Riparian vegetation, combined with historic dredger tailings still constrains the river in most places, although a few sites show modest changes. Below the North Fork Trinity, the river enters a bedrock canyon, and little change is possible due to a lack of alluvial conditions until near Hawkins Bar.

Tributary Delta Accumulations

A number of reports and studies (Ritter 1968, DWR 1979, Fredericksen, Kamine and Associates (FKA) 1980, USFWS and HVT 1999) have documented and/or described significant geomorphic changes at the confluences of many of the tributaries with the mainstem from Lewiston Dam to the North Fork Trinity River. The geomorphic changes primarily occurred as a result of reduced mainstem flows capable of transporting tributary-derived sediments. In general geomorphic changes include: (1) the pre-dam channel narrowed significantly as the tributary deltas built into the mainstem channel and were subsequently stabilized by vegetation, (2) mainstem channel invert aggradation of 2-8 feet occurred, with significant ponding upstream and downstream of aggradation, and (3) significant bank erosion along the bank opposite delta deposits (Rush Creek and Canyon Creek).

The USGS study (Ritter 1968) involved surveying of 2-5 cross sections at the confluence of 8 tributaries (Rush, Grass Valley, Indian Creek, Weaver Creek, Reading Creek, Browns Creek, Canyon Creek, and North Fork Trinity) including sections across the tributary and the mainstem. The sites were established in 1961, and were all resurveyed in 1965. Rush Creek and Grass Valley sites were also resurveyed in 1963. FKA (1980) indicated that the USGS also resurveyed these cross sections in 1970. Earthmoving at the Rush Creek delta in both 1961 and 1965 complicated the analysis of change at this location. Ritter (1968) also installed 37 photo stations of the streambed of the Trinity River, which were photographed in both 1961 and 1965. Qualitative comparison of the photographs showed that almost all sites changed from cobble-pebble to sand-pebble over the 4-year period.

Fredericksen, Kamine and Associates (FKA 1980) produced aerial photograph comparisons of the tributary confluences in 1961 and 1971, and described the known sequence of events at each site based on the work of others, including sediment removal.

Trinity Restoration Associates (1993) and McBain & Trush (1997) mapped the tributary deltas at Deadwood, Rush, and Indian Creeks at various times and locations between 1992 and 1999 using total station surveying equipment. Measurements have occurred before/after high flows on either the tributaries or mainstem as access allowed. Volume changes in the Hamilton ponds were also mapped and computed. The intent of these data was to prepare a coarse sediment budget for the reach between Lewiston Dam and Indian Creek. GMA (unpublished data 2000) re-surveyed Deadwood, Rush, and the Grass Valley ponds.

Appendix I contains aerial photo comparisons of the Rush, Grass Valley, and Indian Creek deltas in 1961, 1971 (from FKA 1980) and 1997, along with the most current survey data for three cross sections at both the Rush Creek and Indian Creek sites. Surveys indicate 2-4 feet of channel aggradation at Rush Creek and 4-10 feet at Indian Creek. These values support the sediment budget computations in the previous section.

SEDIMENT SOURCE ANALYSIS

This section describes the process used to evaluate possible sources of sediment within the Trinity River Watershed and presents the results of these analyses. The sediment source analysis encompasses three primary components: (1) evaluation of the dominant geomorphic processes that deliver sediment to the various stream channels in the Trinity River watershed through field inventory, review of pertinent documents, and discussions with those involved with current studies in the basin or other nearby basins and (2) measurement of various parameters, such as landslide size/type/associated land use, road length, and harvest areas from sequential aerial photography.

The sediment source portion of this analysis combines office-based aerial photo mapping and GIS analyses with extensive field verification and inventory. For the office-based work, data collection was limited to parameters discernible on aerial photography, thus eliminating identification or mapping of many small-scale features (such as gullies, streamside landsliding, and bank erosion, all of which would be generally hidden beneath the canopy). Given the scale of the photography that was available for this analysis and given the need for consistency between photo sets of differing scales and print qualities, only mass movement features with dimensions (length and width) exceeding 75 feet, or approximately 5000 square feet in area, were identified. Various studies have shown that for many areas of Northern California, sediment delivery to channels is dominated by the contributions of the largest slides (Pitlick 1995, Kelsey et al. 1995, Raines 1998, PWA 1998), although recent sediment source analyses in Mendocino County (GMA 2000, 2001) suggest that smaller slides may be an important component of the sediment budget in certain watersheds.

Sources of sediment in the Trinity watershed include landsliding (deep-seated landslides, shallow-seated landslides or debris slides, and debris flows or torrents), surface erosion (hillslope erosion and road erosion), and fluvial erosion (gullying and streambank erosion). This sediment source investigation included photo-based measurements to estimate landsliding and surface erosion, with considerable field verification surveys of these features. Detailed sample plots were used to estimate the occurrence of small-scale erosional features, as well as legacy roads. Detailed road inventories were used to establish erosion rates by geologic type, road position, and road surfacing. Estimates of fluvial erosion were based field inventories and applied on a stream order basis.

A major constraint on implementation of this study involved access limitations, primarily involving lack of access to private lands, especially industrial timberlands. After a considerable effort was expended in negotiations with Sierra Pacific Industries, by far the largest of the private industrial timberland owners, access for landslide verification, road inventory, channel erosion inventory, or sample plot measurement, was ultimately denied. Information on private lands was only developed by indirect methods involving aerial photo analysis and GIS analysis.

Landslides

Stratification of the watershed, as described in the methods section resulted in the highest priority being placed on the Upper Middle Trinity (UMT) Planning Watershed. As a result, the following mapping occurred or existing information used:

Upper Trinity: 1979 DWR mapping (entire PW)
1999 GMA mapping (147 mi^2 of Upper PW)

Upper Middle Trinity: 1944 GMA mapping (entire PW)

	1979 DWR mapping (entire PW)
	2000 GMA mapping (entire PW)
	1960 or 1970 GMA mapping (Rush Creek and Browns Creek)
	1980 GMA mapping (Rush Creek and Browns Creek)
	1989 GMA mapping (Rush Creek and Browns Creek)
Lower Middle Trinity:	1979 DWR mapping (entire PW)
Lower Trinity:	1979 DWR mapping (entire PW)
	1944 SRNF mapping (Mill, Tish Tang, and Horse Linto Creeks)
	1960 same
	1975 same
	1990 same
	1998 same

1979 DWR Mapping

We digitized the active slides shown on DWR's large paper map of the mainstem Trinity River watershed, as digital files no longer (or perhaps never) existed. 419 slides were identified, distributed throughout the watershed as shown below.

Distribution of DWR 1979 Slides

Planning Watershed	Number
Upper Trinity	280
Upper Middle Trinity	46
Lower Middle Trinity	53
Lower Trinity	40
Total	419

Since none of the typical landslide database information existed for these slides, we had to make a number of assumptions. First, all slides were assumed to have a "definite or probable" certainty, thus none were discarded from further consideration. Second, slides were only sub-divided by debris slide and debris torrent categories, as defined by DWR. We used the average slide thicknesses from our field inventory combined with the GIS area to estimate slide volume. Third, we assumed that the average delivery rates for the two types from our field inventories were applicable to all of the DWR slides. Finally, we intersected road and harvest coverages applicable to the 1979 time period to determine a land use category for each slide. Slides that were located in harvest units were assumed to be harvest-related, while those within a 100-foot buffer of the roads layer were assumed to be road-related. All other slides were assumed to be non-management related. Since digital files of harvest on Forest Service lands since 1980 do not exist, it is likely that harvest-related slides are under estimated by using this method.

DWR 1979 Slides by Land Use Category

Land Use Category	Number	% of Total
Non-Management Related	240	57.3%
Harvest Related	62	14.8%
Road Related	117	27.9%
Total	419	100.0%

We examined the distribution of the DWR slides by geology and found the following results:

Geology at DWR 1979 Slide Locations

Geology at Slide Location	Number	% of Total
Bragdon Formation	9	2.1%
Central Metamorphic Sub-province	28	6.7%
Copley Greenstone	6	1.4%
Eastern Klamath Sub-province	16	3.8%
Galice Formation	13	3.1%
Granitic	71	16.9%
Hayfork Terrane	15	3.6%
North Fork Terrane	10	2.4%
Rattlesnake Creek Terrane	27	6.4%
Ultramafic Rocks	213	50.8%
Weaverville Formation	11	2.6%
TOTAL	419	100.0%

Tables with slide numbers and volumes by Planning Watershed and sub-watershed are provided in Appendix Tables J-1 to J-4.

GMA 1944 - 2000 Mapping

A total of 1044 features (slides) were mapped during this study. Features were given a certainty rating of definite, probable, or questionable, and the results were 158, 546, and 340 slides by each certainty category, respectively. Based on our field verification surveys, we found that most of the "questionable" features were not slides (only 6 of 68 examined in the field were actual slides). As a result, we screened the project database and eliminated all questionable features from further consideration except the 6 we had verified, which resulted in a database of 710 definite or probable landslide features. All of the definite or probably features we examined in the field were actual slides, so no adjustment of those categories was made.

Another portion of the screening process had involved separation of landslide features into two categories based on assessment of sediment delivery: either delivering or non-delivering. Delivering slides are those whose sediment directly enters a watercourse. Non-delivering slides are those whose sediment generation only reaches a watercourse at a rate comparable to background hillslope creep. Features mapped as non-delivering were eliminated from all future analyses. Determination of sediment delivery status is based on the judgment of the geologist performing the mapping and takes into account slide position relative to the adjacent watercourse, slope at terminus of slide or run-out area, and other factors. This screening step eliminated a few of the large, apparently inactive older landslides that were mapped in this study, since these were judged to not be delivering sediment in excess of background creep rates. This included a number of the very slow-moving earthflows slides throughout the watershed, though relatively few of this type were identified in our mapping process.

Landslide Verification Surveys

Landslide verification surveys were performed to: (1) assess whether the features observed were actually slides, (2) establish thickness by slide type, which is needed to perform volume calculations, (3) validate the size of landslides mapped from aerial photography, and (4) validate the land use category assigned to each slide.

We verified 152 of the features mapped. 68 of these were mapped as "questionable", and when field verified, only 6 of the 68 turned out to actually be landslides. All of the "definite" and "probable" features we examined in the field were indeed slides. The distribution of verified slides by Planning Watersheds and sub-watersheds is shown below.

Verified Slide Numbers by PW

Lower Middle Trinity	10
Upper Middle Trinity	117
Upper Trinity	25
Total	152

Verified Slide Numbers by SW

Canyon Creek	10
Browns Creek	9
Grass Valley Creek	23
Hoadley Gulch	6
Indian Creek	21
Lewiston Lake Area	4
Little Grass Valley Creek	7
Poker Bar Area	1
Reading Creek	11
Rush Creek	15
Weaver Creek	20
East Fork Trinity River	6
Minnehaha Creek	2
Ramshorn Creek	1
Snowslide Gulch Area	1
Stuart Arm Area	3
Stuart Fork	2
Upper Trinity River	10

Each of the slides verified in the field were walked and dimensions (width, length, and thickness) measured. The average slide thicknesses for four categories verified (no earthflows were field verified) are shown in the table below along with the number of slides measured to develop the average. Earthflows were assigned a thickness of 10 feet, based on other values in the literature (GMA 2001b). With the exception of debris torrents, the observed thicknesses fall within the ranges of other recent sediment source analyses on the north coast. Mendocino Redwood Company (1999) found, based on extensive field inventories, that road-related slides in the Albion River watershed in Mendocino County had a mean thickness of 5.5 feet, while non-road related slides had an average thickness of only 4.0 feet. These values are similar but somewhat larger than those found by MRC in the Noyo (MRC 1999).

Stillwater Sciences (1999) used 1.3 m (4 feet) for shallow landsliding in the South Fork Eel Basin, based on average thicknesses from Kelsey et al. (1995) in the Redwood Creek Basin, and Kelsey (1977) from the Van Duzen basin. Exactly the reverse of the Albion landslide depths was found in the Garcia River watershed, where data from surveys conducted by Louisiana-Pacific showed that landslides averaged a depth of 5.5 feet while road fill failures averaged 4.0 feet in depth.

Our field measurements in the Trinity watershed found that the thicknesses of debris torrents averaged 9.1 feet, which is considerably larger than our other data and most other measurements in the literature. As shown in the table below, 21 debris torrents were examined in the field to develop the average value. The explanation for this large thickness, we believe, is based on the magnitude of the storm causing these features. The January 1997 event was an unusually intense rain-on-snow storm. Numerous very large debris torrents occurred during that storm, particularly in the rain-on-snow zone (4,000-6,000 feet) in the Upper Trinity PW.

Slide Type	Number Verified	Average Verified Slide Thickness (ft)
Debris Torrents	21	9.07
Debris Slides	43	4.55
Inner Gorge Debris Slides	16	3.50
Gullies	8	2.81

We also compared field measured slide area, computed from average width multiplied by average length, with the GIS area for the feature. 88 landslides had verification measurements collected in the field. The table below shows the number of slides in categories that relate the ratio of the aerial photo mapped slide area versus the area field measured. The categories are ranges defined as a plus or minus percentage around a perfect match. For example, we found 23 slides that the ratio of the areas was within 10% of a perfect match. 40 slides, or almost 50% of the slides field-verified, were within a range of +/- 20%. 78% of the slides were within a range of +/- 40%. 51 of the 88 slides had a ratio of less than one (the GIS area was smaller than the field verified area), while 37 were greater than one. The average ratio for all 88 slides was 1.04, which we feel indicates that the aerial photo mapping was fairly accurately done, and thus the values derived should be reasonable, given that only 15% of the slides were verified. This percentage is higher than that achieved in the South Fork Trinity (Raines 1998).

Percent Category of Area Aerial Photo Mapping vs Field Verifcation	Number of Verified Slides
+/- 10%	23
+/- 20%	40
+/- 30%	56
+/- 40%	69
+/- 50%	74
>50%	7
<50%	7
<1.0	51
>1.0	37
Average Ratio :	1.04

Sediment Delivery Ratios and Volume-to-Weight Conversions

Sediment delivery factors vary considerably in the literature, from 40-100% depending upon slide type and position. Based on our field investigations in 2001, we found an average delivery for debris torrents of 90% and debris slides of 70%. All field-verified landslides had specific delivery factors based on field observations. Other studies have used 80% for riparian roads and 50% for shallow landslides (Cafferata/Stillwater Sciences, pers. comm. 1999). PWA selected 40% for both road and hillslope landslides in the North Fork Elk River watershed. In this study, delivering slides were placed into four categories based on estimated percent delivery: <3%, 3-33%, 33%-66%, and >66%. Volume calculations used the midpoint of each of these percent delivery classes (0.02, .18, .50, and .83, respectively) as factors to adjust slide volumes. We converted volumes (area x thickness, in yd^3) to weight using a factor of 100 pounds/ft^3, or 1.35 tons/yd^3.

Slide Analysis

Following the verification analysis, the remaining dataset was queried by landslide type, year, underlying geology, number of slides and area, and the locations were separated into sub-watershed areas for evaluation at that level. Summary tables for the Planning Watersheds and each sub-watershed were prepared for use in interpreting the data and performing volume calculations. Of the 710 slides mapped over the various photo periods, 294 or 41.4 % were debris slides, 272 or 38.3 % were debris flows/torrents, 77 or 10.8 % were inner gorge debris slides, 35 or 4.9% were gullies, and 32 or 4.5 % were earthflows.

GMA Mapped Landslides by Type

Landslide Type	Number
Debris Torrents	272
Debris Slides	294
Earthflows	32
Gullies	35
Inner Gorge Debris Slides	77
TOTAL	**710**

We queried the database to evaluate the distribution of landslides by type by geologic terrane. The Central Metamorphic sub-province, ultramafic rocks, and granitic rocks account for about 82% of the landslides mapped by GMA. It should be noted that we did not map landslides in the Lower Middle Trinity, where the most of the Hayfork and North Fork Terranes are located, so it is not surprising that those two terranes have low numbers. These data confirm DWR’s general geologic instability analysis that suggested that the Bragdon Formation, Copley Greenstone, and Eastern Klamath sub-province are all relatively stable terranes.

GMA MAPPED LANDSLIDES BY TYPE AND GEOLOGY

	LANDSLIDE TYPE										TOTAL	
	Inner Gorge		Debris Torrents		Earthflows		Gullies		Debris Slides			
Geological Formation	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%
Bragdon Formation	5	6.5%	5	1.8%			1	2.9%	19	6.5%	30	4.2%
Central Metamorphic Subprovince	33	42.9%	72	26.5%			18	51.4%	103	35.0%	226	31.8%
Copley Greenstone	1	1.3%								0.0%	1	0.1%
Eastern Klamath Subprovince	2	2.6%	2	0.7%	3	9.4%	3	8.6%	4	1.4%	14	2.0%
Granitic	14	18.2%	63	23.2%	9	28.1%	2	5.7%	64	21.8%	152	21.4%
Hayfork Terrane	1	1.3%	4	1.5%			1	2.9%	13	4.4%	19	2.7%
North Fork Terrane	7	9.1%	3	1.1%			3	8.6%	16	5.4%	29	4.1%
Ultramafic Rocks	14	18.2%	110	40.4%	20	62.5%	4	11.4%	61	20.7%	209	29.4%
Weaverville Formation			13	4.8%			3	8.6%	14	4.8%	30	4.2%
TOTAL	**77**		**272**		**32**		**35**		**294**		**710**	**100.0%**

GMA Upper Middle Trinity PW Landslide Results

Table 29 shows the number of landslides mapped by GMA in the 1944 and 2000 periods, combined with the DWR 1979 data for the Upper Middle Trinity Planning Watershed. The data are sorted by sub-watershed and by land use category. The number of slides increased dramatically in the most recent period, going from 64 slides in 1944, to 50 slides in 1979, to 250 slides in 2000. This trend is consistent among all sub-watersheds. Reading Creek was found to have the largest number in 2000 with 49, followed by Browns Creek, Indian Creek, and Grass Valley Creek. The number of road-related landslides increased from 26% of the total in 1944 to 36% in 1979, and remained at 36% in 2000. The number of harvest-related slides increased from 2% in 1944, to 24% in 1979, to 31% in 2000. The forest, or non-management related slides decreased from 72% in 1944 to 40% in 1979 to 33% in 2000.

Although comparisons between the number of slides is useful at one level, it is the comparison between delivered sediment volumes by type, period, and watershed location that are of primary importance in evaluating both high risk areas for certain slide types and also changes in sediment delivery over time. Table 30 presents estimates of delivered slide volume for the 1944, 1979, and 2000 periods. Road-related volumes declined from 37% in 1944, to 23% in 1979, but then increased to 27% in 2000. Harvest-related landslide volumes increase from essentially 0 in 1944, to 23% in 1979, and remained at 21% in 2000. Forest slides declined from 63% in 1944, to 54% in 1979, to 52% in 2000. Weaver Creek and Indian Creek were the two largest producers in the 2000 period. Notably, Rush Creek and Weaver Creek were dominated by non-management related landslides in the 2000 period (both at 94% of the total), undoubtedly related to rain-on-snow debris torrents and slides from the 1997 storm event. In most of the remaining sub-watersheds, the combined management-related landslides (roads and harvests) make up 50-90% of the slides. Totals for the entire PW mask significant differences between the rate and cause of landsliding in the various sub-watersheds.

Two sub-watersheds, Rush Creek and Browns Creek, were also mapped in either 1960 or 1970, and 1989 to see if additional detail in the chronology of landsliding became apparent using roughly 10 or 15-year periods instead of 20+ year periods. The results for both numbers of slides and slide volumes are shown in Table 31. The results seem to show that management and non-management related landslides occur in cyclical patterns in the Rush Creek watershed. We interpret the large volumes of non-management slides seen in 1979 and 2000 to reflect the passage of the two most intense storms in this part of the watershed probably this century, 1974 and 1997. Apparently, both of these storms produced intense rain-on-snow conditions in the Rush Creek watershed, with the result of generating a number of very large slides. The same increase in slide volumes is seen during periods containing large storm events in the Browns Creek watershed, however, in this case, 78-100% of the slide volumes after 1960 are management-related, mostly occurring in harvested areas.

Six Rivers National Forest Mapping

Six Rivers National Forest has recently completed detailed landslide mapping in a portion of their lands in the Lower Trinity Planning Watershed, including Mill, Tish Tang, and Horse Linto Creeks. They graciously provided their pre-publication data for use in the sediment source analysis (M. Smith, pers. comm. 2001). We compiled their data for the three tributary watersheds only for those lands outside of the Hoopa Valley Indian Reservation, and the data are presented in Table 32. The results have several notable findings: (1) 57-87% of the slide volume occurred in the 1960-1975 period, obviously related to the large December 1964 flood event, (2) volumes since 1975 have been less than 5% of the total reflecting generally small storms in the lower watershed in the last 25 years, (3) management-related slides totaled only 15.3% of the total slide volume, while almost 85% were judged to have natural causes, and (4) road-related slides produced 12% of the total, while harvest-related slides were only 1.1%.

Summary of Landslide Volumes by PW

Table 33 summarizes all of the landslide volume data compiled for this report. Only the Upper Middle Trinity PW has data for all three periods. In addition, data shown for both the Upper Trinity and the Lower Trinity are only for portions of those planning watersheds, limited to the available data. The results for the Upper Middle Trinity PW have been previously discussed.

Table 34 is an alternate analysis of landslide volume, by estimating volumes for the entire Lower Middle and Lower Trinity PW simply as a percent of the DWR 1979 volume.

Conclusions: In general, there appears to be a consistent pattern between road construction, harvest disturbance, and resulting sediment production from landslides. Much larger volumes of sediment delivery from landslides were found during periods containing large storm events. Sediment production after the 1979 period in the Lower Trinity watershed has been dramatically lower, which is attributed to a combination of lesser amounts of harvest on the USFS land, with substantially improved harvest implementation following the 1973 change in the Forest Practice Rules, and a lack of large storms.

Confidence in Landslide Analysis

Although few datasets are available to compare the difference between field-based and aerial photography-based landslide analyses, a recent study by the Oregon Department of Forestry (1999) following the 1996 storms provides additional confirmation of the challenges facing aerial photo-based landslide interpretations. Prior to the ODF study, relatively little was known about potential biases in air photo inventories of landslides. Certainly, forest canopy may make detection of landslides more difficult, and it seems reasonable to suspect that a higher percentage of landslides in a recently harvested area may be visible compared to that visible in a mature forest.

ODF found that air-photo surveys detected a greater percentage of landslides in recently clearcut stands versus uncut or mature stands as compared to the ground survey results for the same age class. At one site (Mapleton), 59% (17 of 29) of landslides observed on the ground were visible in air photos at 1:6,000 scale for forest stands clearcut within the last nine years. However, for landslides found in stands over 100 years old, only 5% (2 of 38) of landslides observed on the ground were visible in the 1:6,000 scale photos.

This bias towards detecting more landslides within younger forest stands using air photos may significantly affect the ratio of landslide densities and erosion volume per acre for recently clearcut stands compared to mature stands. ODF (1999) found that if one were comparing landslide density using 1:6,000 air photo analysis, the ratio of landslides in the clearcut stands versus those in mature forest stands is about 21:1, while for ground-based measurements that ratio is about 2:1. For 1:24,000 scale air photo analysis, the clearcut to mature forests ratio of landslide density is 17:1.

ODF found that use of aerial photographs for identification of shallow landslides will likely result in biased and incomplete landslide inventories. This bias significantly underestimates the landslide frequency and erosion volume across all forest stand age classes. At two sites, for example, 72 percent of all landslides identified from the ground-based survey were not detected using even 1:6,000 aerial photographs. The majority (72 to 98 percent) of shallow-rapid landslides were not visible on aerial photographs of any scale. In terms of erosion volume, the landslides that were not identified from aerial photographs accounted for 53 percent and 41 percent of the total landslide related sediment volume delivered to stream channels. Landslide identification is most problematic in areas with mature or semi-mature timber. For instance, roughly 50 percent of the landslides can be detected in recently harvested areas (0-9 years old) but less than 5 percent of the landslides can be detected in mature stands (older than 100 years).

To address these concerns over small-scale features, we used sample plot measurements to establish average rates (tons/mi^2/yr) for various small-scale features.

Comparison to mass wasting rates developed in other north coast California watersheds with similar geology suggests that the results of this study are reasonable. Recent work within the adjacent SF Trinity River, the Van Duzen River, and Redwood Creek watersheds provides the best basis for comparison. Raines (1998) estimated rates of mass wasting for the South Fork Trinity River watershed at between 21 and 1,985 tons/mi^2/yr for four planning watersheds for a 47-year period between 1944 and 1990. In Grouse Creek, Raines and Kelsey (1991) estimated rates at 4,330 tons/mi^2/yr for budget period of 1960-1989. PWA (1999) estimated average sediment yields from all sources of 2,690 tons/mi^2/yr for the Van Duzen River. CRWQCB estimated mass wasting in Redwood Creek at 2,050 tons/mi^2/yr for the period 1954-1997.

SAMPLE PLOT EROSION INVENTORY

In order to assess the relative contribution of smaller slide features, detailed mapping in the watershed study area was also undertaken. Although it was originally intended that the number of detailed study sites per geologic type would be a function of the area covered by each geologic terrane, this became infeasible due to the access limitations on private property, particularly in the Upper Middle Trinity PW. Although we determined the geology of each sample plot, we ended up combining all sample plots into one dataset from which average values were computed. Due to the access constraints, some of the geologic terranes were represented by only a few plots, and thus there were insufficient data to produce reliable results. Within the Upper Middle Trinity PW, sites were randomly selected. Depending on access limitations, initially selected sites may have to be rejected and another site randomly chosen. The size of each site was be approximately 40 acres, which provided a manageable size and often has easily determined boundaries due to the subdivision of sections (40 acres being 1/16th of a square mile (640 acres per section)). A total of 40 detailed sample plots were mapped, with almost all of these sites in the Upper Middle Trinity PW. All of these sites were located on public land, thus the effects of management activities on private lands could not be ascertained by this method.

Once a sample plot was selected, field personnel mapped all erosional features within the boundaries of the plot by walking its entire area. Each feature had the following data recorded: (1) type of sediment source, (2) any apparent land use or management associations, (3) area, thickness and volume of erosion, (4) estimate of the percentage of sediment delivered to the stream, (5) estimate of the features age, and (6) specific location characteristics such as geomorphic form, hillslope steepness, dominant vegetation, and canopy cover. All data was entered on a data form that was then input into the project database.

Data analysis included evaluation of sediment delivery by process (slides, gullies, rill erosion, bank erosion) and by land use association (non-management, harvest-related, road related). Data collected allowed differentiation between system roads (currently in use) and abandoned or legacy roads. Volumes were computed and rates computed after selecting a typical time period for which the observed features were determined to be representative. These rates were then applied on a per square mile basis to all watershed areas with the following exception: management-related yields were not computed for those areas in wilderness areas.

Figure 31 shows the locations of the sample plots in the vicinity of the Upper Middle Trinity PW. A few additional sample plots were located further north in the Upper Trinity PW but could not be shown on this figure. The table below shows the distribution of sample plots by geologic terrane.

Distribution of Sample Plot Sites by Geology

Geologic Terrane	Number
Bragdon Formation	6
Central Metamorphic Sub-province	10
Eastern Klamath Sub-province	2
Granitic	8
Hayfork Terrane	8
North Fork Terrane	1
Ultramafic Rocks	2
Weaverville Formation	3
TOTAL	40

Road-related erosion in the sample plots was distributed into legacy roads and active, system roads. Almost all of the road-related erosion was found on abandoned or "legacy" roads, in part because the sample plots were selected to generally avoid roads, as detailed road inventories were also underway. As seen in the table below, 99 erosion sites on legacy roads were found, grouped into four types of erosional process. A sediment yield of 1,951 tons was measured, which equates to 780 tons/mi^2 as the 40 sample plots totaled 2.5 mi^2. We assumed that the roads had been abandoned for 30 years, to that the average unit area rate was 26 tons/mi^2/year.

Sample Plot Data and Analysis for Legacy Roads

# of Sites	Type	Yield			
		(yd^3)	(tons)	(tons/mi^2)	tons/mi^2/yr)
75	Gully	677.8	915.1	366.0	12.2
11	Rill	144.6	195.2	78.1	2.6
8	Road Cut	134.1	181.0	72.4	2.4
5	Road Fill	488.3	659.3	263.7	8.8
99	Total	1444.8	1950.5	780.2	26.0

Notes: Conversion from cubic yards to tons using 1.35 t/yd^3
Time period over which yield averaged assumed to be 30 years

238 erosion sites were inventoried on the 40 sample plots. The erosion volume and delivered sediment yield were both computed by process as shown in the table below. We estimated that only 32% or 6, 287 yd^3 of the total erosion volume was actually delivered to a stream channel. Most of the features observed were fairly small and shallow. The average slide area was just over 2,000 ft^2, while the average slide thickness was about 2.5 feet. Shallow debris slides were found to be 57% of the volume delivered, with gullies the next largest source at 18%. Sediment yields were assumed to reflect a 20-year period and totaled 169.8 tons/mi^2/year, as shown in the table below.

Sample Plot Erosion Volume and Yield by Process

Process	Erosion Volume (yd^3)	Sediment Yield (yd^3 delivered)	Avg. Thickness (feet)	% of Total	Yield (yd^3/mi^2)	Yield (tons/mi^2/yr)
Gully	1,944	1,143	1.51	18.2%	457.3	30.9
Slide	14,022	3,594	2.30	57.2%	1437.7	97.0
Bank Erosion	467	467	1.29	7.4%	186.7	12.6
Road Cut Erosion	347	134	1.43	2.1%	53.6	3.6
Road Fill Erosion	933	488	1.63	7.8%	195.3	13.2
Rilling	1,064	239	0.05	3.8%	95.7	6.5
Debris Torrent	1,014	222	3.00	3.5%	88.7	6.0
Total	**19,791**	**6,287**		**100.0%**	**2,515**	**169.8**

The sample plot data were analyzed by land use category to enable unit rates to be applied in the context of the sediment budget. All sites with sediment yields were sorted by land use and are summarized in the table below. 50.6% of the sediment yield occurred in "forest" sites, those judged to be either old growth or more often, mature second growth, but considered to be non-management related. Three values were taken from the sample plot data and used in the development of sediment budgets: 110 tons/mi^2/yr for small-scale slides, 15 tons/mi^2/yr for harvest based small-scale erosional features, and 26 tons/mi^2/yr for erosion of legacy roads.

Sample Plot Data by Land Use

LAND USE	Yield (yd^3)	% of Total	Category	Yield (yd^3)	Yield (tons)	Yield (tons/mi^2/yr)
Brush	944.2	15.1%	Non-Mgmt	4101.6	5537.1	110.7
Forest	3157.3	50.6%				
Harvest	574.0	9.2%	Harvest	574.0	774.9	15.5
Road RC	135.4	2.2%	Roads	1562.8	2109.8	42.2
Road RF	1427.4	22.9%				
Total	6238.4	100.0%		6238.4	8421.8	168.4

SURFACE EROSION

Accelerated surface erosion from land management activities is well recognized. Erosion from road surfaces is often a persistent source of sediment in logged basins due to the large network of dirt roads associated with harvest activities and the increased connectivity of the roads to the stream channels. Numerous studies have documented the role of road construction in increased sediment yields (e.g. Reid and Dunne 1984, Rice et al. 1979). Road-related sediment is a major factor in most North Coast watersheds. The location of roads on basin slopes (near stream, mid-slope, and ridge top) can have major effects on both fluvial and mass wasting processes (Cafferata and Spittler 1998, Jones et al. 2000).

The surface erosion section of the source analysis includes 2 primary components: (1) road surface erosion; and (2) hillslope erosion from skid roads and harvest areas. Considerable field road inventory was undertaken to establish rates for various road-related erosional processes. Due to access limitations, extensive field inventories of surface erosion from harvest activities were not possible.

Road Surface Erosion

Field Inventory Results

We completed detailed field inventories on 101.75 miles of roads in the mainstem Trinity River watershed. Some 1600 drainage features or other erosion sites were individually measured and compiled into the database. The results of our 2001 Field inventories are shown in Tables 35 and 36. We attempted to determine road-related erosion rates for seven different geologies, 3 road surface types, and 3 road slope positions. Unfortunately, given the number of categories, the amount of road mileage inventoried in some categories was fairly small, and the results may not be representative of a larger sample. After review of the results, we decided not to use the results in a specific category unless there had been at least 4 miles of inventory completed. For those areas with lesser inventory mileages, we used the mean value for that category. Rates are divided into three categories: (1) cutbank erosion, (2) road surface erosion, and (3) other erosion, which included gullies and fill failures.

Table 35 presents the erosion rates by geology and road slope position. In general and not surprisingly, riparian roads were found to delivery sediment at higher unit rates than mid-slope or ridge roads, although mid-slope roads in granitic terranes showed very high rates. Cutbank erosion was found to have the highest average unit rates for all slope positions, followed by road surface erosion, and finally other erosion. Unit cutbank erosion rates on riparian roads averaged about 3 times more sediment production than from road surface erosion, and almost 5 times greater than other sources. Mean unit rates for mid-slope and ridge roads followed this same general trend.

Table 36 presents the erosion rates by geology and road surfacing type. On average, about 3 times more cutbank erosion was found on paved and rocked roads than on native roads, mostly due to the larger road cuts that are found along wider and larger paved and rocked roads. On the other hand, road surface erosion was found to be highest on native roads at 31.5 tons/mi/year, with rocked roads at 19.8 tons/mi/year, and paved roads at 2.1 tons/mi/year. Other erosion rates were very similar for all surfacing types at 5.7-6.4 tons/mi/year. The highest rates of cutbank erosion were found in roads in granitic terranes, with paved roads having the highest unit rate. The highest rates of road surface erosion were found in the Central Metamorphic sub-province, followed by granitic terranes. Other erosion rates were highest in the North Fork and granitic terranes.

GIS Road Analysis

Road data were developed from various sources and compiled into the project GIS. USFS provided much of the base data, which had originally been obtained from the USGS topographic maps. USGS cartographic feature files matching the standard 7.5-minute quad were corrected by USFS to the USGS Digital Orthophoto Quads (DOQs). The RCD road coverage for the Grass Valley Creek area was determined to be generally more accurate than USFS roads in this area. For this reason, RCD road segments were merged with the overall USFS coverage. The duplicated USFS road segments were deleted where obvious USFS-RCD road redundancy occurred. Also, roads identified on the aerial photos that were missing from the merged USFS-RCD coverage were added by GMA. All segments in the Trinity River Priority Area (Upper Middle Trinity) were assigned a year corresponding to the set of aerial photos on which the roads were first observed.

According to the GIS road coverage developed in this study, there are currently 4,564 miles of roads in the Trinity Watershed, which translates to a basin-wide road density of 2.24 mi/mi^2. Table 37 shows the existing road network distributed by planning watershed and sub-watershed. The highest road density in the four planning watersheds basin was found in the Upper Middle Trinity PW with a density of 4.17 mi/mi^2, followed by the Upper Trinity PW (2.50 mi/mi^2), the Lower Trinity PW (2.43 mi/mi^2), and the Lower Middle Trinity PW (1.05 mi/mi^2). The highest road density in the 70 sub-watersheds was found in the Stuart Arm area of the Upper Trinity PW at 5.89 mi/mi^2, followed by Grass Valley Creek at 5.67, Hatchet Creek at 5.64, Buckeye Creek at 5.24, Rush Creek at 5.20, and Soldier Creek at 5.05.

All roads within the Trinity River Watershed were stratified into three categories: riparian, mid-slope, and ridge-top by analysis of the GIS database. These slope positions form the basis of the estimating sediment production from roads. Slope positions were assigned using the following methodology. To determine the location of Riparian roads, all Class I and Class II streams were buffered by 200 feet on either side. All roads segments within this buffer were considered Riparian. To determine the location of Ridge roads, ridgelines were identified by creating watershed boundaries from the 10-meter DEM with a minimum area of approximately 75 acres. Next all Class I streams were buffered by 500 feet to clip the watershed boundaries away from the riparian zone. The resulting ridgeline coverage was then buffered by 100 feet on either side. All roads segments within this buffer were considered Ridge roads. All the roads segments that didn’t fall into the 200 foot riparian buffer or the 100 foot ridge buffer were considered to be Mid-Slope.

Surface types were assigned according to data included with the original coverages from USFS and RCD, and all segments added by GMA were assumed to be native because of their locations.

Upper Middle Trinity Road History

Table 38 presents the results of our mapping of the road network over time based on the sequential aerial photographs for the Upper Middle Trinity PW. The miles of roads by slope position type constructed by period for each SW are shown. Table 39 shows the cumulative road miles by slope position type and year. Of the current total of 1,340 miles of roads, 23.1% were existing in 1944, 35.4% were added in the 1944-1980 period, 14.3% were constructed in the 1980-1989 period, while 27.2% were created in the most recent 1989-2000 period, although the latter period may include some roads that were actually constructed earlier, due to the methods used and available information on road construction dates. The road construction mirrors the progress of second growth timber harvest through the watershed, with average annual construction rates between 1944 and 1989 remaining similar, and then a substantial

increase in recent times as harvest levels increased on private lands. The largest amounts of road construction in the most recent period occurred in Browns, Indian, and Weaver Creek sub-watersheds.

Despite the significant increase in road density, the advantage of recently constructed roads over earlier roads is that construction standards have markedly improved in the past 25 years, thereby reducing the relative impact of these features. In addition, most of these recent roads are mid-slope and ridge-top roads, providing access for cable-yarding harvest techniques. As found in our road erosion rate inventory, ridge-top roads generally deliver substantially less sediment to watercourses than roads near stream courses (riparian roads) or mid-slope roads. Of the 365 miles constructed between 1989 and 2000, only 57.4 miles or 15.6% were riparian roads, while the vast majority (66.7%) were mid-slope roads and the remaining 17.5% were ridge roads.

We also evaluated the distribution road surface types by road slope position as shown in Table 40.

Road Surface Erosion Calculations

The method used to compute sediment production from roads is based on stratification by slope position, surfacing type, and geologic terrain, and then application of unit rates (tons/mi/yr). Unit rates have already taken into account delivery, surfacing, and cover factors, as described in the methods section. All of the roads in a given sub-watershed were stratified geology, then by slope position, and then by road surface type. This created 63 categories of road segments. The appropriate unit rate was applied to each length of road defined by these categories. As noted previously, many of the road segment categories used mean unit rates rather than specific to that individual category, since there had not been sufficient field inventory in all possible categories to establish reasonable values.

A summary table of the road surface erosion calculations by planning watershed is shown in Table 41, while detailed values by sub-watershed are located in Appendix F. The computed rates track very closely with road density, with the Upper Middle Trinity PW having by far the highest rate, 130 tons/mi^2/yr, compared to rates of 49 and 46 tons/mi^2/yr for the Lower and Upper Trinity PW's respectively, and only 22 tons/mi^2/yr for the Lower Middle Trinity PW, which has a very low road density (1.05).

Confidence in the Roads Analysis

The method of characterizing sediment delivery from roads used in this sediment source analysis has a number of limitations, and is only considered an approximation based on the presently available information. This analysis does provide a reasonable method for estimating sediment yield from surface erosion from roads, particularly over such a large area as the entire mainstem Trinity River watershed. Refinement of these values could occur during implementation phases when detailed road inventories are developed, particularly on private lands. As noted previously, we had no way of quantifying the extent of abandoned roads or restored roads, although we estimate that this is probably less than 10% of the existing total miles. This study lacked precise information on actual type of roads in all cases or their actual use rates.

A number of limitations of the road analysis are worth mentioning:

- Yields may be overestimated for abandoned roads that are not so indicated in the GIS coverages
- Yields may be over-estimated for some paved roads such as highways and county roads which have higher levels of maintenance
- Some roads considered native in this report may in fact be rocked or have rocked sections

- There are no estimates for sediment yields caused by culvert failure and washout, although in some watershed analyses or road assessments these have been considered significant volume sources
- Road surface slope is not specifically taken into account, although typically more drainage features exist for steeper roads and these would have been evaluated in the field inventories
- Traffic or use patterns and rates are particularly difficult to accurately describe

We assumed that any road included in the GIS probably still delivered some sediment, particularly because these older roads were built to far different standards than roads constructed in the last 10-25 years. That older roads often still produce considerable sediment is borne out by findings in the various studies (Toth 1991, Mills 1991, ODF 1999). Toth reported the results of a road damage inventory conducted in Washington that found that roads constructed in the last 15 years survived a landslide-inducing storm with minimal damage, while roads constructed earlier had very high damage rates. Road monitoring in Oregon has documented similar findings (Mills 1991). The recent ODF (1999) study found that although landslides associated with old roads were typically smaller than the landslides associated with actively used roads, they were still several times larger on average than landslides not associated with roads. Of the 506 slides mapped by ODF, 20 were associated with old roads and 37 were associated with active roads, while the erosion volume from old roads was 54,700 yd^3 vs. 65,000 yd^3 for the active roads. Overall, nineteen percent of the sediment volume delivered to stream channels came from landslides associated with old roads. Based on this information, exclusion of old or even abandoned roads from the analysis should not occur without extensive field verification. As a result of our sample plot investigation, we were able to isolate the sediment delivery for “legacy” roads versus active, system roads, and those estimates are described in sample plot section of this report.

The computed values for the mainstem Trinity River watershed are similar, but slightly smaller than road erosion rates reported for the SF Trinity watershed (Raines 1998), which were developed using a more sophisticated GIS based road model, SEDMOD.

Hillslope Erosion

Hillslope surface erosion processes include rainsplash, sheetwash erosion, rilling, and gullying. Surface erosion of soil occurs where mineral soil is exposed, soil compaction has reduced rainfall infiltration rates, or run off is concentrated. Since much of the sediment mobilized by surface erosion processes is deposited on the slope and subsequently stabilized by vegetation, this sediment category only addresses that portion of sediment from erosion on hillslopes that is actually delivered to the stream system.

Sediment yield from hillslope surface erosion was estimated for areas of timber harvest. Sediment yield estimates are based on erosion rates reported in the literature for this general area.

There is considerable variation in estimates from the literature in the role of timber harvest, including skid roads, in sediment production and delivery to stream channels. Since skid roads are generally not linked as directly to stream channels as roads typically are, drainage practices (proper installation of water bars, etc.) are of primary importance in determining whether significant sediment production and delivery will occur. Properly drained skid roads will probably revegetate within 5-10 years

(Cafferata/Stillwater Sciences, pers. comm. 1999), leading to relatively minor and short-lived sediment production. In contrast, roads produce sediment every year, even without large storm events. On the other hand, recent research (Ramos 1995, unpublished, cited by Cafferata/Stillwater Sciences, pers.

comm. 1999) in Juan Creek, also located in Mendocino County, indicates that skid roads in intensively harvested areas may produce as much sediment as roads. As a result of these site-specific characteristics that control sediment generation, extensive direct field observations would be the only way to obtain reliable information on the role of skid roads and surface erosion from other harvest related activities.

Given the limitations of this study, evaluation of sediment production and delivery from harvested areas has been undertaken using indirect methods only.

GIS Harvest Area Analysis

Timber harvest is by far the single largest land use activity in the mainstem Trinity River watershed. The sediment yield estimate from harvest activities includes erosion from skid roads and yarding trails, cable-yarding corridors, and from exposure of mineral soil by any of the related harvesting activities.

At the beginning of this study, no harvest information for the watershed was available in a GIS-based format. To resolve this important data gap, GMA digitized a paper copy of the timber harvest areas by decade map that DWR (1980) had developed. DWR Harvest areas were digitized by decade from prior to the 1950s through the 1970s, which included harvesting on both National Forest and private timberlands. In addition, private timber harvest areas were digitized from hardcopy Timber Harvest Plan maps obtained from the California Department of Forestry (CDF) for years 1980-2001. These two geospatial data sets were then merged to simplify analysis. In addition, harvest data was obtained from the USFS (J. Perry, pers. comm. 2001) in spreadsheet form, listed by ranger district, year of harvest, acreage, and forest compartment number, among other variables. These data were only obtained for the Shasta-Trinity National Forest and the Big Bar, Weaverville, and Hayfork Ranger Districts. No additional USFS data was obtained for the Six Rivers National Forest or for the McCloud Ranger District area of the Shasta-Trinity National Forest (upper portions of the East Fork Trinity River). The USFS data were compiled by compartment by decade and compared to the acreages obtained from the DWR data. Where obvious discrepancies existed, the USFS data were added to the number of acres harvested in a particular watershed. All USFS harvest data post 1980 were added to the appropriate sub-watershed harvest area listing.

Table 42 and Figure 32 provide a history of timber harvest in the watershed from about 1940 to 2000. Detailed figures for each planning watershed and tables of harvest areas by sub-watershed are included in Appendix E. The data indicate that as a whole, about 31% of the watershed has been harvested in the past 60 years. If the 32% of the watershed is wilderness is removed, than the basin-wide percentage goes up to 45%. According to the harvest history developed, rates were high in the 1950s and 1960s and peaked in the 1970s with 117,000 acres harvested. Rates declined sharply in the 1980s to about 44,000 acres, but have increased in the 1990s to about 59,000 acres.

Harvest Surface Erosion

To compute surface erosion rates from the harvest acreage data requires selection of a yield or sediment delivery function and selection of a time function to characterize the change in sediment delivery over time, as revegetation occurs and the site stabilizes. Without the benefit of field work, we were limited to

the application of use of previously developed yield functions developed by previous researchers. To estimate erosion from harvest units, we used erosion rates reported by Lewis and Rice (1989), and used subsequently by Raines (1998). Lewis and Rice erosion estimates are based on measurements made in the mid-1980's from 261 harvest units logged between 1978 and 1979 on ground similar to that in the South Fork Trinity River, which may be more erosive including some sites in that basin. Erosion rates from harvested units reported by McCashion and Rice (1983) and Lewis and Rice (1989) are 2.82 yd3/ac and 0 to 5.39 yd3/ac, respectively, for sites without large erosion features. Sites with large erosion features would have been measured and included in landslide inventories. Erosion rates for harvested slopes reported by Lewis and Rice (1989) were similar to those from Datzman (1978) and McCashion and Rice (1983) for harvest sites in Northwestern California.

We used 4 tons/ac for all harvest areas from 1980 to present, except that rates on the highly unstable Shasta Bally decomposed granite terrane with increased by an order of magnitude. To be conservative, erosion rates were tripled to 12 tons/ac for the period 1940 to 1970 to account for the unregulated harvest practices that were prevalent then. In the 1970s, we multiplied one half of the acreage at 12 tons/ac and the other half at 4 tons/ac, to account for the advent of forest practice regulations in 1973.

Table 43 shows the computed surface erosion from harvest units for the various sediment budget periods. The results suggest a peak in surface erosion occurring earlier than the peak in harvest rates seen in the 1970s period. This reflects the choice of rates and in particular the large number of acres harvested in the Grass Valley and Little Grass Valley watersheds in this period. Computed amounts have decreased in each budget period since the 1950s, at first reflecting low levels of harvest on the unstable granitic terrane in the 1960s and 1970s, then followed by a substantial rate reduction following changes in the forest practice rules in 1974. Volumes of surface erosion in the 1990s continued to decline from the 1980s values because very little harvest on granitic terrane occurred, as most of the land in the watershed had been purchased by BLM in the early 1990s. In the 1990s, surface erosion from harvest in the Upper Middle Trinity PW dominated sediment production from this activity watershed wide, with 392,018 tons or 80% of the total computed harvest-related sediment yield generated in just 15.8% of the entire watershed.

Surface Erosion from Fire

Although we originally intended to compute surface erosion from fires in the mainstem Trinity River watershed, lack of credible erosion data combined with the passage of several dry winters after the massive Big Bar fire, may have greatly reduced the risk of significant erosion problems. We compiled two GIS coverages for fires in the watershed, a polygon coverage of larger fires, and a point coverage of smaller fires. These two coverages were merged and data on burned acres by planning watershed and sub-watershed by decade were obtained. Detailed sub-watershed tables of fire acreages by decade are located in Appendix H.

FIRE AREAS BY DECADE BY PLANNING WATERSHED, 1910-2000

Upper Trinity SW	FIRE AREAS BY DECADE (acres) 1910s	1920s	1930s	1940s	1950s	1960s	1970s	1980s	1990s	TOTAL
UPPER TRINITY	285.9	10,372.7	3,886.6	999.3	3,604.3	273.8	176.0	4,986.0	144.4	24,728.9
UPPER MIDDLE TRINITY	20.0	286.3	1,761.3	99.4	1,975.4	17,547.5	34.3	189.7	1,983.9	23,897.6
LOWER MIDDLE TRINITY	264.1	988.9	17,639.5	14,439.0	11,342.9	147.3	2,271.1	42,691.1	68,206.7	########
LOWER TRINITY	1,053.6	309.5	836.5	119.5	2,523.4	63.9	73.7	283.1	55,548.8	60,811.8
										-
TOTAL FOR PW BY DECADE	1,623.6	11,957.2	24,123.9	15,657.2	19,445.9	18,032.4	2,555.1	48,149.8	########	########
% OF TOTAL PERIOD	0.6%	4.5%	9.0%	5.9%	7.3%	6.7%	1.0%	18.0%	47.1%	100.0%

Fluvial Erosion

Numerous studies have indicated that fluvial erosion, whether from road diversions and washouts, road drainage-induced gullies, natural gullies, bank erosion or small streamside landslides, can be a major component of the watershed sediment sources. Quantification of these components requires considerable field investigation in order to develop reliable information. In this study, we have obtained values on road-related gullies during the course of our road field inventories. Unfortunately, it is very difficult to develop rates for culvert and crossing failures and road diversions, unless fieldwork is undertaken shortly after a large flood event or the agencies or stakeholders maintaining the roads have kept detailed records. In this study, we used an approach similar to that implemented in the South Fork Trinity (Raines 1998, Llanos 1998), where field inventories developed unit rates by stream order, then the GIS was used to compute miles of streams by stream order category.

To develop watershed specific estimates for bank erosion/small streamside mass wasting, we walked most of the accessible tributary channels in the Upper Middle Trinity PW, including reaches of Grass Valley, Little Grass Valley, Rush, Weaver, and Deadwood Creeks. The following table lists the results of the field inventories.

Results of Channel Bank Erosion Inventory

Stream Name	Channel Length Surveyed (miles)	Sediment Yield (tons)	Unit Length Yield (tons/mile)	Annual Unit Yield Rate (tons/mi/yr)
Little Grass Valley Ck.	7.20	3,420	475.0	23.8
Grass Valley Ck.	7.83	6,766	864.1	43.2
Weaver Ck.	4.83	1,575	326.1	16.3
Rush Ck.	6.58	718	109.1	5.5
Deadwood Ck.	0.66	364	551.5	27.6
Totals or Average	27.1	12,843	473.9	23.7

Based on the field inventories, we developed the following annual unit rates by stream order:

Selected Annual Unit Rates for Channel Bank Erosion by Stream Order

Stream Order	1	2	3	4	5	6	7	8
Unit Rate (t/mi/yr)	2.5	5	10	15	30	43	85	170

Miles of channel length for each stream order were computed by planning watershed as shown below, while detailed tables by sub-watershed are located in Appendix G.

