U.S. ENVIRONMENTAL PROTECTION AGENCY
REGION 9

SOUTH FORK TRINITY RIVER AND HAYFORK CREEK SEDIMENT TOTAL MAXIMUM DAILY LOADS

December 1998

APPROVED BY:

Alexis Strauss Acting Director Water Division EPA Region 9	Date

TABLE OF CONTENTS

Executive Summary

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

The South Fork Trinity River is a tributary to the Trinity River, in the Klamath River Basin of northern California. The watershed is primarily forested, and is located within Trinity and Humboldt Counties. The purpose of the South Fork Trinity River Sediment Total Maximum Daily Load (TMDL) is to identify loading allocations that, when implemented, are expected to result in the attainment of applicable water quality standards for sediment. The South Fork Trinity River watershed is included on California's Clean Water Act (CWA) Section 303(d) list as water quality limited due to sediment. The sedimentation in the South Fork Trinity River watershed was judged to exceed the existing Water Quality Standards (WQS) necessary to protect the beneficial uses of the basin, particularly the cold water fishery. Accelerated erosion from land use practices and natural sources impacts the migration, spawning, reproduction, and early development of cold water fish such as spring and fall run chinook salmon and steelhead trout.

This TMDL addresses sediment loading in the entire South Fork Trinity River basin, including Hayfork Creek and other tributaries. The components of the TMDL are: a **problem statement**, including assessment of instream and upslope conditions; identification of instream **numeric targets**, intended to interpret and apply the narrative WQS and represent acceptable instream conditions for cold water fish; an **analysis of significant sediment sources** that have in the past or are presently impacting the stream system; a **linkage analysis** to assess the magnitude of reductions necessary to attain the numeric targets; an **allocation of loads**, which distributes needed load reductions among various sources; and several other sections designed to address considerations set forth in Section 303(d) of the Clean Water Act or the implementing regulations at 40 CFR 130.7.

The TMDL was developed by reviewing and analyzing existing data on instream resources and desired conditions. Numeric targets were developed (Table E-1) based on literature sources, existing data for the South Fork, and best professional judgment. The values of the indicators selected are expected to vary on an inter-annual basis, and the target values will be achieved over the long term. For these reasons, the instream targets are expressed as a long-term running averages, and a weight-of-evidence approach is suggested in determining progress toward the targets. This will also serve the purpose of documenting trends. For some targets, a lack of adequate existing data suggested the need to express the targets in terms of improving trends. Hillslope targets are also included to ensure that watershed conditions will progress toward necessary water quality improvements in the long term and in the face of naturally-fluctuating instream conditions.

A sediment source analysis was developed to determine sources and quantities of sediment delivery to the stream system. Sediment delivery to the stream averaged 1,053 tons/mi^2/yr over the period 1944-1990. The source analysis utilized air photo analysis, modeling and literature-based erosion rates to estimate sediment production over the period. The dominant process in the basin is mass wasting (landsliding and debris flow), accounting for approximately 64% of the basin-wide sediment delivery. Most of the landslides occurred in the 1960-1975 period, although specific quantities for each time period have not been determined. Most of the mass wasting sediment delivery is associated with non management-related sources in the Upper and Lower South Fork sub-basins. It is likely that the quantity associated with management in some locations is underestimated due to cumulative effects, and in other cases some mass wasting due to natural causes may be classified as management-associated. Seventy-eight percent of landslide volumes in the lower South Fork Trinity River (USFS 1996, as modified by Raines 1998) were identified as inner gorge features, and 92% of those landslides were assigned to natural causes. It is likely

that some of these were caused by cumulative upstream effects of management during the 1964 flood, but were not apparent in the analysis. The Hayfork Creek Area, by contrast, produces less sediment overall, and is more influenced by road-related erosion than by mass wasting. Road-related sediment delivery has continued to increase from 1944 to the present time.

Table E-2 compares numeric target values with existing conditions. While the needed water quality improvements varies for each of the indicators, an overall improvement of about 30% is reasonable to achieve target conditions. Because the linkages between sediment sources in the watershed with instream conditions are generally indirect, highly variable, and not well understood, a one-to-one correspondence was used to determine necessary reductions. This is not intended to represent direct cause-and-effect linkages, but is considered to represent a conservative approximation of the quantities of sediment reduction needed.

Reductions of 30% from the historical loading rate were allocated to various sources by estimating the percentage of controllable loads for each source. This reduction represents a conservative approach to identifying the load reductions needed for the South Fork Trinity River basin. Table E-3 summarizes both the sediment source delivery for the basin and the allocations. An explicit margin of safety, allocating 63 tons/mi^2/yr, is used and is assumed to account for management sources that are incorrectly identified as non-management related. In addition, qualitative adjustments were made to account for other uncertainties. For example, many conservative assumptions were made in developing the source analysis, and bank erosion estimates are considered high.

This TMDL addresses sediment impairment only. High temperatures were identified as additional sources of impairment in the 1998 303(d) listing process, but time constraints prevent EPA from including both sediment and temperature impairments in this TMDL. Impairments specifically related to temperature impairments will be addressed in a future TMDL.

Table E-1: Indicators and Targets

Desired Condition Indicator	Target Value[1]	Notes
1. Fish Population Recovery: *Diminished fish population is the strongest indication of impaired habitat conditions; thus, recovered populations are the strongest indication of recovered habitat conditions. EPA recognizes, however, that populations depend upon factors both within and outside of the basin. If the fish population recovery targets are attained, it is clear that WQS related to the cold water fishery have been attained, and other targets should be re-evaluated to determine if an adjustment is appropriate. If the fish population recovery targets are not attained despite other targets being attained, the fish population may be more affected by factors outside of the basin and progresss toward attaining other targets should continue.*		
1a. Spring Chinook Escapement	4,000	Targets are for naturally-reproducing escapement. Fish population targets are not required to be reached to demonstrate attainment of WQS.
1b. Fall Chinook Escapement	3,000	
2. Channel Form & Structure Recovery: *Channel form indicators should show an overall movement of existing elevated levels of in-channel substrate out of the basin and overall increased depths of pools (approaching conditions prior to 1964 flood). Indicators address movement of 1964 in-channel flood deposits and improving habitat conditions.*		
2a. Number/Depth of Mainstem South Fork Pools	Increasing trend	Overall increased number of pools greater than 15 feet depth and increase in maximum depth of individual pools within reaches tracked over time.
2b. Tributary Pool Recovery-V*	0.21 western tribs; 0.10 other tribs	Reference: Lisle and Hilton 1992, Hilton and Lisle 1993, Knopp 1993, Lisle, pers. comm. 1998. Western tribs are those subwatershed areas in predominantly “fines-rich” geology west of the mainstem South Fork Trinity River.
2c. Increased channel complexity: channel thalweg profile and cross section surveys	Increasing trend of improvement	Evaluated as variation from mean thalweg profile slope and cross section/profile changes in response reaches, indicating increased pool depth/channel complexity and downstream sediment movement.
3. Improved Substrate Size Distribution: *High proportions of fine sand in spawning gravel and in pools are linked with decreased fish populations and decreased spawning success (e.g., Chapman 1988, PWA 1994).*		
3a. Substrate sediment < 0.85 mm	≤14% by volume	Measured in potential spawning gravels and evaluated as long-term running averages; addresses embryo development and emergence. Reference: Burns 1970, Cederholm et. al 1981, Chapman 1988, Peterson et. al 1992, Borok and Jong 1997.
4. Decreased Sediment Delivery: *Addresses the need to achieve adequate watershed conditions to ensure adequate water quality and to reduce temporarily “controlled” water quality impairments in order to achieve desired stream conditions.*		
4a. Stream crossings with diversion potential	≤1%	Reference: Weaver and Hagans 1994; D. Hagans, pers. comm., 1998, C. Tarwater, pers. comm., 1998, Furniss et. al 1998. Only those crossings that cannot be corrected without compromising safety are expected to fall within the 1% value.
4b. Stream crossings with significant crossing failure potential	≤1%	Culverts and crossings designed to pass the 100 year flood, including snowmelt, and associated debris and sediment, targeting crossings with highest probability of failure and highest consequences (damage to aquatic resources, large volumes of fill, etc.). Reference: Flanagan et. al 1998. Adequate justification (e.g., public safety concerns and insigificant risk to aquatic resources) would be expected to explain those crossings that are not upgraded. These are expected to fall within the 1% value.
4c. Annual road inspection/maintenance	all roads, or closure	All roads would be inspected annually prior to winter. Conditions that are likely to deliver sediment to streams would be corrected, otherwise roads will be hydrologically closed/disconnected (fills and culverts removed, natural hydrology of hillslope largely restored).
4d. Road location, surfacing, hydrologic connectivity, sidecast	minimized sediment delivery	1) All roads alongside inner gorge areas or in potentially unstable headwall areas should be removed unless alternative road locations are unavailable and need for road is clearly justified. 2) Road surfacing, drainage methods and maintenance are appropriate to their use patterns and intensities. 3) hydrologic connectivity is assessed and reduced to the extent feasible. 4) Sidecast/fill on steep or potentially unstable slopes pulled back/stabilized.
4e. Timber harvest sediment delivery potential	Avoided subject to geological investigation	No clearcut harvesting and/or tractor yarding in steep, potentially unstable streamside areas unless a detailed geological assessment shows no potential for increased sediment delivery to water courses.

[1] Instream targets are to be evaluated on a weight-of-evidence basis as a long-term rolling averages, as specified in the monitoring plan currently under development. Inter-annual variability is expected in the values.

Table E-2: Comparison of Existing and Historic Conditions with Numeric Targets

Indicator/Target[1]	Existing Conditions	Improvement Needed
4,000 spring chinook spawners	Last 5-10 yrs: 400-700/yr avg	6-10 x current numbers for spring chinook. Probably influenced by improved pool habitat as excess sediment continues to move out of the system. Attaining the target may be influenced by factors outside of the basin.
3,000 fall chinook spawners	1993-97: 1,400/yr avg 1988-97: 800/yr avg	2-4 x current numbers for fall chinook. Probably influenced by improved pool habitat as excess sediment continues to move out of the system. Attaining the target may be influenced by factors outside of the basin.
Mainstem Pool Depth	Baseline monitoring underway	Improving trend indicating deepening of large pools and increased number of pools deeper than 15 ft.
V* 0.21 in western tributaries: 0.10 elsewhere	Avg 0.36 in Grouse Ck; 0.069-0.12 in 5 tributaries	Grouse Creek samples indicate a need for 42% reduction in fines. Basinwide, reduction of 0-17% indicated by existing data, but reductions would depend upon monitoring results.
Improving trend suggested by thalweg and cross-section surveys	Baseline monitoring underway	Improving trend indicating continued downstream movement of sediment, deepening of pools and increase in overall habitat complexity.
≤14% sediment <0.85 mm	17% all samples; 18% all SFTR samples	Existing data reflects impairment from excess fine sediment, suggesting approximately an 18% reduction in fines overall, or a 22% reduction in South Fork mainstem stations.
≤1% of all stream crossings w/ diversion potential	37% avg in 4 Upper SFTR subwatersheds; estimated appx. 50-65% of all crossings in the basin	Appx. 35-60% of existing crossings should be upgraded basinwide.
≤ 1% significant crossing failure	not known	Assess risk; improving trend until target conditions are met.
All roads inspected annually & maintained or hydrologically closed.	Appx 20% USFS roads; appx. 33% industrial roads	20-33% reduction overall in inadequately maintained roads (100% reduction of existing inadequately maintained roads)
No roads in inner gorge/headwalls, appropriate surfacing, reduced hydrologic connectivity, no fill/sidecast on steep slopes	Existing level of risk is not known basinwide	Assess risk; improving trend until target conditions are met.
Timber harvest: No clearcut/tractor yarding on steep slopes	Existing level is not known basinwide.	Assess risk; mproving trend until target conditions are met.

[1] Instream targets are intended to be assessed over long-term running averages; significant inter-annual variability is expected.

Note: See Numeric Targets Chapter (3) for sources and additional explanation.

Table E-3: Summary of TMDL and Allocations for the South Fork Trinity RiverWatershed

a	b	c	d	e
Source Mechanism	**Historic Sediment Load 1944-1990[1] (t/mi²/yr)**	**Percent Controllable[2]**	**Controllable Load[3] (t/mi²/yr)**	**Remaining Load (Allocation)[4] (t/mi²/yr)**
Management Sources				
Harvest-Mass Wasting	75	60%	45	30
Harvest-Surface Erosion	22	85%	19	3
Roads-Mass Wasting	80	80%	64	16
Roads-Surface Erosion	71	85%	60	11
Roads-Washouts, gullies, small slides	42	85%	36	6
Cumulative/Other-MassWasting and Bank Erosion	81	35%	29	52
SUBTOTAL-Harvest	*97*	*66%*	*64*	*31*
SUBTOTAL-Roads	*193*	*83%*	*160*	*33*
Total Management Sources	371	68%	253	118
Non Management Sources				
Mass Wasting	521	0%	0	521
Surface Erosion	16	0%	0	16
Bank Erosion	145	0%	0	145
Total Non Management Sources	682	0%	0	682
Margin of Safety[5]			63	(63)
TOTALS	1,053	30%	316	737

[1] The estimated historic sediment load for each source.

[2] The percent of that historic load that is estimated as controllable. Controllable discharges are those discharges resulting from human activities that can influence the quality of the waters of the State and that can be reasonably controlled.

[3] The load that is estimated as controllable (the percent controllable multiplied by the historic load).

[4] The difference between the historic load estimate and the controllable load estimate. This is the estimated load at which salmonids in the South Fork basin would no longer be limited by sediment.There are no point sources in the basin; therefore, no waste load allocation is included.

[5] The margin of safety is defined as the portion of the load allocation that is reserved. It is assumed that the reserved load actually represents controllable management sources that have been assigned in the source analysis to non-management sources.

1. INTRODUCTION

The South Fork Trinity River (SFTR) has historically been recognized as a major producer of chinook and coho salmon and steelhead trout (PWA 1994). The South Fork originates in the North Yolla Bolly Mountains about 50 miles southwest of Redding, and runs northwest for approximately 90 miles before reaching its confluence with the Trinity River near Salyer (Figure 1). It flows mostly through Trinity County, forming the boundary between Trinity and Humboldt Counties in its lower 12 miles. The South Fork and its main tributary, Hayfork Creek, are both undammed. The South Fork Trinity River is the largest undammed river in California, and constitutes 31 percent of the Trinity River sub-basin, and 6 percent of the Klamath basin (USDA FS 1998). The 56 mile stretch from Forest Glen to the mouth is protected by the California Wild and Scenic Rivers Act.

The fishery in the South Fork has declined dramatically since the flood of December 1964. Unstable geology and erosion-producing land use practices have been blamed for the many mass wasting events triggered by that flood, which resulted in dramatic instream changes, including channel widening, aggradation, and loss of pool depth, all of which adversely affect the fishery. Since that time, further channel changes suggest improvements in some locations, while continued, chronic sediment inputs may be hindering a more complete or faster recovery overall. The chinook salmon spawning run has increased slightly in the last several years, and sediment slugs continue to move downstream, which may suggest the beginnings of a trend toward recovery.

The purpose of the South Fork Trinity River Sediment Total Maximum Daily Load (TMDL) is to identify reductions of sediment delivery to the river system that, when implemented, are expected to result in the attainment of applicable water quality standards, including adequate salmonid habitat.

303(d) LIST AND TMDL PROCESS

Section 303(d)(1)(A) of the Clean Water Act requires that "Each State shall identify those waters within its boundaries for which the effluent limitations...are not stringent enough to implement any water quality standard applicable to such waters." The South Fork Trinity River watershed is included on California's Clean Water Act (CWA) Section 303(d) list as water quality limited due to sediment. The level of sedimentation in the South Fork Trinity River watershed was judged to exceed the existing Water Quality Standards (WQS) necessary to protect the beneficial uses of the basin, particularly the cold water fishery. Accelerated erosion from land use practices and other causes adversely affects the ability of the stream system to support cold water fish such as chinook salmon and steelhead trout.

The requirements of a TMDL are described in 40 CFR 130.2 and 130.7 and Section 303(d) of the CWA, as well as in various guidance documents (e.g., U.S. EPA, 1991). Essentially, the TMDL is a plan to achieve water quality standards, by describing an appropriate loading capacity for the water body, with an analysis based on the best existing available information. The loading capacity of the water body under the TMDL is defined as "the sum of the individual wasteload allocations for point sources and load allocations for nonpoint sources and natural background" (40 CFR 130.2) such that the capacity of the waterbody to assimilate pollutant loadings (the Loading Capacity) is not exceeded. There are no point sources of sediment in the South Fork Trinity River watershed.

Organization of Document

This TMDL includes: an assessment of the pollutant problems and impacts on the beneficial uses (Chapter 2), development of numeric targets that interpret and apply the WQS (Chapter 3), an assessment of the sources of the pollutant (Chapter 4), an estimation of loading capacity and linkages (Chapter 5) and associated load allocations to meet WQS (Chapter 6). It also considers seasonal variations and includes a margin of safety to account for uncertainty in the analysis (Chapter 7). Suggestions for the State's implementation and monitoring plans are summarized briefly in Chapter 8, and Chapter 9 describes the public participation process in the TMDL development. References are listed in Chapter 10, and Chapter 11 contains a glossary.

Sub-basins and Subwatershed Areas

The South Fork Trinity River Basin can be divided into three main sub-basins (Figure 2): the upper South Fork sub-basin, from the headwaters to its confluence with Hayfork Creek; the lower South Fork sub-basin, including tributaries that drain directly to the South Fork Trinity River from the Hayfork Creek confluence downstream to the confluence with the mainstem Trinity River (not a sub-basin in the hydrological sense since it is downstream of the other two sub-basins); and the Hayfork Creek sub-basin.

These three sub-basins are distinct from one another. The Upper South Fork sub-basin is fairly steep and mountainous, with highly erodible, steep, short tributaries west of the mainstem and steeper but more lengthy and complex tributaries east of the mainstem. Tributaries entering the Lower South Fork are similar, although the mainstem itself includes a very low gradient reach in the Hyampom Valley as well as a steeper reach downstream of that flowing through an entrenched gorge. The Hayfork Creek sub-basin, which is particularly distinct from the Upper and Lower South Fork Trinity River sub-basins, is relatively stable geologically. The forested headwaters contain high gradient reaches of the stream, leading to the broad, flat Hayfork Valley, leading to a steeper reach entering the mainstem South Fork Trinity River at the Hyampom Valley.

Much of the readily available information has been further divided into 19 smaller subwatershed areas (also shown on Figure 2). Many of these are not hydrological subwatersheds, since they may drain several distinct tributaries on one or both sides of the South Fork Trinity River or Hayfork Creek, or may be bordered by the mainstem South Fork Trinity River. Nevertheless, considering these subwatershed areas can in some cases facilitate a more complete understanding of the basin and the influence of management activities on water quality as well as a focus on specific areas with the greatest degree of impairment to the stream system.

Sediment TMDL

The South Fork Trinity River basin was first added to the 303(d) list for sediment in 1992. The Environmental Protection Agency (EPA) has oversight authority the state of California for the 303(d) program and is required to review and either approve or disapprove the TMDLs submitted by states. Pursuant to a consent decree entered in the United States District Court, Northern District of California, (*Pacific Coast Federation of Fishermen's Associations, et al. v. Marcus*, No. 95-4474 MHP, March 11, 1997) EPA committed to ensuring that TMDLs would be established for 18 rivers by December 31, 2007. EPA also developed a supplemental TMDL Establishment Schedule, under which TMDLs would be established by December 31, 1998, for the South Fork Trinity River and Hayfork Creek basins. Although

Hayfork is included as a separate “unit” in the Supplemental TMDL Establishment Schedule, EPA has determined that it is most appropriate from a watershed planning standpoint to establish one TMDL covering the entire South Fork Trinity River watershed, including Hayfork Creek and other smaller tributaries. Thus, this TMDL covers Hayfork Creek as well as the mainstem South Fork.