GIS ANALYSIS OF CHANNEL LENGTH BY STREAM ORDER

	MILES OF CHANNEL BY STREAM ORDER CATEGORY								
PLANNING WATERSHED	1	2	3	4	5	6	7	8	TOTAL
UPPER TRINITY	3,473.1	1,113.8	560.3	264.4	136.9	72.2	24.5	24.1	5,669
UPPER MIDDLE TRINITY	1,127.9	492.9	227.4	104.2	77.9	27.8	-	30.5	2,089
LOWER MIDDLE TRINITY	2,437.5	1,045.9	501.3	281.0	112.6	79.7	17.6	56.3	4,532
LOWER TRINITY	1,017.8	437.0	197.3	107.2	54.9	32.5	-	31.0	1,878
ENTIRE WATERSHED	8,056	3,090	1,486	757	382	212	42	142	14,167

Some 14,167 miles of channels exist in the mainstem Trinity River watershed, of which 57% are Stream Order 1, based on a GIS analysis of the entire watershed using 10-acre watershed areas to define Order 1.

Application of the annual unit rates resulted in the following summary table, while the detailed tables by sub-watershed are located in Appendix G.

BANK EROSION BY STREAM ORDER

	TONS OF BANK EROSION BY STREAM ORDER CATEGORY								
PLANNING WATERSHED	1	2	3	4	5	6	7	8	TOTAL
UPPER TRINITY	86,827	55,688	56,025	39,653	41,070	32,499	22,041	43,380	377,182
UPPER MIDDLE TRINITY	28,197	24,647	22,743	15,627	23,370	12,528	-	54,882	363,987
LOWER MIDDLE TRINITY	60,937	52,294	50,130	42,149	33,777	35,843	15,795	50,643	341,567
LOWER TRINITY	25,444	21,851	19,732	16,076	16,482	14,621	-	55,746	339,902
ENTIRE WATERSHED	201,404	154,480	148,630	113,504	114,699	95,490	37,836	204,651	1,422,638

Legacy Mining Effects

The first 100 years of Trinity County history were dominated by mining. Gold placer mines along the Trinity River and its tributaries provided the primary source of mineral wealth in the county since Colonel Pierson Reading discovered gold in 1848 near Douglas City. Mining included everything from small sluice box operations to the largest hydraulic mine in the world for many years, the La Grange Mine, which operated from 1851-1942 under various names and owners (O'Brien 1965). In 1901, bucketline dredging began and continued through the late 1950s. Between 1880 and 1962, an estimated $60,000,000 of mineral products was produced (O'Brien 1965). A significant amount of land disturbance occurred as a result of these mining activities, and in some instances, sediment impacts from this historic mining continue even to the present. Although subsequent re-growth of trees has obscured much of the more obvious mining locations, there remain numerous scars of hydraulic mining and the tailings piles of dredging operations.

Unfortunately, there is no inventory available of the extent of land disturbance from historic mining practices, nor the present condition of the mines. Impacts range from obvious, such as at the Diener Mine near Trinity Center and the former La Grange mine in Oregon Gulch, to subtle, such as in changes in vegetation, bare soil, and drainage density of various mined areas around Weaverville such as Garden Gulch and Sidney Gulch areas. The highest concentrations of sediment collected during this study, with the exception of runoff from a construction site gully, came from the small creek draining the Diener Mine. With the topsoil removed, very little vegetation has been able to re-occupy the site in over a hundred years since mining ended, and extensive areas of mineral soil remain exposed. Over 300 placer mines and claims are listed in O'Brien (1965), while DWR (1980) noted that over 500 claims are listed in the county. Without as estimate of the surface area involved, it is difficult to develop the relative sediment contribution of these historic mining areas. In general, with the passage of so many years since there was active mining at many of these locations, it is expected that sediment delivery has diminished, though still substantial in localized areas.

One type of historic mining activity that it was possible to develop an estimate of sediment yields is related to the delivery system for water for the larger hydraulic mines. Extensive networks of ditches, tunnels, and siphons were developed to convey large volumes of water from remote higher elevation drainage areas to these hydraulic mines. When these mines were shut down, the ditches were abandoned without any continuing maintenance or restoration. These ditches often divert and trap surface runoff and shallow groundwater flows and with no maintenance, have often caused slides and gullies. In an effort to quantify the sediment delivery from these historic features, we walked several sections of ditches and inventoried the gullies and landslides observed. In 1.3 miles of the La Grange ditch, we found 10 gullies and 4 debris slides. The volumes of these features were measured in the field, and when a period of 80 years is assumed since abandonment, rates of 23 and 49 tons/mi/year were obtained. The number of miles of ditches were compiled from descriptions in O'Brien (1965). There were 20, 253, and 55 miles of ditches reported in the Upper Trinity, Upper Middle Trinity, and Lower Middle Trinity PW, respectively. The locations of these ditches were delineated by sub-watershed, when possible. We believe these numbers to be on the low side, since it is highly unlikely that all ditch alignments were described in O'Brien (1965).

Changes in Alluvial Storage

Due to the relatively confined nature of most of the main stream channels in the Trinity River watershed, fluvial-induced change in alluvial storage in these areas is considered a relatively small term in the sediment budget for these portions of the watershed. While this may not be the case for portions of the mainstem, where somewhat more extensive alluvial deposits are present, there were no data to support calculations of changes in alluvial storage. The little data available suggests that along the mainstem in the Upper Middle Trinity PW, which is greatly affected by the upstream dam regulation and where the channel has narrowed, sediment storage has increased. As the channel has been stabilized by encroaching riparian vegetation, the sediment deposition creating the well-known riparian berms has likely increased alluvial storage. In addition, the deltas created at major tributary confluences have undoubtedly resulted in an increase in alluvial storage.

In narrow tributary channels, opportunities for significant changes in the storage of alluvial deposits are also often limited. In many of the larger tributaries, however, there is some evidence that alluvial storage has increased following the January 1997 flood event. This is certainly the case in portions of Weaver, Rush, and Indian Creeks where obvious large slides that occurred in the 1997 storm have deposited significant volumes along channel margins, floodplain areas, and even instream. In part, one of the important roles of functional floodplains in tributary channels is the storage of large sediment volumes generated from unusual events. The floodplains act to store these materials for a time frame of years to decades and slowly meter out the sediment during smaller events in intervening years. Unfortunately, other than qualitative observations, data do not exist to describe this effect. Many of these alluvial tributary areas on the larger tributaries such as Browns, Indian, reading, and Weaver were not accessible due to private ownership of these areas. We floated Rush and Indian Creeks by kayak to evaluate sediment storage qualitatively, and observed considerable evidence of aggrading channel conditions, particularly along Indian Creek. Conifers were observed rooted into the bottom of the channel, and on the relatively fresh, exposed floodplain surfaces, numerous partially buried tree trunks were seen.

SUBSTRATE QUALITY INVESTIGATION

Overview

The Trinity River Restoration Program has long recognized that physical instream habitat restoration and monitoring is an important component of rehabilitation of the mainstem Trinity River. Numerous documents have described the influx of fine sediments to the mainstem Trinity River from the Rush Creek to Indian Creek tributary watersheds, primarily Grass Valley Creek, that have impacted spawning gravel quality. Salmon lay their eggs under 1’-2’ of gravel, thereby protecting the eggs from predation and exposure to high flows during their four to eight week incubation period. Crucial to the eggs’ survival is the ability of the gravels to permit water flow through them to supply dissolved oxygen and to remove waste. Spawning gravel is the first habitat encountered by a generation of salmon and the characteristics of that gravel are vital to the eventual success of that run.

Goals and Objectives

In WY2001, GMA conducted an investigation into spawning gravel quality along the mainstem Trinity River and its tributaries between Lewiston Dam and Junction City. Funding for the work came from the Trinity River Restoration Program, through the Trinity County Grants Program and from USEPA as part of this sediment source analysis.

The goals of this project was to develop baseline data that will assist in: (1) providing monitoring data for gravel quality between Lewiston Dam and Junction City, (2) providing monitoring data to evaluate the effectiveness of restoration actions to date in various sub-watersheds, (3) providing information useful for completing the TMDL by identifying current substrate quality in high priority portions of the mainstem Trinity River.

The following objectives were developed to accomplish the goals outlined above:

(a) Establish baseline substrate composition and permeability conditions for long-term trend monitoring in the Trinity River and tributaries.

(b) Assess the relationship between substrate composition and permeability.

(c) Evaluate the longitudinal changes to gravel quality along the mainstem Trinity River to assess the influence of tributary derived sediments.

(d) Estimate survival rate of eggs to fry emergence for chinook salmon along the mainstem Trinity River using several indexes.

Study Sites

This project focused on (1) the section of the Trinity River from Lewiston Dam to Junction City that receives the majority of the mainstem salmon spawning and has been the most impacted by reduced flows, and thus tributary-derived sediments, and (2) major tributaries between Lewiston Dam and the North Fork Trinity River. Eight mainstem study sites were selected to: 1) represent river sections below key tributaries; 2) sample known spawning areas identified on aerial photos in 1999 by USFWS and/or used by chinook spawners during fall, 2000; and 3) permit access for sampling equipment and removal of substrate for lab treatment. The latter depended on areas where there was public land access (BLM or USFS) or where private landowners allowed admittance. Sample cross sections were selected which exhibited good spawning characteristics and had spawning redds nearby but which were not themselves disturbed by spawning, that is, areas which fish would, but had not yet, selected to spawn. The nine tributary sites were typically located near the confluence with the mainstem, again, depending on access. Both Reading and Browns Creek samples were collected some distance upstream, as private property prevented access in the lowermost reaches. The mainstem sites are shown in Figure 33.

Methods

The following section briefly describes the methods used in this study. For more detailed description, please refer to GMA (2001a). Surface pebble counts following methods described by Wolman (1954) were made at each site using a "gravelometer" template.

Intragravel permeability was measured at ten locations along or adjacent to each cross section (Figure 34) using a modified Terhune (1958) method with a backpack electric pump. Two samples were taken within each of the two bulk sample areas. The permeability standpipe was driven into the gravel until the bottom of the perforated portion was 35 cm below the bed surface. This depth was selected because a concurrent freeze core study of chinook salmon spawning indicated this as an average depth of egg deposition (Danni Everson, personal communication).

At each site, two bulk samples were taken along the cross section in undisturbed locations that matched the spawning characteristics of the area. We used a McNeil type method but our samplers were either 18" or 24" diameter cylinders that were worked down into the gravel bed, removing the bed material into buckets until the hole was excavated to a depth of 1.0-1.4'. The top surface layer, defined as the depth of the largest surface particle was kept separate from the subsurface. Once removed, samples were field sieved in rocker boxes through a 16 mm screen and the finer fraction bagged for transport to our lab.

Results

Bulk samples were combined to yield a single mean subsurface particle size distribution for each site and all ten permeability samples combined and a mean site permeability calculated. Table 44 includes these and several gravel indexes generated from the mean distribution to describe the baseline gravel quality for each section of the Trinity River for use with long-term trend monitoring.

The mean site values were plotted versus mainstem river miles to evaluate longitudinal changes in substrate quality. Many additional results are found in GMA (2001a). As an example, Figure 35 shows mean permeability along the mainstem against river miles demonstrating a reduction in spawning gravel quality moving downstream. These results are due to the influence of tributary-derived sediments. Of particular note is the dramatic reduction in gravel quality (indicated by increased percentages of fines, decreased D_{84} to D_{16} values, and decreased dg and fredle indexes) between the Rush Creek and Poker Bar site (Table 44). Poker Bar is the first site downstream of the mouth of Grass Valley Creek, recognized as one of the biggest sediment contributors to the mainstem Trinity River.

A notable inconsistency exists between the gravel indexes and permeability at Poker Bar (RM 102.7). Although there are a high percentage of fines, the site permeability is not as low as would normally be expected. A partial explanation is that the fines at Poker Bar are large grain decomposed granite (almost certainly from Grass Valley Creek) as confirmed by the much larger difference between percent fines <2 mm and <1 mm at Poker Bar than at the other sites. The larger grain sizes block the gravel interstices (and probably alevin emergence) but allow more water flow than smaller grains and therefore higher permeability.

Mainstem Trend Analysis

Two datasets are available with which limited trend analyses can be undertaken. In 1980, Fredericksen, Kamine, and Associates collected substrate samples at numerous sites along both the mainstem and in tributaries (FKA 1980), and in 1991-1993, Johns Hopkins University and the University of California, Berkeley conducted a detailed flushing flow investigation at two mainstem sites (Wilcock et al. 1995).

Unfortunately, detailed descriptions of both sample site locations and field methods are not available for the FKA (1980) data, so caution must be used in evaluating the results. Tabular comparisons of the data are presented in Table 45. Longitudinal comparisons are included in Figures 36 and 37 for % fines <2mm and <0.85mm respectively. These figures both indicate that the percent fines has increased at the Lewiston, Rush, Poker Bar, and Indian study sites, while decreasing at the Steelbridge, Steiner, Evans, and Junction City sites. The amount of change at Lewiston is not likely significant, particularly given the uncertainties in methods and locations.

The Poker Bar and Steelbridge sites were selected to allow comparison to similar work (and essentially identical methods) in 1991-93. Our source for the early work was the 1995 report that had figures representing the particle size distributions for bulk samples but not the original data. At Poker bar, we used one of the 1991 study cross sections but not the main study cross section because the spawning area had apparently shifted upstream since then. Unfortunately, the 1995 report does not include information on our cross section so we were unable to measure changes at that site, although visually the site appears finer-grained than in 1993. Our Steelbridge cross section duplicates the main study section of the 1991-93 work and our bulk samples were removed from two of the same spots along the tape. The comparison indicates that both locations, and likely the entire cross section, show an increase in the percentages of smaller fractions since 1992.

Tributaries Trend Analysis
Table 46 compares 1980 and 2001 selected substrate sample parameters for seven tributaries. Again, substantial caution must be used in comparing these datasets. In general, with the exception of Reading Creek, all values are quite comparable, suggesting little change.

Conclusions
Gravel and permeability indexes suggest decreasing quality downstream of major tributaries, which is not surprising given the extent of flow manipulation by the Trinity River Division. However, with the relatively wet series of recent flow years, particularly 1995-1998, one might expect instead to see improvements in substrate conditions. Beginning in 1992, high flow (up to 6800 cfs) releases have periodically been made from the reservoirs upstream. Observations by Wilcock et al. (1995) during such flushing flows, indicated substantial improvement of surface layers from these high flow releases. In particular, between 1995 and 2000, a number of tributary-derived high flow peaks and lengthy reservoir releases have occurred, as listed below. Many of these days of high flows were Safety of Dams releases due to reservoir storage encroachment into the designated flood control pool.

Water Year	# Days > 5000 cfs release at Lewiston
1995	24
1996	6
1997	38
1998	20
1999	0
2000	10

Given the extent of prolonged periods of high flows, one might expect significant improvements in gravel quality. Since this has not been observed, we can suggest two explanations: (a) flows between 5000 and 7000 cfs are ineffective at achieving any sub-surface flushing, or (b) continued tributary sediment inflows have been sufficient to maintain the substrate in a degraded condition. Certainly we know that Grass Valley Creek contributed a substantial, but unknown, amount of fine sediment in 1997 and 1998, when the sedimentation ponds completely filled and spilled sand-sized material into the mainstem. No appreciable bedload sediment delivery into the mainstem occurred from Grass Valley in WY1999-2001.

Available evidence from this study suggests that releases in the vicinity of 5,000-6,000 cfs, whether from Safety of Dams releases, from planned high flow releases, or tributary-derived storm peaks, have been able to accomplish relatively little in terms of cleansing spawning gravels.

SEDIMENT BUDGET

Overview

Typically, a sediment budget quantifies sediment sources (inputs), by each erosional process, as well as changes in the amount of channel-stored sediment, and sediment outputs as measured at a gaging station over a designated time frame or several time periods (Reid and Dunne, 1996). Quantifying sediment sources involves determining the volume of sediment delivered to stream channels by the variety of erosional processes operating within the watershed. For the Trinity River watershed, these can be divided into four primary processes or sediment delivery mechanisms: 1) mass movement (landslides), 2) fluvial erosion (gullies, road and skid trail crossing failures, and stream bank erosion), 3) surface erosion (rills and sheetwash) and 4) land management activities which directly place sediment in stream channels.

The first three processes can deliver sediment to stream channels both naturally and as a result of land use activities. Sediment production by mass movement processes occurs commonly during large, infrequent storm events, whereas fluvial and surface erosional processes can occur during small storms in virtually every water year or as a result of large storms. Direct sedimentation into stream channels by heavy equipment involved with road/railroad construction and timber harvest was probably commonplace in the Trinity River watershed prior to 1974. After passage of the California Forest Practices Act in 1973, the practice of yarding logs down stream channels, which resulted in direct sedimentation into stream channels, was prohibited. However, some areas may still be experiencing elevated sediment yields as a legacy of the former practices. The residence time of such introduced sediments is highly variable, but may well be on the order of decades.

Changes in the amount of sediment stored in stream channels is usually measured in the field by analyzing surveyed channel cross sections or by field surveys which estimate the amount of past channel filling and subsequent downcutting that has occurred. Analyzing changes in channel stored sediment can answer questions such as how much of what type of sediment is transported and where is it deposited, how does introduced sediment interact with sediment which was already in storage in the channel, and how does the transport affect overall stream morphology (Reid and Dunne, 1996).

Quantifying sediment outputs requires determining annual transport rates of bedload and suspended sediment past a given point in the watershed, which is typically measured at a gaging station. Few sites have sufficient data to establish a meaningful record, although use of regional values can provide reconnaissance-level information.

Reid and Dunne (1996) discuss the seven steps involved in the construction of a reconnaissance-level sediment budget. Such a budget uses rapid measurements and estimates of physical processes based on air photo analysis, field evidence and published information and should use the following process:

1. Careful definition of the problem,
2. Collection of background information and data,
3. Subdivision of the watershed an project area into uniform or representative sub-areas,
4. Analysis and interpretation of aerial photography,
5. Field inventory, analysis, and calibration,
6. Data analysis,
7. Checking and verification of results through regional comparisons

The development of a sediment budget for a large watershed area, such as the Trinity River watershed, can best be accomplished by stratifying the area into sub-watershed units of similar characteristics. A sediment budget would be developed for each sub-watershed and these values are combined to provide an estimate of the overall sediment budget for the watershed. In this study, we were able to complete all of the steps listed above only in the Upper Middle Trinity Planning Watershed. As discussed previously, this area was given the highest priority due to its importance for anadromous salmonid habitat.

In developing a sediment budget, the magnitude of each major hillslope and channel erosion process operating in the watershed should be evaluated through a combination of (1) field sampling and verification, (2) analysis of aerial photography, (3) GIS-based computer analysis, and (4) an analysis of existing data and literature, generally from regional sources. We accomplished all of these steps (1-4) in developing this preliminary sediment budget for the Trinity River watershed, although verification access was limited in certain areas. Budgetary and access constraints (permission could not be obtained from large industrial property owners) precluded more detailed or widespread field investigations.

Inputs

<u>Background Rates of Sediment Yield</u>

Selection or determination of background rates of sediment yield is both an important component of a sediment source analysis and, at the same time, a somewhat speculative endeavor. Few data exist regarding such rates, and no generally accepted method is available to compute or estimate such values. Little information could be developed on background rates during our investigation of the Trinity River watershed using the metrics on which the present day sediment budget is estimated, as the earliest aerial photography is from 1944 and significant human disturbance in the watershed well pre-dates these photographs. However, several other methods for assessing background rates were used, including:

1. Using values from the voluminous literature of the mainstem Trinity River watershed and adjoining areas (i.e. Knott 1974, BLM 1995, and Raines 1998).
2. Computing sediment yield from non-management sources in various sub-watersheds.
3. Evaluating sediment transport data for undisturbed watersheds in WY2001 and extrapolating this to a long-term rate.
4. Directly measuring the accumulated delta for Stuart Fork, a relatively undisturbed watershed, now flowing into Trinity Lake.

<u>Literature Values and Other Watershed Areas:</u>

Knott (1974) computed suspended sediment yields based on field measurements of sediment transport in the 1950s and 1960s at the Trinity River at Lewiston, Weaver Creek, North Fork Trinity River, South Fork Trinity, and Trinity River near Hoopa. He then adjusted these short-term values to long-term rates for the 1912-1970 base period. Average annual sediment transport rates are shown below:

AVERAGE ANNUAL ADJUSTED LONG-TERM RATES FROM KNOTT (1974)

Station	Suspended Sediment Discharge (tons)	(tons/mi²)	Bedload Discharge (tons)	(tons/mi²)	Total Load Discharge (tons)	(tons/mi²)
Trinity River at Lewiston	120,000	165				
Weaver Creek nr. Douglas City	34,600	715	4,000	80	38,600	798
North Fork Trinity River at Helena	54,700	362	17,000	110	71,700	475
South Fork Trinity River near Salyer	860,000	958	320,000	360	1,180,000	1,314
Trinity River near Hoopa	2,520,000	1,170	600,000	280	3,120,000	1,454

If we estimate bedload for the Trinity River at Lewiston as 15% of suspended load, then a long-term rate for the upper watershed would be about 190 tons/mi^2/year. These values may reflect long-term rates, but they certainly do not background or non-management rates, except for the North Fork Trinity, which has little human disturbance in it, although this does include the East Fork North Fork Trinity, which has somewhat more roads and mining effects. There is little doubt that the South Fork and near Hoopa values reflect the much more erosive geology in the western part of those watersheds along with the management contributions towards the unprecedented sediment delivery from the December 1964 flood, and therefore would not be representative of the upstream mainstem Trinity River watershed.

Raines (1998) developed management and non-management sediment yields as part of the sediment source analysis for the South Fork Trinity River. Non-management rates were 1,989, 1,102, and 59 tons/mi^2/yr for the 1944-1990 period for the Lower South Fork, Upper South Fork, and Hayfork sub-areas, respectively. The values seem quite low for Hayfork, though the relief is less and precipitation is lower than much of the areas bordering the Trinity Alps. Examining the results for specific sub-basins, such as Smokey Creek, generally considered to be a healthy watershed with little disturbance, shows long-term sediment yields of 356 tons/mi^2/yr.

Background rates for coastal Mendocino County in the Noyo, Big, and Albion watersheds were estimated at 275-325 tons/mi^2/yr by GMA (1999, 2001a, 2001b) based on long-term sediment yields from the Caspar Creek watershed as well as unpublished data from geomorphic inventory and assessment from other parts of Jackson Demonstration State Forest (P. Cafferata, pers. comm. 1999). In theory, with higher precipitation and less stable coastal belt Franciscan geology (though much more stable than the mélange terrane of the Central Belt Franciscan), rates from those areas should be higher than in the mainstem Trinity watershed.

<u>Computed Sediment Yields from Reference Watersheds</u>

Computing sediment yields from reference watersheds, such as Manzanita, Prairie, or Big French sub-watersheds in the Lower Middle Trinity PW, or Stuart Fork in the Upper Trinity PW give values in the range of 160-180 tons/mi^2/yr for the downstream watersheds to 200-250 tons/mi^2/yr for Stuart Fork. This includes 110 tons/mi^2/yr from small-scale features observed in the sample plots, bank erosion based on the miles of various order stream channels, and creep estimated at 30 tons/mi^2/yr, plus a variable amount of natural larger scale landsliding, depending on watershed factors, including geology, slope, and precipitation.

Adjusting Observed WY 2001 Sediment Transport Data to Long-term Rates

As seen in the sediment transport section of this report, sediment yields from either undisturbed, reference watersheds, or much less disturbed, typically upstream, portions of sub-watersheds in WY2001 were in the range of 1-12 tons/mi^2/yr. For other watersheds in the Upper Middle Trinity, the following data present the relationship:

Station	Long-term 1981-2001 (tons/mi^2/yr)	WY2001 (tons/mi^2/yr)	WY2001 as % of Longer-term rate
Deadwood	547	32	5.9%
Rush Creek	266	15	5.6%
Grass Valley	1,146	142	12.4%
Indian Ck	3,649	690	18.9%
Weaver Ck	331	19	5.7%
Reading Ck	779	75	9.6%
Browns Ck	715	65	9.1%
NF Trinity	475	12	2.5%

Interestingly, the lower amount of watershed disturbance, the smaller the percent of the longer-term rate WY2001 was. We would interpret this to indicate that more highly disturbed watersheds deliver sediment chronically, in a sense less directly dependent on the "wetness" of the water year. These data might suggest a multiplier of 40-50 for reference watersheds to convert WY2001 rates into a longer-term rate. When this relationship is applied to a reference watershed such as Manzanita, yields of 80-100 tons/mi2/yr result, which are in the general range of non-management values obtained by Raines (1998) for Hayfork Creek, which has similar geology, but slightly lower precipitation.

Stuart Fork Delta Measurement:

Since one of the more reliable estimates of long-term sediment yield could come tributary deltas where they are deposited into either natural lakes or man-made reservoirs, we decided to survey the delta of Stuart Fork, a mostly undisturbed tributary flowing into Trinity Lake. When lake levels were low in WY2000 and 2001, we completed detailed field surveys of the entire delta deposit and compared this to a 1955 5-foot contour map prepared by the U.S. Bureau of Reclamation prior to the construction of Trinity Dam. The process involves field surveys, preparation of digital terrain models for both sets of survey

data, and then computing net change between the two surfaces. Figure 38 shows the results of the analysis, with green contour lines showing fill , while red lines represent cut. The volume calculations show 349,870 cubic yards of fill and 138,280 cubic yards of cut. Given the location of some of the cut areas, along the edges of the valley, we suspect that a significant proportion of the cut volume is simply errors resulting from imprecision in the 1955 mapping. To translate volumes into yield, the cubic yards are converted to tons using a multiplier of 1.35 (assuming a bulk density of 100 pounds/cubic foot), and then divided by 40 years, the time since closure of Trinity Dam, and the drainage area. If the net amount from the surveys is used, the result is 114 tons/mi^2/yr. If we use the entire amount of the fill shown to be conservative, discounting all cut, the rate is 188 tons/mi^2/yr. These results then need to be adjusted by the likely amount of finer grained material clays and silts, that would have been carried further out into the reservoir. Based on size analysis data presented in Knott (1974) for suspended sediment samples for the Trinity River at Lewiston (pre-dam), Weaver Creek, and the North Fork Trinity River, clay particles make up about 10% (North Fork Trinity) to 30% (Weaver Creek) of the load. Silts make up 37-43% of the total. Much of the silt is deposited in the delta, while most of the clay in suspension probably travels further out into the lake. We estimate that 30% of the load is not accounted for in the delta surveys, and the above results are adjusted by 1.3. Therefore, we believe the long-term sediment yield from Stuart Fork is between 148 and 244 tons/mi^2/yr.

Background Rate Conclusions

We have developed estimates of background rates for each sub-watershed based on these values described in the previous sections and our professional judgment. These tables are included in Appendix K. Values range from 160-600 tons/mi^2/yr. In many cases, the rate was established using the average annual 20-year non-management sediment yield, although in some watersheds with large volumes from landslide mapping, we adjusted these values downward substantially. We believe that despite large “delivered” sediment volumes from landsliding as developed in the landslide inventory and analysis, much, if not most, of this sediment is actually stored in the watershed in features with various residence times, ranging from years to decades or longer. This storage essentially mitigates for the occurrence of large, infrequent events which deliver tremendous amounts of sediment from hillslopes to the valley floors, and effectively meter such sediment out over a long time frame.

Input Analysis Results

Inputs, by process and at either a planning watershed or a sub-watershed scale, were compiled by combining information from the various sources developed in previous sections of this document. Table 47 summarizes the sediment budget inputs by process for the entire watershed and Planning Watersheds, while sub-watershed values are provided in Appendix tables K-5 through K-8.

Overall, 40.2% of the sediment yield is estimated to be related to existing management, 1.4% to legacy management, and 58.4% to non-management related sources. Rates within Planning Watersheds and sub-watersheds are highly variable, depending on numerous factors including geology, precipitation, effects of large flood events, and the degree of disturbance.

Landsliding volumes range from 51-94% of the total inputs by Planning Watershed, with road inputs (combined landslides and surface erosion) ranging from 10.2-69.5%, harvest-related surface erosion ranging from 0.1-11%, and fluvial erosion from 1.3-3.9%. Very significant differences exist between the Planning Watersheds, depending upon the quality of the data available, the relative disturbance, and the effects of the 1964 and 1997 storm events. Data are most reliable for the Upper Middle Trinity, which

was the focus of the study efforts. In this planning watershed, landslides were 51.3% of the total inputs. 26.5% of the total inputs were non-management related landslide inputs, while 24.8% of the total was judged to be management-related. Harvest related surface erosion was by far the highest in the Upper Middle Trinity, at 11% of the total. Road surface erosion was computed at 13.1% of the total, again, by far the highest of the planning watersheds. Legacy mining produced 4.3% of the total inputs in the Upper Middle Trinity.

Comparison of Tributary Sediment Inputs and Outputs

More detailed data in the Upper Middle Trinity Planning Watershed allow a comparison to be made between the watershed sediment inputs developed in the source analysis, and the computed outflow, or sediment transport, at the lower end of each tributary basin. Table 49 summarizes the combined inputs from the source analysis, the computed sediment transport at the gaging stations located near the confluence with the mainstem, and the difference between the two. Average annual differences are generally 10-15% of the mean annual total, with the exception of two tributaries, Rush Creek and Weaver Creek. The general agreement between inputs and outflows suggests that the results obtained in this study are reasonable. Interestingly, in all cases, tributary transport is less than the sediment inputs, suggesting that either the inputs are somewhat too high, or, and more likely, that there is sediment storage occurring in the system. This is particularly true for Rush and Weaver Creeks, as it is simply not possible for the channel to have transported as much sediment as the input analysis indicates without greater changing its channel form and bed elevation, effects that have not been observed in either system. As noted earlier, we believe that considerable storage of landslide-derived sediment has occurred in both the Rush and Weaver watersheds, although quantitative information to support this judgment does not exist.

CONCLUSIONS

This study has developed estimates of sediment production and delivery by process for the entire Trinity River watershed using a combination of field measurements and indirect techniques, involving aerial photo and GIS-based analyses. Sources were stratified by time period, land use type, and dominant process, in order to assess management and non-management related sediment sources and their relative contributions. Significant changes through time and by land use were found in the mass wasting category. Significant construction of new roads has led to increasing sediment yields from road surface erosion, despite improved practices. Under current conditions (1981-2000 period) for the entire watershed, management-related sediment delivery is estimated to be 41.6% of the total input.

REPORT LIMITATIONS

This report is a reconnaissance-level sediment source analysis and preliminary sediment budget. The constraints under which this work was completed have been well described. Graham Matthews & Associates provide their findings, conclusions, and recommendations after preparing such information in a manner consistent with that level of care and skill ordinarily exercised by members of the profession practicing under similar conditions in the fields of hydrology, fluvial geomorphology, and geology.

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DRAINAGE AREA BY PLANNING WATERSHED AND SUB-WATERSHED

UPPER TRINITY PW Sub-Watershed	Drainage Area (mi²)	Drainage Area (acres)
Bear Creek	4.5	2,880
Buckeye Creek	5.1	3,286
Cedar Creek	7.0	4,485
Coffee Creek	116.4	74,476
Eagle Creek	15.1	9,658
East Fork Stuart Fork	22.6	14,485
East Fork Trinity River	92.8	59,366
East Side Trinity Lake	64.8	41,496
Graves Creek	5.3	3,399
Hatchet Creek	1.9	1,220
Minnehaha Creek	3.8	2,406
Mule Creek	6.3	4,024
Ramshorn Creek	12.8	8,202
Ripple Creek	2.5	1,583
Scorpion Creek	6.8	4,363
Snowslide Gulch Area	12.1	7,722
Squirrel Gulch Area	15.2	9,698
Stoney Creek	5.4	3,479
Stuart Arm Area	34.5	22,080
Stuart Fork	62.5	40,015
Sunflower Creek	2.6	1,654
Swift Creek	56.0	35,852
Tangle Blue Creek	22.0	14,061
Trinity Lake	24.4	15,634
Upper Trinity Mainstem Area	9.9	6,319
Upper Trinity River	63.3	40,505
West Side Trinity Lake	16.9	10,792
TOTAL	**692.4**	**443,138**

LOWER MIDDLE TRINITY PW Sub-Watershed	Drainage Area (mi²)	Drainage Area (acres)
Big Bar Creek Area	45.1	28,839
Big French Creek	38.4	24,565
Canadian Creek Area	33.5	21,418
Canyon Creek	64.0	40,940
Cedar Flat Creek	4.0	2,532
Conner Creek Area	47.6	30,480
Dutch Creek	9.5	6,107
East Fork North Fork Trinity	46.1	29,492
Hawkins Creek	2.6	1,680
Hennessy Creek	2.6	1,688
Italian Creek	3.0	1,951
Little French Creek	6.4	4,092
Manzanita Creek	11.7	7,457
McDonald Creek	2.9	1,864
Mill Creek	6.1	3,893
New River	233.4	149,403
North Fork Trinity	105.0	67,222
Oregon Gulch	7.4	4,758
Prairie Creek	3.2	2,020
Quinby Creek Area	31.5	20,163
Sharber Creek	5.6	3,612
Soldier Creek	7.0	4,475
Swede Creek	3.1	1,955
TOTAL	**719.7**	**460,606**

UPPER MIDDLE TRINITY PW Sub-Watershed	Drainage Area (mi²)	Drainage Area (acres)
Browns Creek	73.5	47,030
Deadwood Creek	9.1	5,829
Grass Valley Creek	26.0	16,631
Hoadley Gulch	3.5	2,233
Indian Creek	33.7	21,555
Lewiston Lake Area	25.1	16,064
Lewiston Lake	1.1	704
Little Grass Valley Creek	10.8	6,927
Poker Bar Area	35.3	22,599
Reading Creek	31.2	19,949
Rush Creek	22.5	14,375
Weaver Creek	49.7	31,781
TOTAL	**321.4**	**205,677**

LOWER TRINITY PW Sub-Watershed	Drainage Area (mi²)	Drainage Area (acres)
Campbell Creek	6.1	3,905
Coon Creek	5.3	3,363
Hoopa Reservation	114.0	72,974
Horse Linto Creek	64.3	41,132
Lower Trinity Mainstem Area	26.9	17,233
Mill Creek	21.9	14,022
Supply Creek	4.8	3,058
Tish Tang Creek	16.7	10,696
Willow Creek	43.1	27,601
Yurok Reservation	0.2	96
TOTAL	**303.2**	**194,080**

PROJECT:

TRINITY RIVER SEDIMENT SOURCE ANALYSIS
Drainage Areas of Planning and Sub-Watersheds

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TABLE

1

OWNERSHIP DISTRIBUTION BY PLANNING WATERSHED

PLANNING WATERSHED		BLM	BOR	State or Local	US Forest Service		Private				Tribal	TOTAL
					National Forest	Wilderness	Smaller Private	Roseburg Resources	Michigan CA Lumber	Sierra Pacific Industries		
UPPER TRINITY	Acres	26.7	-	2,047.1	158,742.6	149,516.0	15,472.6	7,215.8	17,836.1	91,759.1	-	442,616.0
	(mi^2)	0.0	-	3.2	248.0	233.6	24.2	11.3	27.9	143.4	-	691.6
	(%)	0.0%	-	0.5%	35.9%	33.8%	3.5%	1.6%	4.0%	20.7%	-	100.0%
UPPER MIDDLE TRINITY	Acres	41,915.6	510.6	3,816.0	32,808.2	12,885.0	36,943.2	1,867.6	-	74,817.3	-	205,563.5
	(mi^2)	65.5	0.8	6.0	51.3	20.1	57.7	2.9	-	116.9	-	321.2
	(%)	20.4%	0.2%	1.9%	16.0%	6.3%	18.0%	0.9%	-	36.4%	-	100.0%
LOWER MIDDLE TRINITY	Acres	14,014.9	-	1,537.6	165,038.8	252,256.4	20,084.9	155.1	-	7,480.9	-	460,568.5
	(mi^2)	21.9	-	2.4	257.9	394.2	31.4	0.2	-	11.7	-	719.6
	(%)	3.0%	-	0.3%	35.8%	54.8%	4.4%	0.0%	-	1.6%	-	100.0%
LOWER TRINITY	Acres	-	-	-	93,366.6	31.8	27,611.1	-	-	-	73,070.3	194,079.8
	(mi^2)	-	-	-	145.9	0.0	43.1	-	-	-	114.2	303.2
	(%)	-	-	-	48.1%	0.0%	14.2%	-	-	-	37.6%	100.0%
ENTIRE WATERSHED	Acres	55,957.2	510.6	7,400.7	449,956.2	414,689.2	100,111.7	9,238.4	17,836.1	174,057.3	73,070.3	1,302,827.7
	(mi^2)	87.4	0.8	11.6	703.1	648.0	156.4	14.4	27.9	272.0	114.2	2,035.7
	(%)	4.3%	0.0%	0.6%	34.5%	31.8%	7.7%	0.7%	1.4%	13.4%	5.6%	100.0%

Notes: -- From GIS data combined from various sources including Trinity County and USFS

TRINITY RIVER SEDIMENT SOURCE ANALYSIS
Land Ownership in the Mainstem Trinity Watershed

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TABLE 2

SLOPE ANALYSIS BY PLANNING WATERSHED

PLANNING WATERSHED		Acreages in Given Slope Class							Total		
		0-20%	20-30%	30-40%	40-50%	50-60%	60-70%	> 70%	% >50%	Acres	sq mi
UPPER TRINITY	Acres	70,843	63,308	86,739	85,162	65,395	40,341	30,894		442,682	
	(mi^2)	110.69	98.92	135.53	133.07	102.18	63.03	48.27			691.7
	(%)	16.0%	14.3%	19.6%	19.2%	14.8%	9.1%	7.0%	30.9%		
UPPER MIDDLE TRINITY	Acres	29,918	28,498	39,056	39,692	32,223	20,847	15,388		205,622	
	(mi^2)	46.75	44.53	61.02	62.02	50.35	32.57	24.04			321.3
	(%)	14.5%	13.9%	19.0%	19.3%	15.7%	10.1%	7.5%	33.3%		
LOWER MIDDLE TRINITY	Acres	26,270	27,314	47,179	71,440	61,083	59,702	67,317		360,306	
	(mi^2)	41.05	42.68	73.72	111.63	95.44	93.28	105.18			563.0
	(%)	7.3%	7.6%	13.1%	19.8%	17.0%	16.6%	18.7%	52.2%		
LOWER TRINITY	Acres	25,079	24,825	32,547	34,854	30,385	22,982	27,251		197,923	
	(mi^2)	39.19	38.79	50.86	54.46	47.48	35.91	42.58			309.3
	(%)	12.7%	12.5%	16.4%	17.6%	15.4%	11.6%	13.8%	40.7%		
ENTIRE WATERSHED	Acres	152,110	143,945	205,521	231,148	189,086	143,872	140,850		1,206,533	
	(mi^2)	237.67	224.91	321.13	361.17	295.45	224.80	220.08			1,885.2
	(%)	12.6%	11.9%	17.0%	19.2%	15.7%	11.9%	11.7%	39.3%		

Notes: -- From GIS data combined from various sources including Trinity County and USFS

TRINITY RIVER SEDIMENT SOURCE ANALYSIS
Slope Analysis in the Mainstem Trinity Watershed

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TABLE
3

GEOLOGIC TERRANES BY PLANNING WATERSHED

GEOLOGIC TERRANE	UPPER TRINITY		UPPER MIDDLE TRINITY		LOWER MIDDLE TRINITY		LOWER TRINITY		ENTIRE TRINITY	
	(mi^2)	(%)	(mi^2)	(%)	(mi^2)	(%)	(mi^2)	(%)	(mi^2)	(%)
Bragdon Formation	116.69	16.9%	34.98	10.9%	6.04	0.8%	---	---	157.72	7.7%
Central Metamorphic Subprovince	39.26	5.7%	120.79	37.6%	135.28	18.8%	---	---	295.34	14.5%
Copley Greenstone	17.66	2.6%	13.58	4.2%	---	---	---	---	31.24	1.5%
Eastern Klamath Subprovince	55.77	8.1%	8.47	2.6%	---	---	---	---	64.24	3.2%
Franciscan Formation	---	---	---	---	---	---	8.53	2.8%	8.53	0.4%
Galice Formation	---	---	---	---	25.54	3.5%	140.01	46.2%	165.56	8.1%
Granitic	115.19	16.6%	54.47	17.0%	26.98	3.7%	---	---	196.65	9.7%
Hayfork Terrane	---	---	26.02	8.1%	362.86	50.4%	98.60	32.5%	487.48	23.9%
North Fork Terrane	---	---	21.13	6.6%	109.09	15.2%	---	---	130.22	6.4%
Rattlesnake Creek Terrane	---	---	---	---	14.24	2.0%	42.76	14.1%	57.00	2.8%
South Fork Mountain Schist	---	---	---	---	---	---	13.36	4.4%	13.36	0.7%
Ultramafic Rocks	338.11	48.8%	13.72	4.3%	39.66	5.5%	---	---	391.50	19.2%
Weaverville Formation	9.72	1.4%	28.14	8.8%	---	---	---	---	37.86	1.9%
TOTAL	692.41	100.0%	321.32	100.0%	719.71	100.0%	303.25	100.0%	2036.69	100.0%

Data Source: Digitized Geologic Maps of DWR (1981) Mainstem Trinity River Erosion Study

TRINITY RIVER SEDIMENT SOURCE ANALYSIS
Geologic Terrane Distribution in the Mainstem Trinity Watershed

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TABLE
4

Active gaging stations for Mainstem Trinity River Basin, stations listed in downstream order.

Station No.	Station name	Station type	Agency or Organization	Period of record (water year)	Drainage area (mi^2)
Reach location					
Mainstem Trinity River Basin above Lewiston Dam					
11523200	Trinity River above Coffee Creek, near Trinity Center	Streamflow	USGS	1957-present	149
11525400	Clair Engle Lake near Lewiston	Lake level	USBR	1960-present	692
LEW	Lewiston Reservoir	Lake level	USBR		
11525430	Judge Francis Carr Powerplant near French Gulch	Diversion flow	USBR	1963-present	
Mainstem Trinity River Basin below Lewiston Dam					
11525500	Trinity River at Lewiston	Streamflow	USGS	1912-present	719
	Deadwood Creek near Lewiston	Streamflow	HVT	1998-present	9.11
	Rush Creek near Lewiston	Streamflow	HVT	1996-present	22.4
11525600	Grass Valley Creek at Fawn Lodge, near Lewiston	Streamflow	USGS	1975-preset	30.8
	Trinity River below Limekiln Gulch, near Douglas City	Streamflow	HVT	1998-present	93
	Indian Creek near Douglas City	Streamflow	HVT	1997-present	33.4
	Weaver Creek near Weaverville	Streamflow	DWR	2001-present	
	Reading Creek near Douglas City	Streamflow	HVT	2001-present	30.78
	Browns Creek near Douglas City	Streamflow	HVT	2001-present	72.47
	Trinity River at Douglas City	Streamflow	HVT	1995-present	
	Trinity River at Junction City	Streamflow	HVT	1995-present	
	North Fork Trinity River near Helena	Streamflow	DWR	2001-present	150
11527000	Trinity River near Burnt Ranch	Streamflow	USGS	1931-40, 1956-present	1,439
11530000	Trinity River at Hoopa	Streamflow	USGS	1912-14, 1916-18, 1931-present	2,853

TRINITY RIVER SEDIMENT SOURCE ANALYSIS

Active Gaging Stations in the Mainstem Trinity Watershed

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TABLE 5

Discontinued gaging stations for Mainstem Trinity River Basin, stations listed in downstream order.

Reach location Station No.	Station name	Station type	Agency or Organization	Period of record (water year)	Drainage area (mi^2)
Mainstem Trinity River Basin above Lewiston Dam					
11523700	Coffee Creek near Trinity Center	Streamflow	USGS	1911-13, 1958-66	107
11524000	Trinity River near Trinity Center	Streamflow	USGS	1911-13	300
11525000	East Fork Trinity River near Trinity Center	Streamflow	USGS	1910-14	109
Mainstem Trinity River Basin below Lewiston Dam					
11525655	Trinity River below Limekiln Gulch, near Douglas City	Streamflow	USGS	1981-91	812
11525800	Weaver Creek near Douglas City	Streamflow	USGS	1959-69	48.4
11525900	Browns Creek near Douglas City	Streamflow	USGS	1957-67	71.6
11526000	Trinity River near Douglas City	Streamflow	USGS	1944-51	1,014
11526500	North Fork Trinity River at Helena	Streamflow	USGS	1911-13, 1957-83	151
11527400	New River at Denny	Streamflow	USGS	1959-69	173
11527500	New River near Denny	Streamflow	USGS	1928-29	180
11528000	Trinity River near China Flat	Streamflow	USGS	1912-13	1,733
11529800	Willow Creek near Willow Creek	Streamflow	USGS	1959-74	40.9
	Horse Linto Creek, near Trinity River	Streamflow	USFS	1994-95	
	Tish Tang Creek, downstream	Streamflow	Hoopa Tribe	1993-95	
	Tish Tang Creek, upstream	Streamflow	Hoopa Tribe	1995	
11530020	Supply Creek near Hoopa	Streamflow	USGS	1981-87	15.8
	Supply Creek	Streamflow	Hoopa Tribe	1995	
	Mill Creek, downstream	Streamflow	Hoopa Tribe	1993-95	
	Mill Creek, upstream	Streamflow	Hoopa Tribe	1995	

TRINITY RIVER SEDIMENT SOURCE ANALYSIS
Discontinued Gaging Stations in the Mainstem Trinity Watershed

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TABLE
6

TABLE 7
ANNUAL MAXIMUM PEAK DISCHARGE FOR MAINSTEM USGS GAGES, 1912-2000

Water Year	Trinity River above Coffee Creek	Trinity River at Lewiston	Trinity River below Douglas City	Trinity River near Burnt Ranch	Trinity River at Hoopa
1912		11,600			63,100
1913		8,050			17,800
1914		26,900			89,000
1915		23,000			
1916		23,500			
1917		10,600			71,200
1918		8,050			20,900
1919		21,800			
1920		3,060			
1921		18,500			
1922		7,700			
1923		4,530			
1924		8,920			
1925		20,000			
1926		17,100			
1927		31,900			
1928		28,700			
1929		4,690			
1930		24,800			
1931		5,180			
1932		8,840		16,800	27,400
1933		8,600		13,200	22,500
1934		12,400		18,500	20,600
1935		8,970		15,200	30,200
1936		16,500		31,000	73,100
1937		13,500		23,400	39,700
1938		37,000		71,800	105,000
1939		4,370		9,110	31,800
1940		40,300		80,700	124,000
1941		32,500			79,000
1942		28,900			69,000
1943		7,350			64,100
1944		5,560			13,200
1945		8,990	11,500		34,800
1946		21,400	24,900		74,500
1947		8,390	10,300		34,000
1948		39,700	41,800		73,000
1949		15,700	22,500		54,100
1950		6,360	7,080		34,000
1951		39,300	41,200		72,500
1952		19,500			88,400
1953		17,900			98,200
1954		19,700			60,600
1955		6,880			22,100
1956	11,400	71,600		172,000	190,000
1957		23,500		36,200	61,900
1958	12,800	37,500		81,500	125,000
1959	10,800	21,200		39,300	77,800
1960	3,750	17,900		31,400	85,700
1961	6,270	1,200		11,000	36,300
1962	2,400	1,670		7,460	23,800
1963	8,990	12,700		17,100	54,700
1964	4,520	570		15,800	62,300
1965	20,800	392		78,100	231,000
1966	2,780	1,030		5,360	46,500
1967	5,720	2,640		14,000	56,400
1968	3,650	273		20,100	51,300
1969	4,640	1,450		17,500	71,400
1970	13,600	6,500		33,600	115,000
1971	3,270	864		25,000	96,900
1972	3,920	276		25,400	97,700
1973	2,840	644		8,820	45,000
1974	26,500	14,400		68,100	145,000
1975	3,770	2,260		9,780	66,000
1976	1,730	1,060		5,560	32,000
1977	555	267		1,710	2,690
1978	8,250	754		20,700	62,200
1979	2,740	923		9,790	28,000
1980	5,580	2,860		15,200	63,800
1981	5,590	961		13,800	40,900
1982	14,500	4,870		39,200	104,000
1983	6,380	8,780		41,500	122,000
1984	2,840	6,480		16,300	42,000
1985	2,630	860		10,900	43,300
1986	8,150	6,320		37,500	116,000
1987	5,850	827		12,000	38,500
1988	3,890	634		14,300	44,400
1989	10,100	1,980		16,600	47,100
1990	6,330	691		12,100	39,700
1991	1,650	2,860		7,070	26,900
1992	3,630	6,580		8,890	16,700
1993	11,300	3,270		17,400	68,800
1994	1,480	1,630		3,050	13,300
1995	7,880	7,060		35,800	83,600
1996	4,550	6,390		14,700	47,000
1997	20,100	6,970		69,900	122,000
1998	10,500	6,190		34,000	73,900
1999	3,120	2,000		8,370	33,400
2000	5,010	5,430		12,300	47,800

TABLE 8
TRINITY RIVER SEDIMENT SOURCE ANALYSIS
Tributary Stations, Annual Maximum Peak Discharge

	Coffee near Coffee Creek	Deadwood near Lewiston	Rush near Lewiston	Grass Valley at Fawn Lodge	Indian near Douglas City	Weaver near Douglas City	Reading near Douglas City	Browns near Douglas City	NF Trinity at Helena	New River above Denny	Willow near Willow Creek
1956											
1957								1,530	6,150		
1958	3,240							3,950	11,000		
1959	2,290					1,750		1,830	13,500		
1960	1,780					2,300		1,690	12,600	9,460	4,940
1961	2,050					1,900		932	6,740	5,940	1,760
1962	1,340					1,550		1,290	3,290	2,100	4,860
1963	3,360					2,920		1,270	7,890	9,580	5,190
1964	1,620					2,860		1,660	4,820	6,980	5,260
1965	17,700					3,980		3,790	35,800	60,000	17,000
1966	1,500					474		443	2,040	5,700	3,100
1967						1,480		1,910	5,220	5,830	2,280
1968						2,380			10,300	8,600	1,650
1969						1,590			5,830	8,440	2,490
1970									12,800		2,600
1971									11,500		6,420
1972									10,000		7,580
1973									3,590		1,450
1974									20,000		4,240
1975									2,850		
1976				115					3,020		
1977				38					764		
1978				2,080					7,980		
1979				394					5,610		
1980				1,030					5,610		
1981				610							
1982				1,030							
1983				4,140							
1984				982							
1985				495							
1986				2,500							
1987				570							
1988				441							
1989				536							
1990				332							
1991				76							
1992				644							
1993				548							
1994				124							
1995		430		2,270							
1996				256							
1997		330	4,400	2,460	2,780						
1998		525	1,570	2,020	1,625						
1999		94	433	359	313						
2000		228	558	288	2,150						
2001	1,530	188	291	1,032	1,330	1,000	528	1,510	1,520		

Note: WY 2001 data are provisional at this time. All data prior to 1994 from USGS records.

SUMMARY OF STREAMFLOW AND SEDIMENT DATA COLLECTION -- WY 2000

SITE #	SITE	STREAMFLOW # OF MSMTS	SEDIMENT # OF SAMPLES TURBIDITY (NTU)	SSC (mg/l)
1	Alder Gulch at Goose Ranch Road		2	---
2	Barleyfield Creek at Reading Creek Road		1	---
3	Baxter Gulch at Troll Road		1	---
4	Bear Creek at Bear Creek Loop		2	---
5	Bell Creek at FS Rd 402		2	1
6	Big French Creek near Hwy 299	4	3	1
7	Blanchard Flat Creek at Deerlick Springs Road		1	---
8	Boise Creek at Hwy 299	3	6	1
9	Browns Creek ab EFat Road 31N02 bridge		1	---
10	Browns Creek above Hazel Gulch		1	---
11	Browns Creek at Deerlick Springs Road		1	---
12	Browns Creek at Highway 3		1	---
13	Browns Creek near Douglas City	9	6	7
14	Browns Creek Trib #1 d/s Horsemane Creek		1	---
15	Buckeye Creek at Highway 3	2	6	2
16	Buckeye Creek at Rush Creek Campground		2	---
17	Canyon Creek at Junction City		1	---
18	Cedar Creek above Horse Linto	3	6	2
19	Cedar Creek nr TC 106	3	8	3
20	Cedar Flat Creek near Hwy 299		6	2
21	China Gulch at Forest Service Road #34N77		3	---
22	Coffee Creek at Highway 3	4	8	4
23	Coon Creek at FS Rd 4	3	6	2
24	Croften Gulch below Highway 3		3	---
25	Davis Creek at Highway 3		5	2
26	Deadwood Creek near Lewiston	16	10	6
27	Diener Mine Creek at Highway 3		3	1
28	Dump Creek at Highway 3		2	---
29	Dutch Creek FS Rd 413	3	5	2
30	Eagle Creek at Eagle Creek Loop Road		3	2
31	East Branch at East Weaver Road	1	3	---
32	East Fork of Stuart Fork at Guy Covington Drive		7	3
33	East Fork of the Trinity River at TC 106		6	3
34	East Fork Trinity above North Fork Trinity		3	1
35	East Fork Willow Creek above confluence	3	6	1
36	East Weaver Creek above East Branch Confl		1	
37	East Weaver Creek at Highway 3	2	9	5
38	East Weaver Creek near Mill Street	3	8	5
39	East Weaver Creek near Wilderness Boundary	2	3	---
40	Five Cent Gulch at Highway 3		3	---
41	Flume Creek at Highway 3		3	1
42	Garden Gulch at Highway 299		3	---
43	Grass Valley Creek at Fawn Lodge	USGS	8	1
44	Grass Valley Creek at Lewiston Road		4	1
45	Graves Creek at Highway 3	2	5	3
46	Gray Creek at Hwy 299		1	---
47	Greenhorn Gulch at Greenhorn Drive		1	---
48	Greg Creek at Hwy 299	3	6	1
49	Halls Gulch at East Fork Trinity Road		1	---
50	Hatchet Creek at Highway 3	3	7	2
51	Hawkins Creek FS Rd 442	3	4	2
52	Hennessey Creek at Hwy 299	2	6	2
53	Hoadley Gulch at Schoolhouse Road		9	3
54	Horse Linto Creek above Cedar Creek		6	2
55	Indian Creek at Indian Creek Road		2	---
56	Indian Creek at Trinity County 336, MP 7		1	---
57	Indian Creek near Douglas City	16	18	---
58	Italian Creek near Hwy 299		3	---
59	Last Chance Gulch at Highway 3		3	---
60	Little Bear Lake Creek at Highway 3		2	---
61	Little Browns Creek at Browns Mountain Road	3	13	6
62	Little Browns Creek at Highway 3		10	5
63	Little Browns Creek at Roundy Road		3	---
64	Little Browns Creek below China Gulch		2	2
65	Little Creek at Highway 3		3	---
66	Little French Creek near Hwy 299		2	1
67	Little Grass Valley Creek near Trinity Dam Blvd		6	2
68	Little Trinity River at Parks Creek Rd		1	1
69	Long Gulch at Highway 3		3	---
70	Madden Creek FS Rd 6		5	2

Note: Large numbers of discharge measurements at Browns, Deadwood, Indian, Reading, and Rush are by Hoopa Valley Tribe for Trinity River Restoration Program. The HVT also collected many of the sediment samples at these sites

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TABLE
9a

SUMMARY OF STREAMFLOW AND SEDIMENT DATA COLLECTION -- WY 2000

SITE #	SITE	STREAMFLOW # OF MSMTS	SEDIMENT # OF SAMPLES TURBIDITY (NTU)	SSC (mg/l)
71	Manzanita Creek at Hwy 299		5	2
72	Maple Creek FS Rd 413	2	3	2
73	McDonald Creek at Hwy 299	2	6	2
74	McIntyre Gulch at Steelbridge Road		2	1
75	Middleton Creek at Deerlick Springs Road		1	---
76	Mill Creek near Highway 299	12	6	2
77	Minnehaha Creek at Eagle Creek Loop		3	1
78	Mule Creek at Highway 3	3	11	5
79	New River Above Devils Canyon		2	---
80	New River Below Devils Canyon		2	---
81	North Fork Creek at Highway 3		1	---
82	North Fork of Swift Creek at TC 123	4	7	3
83	North Fork Trinity above Efork NF Trinity	3	3	1
84	Oregon Gulch at Sky Ranch Rd.	4	9	4
85	Panther Creek at FS Rd 402		2	1
86	Panwauket Creek at Reading Creek Road		2	---
87	Prairie Creek near Hwy 299		2	---
88	Quimby Creek at FS Rd 402		2	---
89	Ramshorn Creek at Highway 3	2	6	4
90	Reading Creek at Blanchard Flat Road		3	---
91	Reading Creek near Douglas City	12	19	4
92	Ripple Creek at Eagle Creek Loop Rd		3	1
93	Road Ditch #1 at East Weaver Road		3	---
94	Road Ditch #1 at Reading Creek Road		1	---
95	Road ditch 7N30D at Horse Linto		1	---
96	Road Ditch at China Gulch Road		3	---
97	Road Ditch at Rush Creek upstream Highway 3		2	---
98	Road Ditch Hwy 299 below Greg Creek		5	1
99	Rush Creek at Highway 3		3	---
100	Rush Creek at Rush Creek Road		3	---
101	Rush Creek below Highway 3		1	---
102	Rush Creek below Trib #4 Confluence		2	---
103	Rush Creek near Lewiston	15	11	5
104	Rush Creek near Wilderness		2	---
105	Rush Creek Trib #1 at Rush Creek Estates Road		3	---
106	Rush Creek Trib#2 at Rush Creek Road		5	---
107	Rush Creek Trib #3 at Rush Creek Road		4	---
108	Rush Creek Trib #3a at Rush Creek Road		2	---
109	Rush Creek Trib #3b at Rush Creek Road		2	---
110	Rush Creek Trib #3c at Rush Creek Road		2	---
111	Rush Creek Trib #4 at Rush Creek Road		3	---
112	Schofield Gulch at East Weaver Road		3	---
113	Scorpion Creek at Highway 3	2	7	4
114	Scott Mountain Creek at Highway 3		1	---
115	Sharber Creek FS Rd 445	2	6	1
116	Sidney Gulch at Memorial Drive		3	---
117	Sidney Gulch at Mill Street	3	9	4
118	Snipe Gulch at Knight Electronics		1	---
119	Snow Gulch at Rush Creek Confluence		2	1
120	Snow Gulch at TC 106		5	1
121	Soldier Creek FS Rd 33N47 second crossing	3	5	2
122	South Fork Trinity River at Hwy 299 bridge		6	---
123	Squirrel Gulch at TC 106		6	2
124	Stoney Creek at Highway 3	3	5	1
125	Stoney Creek Parking Lot (roadside ditch)		1	---
126	Sunflower Creek at Highway 3	2	5	1
127	Swede Creek near Hwy 299		3	1
128	Tangle Blue Creek at Highway 3		7	3
129	Ten Cent Gulch at Highway 3		3	---
130	Trinity River above Coffee Creek	USGS	4	3
131	Trinity River above confluence with South Fork		5	---
132	Trinity River at Lewiston Bridge	USGS	1	---
133	Trinity River at Parks Creek Rd	4	7	3
134	Trinity River below Limekiln Gulch	12	1	---
135	Weaver Creek near Douglas City	12	15	7
136	West Fork Little Creek at Highway 3		1	---
137	West Weaver Creek at Highway 299	2	9	6
138	West Weaver Creek at Mill Street	3	10	4
139	Willow Creek above East Fork	3	7	1
140	Willow Creek above Three Creeks		2	1
141	Willow Creek at Hwy 96		7	2
142	Willow Creek below Three Creeks		6	---

Note: Large numbers of discharge measurements at Browns, Deadwood, Indian, Reading, and Rush are by Hoopa Valley Tribe for Trinity River Restoration Program. The HVT also collected many of the sediment samples at these sites

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TABLE
9b

SUMMARY OF STREAMFLOW AND SEDIMENT DATA COLLECTION -- WY 2001

SITE #	SITE	STREAMFLOW # OF MSMTS	SEDIMENT # OF SAMPLES TURBIDITY (NTU)	SSC (mg/l)
6	Big French Creek near Hwy 299	2	3	3
7	Blanchard Flat Creek at Deerlick Springs Road		2	2
8	Boise Creek at Hwy 299		8	8
9	Browns Creek ab EFat Road 31N02 bridge	2	5	4
11	Browns Creek at Deerlick Springs Road		4	4
13	Browns Creek near Douglas City	16	13	13
20	Cedar Flat Creek near Hwy 299		6	6
23	Coon Creek at FS Rd 4		1	1
26	Deadwood Creek near Lewiston	14	18	18
29	Dutch Creek FS Rd 413		2	2
34	East Fork Trinity above North Fork Trinity		2	2
35	East Fork Willow Creek above confluence		7	7
37	East Weaver Creek at Highway 3		1	1
38	East Weaver Creek near Mill Street		6	6
43	Grass Valley Creek at Fawn Lodge		8	7
44	Grass Valley Creek at Lewiston Road	5	12	12
48	Greg Creek at Hwy 299		10	10
52	Hennessey Creek at Hwy 299		5	5
53	Hoadley Gulch at Schoolhouse Road		3	2
57	Indian Creek near Douglas City	15	16	15
58	Italian Creek near Hwy 299		2	2
61	Little Browns Creek at Browns Mountain Road	2	14	14
62	Little Browns Creek at Highway 3		5	5
63	Little Browns Creek at Roundy Road		2	2
65	Little Creek at Highway 3	2	13	11
66	Little French Creek near Hwy 299		1	1
67	Little Grass Valley Creek near Trinity Dam Blvd	3	9	8
71	Manzanita Creek at Hwy 299	3	5	5
72	Maple Creek FS Rd 413		2	2
73	McDonald Creek at Hwy 299		10	10
75	Middleton Creek at Deerlick Springs Road	2	5	5
76	Mill Creek near Highway 299	1	9	9
83	North Fork Trinity above EFork NF Trinity		3	3
84	Oregon Gulch at Sky Ranch Rd.		9	9
91	Reading Creek near Douglas City	15	15	14
99	Rush Creek at Highway 3		2	2
103	Rush Creek near Lewiston	13	7	7
104	Rush Creek near Wilderness	4	1	1
106	Rush Creek Trib#2 at Rush Creek Road		1	1
115	Sharber Creek FS Rd 445		2	2
117	Sidney Gulch at Mill Street		4	4
121	Soldier Creek FS Rd 33N47 second crossing		3	3
143	Spring Gulch at Deerlick Springs Road		3	3
122	South Fork Trinity River ab Trinity		7	
127	Swede Creek near Hwy 299		1	1
131	Trinity River above confluence with South Fork		7	
135	Weaver Creek near Douglas City		11	11
137	West Weaver Creek at Highway 299		1	1
138	West Weaver Creek at Mill Street		6	6
139	Willow Creek above East Fork		7	7

Note: Large numbers of discharge measurements at Browns, Deadwood, Indian, Reading, and Rush are by Hoopa Valley Tribe for Trinity River Restoration Program. The HVT also collected many of the sediment samples at these sites

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TABLE

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SUMMARY OF MAXIMUM SEDIMENT VALUES OBSERVED -- WY 2000 and WY 2001

SITE #	SITE	WY2000 MAXIMUM OBSERVED		WY2001 MAXIMUM OBSERVED	
		TURBIDITY (NTU)	TSS (mg/l)	TURBIDITY (NTU)	SSC (mg/l)
1	Alder Gulch at Goose Ranch Road	95.5			
2	Barleyfield Creek at Reading Creek Road	246.0			
3	Baxter Gulch at Troll Road	32.2			
4	Bear Creek at Bear Creek Loop	1.3			
5	Bell Creek at FS Rd 402	4.6			
6	Big French Creek near Hwy 299	33.4		14.0	47.8
7	Blanchard Flat Creek at Deerlick Springs Road	132.0		200.0	117.8
8	Boise Creek at Hwy 299	50.9		32.0	149.6
9	Browns Creek ab EFat Road 31N02 bridge	48.0		91.7	338.0
10	Browns Creek above Hazel Gulch	76.5			
11	Browns Creek at Deerlick Springs Road	407.0		217.0	863.0
12	Browns Creek at Highway 3	168.0			
13	Browns Creek near Douglas City	555.0	854.0	263.0	774.0
14	Browns Creek Trib #1 d/s Horsemane Creek	149.0			
15	Buckeye Creek at Highway 3	63.6	112.0		
16	Buckeye Creek at Rush Creek Campground	88.4			
17	Canyon Creek at Junction City	34.8	54.0		
18	Cedar Creek above Horse Linto	344.0			
19	Cedar Creek nr TC 106	45.4			
20	Cedar Flat Creek near Hwy 299	39.5		8.1	17.3
21	China Gulch at Forest Service Road #34N77	61.3			
22	Coffee Creek at Highway 3	41.4			
23	Coon Creek at FS Rd 4	43.1		3.2	10.1
24	Croften Gulch below Highway 3	77.7			
25	Davis Creek at Highway 3	12.2			
26	Deadwood Creek near Lewiston	266.0	412.0	310.0	871.0
27	Diener Mine Creek at Highway 3	911.0	3,630.0		
28	Dump Creek at Highway 3	183.0			
29	Dutch Creek FS Rd 413	101.6		5.8	8.7
30	Eagle Creek at Eagle Creek Loop Road	33.1	76.0		
31	East Branch at East Weaver Road	17.5			
32	East Fork of Stuart Fork at Guy Covington Drive	21.6			
33	East Fork of the Trinity River at TC 106	33.9	42.0		
34	East Fork Trinity above North Fork Trinity	56.3		0.3	0.9
35	East Fork Willow Creek above confluence	7.4		2.8	9.5

SITE #	SITE	WY2000 MAXIMUM OBSERVED		WY2001 MAXIMUM OBSERVED	
		TURBIDITY (NTU)	TSS (mg/l)	TURBIDITY (NTU)	SSC (mg/l)
36	East Weaver Creek above East Branch Confl	16.2			
37	East Weaver Creek at Highway 3	31.5		27.0	35.7
38	East Weaver Creek near Mill Street	54.3	166.0	190.0	160.0
39	East Weaver Creek near Wilderness Boundary	5.0			
40	Five Cent Gulch at Highway 3	66.6			
41	Flume Creek at Highway 3	33.5			
42	Garden Gulch at Highway 299	56.5			
43	Grass Valley Creek at Fawn Lodge	67.9	192.0	300.0	1,282.0
44	Grass Valley Creek at Lewiston Road	57.7	121.0	307.0	1,323.0
45	Graves Creek at Highway 3	13.1	10.0		
46	Gray Creek at Hwy 299	136.0			
47	Greenhorn Gulch at Greenhorn Drive	4.5			
48	Greg Creek at Hwy 299	142.4		260.0	374.0
49	Halls Gulch at East Fork Trinity Road	12.8			
50	Hatchet Creek at Highway 3	46.8			
51	Hawkins Creek FS Rd 442	90.1			
52	Hennessey Creek at Hwy 299	53.3		34.0	66.0
53	Hoadley Gulch at Schoolhouse Road	133.0	254.0	270.0	128.0
54	Horse Linto Creek above Cedar Creek	56.0			
55	Indian Creek at Indian Creek Road	790.0	2,030.0		
56	Indian Creek at Trinity County 336, MP 7	7.9	12.0		
57	Indian Creek near Douglas City	860.0	5,640.0	700.0	4,351.0
58	Italian Creek near Hwy 299	8.4			
59	Last Chance Gulch at Highway 3	122.0			
60	Little Bear Lake Creek at Highway 3	19.6	27.0		
61	Little Browns Creek at Browns Mountain Road	74.9		120.0	150.0
62	Little Browns Creek at Highway 3	48.1		450.0	388.0
63	Little Browns Creek at Roundy Road	26.5		16.0	4.5
64	Little Browns Creek below China Gulch	42.5			
65	Little Creek at Highway 3	226.0		215.0	399.0
66	Little French Creek near Hwy 299	5.3		13.0	37.6
67	Little Grass Valley Creek near Trinity Dam Blvd	292.0	625.0	400.0	2,115.0
68	Little Trinity River at Parks Creek Rd	12.1	18.0		
69	Long Gulch at Highway 3	37.4			
70	Madden Creek FS Rd 6	73.6			

Notes: TSS = Total Suspended Solids, SSC = Suspended Sediment Concentration

TRINITY RIVER SEDIMENT SOURCE ANALYSIS
Maximum Observed Values
WY2000 and WY2001 Sites

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TABLE
11a

SUMMARY OF MAXIMUM SEDIMENT VALUES OBSERVED -- WY 2000 and WY 2001

SITE #	SITE	WY2000 MAXIMUM OBSERVED		WY2001 MAXIMUM OBSERVED	
		TURBIDITY (NTU)	TSS (mg/l)	TURBIDITY (NTU)	SSC (mg/l)
71	Manzanita Creek at Hwy 299	79.8		14.5	82.9
72	Maple Creek FS Rd 413	82.6		3.0	5.9
73	McDonald Creek at Hwy 299	60.1		35.5	123.0
74	McIntyre Gulch at Steelbridge Road	305.0			
75	Middleton Gulch at Deerlick Springs Road	347.0		195.0	538.0
76	Mill Creek near Highway 299	113.4		75.0	226.0
77	Minnehaha Creek at Eagle Creek Loop	48.7	74.0		
78	Mule Creek at Highway 3	121.8	187.0		
79	New River Above Devils Canyon	9.9			
80	New River Below Devils Canyon	11.0			
81	North Fork Creek at Highway 3	8.0			
82	North Fork of Swift Creek at TC 123	24.3	32.0		
83	North Fork Trinity above EFork NF Trinity	41.7		1.0	2.9
84	Oregon Gulch at Sky Ranch Rd.	252.0	423.0	383.0	1,045.0
85	Panther Creek at FS Rd 402	3.2			
86	Panwauket Creek at Reading Creek Road	737.0			
87	Prairie Creek near Hwy 299	2.6			
88	Quimby Creek at FS Rd 402	3.0			
89	Ramshorn Creek at Highway 3	14.2			
90	Reading Creek at Blanchard Flat Road	599.0	1,380.0		
91	Reading Creek near Douglas City	784.0	3,160.0	617.0	3,329.0
92	Ripple Creek at Eagle Creek Loop Rd	21.0	25.0		
93	Road Ditch #1 at East Weaver Road	133.5			
94	Road Ditch #1 at Reading Creek Road	1,039.0			
95	Road ditch 7N30D at Horse Linto	83.4			
96	Road Ditch at China Gulch Road	289.0			
97	Road Ditch at Rush Creek upstream Highway 3	610.0			
98	Road Ditch Hwy 299 below Greg Creek	944.0			
99	Rush Creek at Highway 3	14.4		32.0	41.1
100	Rush Creek at Rush Creek Road	94.3			
101	Rush Creek below Highway 3	21.0			
102	Rush Creek below Trib #4 Confluence	45.1			
103	Rush Creek near Lewiston	149.3		60.0	207.0
104	Rush Creek near Wilderness	6.0		23.0	26.2
105	Rush Creek Trib #1 at Rush Creek Estates Road	88.0			
106	Rush Creek Trib#2 at Rush Creek Road	743.0			
Notes:	TSS = Total Suspended Solids, SSC = Suspended Sediment Concentration				

SITE #	SITE	WY2000 MAXIMUM OBSERVED		WY2001 MAXIMUM OBSERVED	
		TURBIDITY (NTU)	TSS (mg/l)	TURBIDITY (NTU)	SSC (mg/l)
107	Rush Creek Trib #3 at Rush Creek Road	33.1			
108	Rush Creek Trib #3a at Rush Creek Road	91.7			
109	Rush Creek Trib #3b at Rush Creek Road	104.6			
110	Rush Creek Trib #3c at Rush Creek Road	24.8			
111	Rush Creek Trib #4 at Rush Creek Road	33.0			
112	Schofield Gulch at East Weaver Road	27.6			
113	Scorpion Creek at Highway 3	34.3			
114	Scott Mountain Creek at Highway 3	4.4			
115	Sharber Creek FS Rd 445	109.9		7.0	46.6
116	Sidney Gulch at Memorial Drive	53.9			
117	Sidney Gulch at Mill Street	97.2		140.0	154.0
118	Snipe Gulch at Knight Electronics	57.3			
119	Snow Gulch at Rush Creek Confluence	488.0	1,250.0		
120	Snow Gulch at TC 106	35.2			
121	Soldier Creek FS Rd 33N47 second crossing	60.3		4.0	18.8
122	South Fork Trinity River at Hwy 299 bridge	479.0		90.0	
143	Spring Gulch at Deerlick Springs Rd			325.0	736.0
123	Squirrel Gulch at TC 106	84.3			
124	Stoney Creek at Highway 3	68.4			
126	Sunflower Creek at Highway 3	12.2	13.0		
127	Swede Creek near Hwy 299	26.0		5.2	22.0
128	Tangle Blue Creek at Highway 3	27.2			
129	Ten Cent Gulch at Highway 3	52.4			
130	Trinity River above Coffee Creek	45.7	69.0		
131	Trinity River above confluence with South Fork	152.6		230.0	
132	Trinity River at Lewiston Bridge	107.0			
133	Trinity River at Parks Creek Rd	20.0	25.0		
134	Trinity River below Limekiln Gulch	5.9			
135	Weaver Creek near Douglas City	192.0		95.0	354.0
136	West Fork Little Creek at Highway 3	330.0			
137	West Weaver Creek at Highway 299	27.0		4.8	3.0
138	West Weaver Creek at Mill Street	159.0	238.0	85.0	204.0
139	Willow Creek above East Fork	63.0		31.0	125.0
140	Willow Creek above Three Creeks	19.9			
141	Willow Creek at Hwy 96	38.5			
142	Willow Creek below Three Creeks	32.7			

TRINITY RIVER SEDIMENT SOURCE ANALYSIS
Maximum Observed Values
WY 2000 and WY 2001 Sites

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TABLE
11b

MAXIMUM OBSERVED TURBIDITY VALUES IN WY 2000 SORTED BY CATEGORY

NTU Category	Site	NTU	Watershed Issues and Possible Causes
>500 NTU	Diener Mine Creek at Highway 3	911	Abandoned hydraulic mine, bare soil
	Indian Creek near Douglas City	860	High flow, large slides, Timber Harvest
	Reading Creek near Douglas City	784	High flow, Timber Harvest
	Rush Creek Trib#2 at Rush Creek Road	743	1997 Debris torrent from Harvest area still bleeding
	Panwauket Creek at Reading Creek Road	737	Mining, Timber Harvest
	Browns Creek near Douglas City	555	Roads, Timber Harvest
250-500 NTU	Snow Gulch at Rush Creek Confluence	488	Browns Mountain Fire & Salvage logging
	South Fork Trinity River at Hwy 299 bridge	479	Geologic instability, roads, timber harvest
	Browns Creek at Deerlick Springs Road	407	Roads, Timber Harvest
	Middleton Gulch at Deerlick Springs Road	347	Roads, Timber Harvest
	Cedar Creek above Horse Linto	344	Big Bar Fire
	West Fork Little Creek at Highway 3	330	Highway 3, Timber Harvest, Fire
	Little Grass Valley Creek near Trinity Dam Blvd	292	Highway 299, Timber Harvest
	Deadwood Creek near Lewiston	266	Roads, Timber Harvest
	Oregon Gulch at Sky Ranch Rd.	252	Highway 299, La Grange Mine Legacy, Aggregate produ
100-250 NTU	Barleyfield Creek at Reading Creek Road	246	
	Little Creek at Highway 3	226	Highway 3, Timber Harvest, Fire
	Weaver Creek near Douglas City	192	Urbanization, roads, timber harvest
	Dump Creek at Highway 3	183	Exposed soil, roads
	West Weaver Creek at Mill Street	159	Roads, Highway 299, Timber Harvest
	Trinity River above confluence with South Fork	153	Cumulative effects
	Rush Creek near Lewiston	149	Roads, Highway 3, Timber Harvest, Fire
	Blanchard Flat Creek at Deerlick Springs Road	132	Roads, Grazing, Timber Harvest
	Last Chance Gulch at Highway 3	122	Roads
	Mule Creek at Highway 3	122	Roads and Timber Harvest
	Mill Creek near Highway 299	113	Roads and Timber Harvest
	Dutch Creek FS Rd 413	102	Roads and Timber Harvest
50-100 NTU	Sidney Gulch at Mill Street	97.2	Legacy mining, Urbanization, Roads, Timber Harvest
	Buckeye Creek at Rush Creek Campground	88.4	Highway 3
	Squirrel Gulch at TC 106	84.3	Roads and Timber Harvest
	Maple Creek FS Rd 413	82.6	Roads and Timber Harvest
	Manzanita Creek at Hwy 299	79.8	Undisturbed
	Little Browns Creek at Browns Mountain Road	74.9	Roads, Fire, Urbanization, Timber Harvest
	Madden Creek FS Rd 6	73.6	Unstable Geology, Timber Harvest
	Stoney Creek at Highway 3	68.4	Roads and Timber Harvest
	Grass Valley Creek at Fawn Lodge	67.9	Unstable Geology, Highway 299, Roads, Timber Harvest
	Buckeye Creek at Highway 3	63.6	Roads and Timber Harvest
	Soldier Creek FS Rd 33N47 second crossing	60.3	Roads and Timber Harvest
	Horse Linto Creek above Cedar Creek	56.0	Historic practices, but little recent disturbance
	East Weaver Creek near Mill Street	54.3	Development, Roads, Timber Harvest, Highway 3
10-50 NTU	Minnehaha Creek at Eagle Creek Loop	48.7	Some roads and harvest
	Browns Creek ab EF at Road 31N02 bridge	48.0	Upstream of most timber harvest
	Trinity River above Coffee Creek	45.7	Cumulative effects, but low-flow year
	North Fork Trinity above EFork NF Trinity	41.7	Mostly in Wilderness
	Coffee Creek at Highway 3	41.4	Roads, 1997 slides, but low-flow year
	Canyon Creek at Junction City	34.8	Roads, Mining, Fires
	Big French Creek near Hwy 299	33.4	Mostly undisturbed basin
	West Weaver Creek at Highway 299	27.0	Some Roads and Timber Harvest upstream, low flows
	Rush Creek at Highway 3	14.4	Some highway runoff, otherwise low disturbance
<10 NTU	New River Above Devils Canyon	9.9	Low-flow year
	Italian Creek near Hwy 299	8.4	Mostly undisturbed basin
	Rush Creek near Wilderness	6.0	Undisturbed basin
	Little French Creek near Hwy 299	5.3	Mostly undisturbed basin
	East Weaver Creek near Wilderness Boundary	5.0	Mostly undisturbed basin
	Greenhorn Gulch at Greenhorn Drive	4.5	Mostly undisturbed basin
	Prairie Creek near Hwy 299	2.6	Undisturbed basin
	Bear Creek at Bear Creek Loop	1.3	Undisturbed basin

PROJECT:

TRINITY RIVER SEDIMENT SOURCE ANALYSIS

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TABLE

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UPSTREAM-DOWNSTREAM COMPARISONS DURING SINGLE STORM EVENT

RUSH CREEK WATERSHED

Date: 2/14/2000 All samples collected 0850-0931 hrs

Mainstem Site / Tributary Site	NTU (Mainstem)	NTU (Tributary)	GENERAL SOURCE DESCRIPTION
Rush Creek near Wilderness	6.0		Essentially undisturbed upstream
Buckeye Creek at Rush Creek Campground		88.4	Runoff from Highway 3, Timber Harvest
Bear Creek at Highway 3		54.8	Roads and Houses, Timber Harvest
Rush Creek at Highway 3	14.4		
Road Ditch at Rush Creek upstream Highway 3		610.0	Culvert on Left Bank just upstream bridge
Rush Creek below Highway 3	21.0		
Rush Creek Trib #1 at Rush Creek Estates Road		50.0	Highway 3, USFS old Harvest, Roads
Rush Creek Trib#2 at Rush Creek Road		743.0	1997 Debris torrent on USFS Harvest
Rush Creek Trib #3 at Rush Creek Road		33.1	China Gulch Road Runoff, Timber Harvest
Rush Creek Trib #3a at Rush Creek Road		91.7	China Gulch Road Runoff, Timber Harvest
Rush Creek Trib #3b at Rush Creek Road		104.6	Road and Timber Harvest
Rush Creek Trib #3c at Rush Creek Road		24.8	USFS Old Timber Harvest Area
Rush Creek Trib #4 at Rush Creek Road		33.0	USFS Old Timber Harvest Area
Rush Creek below Trib #4 Confluence	45.1		-- Baxter Gulch and other Timber Harvest areas
Rush Creek at Rush Creek Road	94.3		contribute between these two sites
Snow Gulch at Rush Creek Confluence		340.0	Browns Mtn Fire, Roads, Gullies
Rush Creek near Lewiston	149.3		

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UPSTREAM-DOWNSTREAM COMPARISONS DURING SINGLE STORM EVENT

WEAVER CREEK WATERSHED

Date: 2/14/2000 All samples collected 0946-1049 hrs

Mainstem Site	Tributary Site	NTU	NTU	GENERAL SOURCE DESCRIPTION
West Weaver Creek at Highway 299		27.0		Some Roads and Timber Harvest
West Weaver Creek at Mill Street		103.3		Highway 299, Houses and Roads, Timber Harvest, Mining
Sidney Gulch at Memorial Drive		53.0		Roads, Timber Harvest, Historic Mining
	Garden Gulch at Highway 299		56.5	Roads, Timber Harvest, Historic Mining
	Ten Cent Gulch at Highway 3		48.1	Roads and Houses, Historic Mining
	Five Cent Gulch at Highway 3		52.8	Roads and Houses
	Dump Gulch at Highway 3		182.9	Exposed soil, roads
Sidney Gulch at Mill Street		37.1		Urbanization, Roads, Timber Harvest
East Weaver Creek near Forest Boundary		5.0		Little disturbance upstream
	Schofield Gulch at East Weaver Road		27.1	Roads and Timber Harvest
	Road Ditch #1 at East Weaver Road		79.1	Roads
East Weaver Creek above East Branch		28.6		Roads, Houses, Timber Harvest
	East Branch		17.5	Roads, Houses, Timber Harvest
East Weaver Creek at Highway 3		31.5		Roads, Houses, Timber Harvest
	Croften Gulch near Highway 3		77.7	Highway 3, Roads, Houses
East Weaver Creek at Mill Street		52.8		Cumulative Effects
Little Browns Creek at Roundy Road		26.5		Modest disturbance, some Roads, Harvest
Little Browns Creek at Highway 3		48.1		Highway 3, Timber Harvest, Roads, Bank Erosion
	China Gulch Road Ditch		170.2	Roads
	China Gulch at FS Road		42.9	China Gulch Road Runoff, Timber Harvest
	Long Gulch at Highway 3		35.3	Modest Disturbance
	Last Chance Gulch at Highway 3		122.2	Roads, Highway 3, Timber Harvest
Little Browns Creek at Browns Mountain Road		74.9		Roads, Timber Harvest, Fire
Weaver Creek near Douglas City		192.1		Cumulative Effects, Bank Erosion, Slides

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TABLE

14

UPSTREAM-DOWNSTREAM COMPARISONS DURING SINGLE STORM EVENT

BROWNS CREEK WATERSHED

Date: 2/14/2000 All samples collected 1430-1535 hrs

Mainstem Site / Tributary Site	NTU (Mainstem)	NTU (Tributary)	GENERAL SOURCE DESCRIPTION
Browns Creek above East Fork at Road 31N02 bridge	47.9		Some Roads and Timber Harvest
Browns Creek above Hazel Gulch	76.5		Roads and Timber Harvest
Browns Creek Trib #1 downstream Horsemane Creek		148.9	Roads and Timber Harvest
Middleton Gulch at Deerlick Springs Road		347.0	Roads and Timber Harvest
Browns Creek at Deerlick Springs Road	407		Timber Harvest, Roads, Development
Blanchard Flat Creek at Deerlick Springs Road		132.0	Roads, Grazing, Timber Harvest
Browns Creek at Highway 3	167.7		Cumulative Effects
Little Creek at Highway 3		226.0	Highway 3, Timber Harvest, Fire
West Fork Little Creek at Highway 3		330.0	Highway 3, Timber Harvest, Fire

TRINITY RIVER SEDIMENT SOURCE ANALYSIS
Intra-Storm Synoptic Turbidity Measurements

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TABLE 15

TRINITY RIVER SEDIMENT SOURCE ANALYSIS

COMPARISON OF HISTORIC MAINSTEM USGS SUSPENDED SEDIMENT DISCHARGE

WATER YEAR	TRINITY RIVER AT LEWISTON (tons)	% OF LOAD AT HOOPA (%)		TRINITY RIVER NEAR HOOPA (tons)	SF TRINITY RIVER NEAR SALYER (tons)	% OF LOAD AT HOOPA (%)
1957	109,727	6.5%		1,688,000	425,000	25.2%
1958	554,807	7.5%		7,423,000	2,501,000	33.7%
1959	71,624	3.3%		2,193,000	349,600	15.9%
1960	62,498	3.7%		1,682,000	408,900	24.3%
1961	2,150	0.6%	*	368,600	198,600	53.9%
1962				336,000	113,800	33.9%
1963	AVG	5.2%		1,684,000	757,900	45.0%
1964				672,600	289,500	43.0%
1965				33,740,000	10,340,000	30.6%
1966				7,240,000	1,676,000	23.1%
1967				6,539,000	1,838,000	28.1%
1968				3,386,000		
1969				7,608,000	AVG	32.4%
1970				7,658,000		

Notes: * Streamflow affected by Reservoir, not used in average

Lewiston Data computed by GMA from USGS discrete SS samples 1957-1961 using mean daily flows
All other data, published USGS values from Knott (1974)

TRINITY RIVER SEDIMENT SOURCE ANALYSIS
Historic Mainstem Suspended Sediment Loads

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TABLE 16

SEDIMENT TRANSPORT DATA FOR GRASS VALLEY CREEK AND TRINITY RIVER BELOW LIMEKILN GULCH

Grass Valley Creek at Fawn Lodge

WY	Suspended Sediment (tons)	Bedload (tons)	Total Sediment Discharge (tons)	Qb as % of Total
1976	754	330	1,084	30.5%
1977	126	-	126	0.0%
1978	78,306	na	78,306	
1979	2,861	2,287	5,148	44.4%
1980	13,552	7,546	21,098	35.8%
1981	3,877	277	4,154	6.7%
1982	7,127	2,592	9,719	26.7%
1983	304,673	37,359	342,032	10.9%
1984	9,714	7,472	17,186	43.5%
1985	977	793	1,770	44.8%
1986	59,855	6,703	66,558	10.1%
1987	4,354	443	4,797	9.2%
1988	1,211	85	1,296	6.6%
1989	2,560	1,391	3,951	35.2%
1990	1,393	548	1,941	28.2%
1991	232	403	635	63.4%
1992	3,126	1,817	4,943	36.8%
1993	1,895	928	2,823	32.9%
1994	83	2	85	2.3%
1995	65,595	39,049	104,644	37.3%
1996	2,015	159	2,174	7.3%
1997	15,750	14,098	29,848	47.2%
1998	77,446	49,869	127,315	39.2%
1999	958	436	1,394	31.3%
2000	3,393	6,878	10,271	67.0%
Total 76-00	661,837	181,465	843,302	
% Total	78.5%	21.5%		
Tons/mi^2/yr	860	236	1,095	

Trinity River below Limekiln Gulch

WY	Suspended Sediment (tons)	Bedload (tons)	Total Sediment Discharge (tons)	Qb as % of Total
1982	47,865	16,972	64,837	26.2%
1983	315,916	228,186	544,102	41.9%
1984	26,338	9,123	35,461	25.7%
1985	1,922	-	1,922	0.0%
1986	66,416	8,150	74,566	10.9%
1987	2,618	30	2,648	1.1%
1988	1,478	-	1,478	0.0%
1989	4,060	228	4,288	5.3%
1990	1,826	1	1,827	0.1%
1991	1,913	67	1,980	3.4%
1992				
1993				
1994				
1995				
1996				
1997				
1998				
1999	11,747	690	12,437	5.5%
2000	45,155	5,793	50,948	11.4%
Total 82-00	527,254	269,240	796,494	
% Total	66.2%	33.8%		
Tons/mi^2/yr	472	241	714	

Notes: All Grass Valley data from USGS published records
Trinity River below Limekiln, WY 1982-1991, from USGS published records
Trinity River below Limekiln, WY 1999-2000, from HVT unpublished records

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TABLE 17

TOTAL LOAD SEDIMENT TRANSPORT DATA FROM TRINITY RIVER RESTORATION PROGRAM, WY1997-2001

WATER YEAR	Deadwood Ck near Lewiston	Rush Creek near Lewiston	Grass Valley at Fawn Lodge	Trinity River below Limekiln Gl.	Indian Ck near Douglas City	Weaver Ck near Douglas City	Reading Ck near Douglas City	Browns Ck near Douglas City
	(all values in tons)							
1997	270	65,200	29,848		44,600			
1998	12,303	29,322	127,315		167,018			
1999	98	2,093	1,394	12,437	2,278			
2000	1,360	1,282	10,271	50,948	77,865			
2001	328	341	3,553	7,251	23,181	921	2,791	5,415
Total	14,359	98,237	172,382	70,636	314,942	921	2,791	5,415
Mean Yr	2,872	19,647	34,476	23,545	62,988	921	2,791	5,415
tons/mi^2/yr	315	875	1,119	253	1,870	19	91	75

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TABLE
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WY2001 SEDIMENT TRANSPORT SUMMARY

Watershed / Sub-Watershed Site		Total Sediment Load (tons)	Total Sediment Load (tons/mi^2)
UPPER TRINITY			
Coffee Creek		2,857	25
Trinity River at Parks Creek Rd.		158	3
East Fork Trinity River		751	8
UPPER MIDDLE TRINITY			
Deadwood		292	32
Rush			
	Campground	14	2
	Rush Creek nr Lewiston	341	15
Hoadley		136	39
Grass Valley Creek			
	Little Grass Valley	2,242	210
	GVC @ Fawn Lodge	3,553	115
	GVC @ Lewiston Road	5,189	142
Indian		23,181	690
Weaver			
	East Weaver at Mill Street	145	11
	West Weaver at Hwy 299	4	1
	West Weaver at Mill Street	84	10
	Little Browns Creek at BM Rd	86	7
	Weaver Creek nr Douglas City	921	19
Reading		2,427	79
Browns			
	Little Creek at Hwy 3	193	17
	Browns Creek ab. East Fork	605	23
	Middleton Gulch	154	44
	Browns Creek nr. Douglas City	4,709	65
Trinity River below Limekiln Gulch		7,250	
LOWER MIDDLE TRINITY			
Oregon Gulch		151	20
Manzanita Creek		27	2
Big French Creek		84	2
Mill Creek		32	5
North Fork Trinity River		1,828	12

Notes: All data from calculations by GMA, this study, based on continuous streamflow records and sediment transport data

PROJECT:

TRINITY RIVER SEDIMENT SOURCE ANALYSIS
WY2001 Sediment Load Data

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TABLE

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ESTIMATED SEDIMENT LOADS FOR MAJOR TRIBUTARIES IN UPPER MIDDLE TRINITY PLANNING WATERSHED

WATER YEAR	Grass Valley at Fawn Lodge (tons)	Deadwood near Lewiston (tons)	Rush Creek near Lewiston (tons)	*Combined Tribs Upstream TRLG (tons)*	Trinity River below Limekiln Gl. (tons)	Indian Ck near Douglas City (tons)	Weaver Ck near Douglas City (tons)	Reading Ck near Douglas City (tons)	Browns Ck near Douglas City (tons)	*Combined Tribs Downstream TRLG (tons)*	TOTAL TRIBUTARY INPUT (tons)
1981	4,154	103	973	5,230		8,539	1,923	1,200	3,049	14,712	19,941
1982	9,719	521	2,852	13,092	64,837	31,799	6,118	7,820	11,974	57,712	70,804
1983	342,032	63,905	44,650	450,586	544,102	496,617	140,756	98,458	200,350	936,180	1,386,767
1984	17,186	993	4,034	22,212	35,461	52,724	9,190	15,925	20,449	98,288	120,500
1985	1,770	66	566	2,402	1,922	4,992	1,114	839	1,802	8,748	11,150
1986	66,558	2,873	6,142	75,573	74,566	106,435	15,685	56,765	43,657	222,542	298,116
1987	4,797	128	812	5,738	2,648	8,380	1,691	1,825	3,117	15,013	20,751
1988	1,296	22	374	1,692	1,478	2,417	670	193	808	4,088	5,780
1989	3,951	119	818	4,888	4,288	8,240	1,690	1,594	3,041	14,565	19,453
1990	1,941	17	261	2,219	1,827	1,789	475	160	608	3,033	5,251
1991	635	8	201	844	1,980	1,123	347	46	359	1,875	2,719
1992	4,943	277	1,819	7,039	25,841	19,259	3,839	3,687	7,138	33,923	40,961
1993	2,823	198	1,834	4,855	16,318	16,735	3,681	2,222	5,996	28,634	33,489
1994	85	5	167	258	7,829	803	277	25	248	1,353	1,611
1995	104,644	13,176	17,022	134,843	125,476	352,206	47,015	59,065	149,950	608,235	743,079
1996	2,174	113	1,349	3,636	57,723	11,070	2,618	1,072	3,865	18,624	22,260
1997	29,848	6,634	7,611	44,094	211,320	44,600	21,665	159,019	72,480	297,764	341,858
1998	127,315	14,674	22,921	164,910	305,073	167,018	61,440	76,112	186,190	490,761	655,671
1999	1,394	88	5,060	6,542	12,437	2,278	2,694	1,255	3,983	10,211	16,753
2000	10,271	396	5,060	15,727	50,948	77,865	10,606	15,595	22,684	126,750	142,477
2001	3,553	328	341	4,222	7,251	23,181	921	419	5,415	29,936	34,158
Total	741,093	104,642	124,867	970,601	1,553,325	1,438,070	334,416	503,298	747,164	3,022,947	3,993,549
Yr Mean	35,290	4,983	5,946	46,219	77,666	122,898	15,925	23,967	51,795	143,950	190,169
tons/mi^2/yr	1,146	547	266	497	835	3,649	331	779	715	778	742

Notes: Grass Valley (1981-2000) and Trinity River below Limekiln (1982-1991) data from published USGS records
Streamflow data for 1997-2001 available from continuous stage records for Deadwood, Rush, and Indian Creeks
All other streamflow used for sediment transport calculations is synthetic, based on mean daily flows of Grass Valley Creek adjusted by drainage area ratio
Sediment transport values computed separately for bedload and suspended load based on WY1998-2001 data, as available

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TABLE

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TRINITY RIVER SEDIMENT SOURCE ANALYSIS

ANNUAL SEDIMENT TRANSPORT VALUES FOR 3 MAINSTEM TRINITY RIVER SITES

BASED ON HISTORIC AND SYNTHETIC FLOW RECORDS

WATER YEAR	LEWISTON Total by WY Bedload	LEWISTON Total by WY Bedload >8	LEWISTON Total by WY Bedload <8	LIMEKILN Total by WY SSS	LIMEKILN Total by WY Bedload	LIMEKILN Total by WY Bedload >8	LIMEKILN Total by WY Bedload <8	DOUGLAS CITY Total by WY SSS	DOUGLAS CITY Total by WY Bedload	DOUGLAS CITY Total by WY Bedload >8	DOUGLAS CITY Total by WY Bedload <8
1981	-	-	-	3,947	-	-	-	7,123	0	-	0
1982	42	41	1	32,147	1,768	496	1,272	47,394	3,782	1,375	2,408
1983	46,266	41,702	4,564	245,076	57,760	31,423	26,337	394,885	146,825	93,515	53,310
1984	2,717	2,462	256	54,010	6,242	2,595	3,647	77,465	11,071	5,003	6,068
1985	-	-	-	2,970	-	-	-	5,120	0	-	0
1986	6,005	5,417	588	57,190	12,100	6,496	5,604	79,892	18,315	10,142	8,173
1987	-	-	-	4,641	-	-	-	7,446	2	-	2
1988	-	-	-	3,094	-	-	-	5,117	-	-	-
1989	-	-	-	8,687	-	-	-	11,991	8	-	8
1990	-	-	-	2,487	-	-	-	3,926	-	-	-
1991	-	-	-	4,536	18	-	18	5,811	26	-	26
1992	3,549	3,199	350	25,271	5,322	2,852	2,470	30,499	5,593	3,017	2,576
1993	-	-	-	17,852	464	40	424	25,196	750	109	641
1994	-	-	-	9,790	-	-	-	11,704	-	-	-
1995	9,290	8,400	890	110,821	21,867	11,084	10,783	161,044	38,050	21,078	16,972
1996	3,879	3,508	371	53,115	9,155	4,483	4,672	58,009	7,896	3,680	4,216
1997	33,588	30,258	3,330	180,992	55,936	32,583	23,353	235,009	102,211	67,610	34,600
1998	18,972	17,149	1,822	263,023	56,330	29,020	27,310	410,515	127,390	75,776	51,614
1999	-	-	-	13,329	1	-	1	20,457	1	-	1
2000	2,128	1,933	195	44,444	4,951	2,072	2,879	60,336	8,369	3,885	4,485
	126,436	114,069	12,367	1,137,422	231,913	123,142	108,772	1,658,941	470,289	285,190	185,099

Notes:
- -- Sediment transport calculations performed using historic (Lewiston 1981-2000, Limekiln 1981-1991, 1998-2000, Douglas City 1996-2000) and synthetic (all other years) mean daily discharges
- -- Lewiston Bedload rating curves from McBain & Trush 1997 (no additional data has been collected at that site since then)
- -- Limekiln SSS rating curve from GMA this study
- -- Limekiln Bedload rating curves (non-linear) from McBain & Trush 1997, updated to fit WY2000 data
- -- Douglas City used same equations as Limekiln, as no sediment transport data have been collected at that site

TRINITY RIVER SEDIMENT SOURCE ANALYSIS

Mainstem Sediment Transport Calculations, 1981-2000, 3 Sites

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TABLE

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TRINITY RIVER SEDIMENT SOURCE ANALYSIS

ANNUAL SEDIMENT TRANSPORT VALUES FOR 3 MAINSTEM TRINITY RIVER SITES

BASED ON HISTORIC AND SYNTHETIC FLOW RECORDS WITH ROD FLOW RECOMMENDATIONS

WATER YEAR	LEWISTON Total by WY Bedload	LEWISTON Total by WY Bedload >8	LEWISTON Total by WY Bedload <8	LIMEKILN Total by WY SSS	LIMEKILN Total by WY Bedload	LIMEKILN Total by WY Bedload >8	LIMEKILN Total by WY Bedload <8	DOUGLAS CITY Total by WY SSS	DOUGLAS CITY Total by WY Bedload	DOUGLAS CITY Total by WY Bedload >8	DOUGLAS CITY Total by WY Bedload <8
1981	228	212	16	27,609	1,558	443	1,115	32,895	1,909	586	1,323
1982	101,422	91,695	9,728	189,221	69,767	45,440	24,327	211,801	76,162	49,440	26,722
1983	122,250	110,463	11,787	308,493	103,903	64,407	39,495	464,261	202,132	133,993	68,138
1984	28,055	25,308	2,747	142,922	29,467	16,172	13,295	170,556	35,870	19,584	16,286
1985	228	212	16	26,863	1,573	451	1,122	30,356	1,784	536	1,248
1986	31,343	28,263	3,080	144,830	35,373	20,112	15,261	172,493	43,615	25,060	18,556
1987	228	212	16	27,175	1,589	453	1,136	31,307	1,847	557	1,290
1988	228	212	16	26,515	1,531	428	1,103	30,539	1,853	553	1,300
1989	3,879	3,509	370	58,960	6,625	2,904	3,722	64,572	7,371	3,290	4,081
1990	228	212	16	25,927	1,465	410	1,056	28,743	1,591	452	1,139
1991	-	-	-	8,861	-	-	-	11,119	-	-	-
1992	228	212	16	29,123	1,699	500	1,199	36,389	2,171	694	1,478
1993	25,338	22,846	2,491	95,432	23,570	13,719	9,850	110,512	27,430	16,079	11,351
1994	-	-	-	9,617	-	-	-	11,491	-	-	-
1995	108,546	98,115	10,431	220,476	82,619	53,053	29,566	273,027	101,561	65,364	36,196
1996	28,442	25,650	2,792	129,514	31,464	18,004	13,460	134,743	28,003	15,404	12,599
1997	58,926	53,105	5,821	262,725	79,230	46,225	33,005	317,467	125,600	81,253	44,347
1998	108,115	97,754	10,360	317,078	110,484	69,265	41,219	464,666	188,393	122,417	65,977
1999	25,338	22,846	2,491	99,295	24,267	14,253	10,014	109,327	25,537	15,057	10,480
2000	6,007	5,442	565	96,318	11,657	4,988	6,669	114,854	15,716	7,116	8,600
	649,028	586,270	62,758	2,246,955	617,841	371,227	246,614	2,821,118	888,545	557,436	331,110

Notes:
-- Sediment transport calculations performed using historic (Lewiston 1981-2000, Limekiln 1981-1991, 1998-2000, Douglas City 1996-2000) and synthetic mean daily discharges (all other years) with the flow release schedule from the ROD superimposed on the combined historic and synthetic flows
-- Lewiston Bedload rating curves from McBain & Trush 1997 (no additional data has been collected at that site since then)
-- Limekiln SSS rating curve from GMA this study
-- Limekiln Bedload rating curves (non-linear) from McBain & Trush 1997, updated with WY2000 data
-- Douglas City used same equations as Limekiln, as no sediment transport data have been collected at that site