Water Temperature

Temperatures in the lower South Fork and selected tributaries, particularly the lower portion of Hayfork Creek, have been implicated as being too high to fully support aquatic habitat. Existing information suggests that high temperatures could result from: natural conditions (i.e., the lower South Fork was always relatively warm in the summer, even prior to active land management in the basin), water diversions (particularly in Hayfork Creek), loss of riparian vegetation in selected locations, and excess sedimentation that resulted in channel widening and decreased water depths.

In 1998, the North Coast Regional Water Quality Control Board (NCRWQCB) added temperature impairment to its 303(d) list for the South Fork Trinity River. In response to this, several individuals representing private industry and public industry assembled temperature from a variety of sources in an effort to begin a collective monitoring process (Farber et. al 1998). While it is possible that further analysis in the future may reveal temperature conditions to be a greater limiting factor than sediment in some locations, this TMDL addresses sediment issues only. Because the Consent Decree does not require this TMDL to address to address the temperature impairment, a separate TMDL for temperature will be established in the future.

Implementation and Monitoring

Upon establishment of the TMDL by EPA, the State is required to incorporate the TMDL, along with appropriate implementation measures, into the State Water Quality Management Plan (40 CFR 130.6(c)(1), 130.7). The North Coast Regional Water Quality Control Board Basin Plan and applicable state-wide plans serve as California’s Water Quality Management Plan governing the South Fork Trinity River watershed.

There are no implementation or monitoring plans included as part of this document because they are not required components of a TMDL. The main responsibility for water quality management and monitoring resides with the State. Moreover, the NCRWQCB is in the process of developing an implementation and monitoring plan for this TMDL. However, EPA and the State have worked cooperatively through the TMDL development process, and EPA has reviewed a preliminary draft of the implementation plan (NCRWQCB 1998). This TMDL does contain implementation and monitoring recommendations that may contribute to the States efforts.

BASIN CHARACTERISTICS

The South Fork Trinity River basin consists of approximately 932 square miles of primarily mountainous forested lands, with two broad agricultural valleys occupied by the towns of Hayfork and Hyampom. Elevations in the basin range from more than 7,800 feet above sea level in the headwater areas of the North Yolla Bolly Mountains, to less than 400 feet at the confluence with the Trinity River.

Logging began as early as 1949 in the Grouse Creek subwatershed area, and grew in intensity throughout the basin beginning in the 1960s (USDA FS 1995). Of the 80 percent of the basin that was originally occupied by forest, about half had been logged by 1977 (DWR 1979). The mainstem South Fork is steep and rocky at its headwaters, flat and alluvial in the Hyampom Valley. In its lower reach, extending to the confluence with the Trinity River, its gradient is moderate and it is confined within a canyon. Its tributaries are mostly short, steep mountain streams, with the exception of Hayfork Creek through the Hayfork Valley, where the gradient is very gentle.

Ownership

Approximately 80 percent of the basin is public land managed by the U.S. Forest Service (USFS), with about a third of that managed by Six Rivers National Forest in the lower portion of the basin, and the upper two thirds managed by Shasta-Trinity National Forest (Figure 3). The U.S. Bureau of Land Management (BLM) manages a small parcel in the basin. Three timber companies, Simpson Timber Company, Sierra Pacific Industries and Forest Products, own parcels in several tributaries. The remainder of the watershed is owned privately, by individuals for residences and, particularly in the Hayfork Valley, agricultural operations. There are no formal tribal lands in the watershed, but two Indian tribes, which are not formally recognized by the federal government at the present time, claim ancestral rights to lands in the upper South Fork (Nor Elmuk Band of Wintu Indians) and Madden (Old Campbell) Creek, a tributary to the lower South Fork (Tsnungwe Tribe). The Hoopa Valley Tribe also claims ancestral rights to tributary areas of the lower South Fork. However, there is no formally recognized Indian Country in the basin.

Geology

The South Fork Trinity River drains an area containing steep, unstable slopes adjacent to some of the most rapidly eroding terrain in the United States. Rivers to the south and west, such as the Eel, have some of the highest recorded suspended sediment loads in the world (Judson and Ritter, 1964). The South Fork basin straddles the boundary between the Coast Ranges and the Klamath Mountains geologic provinces. The Coast Ranges are underlain by the Franciscan Assemblage, a highly deformed, faulted and sheared complex of partly metamorphosed marine sedimentary and volcanic rocks. Geologic units in the Coast Range Province include the South Fork Mountain Schist, which is highly erodible. Units in the more stable metamorphic and intrusive basement of the Klamath Mountains geologic province include the Galice Formation, Rattlesnake Creek Terrane and the Hayfork Terrane, which includes scattered granitic and ultramafic intrusions. Areas to the east of the mainstem, including most of the Hayfork Creek sub-basin, are generally more stable than the steep slopes of South Fork Mountain and the lower basin.

Figure 4 depicts instability and erosion hazard ratings for the South Fork Trinity River watershed, developed by the California Department of Water Resources (DWR 1982). Very high and extreme rated areas are almost exclusively found on the eastern slope of South Fork Mountain (primarily the west side of the South Fork mainstem, including the Grouse Creek, Old Campbell Creek and lower mainstem areas), while the Hayfork Creek basin and much of the upper South Fork sub-basin, particularly east of the mainstem, is considered to represent only moderate hazard.

Precipitation

Precipitation is highly seasonal, typical of California, with 90 percent falling between October and April. A portion of the annual precipitation falls as snow at the higher elevations (generally higher than about 2,000 ft). Annual precipitation ranges from about 35 inches in the Hayfork Valley to over 80 inches on the west side of the basin along the northern end of South Fork Mountain (Figure 5). Generally, unstable areas on the

west side of the South Fork mainstem also receive the highest rain and snowfall. The combination of heavy rainfall and unstable geology results in highly unstable landscape in the western portion of the basin. Occasionally, rain falls on the existing snowpack, which can result in exceptionally intense flooding.

The basin landscape and its responses to management activities reflect its geology. Accordingly, where feasible, the TMDL presents information or recommendations relative to geology. To the extent that information is available, the TMDL discusses specific locations where water quality standards are being met, and focuses on areas where the sources of sediment are most problematic and where corrections are most achievable.

TMDL Development Process

This TMDL was developed with the benefit of significant public input. EPA obtained much input from members of the South Fork Trinity River Coordinated Resource Management Plan (CRMP), a group of local stakeholders and government agency representatives organized several years ago to work together to make improvements in the basin. EPA staff attended several CRMP meetings to present findings and solicit feedback. EPA also spoke with and solicited input from other individuals and groups not directly associated with the CRMP. This process is described in Chapter 9.

2. PROBLEM STATEMENT

Introduction

Past and present land use practices have accelerated natural erosion processes in the South Fork Trinity River basin, resulting in increased sedimentation in the river channels and decreased support of the cold water fishery, evidenced by significantly decreased runs of spawning salmonids. In particular, available data and anecdotal observations indicate that, following the December 1964 flood, numerous landslides and debris flows delivered considerable quantities of sediment to the stream channel in some reaches, resulting in formation of river deltas in some locations, channel aggradation and widening, decreased depths and numbers of pools, decreased numbers of fish, increases in fine sediments in the bed material, and, apparently, increases in temperatures associated with decreased depths and loss of riparian canopy (Haskins & Irizarry 1988, PWA 1994, Matthews 1998). The overall quantity of sediment delivery to the stream has decreased since then, but chronic inputs of sediment from roads as well as episodic inputs from washouts and mass wasting continues (Matthews 1998, Raines 1998, D. Hagans, pers. comm. 1998, M. Smith, pers. comm. 1998).

Limitations to the water quality related to the effects of accelerated erosion rates are not equally distributed throughout the basin. The worst effects have been found in the more erodible portions of the basin in the Upper and Lower South Fork sub-basins, particularly west of the mainstem, and in areas where land management practices are most intense. Smaller tributaries generally have been affected less severely than mainstem lower-gradient reaches. The impacts have been most notable in the Hyampom Valley, with most of the sediment being delivered from South Fork Mountain tributaries, particularly Grouse Creek and Pelletreau Creek subwatersheds, both of which have been heavily logged since the 1940s (PWA 1994).

The logging boom expanded through the basin in the 1960s, and probably exacerbated the detrimental effects of the 1964 flood. In particular, many logging practices on the erodible geology of the western basin altered the natural hillslope hydrology--e.g., through construction of roads and stream crossings--causing additional erosion and sediment impairment. Continued accelerated sediment production is found in many of these areas, particularly where large-scale forest fires have further exacerbated the problems. Some continued in-channel changes are also part of the natural cycle of adjustments to natural and management-induced events that would be expected following a major disturbance such as the 1964 flood.

The Action Plan for Restoration of the South Fork Trinity River Watershed and its Fisheries (PWA 1994) contains a summary of known resource conditions and constraints. Its main recommendations for restoration in the basin include reducing future sediment yield to the South Fork Trinity River. It also includes recommendations related specifically to temperature reductions, which this TMDL does not specifically address. Several members of the South Fork CRMP (Coordinated Resource Management Plan) group have begun to investigate the temperature issue in the South Fork basin (Farber et. al 1998).

Many studies have also been conducted by the California Department of Water Resources (DWR), California Department of Fish and Game (CDFG) and the U.S. Forest Service (USFS), both Six Rivers and Shasta-Trinity National Forests. These agencies and private landowners have continued to montor water quality conditions in the basin. The Action Plan (PWA 1994) summarizes most monitoring up through about 1993.

Water Quality Standards

Water quality standards (WQS) adopted for the South Fork Trinity River basin are contained in the Water Quality Control Plan for the North Coast Region (the Basin Plan, NCRWQCB, 1994). The WQS for the South Fork Trinity River are comprised of the **beneficial uses of water** and the **water quality objectives** designed to protect the most sensitive of the beneficial uses. In the South Fork Trinity River, the most sensitive beneficial uses addressed in the TMDL include: cold freshwater habitat (COLD); migration of aquatic organisms (MIGR); and spawning, reproduction, and/or early development (SPAWN). These are all existing designated beneficial uses in the basin (Table 1). The water quality objectives addressed include settleable material and sediment (Table 2). There are no numeric objectives for these parameters.

Table 1: Summary of Existing Beneficial Uses Addressed in the South Fork Trinity River TMDL

Beneficial Water Uses	**Description**
Cold Freshwater Habitat (COLD)	Uses of water that support cold water ecosystems including, but not limited to, preservation or enhancement of aquatic habitat, vegetation, fish, or wildlife, including invertebrates.
Migration of Aquatic Organisms (MIGR)	Uses of water that support habitat necessary for migration or other temporary activities by aquatic organisms, such as anadromous fish.
Spawning, Reproduction, and/or Early Development (SPAWN)	Uses of water that support high quality aquatic habitats suitable for reproduction and early development of fish.

Source: NCRWQCB, 1994

Table 2: Summary of Water Quality Objectives Addressed in the South Fork Trinity River TMDL

Water Quality Objective	**Narrative Objective Description**
Settleable Material	Water shall not contain substances that result in deposition of material that causes nuisance or adversely affect beneficial uses.
Sediment	The suspended sediment load and suspended sediment discharge rate of surface water shall not be altered in such a manner as to cause nuisance or adversely affect beneficial uses.

Source: NCRWQCB, 1994

Beneficial Use Issues for Salmonids in the Basin

The cold water fishery is the most impaired beneficial use in the basin. Fish populations in the basin depend on a number of internal and external factors, including: habitat availability and quality (determined by stream flow, channel form and structure, and physical barriers); water temperature; water chemistry; food supply; and predation. For anadromous salmonids, these factors are important at the spawning and rearing sites as well as along the migration route and in the ocean. *This TMDL addresses only those factors related to sediment discharge in the basin, such as excess fine sediment in spawning gravels, or secondary problems (e.g., habitat limitations) caused by excess aggradation.*

Six known stocks and runs of anadromous fish utilize the South Fork Trinity River watershed. The most abundant historically is the spring-run chinook salmon (*Oncorhyncus tshawytscha*). The second most abundant, historically and currently, is the fall-run chinook, which is also a significant indicator of the fish population in the basin.

Other cold-water species include winter and summer steelhead (*O. mykiss*), coho salmon (*O. kisutch*), and pacific lamprey (*Lampetra pacifica*). Chum salmon (*O. keta)* have been infrequently observed in the watershed (PWA 1994).

Although relatively little data exist to document the historical fish population, there are many accounts of an abundant fishery, ie. "A local fisherman reports that the South Fork of the Trinity River is full of salmon and small trout….and there is one hole in which there is at least 1,000 salmon." (Trinity Journal, 1936, as reported in PWA 1994). Fish counts declined dramatically following the December 1964 flood. For example, in 1963 and 1964, the spawning spring chinook population was estimated at 10,000 or more fish; complete surveys were not conducted in the 1960s following the December 1964 flood, but estimates in the period that followed that flood ranged from as few as a dozen in some years during the 1970s and 1980s. Fall-run chinook spawners were estimated at over 3,300 in 1963. Later counts estimated 500 or fewer fish in the late 1980s, with somewhat higher numbers documented only in the last few years (as high as 1,835 in 1996) (Healey 1963, LaFaunce 1967, LaFaunce 1975, Jong & Mills 1994, PWA 1994, Jong 1997). Other species, including steelhead, also declined in number, although data are more scarce.

Life Cycle and Habitat Requirements

Salmonids are born in fresh water streams where they spend one to several years of their lives feeding, growing, and hiding from predators. Once they are large enough, they undergo a physiological change allowing them to swim to the ocean, where they then spend the next one to several years. Salmonids return to the streams in which they were born to lay eggs and begin the life cycle again. Salmonid stocks that hold over the summer period prior to spawning, such as spring chinook, require deep pools for holding habitat. All salmonids require gravels free from excessive fine sediment to lay their eggs and for the eggs to develop into free-swimming fish. They also require deep, cool pools for the young fish to feed and grow while protected from predators.

Potential Effects of Sediment on South Fork Salmonid Stocks

Land management activities can increase erosion beyond natural rates through mass wasting (landsliding), fluvial erosion (gullying and stream bank erosion), and surface erosion (sheetwash). Excess sediment can enter the stream, filling in deep pools and silting in potential spawning gravels to the detriment of salmonids. Stream systems on the north coast, including the South Fork Trinity River, are generally prone to high rates of storm-induced erosion and sediment production (USDA River Basin Planning Staff 1972, CDWR 1979). Land management activities can accelerate this natural process, overwhelming the stream channel's ability to move the delivered sediment. Historic land use practices, in particular, appear to have had a major impact. Current land uses may add to the impacts or hinder the stream system's natural recovery.

While many of the past and present effects of the December 1964 flood are part of the natural variation in sediment supply, it is clear that additional stresses have been caused by management activities. The oversupply of sediment in the South Fork basin resulted in pool filling, decreased spawning habitat, lowered invertebrate production and increased temperatures (PWA 1994).

Land management activities that historically and currently contributed to the decline in the cold water fishery include: timber operations, with road building on erodible terrain likely being the greatest cause of concern; agricultural operations such as ranching, with bank erosion contributing to excess sediment and diversion of water leading to higher water temperatures and nutrient contributions; and mining operations, although there are very few mining operations in the basin. Residential land uses probably do not contribute significant amounts to the problem.

PROBLEM STATEMENTS AND SUMMARY OF EXISTING CONDITIONS

General Problem Statement

Excess sediment delivery to streams in the South Fork Trinity River basin has resulted in wider, shallower, and more homogeneous stream channels and fish habitat than would have occurred without management influences, as well as excess quantities of fine sediments in pools for juvenile rearing and adult holding habitat and spawning gravels. This has resulted in limitations for the cold water fishery, including sedimented or armored spawning riffles, impaired invertebrate production, and limited pool habitat (CH2MHill 1985, in Haskins and Irizarry 1988, PWA 1994, Borok and Jong 1997).

Specific Problem Statements

1. Decline in Fish Populations

This statement relates directly to the COLD beneficial use. Although the populations of spring and fall-run chinook, winter and summer steelhead have all declined, the best documented and most dramatically affected is the spring-run chinook. This species depends on deep, cool pools for holding throughout the summer months, and its decline suggests it has not adequately adapted to pool filling and increased summer temperatures (USFS 1998b). Spring chinook populations have dropped to less than 10% of their original sizes. Fall-run chinook have declined in number to less than half of their original population. Other stocks are less well documented (PWA 1994).

Locations of Greatest Concern: According to Jong (1995, citing various sources), anadromous salmonids generally spawn in the mainstem South Fork between the mouth and the confluence with the East Fork of the South Fork, and in many tributaries, including Hayfork Creek. Spring-run chinook generally hold and spawn in the South Fork Trinity River between Grouse Creek (River Mile 18.8, Km 30.2) and the East Fork (River Mile 73.5, Km 118.3). Fall-run chinook generally utilize the lower three miles of Hayfork Creek, and the mainstem South Fork from the mouth to the upper reaches of Hyampom Gorge near River Mile 31, Km 50). Fall chinook used to spawn in the South Fork up to 2 miles above Hyampom. Now, only a few are found above the South Fork bridge in Hyampom (Haskins and Irizarry 1988). Steelhead are found in tributaries of the Hyampom Valley, Hayfork Creek drainages and the East Fork. Coho salmon are infrequently observed, but have been found occasionally in the lower to middle South Fork Trinity River and tributaries.

2. Channel Aggradation

Large areas of the South Fork aggraded significantly following the 1964 flood, particularly in the area of the Hyampom Valley (PWA 1994, Matthews 1998). This has caused loss of instream habitat, loss of habitat complexity, degradation of the stream’s ability to effectively move sediment downstream, and excess fine sediment in pools. This statement relates to the SPAWN and COLD beneficial uses and the potential for sediment and settleable material to impact spawning substrate.

3. Deposition of Fine Sediments

Mass wasting and chronic inputs of fine sediment from roads and other sources has resulted in excess fine sediment in spawning gravels, and filling of pools with fine sediment in some locations. This can limit the development of eggs into fry and can secondarily limit the production of macroinvertebrates that function as a food source for the fish (Borok and Jong 1997). This statement relates to the SPAWN and COLD beneficial uses and the potential for sediment and settleable material to impact spawning substrate and pool habitat.

4. Lack of Suitable Pools for Rearing Habitat

Prior to the 1964 flood, the Upper South Fork Trinity River mainstem was characterized by scattered large, deep pools, interspersed with shallow pools, riffles and rapids. Gravel and fine sediments deposited during and after that flood infilled large pools, aggraded and broadened riffles, and destroyed riparian vegetation, leaving a wide flood plain, shallow pools and riffles with occasional deeper pools (Haskins and Irizarry 1988). Pools are potentially critical in terms of both rearing habitat and over-summer holding habitat for spring chinook. Excess delivery of fine and coarse sediment to the stream system reduces the number, depth and volume of mainstem and tributary pools, which in turn may result in increased summer temperatures. This statement relates to the SPAWN, COLD and MIGR beneficial uses, as well as the potential for sediment and settleable material to adversely affect pool habitat.

CDFG’s survey of the spring chinook in the basin in 1994-1995 (Dean 1996a) indicated that many of the fish were holding in 16 pools, with only one of these located downstream of Hyampom and none upstream of Forest Glen. Low water levels and high temperatures appeared to limit production. However, observations also showed that the availability of pools was adequate for the population at that time (estimated at only 472 adult spawners). Some pools that were judged to be “good habitat” were underutilized (1-2 fish), generally when those pools were located in areas of heavy human use. Conversely, “poor quality” pools in isolated areas often contained more fish. Since so many fish are holding in relatively few pools, additional pool habitat may be needed.