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TABLE 22

TRINITY RIVER SEDIMENT SOURCE ANALYSIS

ANNUAL SEDIMENT TRANSPORT VALUES FOR MAINSTEM TRINITY RIVER AND TRIBUTARY SITES
BETWEEN LEWISTON AND LIMEKILN GULCH BASED ON HISTORIC AND SYNTHETIC FLOW RECORDS

WATER YEAR	Trinity River Lewiston	Grass Valley Creek		Deadwood Creek		Rush Creek		*Combined Tribs & Lewiston Upstream TRLG*		Trinity River bel. Limekiln		Difference TRLG - Combined Load	
	Bedload	Suspended	Bedload	Suspended	Bedload	Suspended	Bedload	Suspended	Bedload	Suspended	Bedload	Suspended	Bedload
1981	-	3,877	277	55	47	627	346	4,559	671	3,947	-	(611)	(671)
1982	42	7,127	2,592	325	197	1,818	1,034	9,270	3,865	32,147	1,768	22,876	(2,097)
1983	46,266	304,673	37,359	53,204	10,700	27,343	17,307	385,220	111,632	245,076	57,760	(140,144)	(53,872)
1984	2,717	9,714	7,472	647	346	2,552	1,481	12,914	12,016	54,010	6,242	41,096	(5,774)
1985	-	977	793	37	28	365	201	1,380	1,022	2,970	-	1,590	(1,022)
1986	6,005	59,855	6,703	2,090	783	3,838	2,304	65,783	15,796	57,190	12,100	(8,594)	(3,696)
1987	-	4,354	443	78	51	520	292	4,952	786	4,641	-	(311)	(786)
1988	-	1,211	85	10	12	244	130	1,465	227	3,094	-	1,629	(227)
1989	-	2,560	1,391	70	49	524	294	3,154	1,734	8,687	-	5,533	(1,734)
1990	-	1,393	548	8	9	170	91	1,571	648	2,487	-	916	(648)
1991	-	232	403	3	5	132	69	367	477	4,536	18	4,170	(459)
1992	3,549	3,126	1,817	162	115	1,161	658	4,449	6,138	25,271	5,322	20,822	(816)
1993	-	1,895	928	105	93	1,178	656	3,177	1,677	17,852	464	14,675	(1,213)
1994	-	83	2	2	3	111	57	196	62	9,790	-	9,594	(62)
1995	9,290	65,595	39,049	10,365	2,811	10,557	6,466	86,517	57,616	110,821	21,867	24,303	(35,749)
1996	3,879	2,015	159	54	59	870	479	2,940	4,575	53,115	9,155	50,176	4,580
1997	33,588	15,750	14,098	90	180	30,500	34,700	46,340	82,566	180,992	55,936	134,652	(26,630)
1998	18,972	77,446	49,869	8,785	3,519	20,857	8,465	107,088	80,825	263,023	56,330	155,935	(24,494)
1999	-	958	436	54	44	780	1,313	1,792	1,793	13,329	1	11,537	(1,792)
2000	2,128	3,393	6,878	810	550	670	612	4,873	10,168	44,444	4,951	39,571	(5,217)
						284	57						
Total	126,436	566,238	171,302	76,953	19,601	105,100	77,011	748,007	394,293	1,137,422	231,913	389,415	(162,379)
Yr Mean	6,322	28,312	8,565	3,848	980	5,255	3,851	35,619	18,776	56,871	11,596	19,471	(8,119)
tons/mi^2/yr	3,161	916	277	422	108	235	172	383	202	612	125		

Notes:
- -- Mainstem sediment loads computed from combination of historic (Lewiston 1981-2000, Limekiln 1981-1991, 1998-2000) and synthetic mean daily discharge
- -- Tributary sediment loads computed from combination of historic (Grass Valley 1981-2000, Deadwood and Rush 1996-2000) and synthetic mean daily discharge
- -- Mainstem sediment rating curves from 1996-2000 data
- -- Tributary sediment rating curves from WY2000 and 2001 data, except Grass Valley which are all USGS records from the Fawn Lodge site
- -- Data collected by GMA for this study suggests that the lower 6 mi2 of Grass Valley Watershed (below Fawn Lodge) increase loads by over 40%, at least in WY2001
- -- Tributary values from Rush and Deadwood 1997-2000 from Hoopa Valley Tribe monitoring for the Trinity River Restoration Program
- -- All values in tons

TRINITY RIVER SEDIMENT SOURCE ANALYSIS
Mainstem and Tributary Sediment Transport, 1981-2000
Lewiston to Limekiln Study Reach

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TABLE 23

TRINITY RIVER SEDIMENT SOURCE ANALYSIS

ANNUAL SEDIMENT TRANSPORT VALUES FOR MAINSTEM TRINITY RIVER AND TRIBUTARY SITES
BETWEEN LEWISTON AND LIMEKILN GULCH BASED ON COMBINED HISTORIC FLOWS AND ROD FLOW PRESCRIPTIONS

WATER YEAR	Trinity River Lewiston	Grass Valley Creek		Deadwood Creek		Rush Creek		*Combined Tribs & Lewiston Upstream TRLG*		Trinity River bel. Limekiln		Difference TRLG - Combined Load	
	Bedload	Suspended	Bedload	Suspended	Bedload	Suspended	Bedload	Suspended	Bedload	Suspended	Bedload	Suspended	Bedload
1981	228	3,877	277	55	47	627	346	4,559	898	27,609	1,558	23,051	659
1982	101,422	7,127	2,592	325	197	1,818	1,034	9,270	105,245	189,221	69,767	179,951	(35,477)
1983	122,250	304,673	37,359	53,204	10,700	27,343	17,307	385,220	187,616	308,493	103,903	(76,727)	(83,714)
1984	28,055	9,714	7,472	647	346	2,552	1,481	12,914	37,354	142,922	29,467	130,008	(7,887)
1985	228	977	793	37	28	365	201	1,380	1,250	26,863	1,573	25,483	323
1986	31,343	59,855	6,703	2,090	783	3,838	2,304	65,783	41,133	144,830	35,373	79,047	(5,760)
1987	228	4,354	443	78	51	520	292	4,952	1,013	27,175	1,589	22,223	576
1988	228	1,211	85	10	12	244	130	1,465	454	26,515	1,531	25,049	1,077
1989	3,879	2,560	1,391	70	49	524	294	3,154	5,613	58,960	6,625	55,806	1,013
1990	228	1,393	548	8	9	170	91	1,571	876	25,927	1,465	24,356	590
1991	-	232	403	3	5	132	69	367	477	8,861	-	8,494	(477)
1992	228	3,126	1,817	162	115	1,161	658	4,449	2,817	29,123	1,699	24,674	(1,118)
1993	25,338	1,895	928	105	93	1,178	656	3,177	27,015	95,432	23,570	92,255	(3,445)
1994	-	83	2	2	3	111	57	196	62	9,617	-	9,422	(62)
1995	108,546	65,595	39,049	10,365	2,811	10,557	6,466	86,517	156,872	220,476	82,619	133,959	(74,253)
1996	28,442	2,015	159	54	59	870	479	2,940	29,139	129,514	31,464	126,575	2,325
1997	58,926	15,750	14,098	90	180	30,500	34,700	46,340	107,904	262,725	79,230	216,385	(28,674)
1998	108,115	77,446	49,869	8,785	3,519	20,857	8,465	107,088	169,968	317,078	110,484	209,990	(59,484)
1999	25,338	958	436	54	44	780	1,313	1,792	27,131	99,295	24,267	97,503	(2,863)
2000	6,007	3,393	6,878	810	550	670	612	4,873	14,048	96,318	11,657	91,445	(2,390)
						284	57						
Total	649,028	566,238	171,302	76,953	19,601	105,100	77,011	748,007	916,884	2,246,955	617,841	1,498,948	(299,043)
Yr Mean	32,451	28,312	8,565	3,848	980	5,255	3,851	35,619	43,661	112,348	30,892	74,947	(14,952)
tons/mi^2/yr	16,226	916	277	422	108	235	172	383	469	1,208	332		

Notes:
- -- Mainstem sediment loads computed from combination of historic (Lewiston 1981-2000, Limekiln 1981-1991, 1998-2000) and synthetic mean daily discharge
- -- Tributary sediment loads computed from combination of historic (Grass Valley 1981-2000, Deadwood and Rush 1996-2000) and synthetic mean daily discharge
- -- Mainstem sediment rating curves from 1996-2000 data
- -- Tributary sediment rating curves from WY2000 and 2001 data, except Grass Valley which are all USGS records from the Fawn Lodge site
- -- Data collected by GMA for this study suggests that the lower 6 mi^2 of Grass Valley Watershed (below Fawn Lodge) increase loads by over 40%, at least in WY2001
- -- Tributary values from Rush and Deadwood 1997-2000 from Hoopa Valley Tribe monitoring for the Trinity River Restoration Program
- -- All values in tons

TRINITY RIVER SEDIMENT SOURCE ANALYSIS
Mainstem and Tributary Sediment Transport, 1981-2000
Lewiston to Limekiln Study Reach, with ROD Flow Prescription

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TRINITY RIVER SEDIMENT SOURCE ANALYSIS

ANNUAL SEDIMENT TRANSPORT VALUES FOR MAINSTEM TRINITY RIVER AND TRIBUTARY SITES
BETWEEN LIMEKILN GULCH AND DOUGLAS CITY BASED ON HISTORIC FLOWS

WATER YEAR	Trinity River bel. Limekiln		Indian Creek		Weaver Creek		Reading Creek		*Combined Tribs & Limekiln Upstream TRDC*		Trinity River nr. Douglas City		Difference TRDC - Combined Load	
	Suspended	Bedload	Suspended	Bedload	Suspended	Bedload	Suspended	Bedload	Suspended	Bedload	Suspended	Bedload	Suspended	Bedload
1981	3,947	-	3,780	4,759	1,666	257	1,043	157	10,437	5,173	7,123	0	(3,314)	(5,172)
1982	32,147	1,768	14,769	17,030	5,105	1,013	6,800	1,020	58,821	20,831	47,394	3,782	(11,426)	(17,049)
1983	245,076	57,760	310,050	186,567	94,330	46,426	85,615	12,842	735,072	303,595	394,885	146,825	(340,187)	(156,770)
1984	54,010	6,242	25,152	27,572	7,456	1,734	13,848	2,077	100,466	37,625	77,465	11,071	(23,001)	(26,554)
1985	2,970	-	2,231	2,761	962	152	730	109	6,893	3,023	5,120	0	(1,772)	(3,023)
1986	57,190	12,100	53,397	53,038	11,966	3,719	49,361	7,404	171,914	76,261	79,892	18,315	(92,021)	(57,947)
1987	4,641	-	3,849	4,531	1,427	263	1,587	238	11,504	5,033	7,446	2	(4,058)	(5,031)
1988	3,094	-	1,007	1,409	603	68	168	25	4,872	1,502	5,117	-	246	(1,502)
1989	8,687	-	3,758	4,481	1,433	257	1,386	208	15,265	4,946	11,991	8	(3,274)	(4,939)
1990	2,487	-	757	1,032	424	51	139	21	3,808	1,104	3,926	-	118	(1,104)
1991	4,536	18	450	673	317	30	40	6	5,343	728	5,811	26	468	(702)
1992	25,271	5,322	8,819	10,440	3,236	603	3,206	481	40,532	16,846	30,499	5,593	(10,033)	(11,253)
1993	17,852	464	7,432	9,303	3,176	505	1,932	290	30,392	10,562	25,196	750	(5,196)	(9,812)
1994	9,790	-	311	492	256	21	22	3	10,379	516	11,704	-	1,325	(516)
1995	110,821	21,867	182,664	169,541	34,198	12,817	51,361	7,704	379,044	211,929	161,044	38,050	(218,000)	(173,879)
1996	53,115	9,155	4,802	6,268	2,293	325	932	140	61,142	15,887	58,009	7,896	(3,133)	(7,992)
1997	180,992	55,936	8,100	36,500	15,464	6,201	138,278	20,742	342,834	119,379	235,009	102,211	(107,825)	(17,168)
1998	263,023	56,330	125,681	41,337	45,546	15,894	66,185	9,928	500,435	123,489	410,515	127,390	(89,920)	3,901
1999	13,329	1	2,007	271	2,359	335	1,092	164	18,787	771	20,457	1	1,670	(770)
2000	44,444	4,951	32,544	45,321	8,685	1,922	13,561	2,034	99,233	54,228	60,336	8,369	(38,897)	(45,859)
Total	1,137,422	231,913	791,561	623,328	240,902	92,594	437,286	65,593	2,607,171	1,013,428	1,658,941	470,289	(948,230)	(543,139)
Yr Mean	56,871	11,596	39,578	31,166	12,045	4,630	21,864	3,280	124,151	48,258	82,947	23,514	(47,411)	(27,157)
tons/mi^2/yr	612	125	1,175	925	251	96	710	107	1,335	519	892	253		

Notes:
- -- Mainstem sediment loads computed from combination of historic (Limekiln 1981-1991, 1998-2000, Douglas City 1996-2000) and synthetic mean daily discharge
- -- Tributary sediment loads computed from combination of historic (Indian 1997-2000) and synthetic mean daily discharge
- -- Mainstem sediment rating curves from 1996-2000 data
- -- Tributary sediment rating curves from WY2000 and 2001 data
- -- Tributary values from Indian 1997-2000 from Hoopa Valley Tribe monitoring for the Trinity River Restoration Program
- -- All values in tons

TRINITY RIVER SEDIMENT SOURCE ANALYSIS
Mainstem and Tributary Sediment Transport, 1981-2000
Limekiln to Douglas City Study Reach

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TRINITY RIVER SEDIMENT SOURCE ANALYSIS

ANNUAL SEDIMENT TRANSPORT VALUES FOR MAINSTEM TRINITY RIVER AND TRIBUTARY SITES
BETWEEN LIMEKILN GULCH AND DOUGLAS CITY BASED ON COMBINED HISTORIC FLOWS AND ROD FLOW PRESCRIPTIONS

WATER YEAR	Trinity River bel. Limekiln		Indian Creek		Weaver Creek		Reading Creek		*Combined Tribs & Limekiln Upstream TRDC*		Trinity River nr. Douglas City		Difference TRDC - Combined Load	
	Suspended	Bedload	Suspended	Bedload	Suspended	Bedload	Suspended	Bedload	Suspended	Bedload	Suspended	Bedload	Suspended	Bedload
1981	27,609	1,558	3,780	4,759	1,666	257	1,043	157	34,099	6,730	32,895	1,909	(1,204)	(4,822)
1982	189,221	69,767	14,769	17,030	5,105	1,013	6,800	1,020	215,895	88,831	211,801	76,162	(4,094)	(12,669)
1983	308,493	103,903	310,050	186,567	94,330	46,426	85,615	12,842	798,489	349,737	464,261	202,132	(334,227)	(147,606)
1984	142,922	29,467	25,152	27,572	7,456	1,734	13,848	2,077	189,378	60,850	170,556	35,870	(18,821)	(24,979)
1985	26,863	1,573	2,231	2,761	962	152	730	109	30,786	4,596	30,356	1,784	(430)	(2,812)
1986	144,830	35,373	53,397	53,038	11,966	3,719	49,361	7,404	259,554	99,535	172,493	43,615	(87,061)	(55,919)
1987	27,175	1,589	3,849	4,531	1,427	263	1,587	238	34,038	6,622	31,307	1,847	(2,731)	(4,775)
1988	26,515	1,531	1,007	1,409	603	68	168	25	28,292	3,033	30,539	1,853	2,247	(1,180)
1989	58,960	6,625	3,758	4,481	1,433	257	1,386	208	65,537	11,572	64,572	7,371	(965)	(4,200)
1990	25,927	1,465	757	1,032	424	51	139	21	27,248	2,569	28,743	1,591	1,495	(978)
1991	8,861	-	450	673	317	30	40	6	9,668	709	11,119	-	1,451	(709)
1992	29,123	1,699	8,819	10,440	3,236	603	3,206	481	44,384	13,223	36,389	2,171	(7,995)	(11,052)
1993	95,432	23,570	7,432	9,303	3,176	505	1,932	290	107,972	33,668	110,512	27,430	2,540	(6,238)
1994	9,617	-	311	492	256	21	22	3	10,206	516	11,491	-	1,284	(516)
1995	220,476	82,619	182,664	169,541	34,198	12,817	51,361	7,704	488,699	272,681	273,027	101,561	(215,673)	(171,121)
1996	129,514	31,464	4,802	6,268	2,293	325	932	140	137,541	38,196	134,743	28,003	(2,797)	(10,193)
1997	262,725	79,230	8,100	36,500	15,464	6,201	138,278	20,742	424,567	142,673	317,467	125,600	(107,100)	(17,073)
1998	317,078	110,484	125,681	41,337	45,546	15,894	66,185	9,928	554,490	177,643	464,666	188,393	(89,823)	10,751
1999	99,295	24,267	2,007	271	2,359	335	1,092	164	104,753	25,037	109,327	25,537	4,574	500
2000	96,318	11,657	32,544	45,321	8,685	1,922	13,561	2,034	151,107	60,934	114,854	15,716	(36,254)	(45,219)
Total	2,246,955	617,841	791,561	623,328	240,902	92,594	437,286	65,593	3,716,703	1,399,356	2,821,118	888,545	(895,585)	(510,810)
Yr Mean	112,348	30,892	39,578	31,166	12,045	4,630	21,864	3,280	176,986	66,636	141,056	44,427	(44,779)	(25,541)
tons/mi^2/yr	1,208	332	1,175	925	251	96	710	107	1,903	717	1,517	478		

Notes:
-- Mainstem sediment loads computed from combination of historic (Lewiston 1981-2000, Limekiln 1981-1991, 1998-2000) and synthetic mean daily discharge
-- Tributary sediment loads computed from combination of historic (Grass Valley 1981-2000, Deadwood and Rush 1996-2000) and synthetic mean daily discharge
-- Mainstem sediment rating curves from 1996-2000 data
-- Tributary sediment rating curves from WY2000 and 2001 data, except Grass Valley which are all USGS records from the Fawn Lodge site
-- Data collected by GMA for this study suggests that the lower 6 mi^2 of Grass Valley Watershed (below Fawn Lodge) increase loads by over 40%, at least in WY2001
-- Tributary values from Rush and Deadwood 1997-2000 from Hoopa Valley Tribe monitoring for the Trinity River Restoration Program
-- All values in tons

TRINITY RIVER SEDIMENT SOURCE ANALYSIS
Mainstem and Tributary Sediment Transport, 1981-2000
Limekiln to Douglas City Study Reach, with ROD Flow Prescription

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TRINITY RIVER SEDIMENT SOURCE ANALYSIS

SUMMARY OF SEDIMENT TRANSPORT VALUES FOR MAINSTEM TRINITY RIVER AND TRIBUTARY SITES, 1981-2000
BETWEEN LEWISTON AND LIMEKILN GULCH COMPARING HISTORIC AND ROD FLOW REGIMES

BETWEEN LEWISTON AND LIMEKILN GULCH BASED ON HISTORIC FLOWS ONLY

WATER YEAR	Trinity River Lewiston	Grass Valley Creek		Deadwood Creek		Rush Creek		*Combined Tribs & Lewiston Upstream TRLG*		Trinity River bel. Limekiln		Difference TRLG - Combined Load	
	Bedload	Suspended	Bedload	Suspended	Bedload	Suspended	Bedload	Suspended	Bedload	Suspended	Bedload	Suspended	Bedload
Total	126,436	566,238	171,302	76,953	19,601	104,816	76,954	748,007	394,293	1,137,422	231,913	444,059	24,021
Yr Mean	6,322	28,312	8,565	3,848	980	5,241	3,848	35,619	18,776	56,871	11,596	22,203	1,201
tons/mi^2/yr	3,161	916	277	422	108	234	172	383	202	612	125		

BETWEEN LEWISTON AND LIMEKILN GULCH BASED ON HISTORIC FLOWS COMBINED WITH ROD FLOW PRESCRIPTIONS

WATER YEAR	Trinity River Lewiston	Grass Valley Creek		Deadwood Creek		Rush Creek		*Combined Tribs & Lewiston Upstream TRLG*		Trinity River bel. Limekiln		Difference TRLG - Combined Load	
	Bedload	Suspended	Bedload	Suspended	Bedload	Suspended	Bedload	Suspended	Bedload	Suspended	Bedload	Suspended	Bedload
Total	649,028	566,238	171,302	76,953	19,601	105,100	77,011	748,007	916,884	2,246,955	617,841	1,498,948	(299,043)
Yr Mean	32,451	28,312	8,565	3,848	980	5,255	3,851	35,619	43,661	112,348	30,892	74,947	(14,952)
tons/mi^2/yr	16,226	916	277	422	108	235	172	383	469	1,208	332		

INCREASED SEDIMENT TRANSPORT POTENTIAL FROM ROD FLOW PRESCRIPTIONS APPLIED TO 1981-2000 HISTORIC FLOWS

	Trinity River Lewiston	Trinity River bel. Limekiln	
	Bedload	Suspended	Bedload
Total	522,591	1,109,533	385,928
Yr Mean	26,130	55,477	19,296
tons/mi^2/yr	13,065	597	207

Notes: All values in tons

TRINITY RIVER SEDIMENT SOURCE ANALYSIS
Mainstem and Tributary Sediment Transport, 1981-2000
Lewiston to Limekiln Study Reach

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TABLE 27

TRINITY RIVER SEDIMENT SOURCE ANALYSIS

SEDIMENT TRANSPORT VALUES FOR MAINSTEM TRINITY RIVER AND TRIBUTARY SITES, 1981-2000
BETWEEN LIMEKILN GULCH AND DOUGLAS CITY COMPARING HISTORIC AND ROD FLOW REGIMES

BETWEEN LIMEKILN GULCH AND DOUGLAS CITY BASED ON HISTORIC FLOWS ONLY

WATER YEAR	Trinity River bel. Limekiln		Indian Creek		Weaver Creek		Reading Creek		*Combined Tribs & Limekiln Upstream TRDC*		Trinity River nr. Douglas City		Difference TRDC - Combined Load	
	Suspended	Bedload	Suspended	Bedload	Suspended	Bedload	Suspended	Bedload	Suspended	Bedload	Suspended	Bedload	Suspended	Bedload
Total	1,137,422	231,913	791,561	623,328	240,902	92,594	437,286	65,593	2,607,171	1,013,428	1,658,941	470,289	(948,230)	(543,139)
Yr Mean	56,871	11,596	39,578	31,166	12,045	4,630	21,864	3,280	124,151	48,258	82,947	23,514	(47,411)	(27,157)
tons/mi^2/yr	612	125	1,175	925	251	96	710	107	1,335	519	892	253		

BETWEEN LIMEKILN GULCH AND DOUGLAS CITY BASED ON HISTORIC FLOWS COMBINED WITH ROD FLOW PRESCRIPTIONS

WATER YEAR	Trinity River bel. Limekiln		Indian Creek		Weaver Creek		Reading Creek		*Combined Tribs & Limekiln Upstream TRDC*		Trinity River nr. Douglas City		Difference TRDC - Combined Load	
	Suspended	Bedload	Suspended	Bedload	Suspended	Bedload	Suspended	Bedload	Suspended	Bedload	Suspended	Bedload	Suspended	Bedload
Total	2,246,955	617,841	791,561	623,328	240,902	92,594	437,286	65,593	3,716,703	1,399,356	2,821,118	888,545	(895,585)	(510,810)
Yr Mean	112,348	30,892	39,578	31,166	12,045	4,630	21,864	3,280	176,986	66,636	141,056	44,427	(44,779)	(25,541)
tons/mi^2/yr	1,208	332	1,175	925	251	96	710	107	1,903	717	1,517	478		

INCREASED SEDIMENT TRANSPORT POTENTIAL FROM ROD FLOW PRESCRIPTIONS APPLIED TO 1981-2000 HISTORIC FLOWS

WATER YEAR	Trinity River bel. Limekiln		Trinity River nr. Douglas City	
	Suspended	Bedload	Suspended	Bedload
Total	1,109,533	385,928	1,162,177	418,257
Yr Mean	55,477	19,296	58,109	20,913
tons/mi^2/yr	597	207	625	225

Notes: -- All values in tons

TRINITY RIVER SEDIMENT SOURCE ANALYSIS
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Limekiln to Douglas City Study Reach

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TABLE 28

Upper Middle Trinity Planning Watershed

LANDSLIDE NUMBERS BY PERIOD BY LAND USE BY SUB-WATERSHED, 1944-2000

	LANDSLIDE NUMBERS											
	1944				1979				2000			
Sub-Watershed	**Road**	**Harvest**	**Forest**	**Total**	**Road**	**Harvest**	**Forest**	**Total**	**Road**	**Harvest**	**Forest**	**Total**
Browns Creek			4	4	1	2		3	18	16	12	46
Deadwood Creek									1		1	2
Grass Valley Creek	4	1	1	6					6	30	2	38
Hoadley Gulch									3	2		5
Indian Creek			11	11		2		2	23	6	11	40
Lewiston Lake												
Lewiston Lake Area			1	1	5	1	1	7	3		2	5
Poker Bar Area	3		12	15		2	4	6	6	4	5	15
Reading Creek	1		4	5					18	15	16	49
Rush Creek	3			3	3	3	10	16	3	1	13	17
Weaver Creek	6		13	19	9	2	5	16	8	4	21	33
TOTAL BY LAND USE	17	1	46	64	18	12	20	50	89	78	83	250
% OF TOTAL IN PERIOD	26.6%	1.6%	71.9%	100.0%	36.0%	24.0%	40.0%	100.0%	35.6%	31.2%	33.2%	100.0%

TRINITY RIVER SEDIMENT SOURCE ANALYSIS
Upper Middle Trinity Planning Watershed
Landslide Inventory, 1944-2000

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TABLE
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Upper Middle Trinity Planning Watershed

LANDSLIDE VOLUMES BY PERIOD BY LAND USE BY SUB-WATERSHED, 1944-2000

Sub-Watershed	LANDSLIDE VOLUMES (tons)											
	1944				1979				2000			
	Road	Harvest	Forest	Total	Road	Harvest	Forest	Total	Road	Harvest	Forest	Total
Browns Creek			37,360	37,360	4,336	171,853		176,189	70,081	141,063	58,007	269,151
Deadwood Creek									76		56,398	56,474
Grass Valley Creek	22,574	3,262	7,271	33,107					9,143	217,201	8,386	234,730
Hoadley Gulch									4,830	7,472		12,302
Indian Creek			67,032	67,032		104,468		104,468	977,110	162,031	112,176	1,251,317
Lewiston Lake												-
Lewiston Lake Area			49,462	49,462	287,888	36,508	102,718	427,115	2,150		13,796	15,946
Poker Bar Area	35,146		171,756	206,902		55,449	161,601	217,050	49,567	196,940	9,904	256,410
Reading Creek	2,198		75,826	78,024					27,211	144,299	154,160	325,670
Rush Creek	88,621			88,621	165,672	172,511	1,115,399	1,453,582	30,901	1,883	541,519	574,303
Weaver Creek	124,878		62,224	187,102	189,977	108,947	169,334	468,258	20,512	63,650	1,306,807	1,390,968
TOTAL	273,417	3,262	470,932	747,610	647,873	649,736	1,549,053	2,846,662	1,191,582	934,539	2,261,151	4,387,272
% OF TOTAL IN PERIOD	36.6%	0.4%	63.0%	100.0%	22.8%	22.8%	54.4%	100.0%	27.2%	21.3%	51.5%	100.0%

TRINITY RIVER SEDIMENT SOURCE ANALYSIS

Upper Middle Trinity Planning Watershed

Landslide Inventory, 1944-2000

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LANDSLIDE NUMBERS BY PERIOD BY LAND USE BY SUB-WATERSHED, 1944-2000

Selected Sub-Watersheds, Upper Middle Trinity Planning Watershed

LANDSLIDE NUMBERS

Sub-Watershed	1944				1960 or 1970				1979 and 1980				1989				2000			
	Management-related		Non Mgmt-related		Management-related		Non Mgmt-related		Management-related		Non Mgmt-related		Management-related		Non Mgmt-related		Management-related		Non Mgmt-related	
	Road	Hvst	Forest	Total	Road	Hvst	Forest	Total	Road	Harvest	Forest	Total	Road	Hvst	Forest	Total	Road	Harvest	Forest	Total
Browns Ck			4	4	3		4	7	1	2		3		3	3	6	18	16	12	46
% of Total			100.0%		42.9%		57.1%		33.3%	66.7%				50.0%	50.0%		39.1%	34.8%	26.1%	
Rush Ck	3			3	5		6	11	3	3	10	16	3		1	4	3	1	13	17
% of Total	100.0%				45.5%		54.5%		18.8%	18.8%	62.5%		75.0%		25.0%		17.6%	5.9%	76.5%	
TOTAL	3	0	4	7	8	0	10	18	4	5	10	19	3	3	4	10	21	17	25	63
% OF TOTAL	42.9%	0.0%	57.1%		44.4%		55.6%		21.1%	26.3%	52.6%		30.0%	30.0%	40.0%		33.3%	27.0%	39.7%	

LANDSLIDE VOLUMES (tons)

Sub-Watershed	1944				1960 or 1970				1979 and 1980				1989				2000			
	Management-related		Non Mgmt-related		Management-related		Non Mgmt-related		Management-related		Non Mgmt-related		Management-related		Non Mgmt-related		Management-related		Non Mgmt-related	
	Road	Hvst	Forest	Total	Road	Hvst	Forest	Total	Road	Harvest	Forest	Total	Road	Hvst	Forest	Total	Road	Harvest	Forest	Total
Browns Ck			37,360	37,360	19,819		31,376	51,195	4,336	171,853		176,189		50,310	7,102	57,411	70,081	141,063	58,007	269,151
% of Total			100.0%		38.7%		61.3%		2.5%	97.5%				87.6%	12.4%		26.0%	52.4%	21.6%	
Rush Ck	88,621			88,621	55,425		121,680	177,106	165,672	172,511	1,115,399	1,453,582	28,388		9,522	37,910	30,901	1,883	541,519	574,304
% of Total	100.0%				31.3%		68.7%		11.4%	11.9%	76.7%		74.9%		25.1%		5.4%	0.3%	94.3%	
TOTAL	88,621	0	37,360	125,982	75,244	0	153,057	228,301	170,008	344,364	1,115,399	1,629,770	28,388	50,311	16,624	95,322	100,982	142,946	599,526	843,455
% OF TOTAL	70.3%	0.0%	29.7%		33.0%	0.0%	67.0%		10.4%	21.1%	68.4%						12.0%	16.9%	71.1%	

Notes: Browns Creek had aerial coverage in 1960, Rush Creek in 1970. Rush Creek was also mapped in 1980 and combined with 1979.

TRINITY RIVER SEDIMENT SOURCE ANALYSIS
Upper Middle Trinity Planning Watershed
Landslide Inventory, Selected Sub-Watersheds, 1944-2000

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TABLE 31

SIX RIVERS NATIONAL FOREST

LANDSLIDES BY PERIOD BY LANDUSE BY SUB-WATERSHED

TISH TANG CREEK

	Management-Related					
YEAR	Road	Harvest	Cumulative	Natural	TOTAL	% by Period
1944	22,922			27,152	50,074	6.2%
1960	11,461			30,540	42,001	5.2%
1975	488,833	14,915	62,328	134,429	700,505	87.3%
1990				9,742	9,742	1.2%
1998					-	0.0%
TOTAL	523,215	14,915	62,328	201,864	802,322	
	65.2%	1.9%	7.8%	25.2%	100.0%	
Tons/mi^2/yr	454.1	12.9	54.1	175.2	696.3	

MILL CREEK

	Management-Related					
YEAR	Road	Harvest	Cumulative	Natural	TOTAL	% by Period
1944				287,574	287,574	41.2%
1960	1,718			10,397	12,114	1.7%
1975	9,049	7,245		382,822	399,116	57.1%
1990					-	0.0%
1998					-	0.0%
TOTAL	10,767	7,245	-	680,792	698,804	
(%)	1.5%	1.0%	0.0%	97.4%	100.0%	
Tons/mi^2/yr	7.1	4.8	0.0	450.5	462.4	

HORSE LINTO CREEK

	Management-Related					
YEAR	Road	Harvest	Cumulative	Natural	TOTAL	% by Period
1944	40,728			1,180,738	1,221,466	23.5%
1960	26,126			578,672	604,798	11.7%
1975	516,883	35,921	111,433	2,466,459	3,130,696	60.4%
1990	34,728	21,438		167,812	223,978	4.3%
1998	5,209			747	5,955	0.1%
TOTAL	623,673	57,359	111,433	4,394,428	5,186,894	
	12.0%	1.1%	2.1%	84.7%	100.0%	
Tons/mi^2/yr	140.6	12.9	25.1	990.5	1169.1	

Notes: All data from Six Rivers National Forest (M. Smith, pers. comm. 2001)

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LANDSLIDE VOLUMES BY PERIOD BY LAND USE BY PLANNING WATERSHED, 1944-2000

Data from Landslide Inventories

Sub-Watershed	LANDSLIDE VOLUMES (tons)											
	1944				1979				1999 OR 2000			
	Road	Harvest	Forest	Total	Road	Harvest	Forest	Total	Road	Harvest	Forest	Total
UPPER TRINITY												
(tons)					**5,304,752**	**3,952,613**	**15,069,614**	**24,326,979**	**134,005**	**21,690,898**	**21,677,967**	**43,502,870**
(% by PW)					21.8%	16.2%	61.9%		0.3%	49.9%	49.8%	
($tons/mi^2/yr$)					511	381	1,453	2,345	13	2,091	2,090	4,193
UPPER MIDDLE TRINITY												
(tons)	**273,417**	**3,262**	**470,932**	**747,610**	**645,032**	**641,171**	**1,542,628**	**2,828,831**	**1,191,582**	**934,539**	**2,261,151**	**4,387,272**
(% by PW)	36.6%	0.4%	63.0%		22.8%	22.7%	54.5%		27.2%	21.3%	51.5%	
($tons/mi^2/yr$)	57	1	98	155	134	133	320	587	247	194	469	911
LOWER MIDDLE TRINITY												
(tons)					**3,152,543**	**-**	**13,457,229**	**16,609,772**				
(% by PW)					19.0%		81.0%					
($tons/mi^2/yr$)					292		1,247	1,539				
LOWER TRINITY												
(tons)					**16,968,427**	**1,686,244**	**2,274,999**	**20,929,670**	**40,337**	**64,617**	**193,356**	**298,310**
(% by PW)					81.1%	8.1%	10.9%		13.5%	21.7%	64.8%	
($tons/mi^2/yr$)					3,731	371	500	4,602	9	14	43	66
TOTAL BY LAND USE	**273,474**	**3,262**	**471,030**	**747,766**	**26,070,753**	**6,280,028**	**32,344,471**	**64,695,252**	**1,365,924**	**22,690,055**	**24,132,473**	**48,188,452**
% OF TOTAL IN PERIOD	36.6%	0.4%	63.0%		40.3%	9.7%	50.0%		2.8%	47.1%	50.1%	

-- 1979 slides areas digitized from maps prepared by DWR (1980), then converted to volumes using average thicknesses and delivery percentages by type developed in this study. Land use assigned by intersection of buffered road or digitized harvest areas
-- Upper Middle Trinity mapped in 1944 and 2000 this study
-- Portions of Upper Trinity above Trinity Lake mapped this study using 1999 aerial photography. Coverage area about 200 mi^2.
-- Lower Trinity in 2000 covers only Six Rivers National Forest Area in Mill, Tish Tang, and Horse Linto watersheds. Data from M. Smith (pers. com. 2001)

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LANDSLIDE VOLUMES BY PERIOD BY LAND USE BY PLANNING WATERSHED, 1944-2000

ALTERNATE LANDSLIDE VOLUME ANALYSIS FOR WATERSHEDS WITHOUT COMPLETE INVENTORY

	LANDSLIDE VOLUMES (tons)											
	1944				1979				1999 OR 2000			
Sub-Watershed	Road	Harvest	Forest	Total	Road	Harvest	Forest	Total	Road	Harvest	Forest	Total
UPPER TRINITY												
(tons)					**5,304,752**	**3,952,613**	**15,069,614**	**24,326,979**	**134,005**	**21,690,898**	**21,677,967**	**43,502,870**
(% by PW)					21.8%	16.2%	61.9%		0.3%	49.9%	49.8%	
(tons/mi^2/yr)					384	286	1,089	1,759	10	1,568	1,567	3,145
UPPER MIDDLE TRINITY												
(tons)	**273,417**	**3,262**	**470,932**	**747,610**	**645,032**	**641,171**	**1,542,628**	**2,828,831**	**1,191,582**	**934,539**	**2,261,151**	**4,387,272**
(% by PW)	36.6%	0.4%	63.0%		22.8%	22.7%	54.5%		27.2%	21.3%	51.5%	
(tons/mi^2/yr)	43	1	73	116	100	100	240	440	185	145	352	683
LOWER MIDDLE TRINITY												
(tons)					**3,152,543**	**-**	**13,457,229**	**16,609,772**	**315,254**	**157,627**	**1,345,723**	**1,818,604**
(% by PW)					19.0%		81.0%		17.3%	8.7%	74.0%	
(tons/mi^2/yr)					219		935	1,154	22	11	94	126
LOWER TRINITY												
(tons)					**16,968,427**	**1,686,244**	**2,274,999**	**20,929,670**	**848,421**	**84,312**	**341,250**	**1,273,983**
(% by PW)					81.1%	8.1%	10.9%		66.6%	6.6%	26.8%	
(tons/mi^2/yr)					2,798	278	375	3,451	140	14	56	210
TOTAL BY LAND USE	**273,460**	**3,262**	**471,005**	**747,727**	**26,070,753**	**6,280,028**	**32,344,471**	**64,695,252**	**2,174,008**	**22,709,750**	**24,280,368**	**49,164,126**
% OF TOTAL IN PERIOD	36.6%	0.4%	63.0%		40.3%	9.7%	50.0%		4.4%	46.2%	49.4%	

Notes -- 1979 slides areas digitized from maps prepared by DWR (1980), then converted to volumes using average thicknesses and delivery percentages by type developed in this study. Land use assigned by intersection of buffered road or digitized harvest areas

-- Upper Middle Trinity mapped in 1944 and 2000 this study

-- Only portions of Upper Trinity above Trinity Lake mapped this study using 1999 aerial photography. Coverage area was 147 mi^2.

-- Lower Trinity in 2000 estimated at 5% of 1979 period, due to lower significance of 1997 storm in the west part of the watershed. Forest estimated at 15% to generally align with SRNF data.

-- Lower Middle Trinity estimated at 10% of 1979 period, due to lesser significance of 1997 storm in that part of the watershed. Harvest assumed to be 50% of road related slide volumes.

TRINITY RIVER SEDIMENT SOURCE ANALYSIS

Landslide Analysis by Planning Watershed, 1944-2000

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TABLE

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SUMMARY OF ROAD-RELATED EROSION RATES BY GEOLOGY AND ROAD SLOPE POSITION FROM 2001 FIELD INVENTORIES

			CUTBANK EROSION		ROAD SURFACE EROSION		OTHER EROSION		
Geology	**Surface Type**	**Miles**	**Tons**	**t/mi/yr**	**Tons**	**t/mi/yr**	**Tons**	**Avg Road Age**	**t/mi/yr**
Granitic Rocks	Riparian	7.13	10,447.4	21.10	7,146.5	6.28	2,016.9	49	5.76
	Mid-Slope	1.63	11,125.9	136.15	1,301.1	6.28	735.1	50	9.02
	Ridge	-----	-----	-----	-----	-----	-----	-----	-----
North Fork Terrane	Riparian	5.11	5,783.9	42.95	2,730.3	10.30	4,910.6	40	24.04
	Mid-Slope	4.93	2,043.5	8.71	1,168.7	4.60	4,658.6	60	15.75
	Ridge	0.88	90.4	2.57	212.3	6.05	-	40	0.00
Hayfork Terrane	Riparian	10.42	22,629.9	57.12	3,282.8	8.94	636.6	40	1.53
	Mid-Slope	8.78	2,313.9	5.38	489.5	1.35	481.6	60	0.91
	Ridge	1.61	931.7	14.43	275.8	4.27	-	45	0.00
Bragdon Formation	Riparian	0.92	12.7	0.38	209.7	6.30	148.5	30	5.40
	Mid-Slope	1.65	4.5	0.08	475.5	8.38	47.7	60	0.48
	Ridge	0.95	9.8	0.28	142.1	2.52	6.8	36	0.20
Central Metamorphic Subprovince	Riparian	18.02	23,634.9	25.51	34,009.9	36.90	7,727.2	49	8.75
	Mid-Slope	9.04	4,743.0	9.57	6,133.0	12.78	616.1	60	1.14
	Ridge	0.52	30.1	11.03	281.6	8.96	202.9	52	7.45
Weaverville Formation	Riparian	5.79	6,807.8	19.87	761.8	2.57	221.0	30	1.27
	Mid-Slope	2.00	101.2	0.84	56.5	0.20	190.1	60	1.58
	Ridge	1.03	1,539.0	24.92	50.2	0.66	18.0	30	0.58
Ultramafic Rocks & Gabbro Rocks	Riparian	14.71	22,895.4	32.90	4,379.2	5.93	1,630.5	32	3.46
	Mid-Slope	6.30	1,526.4	6.46	534.5	1.70	1,868.3	41	7.24
	Ridge	0.34	-----	-----	-----	-----	-----	-----	-----
Total Road Miles Inventoried:		**101.75**							

Mean Values:		Cutbank t/mi/yr	Road Surface t/mi/yr	Other t/mi/yr
	Riparian	33.24	11.82	7.47
	Mid-Slope	27.72	5.85	5.76
	Ridge	10.64	4.49	1.65

TRINITY RIVER SEDIMENT SOURCE ANALYSIS
Results of 2001 Road Field Inventories

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TABLE
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SUMMARY OF ROAD-RELATED EROSION RATES BY GEOLOGY AND ROAD TYPE FROM 2001 FIELD INVENTORIES

Geology	Surface Type	Miles	CUTBANK EROSION Tons	CUTBANK EROSION t/mi/yr	ROAD SURFACE EROSION Tons	ROAD SURFACE EROSION t/mi/yr	OTHER EROSION Tons	OTHER EROSION Avg Road Age	OTHER EROSION t/mi/yr
Granitic Rocks	Native	2.66	1,404.7	11.2	3,772.1	40.1	1,472.7	46	12.0
	Paved	5.00	17,793.0	71.0	592.6	5.5	809.4	50	3.2
	Rocked	1.10	2,375.7	36.1	2,700.9	16.9	469.9	60	7.1
North Fork Terrane	Native	0.60	39.4	2.2	293.6	8.2	-	40	0.0
	Paved	5.00	2,704.0	9.0	265.1	0.9	7,223.2	60	24.1
	Rocked	5.32	5,174.5	20.0	4,093.3	13.4	2,346.1	40	11.0
Hayfork Terrane	Native	0.30	-	-	9.5	0.8	-	40	0.0
	Paved	7.79	11,712.8	25.1	291.5	0.6	482.3	60	1.0
	Rocked	12.73	966.8	26.5	3,697.7	7.1	636.0	45	1.1
Bragdon Formation	Native	1.43	2.3	0.1	467.5	8.2	19.8	30	0.5
	Paved	0.12	2.6	0.0	6.5	0.9	72.0	60	10.3
	Rocked	1.96	13.1	0.3	517.0	5.2	111.1	36	1.6
Central Metamorphic Subprovince	Native	5.35	1,627.5	6.8	13,820.1	53.3	650.1	49	2.5
	Paved	13.46	18,572.8	23.0	3,041.1	4.0	311.2	60	0.4
	Rocked	8.77	8,093.0	22.9	22,572.6	50.9	4,592.8	52	10.1
Weaverville Formation	Native	0.76	8.5	0.4	175.8	0.6	11.3	30	0.5
	Paved	7.11	8,348.3	19.6	380.3	1.1	407.0	60	1.0
	Rocked	0.95	91.1	3.0	373.7	9.8	10.8	30	0.4
Ultramafic Rocks & Gabbro Rocks	Native	4.51	912.8	6.6	186.4	1.0	625.3	32	4.3
	Paved	5.05	4,626.3	21.2	157.0	0.6	982.8	41	4.7
	Rocked	11.78	18,882.8	32.9	5,283.9	7.7	1,890.7	49	3.3
Total Road Miles Inventoried:		**101.75**							

Mean Values:		Cutbank t/mi/yr	Road Surface t/mi/yr	Other t/mi/yr
	Native	8.22	31.48	6.27
	Paved	28.14	2.12	5.74
	Rocked	25.56	19.77	6.37

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ROAD LENGTH AND ROAD DENSITY BY PLANNING WATERSHED AND SUB-WATERSHED

UPPER TRINITY PW Sub-Watershed	Drainage Area (mi^2)	Total Road Length (miles)	Road Density (mi/mi^2)
Bear Creek	4.5	0.2	0.04
Buckeye Creek	5.1	26.9	5.24
Cedar Creek	7.0	28.7	4.09
Coffee Creek	116.4	73.2	0.63
Eagle Creek	15.1	15.4	1.02
East Fork Stuart Fork	22.6	65.2	2.88
East Fork Trinity River	92.8	354.1	3.82
East Side Trinity Lake	64.8	258.6	3.99
Graves Creek	5.3	21.9	4.13
Hatchet Creek	1.9	10.8	5.64
Minnehaha Creek	3.8	5.1	1.35
Mule Creek	6.3	22.7	3.60
Ramshorn Creek	12.8	30.3	2.37
Ripple Creek	2.5	10.1	4.09
Scorpion Creek	6.8	12.6	1.85
Snowslide Gulch Area	12.1	44.3	3.67
Squirrel Gulch Area	15.2	53.5	3.53
Stoney Creek	5.4	19.2	3.54
Stuart Arm Area	34.5	203.1	5.89
Stuart Fork	62.5	21.3	0.34
Sunflower Creek	2.6	8.8	3.39
Swift Creek	56.0	100.4	1.79
Tangle Blue Creek	22.0	44.4	2.02
Trinity Lake	24.4	0.5	0.02
Upper Trinity Mainstem Area	9.9	33.9	3.44
Upper Trinity River	63.3	196.7	3.11
West Side Trinity Lake	16.9	69.3	4.11
TOTAL	**692.4**	**1731.1**	**2.50**

LOWER MIDDLE TRINITY PW Sub-Watershed	Drainage Area (mi^2)	Total Road Length (miles)	Road Density (mi/mi^2)
Big Bar Creek Area	45.1	92.7	2.06
Big French Creek	38.4	21.3	0.56
Canadian Creek Area	33.5	36.6	1.09
Canyon Creek	64.0	53.0	0.83
Cedar Flat Creek	4.0	12.2	3.07
Conner Creek Area	47.6	120.1	2.52
Dutch Creek	9.5	24.1	2.52
East Fork North Fork Trinity	46.1	36.7	0.80
Hawkins Creek	2.6	7.1	2.70
Hennessy Creek	2.6	6.0	2.29
Italian Creek	3.0	5.1	1.67
Little French Creek	6.4	1.6	0.24
Manzanita Creek	11.7	0.4	0.04
McDonald Creek	2.9	8.8	3.04
Mill Creek	6.1	18.3	3.01
New River	233.4	134.8	0.58
North Fork Trinity	105.0	5.4	0.05
Oregon Gulch	7.4	25.2	3.39
Prairie Creek	3.2	2.4	0.76
Quinby Creek Area	31.5	91.9	2.92
Sharber Creek	5.6	10.7	1.90
Soldier Creek	7.0	35.3	5.05
Swede Creek	3.1	5.2	1.71
TOTAL	**719.7**	**754.9**	**1.05**

UPPER MIDDLE TRINITY PW Sub-Watershed	Drainage Area (mi^2)	Total Road Length (miles)	Road Density (mi/mi^2)
Browns Creek	73.5	245.4	3.34
Deadwood Creek	9.1	44.9	4.93
Grass Valley Creek	26.0	147.3	5.67
Hoadley Gulch	3.5	17.2	4.92
Indian Creek	33.7	130.8	3.89
Lewiston Lake Area	25.1	104.7	4.17
Lewiston Lake	1.1	--	--
Little Grass Valley Creek	10.8	52.3	4.83
Poker Bar Area	35.3	175.2	4.96
Reading Creek	31.2	91.5	2.94
Rush Creek	22.5	116.8	5.20
Weaver Creek	49.7	214.3	4.32
TOTAL	**321.4**	**1340.5**	**4.17**

LOWER TRINITY PW Sub-Watershed	Drainage Area (mi^2)	Total Road Length (miles)	Road Density (mi/mi^2)
Campbell Creek	6.1	11.5	1.89
Coon Creek	5.3	10.6	2.01
Hoopa Reservation	114.0	336.8	2.95
Horse Linto Creek	64.3	116.1	1.81
Lower Trinity Mainstem Area	26.9	77.4	2.87
Mill Creek	21.9	50.1	2.29
Supply Creek	4.8	13.6	2.85
Tish Tang Creek	16.7	8.5	0.51
Willow Creek	43.1	112.4	2.61
Yurok Reservation	0.2	0.4	2.95
TOTAL	**303.2**	**737.4**	**2.43**

PROJECT:

TRINITY RIVER SEDIMENT SOURCE ANALYSIS

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TABLE

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UPPER MIDDLE TRINITY PLANNING WATERSHED

ROAD CONSTRUCTION HISTORY BY SLOPE POSITION BY SUB-WATERSHED

	MILES OF ROAD IN GIVEN POSITION CATEGORY BY YEAR												Sub-Watershed			
Sub-Watershed	**Mid-Slope**				**Ridge**				**Riparian**				**ALL ROADS**			
	1944	1980	1989	2000	1944	1980	1989	2000	1944	1980	1989	2000	1944	1980	1989	2000
Browns Creek	30.5	64.2	13.9	63.9	4.4	15.7	4.3	13.8	15.4	12.3	0.3	6.7	50.4	92.1	18.5	84.5
Deadwood Creek	4.8	6.5	2.9	11.4	1.8	1.2	0.3	5.4	4.6	2.1	0.8	3.2	11.2	9.8	3.9	20.0
Grass Valley Creek	13.6	17.8	22.2	25.4	2.5	5.5	4.5	6.6	7.3	9.3	24.3	8.3	23.5	32.6	51.0	40.2
Hoadley Gulch	2.1	2.8	1.6	2.2	0.4	0.8	0.1	0.6	1.8	1.5	2.5	0.7	4.3	5.2	4.2	3.5
Indian Creek	10.7	24.6	6.8	41.8	1.5	4.7	1.5	12.2	2.7	7.8	7.8	8.7	14.9	37.1	16.1	62.7
Lewiston Lake Area	13.6	31.5	10.4	7.2	3.1	9.8	2.6	2.4	5.3	13.5	3.7	1.6	22.0	54.8	16.8	11.2
Little Grass Valley Creek	4.1	1.8	10.4	5.4	1.4	0.1	1.8	1.7	4.4	3.9	14.7	2.7	9.9	5.7	26.9	9.7
Poker Bar Area	25.5	41.7	10.3	29.4	4.1	11.0	2.1	8.3	13.7	14.1	5.9	9.1	43.3	66.7	18.3	46.8
Reading Creek	14.1	37.6	0.0	17.3	1.7	7.6	0.0	3.2	3.4	4.6	0.0	2.0	19.2	49.8	0.0	22.5
Rush Creek	15.6	22.3	13.0	14.9	3.3	5.7	3.6	2.4	11.2	13.1	5.2	6.5	30.2	41.1	21.8	23.7
Weaver Creek	41.6	41.2	8.8	24.7	9.9	16.4	3.1	7.6	29.0	22.2	2.0	7.9	80.6	79.8	13.8	40.2
TOTAL	176.3	292.1	100.3	243.6	34.3	78.4	24.0	64.0	98.8	104.4	67.2	57.4	309.4	474.8	191.4	365.0
% by Period of Position Type	21.7%	36.0%	12.3%	30.0%	17.1%	39.1%	11.9%	31.9%	30.1%	31.8%	20.5%	17.5%	23.1%	35.4%	14.3%	27.2%

Notes: Base data from GIS coverages combining road information from state, federal, and local agencies, augmented by mapping from 2000 aerial photographs
See text for definition of road slope position, as well as methods to develop these data

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UPPER MIDDLE TRINITY PLANNING WATERSHED

ROAD CONSTRUCTION HISTORY BY SLOPE POSITION BY SUB-WATERSHED

Sub-Watershed	CUMULATIVE MILES OF ROAD IN GIVEN POSITION CATEGORY BY YEAR												Sub-Watershed			
	Mid-Slope				**Ridge**				**Riparian**				**ALL ROADS**			
	1944	1980	1989	2000	1944	1980	1989	2000	1944	1980	1989	2000	1944	1980	1989	2000
Browns Creek	30.5	94.7	108.6	172.5	4.4	20.1	24.4	38.2	15.4	27.6	27.9	34.6	50.4	142.5	160.9	245.4
Deadwood Creek	4.8	11.3	14.3	25.6	1.8	2.9	3.2	8.6	4.6	6.7	7.5	10.7	11.2	21.0	24.9	44.9
Grass Valley Creek	13.6	31.4	53.6	79.0	2.5	8.1	12.6	19.1	7.3	16.6	40.9	49.2	23.5	56.1	107.1	147.3
Hoadley Gulch	2.1	4.9	6.5	8.7	0.4	1.3	1.4	2.0	1.8	3.3	5.8	6.5	4.3	9.5	13.7	17.2
Indian Creek	10.7	35.3	42.1	83.9	1.5	6.2	7.7	19.9	2.7	10.5	18.4	27.0	14.9	52.0	68.1	130.8
Lewiston Lake Area	13.6	45.1	55.5	62.7	3.1	12.9	15.5	17.9	5.3	18.8	22.5	24.2	22.0	76.8	93.6	104.7
Little Grass Valley Creek	4.1	5.8	16.2	21.6	1.4	1.5	3.3	5.0	4.4	8.3	23.0	25.7	9.9	15.7	42.6	52.3
Poker Bar Area	25.5	67.2	77.5	107.0	4.1	15.1	17.2	25.5	13.7	27.7	33.7	42.8	43.3	110.1	128.4	175.2
Reading Creek	14.1	51.8	51.8	69.1	1.7	9.2	9.2	12.4	3.4	8.0	8.0	10.0	19.2	69.0	69.0	91.5
Rush Creek	15.6	37.9	50.9	65.8	3.3	9.1	12.7	15.1	11.2	24.3	29.5	36.0	30.2	71.3	93.1	116.8
Weaver Creek	41.6	82.8	91.6	116.3	9.9	26.3	29.4	37.0	29.0	51.2	53.2	61.1	80.6	160.3	174.2	214.4
TOTAL	176.3	468.4	568.6	812.2	34.3	112.7	136.7	200.7	98.8	203.2	270.3	327.7	309.4	784.3	975.6	1340.6
% by Period of Position Type	21.7%	57.7%	70.0%	100.0%	17.1%	56.2%	68.1%	100.0%	30.1%	62.0%	82.5%	100.0%	23.1%	58.5%	72.8%	100.0%

Notes: Base data from GIS coverages combining road information from state, federal, and local agencies, augmented by mapping from 2000 aerial photographs
See text for definition of road slope position, as well as methods to develop these data

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UPPER MIDDLE TRINITY PLANNING WATERSHED

DISTRIBUTION OF ROAD MILES BY SLOPE POSITION BY SURFACE TYPE BY SUB-WATERSHED

Sub-Watershed	Drainage Area	MILES OF ROAD IN GIVEN POSITION CATEGORY BY SURFACE TYPE												Sub-Watershed	
		Mid-Slope				**Ridge**				**Riparian**				Total	Road Density
	(mi^2)	Native	Rocked	Paved	Total	Native	Rocked	Paved	Total	Native	Rocked	Paved	Total	(mi)	(mi/mi^2)
Browns Creek	73.48	155.2	8.2	9.1	172.5	36.0	1.1	1.1	38.2	25.6	3.3	5.7	34.6	245.4	3.34
Deadwood Creek	9.11	25.6	0.0	0.0	25.6	8.6	0.0	0.0	8.6	10.7	0.0	0.0	10.7	44.9	4.93
Grass Valley Creek	25.99	70.9	3.1	5.0	79.0	17.4	1.5	0.3	19.1	46.4	0.3	2.5	49.2	147.3	5.67
Hoadley Gulch	3.49	5.6	2.8	0.3	8.7	1.3	0.7	0.0	2.0	4.3	1.4	0.7	6.5	17.2	4.92
Indian Creek	33.68	78.9	5.0	0.0	83.9	19.5	0.4	0.0	19.9	25.9	1.1	0.1	27.0	130.8	3.89
Lewiston Lake Area	25.06	44.8	7.0	11.0	62.7	13.9	2.8	1.1	17.9	19.4	2.1	2.6	24.2	104.7	4.18
Little Grass Valley Ck	10.82	18.6	1.8	1.3	21.6	4.5	0.3	0.2	5.0	21.4	0.1	4.2	25.7	52.3	4.83
Poker Bar Area	35.31	81.3	0.1	25.5	107.0	22.3	0.0	3.2	25.5	31.9	0.0	10.8	42.8	175.2	4.96
Reading Creek	31.17	63.5	3.8	1.8	69.1	12.1	0.2	0.1	12.4	7.2	2.2	0.6	10.0	91.5	2.94
Rush Creek	22.46	55.3	3.8	6.6	65.8	11.3	2.7	1.0	15.1	29.0	2.3	4.7	36.0	116.8	5.20
Weaver Creek	49.66	91.3	2.8	22.2	116.3	31.6	1.5	3.8	36.9	39.8	1.6	19.8	61.1	214.3	4.32
TOTAL	320.23	691.0	38.4	82.8	812.2	178.6	11.2	10.8	200.6	261.6	14.3	51.8	327.7	1340.5	4.19
% of Position Type		85.1%	4.7%	10.2%		89.0%	5.6%	5.4%		79.8%	4.4%	15.8%			
% of Watershed Total		51.6%	2.9%	6.2%	60.6%	13.3%	0.8%	0.8%	15.0%	19.5%	1.1%	3.9%	24.4%		

Notes: Base data from GIS coverages combining road information from state, federal, and local agencies, augmented by mapping from 2000 aerial photographs
See text for definition of road slope position and surface types, as well as methods to develop these data

TRINITY RIVER SEDIMENT SOURCE ANALYSIS
Road Distribution by Slope Position and Surface Type

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TABLE 40

COMPUTED EROSION FROM ROADS BY TYPE BY PLANNING WATERSHED, EXISTING CONDITIONS

Planning Watershed	Drainage Area (mi^2)	Total Road Length (miles)	COMPUTED ACTIVE ROAD EROSION BY TYPE: CUTBANK EROSION (tons)	ROAD SURFACE EROSION (tons)	OTHER ROAD EROSION (tons)	TOTAL (tons)	AVERAGE AREA RATE ($tons/mi^2/yr$)	AVERAGE ROAD MILE RATE (tons/mi/yr)
Upper Trinity	692.4	1731.1	103,367	119,121	94,287	316,775	45.7	17.6
Upper Middle Trinity	321.4	1340.5	140,173	201,734	76,799	418,706	130.3	31.2
Lower Middle Trinity	719.7	754.9	57,026	63,575	41,315	161,916	22.5	19.3
Lower Trinity	303.2	737.4	66,646	45,018	37,928	149,592	49.3	20.3
TOTAL	2036.7	4564.0	367,211	429,449	250,329	1,046,988	51.4	22.9
PERCENT OF TOTAL			35.1%	41.0%	23.9%			

Notes: -- Existing conditions includes a 10-year period
-- Rates used in calculations based on 2001 field inventory data, stratified by Geology, Slope Position, and Surface Type

TRINITY RIVER SEDIMENT SOURCE ANALYSIS
Summary of Computed Road Erosion by Planning Watershed

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TABLE 41

HARVEST AREAS BY PERIOD BY PLANNING WATERSHED, 1940-2000

Planning Watershed	Drainage Area (acres)	HARVEST AREAS BY DECADE 1940 (acres)	1950 (acres)	1960 (acres)	1970 (acres)	1980 (acres)	1990 (acres)	TOTAL (acres)	% AREA HARVESTED
UPPER TRINITY	443,138	**9,331**	**24,019**	**34,626**	**56,918**	**13,885**	**17,816**	**156,595**	**35.3%**
		6.0%	**15.3%**	**22.1%**	**36.3%**	**8.9%**	**11.4%**		
UPPER MIDDLE TRINITY	205,638	**351**	**39,302**	**15,094**	**18,673**	**25,692**	**34,465**	**133,577**	**65.0%**
		0.3%	**29.4%**	**11.3%**	**14.0%**	**19.2%**	**25.8%**		
LOWER MIDDLE TRINITY	460,606	**103**	**6,069**	**13,905**	**29,643**	**4,086**	**5,157**	**58,963**	**12.8%**
		0.2%	**10.3%**	**23.6%**	**50.3%**	**6.9%**	**8.7%**		
LOWER TRINITY	194,080	**1,035**	**16,269**	**23,407**	**11,434**	**-**	**1,875**	**54,020**	**27.8%**
		1.9%	**30.1%**	**43.3%**	**21.2%**	**0.0%**	**3.5%**		
TOTAL	1,303,462	**10,821**	**85,658**	**87,031**	**116,668**	**43,664**	**59,313**	**403,155**	**30.9%**
% OF TOTAL IN PERIOD		**2.7%**	**21.2%**	**21.6%**	**28.9%**	**10.8%**	**14.7%**		

Notes: Data sources: Most pre-1980 data from harvest maps prepared by DWR (1980) which were digitized for this study
1980 and 1990 Data combined from THP maps obtained from CDF and digitized, and USFS Compartment Records
1940 refers to DWR pre-1950 category
No data from USFS (Six Rivers NF) or Hoopa Reservation Harvests since 1977 are included in Lower Trinity PW

TRINITY RIVER SEDIMENT SOURCE ANALYSIS
Summary of Harvest Areas by Planning Watershed

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TABLE 42

COMPUTED SURFACE EROSION FROM HARVEST AREAS BY PLANNING WATERSHED, 1940-2000

Planning Watershed	Drainage Area (acres)	COMPUTED SURFACE EROSION FROM HARVEST AREAS 1940 (tons)	1950 (tons)	1960 (tons)	1970 (tons)	1980 (tons)	1990 (tons)	TOTAL (tons)	% TOTAL AREA
UPPER TRINITY	443,138	111,973	288,233	415,508	455,341	55,540	71,264	1,397,861	21.5%
		8.0%	20.6%	29.7%	32.6%	4.0%	5.1%		
UPPER MIDDLE TRINITY	205,638	13,132	2,179,798	489,068	438,133	482,012	392,018	3,994,162	61.5%
		0.3%	54.6%	12.2%	11.0%	12.1%	9.8%		
LOWER MIDDLE TRINITY	460,606	1,239	72,822	166,857	237,146	16,344	20,627	515,035	7.9%
		0.2%	14.1%	32.4%	46.0%	3.2%	4.0%		
LOWER TRINITY	194,080	12,422	195,226	280,887	91,470	-	7,500	587,505	9.0%
		2.1%	33.2%	47.8%	15.6%	0.0%	1.3%		
TOTAL	1,303,462	138,767	2,736,080	1,352,320	1,222,090	553,897	491,410	6,494,563	100.0%
% OF TOTAL IN PERIOD		2.1%	42.1%	20.8%	18.8%	8.5%	7.6%		

Notes: Data sources:
- -- Base data (harvest acres) from combination of DWR (1980), USFS records, and THP maps from CDF
- -- Erosion rates were assigned as follows: pre-1970 12 tons/acre, 1970 period one half of acreage at 12 tons/acre and one half at 4 tons/acre, 1980 and later 4 tons/acre
- -- For areas in each watershed underlain by erodible Shasta Bally Batholith, rates were increased by a factor of 10
- -- 1940 refers to DWR pre-1950 category
- -- No data from USFS (Six Rivers NF) or Hoopa Reservation Harvests since 1977 are included in Lower Trinity PW

TRINITY RIVER SEDIMENT SOURCE ANALYSIS
Summary of Surface Erosion from Harvest Areas by Planning Watershed

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TABLE 43

Mean cumulative particle size distribution, gravel quality indexes, and mean permeability per site for eight mainstem Trinity River sites.

SITE	LEWISTON	RUSH	POKER	STEELBRIDGE	INDIAN	STEINER	EVANS	JUNCTION
RIVER MILE	111.5	107.4	102.7	98.95	95.3	91.95	84.1	80.3
TOTAL DRY WEIGHT (KG) COMBINED SUBSURFACE	534.34	633.52	437.16	707.63	589.40	589.90	389.21	581.54
SIEVE SIZE	CUM. % FINER THAN (COMBINED SUBSURFACE)							
360	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
256	95.75%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
180	91.53%	97.09%	100.00%	95.44%	98.73%	97.35%	100.00%	92.06%
128	82.75%	91.41%	100.00%	92.39%	94.07%	89.33%	97.75%	82.89%
90.5	76.26%	81.10%	99.82%	81.08%	85.04%	81.74%	91.67%	74.45%
64	69.43%	74.27%	98.63%	75.26%	77.04%	76.19%	87.24%	68.27%
45.3	56.62%	67.97%	94.98%	67.62%	66.21%	68.19%	81.45%	59.99%
32	40.66%	59.64%	88.72%	58.75%	55.68%	59.21%	70.72%	52.53%
22.6	26.68%	51.85%	82.62%	51.40%	47.59%	51.26%	61.10%	45.63%
16	14.88%	44.03%	77.09%	44.40%	40.54%	43.69%	55.57%	39.48%
11.2	9.23%	37.34%	72.53%	38.21%	35.16%	37.60%	47.32%	34.47%
8	6.46%	31.16%	68.50%	33.01%	30.00%	31.99%	40.07%	29.87%
5.6	5.12%	25.91%	64.43%	28.91%	25.31%	26.93%	33.78%	25.96%
4	4.21%	21.91%	58.05%	25.19%	21.60%	23.02%	29.07%	22.99%
2.83	3.28%	17.48%	44.89%	20.31%	17.87%	19.12%	24.38%	19.78%
2	2.52%	13.10%	30.01%	15.74%	14.67%	15.68%	20.11%	16.56%
1.4	1.83%	8.45%	18.06%	11.49%	11.99%	12.27%	15.38%	12.72%
1	1.36%	5.25%	12.34%	8.59%	9.29%	9.49%	11.17%	9.04%
0.85	1.19%	4.14%	10.47%	7.25%	8.05%	8.29%	9.33%	7.36%
0.5	0.74%	1.84%	5.49%	3.23%	4.33%	4.32%	3.90%	2.85%
0.25	0.30%	0.45%	1.22%	0.68%	1.16%	1.06%	0.73%	0.49%
0.125	0.08%	0.10%	0.24%	0.17%	0.28%	0.25%	0.18%	0.11%
0.063	0.03%	0.03%	0.07%	0.06%	0.12%	0.08%	0.12%	0.04%
Pan	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
PARTICLE SIZE DISTRIBUTION VALUES FROM SEDSIZE								
D84	133.88	98.51	24.45	97.56	86.57	99.68	52.59	132.94
D75	84.59	66.24	13.59	63.18	59.63	60.57	36.38	92.38
D50	39.21	20.85	3.24	21.12	25.09	21.37	12.66	28.18
D25	21.68	5.24	1.75	3.95	5.5	4.79	2.97	5.07
D16	16.56	2.51	1.25	2.02	2.29	2.04	1.47	1.89
dg	39.49	17.01	4.33	15.61	16.33	15.67	10.23	19.37
FREDLE	19.99	4.78	1.55	3.90	4.96	4.41	2.92	4.54
% FINES<2mm	2.52%	13.10%	30.01%	15.74%	14.67%	15.68%	20.11%	16.56%
% FINES <1mm	1.36%	5.25%	12.34%	8.59%	9.29%	9.49%	11.17%	9.04%
% FINES <0.85mm	1.19%	4.14%	10.47%	7.25%	8.05%	8.29%	9.33%	7.36%
MEAN PERMEABILITY/SITE								
	7,568 cm/hr	2,587 cm/hr	1,500 cm/hr	1,431 cm/hr	827 cm/hr	605 cm/hr	244 cm/hr	1,039 cm/hr
ESTIMATED CHINOOK SURVIVAL/SITE FROM PERMEABILITY								
	49%	33%	26%	25%	17%	13%	0%	20%

Source: GMA (2001a)

PROJECT:

TRINITY RIVER SEDIMENT SOURCE ANALYSIS

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TABLE

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TRINITY RIVER SUBSTRATE TREND ANALYSIS

2001 SAMPLES (from GMA, 2001a)

SITE	LEWISTON	RUSH	POKER	STEELBRIDG	INDIAN	STEINER	EVANS	JUNCTION
RIVER MILE	111.5	107.4	102.7	98.95	95.3	91.95	84.1	80.3
TOTAL DRY WEIGHT (KG) COMBINED SUBSURFACE	534.34	633.52	437.16	707.63	589.40	589.90	389.21	581.54
D84	133.88	98.51	24.45	97.56	86.57	99.68	52.59	132.94
D75	84.59	66.24	13.59	63.18	59.63	60.57	36.38	92.38
D50	39.21	20.85	3.24	21.12	25.09	21.37	12.66	28.18
D25	21.68	5.24	1.75	3.95	5.5	4.79	2.97	5.07
D16	16.56	2.51	1.25	2.02	2.29	2.04	1.47	1.89
2001 dg	39.49	17.01	4.33	15.61	16.33	15.67	10.23	19.37
2001 FREDLE	19.99	4.78	1.55	3.90	4.96	4.41	2.92	4.54
2001 % FINES<2mm	2.52%	13.10%	30.01%	15.74%	14.67%	15.68%	20.11%	16.56%
% FINES <1mm	1.36%	5.25%	12.34%	8.59%	9.29%	9.49%	11.17%	9.04%
2001 % FINES <0.85mm	1.19%	4.14%	10.47%	7.25%	8.05%	8.29%	9.33%	7.36%
TAPPEL & BJORNN CHINOOK SURVIVAL	96%	85%	8%	77%	80%	76%	60%	81%
TAPPEL & BJORNN STEELHEAD SURVIVAL	94%	87%	44%	74%	72%	70%	61%	75%

1980 SAMPLES (from FKA, 1981)

SITE	LEWISTON	RUSH	GVC	U/S STEEL BRIDGE	D/S INDIAN	D/S DOUGLAS CITY	D/S EVANS BAR	U/S CANYON
D84	59.98	98.72	107.84	51.53	49.87	65.53	55.61	49.28
D75	50.23	79.69	93.16	38.12	37.42	54.11	38.85	35.02
D50	36.16	37.73	60.96	13.74	20.97	22.24	13.30	16.68
D25	24.27	12.04	15.06	2.28	17.11	4.71	2.64	2.74
D16	16.30	7.34	5.42	0.95	3.52	1.64	1.26	1.16
1980 dg	31.25	26.64	23.75	7.00	13.06	10.36	8.23	7.57
1980 FREDLE	21.55	10.46	9.49	1.71	8.22	3.05	2.15	2.10
1980 % FINES<2mm	0.75%	6.34%	11.08%	23.36%	12.53%	18.25%	22.14%	23.52%
%FINES<1mm	0.53%	3.10%	6.82%	16.56%	7.53%	11.56%	13.18%	14.18%
1980 % FINES <0.85mm	0.48%	2.49%	5.85%	14.94%	6.65%	10.22%	11.29%	11.31%
TAPPEL & BJORNN CHINOOK SURVIVAL	95%	94%	95%	42%	85%	66%	52%	59%
TAPPEL & BJORNN STEELHEAD SURVIVAL	95%	92%	83%	33%	77%	60%	50%	53%

TRINITY RIVER SEDIMENT SOURCE ANALYSIS
Mainstem Substrate Trend Analysis, 1980 and 2001

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TABLE
45

TRIBUTARY SUBSTRATE TREND ANALYSIS

	SITE						
SUBSTRATE DESCRIPTOR	RUSH Cr	GRASS VALLEY Cr	INDIAN Cr	READING Cr	BROWNS Cr	CANYON Cr	NORTH FORK TRINITY
2001 D50	28.12	42.01	21.49	44.16	18.34	24.91	10.72
1980 D50	23.13	32.54	18.57	15.14	17.16	29.43	24.38

SITE	RUSH Cr	GRASS VALLEY Cr	INDIAN Cr	READING Cr	BROWNS Cr	CANYON Cr	NORTH FORK TRINITY
2001 dg	18.48	25.81	13.70	24.03	12.38	15.16	9.67
1980 dg	18.44	11.49	7.38	8.08	12.27	16.24	19.32

SITE	RUSH Cr	GRASS VALLEY Cr	INDIAN Cr	READING Cr	BROWNS Cr	CANYON Cr	NORTH FORK TRINITY
2001 FREDLE	5.80	6.66	3.37	7.67	3.59	4.25	3.11
1980 FREDLE	8.04	3.40	1.91	1.92	4.52	7.17	6.50

SITE	RUSH Cr	GRASS VALLEY Cr	INDIAN Cr	READING Cr	BROWNS Cr	CANYON Cr	NORTH FORK TRINITY
2001 % FINES <0.85mm	7.60%	5.08%	9.11%	3.72%	7.44%	6.64%	6.19%
1980 %FINES<0.85mm	6.14%	7.75%	9.30%	12.86%	6.36%	6.10%	5.81%

SITE	RUSH Cr	GRASS VALLEY Cr	INDIAN Cr	READING Cr	BROWNS Cr	CANYON Cr	NORTH FORK TRINITY
2001 T&B CHINOOK SURVIVAL	84%	90%	72%	91%	75%	81%	68%
1980 T&B CHINOOK SURVIVAL	85%	76%	44%	50%	77%	90%	83%

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TABLE
46

SEDIMENT INPUT SUMMARY BY PLANNING WATERSHED, EXISTING CONDITIONS, Table 1 of 2

		LANDSLIDES FROM AERIAL MAPPING			VARIOUS PROCESSES FROM SAMPLE PLOT DATA			SURFACE EROSION COMPUTED OR FROM FIELD INVENTORIES			
									ROAD		
Sub-Watershed	Drainage Area (mi^2)	Non-Mgm't Landslides (tons)	Harvest Related Landslides (tons)	Road Related Landslides (tons)	Brush/Forest Non-Mgmt (tons)	Legacy Roads (tons)	Harvest Related (tons)	Harvest Related (tons)	Cut-Bank Erosion (tons)	Tread Erosion (tons)	Other Erosion (tons)
UPPER TRINITY	691.6	33,222,501	11,584,768	3,750,735	3,803,731	595,246	343,411	126,805	516,834	595,605	471,434
UPPER MIDDLE TRINITY	321.2	2,261,151	934,539	1,191,582	942,443	200,628	115,747	940,186	380,752	527,661	210,206
LOWER MIDDLE TRINITY	719.6	13,457,229	-	3,152,543	1,647,935	169,294	97,669	36,971	114,052	127,149	82,630
LOWER TRINITY	303.2	5,258,708	1,831,206	18,070,073	667,006	157,656	90,955	7,500	133,291	90,037	75,856
TOTAL BY LAND USE		54,199,590	14,350,513	26,164,932	7,061,115	1,122,824	647,783	1,111,462	1,144,929	1,340,452	840,125
% OF TOTAL IN CATEGORY											

Notes: -- Non-management landslides are those mapped as occurring in brush and forest areas, apparently not related to disturbance. Since USFS harvest areas are not available in GIS format, landslides occurring in older harvest areas may be shown as non-management.

-- Harvest-related landslide category includes all those occurring in harvested areas as determined by digitizing of DWR (1980) harvest maps and digitizing of CDF THP data for 1979-2001.

-- Road-related landslides includes all slides judged to have been caused by road construction including changes to drainage patterns.

-- Landslide values for the Upper Trinity PW for the following sub-watersheds are from 1999 aerial interpretation (Bear, Eagle, Graves, Minnehaha, Ramshorn, Ripple, Sunflower, Tangle Blue, and Upper Trinity Mainstem Area), all others from DWR (1979) data.

-- Landslide values for Lower Middle Trinity and the Lower Trinity estimated from DWR 1979 data, except as noted below.

-- Landslide values for Campbell, Hoopa, Supply, and Willow Creek based on 1979 data. Landslides in Horse Linto, Mill, and Tish Tang from SRNF 1975 mapping period. Data not available for all sub-watershed areas, see detailed Planning Watershed budget.

TRINITY RIVER SEDIMENT SOURCE ANALYSIS
Sediment Input Summary by Planning Watershed

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SEDIMENT INPUT SUMMARY BY PLANNING WATERSHED, EXISTING CONDITIONS, Table 2 of 2

Sub-Watershed	Drainage Area (mi^2)	LEGACY MINING Ditches Slides (tons)	LEGACY MINING Ditches Gullies (tons)	CREEP (tons)	BANK EROSION (tons)	TOTAL INPUTS EXISTING MANAGEMENT RELATED (tons)	TOTAL INPUTS LEGACY MANAGEMENT RELATED (tons)	TOTAL INPUTS EXISTING NON-MANAGEMENT RELATED (tons)	TOTAL INPUTS TOTAL INPUTS (tons)
UPPER TRINITY	691.6	19,600	9,200	1,037,381	1,885,910	17,389,592	624,046	39,949,523	57,963,161
UPPER MIDDLE TRINITY	321.2	247,940	116,380	257,030	222,110	4,300,673	564,948	3,682,734	8,548,355
LOWER MIDDLE TRINITY	719.6	53,900	25,300	431,818	784,420	3,611,015	248,494	16,321,402	20,180,911
LOWER TRINITY	303.2	-	-	199,032	339,902	20,238,232	140,849	6,272,519	26,651,600
TOTAL BY LAND USE		321,440	150,880	1,925,261	3,232,341	45,539,511	1,578,337	66,226,178	113,344,026
% OF TOTAL IN CATEGORY						40.2%	1.4%	58.4%	

Notes:

-- Sample plot data indicate a non-management sediment delivery of 110tons/mi^2/yr from various sources including small slides, channel bank erosion, and rilling.

-- Legacy roads are computed at 26 tons/mi2/yr from sample plot data and includes abandoned roads causing sediment delivery via cut and fill slope failures, and gullies.

-- Harvest -related surface erosion is computed using 4 tons/acre, except for harvest on Shasta Bally Batholith areas, which was assigned a rate of 40 tons/acre.

-- Road surface erosion is based on101.75 miles of road inventories conducted in Trinity River watershed in 2001.

-- Legacy mining includes gullies and small slides from historic ditches used to transport water to hydraulic mining sites. 2 miles of ditches were field inventoried to develop rates of 49 ton/mi/yr for slides and 23 tons/mi/yr for gullies.

-- Creep was estimated at 30 tons/mi2/yr, based on a significant reduction from coastal rates due to much more stable geology and lower uplift rates. Coastal rate of 75 tons/mi2/y was based on work of Roberts and Church (1986) and Stillwater Sciences (1999).

-- Bank rosion computed using rates set for each stream order, based on field verification of rates in order 3, 4, 5 channels. 24 miles of channels were walked. Only sites larger than 10CY recorded, so this values does not include creep.

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COMPARISON OF TRIBUTARY SEDIMENT INPUTS AND OUTPUTS, UPPER MIDDLE TRINITY PW, 1980-2000

SEDIMENT SOURCE ANALYSIS RESULTS (INPUTS), 1980-2000

	Deadwood Ck	Rush Ck	Grass Valley Ck	Indian Ck	Weaver Ck	Reading Ck	Browns Ck
Total	117,621	1,096,040	1,231,256	1,558,226	2,364,716	536,718	784,685
Yr Mean	5,881	54,802	61,563	77,911	118,236	26,836	39,234
tons/mi2/yr	646	2,452	1,673	2,319	2,459	872	541

COMPUTED SEDIMENT TRANSPORT NEAR CONFLUENCE WITH MAINSTEM (OUTPUTS), 1981-2000

	Deadwood Ck	Rush Ck	Grass Valley Ck	Indian Ck	Weaver Ck	Reading Ck	Browns Ck
Total	96,553	181,770	958,801	1,414,889	333,495	502,879	741,749
Yr Mean	4,828	9,089	47,940	70,744	16,675	25,144	37,087
tons/mi2/yr	530	407	1,303	2,106	347	817	512

DIFFERENCE BETWEEN INPUTS AND OUTPUTS

	Deadwood Ck	Rush Ck	Grass Valley Ck	Indian Ck	Weaver Ck	Reading Ck	Browns Ck
Total	21,068	914,270	272,455	143,337	2,031,221	33,839	42,937
Yr Mean	1,053	45,713	13,623	7,167	101,561	1,692	2,147
tons/mi2/yr	116	2,045	370	213	2,112	55	30

Notes: Grass Valley Fawn Lodge data adjusted by 30% to account for unmeasured downstream contributing watershed area

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TABLE 49

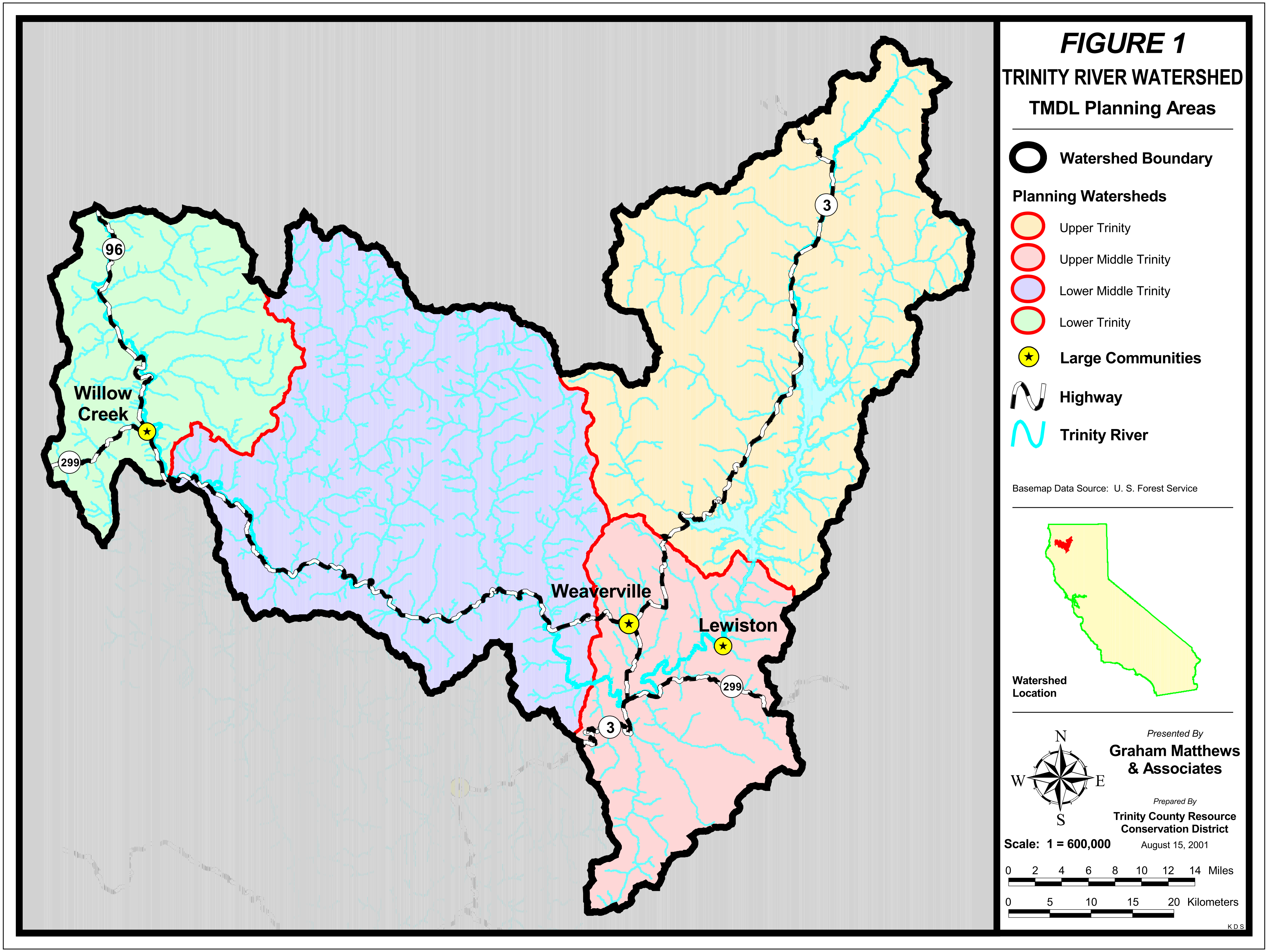


FIGURE 1
TRINITY RIVER WATERSHED
TMDL Planning Areas
Watershed Boundary
Planning Watersheds
Upper Trinity
Upper Middle Trinity
Lower Middle Trinity
Lower Trinity
Large Communities
Highway
Trinity River
Basemap Data Source: U. S. Forest Service
Watershed Location
Presented By
Graham Matthews & Associates
Prepared By
Trinity County Resource Conservation District
August 15, 2001
Scale: 1 = 600,000
0 2 4 6 8 10 12 14 Miles
0 5 10 15 20 Kilometers
N
S
E
W
Willow Creek
Weaverville
Lewiston
96
299
3

FIGURE 2a

TRINITY RIVER WATERSHED

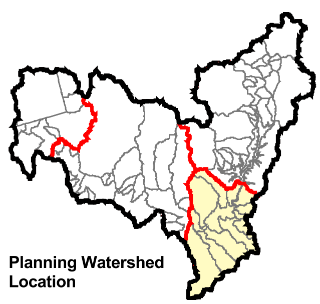
Sub-Watersheds of the Upper Middle Trinity River Planning Watershed

PWS Boundary

Sub-Watersheds

Streams

Basemap Data Source: U. S. Forest Service



Planning Watershed Location

N
W E
S

Scale: 1 = 250,000

0 1 2 3 4 5 6 Miles

0 1 2 3 4 5 6 7 8 Kilometers

Presented By

Graham Matthews & Associates

Prepared By

Trinity County Resource Conservation District

August 15, 2001

KDS

FIGURE 2b

TRINITY RIVER WATERSHED

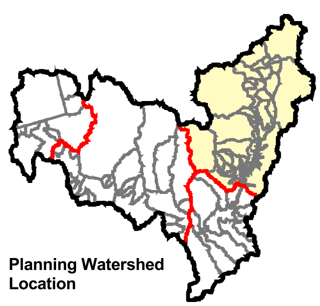
Sub-Watersheds of the Upper Trinity River Planning Watershed

PWS Boundary

Sub-Watersheds

Streams

Basemap Data Source: U. S. Forest Service



Planning Watershed Location

N
W E
S

Presented By

Graham Matthews & Associates

Prepared By

Trinity County Resource Conservation District

August 15, 2001

Scale: 1 = 350,000

0 1 2 3 4 5 6 7 8 Miles

0 1 2 3 4 5 6 7 8 9 10 Kilometers

K D S

FIGURE 2c

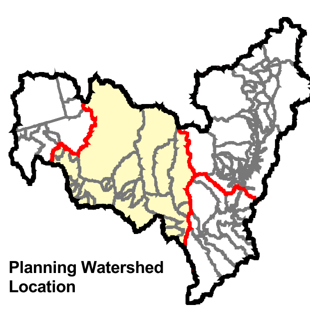
TRINITY RIVER WATERSHED

Sub-Watersheds of the Lower Middle Trinity River Planning Watershed

PWS Boundary

Sub-Watersheds

Streams



Planning Watershed Location

Basemap Data Source: U. S. Forest Service

N W E S

Presented By

Graham Matthews & Associates

Prepared By

Trinity County Resource Conservation District

August 15, 2001

Scale: 1 = 325,000

0 1 2 3 4 5 6 7 8 Miles

0 1 2 3 4 5 6 7 8 9 10 11 Kilometers

K D S

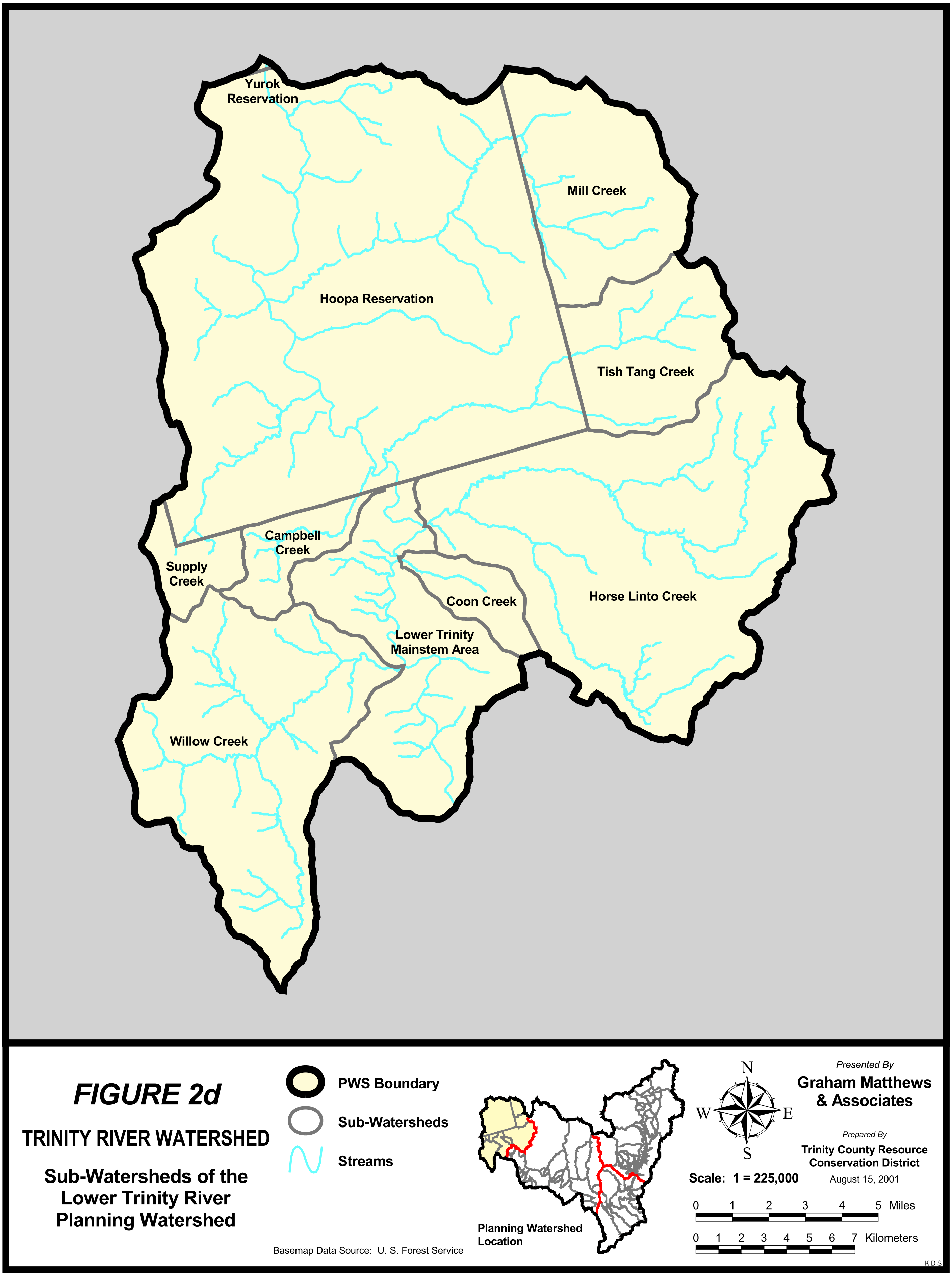


FIGURE 2d

TRINITY RIVER WATERSHED

Sub-Watersheds of the Lower Trinity River Planning Watershed

Presented By
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Prepared By
Trinity County Resource Conservation District

August 15, 2001

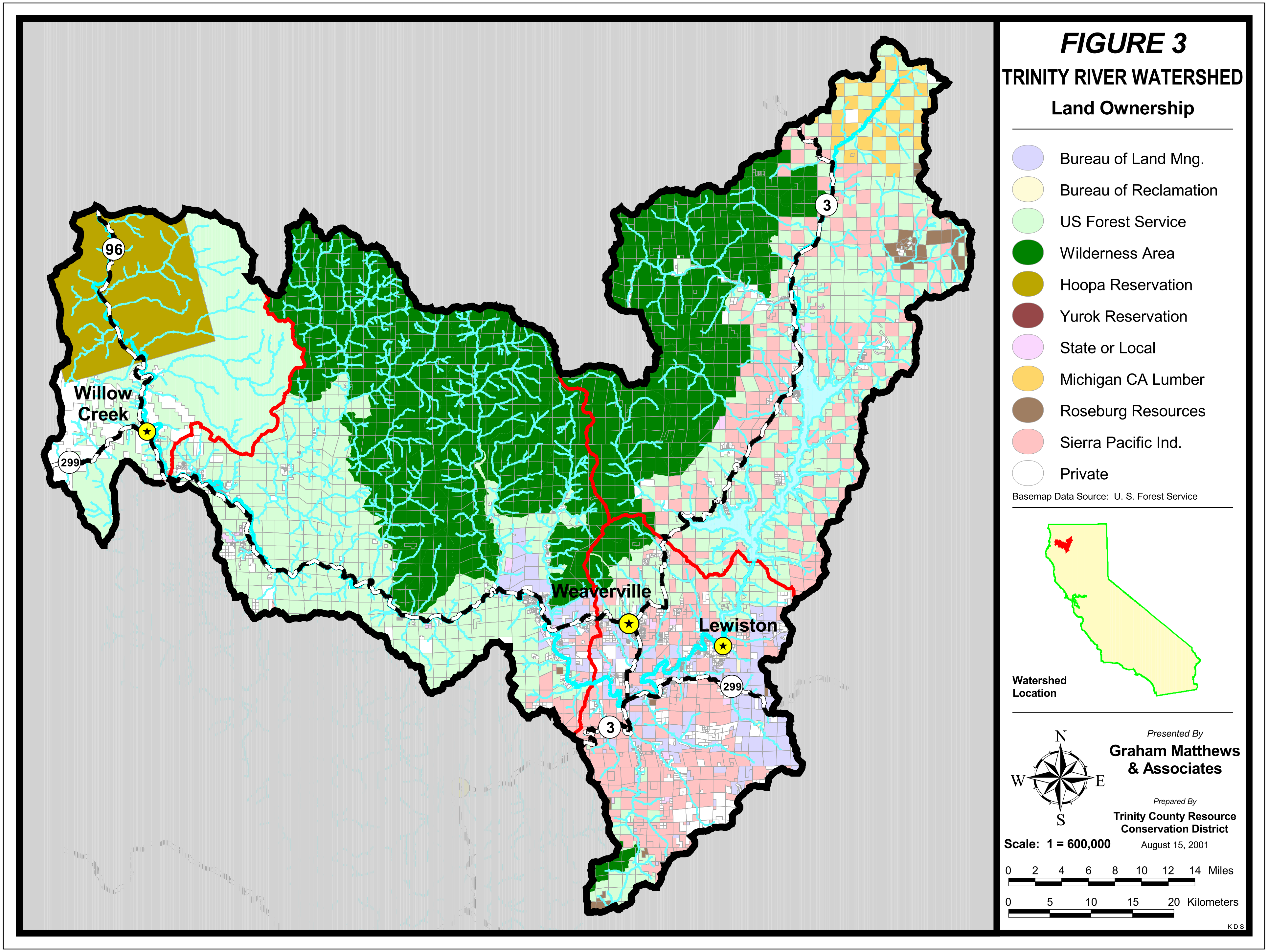


FIGURE 3
TRINITY RIVER WATERSHED
Land Ownership
Bureau of Land Mng.
Bureau of Reclamation
US Forest Service
Wilderness Area
Hoopa Reservation
Yurok Reservation
State or Local
Michigan CA Lumber
Roseburg Resources
Sierra Pacific Ind.
Private
Basemap Data Source: U. S. Forest Service
Watershed Location
Presented By
Graham Matthews & Associates
Prepared By
Trinity County Resource Conservation District
August 15, 2001
Scale: 1 = 600,000
0 2 4 6 8 10 12 14 Miles
0 5 10 15 20 Kilometers
N
S
E
W
Willow Creek
Weaverville
Lewiston
96
299
3
KDS

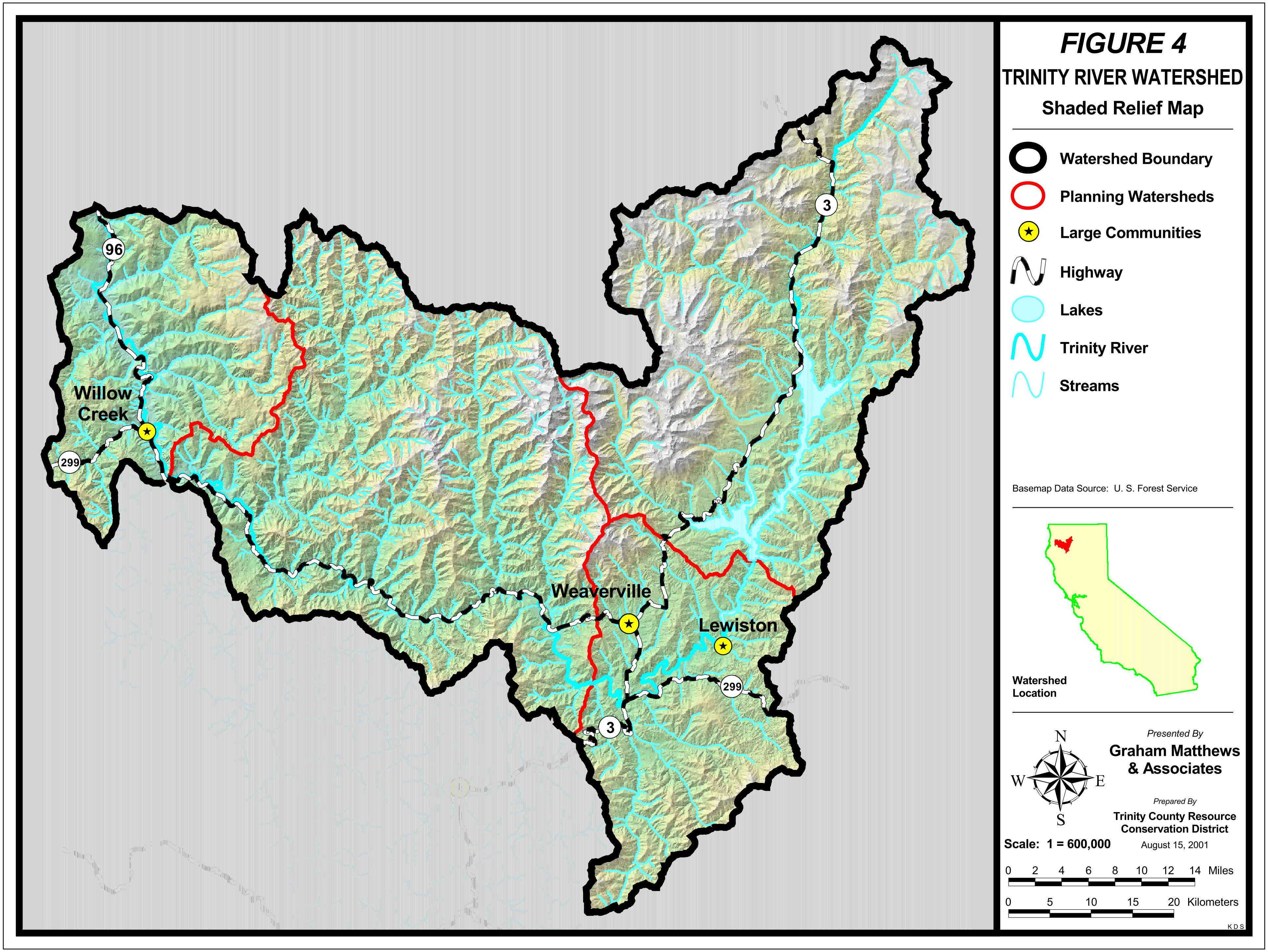


FIGURE 4
TRINITY RIVER WATERSHED
Shaded Relief Map
Watershed Boundary
Planning Watersheds
Large Communities
Highway
Lakes
Trinity River
Streams
Basemap Data Source: U. S. Forest Service
Watershed Location
Presented By
Graham Matthews & Associates
Prepared By
Trinity County Resource Conservation District
August 15, 2001
Scale: 1 = 600,000
0 2 4 6 8 10 12 14 Miles
0 5 10 15 20 Kilometers
N
S
E
W
Willow Creek
Weaverville
Lewiston
96
299
3
KDS