5. Improperly Designed or Maintained Roads

Roads, skid trails and landings in the South Fork basin that are improperly located,designed, constructed or maintained may cause: 1) increased surface erosion and chronic fine sediment production and delivery to streams, and 2) episodic and occasionally catastrophic delivery of fine and coarse sediment to streams from crossing failures, gully development and landslides generated from improper placement. This has direct and immediate adverse impacts immediately downstream from the failures, but it can also affect areas much farther downstream and much farther into the future. This appears to be especially problematic in the highly erodible and unstable geologic terranes in the western third of the watershed. This statement relates to the COLD, SPAWN and MIGR beneficial uses and the potential for sediment and settleable matter to impact stream habitat.

3. NUMERIC TARGETS

Section 303(d)(1)(C) of the Clean Water Act states that TMDLs “shall be established at a level necessary to implement the applicable water quality standards....” The numeric targets developed for the South Fork Trinity River TMDL are intended to interpret the narrative water quality standards adopted in the Basin Plan (NCRWQCB 1994) and provide a basis for determining the success of the TMDL. These targets have been developed by assessing the available information for the basin, reviewing the literature to identify conditions that represent adequate cold water habitat for salmonids, and applying best professional judgement. If long term monitoring data reveal that the targets should be modified, the TMDL can be revised to incorporate those new targets in the future.

Table 3 summarizes the indicators and targets associated with those indicators. The rationale for selection of indicators and associated targets is included in this chapter. Many of these indicators were modified following review and suggestions by the USFS, other agencies, landowners, and members of the public. They were previously discussed and reviewed by members of the TMDL subcommittee of the South Fork CRMP (Coordinated Resource Management Planning).

Basis For Target Selection And Comparison of Existing And Target Conditions

The following indicators were selected as the best means of tracking the ultimate success of the South Fork Trinity River TMDL. For each of the indicators, the proposed target level, the existing condition, the improvements identified as necessary to achieve the proposed target, and an explanation of the basis for the recommendations, are presented.

- Fish Population Recovery
    - S Spring chinook salmon escapement (not required to demonstrate attainment of water quality standards)
    - S Fall chinook salmon escapement (not required to demonstrate attainment of water quality standards)
- Channel Form and Structure Recovery
    - S Mainstem South Fork pool depth
    - S Tributary residual pool volume (V*)
    - S Channel complexity: thalweg profile and cross-sections
- Substrate Size Distribution
    - S Percent fine sediment $\leq$0.85 mm
- Decreased Hillslope/Road-related Sediment Production
    - S Road crossing diversion potential
    - S Road crossing failure potential
    - S Road maintenance/closure
    - S Road location, surfacing, hydrologic connectivity, fill/sidecast
    - S Harvest sediment delivery potential

The numeric targets are intended to describe desired watershed conditions that would lead toward attainment of water quality standards. In considering whether these conditions are met, a weight-of-evidence approach should be taken. No single target value in any individual year should be singled out as indicating either attainment or lack of attainment of water quality standards. Long-term running averages should be taken of the in-stream indicators in particular, since they can only represent increments of improvements which are

Table 3: Indicators and Targets

Desired Condition Indicator	Target Value[1]	Notes
1. Fish Population Recovery: *Diminished fish population is the strongest indication of impaired habitat conditions; thus, recovered populations are the strongest indication of recovered habitat conditions. EPA recognizes, however, that populations depend upon factors both within and outside of the basin. If the fish population recovery targets are attained, it is clear that WQS related to the cold water fishery have been attained, and other targets should be re-evaluated to determine if an adjustment is appropriate. If the fish population recovery targets are not attained despite other targets being attained, the fish population may be more affected by factors outside of the basin and progress toward attaining other targets should continue.*		
1a. Spring Chinook Escapement	4,000	Targets are for naturally-reproducing escapement. Fish population targets are not required to be reached to demonstrate attainment of WQS.
1b. Fall Chinook Escapement	3,000	
2. Channel Form & Structure Recovery: *Channel form indicators should show an overall movement of existing elevated levels of in-channel substrate out of the basin and overall increased depths of pools (approaching conditions prior to 1964 flood). Indicators address movement of 1964 in-channel flood deposits and improving habitat conditions.*		
2a. Number/Depth of Mainstem South Fork Pools	Increasing trend	Overall increased number of pools greater than 15 feet depth and increase in maximum depth of individual pools within reaches tracked over time.
2b. Tributary Pool Recovery-V*	0.21 western tribs; 0.10 other tribs	Reference: Lisle and Hilton 1992, Hilton and Lisle 1993, Knopp 1993, Lisle, pers. comm. 1998. Western tribs are those subwatershed areas in predominantly “fines-rich” geology west of the mainstem South Fork Trinity River.
2c. Increased channel complexity: channel thalweg profile and cross section surveys	Increasing trend of improvement	Evaluated as variation from mean thalweg profile slope and cross section/profile changes in response reaches, indicating increased pool depth/channel complexity and downstream sediment movement.
3. Improved Substrate Size Distribution: *High proportions of fine sand in spawning gravel and in pools are linked with decreased fish populations and decreased spawning success (e.g., Chapman 1988, PWA 1994).*		
3a. Substrate sediment < 0.85 mm	≤. 14% by volume	Measured in potential spawning gravels and evaluated as long-term running averages; addresses embryo development and emergence. Reference: Burns 1970, Cederholm et. al 1981, Chapman 1988, Peterson et. al 1992, Borok and Jong 1997.
4. Decreased Sediment Delivery: *Addresses the need to achiev adequate watershed conditions to ensure adequate water quality, and to reduce temporarily “controlled” water quality impairments in order to achieve desired stream conditions.*		
4a. Stream crossings with diversion potential	≤1%	Reference: Weaver and Hagans 1994; D. Hagans, pers. comm., 1998, C. Tarwater, pers. comm., 1998, Furniss et. al 1998. Only those crossings that cannot be corrected without compromising safety are expected to fall within the 1% value.
4b. Stream crossings with significant crossing failure potential	≤1%	Culverts and crossings designed to pass the 100 year flood, including snowmelt, and associated debris and sediment, targeting crossings with highest probability of failure and highest consequences (damage to aquatic resources, large volumes of fill, etc.). Reference: Flanagan et. al 1998. Adequate justification (e.g., public safety concerns and insigificant risk to aquatic resources) would be expected to explain those crossings that are not upgraded. These are expected to fall within the 1% value.
4c. Annual road inspection/maintenance	all roads, or closure	All roads would be inspected annually prior to winter. Conditions that are likely to deliver sediment to streams would be corrected, otherwise roads will be hydrologically closed/disconnected (fills and culverts removed, natural hydrology of hillslope largely restored).
4d. Road location, surfacing, sidecast	minimized sediment delivery	1) All roads alongside inner gorge areas or in potentially unstable headwall areas should be removed unless alternative road locations are unavailable and need for road is clearly justified. 2) Road surfacing, drainage methods and maintenance are appropriate to their use patterns and intensities. 3) hydrologic connectivity is assessed and reduced to the extent feasible. 4) Sidecast/fill on steep or potentially unstable slopes pulled back/stabilized.
4e. Timber harvest sediment delivery potential	Avoided subject to geologic investigation	No clearcut harvesting and/or tractor yarding in steep, potentially unstable streamside areas unless a detailed geological assessment shows no potential for increased sediment delivery to water courses.

---

[1] Instream targets are to be evaluated on a weight-of-evidence basis as a long-term rolling averages, as specified in the monitoring plan currently under development. Inter-annual variability is expected in the values.

highly dependent on climatic and flow conditions. In fact, given the highly variable nature of the in-stream indicators, it is expected that considerable inter-annual variability of instream indicators will be observed. EPA anticipates that monitoring of numeric targets will document progress toward attainment of TMDL goals, and are not intended to be used as a compliance tools. Neither EPA nor the State will utilize these indicators as compliance tools. However, they have also been developed with the idea that the State can use them as a basis for development of implementation and monitoring plans. The in-stream targets will probably serve best as monitoring parameters over a long-term basis to document trends toward progress within the overall basin. The hillslope and road-related targets may provide a basis for the State to monitor implementation progress.

1. Fish Population Recovery

The diminished fish populations in the basin, which has been documented beginning both with the period of increased timber harvest and record flooding in the basin, are the strongest indication of impaired habitat conditions. Recovered populations would strongly indicate recovered habitat conditions. In the future, if salmonids naturally reproduce at numbers that are close to those observed prior to 1964 or within values consistent with the Trinity River Restoration Program (J. Glase, pers. comm., 1998), it would be reasonable to conclude that habitat conditions are adequately supporting the COLD, MIGR, and SPAWN beneficial uses.

1a. Spring Chinook Salmon Escapement

Target Level: 4,000 naturally-producing fish

Existing Conditions: 1993-97 averaged approximately 700/year (18% of target level)
1988-97 averaged approximately 400/year (10% of target level)

Improvement Needed: Escapement should increase by 6-10 times over current level, unless other targets are clearly met, which would suggest that watershed conditions are adequate to support coldwater aquatic habitat and factors outside of the basin or conditions in other life-cycle stages have a larger influence over the population.

1b. Fall Chinook Salmon Escapement

Target Level: 3,000 naturally-producing fish

Existing Conditions: 1993-97 averaged approximately 1,400/year[1] (47% of target level)
1988-97 averaged approximately 800/year[1] (27% of target level)

Improvement Needed: Escapement should increase by 2-4 times over current level, unless other targets are clearly met, which would suggest that watershed conditions are adequate to support coldwater aquatic habitat and factors outside of the basin or conditions in other life-cycle stages have a larger influence over the population.

Explanation:
Historically, salmonid spawning runs were dramatically larger than they are today; spring chinook represented the largest salmonid runs in the basin. In 1963 and 1964, prior to the December 1964 flood, spring chinook escapement

---

[1] No data available for 1991, 1992, 1994 or 1995.

(the number of returning spawners) was greater than 10,000 fish (Healey 1963, LaFaunce 1967). This is consistent with anecdotal observations of large numbers of fish in the river (Berol 1995). The December 1955 flood probably also affected the fish population temporarily; an aerial redd count in 1958 noted only 101 spring chinook redds (LaFaunce 1967, citing USFWS 1960). However, large sediment deliveries to the stream were not observed between 1944 and 1960. Furthermore, indications are that the spawning run had recovered prior to the 1964 flood. In the early 1960s, the intensity of road building and timber harvest increased significantly. Since the 1964 flood, the spring chinook population has not recovered to anywhere near those former levels. It is possible that the runs in 1963 and 1964 were anomalously large, and the goal of 6,000 spring chinook estimated for the Trinity River Restoration Program may be more reasonable to indicate recovery of the run. It is therefore appropriate to assume approximately 4,000 spring chinook would represent recovery in the South Fork basin (J. Glase, USFWS, pers. comm., 1998).

Fall chinook escapement has not been estimated as consistently as spring chinook. LaFaunce (1967) estimated 3,337 fall chinook in 1964, prior to the flood. No estimates were made again until the 1980s, at which time the escapement was estimated to be as low as 345 in 1990 and as high as 2,640 in 1985 (Jong & Mills 1994). Because the spring chinook run was more significantly affected than the fall run, indicators for both runs are included to provide a more rounded picture of desired conditions. For example, spring chinook return to the basin in the spring and hold in the streams over the summer, while fall chinook run in the fall; over-summer factors may have caused the greater decreases in the spring chinook population. For fall chinook, which haven't diminished in numbers in the South Fork basin as dramatically as spring chinook, 3,000 returning spawners is a reasonable number to indicate population recovery (J. Glase, USFWS, pers. comm., 1998). Steelhead populations have been inconsistently estimated and are not considered an appropriate indicator.

Higher spring chinook escapement in the 1990s may reflect the early stages of population recovery, coincident with apparent movement of sediment downstream (Matthews 1998), or it may reflect better conditions in those particular years. The current size of the spawning population, while growing, still remains at less than 10% of the run in 1963 and 1964, and less than 20% of the Trinity River Restoration Program goal.

The diminished fish populations in the basin, which began both with the period of increased management and the record flood in the basin, are the strongest indication of impaired habitat conditions, and recovered populations will be the strongest indication of recovered habitat conditions. In the future, if salmonids naturally reproduce at numbers that are close to those observed prior to 1964, it would be reasonable to conclude that habitat conditions are adequately supporting the COLD, MIGR, and SPAWN beneficial uses. If sediment has limited habitat by aggrading the channel, then continued downstream movement of sediment would probably be required to restore the habitat conditions.

However, it is also clear that: 1) habitat recovery, in the form of normal watershed processes moving both the natural sediment load and the elevated sediment load (i.e., due to land management activities) through the stream system, is a slow process, and may not be observed for another 50 years or more; and 2) other factors, such as habitat conditions or fishing pressures outside of the South Fork basin (e.g., downstream or ocean conditions) may retard progress on recovery of the fishery even if the habitat conditions have recovered. Thus, while a recovered chinook spawning population would indicate recovery of the beneficial use support and attainment of water quality standards more clearly than any other indicator, it is not required that the spawning population recover in order to demonstrate attainment of water quality standards, if all other targets are met.

2. Channel Form and Structure Recovery

2a. Mainstem South Fork Pool Depth

Target Level:	Number of pools greater than 15 ft in depth and maximum depth of individual pools tracked over time.
Existing Conditions:	Apparent trend toward increased depths and numbers of deep pools
Improvement Needed:	Continued deepening of pools and increased number of deep pools

Explanation:
Prior to the 1964 flood, the South Fork was often described as having scattered large, deep pools interspersed with shallow pools, riffles, and rapids. Internal CDFG memorandums and anecdotal accounts from long-time residents (Berol 1995) reflect the significance of these deep pools for the fishery, as the fish were observed to congregate in these locations. Historical records indicate that these suitable pools often contained several hundred or more fish (LaFaunce 1967, Berol 1995). Survey results after the 1964 flood indicated substantial infilling of pools, with recovery of some pool depth first noted in 1969 (Healey 1969).

The loss of pool depths reflects a loss of physical habitat and probably also resulted in increased temperature stresses on fish. This is an important indicator for the COLD beneficial use, and is particularly critical for spring chinook, which hold in pools for prolonged periods of time during the summer, when stream temperatures are elevated. Large, deep pools are known to stratify, providing critical temperature refugia to the various species of fish. Stratified portions of deep pools may be over 10 degrees cooler than the ambient channel water temperatures (Matthews, pers. comm., 1998).

It has been hypothesized that much of the pool infilling during the 1964 flood was caused by debris torrents from South Fork Mountain tributaries and inner gorge landslides, which delivered enormous quantities of sediment to the channel (DWR 1982). In particular, this sediment could have contained substantial very coarse material (i.e., boulders), which normal streamflows and even infrequent flood flows cannot easily move, indicating that the residence time could be very long. In comparison, areas that filled with more fine-grained material (sand, gravel, and cobbles) would flush out much faster as a function of reduced upstream loading and greater number of flows capable of mobilizing the substrate. Mapping from aerial photographs showed that relatively few debris torrents or inner gorge landslides occurred upstream of Forest Glen (DWR 1982), indicating the potential for more rapid recovery of these areas.

In 1980, CDFG personnel observed that the pool and channel recovery seemed to be proceeding in a downstream direction from the top of the watershed, as the best pool habitat was found above Silver Creek (LaFaunce 1980, unpublished memo). Selected quantitative information also reflects this trend of pool recovery in the upper reaches of the South Fork. In 1970, a CDFG survey from the confluence of the East Fork to Forest Glen found only “about five holes exceeding six feet in depth.” In 1989, the USFS habitat- typed this same reach and their data indicated that there were now 28 pools greater than six feet deep (USDA FS 1998b).

No appropriate literature source or reference streams were found that would adequately represent desirable conditions for the South Fork Trinity River system and serve as a target. Furthermore, few comparable data exist for other reaches of the South Fork. A comprehensive mapping of pools and substrate between the mouth and Forest Glen by DWR (1982) indicated only three pools with depths of 20 feet were found along the 57 mile reach inventoried. Since data were presented only for the maximum and minimum pool depths by reach, the number of pools by depth in each reach are not known. Only four additional reaches were found to have a pool with a maximum depth of 13 feet. The depth of 15 feet as an indicator depth is chosen to reflect anticipated additional deepening that would be necessary to support the fishery.

Recent fisheries investigations (Dean 1996) found up to 21 holding pools being utilized by at least three spring chinook in 1995; however, pool depths were not recorded. Ongoing and recent monitoring by Six Rivers National Forest will provide current conditions for selected reaches, which could then be compared to the DWR data to assess trends for those "response" reaches surveyed.

2b. Tributary Residual Pool Volume (V*)

Target Level:	Mean $\leq$0.21 for western erodible/unstable tributaries (see Figure 6) Mean $\leq$0.10 for other tributaries
Existing Conditions:	Mean 0.36 for two separate studies, totalling 21 pools, in Grouse Creek; Mean 0.069-0.12 for 11-20 pools each on five tributaries
Improvement Needed:	Approximately 42% reduction in fines in Grouse Creek. 0-17% reductions in other locations, depending upon monitoring results.

Explanation:

V* is the fraction of a pool's volume which is filled with fine sediment (Lisle and Hilton 1992), and provides a measure of the in-channel supply of mobile bedload sediment. Sediment delivery to a stream is one of the factors that influence its value. It is related to the quality of fish habitat since salmonids prefer deep, cool pools (COLD beneficial use). Its variance in a reach of stream has been shown to be low enough to provide estimates of mean values with a reasonable amount of effort (Lisle 1993). The use of V* as an indicator is appropriate for small tributaries, but the methodology would be difficult to undertake on the mainstem (T. Lisle, pers. comm., 1998).

A study conducted on over 60 streams representing different levels of disturbance in the North Coast found that V* mean values of less than or equal to 0.21 are representative of good stream conditions (Knopp 1993). That study was undertaken in Franciscan geology, which tends to yield relatively high values of fines to streams. These values would be appropriate for the more erodible and unstable subwatershed areas in the western South Fork basin (see Figure 6), but would be high for other tributaries, where background values of 0.10-0.15 would be expected (Lisle, USFS, pers. comm., 1998). Results of limited sampling on South Fork tributaries indicate V* levels mostly below those levels. In 1990 and 1991, Lisle and Hilton (1992) sampled pools in four tributaries of the South Fork in developing the V* methodology. The number of pools sampled and the average V* values were: Bear Creek - 0.069 for 20 pools; Rattlesnake Creek - 0.12 for 20 pools; North Rattlesnake Creek - 0.11 for 15 pools, and; Grouse Creek - 0.26 for 17 pools. A 1995 study of Grouse Creek (USFS 1995) measured V* below Devastation Slide and found that it averaged 0.46 on 4 pools. Using the results of both studies for Grouse Creek together yields an average V* of 0.36 for that tributary, which is substantially higher than the target. Two of those pools were higher than the maximum targeted V*, at 0.59 and 0.56. The higher V* figures on Grouse Creek are consistent with other sources of information indicating that high levels of fine sediment remains in that stream system. Eleven pools were sampled in 1994 in Rusch Creek, tributary to Hayfork Creek ,with a resultant average V* of 0.09. (Higgins 1994).

It is likely that V* will vary over time for an individual pool or collection of pools, and conditions on many other tributaries in the South Fork basin are not known. This indicator will be most effective if additional monitoring is conducted throughout the basin and if a wide range of tributary conditions will be represented. It is hoped that monitoring in the basin will continue to identify those streams that may be in need of further improvement, as well as those that appear to be in adequate condition.

2c. Channel Complexity: Thalweg Profile and Cross Sections

Target Level:	Increasing trend of channel complexity (variation in profile slope) and cross/section profile changes indicating continued downstream sediment movement
Existing Conditions:	See explanation for existing and historical survey analysis; in addition, USFS is currently conducting a profile survey in selected reaches of the South Fork mainstem.
Improvement Needed:	Continued downstream sediment movement, deepening of pools and development of habitat complexity.

Explanation:
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 floods. This indicator relates to the COLD, MIGR and SPAWN beneficial uses, which are all affected by changes in channel form.