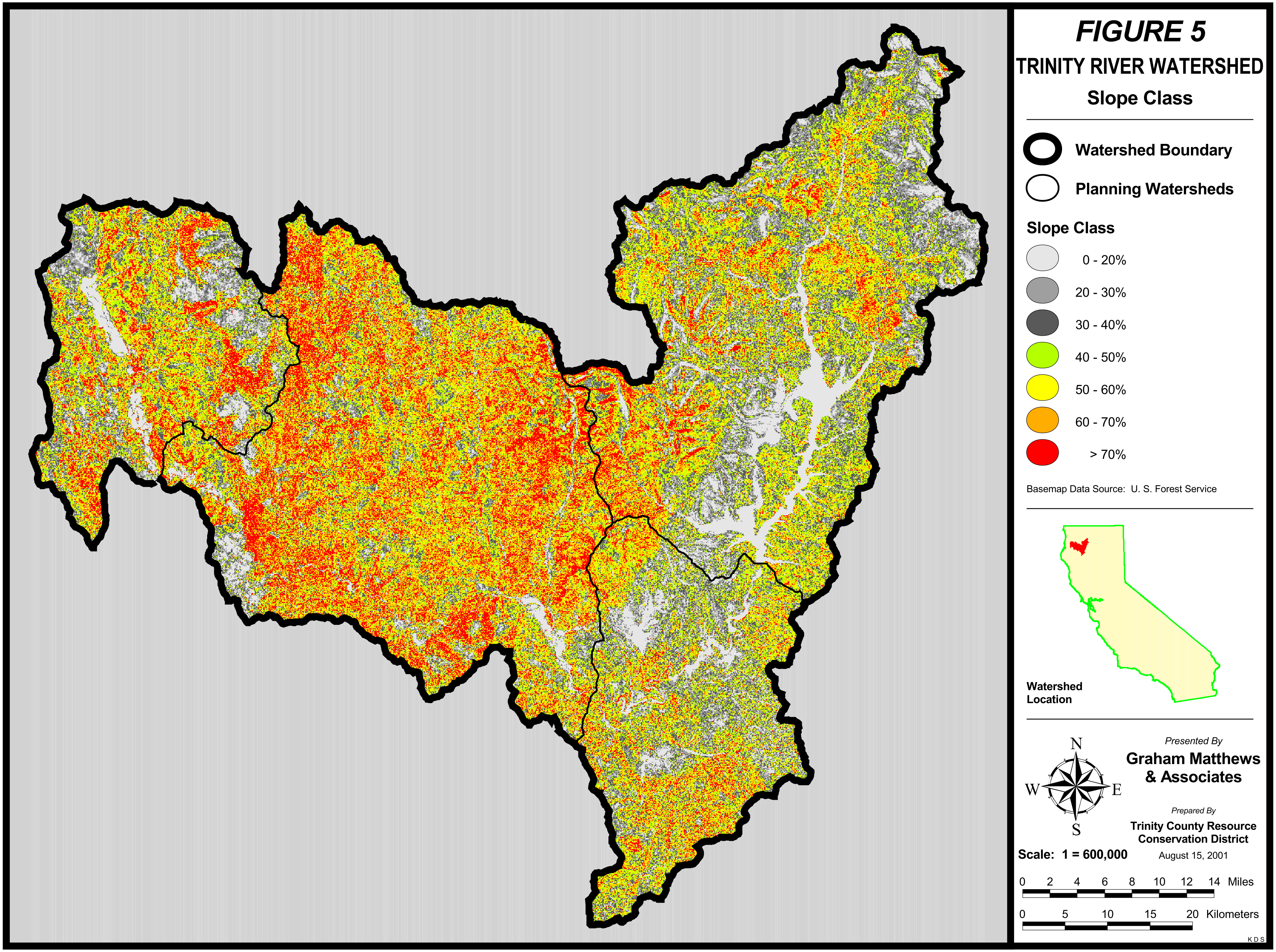


FIGURE 5
TRINITY RIVER WATERSHED
Slope Class
Watershed Boundary
Planning Watersheds
Slope Class
0 - 20%
20 - 30%
30 - 40%
40 - 50%
50 - 60%
60 - 70%
> 70%
Basemap Data Source: U. S. Forest Service
Watershed Location
Presented By
Graham Matthews & Associates
Prepared By
Trinity County Resource Conservation District
August 15, 2001
N
W
E
S
Scale: 1 = 600,000
0 2 4 6 8 10 12 14 Miles
0 5 10 15 20 Kilometers
K D S

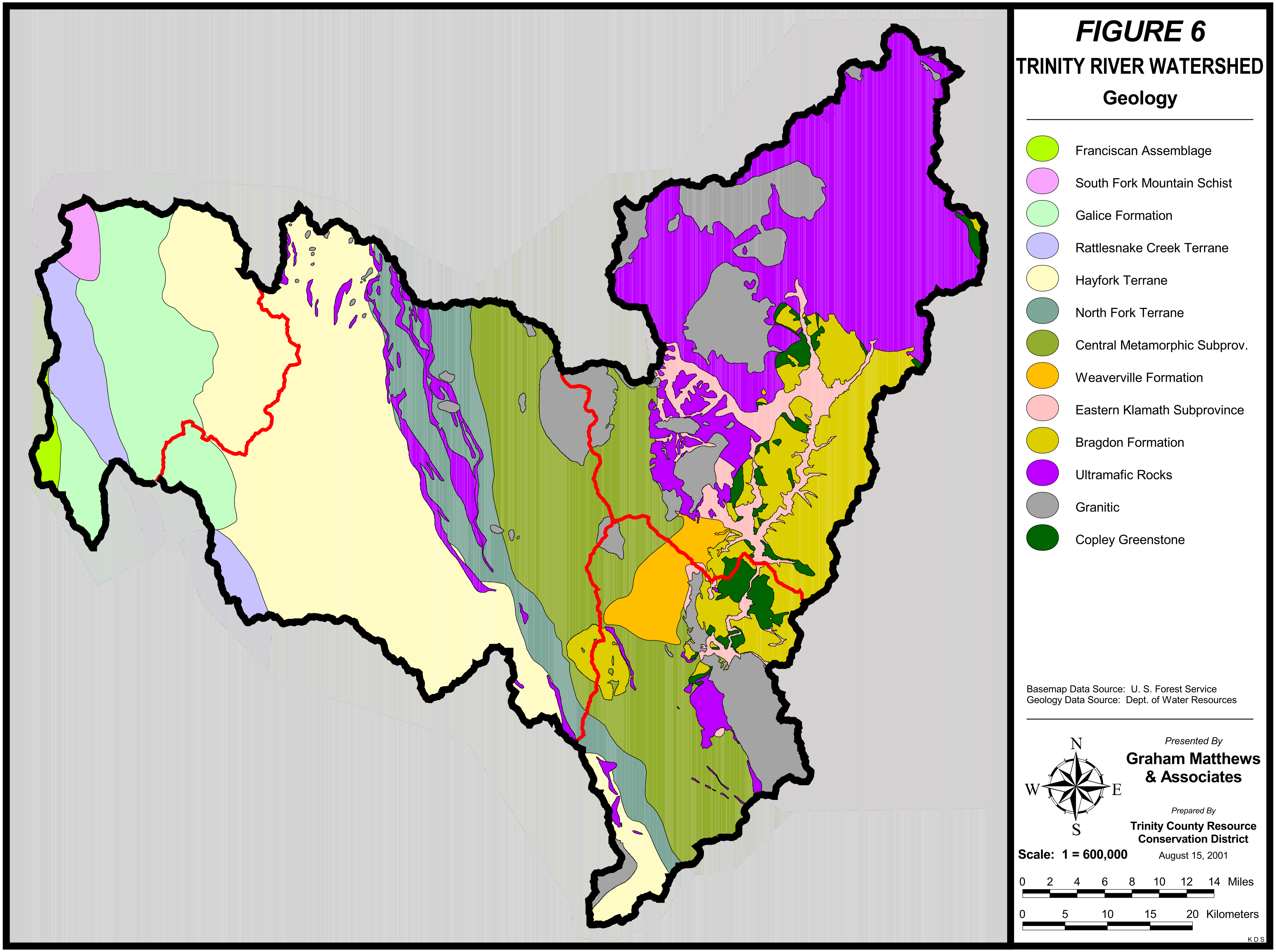


FIGURE 6
TRINITY RIVER WATERSHED
Geology
Franciscan Assemblage
South Fork Mountain Schist
Galice Formation
Rattlesnake Creek Terrane
Hayfork Terrane
North Fork Terrane
Central Metamorphic Subprov.
Weaverville Formation
Eastern Klamath Subprovince
Bragdon Formation
Ultramafic Rocks
Granitic
Copley Greenstone
Basemap Data Source: U. S. Forest Service
Geology Data Source: Dept. of Water Resources
N
W
E
S
Presented By
Graham Matthews & Associates
Prepared By
Trinity County Resource Conservation District
August 15, 2001
Scale: 1 = 600,000
0 2 4 6 8 10 12 14 Miles
0 5 10 15 20 Kilometers
K D S

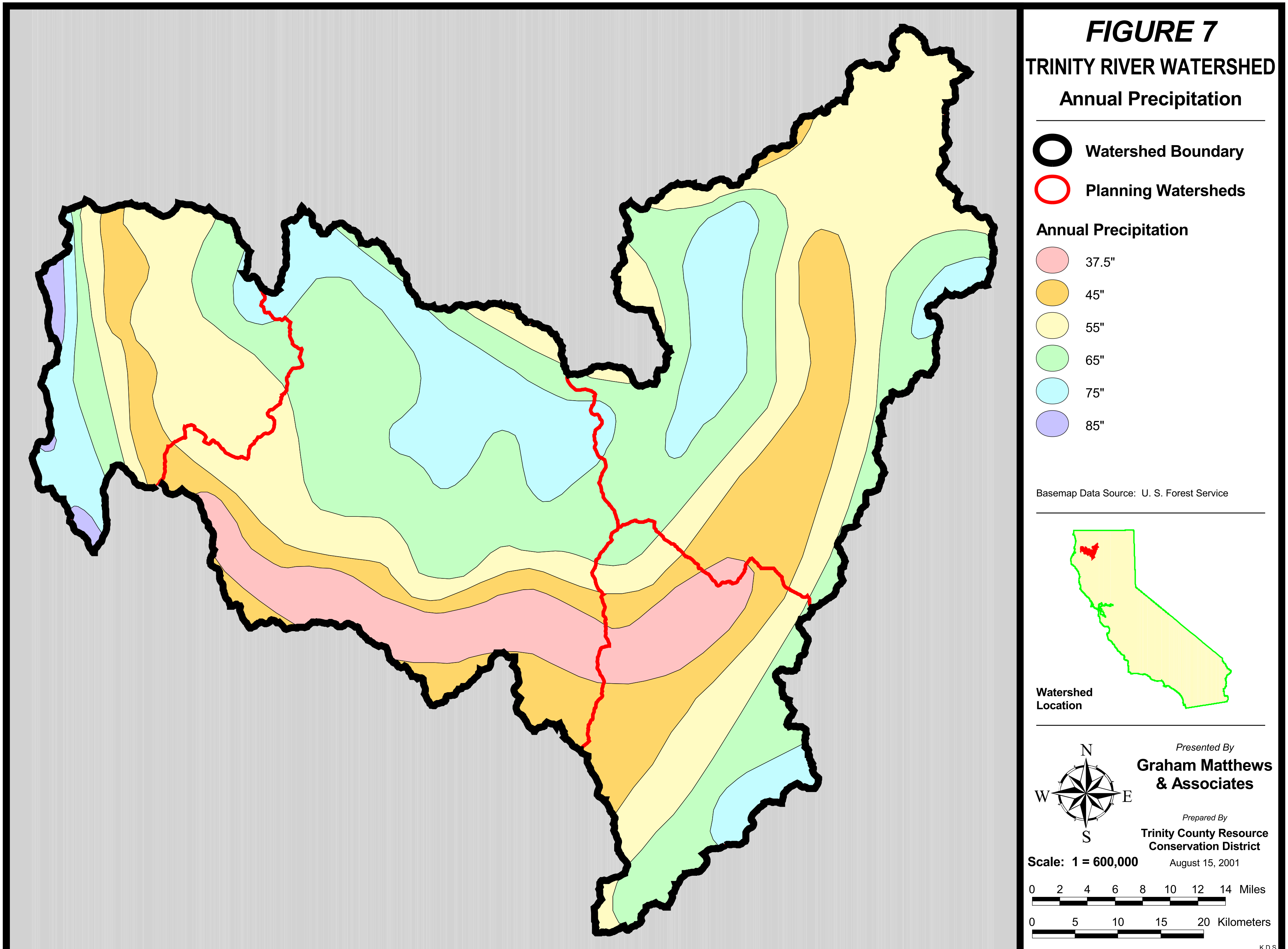
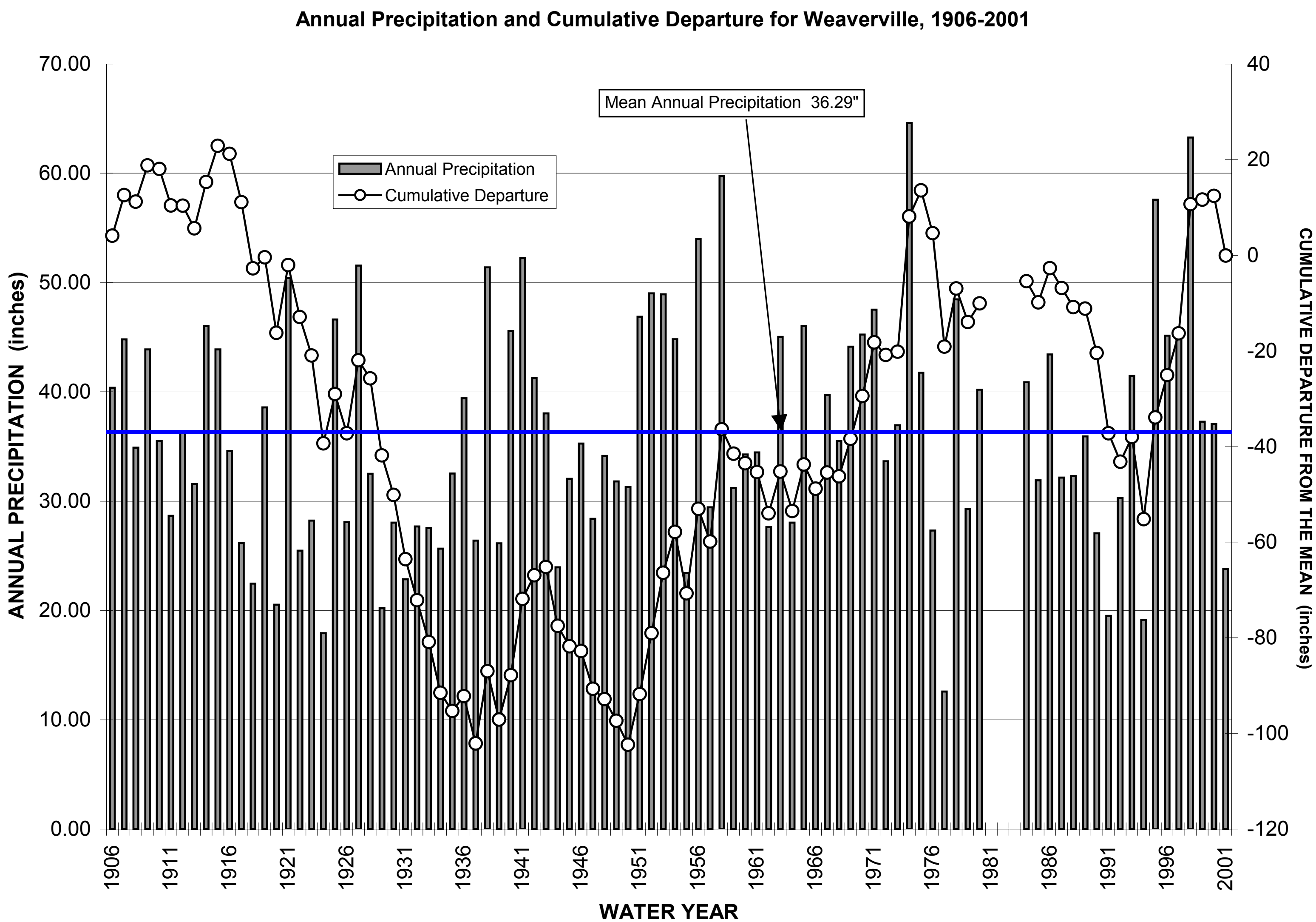


FIGURE 7
TRINITY RIVER WATERSHED
Annual Precipitation
Watershed Boundary
Planning Watersheds
Annual Precipitation
37.5"
45"
55"
65"
75"
85"
Basemap Data Source: U. S. Forest Service
Watershed Location
N
W
E
S
Presented By
Graham Matthews & Associates
Prepared By
Trinity County Resource Conservation District
August 15, 2001
Scale: 1 = 600,000
0 2 4 6 8 10 12 14 Miles
0 5 10 15 20 Kilometers
KDS



TRINITY RIVER SEDIMENT SOURCE ANALYSIS

Annual Precipitation and Cumulative Departure

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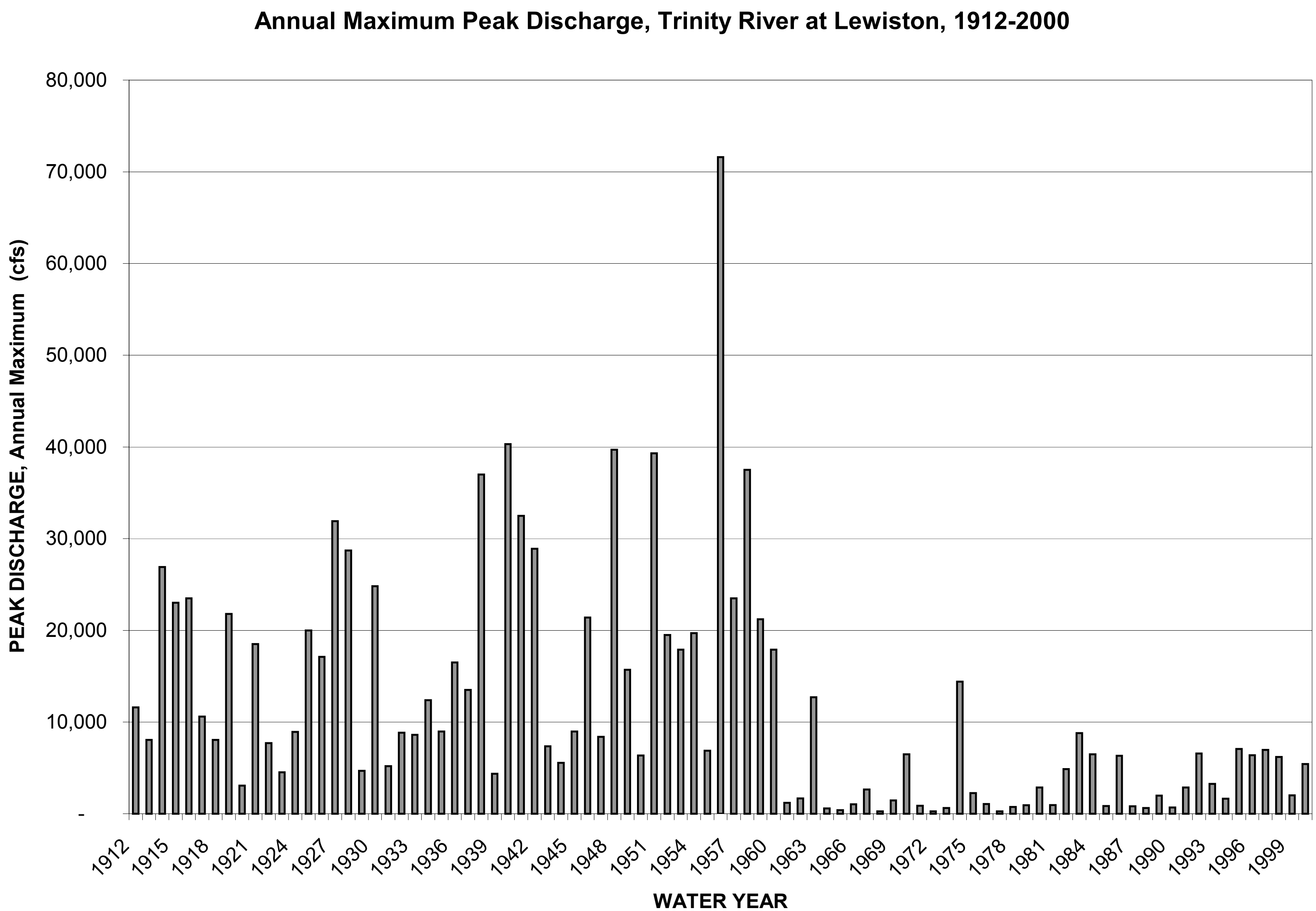
FIGURE

8



TRINITY RIVER SEDIMENT SOURCE ANALYSIS
Annual Maximum Peak Discharge, Trinity River at Lewiston

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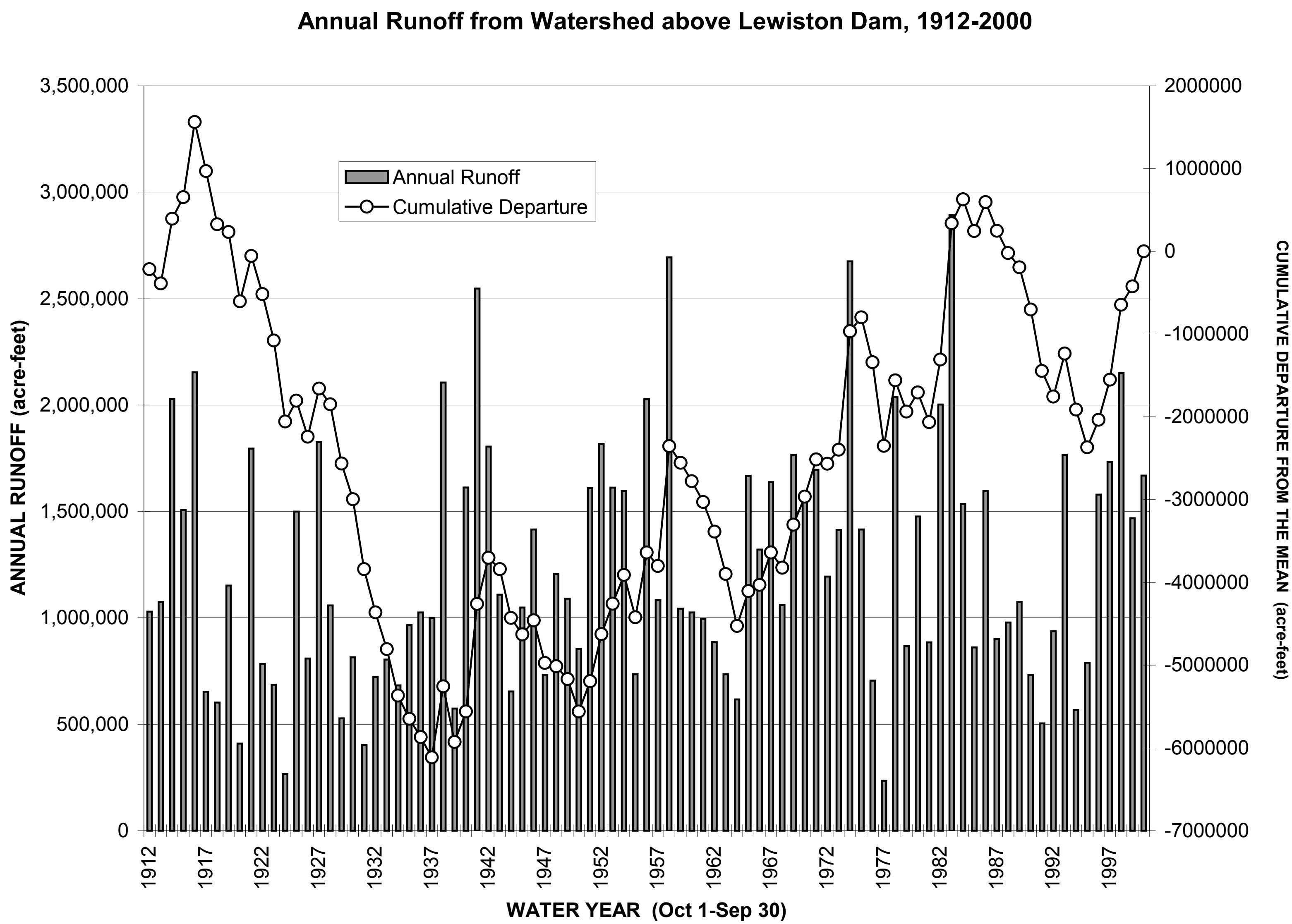
FIGURE

9



TRINITY RIVER SEDIMENT SOURCE ANALYSIS
Annual Maximum Peak Discharge, Trinity River at Lewiston

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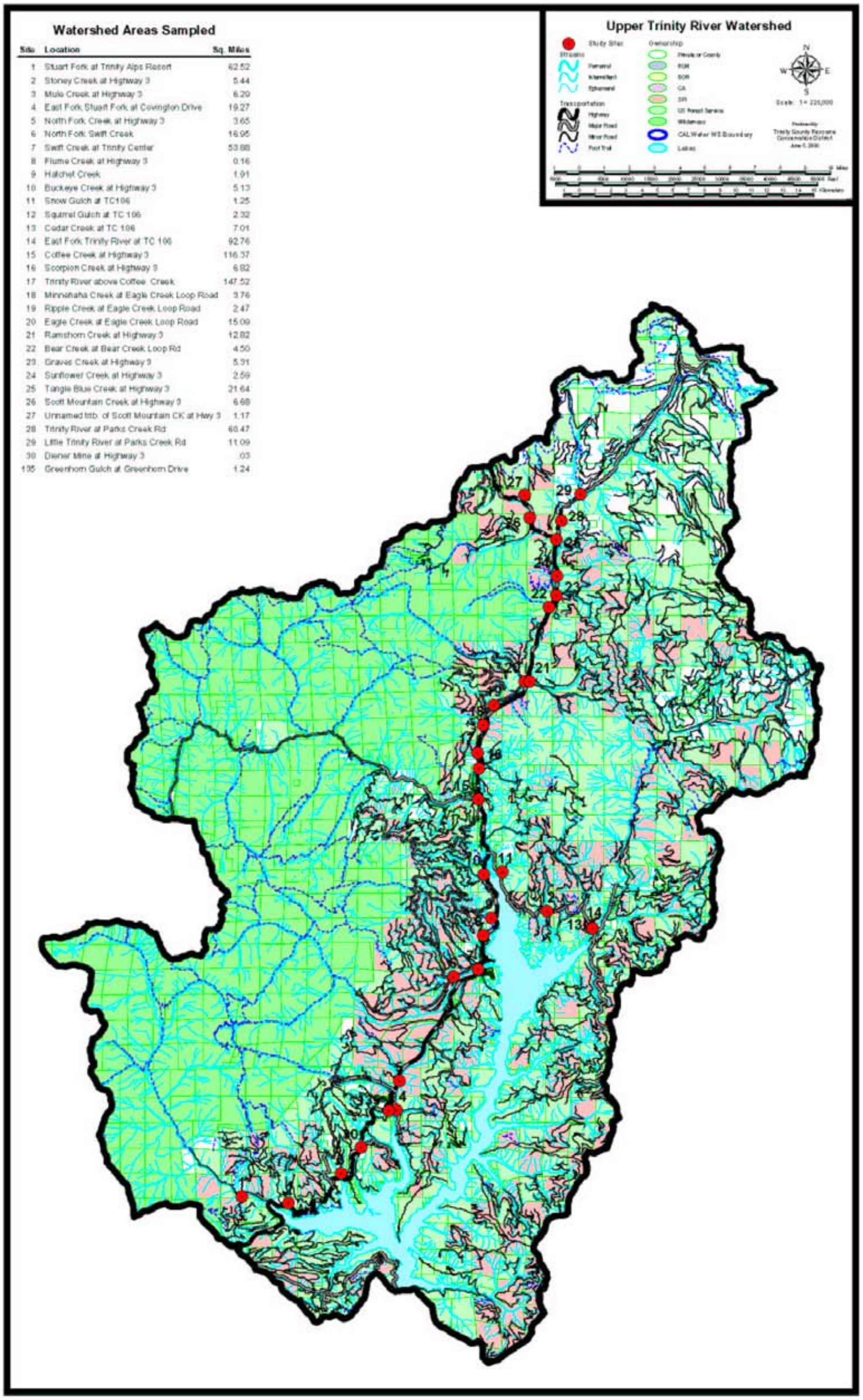
FIGURE
10

Watershed Areas Sampled

Site	Location	Sq. Miles
1	Stuart Fork at Trinity Alps Resort	62.52
2	Stoney Creek at Highway 3	5.44
3	Mule Creek at Highway 3	6.29
4	East Fork Stuart Fork at Covington Drive	19.27
5	North Fork Creek at Highway 3	3.65
6	North Fork Swift Creek	16.95
7	Swift Creek at Trinity Center	53.88
8	Flume Creek at Highway 3	0.16
9	Hatchet Creek	1.91
10	Buckeye Creek at Highway 3	5.13
11	Snow Gulch at TC106	1.25
12	Squirrel Gulch at TC 106	2.32
13	Cedar Creek at TC 106	7.01
14	East Fork Trinity River at TC 106	92.76
15	Coffee Creek at Highway 3	116.37
16	Scorpion Creek at Highway 3	6.82
17	Trinity River above Coffee Creek	147.52
18	Minnehaha Creek at Eagle Creek Loop Road	3.76
19	Ripple Creek at Eagle Creek Loop Road	2.47
20	Eagle Creek at Eagle Creek Loop Road	15.09
21	Ramshorn Creek at Highway 3	12.82
22	Bear Creek at Bear Creek Loop Rd	4.50
23	Graves Creek at Highway 3	5.31
24	Sunflower Creek at Highway 3	2.59
25	Tangle Blue Creek at Highway 3	21.64
26	Scott Mountain Creek at Highway 3	6.68
27	Unnamed trib. of Scott Mountain CK at Hwy 3	1.17
28	Trinity River at Parks Creek Rd	60.47
29	Little Trinity River at Parks Creek Rd	11.09
30	Diener Mine at Highway 3	.03
105	Greenhorn Gulch at Greenhorn Drive	1.24



PROJECT:

TRINITY RIVER SEDIMENT SOURCE ANALYSIS
WY2000 Sample Sites in Upper Trinity PW

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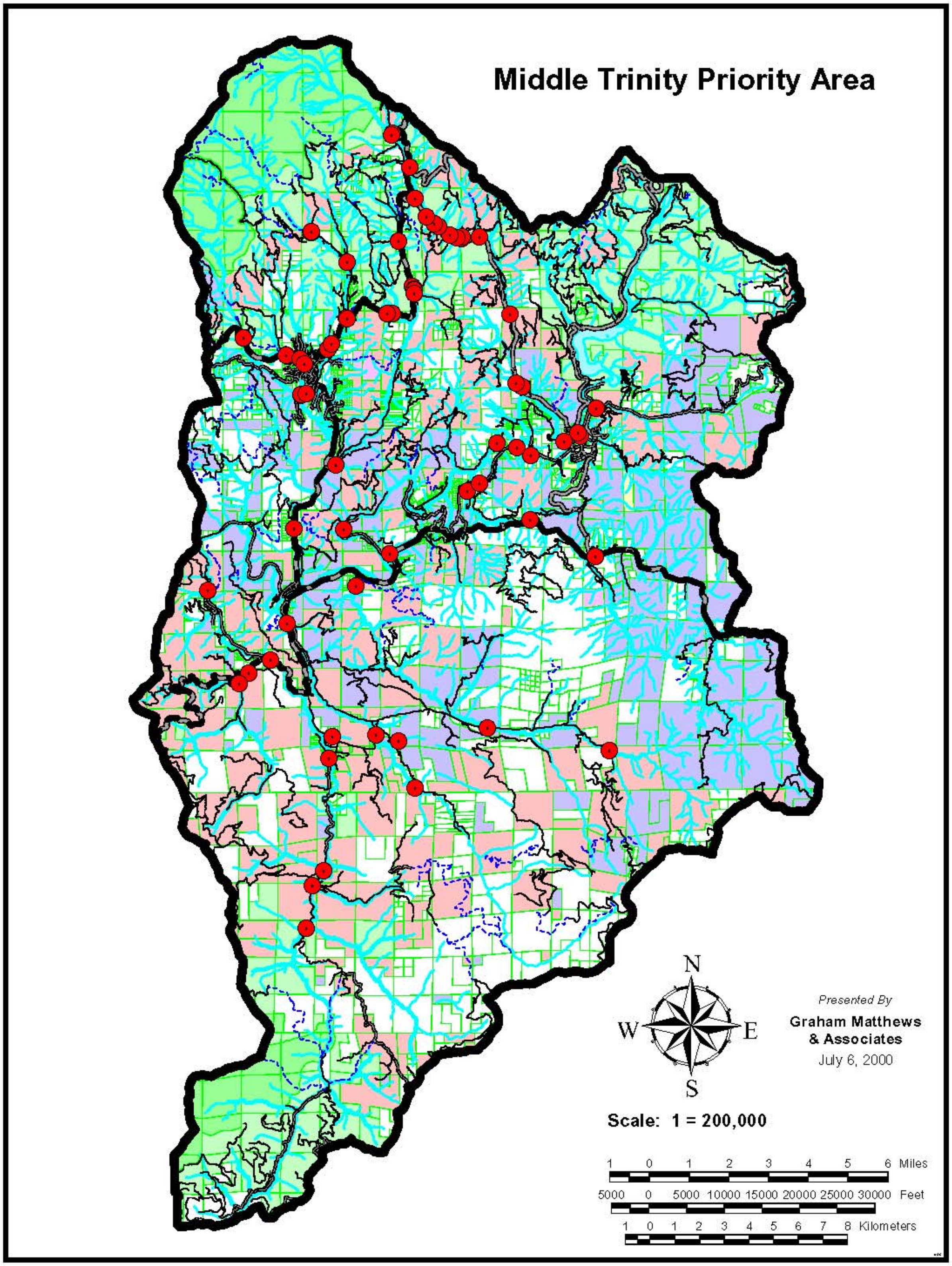
FIGURE

11a



PROJECT:

TRINITY RIVER SEDIMENT SOURCE ANALYSIS
WY2000 Sample Sites in Upper Middle Trinity PW

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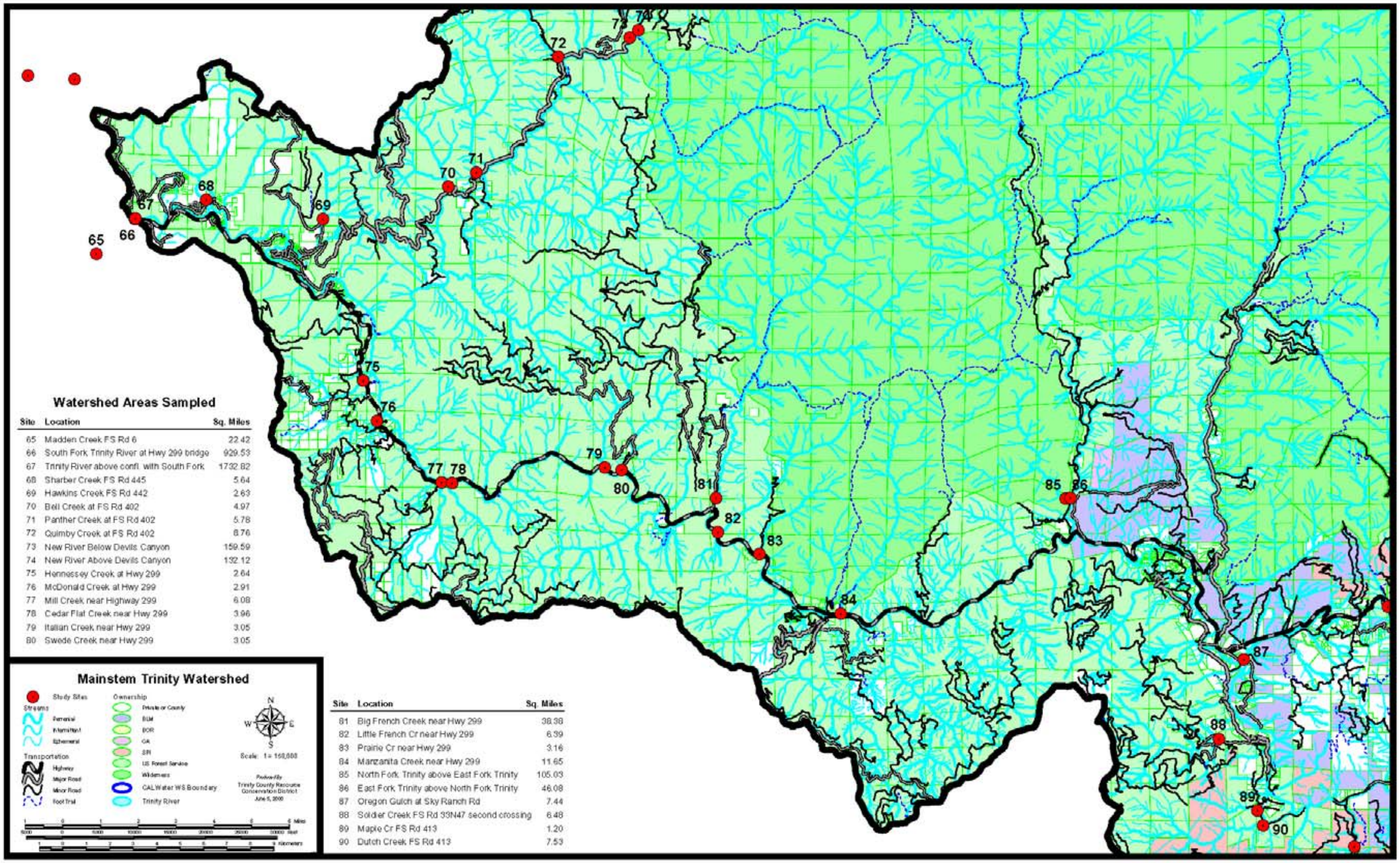
FIGURE

11b



Watershed Areas Sampled

Site	Location	Sq. Miles
65	Madden Creek FS Rd 6	22.42
66	South Fork Trinity River at Hwy 299 bridge	929.53
67	Trinity River above confl. with South Fork	1732.82
68	Sharber Creek FS Rd 445	5.64
69	Hawkins Creek FS Rd 442	2.63
70	Bell Creek at FS Rd 402	4.97
71	Panther Creek at FS Rd 402	5.78
72	Quimby Creek at FS Rd 402	8.76
73	New River Below Devils Canyon	159.59
74	New River Above Devils Canyon	132.12
75	Hennessey Creek at Hwy 299	2.64
76	McDonald Creek at Hwy 299	2.91
77	Mill Creek near Highway 299	6.08
78	Cedar Flat Creek near Hwy 299	3.96
79	Italian Creek near Hwy 299	3.05
80	Swede Creek near Hwy 299	3.05

Site	Location	Sq. Miles
81	Big French Creek near Hwy 299	38.38
82	Little French Cr near Hwy 299	6.39
83	Prairie Cr near Hwy 299	3.16
84	Manzanita Creek near Hwy 299	11.65
85	North Fork Trinity above East Fork Trinity	105.03
86	East Fork Trinity above North Fork Trinity	46.08
87	Oregon Gulch at Sky Ranch Rd	7.44
88	Soldier Creek FS Rd 33N47 second crossing	6.48
89	Maple Cr FS Rd 413	1.20
90	Dutch Creek FS Rd 413	7.53

TRINITY RIVER SEDIMENT SOURCE ANALYSIS
WY2000 Sample Sites in Lower Middle Trinity Watershed

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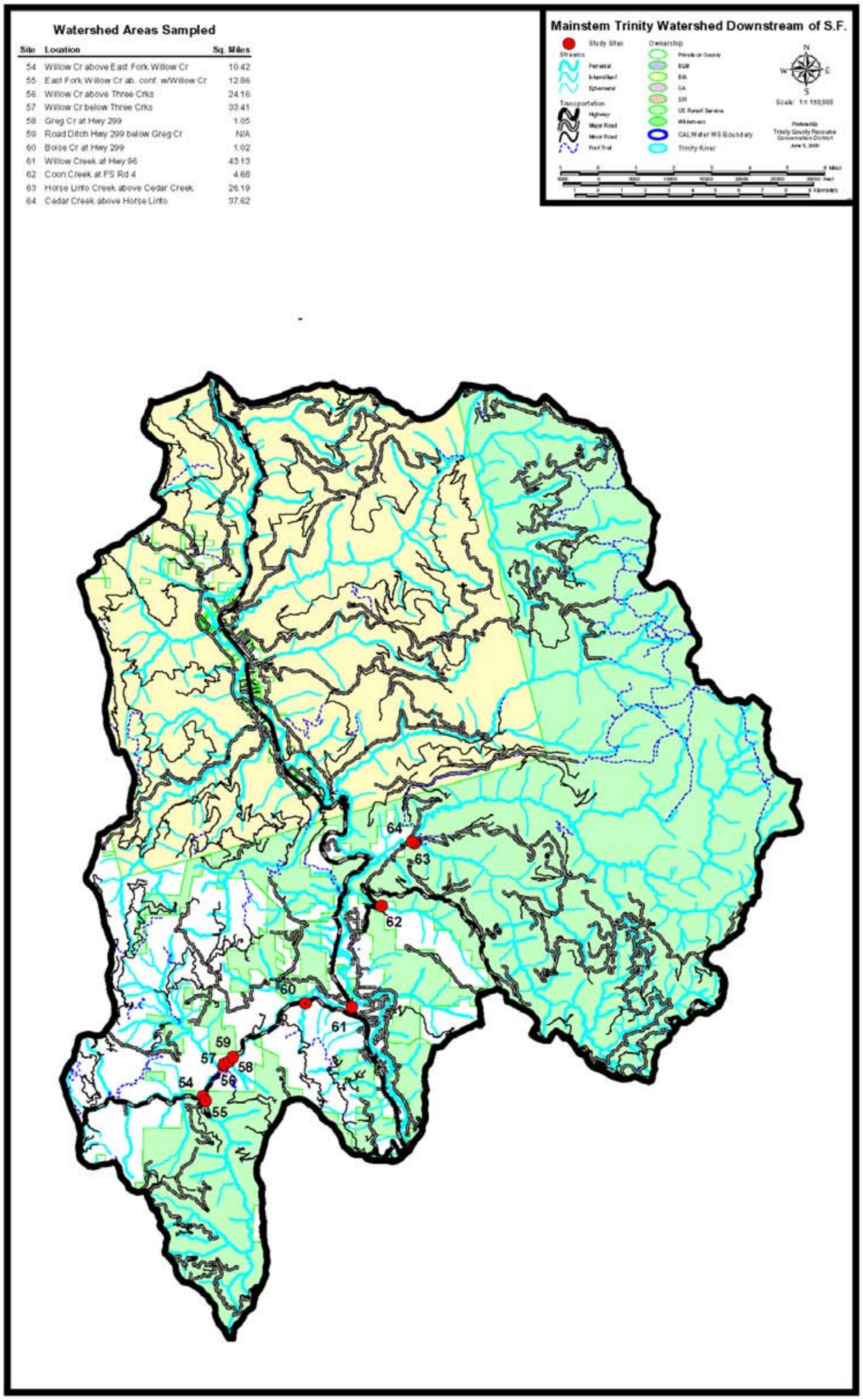
FIGURE

11c



Watershed Areas Sampled

Site	Location	Sq. Miles
54	Willow Cr above East Fork Willow Cr	10.42
55	East Fork Willow Cr ab. conf. w/Willow Cr	12.86
56	Willow Cr above Three Crks	24.16
57	Willow Cr below Three Crks	33.41
58	Greg Cr at Hwy 299	1.05
59	Road Ditch Hwy 299 below Greg Cr	N/A
60	Boise Cr at Hwy 299	1.02
61	Willow Creek at Hwy 96	43.13
62	Coon Creek at FS Rd 4	4.68
63	Horse Linto Creek above Cedar Creek	26.19
64	Cedar Creek above Horse Linto	37.62

PROJECT:

TRINITY RIVER SEDIMENT SOURCE ANALYSIS
WY2000 Sample Sites in Lower Trinity PW

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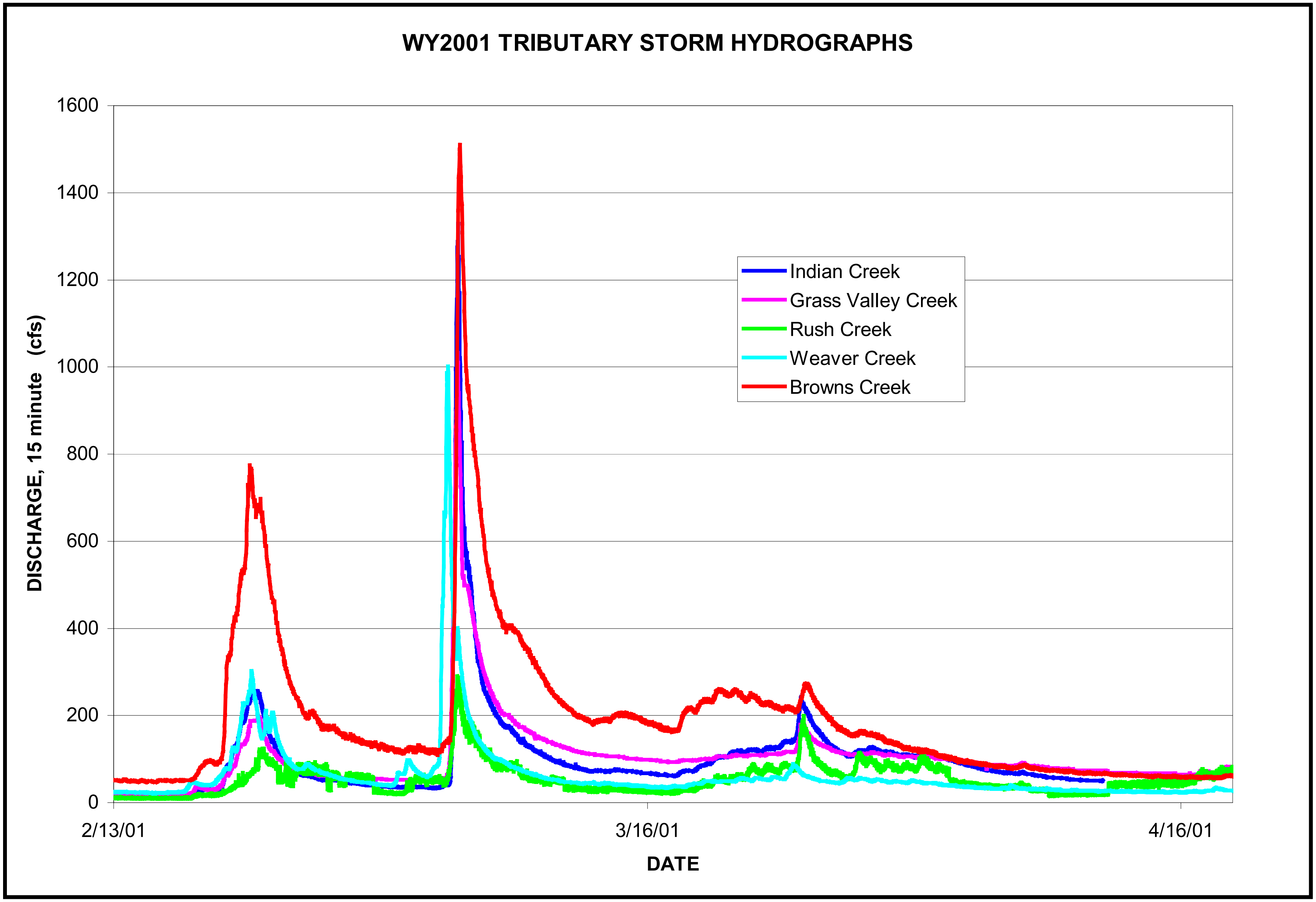
FIGURE

11d



TRINITY RIVER SEDIMENT SOURCE ANALYSIS
WY 2001 Storm Hydrographs
5 Tributary Sites

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FIGURE

12

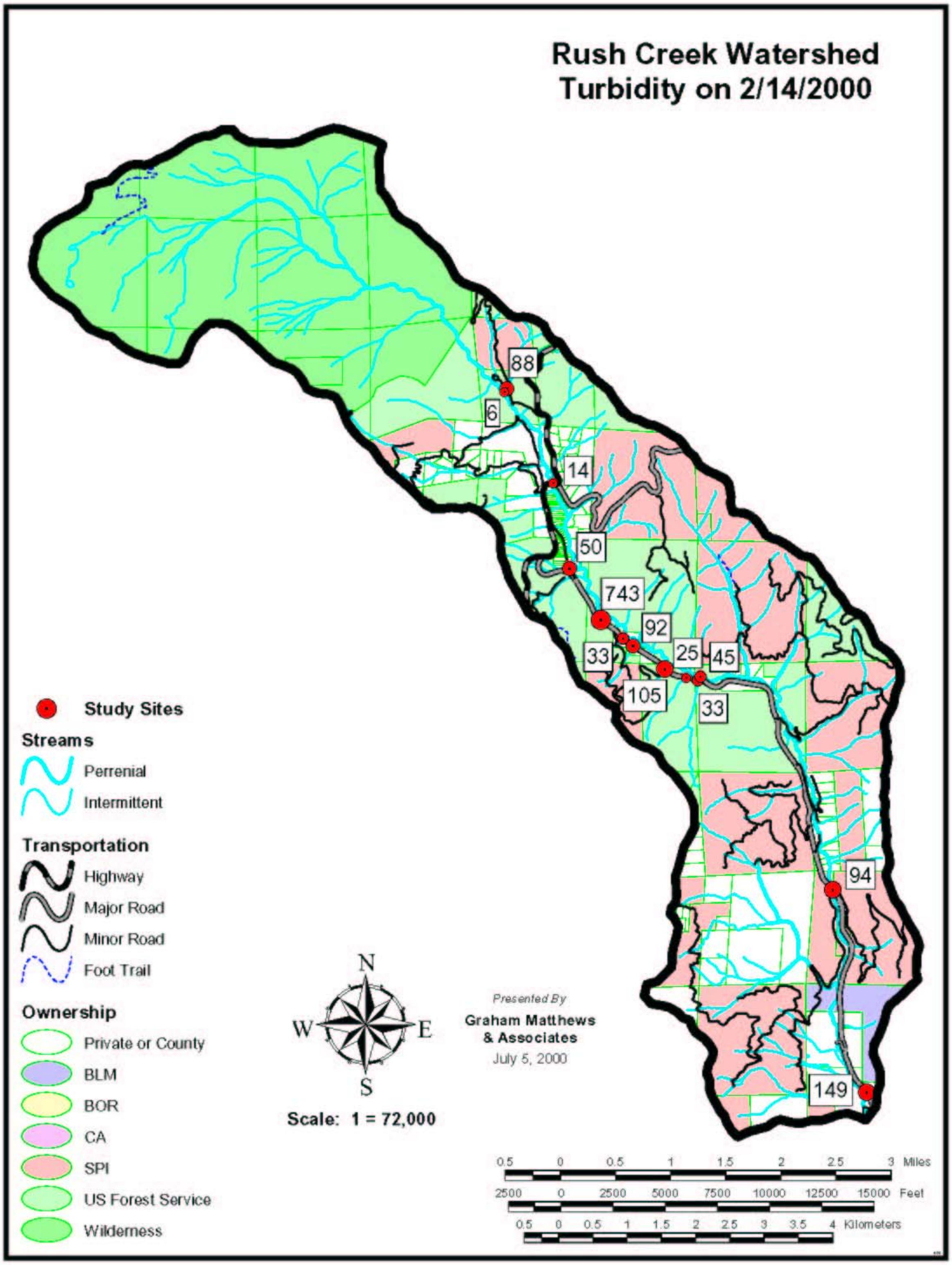

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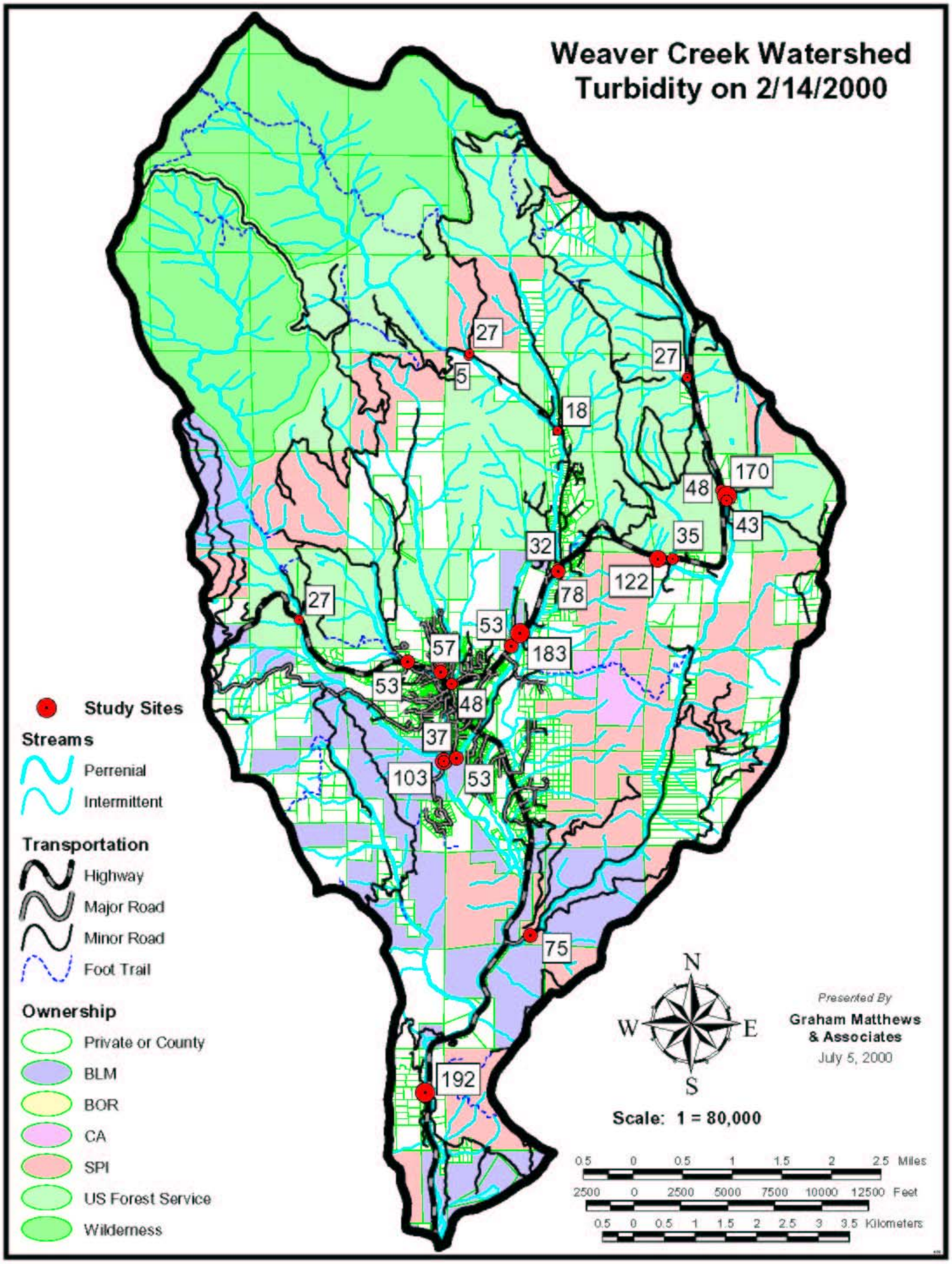
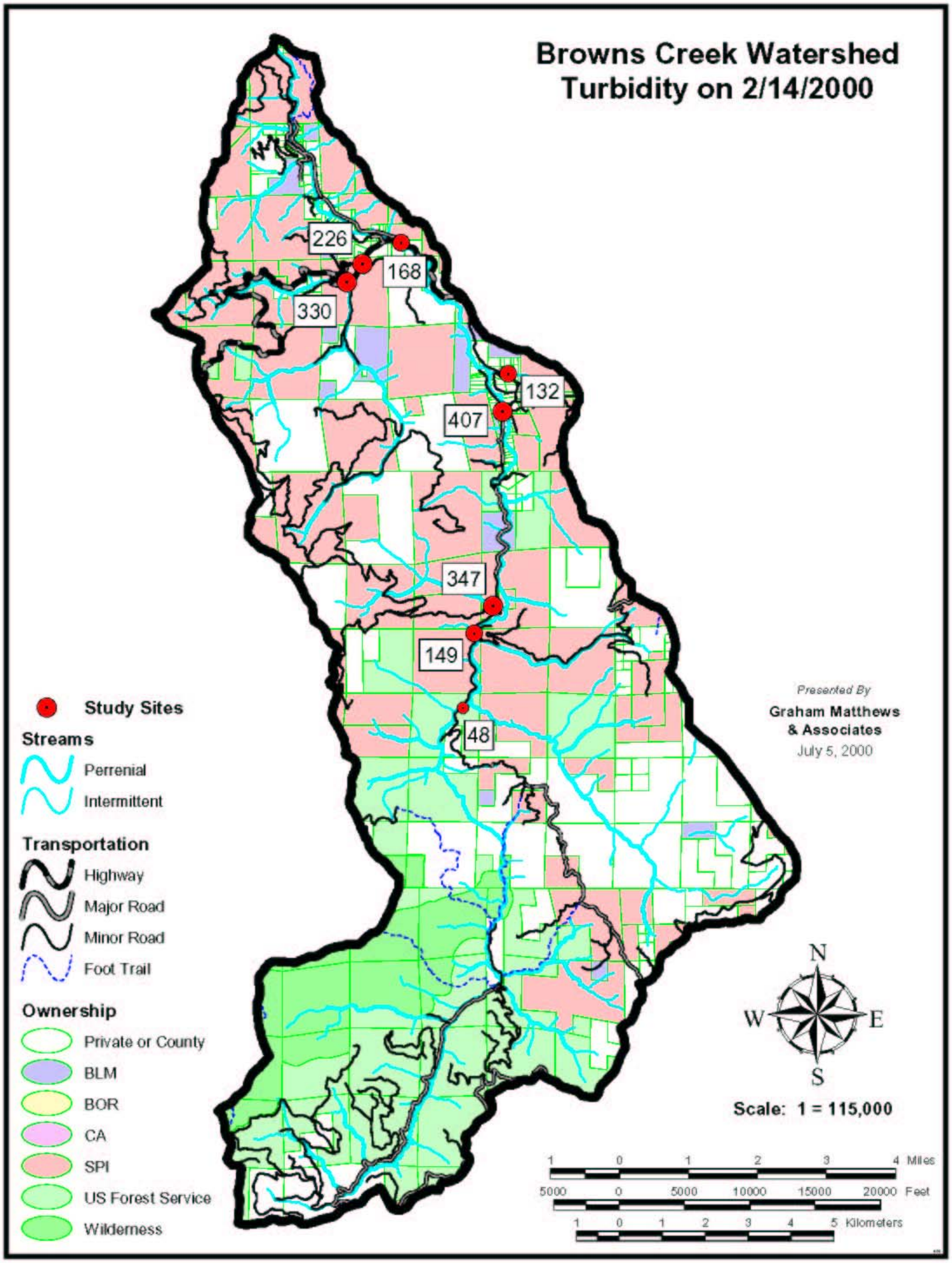
FIGURE

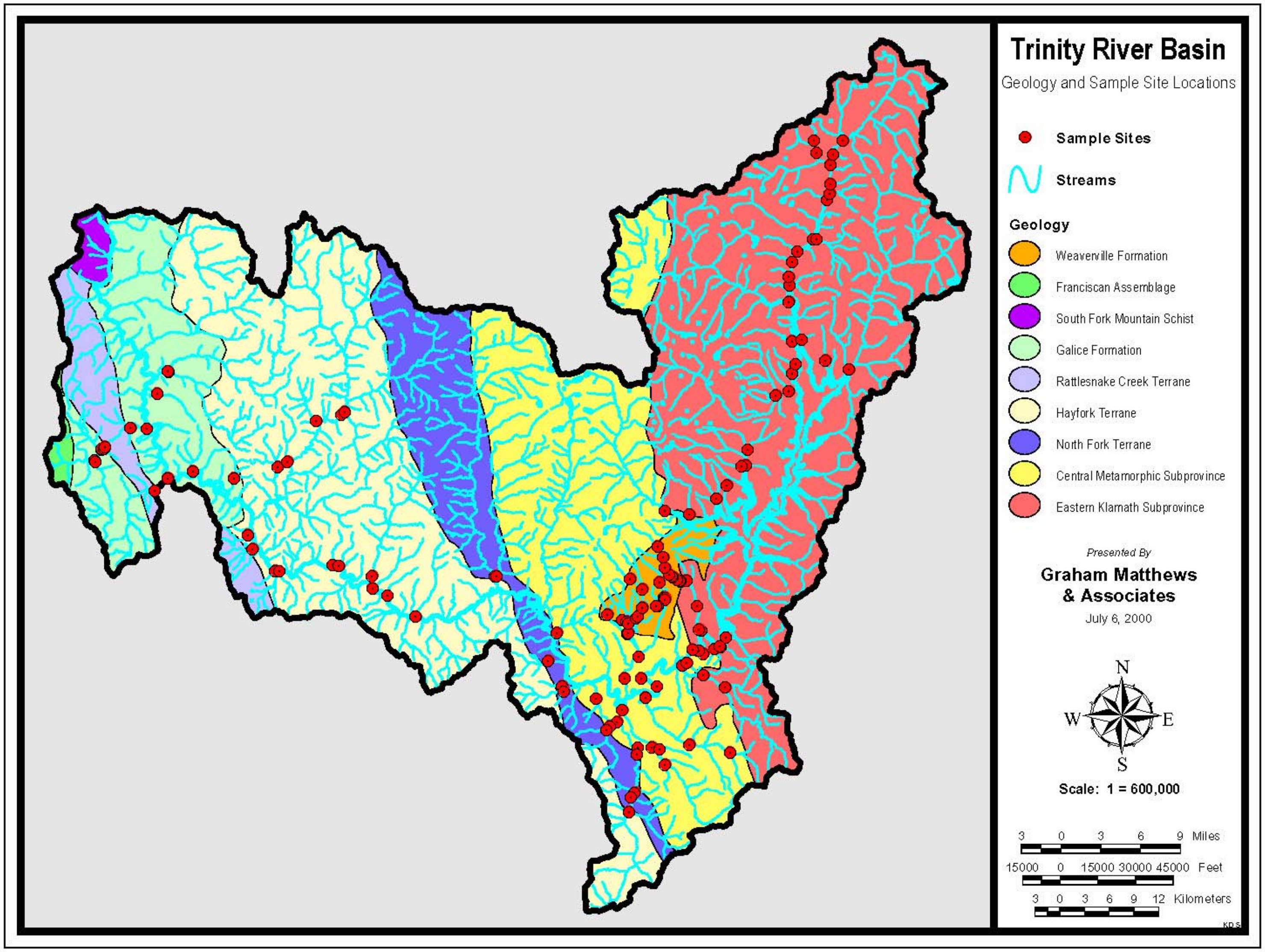
13



PROJECT:	GMA	FIGURE
TRINITY RIVER SEDIMENT SOURCE ANALYSIS Synoptic Storm Sampling Sites in Weaver Creek	**GRAHAM MATTHEWS & ASSOCIATES** Hydrology • Geomorphology • Stream Restoration P.O. Box 1516 Weaverville, CA 96093-1516 (530) 623-5327 ph (530) 623-5328 fax	**14**



PROJECT:	GMA	FIGURE
TRINITY RIVER SEDIMENT SOURCE ANALYSIS Synoptic Storm Sampling Sites in Browns Creek	**GRAHAM MATTHEWS & ASSOCIATES** Hydrology • Geomorphology • Stream Restoration P.O. Box 1516 Weaverville, CA 96093-1516 (530) 623-5327 ph (530) 623-5328 fax	**15**



TRINITY RIVER SEDIMENT SOURCE ANALYSIS
WY2000 Sample Sites in Trinity Watershed by Geologic Terrane

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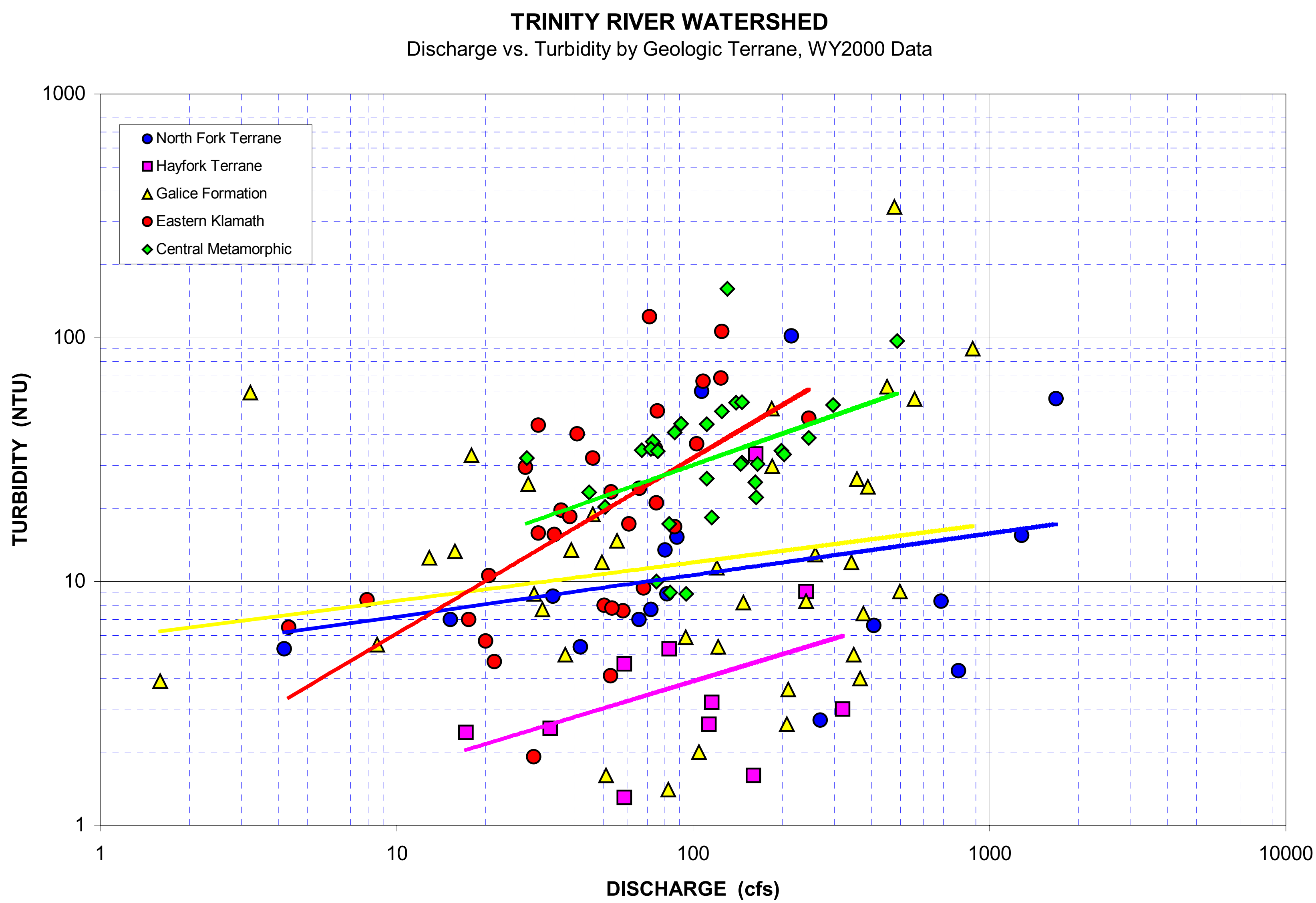
FIGURE

16



TRINITY RIVER SEDIMENT SOURCE ANALYSIS
WY2000 Sample Sites in Trinity Watershed by Geologic Terrane

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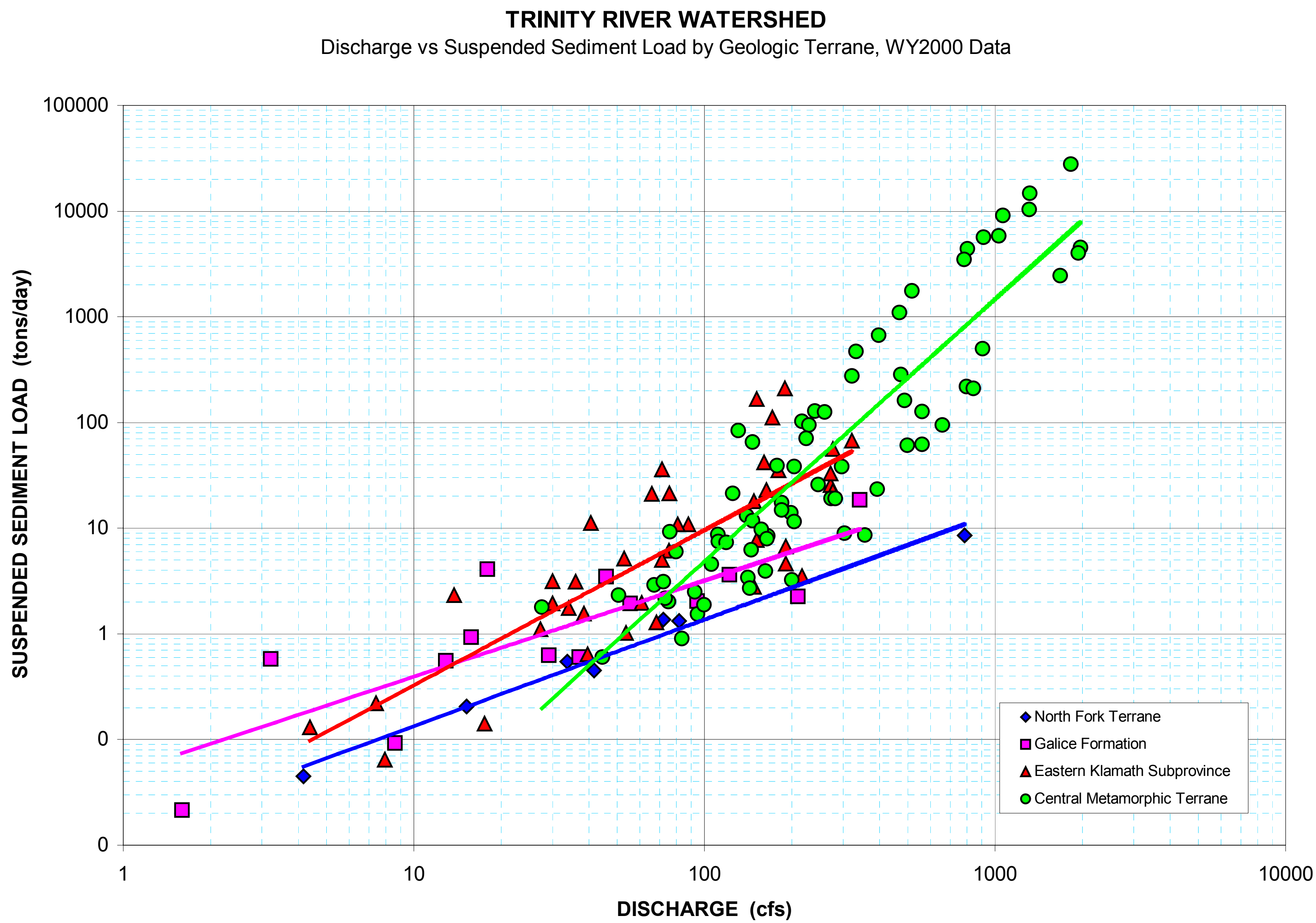
FIGURE
17



TRINITY RIVER SEDIMENT SOURCE ANALYSIS
Discharge vs. Suspended Sediment Load in Trinity Watershed
by Geologic Terrane

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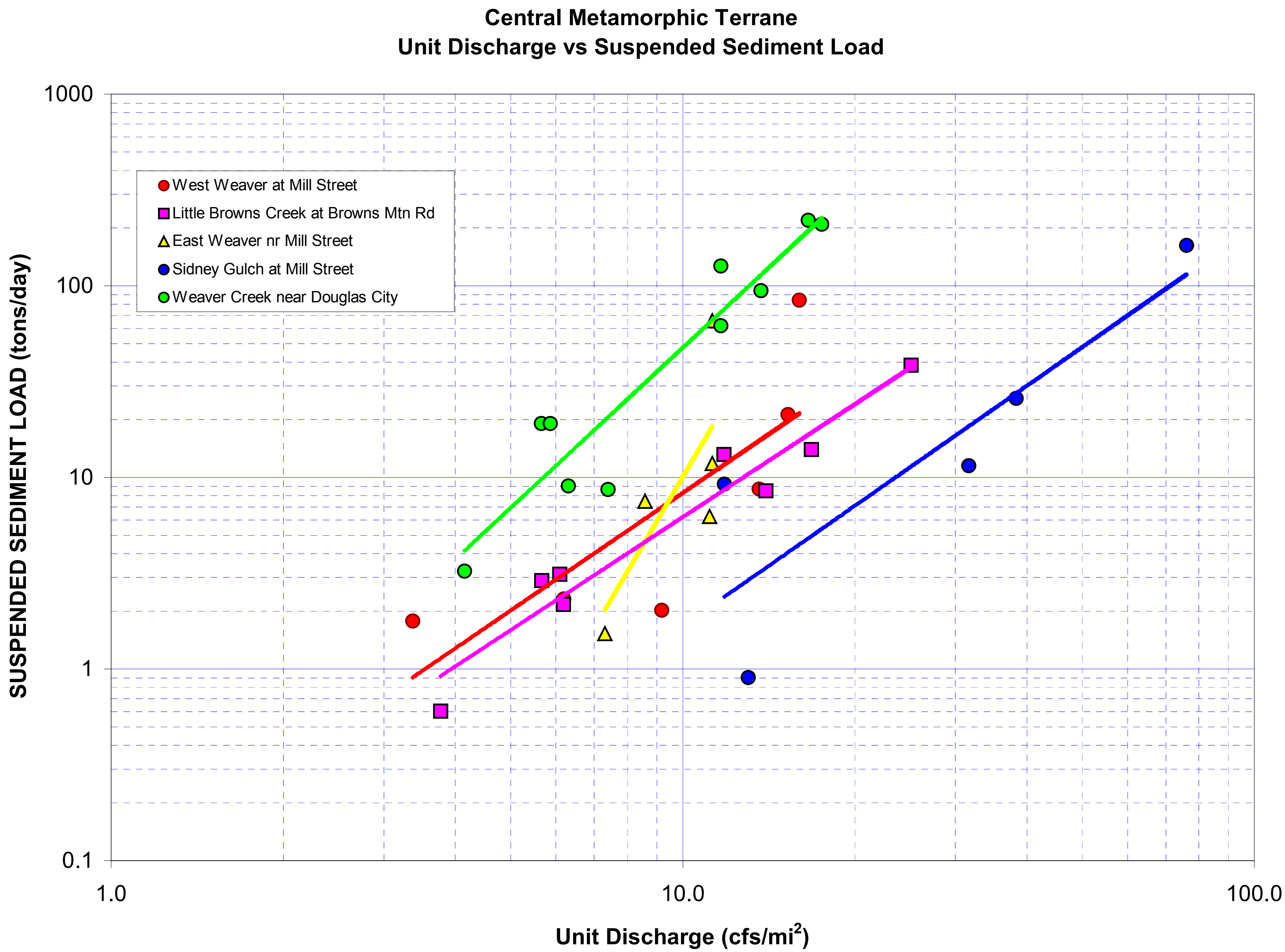
FIGURE
18



TRINITY RIVER SEDIMENT SOURCE ANALYSIS
Unit Discharge vs. SSL, Central Metamorphic Terrane

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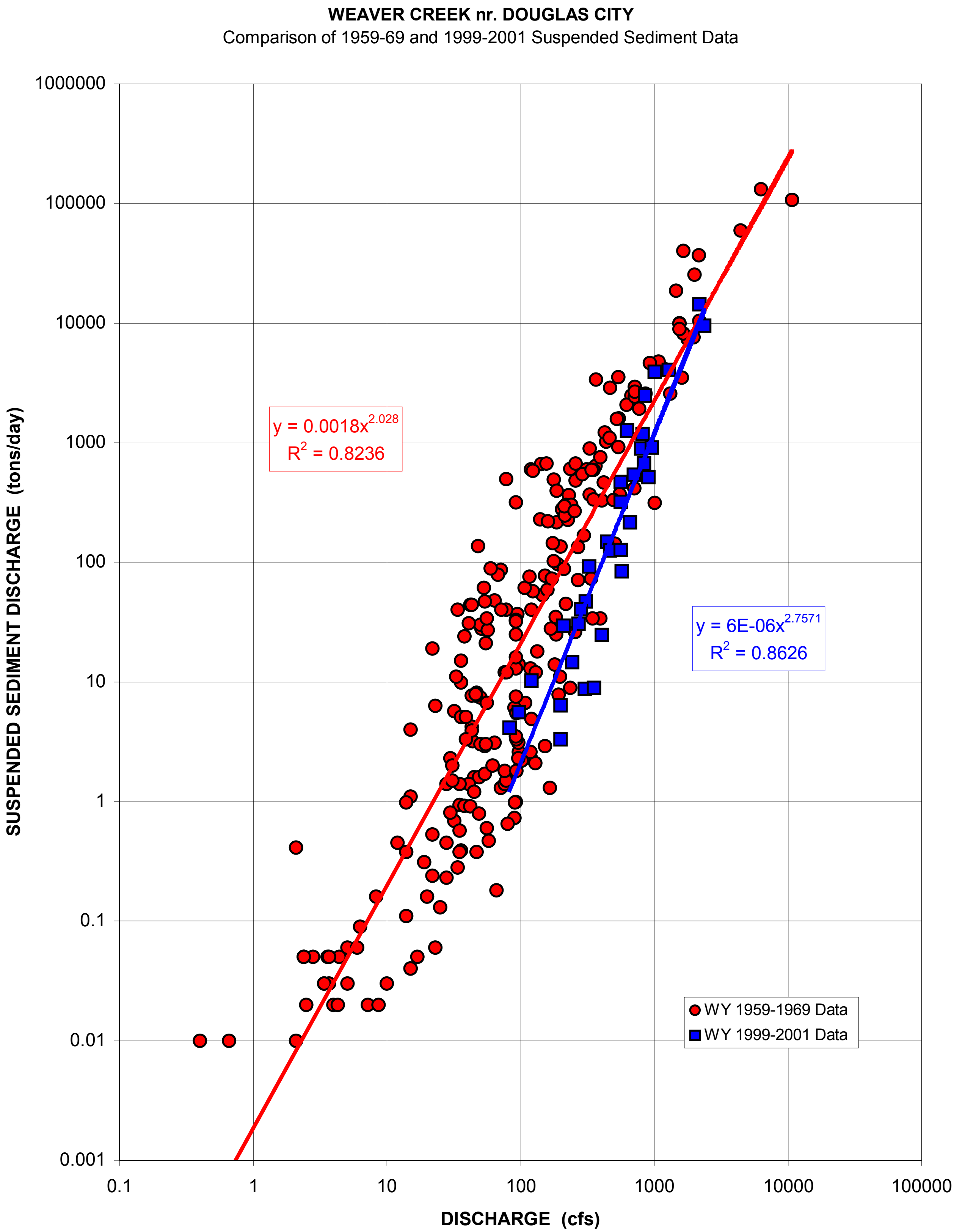
FIGURE
19



PROJECT:

TRINITY RIVER SEDIMENT SOURCE ANALYSIS
Comparison of Historic Suspended Sediment Data

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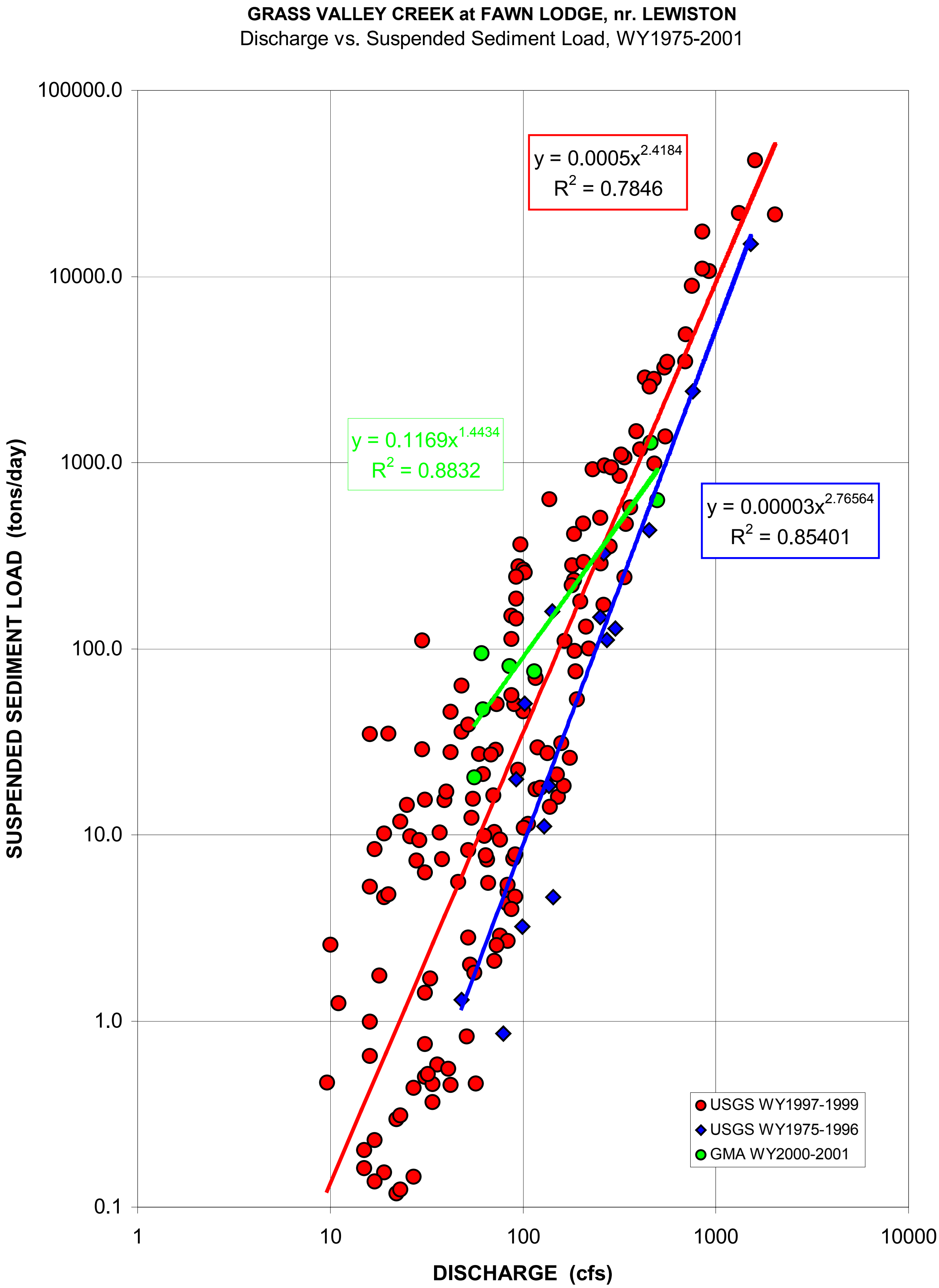
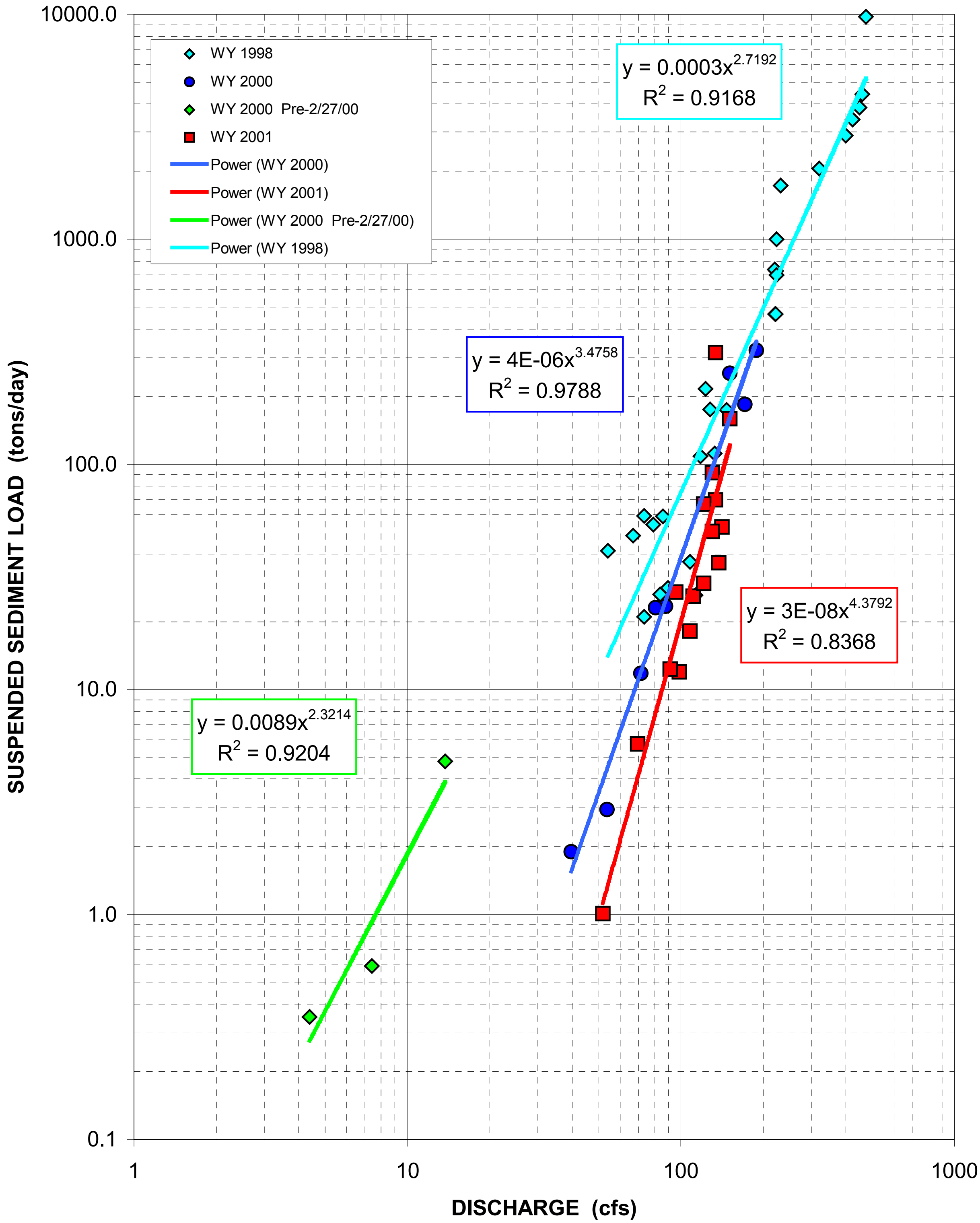
FIGURE

20



PROJECT:	GMA GRAHAM MATTHEWS & ASSOCIATES	FIGURE
TRINITY RIVER SEDIMENT SOURCE ANALYSIS Comparison of Historic Suspended Sediment Data	Hydrology • Geomorphology • Stream Restoration P.O. Box 1516 Weaverville, CA 96093-1516 (530) 623-5327 ph (530) 623-5328 fax	**21**

DEADWOOD CREEK NEAR LEWISTON
Discharge vs. Suspended Sediment Load, WY 1998, WY 2000 and WY 2001



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TRINITY RIVER SEDIMENT SOURCE ANALYSIS
Comparison of Historic Suspended Sediment Data

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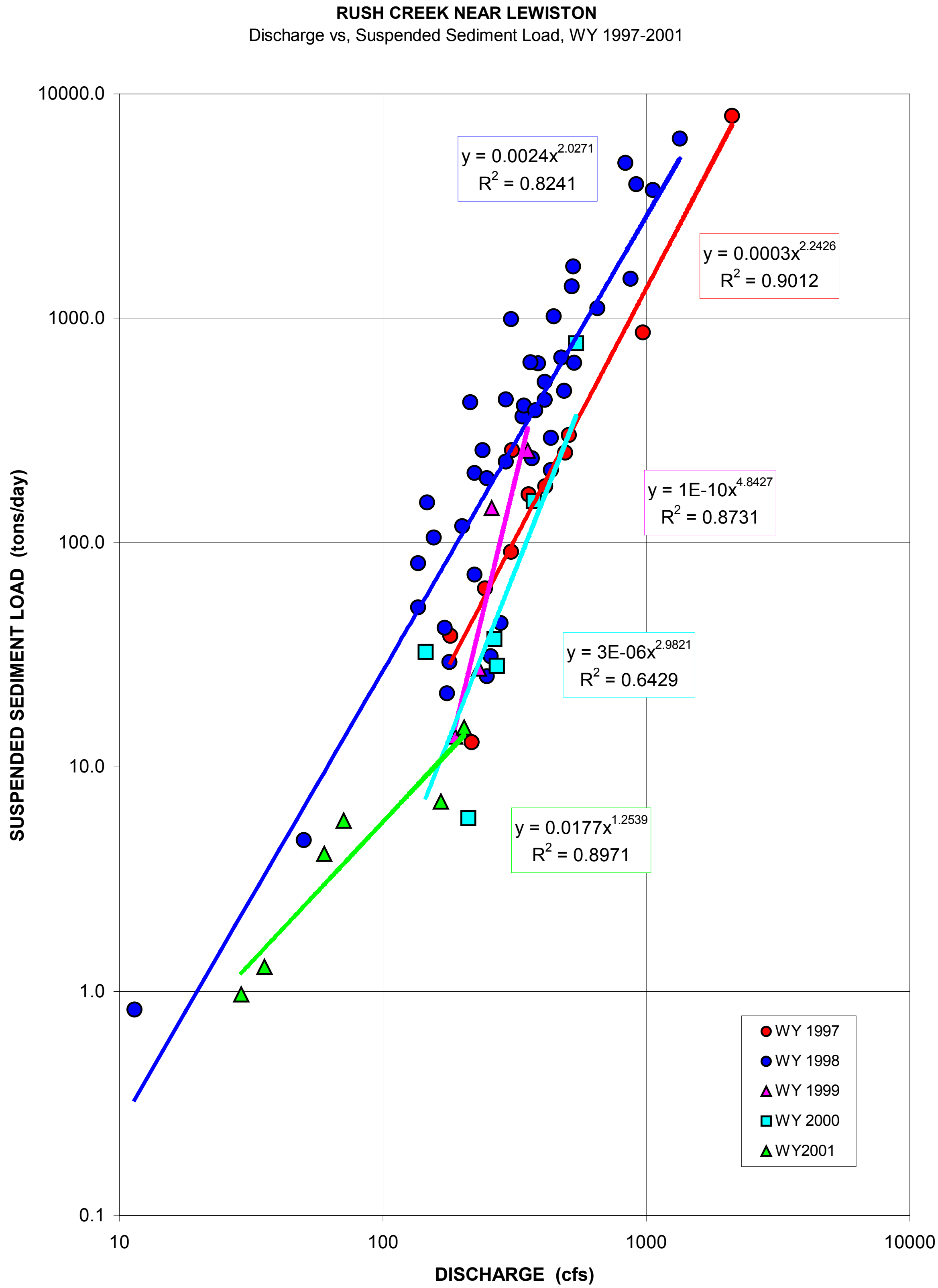
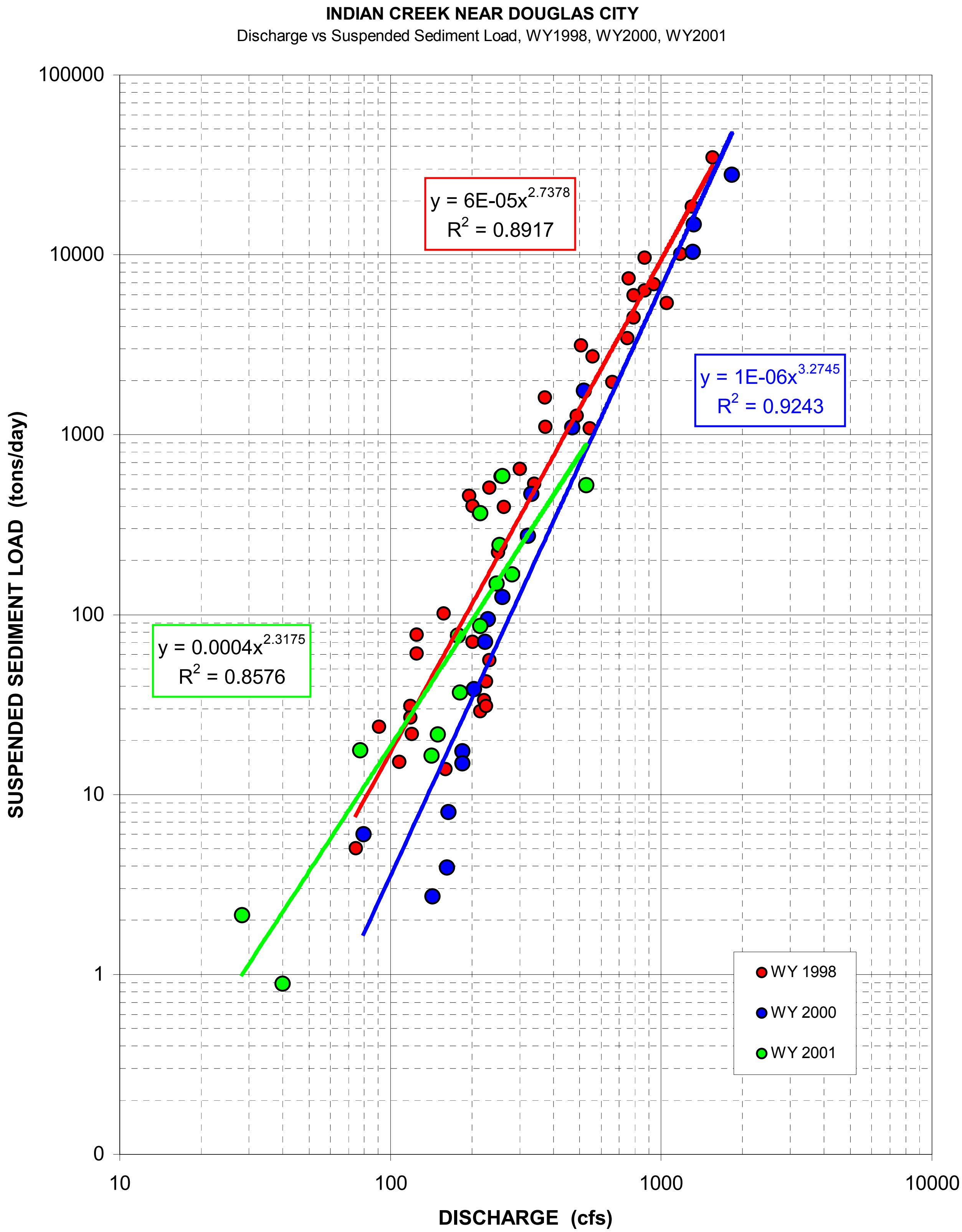
FIGURE

22



PROJECT:	GMA	FIGURE
TRINITY RIVER SEDIMENT SOURCE ANALYSIS Comparison of Historic Suspended Sediment Data	**GRAHAM MATTHEWS & ASSOCIATES** Hydrology • Geomorphology • Stream Restoration P.O. Box 1516 Weaverville, CA 96093-1516 (530) 623-5327 ph (530) 623-5328 fax	**23**



PROJECT:

TRINITY RIVER SEDIMENT SOURCE ANALYSIS
Comparison of WY 1998-2001 Data

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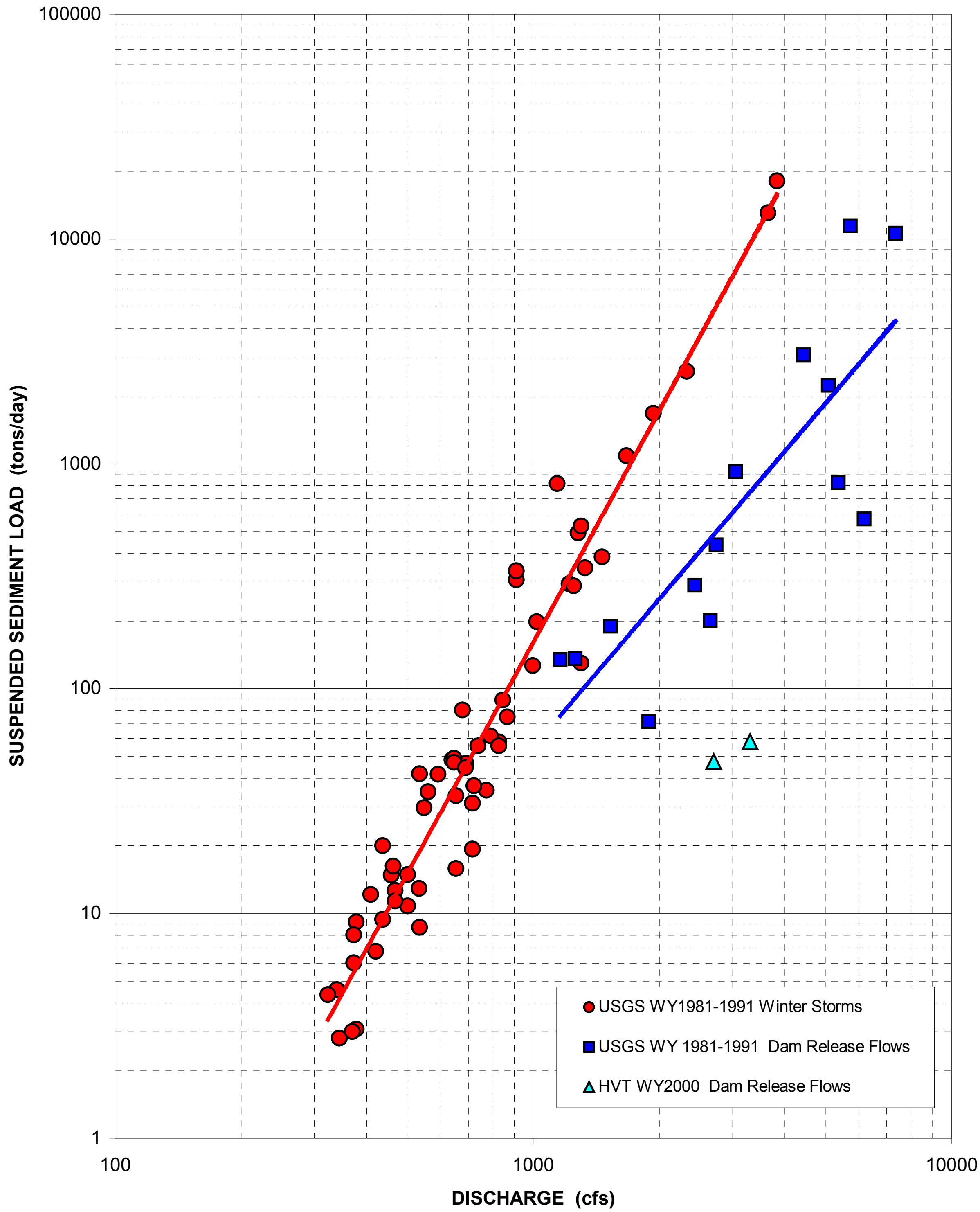
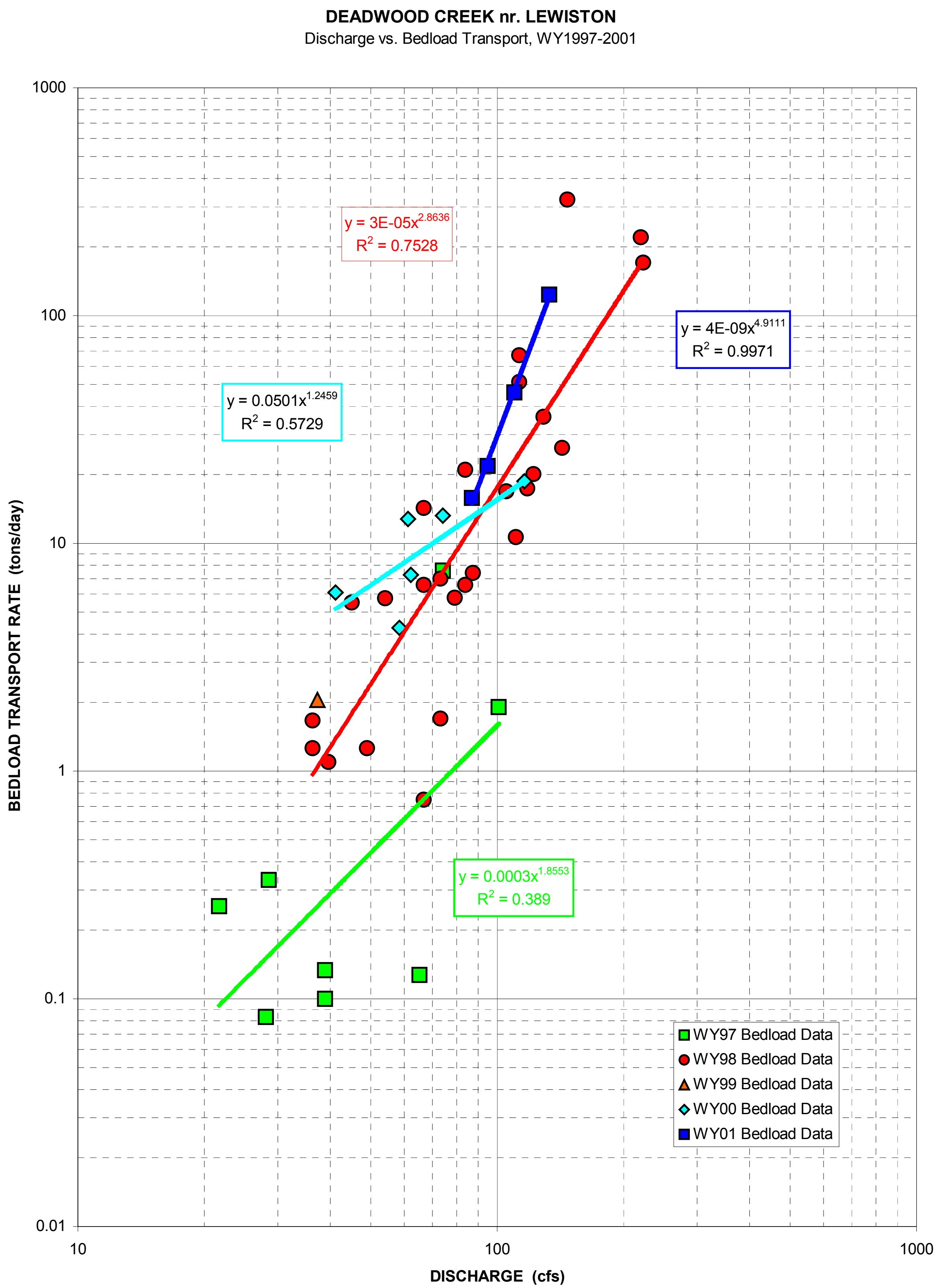
FIGURE