Channel geometry is most often monitored through cross section and profile surveys, both of which are two-dimensional representations of channel shape. The cross section is measured perpendicular to the flow direction, and the longitudinal profile is measured parallel to the flow direction. Clusters of cross sections provide the most useful information (by verifying the magnitude of change), and if spaced closely enough or if the features change relatively gradually in the study area, volume changes may be computed using average end area methods (Matthews 1998). Longitudinal profile surveys (which are typically made along the thalweg or line connecting the deepest point of a given channel cross section) provide information on pool/riffle spacing, pool depths, and channel bed gradient. These surveys need to be made at the same locations in successive years or periods of years (Matthews 1998).

Matthews (1998) analyzed past surveys and USGS gaging station records, which showed that, in general, the sediment accumulated in the upper reaches of the South Fork mainstem from the 1964 flood appears to have largely moved downstream, but that deposits in the Hyampom Valley may require additional time to recover to pre-flood conditions. Records were available for Forest Glen, two stations in Hyampom, Salyer, and two stations in Hayfork Creek. At Salyer, conditions are currently similar to pre-1964 flood conditions, but may respond by aggrading once again and later degrading again as the sediment upstream in Hyampom moves through. Very little data are available for Hayfork, but Matthews' (1998) analysis reveals that the Hayfork Creek stations showed very little response to either the 1955 or 1964 flood, probably reflecting the more stable geology in the area, and possibly also suggesting that local channel hydraulics favor sediment transport (i.e., at the locations of the surveys).

Where cross-section records were available, data showed that the mainstem South Fork Trinity River channel aggraded following the 1955 flood, generally recovering to its former appearance by about 1960, then aggraded more significantly following the 1964 flood. The gravel that accumulated in 1964 has been flushed downstream at the Forest Glen station. One of the Hyampom stations existed only until it was destroyed in the 1964 flood, and the other was established in 1965. The first station showed significant accumulation of additional sediment (about 11 feet overall for the mean bed elevation). It was resurveyed in 1998, showing that the mean bed elevation remains over two feet above its pre-1964 elevation. The other station, which is located at the downstream end of the Hyampom Valley, continued to aggrade for several years following the 1964 flood, but has rapidly degraded since that time. The Salyer gage, 7 miles upstream from the confluence with the mainstem Trinity River, shows dramatic changes over the time period, aggrading 5 feet following the 1955 flood, scouring back about halfway between 1956 and 1964, aggrading another 12-15 feet in the 1964 flood, then filling another four feet by 1965, when the gage was discontinued. By 1980, the channel had downcut about 10 feet from its 1967 level, and by 1998 had dropped approximately another five feet, essentially regaining its pre-1964 flood elevation.

Data available for Pelletreau Creek indicate that it remains aggraded, having accumulated nearly 26 feet of sediment, of which up to 20 feet remained by 1979. Lateral migration of the creek in 1997 prevented re-surveying (Matthews 1998). Similarly, Grouse Creek reportedly developed a 50-foot high delta following the 1964 flood (Matthews 1998). These results are not surprising given that they appear to be among the highest sediment-producing subwatersheds in the basin (PWA 1994, Raines and Kelsey 1991).

The USFS is currently engaged in monitoring selected "response" reaches--those that have exhibited significant changes in the past and are expected to continue to reflect continued downstream movement of sediment deposited in the 1964 flood. USFS plans to compare the results of this data collection to previous records, for example those compiled by Matthews (1998), and will use them to estimate future trends. Re-establishment of good habitat conditions will be reflected by increased pool depths, decreased fine sediment in pools, increased stream profile complexity (suggesting re-establishment and deepening of pools), and continued downstream movement of existing in-channel sediment.

3. Improved Substrate Size Distribution

3a. Percent Fine Sediment ≤0.85 mm

Target Level:	≤ 14%
Existing Conditions:	Average 17% basinwide (including tributaries). South Fork mainstems stations average 18%.
Improvement Needed:	Approximately 18% reduction in fines as a basinwide average; efforts can be focused on South Fork mainstem, requiring a 22% reduction on average.

Explanation:
This indicator particularly relates to the SPAWN beneficial use. Measurement of fine sediment composition in potential spawning gravels is a substitute for the direct measurement of the factors that directly influence successful salmonid reproduction, while not harming the eggs developing in redds (which could happen if the redds were sampled directly). The size fraction defined as "fines" has been variously defined in many studies attempting to define criteria for gravel size quality for fish, but one fairly common particle size for which data have been developed and which has been shown to impact embryo development is ≤ 0.85 mm. Much of the existing data for the South Fork uses a sieve size of 0.85 mm for the fines component, making this some of the most consistent data available for analysis.

Tagart (1976, 1984, cited in Chapman 1988) found that levels of dissolved oxygen are inversely related to the percentage of fines less than 0.85 mm in diameter. Cederholm et al. (1981) determined that coho salmon egg-to-emergence survival was only about 30% at 15% fines <0.85 mm in redds. In a brief review of other papers relating the effects of fine sediment sizes on spawning gravels, Borok and Jong (1997) also cited a paper by Cloern (1976) demonstrating that more than 15% fines <0.85 mm caused a sharp decline in survival. Peterson et al. (1992) also summarized many studies in developing recommendations for Washington state's Timber Fish and Wildlife agreement, and noted that 11% was the average observed in unmanaged streams in the Pacific Northwest. On California's North Coast, Burns (1970) concluded that 17% fines was observed in unmanaged streams; however, other factors probably contributed to that high level, including a pulse of fine sediment immediately following the 1964 flood, which would not reflect typical conditions in unmanaged streams. A target of 14% represents the midpoint between those two indices, and also reflects moderate levels of survival in many of the studies that have been conducted.

The existing data available from the California Department of Fish and Game (CDFG) indicate that some impairment exists in the mainstem South Fork and in some tributaries (see Table 4). It is important to recognize the inherent variability of gravel sampling, even within a single riffle. Repeatable and consistent methods in site selection, sample collection and data analysis can reduce some of this variability. However, some of the available data (USFS 1990) were not used because the results appeared to be anomalous, suggesting that the methods were not comparable. The samples reported by CDFG for 1994 for Grouse Creek include those samples, which could explain in part why the CDFG sample means for this subwatershed are reported as being within the target value. This is inconsistent with other information on for Grouse Creek. CDFG's Grouse Creek samples in 1997 averaged 16%, which is over the target value, as would be expected for this subwatershed.

The data presented in Table 4 are assumed to represent consistent methods, except where noted. Still, results for some tributaries are inconsistent. For example, Hayfork Creek in 1997 had only 13% fines, but in 1994 the samples averaged 24%, which is much higher than would be expected for that tributary. It is possible that the samples were taken at a location or during a period when the fines composition was unusually high. This may also be within the range of expected variability. South Fork mainstem stations are consistently higher than the target values, averaging 17% in 1997, 16% in 1994 and 21% in 1992. Overall, mainstem South Fork samples averaged 18% fines $\leq$0.85 mm, suggesting an average 22% reduction overall is needed for instream values to attain target values. Upper South Fork stations were notably higher in fines than lower South Fork stations (Table 4).

4. Decreased Hillslope/Road-Related Sediment Production

Sediment impairment in the South Fork basin is influenced by episodic events. Linkages between hillslope sediment production and instream sediment detection are complicated by time lags from production to delivery, instream storage, and transport through the system. In limited areas, the linkages can be clarified somewhat. For example, where diversion of water from the road drainage system is possible, sediment can be carried from the road drainage and diverted into the stream. In addition, the crossing itself can fail, potentially delivering the volume of the crossing fill to the stream and possibly adding to this volume by triggering a debris flow. Measuring instream water and substrate conditions, for example, is simply an indirect measurement of an assumed cause-and-effect relationship which probably does not accurately reflect the source of the impairment; more importantly, it is an after-the-fact measurement of impairment, which may prevent adequate protection of the beneficial uses of water. In many cases, timely road inspection and maintenance can prevent many of the failures and associated sediment deliveries from occurring. Appropriate location, design, construction and maintenance of roads can frequently result in minimal sediment delivery. Likewise, some timber harvest activities can result in additional sediment delivery to stream, but appropriate practices can eliminate that delivery.

Table 4: Summary of Substrate Samples, Cumulative % Fine Sediment <0.85 mm

Location	**Mean Value, %**	**Reduction to Meet Target**	**Range of Values, %**	**No. Of Data Points**	**Sample Years**	**Notes**
Lower/Middle SFTR stations	15.7	11%	10.4-18.7	13	97, 94, 93, 92	Only 3 stations ≤14%; 5 stations ≥17%.
Upper SFTR stations	21.0	33%	19.4-27.5	8	97, 94, 92	Highest values near Plummer Creek.
All SFTR stations	17.7	21%	10.4-27.5	21	97, 94, 93, 92	
Madden Creek	11.4	0%	3.4-19.4	2	97	
Grouse Creek	13.9	0%	9.5-18.4	7	97, 89, 88	May include USFS samples that appear anomalous. W/o those samples, only 2 samples (1997), average 15.5%. Low values seem inconsistent with other data on Grouse Creek.
E Fork SFTR	14.8	5%	11.9-18.5	3	97, 94	
Hayfork Creek	18.3	23%	13.1-23.5	2	97, 94	High values seem inconsistent with other information on Hayfork Creek. 1997 value is within target level.
Eltapom Creek	14.2	1%		1	97	
All Data Points	16.3	14%	3.4-27.5	36	97, 94, 93, 92, 89, 88	May include USFS samples that appear anomalous.
All Data Points *w/o '88/89 Grouse Creek data*	16.8	17%	3.4-27.5	31	97, 94, 93, 92	Leaves out 5 Grouse Creek samples that may be part of anomalous data set.

Data points generally represent averages of samples at a station. USFS 1990 data is not included; values appear anomalously low (2-3% average for 13 tributaries and 5% average for mainstem). Methods may not be directly comparable. Other data points are reported by CDFG, and are assumed to be collected under consistent CDFG protocol.
Sources: Borok & Jong 1997, Jong 1995, USFS 1990

Moreover, these hillslope and road-related sediment production sources effectively represent potential or temporarily modified existing impairments. Measures of water conditions do not reflect this *existing* but temporarily "controlled" water quality impairment, which need only be triggered by a particular quantity and quality of precipitation and runoff. These indicators relate directly to the MIGR beneficial use, particularly in locations where sediment from failed crossings impair migration routes. It also relates indirectly to the COLD and SPAWN beneficial uses in association with additional sediment inputs that fill pools or provide excess fine sediments in spawning areas.

Hillslope and road-related targets are included because focusing on instream indicators would not achieve water quality improvements. Hillslope and road targets are also easier to measure and are more controllable. In addition, including these targets will address the problem of instream indicators suggesting that conditions are good while the hillslopes are "loaded guns" of sediment to be delivered in the next large storm event, resulting in immediate consequences as well as potentially irreversible aquatic habitat degradation. Without addressing these hillslope sources, the cycle of degradation could potentially be repeated until some species of aquatic life could no longer recover. Furthermore, these targets were developed in response to public input and requests through the CRMP, which had been developing similar measures independently of the TMDL development.

Roads are the biggest source of controllable sediment delivery in the basin (see Chapter 4). Thus, in a system that may be slowly recovering from previous land management and storm-triggered sediment delivery, controlling the potential for future land management and storm-triggered sediment delivery will ensure that water quality standards are attained for the foreseeable future. In basins where sediment impairment does exist, reduction or elimination of hillslope delivery potential will facilitate recovery.

Roads disrupt the natural drainage pattern of the watercourse, which effectively makes them controlled sediment impairments until they fail, at which time they become clearly measurable sources of impairment. Many existing and potential road sediment deliveries can be corrected relatively easily, resulting in both decreased sediment delivery (attaining water quality standards) and, in most cases, can co-exist with protecting beneficial uses of water. In many cases, lower road maintenance costs result as the roads are made to be "hydrologically maintenance free," retaining or re-establishing natural drainages and avoiding the potential for creation of diversion potential.

Raines (1998) found that roads constructed on highly unstable geologic terranes have a much higher tendency to fail and deliver sediment to the stream system than those in other geologic formations. Roads on the east side of the South Fork mainstem and the Hayfork Creek sub-basin are relatively more stable. This is consistent with findings of the CRMP technical consultant (D. Hagans, pers. comm., 1998). These indicators are intended to target as a first priority the areas of highly erodible geology (South Fork Mountain Schist, Galice Formation, Franciscan and Igneous/Volcanic), which are correlated with areas of highest erosion hazard and road-related sediment deliveries (see Figure 3). These are all generally located on the west side of the South Fork mainstem. In the Upper South Fork subarea, this corresponds with subwatershed areas 6, 7 and 8; in the Lower South Fork subarea, it is in subwatershed areas 14, 17, 18, and 19 (see Figure 6).

4a. Road Crossing Diversion Potential

Target Level:	≤1% of crossings with diversion potential in the basin
Existing Conditions:	37% of crossings on average have diversion potential where inventories have been completed, in the Smoky (47%), East Fork (27%), Plummer (34%) and Upper South Fork/Happy Camp (43%) subwatershed areas (C. Tarwater, pers. comm., 1998). 50-65% of crossings in the basin overall are estimated to have diversion potential (D. Hagans, pers. comm., 1998).
Improvement Needed:	Overall: approx.35-60% of crossings need to have diversion potential eliminated. (D. Hagans, pers. comm., 1998).

Explanation:
Diversion potential is the potential for a road to divert water from its intended drainage system, which could result in road sediment or fill being delivered to the stream. Eliminating diversion potential implies permanently reconfiguring the road so that such potential is eliminated, e.g., by eliminating inboard ditches, outsloping roads, and installing rolling dips at crossings. The diversion potential can be estimated prior to failure, providing a way to protect water quality standards prior to impairment. Quantifying the sediment delivery from the diversion potential is difficult, and is probably most closely estimated by observing diversions that have occurred. A detailed estimation is not available for this analysis; however, anecdotal information from within the watershed supports the use of diversion potential is an appropriate indicator for actual sediment impairment from roads at stream crossings (M. Furniss, pers. comm., 1998).

All deliveries from diversions will degrade water quality to some degree, because they represent sediment that would not normally be introduced into the stream system. However, not every diversion potential can be completely corrected without removing the road itself. In his work on numerous North Coast watersheds, Hagans (pers. comm., 1998) has concluded that the potential delivery of sediment to streams can be eliminated from almost all road diversion potentials can be corrected. Tarwater (pers. comm., 1998), working in the South Fork basin, estimated that all but about 1% of diversion potentials could be corrected, which includes reconfiguring the road so that if a crossing did fail, the water would not divert down the road. In the remaining cases, the roads may be configured such that correcting the diversion potential is either physically impossible or would make the road unsafe for travel. Establishing 1% as an indicator represents the diversions that cannot reasonably be corrected.

Detailed data on diversion potential in the South Fork basin is only available for a few subwatershed areas (USDA FS 1998a, C. Tarwater and T. Viel, pers. comm., 1998). On average, these data show that 37% of the crossings in four Upper South Fork Sub-basin subwatershed areas, have diversion potential. It is possible that this value is approximately correct for other areas of the basin. Except for the USFS "Level III" roads, these were reduced to about 1% during 1998 (C. Tarwater, pers. comm., 1998). Throughout the basin, the amount of diversion potential varies by ownership. Based on data he has collected at various locations and his observations, Hagans (pers. comm., 1998) estimates that 50-65% of the existing road crossings have diversion potential. This suggests that an additional 45-60% of the crossings need to have their diversion potential corrected.

4b. Road Crossing Failure

Target Level: $\leq$ 1% of all roads would potentially fail. Adequate crossing failure protection is defined as culverts and crossings sized to pass the 100 year flood, including snowmelt, and asociated sediment and debris.

Existing Conditions: The number of crossings that could potentially fail is not known at this time.

Improvement Needed: Assess risk; improving trend until target levels are met.

Explanation:
When a road crossing fails, generally due to a culvert being undersized or unfunctional, the fill associated with that failure can be directly delivered to the watercourse. Once a diversion has occurred, it is a directly measurable sediment impairment at the location of the crossing, and it will also affect areas downstream, in quantities and at locations and times that cannot be easily estimated. The quantity of potential sediment delivery can be estimated by estimating the volume of stream crossing fill and assuming the entire volume could enter the stream if the drainage diverted and the crossing failed (see Weaver & Hagans 1994). However, in most crossing failures, the amount of sediment entering the stream exceeds the volume of the fill (D. Hagans, pers. comm., 1998); for example, a debris

torrent may develop from the failure, carrying with it additional sediment torn from the banks of the stream. In a few cases, the volume entering the stream is less than the crossing fill, but in general, the volume of the fill can be estimated as the minimum quantity of sediment delivered (D. Hagans, pers. comm., 1998).

While it is not possible to completely eliminate the potential for failure in a crossing, it is possible to assess the potential for failure and the risk to aquatic resources associated with that failure (i.e., the probability of failure combined with the consequences of failure, i.e., greater volumes of fill would result in higher risk (M. Furniss, pers. comm., 1998). Flanagan et. al (1998) contains methods to assess the risks of failure, and that should be considered in reducing the risk of crossing failure.

Crossings should be designed to pass the 100 year flood, including snowmelt and associated sediment and debris. The risk of failure and potential for sediment delivery should be considered. Risk factors include: an existing diversion potential, the road is located low on the hillslope near a stream (as opposed to at the top of the hillslope), the adjacent stream flows continuously (as opposed to intermittently), a debris flow is likely to be triggered, or risk to aquatic resources is high.

4c. Road Inspection/Maintainance or Closure

Target Level:	All roads will be inspected annuallly and potential deliveries corrected, or the road decommisioned/hydrologically closed.
Existing Conditions:	Approximately 20% of USFS roads are informally abandoned and not maintained; approximately 33% of industrial ownerships contain informally abandoned roads (D. Hagans, pers. comm., 1998).
Improvement Needed:	An additional 20-33% of roads should be maintained or improved to the state of “hydrologically maintenance free.”

Explanation:
Roads that will not or cannot be adequately inspected and maintained are potentially large sources of sediment unless constructed to be hydrologically maintenance free (D. Hagans, pers. comm., 1998). Inspection and maintenance of roads that are not hydrologically maintenance free—i.e., that continue to alter the natural hydrology of the stream and represent a potential sediment delivery—is one way of delaying and/or reducing the potential for sediment impairment. Alternatively, the roads can be upgraded to become hydrologically maintenance free. In general, road inspection should be undertaken annually, and could in most cases be accomplished with a windshield survey. The areas with the greatest potential for sediment delivery should be corrected, prior to the onset of winter conditions.

In the South Fork basin, approximately 20% of USFS roads and 33% of industrial roads are not inspected regularly nor are they formally closed or made hydrologically maintenance free (D. Hagans, pers. comm., 1998). The conditions of these roads may vary from those that are gullied and currently contributing sediment, to those that are overgrown with vegetation or present no notable risk of sediment delivery. Thus, the total mileages and direct sediment impacts are not known, but best professional judgement would indicate that approximately 20% of the USFS roads and 33% of private roads should be inspected or upgraded.

4d. Road Location, Surfacing, Hydrologic Connectivity, Sidecast

Target Level:	1) No roads located in inner gorge areas or potentially unstable headwall areas unless alternative road locations are unavailable and need for the road is clearly justified. 2) Roads are surfaced and drained appropriate to their level and intensity of use. 3)

Hydrologic connectivity is assessed and reduced to the extent feasible. 4) Fill/sidecast on slopes greater than 50% that could potentially deliver sediment to a watercourse are pulled back and stabilized.

Existing Conditions: A value associated with these conditions has not been determined basinwide but is considered by those who work in the basin to be a significant and controllable source of potential delivery.

Improvement Needed: Assess risk; improving trend until target levels are met.

Explanation:
These factors reflect the highest risk of sediment delivery from roads, and should be the highest priorities for correction (C. Cook, M. Furniss, M. Madej, R. Klein, G. Bundros, pers. comm., 1998) Roads located in inner gorges and headwall areas are more likely to fail than roads located in other topographic locations. This is particularly true in the western third of the South Fork basin. Other than ephemperal watercourses, roads should be removed from inner gorge or potentially unstable headwall areas except where alternative road locations are unavilable and the need for the road is clearly justified. Road surfacing and use intensity directly influences sediment delivery from roads. Rock surfacing or paving is appropriate for frequently used roads. Hydrologic connectivity refers to the extent that the road drainage is connected to watercourses. The connectivity can be reduced by outsloping roads, creating road drainage that mimics natural drainage as much as possible, and other factors (M. Furniss, pers. comm., 1998; Weaver and Hagans 1994). Sidecast on steep slopes can trigger earth movements, potentially resulting in sediment delivery to watercourses. This indicator is intended to address the highest risk sediment delivery from roads not covered in other targets.

4e. Timber Harvest

Target Level: No clearcut timber harvesting or tractor yarding in steep, potentially unstable streamside areas.

Existing Conditions: An exact value is not known; however, this practice is not conducted on Forest Service land, but is potentially practiced on some private timber lands.

Improvement Needed: Assess risk; improving trend until target levels are met.

Explanation:
Clearcut and tractor yarding should not be used in steep, unstable streamside areas unless a detailed geological assessment is performed showing no potential for increased sediment delivery to watercourses. The Forest Service does not conduct clearcuts or tractor yarding in streamside areas, in recognition of the increased risk of sediment delivery. However, the Forest Practice Rules does not adequately limit this practice.

4. SOURCE ANALYSIS

The objective of the source analysis is to identify all sources of sediment to the South Fork Trinity River basin, characterize the magnitude of the sources, and demonstrate that all major sediment sources have been considered in establishing the load reductions identified to meet the numeric targets presented in Chapter 3. The methods and results of the analysis, which is based on the work of Raines (1998) and Matthews (1998), are summarized below.

Previous Relevant Investigations

The sediment source analysis presented in this section draws from several studies that have been conducted to determine sediment sources in the South Fork basin over the past quarter century. The only portion of the South Fork basin for which a detailed sediment budget has been prepared is the Grouse Creek subwatershed (Raines and Kelsey 1991). The USFS conducted a landslide inventory of the lower South Fork basin for its Watershed Analysis (USFS 1998b) and also conducted a basinwide assessment of existing channel storage (Llanos 1998).

The Grouse Creek sediment budget (Raines and Kelsey 1991), which was developed for the Six Rivers National Forest, covered the period from 1960 to 1989 and reported a sediment production rate of 1,750 tonnes/km^2/yr (745 t/mi^2/yr) for the 29-year period. Over 86 percent of all sediment was produced by landsliding, which was found to be concentrated in areas of geologic instability and logging and during major storms. Ninety-three percent of all sediment volumes were generated from 1960 to 1975, a period that included four major storm events, the completion of 74 percent of basin logging activity, and 80 percent of road building.

In 1992, the California Department of Water Resources (DWR) produced a report, *South Fork Trinity River Sediment Investigation* (DWR 1992), that consisted primarily of sediment transport modeling at three sites: (1) Forest Glen, (2) below Hyampom, and (3) Salyer. Clusters of cross sections were surveyed at each site to allow for the use of hydraulic and sediment transport models. A summary of the results of the model simulations are also presented in Matthews (1998).

DWR conducted two other sediment investigations in the South Fork basin (Calif. DWR 1979, 1982). These investigations described the watershed characteristics and conditions, as well as geomorphic changes and damage to fishery habitat following the 1964 storm. Two USGS investigations provide estimates for sediment discharge from the South Fork basin for the period 1957-1970(Knott 1974, Hawley and Jones 1969). A 1972 report by the USDA Soil Conservation Service (USDA River Basin Planning Staff, 1972) included sediment source estimates for five Northern California coastal river systems, including the Trinity River basin, with landslide estimates covering the period 1940 to 1965. That report quantified sediment from stream bank erosion, landslides, and sheet and gully erosion from logging, grazing, recreation, croplands, and roads.

1998 South Fork Sediment Source Assessment

The previous investigations all produced data that support the current TMDL development; however, additional data were collected and analyzed to adequately identify and quantify South Fork sediment sources. The 1998 sediment source assessment has identified the following major source categories for which sediment loading estimates have been developed:

- Mass wasting
    - natural
    - harvest-related
    - road-related
- Road surface erosion
- Road washouts and gullies
- Hillslope surface erosion
    - natural
    - harvest-related
- Stream bank erosion

Within each of these categories, a combination of aerial photograph interpretation, field verification, and computer modeling was used to generate sediment loading estimates. Detailed methods are described in the source assessment developed by EPA (Raines 1998) to support development of this TMDL. The 1998 landslide inventory used similar methods employed by the USFS in the 1996 inventory, and included data from the 1996 inventory as well as from the Grouse Creek sediment budget (Raines and Kelsey 1991) in the analysis. In addition, available information related to in-stream channel storage, transport and discharge of sediment are discussed in this chapter.

Mass Wasting

Estimates of sediment contributions from mass wasting within the South Fork basin were compiled from the following three sources:

- Detailed inventory and sediment budget developed for the Grouse Creek subwatershed area for the period from 1960 to 1989 (Raines and Kelsey, 1991).

- 1996 USFS inventory for the lower South Fork area (USFS, 1998b). The Six Rivers National Forest inventory included the area of the Lower South Fork from Sulphur Glade Creek (a South Fork Mountain drainage located approximately midway along the Hidden Valley subwatershed area) downstream to the mouth of the South Fork.

- 1998 EPA inventory for the remainder of the basin, including the Upper South Fork Trinity River above Sulphur Glade and Plummer Creeks and all of Hayfork Creek (Raines 1998). This inventory used protocols similar to the 1996 USFS inventory.

For the 1996 and 1998 inventories, aerial photographs from 1944, 1960, 1975, and 1990 were used to identify the initial appearance and track the fate of landslides over the budget period (1944-1990). The landslides were classified according to:

- 5 size classes (<.32 ac, 0.32-1 ac, 1-3.2 ac, 3.2-10 ac, and >10 ac);
- Process (debris slide, debris torrent, deep-seated landslide, slump, or talus)
- Associated land use visible on the photo (natural, harvest, road, fire, cumulative, range and agriculture);
- Slope position (ridgetop, midslope, midslope with direct stream delivery, and inner gorge);
- Trend (date of first appearance, static, enlarged, recovering, healed);

In the 1996 and 1998 inventories, field-measured relationships between landslide area and delivered volume of slide features were developed and the median volume for each size class was assigned to unmeasured features.

It is important to note that the protocol for this inventory specified allocating landslide volumes to the period of first appearance on the aerial photographs regardless of whether the landslide enlarged in a later period. This tended to result in an overestimation of volume for the early period, and an underestimation for later periods. For example, in the combined 1996 and 1998 landslide inventory databases, 98 of 337 landslides that appeared before 1960 enlarged in a later period. In the Lower South Fork Sub-area, the average enlargement was about 90% (M. Smith, USFS, pers. comm., and Smith and Morrison 1998). However, volumes could not be segregated according to the 15- or 16-year intervals between photo years.

Road Surface Erosion

Sediment delivery to streams from surface erosion of roads was estimated using a GIS-based road erosion/delivery model, SEDMOD, developed by Boise Cascade Corporation (1998, in Raines 1998). The model uses information from an elevation grid along with road and stream layers to estimate which segments of the road system are likely to drain to streams. The relative amount of sediment produced from these road segments is then calculated based on erosion factors drawn from the Washington Department of Natural Resources Standard Methodology for Conducting Watershed Analysis, surface erosion module (WDNR 1995, in Raines 1998), with modifications based on additional empirical road erosion research conducted in the Pacific Northwest. Other data layers employed include geology and precipitation. Field surveys were conducted in the South Fork basin to calibrate the model to the six generalized geologic units and road sediment delivery attributes in the South Fork basin.

GIS road coverage was obtained from Six Rivers National Forest. Some additional roads were added to the data layer from aerial photograph checking, and Sierra Pacific Industries (SPI) supplied road coverage on their property in the eastern Hayfork Creek area. All roads were attributed with construction year, surfacing, and 1998 traffic levels. Traffic levels were then adjusted for each of the three periods based on timber sale records from the Hayfork Ranger District. The model was run twice for each aerial photograph period, using two different basic erosion rates for each geologic unit. The erosion rates used reflect the range of values reported in the literature.

Based on a comparison of model results and field calibration of selected road segments, the modeled road surface erosion rates were reduced by 26 percent to correct for over-prediction of streams on the map-enhanced stream layer. The adjusted model runs were then averaged to obtain an estimate of annual road surface erosion for each budget period. Road surface erosion sediment estimates reported in Raines and Kelsey (1991) were used for the Grouse Creek subwatershed area.

Road Washouts and Gullies

Episodic erosion from roads not captured by surface erosion processes and generally too small to view from aerial photographs include gully failures of stream crossings (washouts), small cutslope and fillslope failures, and gullying of the road tread, ditch, and fillslope. The 1998 road surveys included measurements of these features. Measurements were also available from road data in the East Fork/Smoky Creek Watershed Analysis (USDA FS 1998a) and from the Grouse Creek sediment budget (Raines and Kelsey 1991).

Washout and gully erosion volumes were averaged over the road length of the surveys, and erosion rates were assigned to the remaining road system based on basin location and dominant geology. Measured erosion features were assumed to represent erosion events occurring every 5 to 10 years, so rates were applied to roads multiplied by the number of peak flow events with 5- to 10-year return intervals occurring within that period. Erosion measurements reported for East Fork/Smoky Creek and Grouse Creek were used for those subwatershed areas.

Hillslope Surface Erosion

Plantation data layers from the Shasta-Trinity and Six Rivers National Forests were used to estimate harvest areas and locations. No data layer exists with harvest year and method of harvest, and the harvest data base currently available by management compartment for the Shasta Trinity National Forest does not have data prior to 1985. The plantation data is limited as a harvest surrogate because it does not capture seed tree units, select or partial cut units that were not replanted, or those units re-entered multiple times.

Observations and measurements from 1998 field sampling found that erosion from harvest units delivered to streams where a stream was in close proximity to the harvest unit or where a road that delivered to a stream was near or in the unit. Plantation data were sorted in GIS by subwatershed area, slope classes <40 percent and >40 percent to approximate tractor and cable yarding, and by geology lumped into one of two classes (more erodible or less erodible). Miles of streams and roads delivering to streams through the harvest units were also calculated. Compiling the plantation data in this manner gives a qualitative picture of erosion potential by subbasin over time. Erosion rates were used from literature values developed in northwestern California (Lewis and Rice 1989, in Raines 1998). These 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, including some sites in the South Fork basin. Erosion rates were applied to all plantation areas using a single rate for sites on the west side of the basin (Lewis and Rice analysis unit 1) and another for the east side (Lewis and Rice analysis unit 2) based on their data. The data from Lewis and Rie (1989, in Raines 1998) do not distinguish between harvest method, nor is delivery of erosion to streams explicitly stated. To be conservative, erosion rates were doubled for the period 1960 to 1975 to account for less sensitive ground harvest practices prior to initiation of forest practice regulations in 1973.

A fire history data layer supplied by the Shasta Trinity National Forest was used to tally acres of burn area in each sub-basin. Observations on several 10 year-old burn areas within the basin yielded little evidence of current erosion problems and little measurable evidence of post-burn erosion delivery to streams. Acres of burn area within each sub-area were multiplied by a conservative erosion rate of 5.2 tons/ac for one year based on soil loss simulations for a high disturbance fire (Elliot and others, 1996; Elliot and Robichaud, 1998, in Raines 1998).

Shasta-Trinity vegetation layers allowed identification of non-timbered areas in grass and oak woodland and chaparral acreage by sub-basin. The erosion rate for grass and oak woodland calculated for Grouse Creek was used to estimate erosion from similar areas in the rest of the basin. Chaparral areas are extensive in the Hayfork Creek sub-basins and, although quite brushy, soils have little duff cover and are therefore susceptible to surface erosion. Surface erosion from chaparral sites was estimated by multiplying the chaparral areas within 300 feet of a stream by 1 ton/ac/yr.

Streambank Erosion

Bank erosion measurements applicable to available in the South Fork include those made during the 1997 channel storage work by the Six Rivers National Forest (Llanos, 1998), the Grouse Creek sediment budget (Raines and Kelsey, 1991), and those of USDA River Basin Planning Staff (1972). Erosion rates reported in ac-ft/yr by USDA River Basin Planning Staff (1972) were measured from 1944 and 1965 photographs with field checking of approximately 602 miles of coastal streams throughout all of northern California. Raines and Kelsey (1991) assumed measured bank erosion rates applied to the entire 29-year period of study in Grouse Creek. The time frame assigned to bank erosion from the Six Rivers data was 10 years based on the approximate recurrence interval of the 1997 peak flow event, which may have produced some of the bank erosion. This time frame estimate may be somewhat low, as the erosion may have actually taken place over a longer period, which may yield bank erosion estimates that are somewhat higher than would be expected.

All bank erosion volumes were reported by stream order. A comparison was made among the bank erosion rates, and rates assigned based on different geologic areas of the basin, or averages where values were similar (Raines, 1998). Extrapolated bank erosion for Grouse Creek was compared with that reported by Raines and Kelsey (1991) which is an area with a higher concentration of bank erosion measurements in the basin. The extrapolated rates were 45 percent higher, so adjustments to all sub-basin totals of 30 percent were made based on this relationship (Grouse Creek bank erosion rates were assumed to be low based on the results of this comparison). For Hayfork Creek, first order streams and half of second order streams were also cut from the stream total based on the over-prediction of streams on the stream layer.

A by-product of the road surface erosion model is an estimate of "background" erosion by which to compare road erosion. The background erosion calculation is based on the rate of downslope soil movement, or soil creep, that is then periodically transferred to the stream system through bank erosion or other mass wasting processes. This is a fairly good estimate where mass wasting is not the dominant erosion process and creep rates have been measured. Creep rates used in the model ranged from 0.5 mm/yr in the flat-lying valley fill to 2 mm/yr on schist slopes greater than 30 percent based on Redwood Creek creep rate measurements (Swanston et. al 1983, in Raines 1998). Earthflow and large deep-seated failures with accelerated creep rates are not delineated on the geology data layer in GIS.

Comparison of bank erosion estimates and background from soil creep estimates shows a difference of a factor of 6 to 10 between numbers. The adjusted extrapolated streambank erosion rates predict that all streambanks in the basin are eroding an average of 16 mm/yr, compared with creep rates of 1.0 to 3.0 mm/yr in Redwood Creek. Since the depth and time estimates of bank erosion measurements are not well constrained, an average of the two bank erosion numbers was used for the Upper and Lower South Fork Trinity sub-basins. The creep rate model was used for the Hayfork Creek estimate, as it may better predict bank erosion in that sub-basin due to the low incidence of mass wasting and lower annual precipitation.

It is not possible, given the amount of information that is currently available, to accurately determine how much bank erosion is due to management causes and how much is due to natural erosion. However, for the purposes of this analysis, the same proportions of management- versus non management-associated sediment estimated for all other sources were used to assign bank erosion to management versus non management causes; i.e., 35% was assigned to management sources and 65% was assigned to non management sources. These values were assigned to subareas based on the size of the subarea.

1998 Sediment Source Assessment Results

Table 5 shows a summary of the sediment source analysis for the period 1944 to 1990 for the entire South Fork basin. Sediment production averaged 1,053 tons/mi^2/yr for the analysis period, but was heavily influenced by the 1964 flood. Management-related sources account for about 35% of the sediment delivery to streams, while non management-related sources account for 65% of the total. Mass wasting is by far the dominant process, accounting for approximately 64% of the basin-wide sediment delivery. Most of the mass wasting sediment delivery is associated with non management-related sources in the Upper and Lower South Fork sub-basin. Roads are associated with 19% of the total delivery, twice that of timber harvest. Other land management activities such as mining and agriculture are not specifically accounted for, but are smaller in scale and would account for small portions of the overall yield. Bank erosion has been estimated at 208,300 tons/year, or about 21% of the total, which may be a very high estimate. Sources of uncertainty in the source analysis methods and results are discussed in greater detail in Chapter 7.

Table 6 illustrates that the sediment delivery varies significantly by the major sub-basins. This is due to inherent differences in the dominant underlying geology, geomorphology and local climate in each of the sub-basins, although other factors such as land management activities and roads also influence the results. On a per-unit-area basis, the Lower South Fork sub-basin delivered 2,385 tons/mi^2/yr for the 1944-1990 period, which is more than twice the rate of the Upper South Fork sub-basin (1,050 tons/mi^2/yr) and nearly seven times the rate for the Hayfork sub-basin (361 tons/mi^2/yr). The rate in the Upper South Fork sub-basin is close to the average basinwide (1,053 tons/mi^2/yr). The Upper and Lower South Fork sub-basins are dominated by mass wasting on highly erodible soils. By contrast, the Hayfork sub-basin is relatively more influenced by bank erosion processes (62% of the total sediment yield for the that sub-basin) and surface erosion processes (21% of the total for the sub-basin). Road-related sources in the Hayfork sub-basin (including mass wasting, surface erosion, and washouts and gullies) account for 26% of the sediment delivery in that sub-basin.

Mass Wasting

Landslides are most abundant in the four geologic units that underlie the western portion of the basin. Most of the active landslides are shallow debris slides and most occur in the Galice Formation, which is structurally weak. Inactive, deep-seated landslides are most common in the Rattlesnake Creek Terrane and the South Fork Mountain Schist, which have fine-grained soils and strongly developed foliation that acts as a natural failure plane. (USFS 1998b, citing Haskins 1981). Table 7 summarizes management and non management-related mass wasting for the three major sub-basins.

Significant differences in sediment delivery are apparent between sub-basins; this difference is largely due to the geologic setting of the subareas. Table 7 also highlights subwatershed areas that are located generally on the west side of the South Fork Trinity River, dominated by the more erodible and unstable geologic terranes (see Figure 6). These seven subwatershed areas occupy 32 percent of the South Fork basin land area but generate 89 percent of the total mass wasting in the basin. On a per-unit basis, the west-side subwatershed areas deliver about three times as much sediment from mass wasting as other subwatersheds in the basin. The Lower South Fork Trinity subarea is of particular concern, as its four west-side subwatershed areas generate nearly 60 percent of the mass wasting sediment loading. The Grouse Creek and the Lower South Fork subwatershed areas alone account for nearly half (45 percent) of the mass wasting sediment loading.

Table 5: Sediment Source Analysis Summary 1944-1990

Association/Source	**Sediment Yield (tons/year)[1]**	**Sediment Yield (tons/mi^2/year)[1]**	**Percent of Total**
Management Sources			
Harvest-mass wasting	69,453	75	7
Harvest-surface erosion	20,828	22	2
Roads-mass wasting	74,431	80	8
Roads-surface erosion	66,379	71	7
Roads-washouts, gullies, small slides	39,554	42	4
Cumulative/Other-mass wasting and bank erosion[3]	75,631	81	8
SUBTOTAL-Harvest-related[4]	*90,282*	*124*	*9*
SUBTOTAL-Road-related[4]	*180,363*	*244*	*18*
Total Management -Related Sources[2]	**346,275**	**371**	**35**
Non-management Sources			
Mass wasting	485,250	521	49
Surface erosion (grasslands, fire, chaparral)	14,861	16	2
Bank erosion[3]	135,395	145	14
Total Non Management Sources	**635,506**	**682**	**65**
TOTAL SEDIMENT YIELD	**981,781**	**1,053**	**100**

Source: Raines 1998

[1] 1944-1990, except that Grouse Creek subwatershed data are only for 1960-1989. Tons/year and tons/mi^2/year are adjusted for that subwatershed to account for the shorter budget period. This adjustment probably overestimates Grouse Creek sediment yield, since the time period is shorter but still includes the delivery from the 1964 flood. It is unknown how much sediment may have been produced as a result of management activities in that subwatershed prior to 1960, which would not be included in this estimate but may be significant.

[2] Agriculture and mining are not specifically included but are not considered significant sources.