24

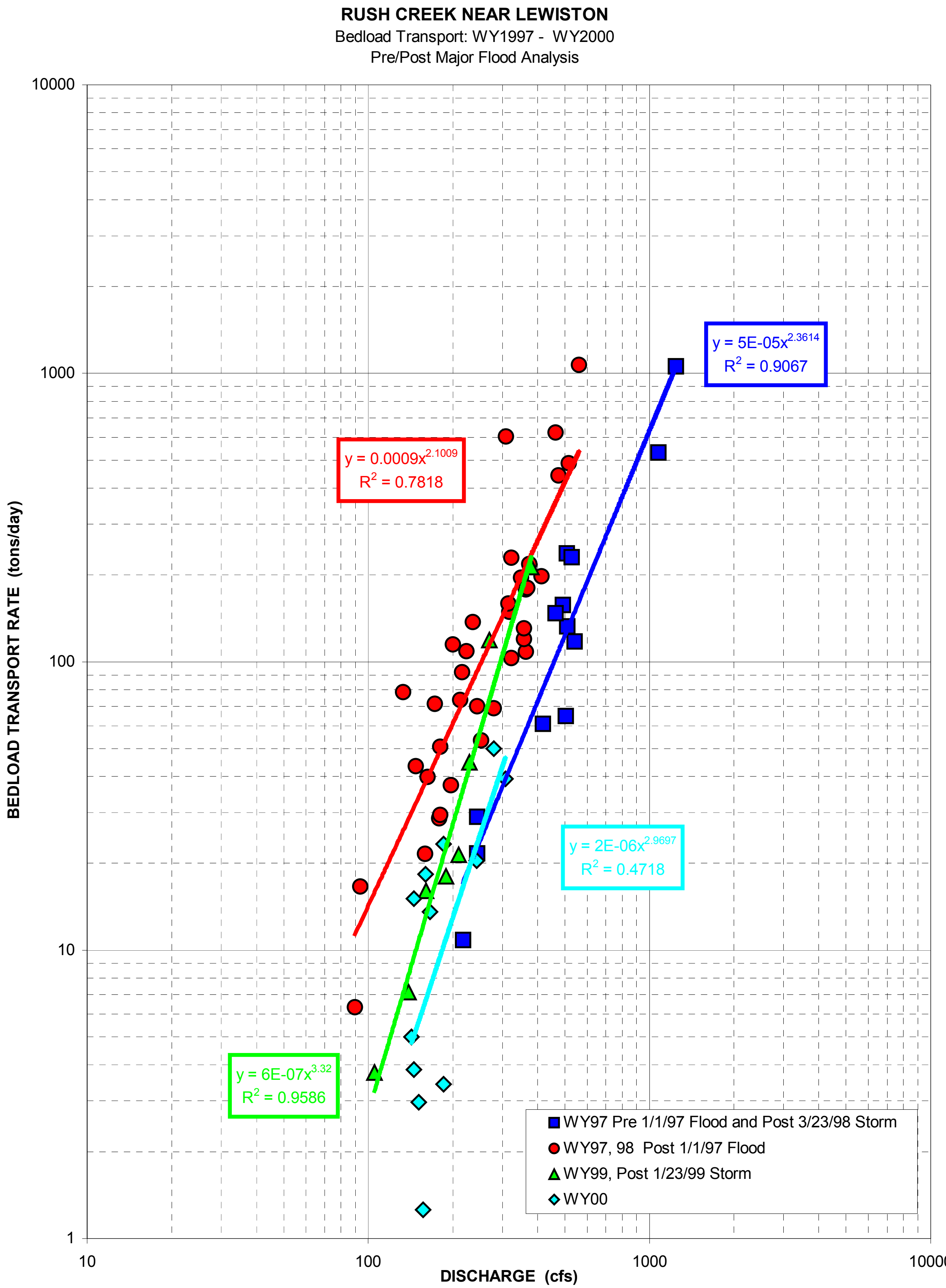
TRINITY RIVER BELOW LIMEKILN GULCH NEAR DOUGLAS CITY
Suspended Sediment Data, WY1981-1991, 2000
Analyzed for Winter Storms and Dam Release Flows



PROJECT:	GMA	FIGURE
TRINITY RIVER SEDIMENT SOURCE ANALYSIS Analysis of WY 1981-2000 Suspended Sediment Data	**GRAHAM MATTHEWS & ASSOCIATES** Hydrology • Geomorphology • Stream Restoration P.O. Box 1516 Weaverville, CA 96093-1516 (530) 623-5327 ph (530) 623-5328 fax	**25**



PROJECT:	GMA	FIGURE
TRINITY RIVER SEDIMENT SOURCE ANALYSIS Comparison of WY 1997-2001 Bedload Data	**GRAHAM MATTHEWS & ASSOCIATES** Hydrology • Geomorphology • Stream Restoration P.O. Box 1516 Weaverville, CA 96093-1516 (530) 623-5327 ph (530) 623-5328 fax	**26**



PROJECT:

TRINITY RIVER SEDIMENT SOURCE ANALYSIS
Comparison of WY 1997-2001 Bedload Data

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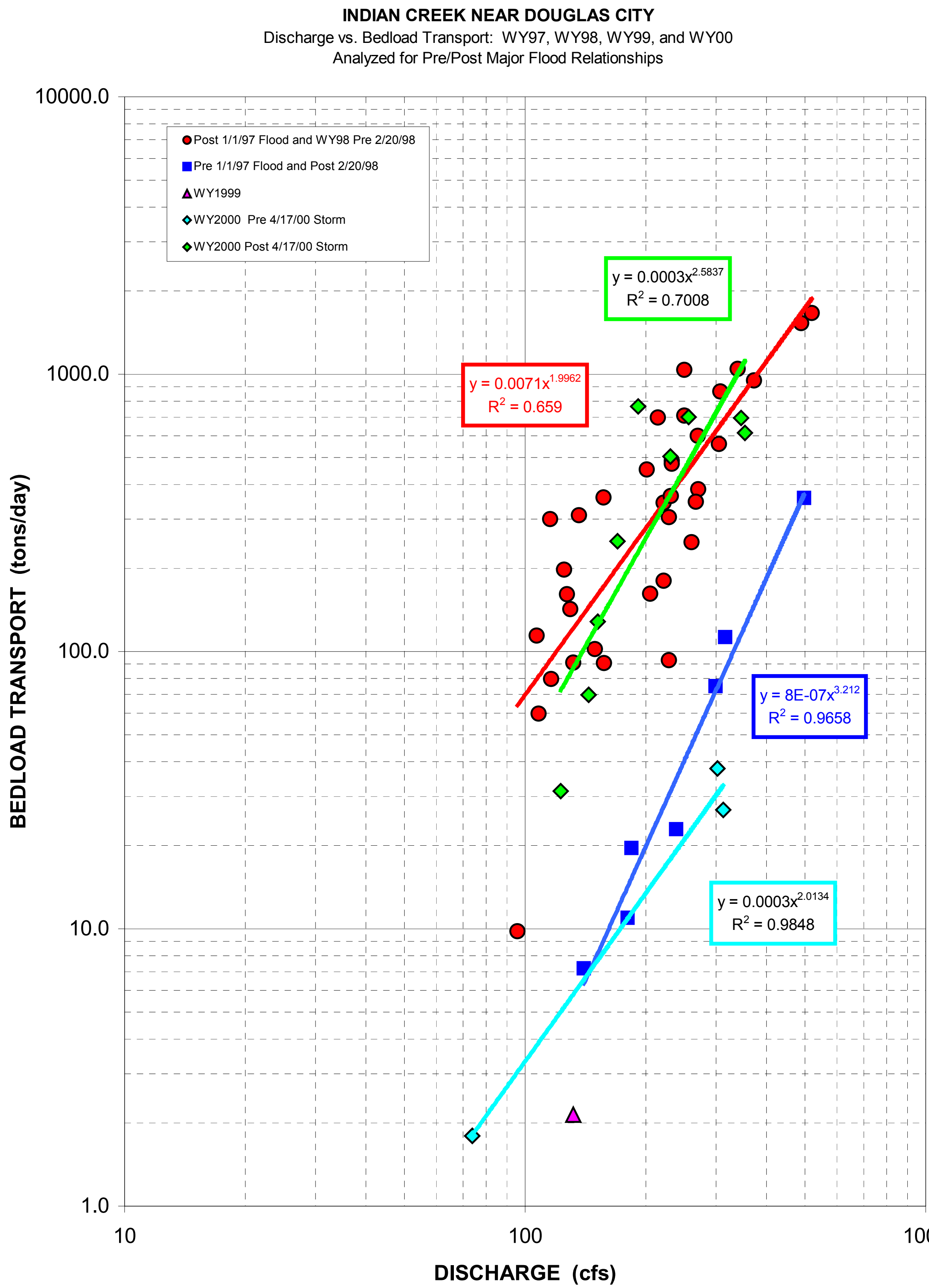
FIGURE

27



PROJECT:

TRINITY RIVER SEDIMENT SOURCE ANALYSIS
Comparison of WY 1997-2000 Bedload Data

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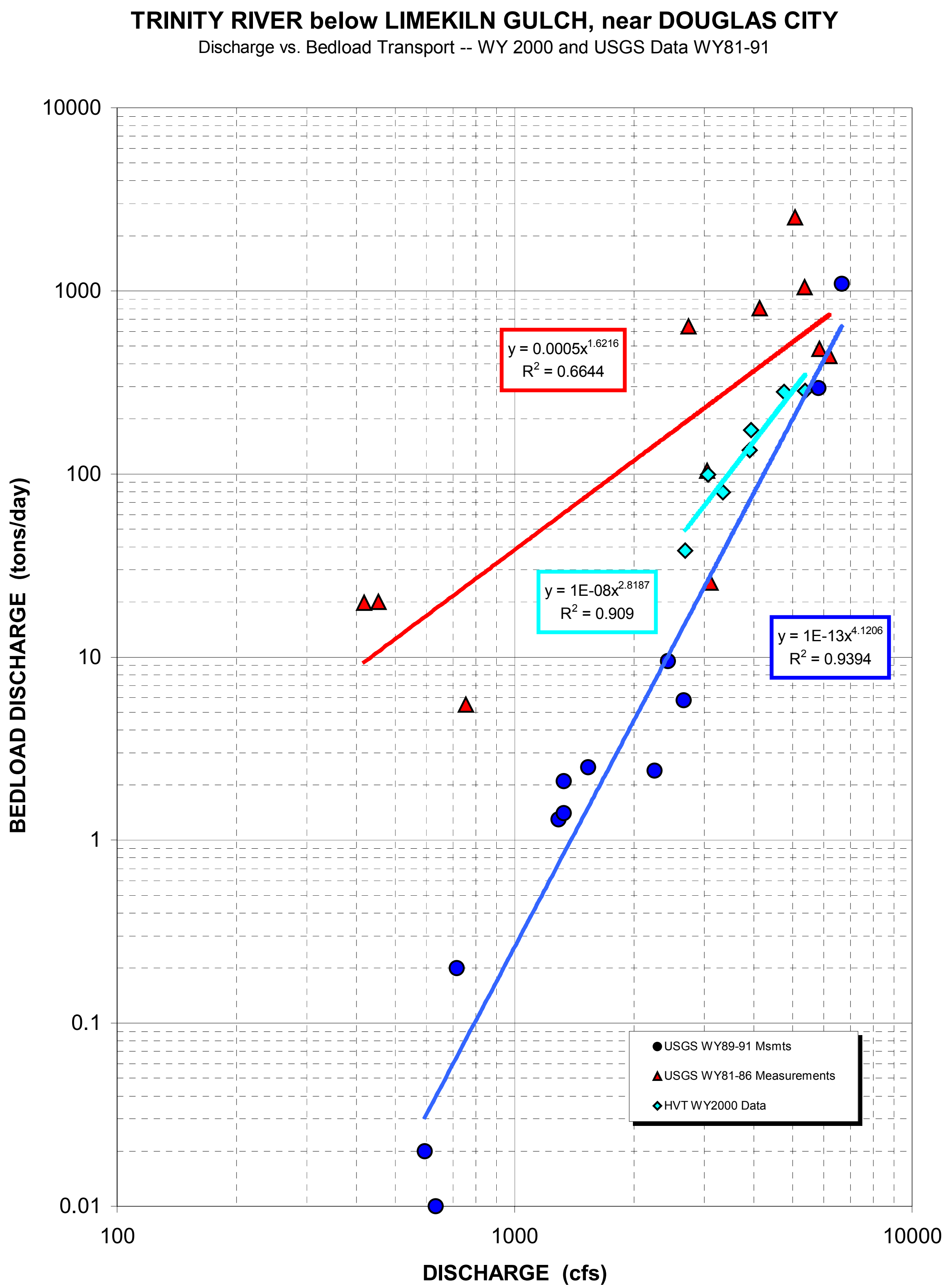
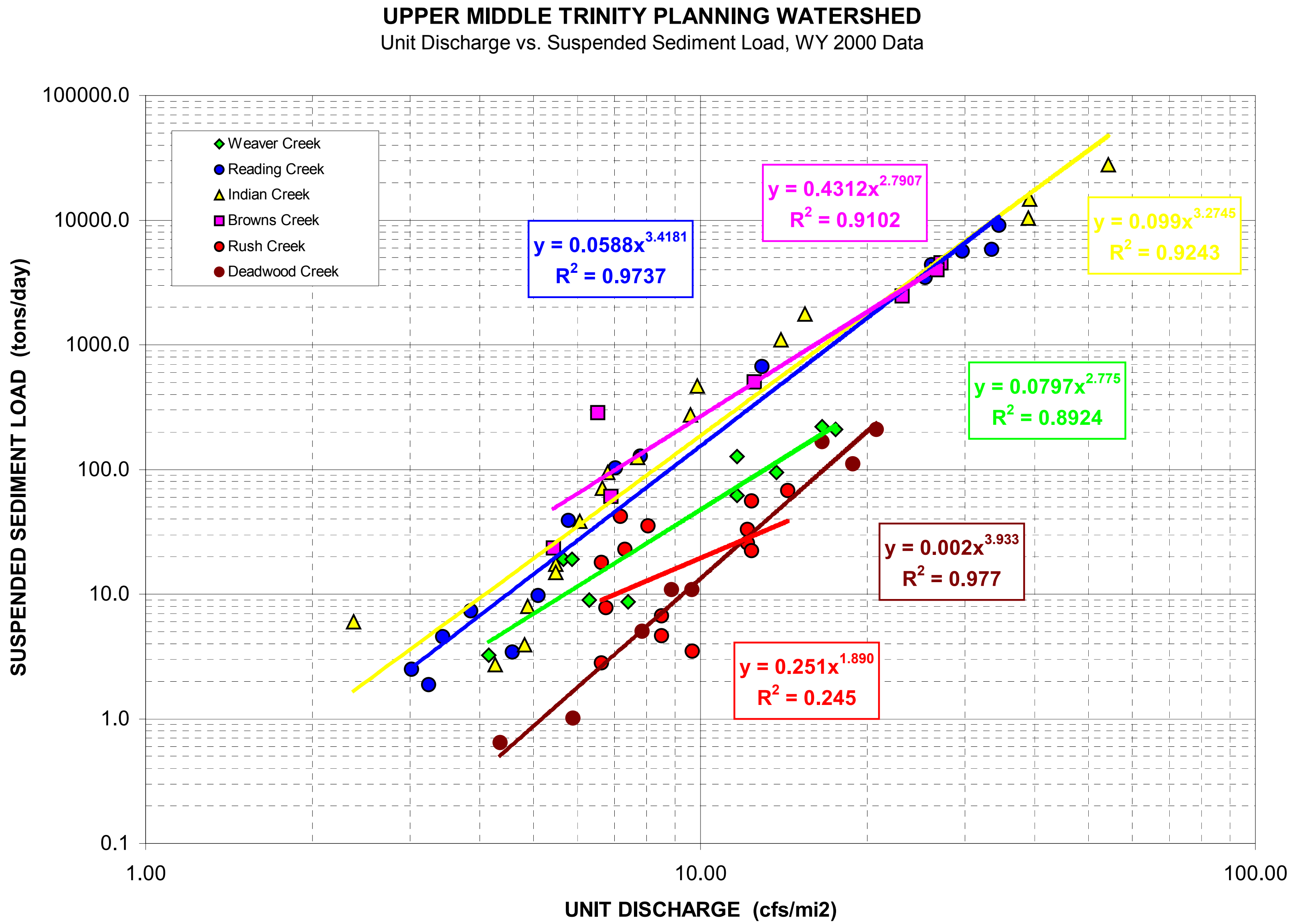
FIGURE

28



PROJECT:	GMA	FIGURE
TRINITY RIVER SEDIMENT SOURCE ANALYSIS Comparison of WY 1981-2000 Bedload Data	GRAHAM MATTHEWS & ASSOCIATES Hydrology • Geomorphology • Stream Restoration P.O. Box 1516 Weaverville, CA 96093-1516 (530) 623-5327 ph (530) 623-5328 fax	29



TRINITY RIVER SEDIMENT SOURCE ANALYSIS
Unit Discharge vs. Suspended Sediment Load

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FIGURE
30

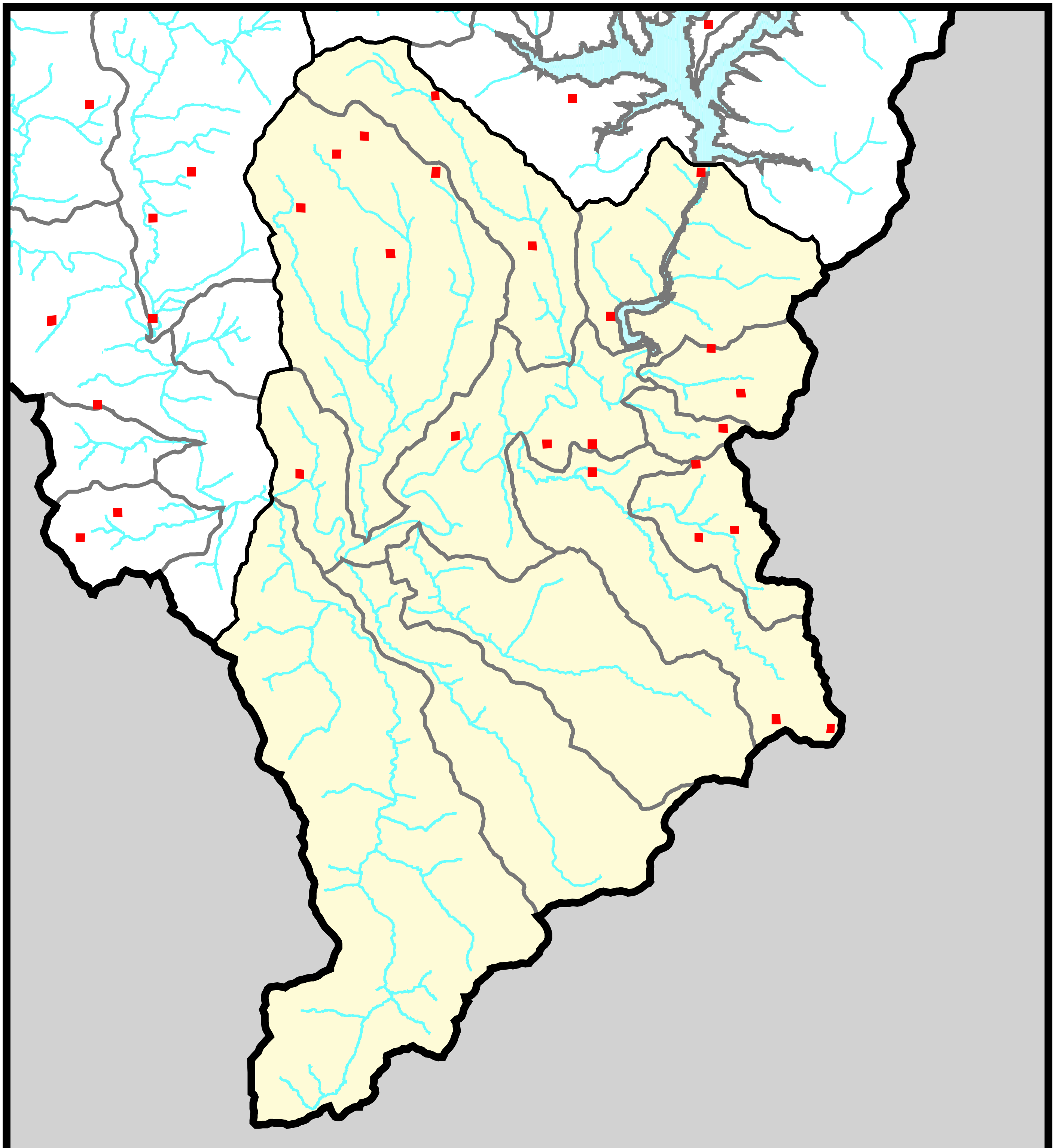
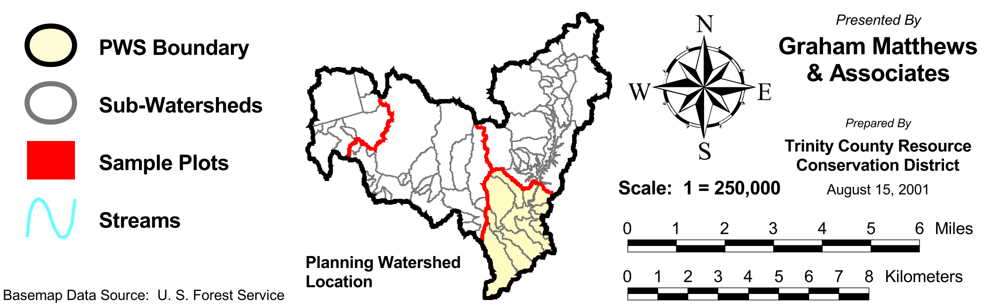


FIGURE 31

TRINITY RIVER WATERSHED

Sample Plot Locations - Upper Middle Trinity River Planning Watershed



Presented By
Graham Matthews & Associates

Prepared By
Trinity County Resource Conservation District

August 15, 2001

KDS

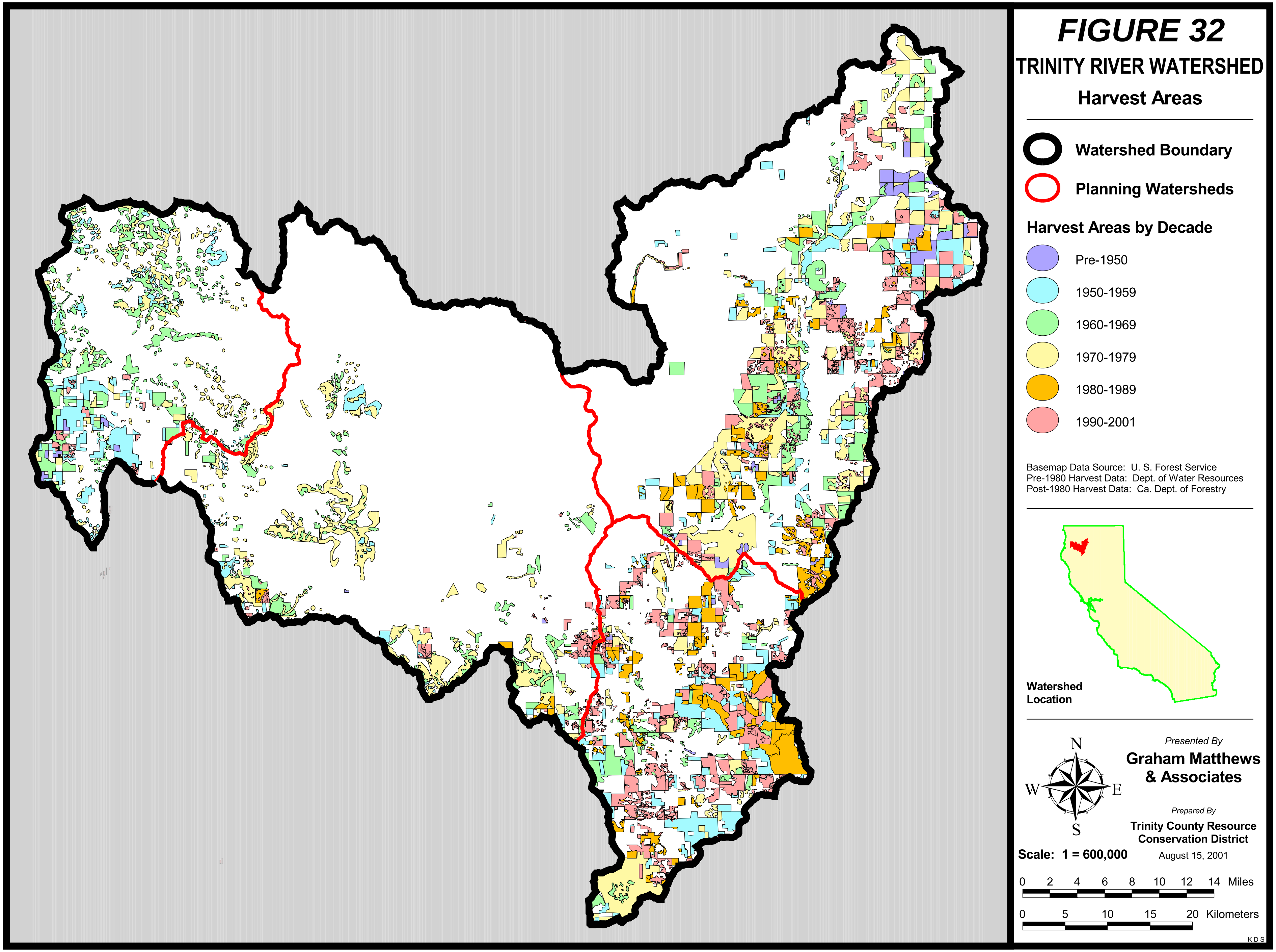
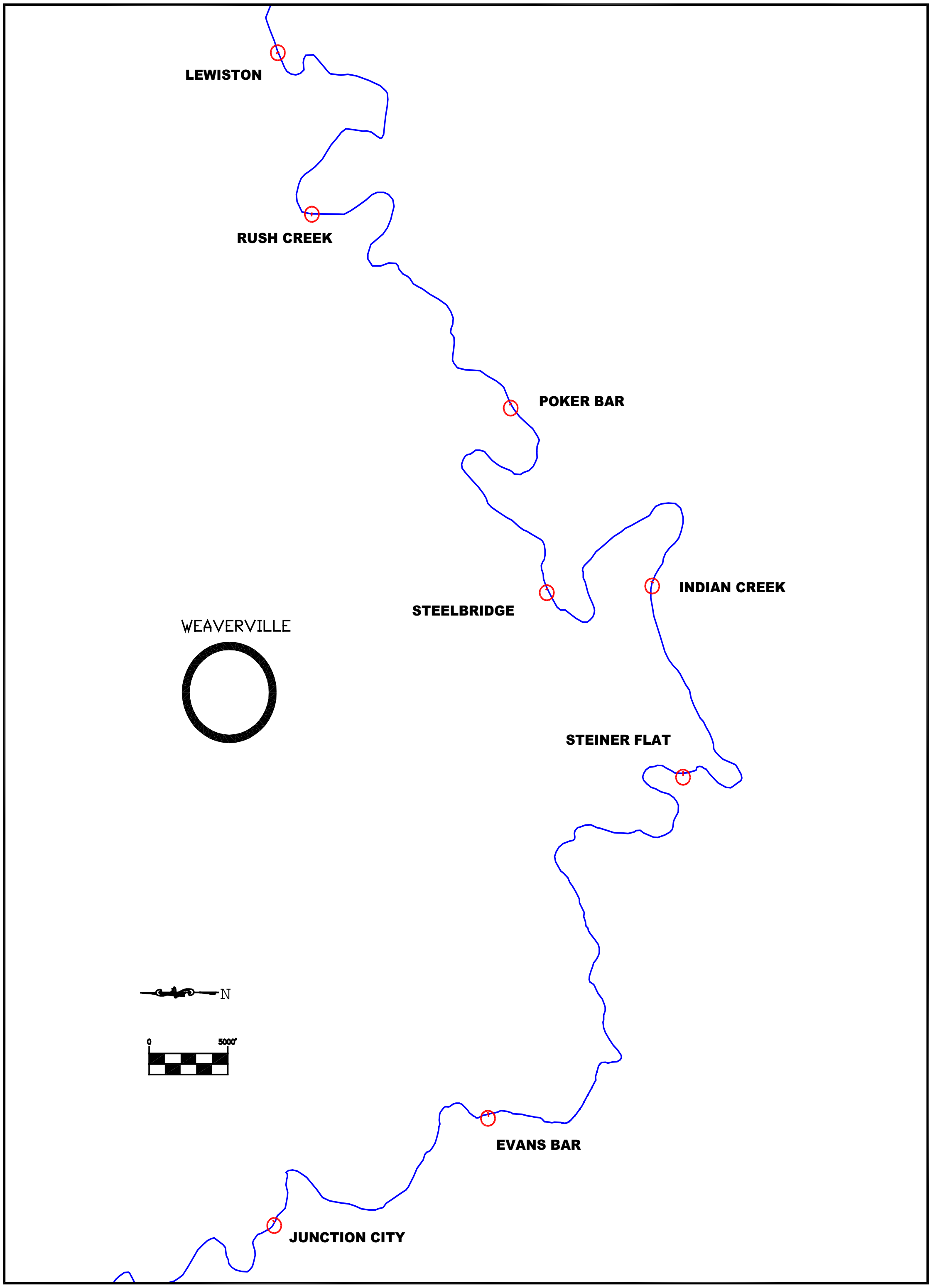
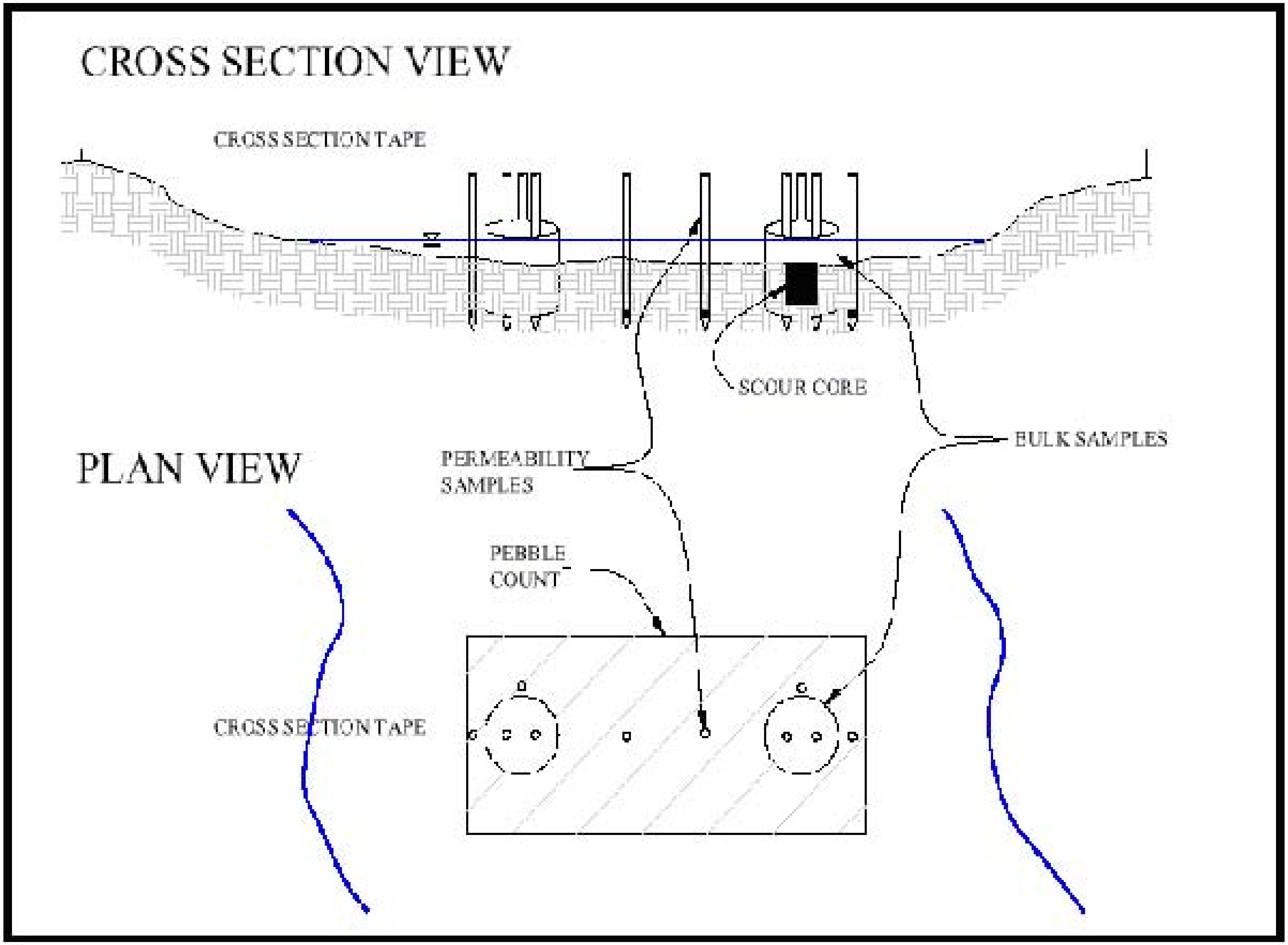


FIGURE 32
TRINITY RIVER WATERSHED
Harvest Areas
Watershed Boundary
Planning Watersheds
Harvest Areas by Decade
Pre-1950
1950-1959
1960-1969
1970-1979
1980-1989
1990-2001
Basemap Data Source: U. S. Forest Service
Pre-1980 Harvest Data: Dept. of Water Resources
Post-1980 Harvest Data: Ca. Dept. of Forestry
Watershed Location
N
W
E
S
Presented By
Graham Matthews & Associates
Prepared By
Trinity County Resource Conservation District
August 15, 2001
Scale: 1 = 600,000
0 2 4 6 8 10 12 14 Miles
0 5 10 15 20 Kilometers
K D S



Source: GMA (2001a)

PROJECT:	GMA	FIGURE
TRINITY RIVER SEDIMENT SOURCE ANALYSIS Location Map of Mainstem Gravel Sampling Sites	**GRAHAM MATTHEWS & ASSOCIATES** Hydrology • Geomorphology • Stream Restoration P.O. Box 1516 Weaverville, CA 96093-1516 (530) 623-5327 ph (530) 623-5328 fax	**33**



Source: GMA (2001a)

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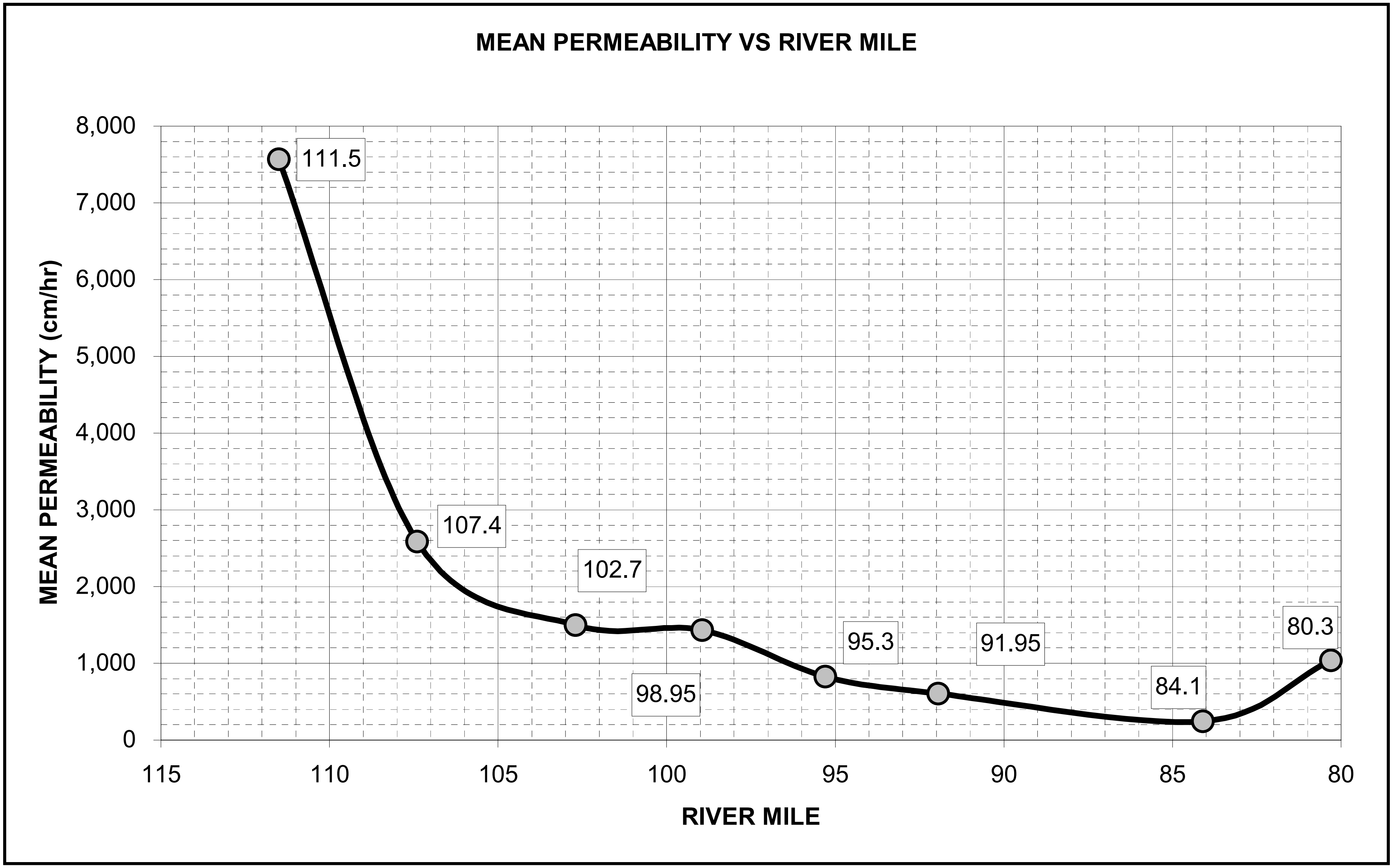
FIGURE

34



Source: GMA (2001a)

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FIGURE

35

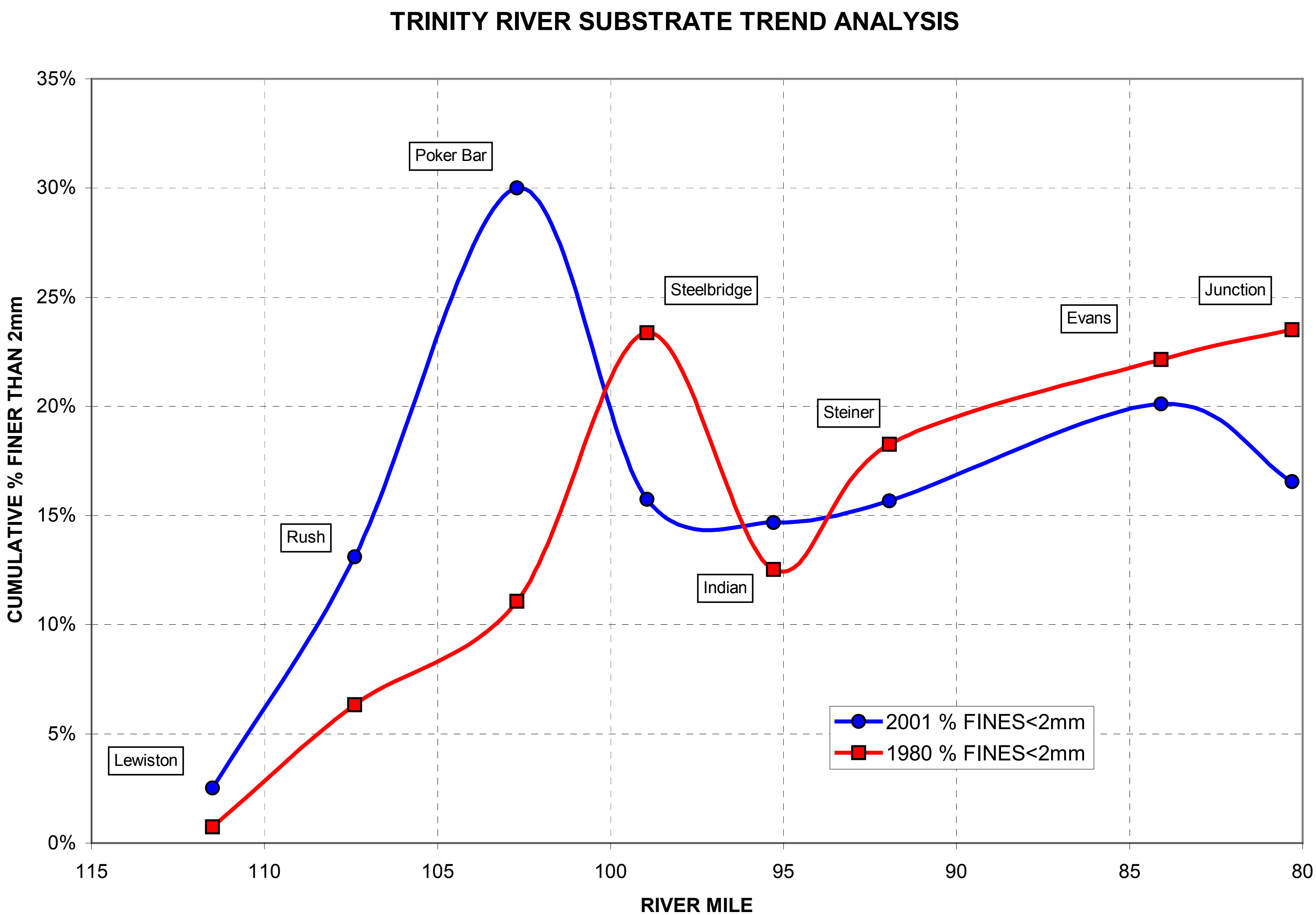

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FIGURE

36

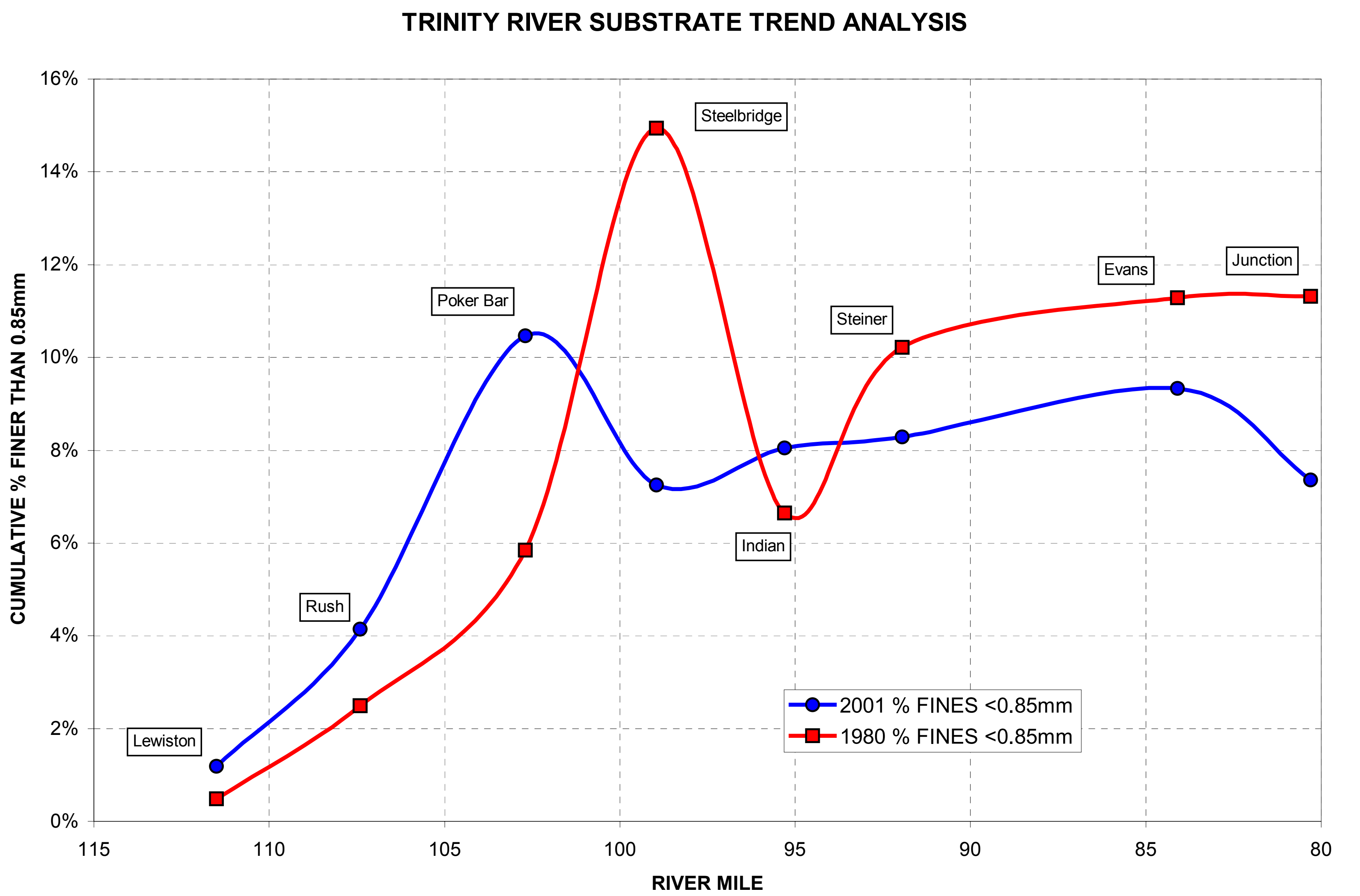

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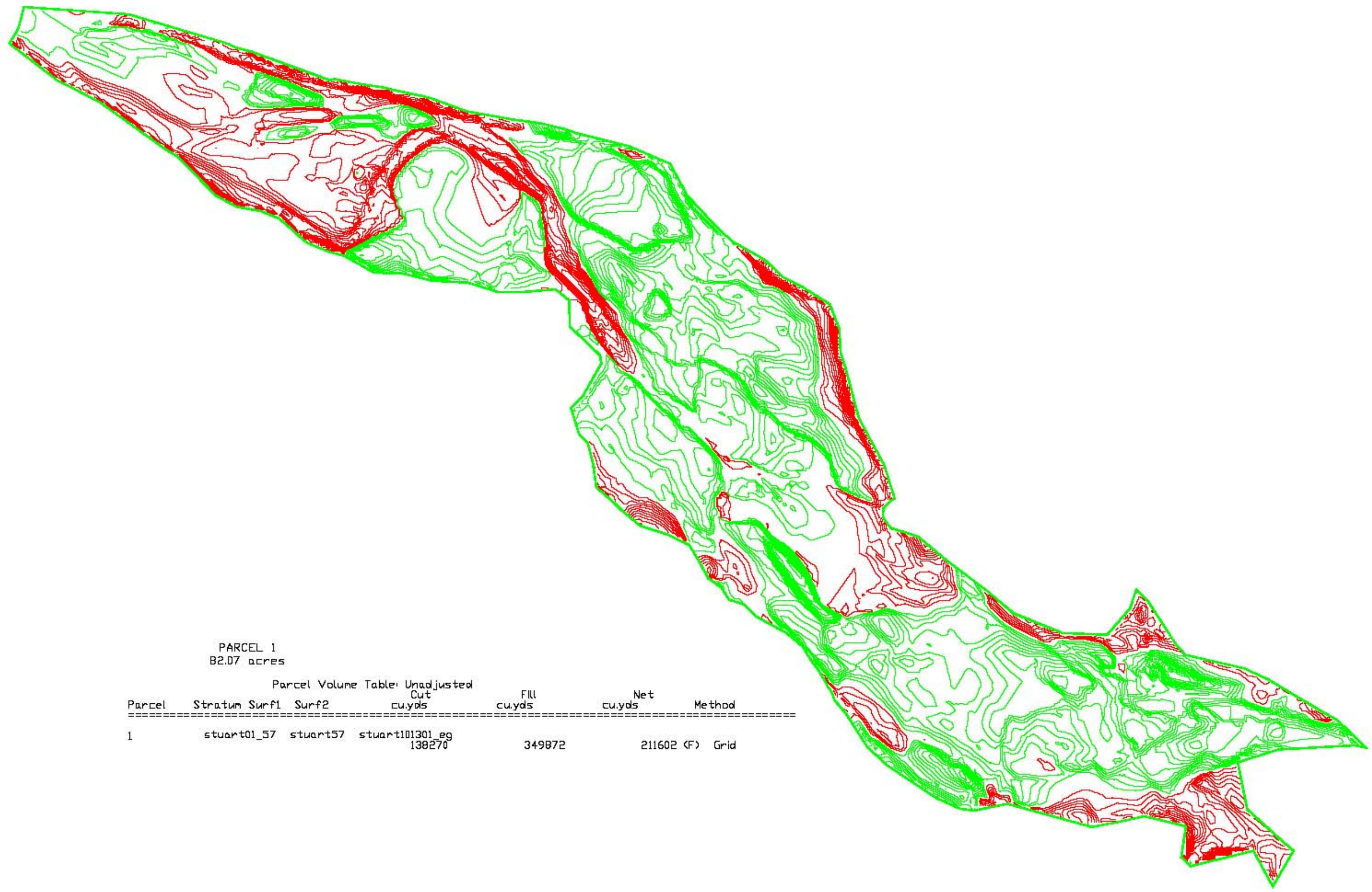
FIGURE

37



PARCEL 1
82.07 acres

Parcel Volume Table: Unadjusted

Parcel	Stratum	Surf1	Surf2	Cut cu.yds	Fill cu.yds	Net cu.yds	Method
1	stuart01_57	stuart57	stuart101301_eg	138270	349872	211602 (F)	Grid

TRINITY RIVER SEDIMENT SOURCE ANALYSIS
Stuart Fork Delta Isopach (cut/fill) Analysis

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FIGURE

38