[3] Bank erosion has been estimated at between 50,000 to 446,000 tons/yr. This represents the best estimate within the range. 35% of that is assigned to management related sources, and 65% to non management sources, based on the proportion of other sources assigned to those causes. An average of the range was used for the Upper and Lower South Fork sub-basins, and the creep rate model was used for the Hayfork Creek sub-basin, due to the lower number of landslides in that sub-basin.

[4] Bank erosion is not included in these estimates.

Table 6: South Fork Trinity River Sub-basin Sediment Delivery Summary, 1944 to 1990

Source	**Upper South Fk**			**Lower South Fk**			**Hayfork**			**TOTAL**		
	t/yr	**t/mi^2/yr**	**%**[a]	**t/yr**	**t/mi^2/yr**	**%**[a]	**t/yr**	**t/mi^2/yr**	**%**[a]	**t/yr**	**t/mi^2/yr**	**%**[b]
Management-Related Sources[c]												
Harvest-Mass Wasting	25,268	74	7	43,062	213	9	1,123	3	1	69,453	75	7
Harvest-Surface Erosion	5,900	17	2	11,493	57	2	3,435	9	2	20,828	22	2
Roads-Mass Wasting	13,546	39	4	60,049	297	12	836	2	1	74,431	80	8
Roads-Surface Erosion	32,724	95	9	12,535	62	3	21,120	55	15	66,379	71	7
Roads-Washouts, gullies, small slides	14,585	43	4	10,288	51	2	14,680	38	10	39,554	42	4
Cumulative/Other-Mass Wasting and Bank Erosion	29,010	85	8	16,169	80	3	30,453	79	22	75,631	80	8
Total Management Sources	**121,033**	**352**	**34**	**153,596**	**760**	**32**	**71,647**	**185**	**51**	**346,275**	**371**	**35**
Non Management Sources												
Mass Wasting	181,412	529	50	297,576	1,473	62	6,262	16	5	485,250	521	49
Surface Erosion (grasslands, fire, chaparral)	7,798	23	2	1,250	6	0	5,813	15	4	14,861	16	2
Bank Erosion[d]	49,829	145	14	29,345	145	6	56,221	145	40	135,395	145	14
Total Non Management Sources	**239,.039**	**697**	**66**	**328,171**	**1,625**	**68**	**68,296**	**176**	**49**	**635,506**	**682**	**65**
TOTAL SEDIMENT SOURCES	**360,071**	**1,050**	**100**	**481,768**	**2,385**	**100**	**139,942**	**361**	**100**	**981,781**	**1,053**	**100**
Sub-basin Land Area (mi^2)	343		36.8%	202		21.7%	387		41.5%	932		100%

a: Percent of sub-basin total.
b: Percent of South Fork basin total.
c: Agriculture and mining not included
d: Bank erosion is probably overestimated relative to other estimates

Source: Raines 1998

Table 7: Mass Wasting by Subwatershed Area (tons)

Subwatershed Area	1944-1990 Mgmt-related MW	% of SFTR total MW	1944 -1990 Non Mgmt MW	% of SFTR total MW
Upper South Fork Sub-basin				
1-Butter Ck	16,900	<1	114,000	<1
2-Plummer Ck	60,400	<1	757,200	3
3-Rattlesnake Ck	42,800	<1	25,300	<1
4-Smoky Ck	12,600	<1	138,400	1
5-East Fk South	295,300	1	582,400	2
6-Upper South Fk*	437,000	2	660,300	2
7-Happy Camp Ck*	368,400	1	930,300	3
8-Hidden Valley*	652,300	2	5,136,900	18
Subtotal Upper South Fk	**1,885,700**	**6**	**8,344,800**	**29**
Hayfork Sub-basin				
9-Corral Ck	41,200	<1	0	0
10-Lower Hayfork Ck	33,000	<1	279,800	<1
11-Middle Hayfork Ck	15,900	<1	0	0
12-Salt Ck	8,300	<1	0	0
13-Upper Hayfork Ck	0	0	8,300	<1
16-Upper Mid Hayfork	0	0	0	0
Subtotal Hayfork	**98,400**	**<1**	**288,100**	**<1**
Lower South Fork Sub-basin				
14-Hyampom*	377,700	<1	1,564,300	5
15-Gulch	25,000	<1	667,600	2
17-Madden Ck*	1,023,200	4	1,491,500	5
18-Grouse Ck (1960-1989)*	2,691,700	9	4,410,800	15
19-Lower South Fork Trinity*	642,400	2	5,554,300	19
Subtotal Lower South Fk	**4,760,000**	**16**	**13,688,500**	**47**
***West-side Subwatersheds**	**6,192,700**	**21**	**19,748,400**	**68**
TOTALS	**6,744,100**	**23**	**22,321,400**	**77**

* West-side subwatershed areas are areas of highly erodible geology (see Figures 4 and 6).

Source: Raines 1998

In the Lower South Fork sub-basin, which accounts for the largest proportion of mass wasting sediment sources, inner gorge landslides account for 78% of all landslides (USFS 1996, as modified by Raines 1998). Two-thirds of these first appeared or enlarged in the 1975 photos, suggesting that they were related to the 1964, 1972 or 1974 floods. Seventy-one percent of the total landslide volume from that database is due to inner gorge failures associated with natural causes.

Non management-related

Non management-related mass wasting is responsible for nearly 50 percent of the estimated total South Fork sediment yield. For the period from 1944 to 1990, non management-related mass wasting accounted for 62, 50, and 5 percent, respectively, of the total sediment delivery in the Lower South Fork, Upper South Fork, and Hayfork Creek subareas. The sediment yield for non management-related mass wasting in the entire South Fork basin was estimated at 521 tons/mi^2/yr. As a comparison with other source assessments for recent TMDLs, this estimate falls is close to the overall mass wasting value presented in the Garcia River TMDL (EPA 1998), but is much higher than non management-related mass wasting in the Garcia basin (112-168 tons/mi^2/yr). While the geology of the South Fork basin is less stable than the Garcia River basin, this may also suggest that the estimate of non-management related landsliding is low (Matthews 1998).

It is highly likely that the non-management related landslides in the analysis includes some landslides that are actually related to cumulative management effects not visible on the aerial photographs (Matthews 1998). In the 1964 flood, many debris torrents caused significant aggradation (from 15 to 20 ft in some locations), which probably then triggered many inner gorge landslides. Even in areas of similar geology, this tended to occur downstream of management areas more than it occurred downstream of unmanaged areas (DWR 1982, Matthews 1998). Thus, non-management landslides may be somewhat underestimated. Using the 1996 landslide database (USFS 1996, as modified by Raines 1998), this would be consistent with the fact that the majority of landsliding features have been identified as inner gorge features, and most of those first appeared in the 1975 photos. However, USFS analysis has suggested that the majority of inner gorge features are not toe-generated and would not be related to such cumulative effects (C. Cook, M. Smith, pers. comm., 1998). Seventy-eight percent of landslide volumes in the 1996 data base were identified as inner gorge features, and 92% of those landslides were assigned to natural causes. Only 1% were determined to be related to harvest activities, and 5% were determined to be road-related (USFS 1996, as modified by Raines 1998).

Harvest-related

Sediment delivery from mass wasting associated with timber harvest is much lower than estimates for non management areas. Sediment delivery from the Lower South Fork, Upper South Fork, and Hayfork Creek sub-basins are estimated at 213, 74, and 3 tons/mi^2/yr, respectively. Harvest-related mass wasting accounts for approximately 7 percent of the total sediment yield in the South Fork basin. Locally, the percentage varies from 1 percent in the Hayfork Creek sub-basin to 9 percent in the Lower South Fork subarea. As discussed above, this may be a low estimate, as some failures assigned to natural causes may be management-related.

Road-related

For the entire basin, sediment yield from mass wasting associated with roads is roughly the same as for harvest areas, comprising about 8% of the total sediment yield. However, as with harvest-related mass wasting, significant variability exists between sub-basins, with the Lower South Fork, Upper South Fork, and Hayfork Creek sediment yield estimated at 297, 39, and 2 tons/mi^2/yr, respectively. As with natural and harvest related mass wasting, road-related mass wasting in the Hayfork Creek sub-basin exhibits significantly lower sediment yields relative to the other sub-basins. Again, this estimate could be low, as some failures assigned to natural causes may be management-related.

Variance Within Time Intervals of the Budget Period

While it is not possible within this analysis to assign *volumes* for each of the time segments within the overall budget period, Table 8 illustrates the *number* of landslide initiations and enlargements associated with those segments. The highest numbers of landslides were observed during the 1960 to 1975 period, undoubtedly triggered primarily by the 1964 flood. The low values associated with the 1975 to 1990 period are probably due to fewer landslide-generating storms (e.g., lack of intense precipitation over already saturated soils or rain-on-snow events), as well as to the possibility that the 1964 flood already triggered many landslides that would have been otherwise triggered in later periods. In addition, land management practices improved with the passage of the Z'berg-Nejedly Forest Practices Act in 1973.

Table 8: Landslide Progression over Time, 1944-1990

PERIOD	NUMBER OF LANDSLIDES								
	MANAGEMENT[1,2]			NON MANAGEMENT[2]			TOTAL[2]		
	New	Enlarged	Static/ Recovering /Healed[3]	New	Enlarged	Static/ Recovering /Healed[3]	New	Enlarged	Static/ Recovering/Healed[3]
Pre-1944[4]	7	0	1	153	0	0	160	0	1
1944-1959[4]	51	1	7	124	14	139	216	15	146
1960-1974	272	19	40	430	67	210	1,033	176	250
1975-1990	45	11	218	32	32	677	93	64	1,105

Source: Raines 1998

[1] Includes road-related, harvest-related, and cumulative/offsite. Landslides related to mining and agriculture, which are expected to be much smaller in number, are not specifically accounted for.
[2] Total includes Grouse Creek data for 1960-1975 and 1975-1990. Grouse Creek data are not segregated by management v. non management associations and are therefore not included in the totals for those periods.
[3] Landslides that are static, recovering, or healed are assumed to deliver little or no sediment to streams.
[4] Grouse Creek data are not available for pre-1960 periods.

Road Surface Erosion

Road surface erosion accounts for 71 tons/mi^2/yr for the entire South Fork basin. It is a relatively significant component (15 percent) of the sediment total in the Hayfork Creek sub-basin, where mass wasting levels are relatively low. Sediment delivery estimates from the Lower South Fork and Upper South Fork are 62 and 95 tons/mi^2/yr, which represents 3 and 9 percent of the total sediment delivery in the respective sub-basins, which are dominated by mass wasting processes. In the entire South Fork basin, road surface erosion accounts for an estimated 7 percent of the total average annual sediment delivery.

Sediment delivery associated with road surface erosion is significantly higher for the 1960 to 1975 and 1975 to 1990 periods (Table 9), as more roads were constructed in those periods to accommodate increased levels of harvest. Higher traffic levels and intense precipitation also influenced the sediment production for the period. The budget period extended to 1990, about the same time that harvest levels began to be dramatically reduced in the national forests. The road model also identifies individual road segments by total annual sediment contributions, which may be helpful for more detailed identification of road-related surface erosion in the future, as well as for future targeting and prioritizing roads for sediment reduction.

Road Washouts and Gullies

Sediment yield associated with washouts, gullies, and small slides accounts for 42 tons/mi^2/yr in the South Fork basin. Sediment yield for the Lower South Fork, Upper South Fork, and Hayfork Creek was estimated as 51, 42, and 38 tons/mi^2/yr, respectively. Because road repair and maintenance can eliminate evidence of gullies and washouts, the estimates provided probably underestimate actual erosion. However, even if the estimated values are doubled, the sediment delivery from these features represents a small percentage of the overall South Fork sediment input.

Table 9: Road Erosion Summary

	Sediment Yield (tons/mi^2/yr)		
	Upper South Fork	**Lower South Fork**	**Hayfork Creek**
1944 to 1960			
Surface erosion	52	38	32
Washouts and gullies	5	5	4
1960-1975			
Surface erosion	119	74	60
Washouts and gullies	65	82	46
1975-1990			
Surface erosion	118	45	74
Washouts and gullies	60	40	66
1944 to 1990			
Surface erosion	95	62	55
Washouts and gullies	43	51	38

Hillslope Surface Erosion

Non Management-related

Sediment delivery from non-management areas was estimated as 16 tons/mi^2/yr for the South Fork basin, which accounts for just under 2 percent of the total sediment delivery. The sediment delivery in the Lower and Upper South Fork sub-basins was similarly low (2 percent or less), whereas hillslope erosion accounted for 4 percent of the total sediment yield in the Hayfork Creek sub-basin. Non-management surface erosion is more significant in Hayfork Creek due to past fires as well as to chaparral vegetation types, which do not protect the surface slopes as well as tree coverage.

Harvest-related

Surface erosion from harvest units is estimated at about 2 percent of each sub-basin, which is similar to rates reported by Raines and Kelsey (1991) for Grouse Creek. The sediment yield estimates for the Lower South Fork, Upper South Fork, and Hayfork Creek are 57, 17, and 9 tons/mi^2/yr, respectively.

Streambank Erosion

Annual average bank erosion for the entire South Fork Trinity River basin may reasonably vary from 50,000 to 446,000 tons/yr. Estimates were developed with considerable uncertainty based on assumptions about time periods associated with bank erosion observations, over-estimates of stream miles based on a GIS layer (J. Werren, pers. comm., 1998) and the lack of certainty in assigning estimates to specific causes. Bank erosion was estimated to account for 22% of the sediment yield in the basin, although it is likely that this is high (Raines 1998).

Changes Since 1990

The sediment budget covered the period 1944-1990, for which complete aerial photograph sets were available, changed significantly in the period from 1990-1998. After 1990, following the listing of the Northern Spotted Owl, as well as other harvesting constraints, timber harvest rates decreased significantly. For example, in the period 1975-1990, 242 million board feet (MMBF) of timber per year were programmed for harvested on the Shasta-Trinity National Forests (including areas outside of the South Fork basin). After 1990, that was reduced to 87 MMBF (36% of former levels), and by 1995, the volume was reduced to 82 MMBF (34% of former levels), consistent with the President’s Forest Plan. The recent reductions also resulted in 50% of land being removed from availability for timber harvest (A. Kallis, pers. comm., 1998). While these figures are not available specifically for the South Fork basin, it is important to consider that the relative rates of reduction also apply to the South Fork basin, and some degree of decreased sediment production is probably associated with the decreased intensity of land management activities.

Conclusions

For much of the South Fork basin, unstable and highly erodible terrain as well as land management activities have resulted in high sediment yields from landslides. The greatest source of sediment loading is mass wasting not associated with management sources. Lands west of the South Fork mainstem are particularly susceptible both to natural mass wasting and to accelerated mass wasting from management activities. The rates of sediment loading generated from these areas are significantly greater than that from other locations.

Overall sediment loading for the 1944-1990 period averaged 1,053 tons/mi^2/yr. Based on the analyses conducted for this TMDL, it is estimated that about two-thirds of sediment load is associated with natural sources and about one-third has been associated with various land management activities. It is likely that some sources of mass wasting is misattributed. The rates vary by location, with about 2,385, 1,050, and 361 tons/mi^2/yr in the Lower South Fork, Upper South Fork and Hayfork Creek sub-basins, respectively. By far the highest rates are found in the seven subwatershed areas in the most erodible geologic terranes west of the South Fork Trinity River mainstem, which are dominated by mass wasting processes.

Sediment delivery associated with mass wasting from all source categories in the 1975 to 1990 period has decreased significantly over the previous period, probably due to factors including:

- The December 1964 flood and other storms during the 1960-1975 period triggered some landslides that might have otherwise been triggered in the later period.
- Storm and flood events were less likely to trigger large landslides in the later period, both due to the character of the events (lower antecedent moisture prior to a peak flow, for example) and in some cases due to lower intensities (prolonged periods of drought with a few large peak flows in between).
- Less intensive and more protective land management practices, such as implementation of Forest Practice Rules and reductions in harvest activities following the listing of the Northern Spotted Owl in 1990 (A. Kallis, pers. comm. 1998).

Surface erosion and washouts and gullying from roads has more than doubled during 1975 to 1990, compared to the 1944 to 1960 time period, in contrast to the reduction of mass wasting in the later period. This may be due to large storms in combination with a much larger road network, more harvested acres, numerous inadequately maintained roads and undersized drainage structures.

Roads generate about twice the levels of sediment loading as timber harvesting. Roads are the most significant component of management-related sediment production. In the Hayfork Creek sub-basin, roads and bank erosion are the most significant components of the overall sediment production, largely due to the fact that mass wasting is a much less significant process in that sub-basin.

The average annual loading rates derived for this TMDL provide useful information for planning only when a long-term monitoring and analysis horizon is applied. Evaluation of sediment loading dynamics over short time periods (e.g., less than about 10 years) is unlikely to yield meaningful results, given that the South Fork basin sediment loading is dominated by infrequent, high magnitude events. Recovery from those events, which can occur naturally but are clearly exacerbated by management activities, can take many decades to complete.

Decreased land management activities have probably reduced present-day rates of sediment production over those determined in the sediment budget process.

5. LINKAGE ANALYSIS

An assessment of the magnitude of instream sediment impairment and associated levels of sediment source reductions needed to address instream problems is necessary to determine the TMDL for the South Fork basin. The result of this assessment is an estimate of the loading capacity— the amount of sediment the South Fork can assimilate and still meet its water quality standards. This section assesses the degree to which sediment reductions are needed from sources in the South Fork watershed to alleviate the instream sediment impairment discussed in the Problem Statement section and quantified in the Numeric Targets section.

The analysis relies on a comparison of existing and historical conditions with target levels for the instream indicators selected in the numeric targets chapter. Although it includes quantitative comparisons, the assessment is largely qualitative due to the high degree of uncertainty inherent in determining a baseline loading, and in inferring linkages between prospective hillslope erosion sources and instream impacts.

However, it is necessary in the TMDL development process to estimate the level of future sediment reductions needed to meet water quality standards. Because there are no reliable direct linkages to evaluate (i.e., the sediment source production-resource impact relationships tend to be separated in time and space) and no reliable methods for modelling those linkages, it is necessary to rely on less certain inferential methods.

Another method of predicting adequate sediment loading in the basin, given its episodic nature, would be to identify reference streams in basins similar to the South Fork but without land management activities, or by identifying loading rates prior to land management activities within the South Fork basin. Unfortunately, neither of these are currently available. EPA believes that future monitoring and evaluation will allow the analysis to be updated as additional information becomes available.

Comparison of Existing Conditions with Target Levels

Linkages between sediment sources in the watershed and instream conditions are generally indirect and highly variable. However, over the long-term, reductions in sediment inputs to the stream system are expected to result in reduced sediment delivery to the channel. Over time, the instream indicators identified in the Numeric Targets chapter should respond to the reduced sediment loading. Table 10 summarizes the comparisons of existing and target conditions. This comparison indicates that stream and watershed conditions are currently inadequate to support healthy habitat.

This analysis uses a one-to-one correspondence between sediment source reductions needed and reductions in stream sediment levels as measured by these indicators. This is not intended to represent direct cause-and-effect linkages. Because the actual relationship between sediment delivery and instream conditions influenced by sediment dynamics is poorly understood, this one-to-one correspondence is considered a conservative approximation of the quantities of sediment reduction needed. If watershed processes and linkages are better understood in the future, it may be feasible to strengthen this analysis. Moreover, what is most important is not the specific quantified results, but rather the general conclusion that substantial sediment loading reductions appear to be necessary to address the instream problems associated with sediment.

This comparison indicates that the minimum amount of sediment reduction needed to attain WQS ranges between 17-42%. Thus, an overall reduction of about 30% is reasonable, and represents approximately the mid-range.

Table 10: Comparison of Existing and Historic Conditions with Numeric Targets

Indicator/Target[1]	Existing Conditions	Improvement Needed
4,000 spring chinook spawners	Last 5-10 yrs: 400-700/yr avg	6-10 x current numbers for spring chinook. Probably influenced by improved pool habitat as excess sediment continues to move out of the system. Attaining the target may be influenced by factors outside of the basin.
3,000 fall chinook spawners	1993-97: 1,400/yr avg 1988-97: 800/yr avg	2-4 x current numbers for fall chinook. Probably influenced by improved pool habitat as excess sediment continues to move out of the system. Attaining the target may be influenced by factors outside of the basin.
Mainstem Pool Depth	Baseline monitoring underway	Improving trend indicating deepening of large pools and increased number of pools deeper than 15 ft.
V* 0.21 in western tributaries: 0.10 elsewhere	Avg 0.36 in Grouse Ck; 0.069-0.12 in 5 tributaries	Grouse Creek samples indicate a need for 42% reduction in fines. Basinwide, reduction of 0-17% indicated by existing data, but reductions would depend upon monitoring results.
Improving trend suggested by thalweg and cross-section surveys	Baseline monitoring underway	Improving trend indicating continued downstream movement of sediment, deepening of pools and increase in overall habitat complexity
≤14% sediment <0.85 mm	17% all samples; 18% all mainstem SFTR samples	Existing data reflects impairment from excess fine sediment, suggesting approximately a 18% reduction in fines overall, or a 22% reduction in South Fork mainstem stations.
≤1% of all stream crossings w/ diversion potential	37% avg in 4 Upper SFTR subwatersheds; estimated appx. 50-65% of all crossings in the basin	Appx. 35-60% of existing crossings should be upgraded basinwide.
≤ 1%s significant crossing failure	not known	Assess risk; improving trend until target conditions are met.
All roads inspected annually & maintained or hydrologically closed.	Appx 20% USFS roads; appx. 33% industrial roads	20-33% reduction overall in inadequately maintained roads (100% reduction of existing inadequately maintained roads)
No roads in inner gorge/headwalls, appropriate surfacing, reduce hydrologic connectivity, no fill/sidecast on steep slopes	Existing level of risk is not known basinwide	Assess risk; improving trend until target conditions are met.
Timber harvest: No clearcut/tractor yarding on steep slopes	Existing level is not known basinwide.	Assess risk; improving trend until target conditions are met.

[1] Instream targets are intended to be assessed over long-term running averages; significant inter-annual variability is expected.

Note: See Numeric Targets Chapter (3) for sources and additional explanation.

Additional reductions based on the uncertainties in the analysis are identified in the Allocations (Chapter 6). Supporting analysis (Matthews 1998) suggests that conditions may be improving, beginning in the upper part of the watershed as sediment continues to move downstream and out of the basin. However, significant sediment loading reductions appear to be necessary to address the instream problems associated with sediment. Load reductions should be more aggressive in the western portion of the basin, where road/stream interactions are more problematic and terrain is more susceptible to landsliding, particularly with management activity. Excessive sediment loading also appears to be more significant in the western portion of the basin than in other parts of the basin. In terrain that is generally less susceptible to landsliding (in the eastern portion of the basin), the channel conditions appear to be less degraded. Overall improvements, particularly re-enlargement of pool habitats and re-establishment of habitat complexity in the mainstem South Fork Trinity River, should create the greatest benefit. In addition, removal of potential road diversions and stream crossing failures, and reduction of road-related sediment throughout the basin, where erosion problems are most significant, will facilitate the continued in-channel improvements.

Conclusion: Estimate of Sediment Loading Capacity in the South Fork Basin

The comparison of existing and target conditions as well as analysis that supported the source assessment suggest that although sediment loadings may be improving in the upper portion of the basin, additional reductions are needed. In order to meet target conditions, improvements of about 30% would be needed. The only indicators with direct linkages to loading are the road-related indicators, but even with those improvements additional detailed analysis including field verification would be needed to estimate the loading associated with the improvements. In EPA’s judgment, assessments that have been conducted throughout the basin indicate that reductions of about 30% are needed in order for the South Fork Basin to meet water quality standards for sediment in the future. This suggests that allowable loading capacity is on the order of 70% of loading rates identified for the 1944-1990 budget period.

This is consistent with the source analysis, which concluded that management sources account for only a third of the overall sediment loading. The source analysis provided the following conclusions: 1) the South Fork system has always had high natural sediment loads typical of many North Coast basins and, though higher than rates observed in other regions, still supported fish habitat; 2) management sources need to be aggressively controlled if loading rates are naturally high; 3) loading reductions directed toward roads and timber harvest activities in the Upper and Lower South Fork sub-basins and toward roads in the Hayfork sub-basin will result in the most effective loading reductions; and 4) it may be most effective for the implementation plan to focus load reduction efforts geographically (and geologically).

Multiplying the average annual loading rate determined for the 1944-1990 period (1,053 tons/square mile) by the 70% allowable annual loadings yields an overall loading capacity estimate of 737 tons/square mile/year. This Loading Capacity meets the regulatory definition at 40 CFR 130.2(f), which states that the loading capacity is “[the greatest amount of loading that a water can receive without violating water quality standards.” In addition, the Load Allocations meet the regulatory requirements at 40 CFR 130.2(g) in that they are “best estimates of the loading, which may range from reasonably accurate estimates to gross allotments....”

As discussed in Chapter 4, considerable uncertainty exists regarding the estimation of sediment production, particularly from mass wasting and bank erosion sources. It is likely that management sources of landsliding from cumulative effects are higher than what is reported in the source analysis (Matthews 1998). Sources of uncertainty are further discussed in Chapter 7. It is probable that at least a portion of the loadings associated with sources that this analysis has characterized as “natural” are in fact caused by cumulative effects of management activities in the basin that are not readily apparent. This occurs because the activities in the basin alter natural hydrology in the watershed, as appears to have happened with the triggering of landslides during the 1964 flood (DWR 1982, Matthews 1998). However, USFS analysis suggests that this may not be the case (C. Cook, M. Smith, pers. comm., 1998). Nevertheless, it may be prudent to consider methods to reduce loading from some natural sources, where feasible, to make up for some of those management-related sources that cannot be adequately controlled given the need for significant load reductions in some areas. In addition, it appears likely that some reductions to the loadings based on the 1944-1990 period have been made, since land management activities have decreased in the basin.

Furthermore, apparent improvements in many of the indicators have been observed, suggesting that, while the system has not yet recovered from the catastrophic 1964 event, it may be on an improving trend. Future monitoring will provide additional evidence that may validate or may change this assumption. Less intensive management activities not accounted for specifically in this analysis may be facilitating that trend.

6. TMDLs AND ALLOCATIONS

The requirements of a TMDL are described in 40 CFR 130.2 and 130.7 and Section 303(d) of the Clean Water Act, as well as in various guidance documents. A TMDL is defined as the sum of the individual wasteload allocations for point sources, and load allocations for nonpoint sources and natural background pollutants, such that the loading capacity of the receiving water is not exceeded. The allocations indicate the amount of pollutant reduction from individual source categories that is required to attain water quality objectives. Allocations may be assigned based on land use, land area, or erosional process.

The South Fork basin allocations have been developed for erosion processes (associated with land use activities where feasible) based on the source analysis. The load allocations have been developed as long term annual average loads per square mile at the basin-wide and sub-basin scales. Sediment storage was not factored into the TMDL, loading capacity, and allocation calculations.

Total Maximum Daily Load Calculation

The TMDL for the South Fork is being expressed as long-term annual average sediment loading per square mile for the entire basin. This meets the regulatory definition that “TMDLs can be expressed in terms of either mass per time, toxicity, or other appropriate measure.” (40 CFR 130.2) This annual TMDL could be converted into daily loads, but expressing the TMDL as an annual average yield is more appropriate for sediment loading. The annual average loading rate for this TMDL should be measured in terms of not less than 10-year rolling annual averages. The longer term annual average timestep is an appropriate approach to account for the large inter-annual variability in sediment loading and the long-term timeframe in which beneficial use impacts occur and change.

This annual average loading per square mile will be referred to as the TMDL for the South Fork Trinity River and Hayfork Creeks. The TMDL is calculated by applying the loading capacity range from the previous section, which was estimated at 737 tons/square mile/year (rounded). The TMDL for the South Fork is therefore estimated to be 737 tons/square mile/year, expressed as 10-year or longer term rolling annual averages.

Load Allocations and Wasteload Allocations

There are no point sources of sediment discharge in the basin; therefore there are no wasteload allocations. The following are the load and wasteload allocations. Explanation is provided below under Explanation of Allocations and Calculations.

The Allocations divide the TMDL among key source categories, including natural background sources. The allocations are derived from the source analysis. The individual load allocations are based on EPA’s assessment of the degree to which loadings from different source categories can actually be controlled or prevented. The controllable fraction of total loads from each source category was estimated, and the remaining loads by category were summed and compared with the TMDL. This analysis reveals that, with the application of reasonable practices to control and prevent future loading, at least an additional 63 tons/mi^2/yr of reductions, or 58,716 tons/yr, would be needed to achieve reductions adequate to meet the TMDL. It is assumed that this amount represents the quantity of sediment produced by management-related mass wasting that was assigned to non-management related causes in the source analysis. If it is determined through further analysis that the quantity of management-related sediment is even greater than the amount that was determined in the source analysis plus the amount allocated to the margin of safety, then the allocations would need to be revised based on that additional information.

“Controllable” sources of sediment are defined as those which are associated with human activity *and* will respond to mitigation, altered land management, or restoration. The percentages are based on an understanding of the available mitigation, land management and/or restoration measures which have been developed for a variety of situations. The percentages reflect professional judgment of how successful the various best management practices (BMPs) generally are in controlling these sources. These assessments of source control potential are generally consistent with though slightly more stringent than those used for the Garcia River sediment TMDL established in 1998 and the Redwood Creek TMDL.

Estimates of controllable percentage of loads for road-related sources are derived from field work in the North Coastal Region by Weaver and Hagans (1994). For example, Hagans (1998, pers. comm.) estimates that about 95% of stream crossing diversions are controllable (Hagans, et al., 1986). Estimates of controllable percentage of harvest and other factors are based on staff judgment and experience. Estimates of natural background loading levels are provided for different mass wasting processes, and it was assumed these sources are not controllable. Allocations for road-related sediment applies to all land use activities including roads for timber, agricultural, and residential activities as well as state and county roads.

Estimates of bank erosion controllability are low in order to reflect the uncertainties in the methods used to develop the estimate of bank erosion sediment delivery. It is assumed that the recommendations made to reduce loading associated with management-related activities will provide collateral reductions in streambank erosion. Because of limited data, no sediment loading estimates were developed for mining, grazing, or other agricultural activities, but these sources are recognized as being a very small contribution to the overall sediment load in the basin. However, it is assumed that all controllable sources, including bank erosion, agriculture and mining, will be reduced to the greatest extent feasible.

Calculations

Table 11 summarizes the information used to calculate the individual allocations. The total historical loads estimated for each source category (column a) are provided in column b. Column c provides an estimate of the percent of the historical load that is controllable. The estimate of controllable load in column d was calculated by multiplying the loads from column b by the controllable percentages in column c. Column e is the remaining load, calculated by subtracting the controllable load (column d) from the historical load (column b). Thus, column e becomes the load allocation. There are no point sources in the watershed and none are expected to be proposed in the near future. Therefore, the wasteload allocation for point sources is zero.

The Margin of Safety was derived by determining the “leftover” or unallocated load amount. This is the difference between the loading (737 tons/mi^2/yr) and the sum of the load allocations based on the controllability of management-related loads. The leftover allocation (63 tons/mi^2/yr) is assumed to account for incorrectly attributed non-management related sources and other uncertainties in the analysis. In addition, the margin of safety is expressed implicitly in conservative assumptions (see Chapter 7).

Conclusion

The Loading Capacity and Allocations of Loads are developed for all major sources of sediment. As part of the supporting documentation, all sources were considered. Certain sources were not quantified, including sediment related to certain agricultural activities. These were accounted for qualitatively in the margin of safety. The sum of the load allocations plus the natural background is less than or equal to the estimated loading capacity and associated TMDL.

Table 11: Summary of TMDL and Allocations for the South Fork Basin

a	b	c	d	e
Source Mechanism	**Historic Sediment Load 1944-1990[1] (t/mi^2/yr)**	**Percent Controllable[2]**	**Controllable Load[3] (t/mi^2/yr)**	**Remaining Load (Allocation)[4] (t/mi^2/yr)**
Management Sources				
Harvest-Mass Wasting	75	60%	45	30
Harvest-Surface Erosion	22	85%	19	3
Roads-Mass Wasting	80	80%	64	16
Roads-Surface Erosion	71	85%	60	11
Roads-Washouts, gullies, small slides	42	85%	36	6
Cumulative/Other-MassWasting and Bank Erosion	81	35%	29	52
SUBTOTAL-Harvest	*97*	*66%*	*64*	*31*
SUBTOTAL-Roads	*193*	*83%*	*160*	*33*
Total Management Sources	371	68%	253	118
Non Management Sources				
Mass Wasting	521	0%	0	521
Surface Erosion	16	0%	0	16
Bank Erosion	145	0%	0	145
Total Non Management Sources	682	0%	0	682
Margin of Safety[5]			63	(63)
TOTALS	1,053	30%	316	737

[1] The estimated historic sediment load for each source.

[2] The percent of that historic load that is estimated as controllable. Controllable discharges are those discharges resulting from human activities that can influence the quality of the waters of the State and that can be reasonably controlled.

[3] The load that is estimated as controllable (the percent controllable multiplied by the historic load).

[4] The difference between the historic load estimate and the controllable load estimate. This is the estimated load at which salmonids in the South Fork basin would no longer be limited by sediment. There are no point sources in the basin, and no waste load allocation.

[5] The margin of safety is defined as the portion of the load allocation that is reserved. It is assumed that the reserved load actually represents controllable management sources that have been assigned in the source analysis to non-management sources.

7. MARGIN OF SAFETY, SEASONAL VARIATION, AND CRITICAL CONDITIONS

Margin of Safety

Section 303(d) of the Clean Water Act and the regulations at 40 CFR 130.7 require that TMDLs be established at levels necessary to attain and maintain the applicable narrative and numerical water quality standards with seasonal variations, and a margin of safety which takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality. The margin of safety can be incorporated into conservative assumptions used to develop the TMDL or added as a separate component of the TMDL (EPA, 1991).

For this TMDL, both implicit and explicit margins of safety are included. In each of the components used to develop the TMDL, assumptions were made where sufficient data was lacking. Conservative assumptions have been made as a way of addressing the uncertainty associated with the data. In addition, an explicit margin of safety has been developed for the allocations. Sixty-three tons/mi^2/yr were allocated to the margin of safety. It was assumed that this would account for a potential underestimation of management-related sources, particularly from the inner gorge failures that may be related to cumulative effects from upstream management but were not apparent in the sediment source analysis.

Table 12 summarizes the uncertainties from the source analysis and other components of the TMDL, and identifies the adjustments that were made to account for them. Most of the uncertainty relates to the sediment source analysis, as described below.

Sources of Uncertainty in the Source Analysis

Analysis of sediment sources is imprecise, and may result in overprediction or underprediction of the sediment volume from individual sources. For this TMDL, uncertainties about the mass wasting and streambank erosion portions of the analysis are most significant. Uncertainties include the following:

- A single volume assigned to various landslide size classes could inaccurately reflect actual volumes.
- A single volume assigned to an individual landslide for the entire budget period could inaccurately represent volumes of sediment production during the budget period, depending upon when the landslide first appeared and whether it enlarged during the budget period.
- Assumptions about the volumes of sediment delivery from the landslide types or slope positions may be incorrect.

- Errors can be made in identifying landslides and in estimating sizes from aerial photographs. This may be particularly true for the 1975 photos, a full decade following the most significant landslide-generating event in the basin. Many of the smaller landslides may have healed or begun to heal in that period.
- The three landslide inventories differed slightly in protocol. For example, the Grouse Creek study (Raines and Kelsey 1991) utilized a budget period of 1960-1989, which could result in an overprediction of sediment delivery relative to the 1996 and 1998 inventories, which utilize a longer budget period. Other differences could result in over- or under-prediction.

Table 12: Supporting Information For Margin of Safety

Uncertainties in TMDL Supporting Documentation	**Adjustments to Account for Uncertainties**
Existing data is limited.	The targets represent the optimal conditions for beneficial use support (salmonids) and include targets for watershed conditions (hillslope and roads).
The role of sediment storage in the mainstem as both a source and sink for sediment is poorly understood.	The TMDL gives no ”credit” for instream storage as a consideration in TMDL determination since current excessive levels of instream stored sediment are significantly impairing beneficial uses. The TMDL is lower than would be the case if instream storage credit were provided.
Higher order, lower gradient tributary streams still contain appreciable quantities of stored sediment both in the active channel and on adjacent terraces/flood plains. It may take decades to remobilize and route currently stored sediments in the active channel of tributaries and as a consequence significant improvements in channel stability and habitat quality may be delayed in many portions of the basin.	More conservative allocations to sources were developed. Further, the TMDL gives no credit for instream storage.
Recognizing and estimating attainable reductions in the risk of sediment delivery from non-road related hillslope mass movement processes was more difficult than for road-related mass movement.	Slightly higher reductions from road-related mass movement sources were developed.
Considerable uncertainty exists in the source analysis.	Loading rates for the 1990-1998 period were not developed. Developing loading rates for this period probably would have shown decreased sediment production. An explicit margin of safety is included to account for additional management-related sources.
Sources such as agriculture and mining are not included in the source analysis.	Bank erosion estimates are high, and an explicit margin of safety is included to account for additional management-related sources.
Linkages between hillslope sediment sources and instream conditions are poorly understood, and temporal/spatial lags associated with the movement of sediment from source to stream impact could result in irreversible sediment impacts.	A broad range of indicators were selected, including those that will address: 1) a protected beneficial use (salmonids) directly; 2) advancement of our understanding of the processes defining the linkages (including continued trend monitoring); 3)instream conditions; and 4) water quality standards protection at the sources of delivery to the stream (e.g., hillslope and road conditions). In addition, assuming a linear relationship between targets and loads is conservative.
The loading reductions are partly based on an assumed success rate for the various conservation measures and/or altered land management activities likely to be employed.	Conservative percent reductions were identified to account for the uncertainty in the effectiveness.

- It is difficult to accurately associate management activities with individual landslides generated by cumulative effects of land management activities upstream of the landslide. It is likely that some inner gorge landslides assigned to natural causes are actually management-related landslides, and that some landslides visible adjacent to management activities in air photos are naturally caused.
- Bank erosion estimates are difficult to predict from a topographically-generated stream network, which overpredicts stream mileage relative to field conditions (Raines 1998, J. Werren, pers. comm., 1998).
- Bank erosion cannot be accurately attributed to management or non-management sources.
- Bank erosion estimates may be inaccurately assigned to sub-basins.
- The road-related surface erosion model may inaccurately reflect actual conditions.
- The road model cannot account for roads that are not included on the coverage, nor can it account for skid trails and landings, unless those generated mass wasting failures.
- Erosion rates or other assumptions may be incorrect.

Conclusion

As Table 12 points out, there are a number of uncertainties associated with the supporting documentation, most notably in the source analysis. Given these uncertainties, conservative assumptions have been made regarding the amount of loading reductions that are needed to attain WQS. This approach is warranted and meets the statutory requirements that a margin of safety take into account any lack of knowledge concerning the relationship between the effluent limitations and water quality.

Continuation of the basinwide monitoring efforts, collection of site-specific data, and refinement of the source assessment in the future will help to reduce the uncertainty associated with the current assessment and will eventually allow for less conservative assumptions.

Seasonal Variation

There is inherent annual and seasonal variation in the delivery of sediment to stream systems. Surface erosion, including erosion from roads, occurs on an annual basis, but primarily as a result of winter rains. The major sources of sediment delivery, such as mass wasting occur as a result of big storms and thus may not be significantly active processes every year. For this reason, the allocations are designed to apply to the sources of sediment, themselves, not the movement of sediment across the landscape or delivery of sediment directly to the stream channel. If implemented as envisioned, potential and existing sediment delivery sites will be identified and the quantity of sediment associated with each site measured or estimated. Then, as a result of mitigation or altered land management, the amount of potential sediment saved from delivery to a waters of the State will be measured or estimated. The relationship between the original measurement or estimate of potential sediment delivery and the amount saved by mitigation will indicate the degree to which the allocation has been achieved.

It is difficult to accurately predict specific impacts of sediment loading at particular times and places on particular salmonid life stages, given spatial and temporal lags between sediment delivery and the occurrence of sediment-related impacts on beneficial uses. In addition, it is infeasible in many cases to predict or control sources at fine spatial and temporal scales. Therefore, the approach in this TMDL is to select indicators to interpret narrative WQS which are believed to provide a good composite picture of instream sediment-related conditions and changes over time. Then, targets and associated TMDLs are set at levels believed to be protective of beneficial uses at key life stages, taking into account the lag effects. In addition, the numeric targets generally represent summer flow conditions. This TMDL accounts for seasonal variation through the conservative articulation of likely cause and effect relationships between sediment loadings and effects on salmonid habitat at different key life stages, and its consideration of lag effects.

Normal winter rains and larger storms will nonetheless have an effect on the assessment of allocations. Storm events which occur after mitigations have been achieved will provide a test of the success of the mitigation. For this reason, EPA encourages further development and implementation of the ongoing monitoring plan.

Critical Conditions

The regulations at 40 CFR 130.7 state that TMDLs shall take into account critical conditions for stream flow, loading and water quality parameters.This TMDL does not explicitly estimate critical flow conditions for several reasons. First, unlike many pollutants (e.g. acutely toxic chemicals) sediment impacts on beneficial uses may occur long after sediment is discharged, often at locations far downstream from the point of discharge. Second, sediment impacts are rarely correlated closely with flow over short time periods. Third, it is impractical to accurately measure sediment loading, transport, and short term effects during high magnitude flow events which usually produce most sediment loading and channel modification in systems such as the South Fork Trinity basin. Therefore, the approach used in this TMDL to account for critical conditions is to use include indicators that can address sediment sources and watershed conditions, addressing lag times from production to delivery, and which are reflective of the net long term effects of sediment loading, transport, deposition, and associated receiving water flows. Instream indicators may be effectively measured at lower flow conditions at roughly annual intervals, and hillslope indicators can assist in tracking the implementation of measures to improve water quality conditions. Inclusion of a large margin of safety helps to ensure that the TMDL will result in beneficial use protection during and after critical flow periods associated with maximum sedimentation events.

Critical conditions concerning stream habitat status and recovery may change substantially following major storms (e.g., storms with a recurrence interval of approximately 50 years or more). Such storms and the associated floods and huge sediment loads can have the effect of changing the channel configuration so dramatically and suddenly that it effectively “recalibrates” the relationships between channel size and flow and sediment conditions for decades to follow. It may be appropriate for the State to reconsider the TMDL and associated allocations following such an event.

8. PUBLIC PARTICIPATION

Federal regulations require that TMDLs be subject to public review (40 CFR 130.7). The State and EPA have provided for public participation through several mechanisms. EPA and Regional Board staff obtained input regarding the TMDL development from the South Fork Trinity CRMP from individuals who participated in the CRMP, and from other individuals who expressed interest in the process. The CRMP is a stakeholders group, whose membership is open, but consisting primarily of representatives of landowners; land managers; conservation groups; local, state, and federal agencies; and other interested members of the public. EPA has updated the CRMP members at over a dozen public meetings in 1997 and 1998, and has regularly sought feedback from individuals in the CRMP.

EPA invited public comment on the EPA draft TMDL in a public notice dated October 19, 1998. That public notice was published in several North Coast and Trinity County newspapers, and was mailed out to individuals on the CRMP as well as to a mailing list of interested parties identified through the CRMP and provided to EPA by the North Coast Regional Water Quality Control Board. The draft TMDL was available for review during the formal comment period, from November 2 to December 2, 1998. It was provided to those who requested it, and it was also posted on the World Wide Web. EPA hosted a joint public hearing on the Redwood Creek and South Fork TMDLs in Eureka, California on November 19, 1998. EPA reviewed comments received in writing during the comment period as well as oral comments made at the public hearing in reaching its final decision on the TMDL. EPA prepared a comment responsiveness summary (USEPA, 1998) that describes how EPA considered public comments in this final decision.

9. IMPLEMENTATION AND MONITORING RECOMMENDATIONS

Federal regulations require the State to identify measures needed to implement TMDLs in the State water quality management plan (40CFR 130.6). EPA has established policies which emphasize the importance of timely development of measures to implement TMDLs that addres nonpoint source discharges (memo from Robert Perciasepe, Assistant Administrator for Water, to EPA Regional Division Directors, August 8, 1997). EPA expects the State to promptly develop and ensure the implementaion of source control measures which are adequate to achieve the allocations in the TMDL.

EPA expects that the State will incorporate the TMDL and associated implementation measures in the State water quality management plan (for this TMDL, the North Coast Regional Water Quality Control Board Basin Plan) (NCRWQCB, 1994), as required by 40 CFR 130.6. EPA expects the State to establish a monitoring and evaluation plan that identifies parties responsible for implementation and timeframes for Regional Board review of monitoring results.

Development of Implementation Plan

The State is currently developing a draft implementation plan, and has published a preliminary draft to solicit comments on the *env-trinity* e-mail server (NCRWQCB 1998). EPA supports development of this plan, which should include reasonable assurances that the nonpoint source load allocations established in the TMDL will be achieved. These assurances may be non-regulatory, regulatory, or incentive-based, consistent with applicable laws and programs. In addition, the plan should include a public participation process and appropriate recognition of other relevant watershed management processes, such as local source water protection programs, state section 319 management programs or state section 303(e) continuing planning. EPA intends to play an active role in assessing whether implementation measures will reasonably assure that the load allocations are met.

EPA has reviewed the State’s draft implementation plan, and supports the key features, which include provisions for:

- Regulatory, non-regulatory and incentive-based options for implementing the provisions of the TMDL.

- Encouraging development of landowner-based sediment reduction plans, from individual landowners or cooperative groups of landowners.

- Specifying requirements for the sediment reduction plans, including baseline inventory, assessment of unstable areas, measures for control and prioritization of sediment delivery, and provisions for monitoring and reporting.

- Alternative land management guidelines for landowners not wishing to submit plans, including measures for roads, landings, and skid trails; prohibited actions in unstable areas; and protection of riparian areas and Class I, II and III watercourses.

- Recognizing parallel regulatory and planning efforts such as Sustained Yield Plans, Non-Industrial Timber Mangement Plans, Habitat Conservation Plans, Ranch Plans, Timber Harvest Plans, and Shasta-Trinity and Six Rivers National Forest Long Range Management Plans and Access and Transportation Management Plans.

- Intent to establish the implementation plan by January 1, 2000, and encouraging landowners to commit to developing sediment reduction plans by January 1, 2003, if that is the option.

The present draft does not contain provisions for requiring or encouraging landowners to complete implementation and sediment control plan efforts within any specific timelines. EPA will encourage the State to complete implementation within 10 years. In addition, EPA will encourage the State to take full opportunity of the salmon conservation planning effort within the coho salmon Trans-Boundary ESU, currently being directed by Trinity County.

The State may also want to consider measures that will facilitate reduction of loading of sources considered to be natural as well as those considered management related and continuation of private and public watershed restoration efforts. This may also be helpful in correcting overall sediment loading, since some existing management-related sources may not be be easily corrected adequately. This may lead to provisions for developing incentives, or load "trading" for reductions from sources that are known to have no management causes.

President's Northwest Forest Plan

The implementation plan should also consider ongoing efforts that may facilitate the implementation of the TMDL. Fc implementation plan should consider the President's Northwest Forest Plan (FSEIS/ROD, 1994), which is operative for all of the USFS ownership in the basin (about 80% of the land area). That plan identifies the South Fork as Tier 1 Key Watershed, which implies that its protection and restoration as a refugia area are a high priority. This designation signifies the presence of habitat for potentially threatened or endangered species or stocks of anadromous salmonids, generally high quality water and fish habitat, or a genuine potential for watershed recovery to eventually provide a refuge for endangered anadromous salmonids.

The Northwest Forest Plan also includes an Aquatic Conservation Strategy (ACS), comprised of identifying key watersheds, conducting watershed analysis, establishing interim riparian reserves, and doing watershed restoration. These activities, and those of the Standards and Guidelines under the ROD, have been incorporated into the Land and Resource Management Plans (LRMPs) of the forests. Furthermore, the South Fork from Forest Glen to the mouth of the river was designated as a component of the California Wild and Scenic Rivers System in 1972, which provides additional protections to the river.

Other Ongoing Implementation Efforts

The State may wish to explicitly consider other efforts that are ongoing to actively coordinate its monitoring efforts. For example, Trinity County is coordinating efforts of counties throughout the range of the Northern California ESU for coho salmon. The main focus is on road maintenance under County jurisdiction. The South Fork CRMP is an organized group of local stakeholders and government agencies working together to make improvements in the South Fork. They have been identifying problem areas and restoration opportunities, and funding restoration work. Their main priorities are in addressing land use and land management activities that could be contributing to water quality problems, including: reducing ongoing and potential erosion and sediment yield from roads, hillslopes and banks, improving water quality and quantity, and providing for streamside riparian protection and improvements. (USFS 1998b)

Monitoring

The USFS and other stakeholders have begun to coordinate in developing monitoring recommendations for the basin, a monitoring process in 1998. In the future, it is hoped that the monitoring undertaken in the basin will continue to advance understanding of critical watershed processes, as well as support tracking of trends and progress toward targets. These monitoring efforts are critical to the success of the TMDL in terms of ensuring and evaluating implementation efforts, tracking progress toward achieving target conditions, revising the TMDL, and developing alternative implementation efforts and land management practices if the data warrant such changes. EPA developed the list of indicators in consideration of future and ongoing monitoring efforts, and encourages inclusion of these indicators into any monitoring plan.

10. REFERENCES

Berol, E. 1995. A river history: conversations with long-term residents of the lower South Fork Trinity River. Prepared for Patrick Truman & Assoc. and South Fork CRMP group (Draft-for review only, Summer 1995).

Boise Cascade Corp. 1998. Technical documentation for SEDMOD: Boise Cascade Road Erosion/Delivery Model, draft, Boise, Idaho. In Raines 1998.

Borok, S.L. and H.W. Jong. 1997. Evaluationof salmon and steelhead spawning habitat quality in the South Fork Trinity River Basin, 1997. Calif. Dept. of Fish and Game Region 1, Inland Fisheries, Administrative Report No. 97-8.

Brown, L. R., P. B. Moyle, and R. M. Yoshiyama. 1994. Historical decline and current status of coho salmon in California. N. Am. J. Fish. Mgt. 14(2): 237-261.

Burns, J.W. 1970. Spawning bed sedimentation studies in north California streams. Pages 253-279 *in* California Fish and Game 56(4).

Calif. Dept. of Water Resources. 1979. South Fork Trinity River watershed erosion investigation. November.

Calif. Dept. of Water Resources. 1982. South Fork Trinity River salmonid habitat enhancement studies. Prepared for Calif. Dept of Fish and Game. March.

Calif. Dept. of Water Resources. 1992. South Fork Trinity River sediment investigation. February. 53 p.

Calif. Dept. of Fish and Game, California Trout, Inc., and USDA Forest Service, Region 5. 1985. Model steelhead stream demonstration project plan final report. Dec.

Chapman, D. W. 1988. Critical review of variables used to define effects of fines in reds of large salmonids. In: Transactions of the American Fisheries Society 117. Pages 1-25

Collins, B.W. and L. Hanson. 1996. Life history, distribution, run size and angler harvest of steelhead in the South Fork Trinity River Basin. Chapter II, Job III, Annual report, Trinity River Basin salmon and steelhead monitoring project 1994-1995 season. CDFG Inland Fisheries Division, Sacramento. May.

Dean, M. 1996a. Life history, distribution, run size, and harvest of spring chinook salmon in the South Fork Trinity R
VII, Annual report, Trinity River Basin salmon and steelhead monitoring project, 1994-1995 season. CDFG, Inlan
Sacramento, May.

Dean, M. 1996b. Survey Report, 1995 Season, Snorkel and Redd Surveys of Spring Chinook Salmon in the South Fork Trinity River Basin. prep. for Huber, Harpham and Assoc.

Elliot, W., and P. Robichaud, 1998. Risk analysis after fire with WEPP. Burned Area Emergency Rehabilitation Course, USDA Forest Service, Rocky Mountain Research Station, March 31, 1998. In Raines 1998.

Elliot, W.J., D.Page-Dumroese, and P.R. Robichaud. 1996. The effects of forest management on erosion and soil productivity. Proceedings, The Soil and Water Conservation Society of America, Symposium on Soil Quality and Erosion Ineraction, Keystone, Colorado, July 7th, 1996. In Raines 1998.

FSEIS/ROD. 1994. President's Forest Plan Record of Decision (fix reference).

Farber, S., D. Ranken, and T. Viel. 1998. Water temperatures in the South Fork Trinity River watershed in northern California. Timber Products Co., Mt. Shasta, USFS-Shasta Trinity National Forest, Redding, NRCS, Weaverville. October 1, 1998.

Flanagan, S.A., M.J. Furniss, T.S. Ledwith, M.A. Love, K. Moore and J. Ory. 1998. Methods for inventory and environmental risk assessment of road drainage crossings. Water/Road Interaction Technology Series (in press). USDA, Forest Service, Technology and Development Program, Draft, September 17. 54 p.

Flosi, G. And F.L. Reynolds. 1994. California salmonid stream habitat restoration manual. Inland Fisheries Division, California Department of Fish and Game, The Resources Agency.

Furniss, M.J., T.S. Ledwish, M.A. Love, B.C. McFadin, and S.A. Flanagan. 1998. Response of road-stream crossings tolarge flood events in Washington, Oregon, and Northern California. Water/Road Interaction Technology Series. Publication 9877 1806-SDTDC. USDA, Forest Service, Technology and Development Program., September. 14 p.

Glase, J.D. and R.A. Barnhart. 1988. Summary of South ForkTrinity River Steelhead Investigations,July1-1987 - May 31, 1988.

Hagans, D. K., W. E. Weaver and M. A. Madej. 1986. Long-term on-site and off-site effects of logging and erosion in the Redwood Creek basin, northern California. In: Papers presented at Amer. Geophys. Union meeting on cumulative effects (9-13 Dec. 1985, San Francisco, Ca.). Tech. Bull. 490, pp. 38-66, National Council of the Paper Industry (NCASI), New York, New York.

Haskins, D.M. and R.A. Irizarry. 1988. A holistic appraisal of cumulative watershed effects on waterhsed condition and fisheries, South Fork Trinity River, Northwestern California. USDA Forest Service, Shasta-Trinity National Forests. August. 41 p.

Healey, T.P. 1963. Salmon surveys, South Fork of the Trinity River. Memo to Fish Management Supervisor, Region 1, CDFG. 12/10/63, 3 p. (Available at Trinity County library)

Healey, T.P. ca. 1971. Studies of steelhead and salmon emigration in the Trinity River, Anadromous Fisheries Branch Administrative Report No. 73-1, California Dept. of Fish and Game, Region 1, Inland Fisheries, May.

Hawley, N.L. and B.L. Jones. 1969. Sediment yield of coastal basins in northern California 1958-1964. Menlo Park, CA: U.s. Geological Survey, Water Resources Division, prepared in cooperation with the Calif. Dept. of Water Resources. June 11. 19 p.

Hickey, John J. 1969. Variation in low-water streambed elevations at selected stream-gaging stations in northwestern California. USDI Geological Survey Water-Supply Paper 1879-E. Washington DC: US GPO, 1969. 33 pp.

Hilton, S. and T.E. Lisle. 1993. Measuring the fraction of pool volume filled with fine sediment. Res. Note PSW-RN-414. l Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture; 11 p.

Jong, B. (H.). 1995 Results of McNeil sediment sampling, South Fork Trinity River Basin, 1994. Memo and job report from CDFG Natural Stocks Assessment Project to files, August 7.

Jong, B. 1997. Jan 30 letter from CDFG Arcata to Dave Cross, USFS, Redding, regarding spring-run chinook and summer-run steelhead counts, citing CDFG sources.

Keller, E. A., and W. N. Melhorn. 1995. Rhythmic spacing and origin of pools and riffles. In: Geological Society of America Bulletin, v. 89. Doc. no. 80509. Pages 723-730

Knopp, C. 1993. Testing indices for cold water fish habitat. Final Report for the North Coast Regional Water Quality Control Board.

Knott, J.M. 1974. Sediment discharge in the Trinity River basin, California. Menlo Park, CA: U.S. Geological Survey Water-Resources Investigation 49-73, prepared in cooperation with the Calif. Dept. of Water Resources. April. 62 p.

LaFaunce, D.A. 1967. A king salmon spawning survey of the South Fork Trinity River, 1964. CDFG, Region 1 Inland Fisheries, Marine Resources Branch. Admin. Rept. 67-10, 13 p. (mimeo) (available at Trinity County library)

LaFaunce, D.A. 1975. Case history South Fork Trinity River (CDFG), April 3. (available at Trinity County library)

Lewis, J. and R. Rice. 1989. Site conditions related to erosion on private timberlands in Northern California: Final Report. Critical Sites Erosion Study, Vol. II, California Dept. of Forestry, Sacramento, Calif., 95 p. In Raines 1998.

Lisle, T.E. and S. Hilton. 1992. The volume of fine sediment in pools: an index of sediment supply in gravel-bed streams. Water Res. Bulletin 28:2, pp. 371-383. Paper No. 91120. April.

Lisle, T. E. 1993. The fraction of pool volume filled with fine sediment in northern California: relation to basin geology and sediment yield. Final Report to the California Division of Forestry and Fire Protection.

Llanos, Antonio. 1998. Summary of Findings: Tributary sediment study, South Fork Trinity River, Draft. U.S.D.A. Six Rivers National Forest. In Raines 1998.

Madej, M.A. and V. Ozaki. l 1996. Channel response to sediment wave propagation and movement, Redwood Creek, California, USA. Earth Surface Process and Landforms Vol. 21, 911-927.

Matthews, G.M. 1998. Summary and analysis of geomorphic data for the South Fork Trinity River. Prepared for Tetra Tech, Inc. Draft, September.

McCashion, J.D., and R. M. Rice, 1983. Erosion on Logging Roads in Northwestern California: How much is avoidable? Journal of Forestry, January, 1983, pp. 23-26. In Raines 1998.

North Coast Regional Water Quality Control Board. 1994. Water Quality Control Plan for the North Coast Region, Santa Rosa, CA.

North Coast Regional Water Quality Control Board. 1998. DRAFT Implementation Plan for SF Trinity River Aquatic Strategy TMDL, published on *env-trinity@igc.apc.org*, November 4, 1998.

Pacific Watershd Associates (PWA). 1994. Action plan for restoration of the South Fork Trinity River watershed and its fisheries, prepared for US Bureau of Reclamation and the Trinity River Task Force, February.

Peterson, N.P., A. Hendry, and T.P. Quinn. 1992. Assessment of cumulative effects on salmonid habitat; some suggested parameters and targets conditions. Timber, Fish and Wildlife. TFW-F3-92-001.

Raines, M.A. and H.M. Kelsey. 1991. Sediment budget for the Grouse Creek Basin, Humboldt County, California. Bellingham, WA: Western Washington University, Department of Geology, in cooperation with Six Rivers National Forest and the Bureau for Faculty Research, Western Washington University. February. 110 pp.

Raines, M. 1998. South Fork Trinity River sediment source analysis, draft. Tetra Tech, Inc. October, 1998.

Reid, L.M. and T. Dunne. 1996. Rapid Evaluation of Sediment Budgets. Reiskirchen, Germany: CATENA VERLAG GMBH, 35447.

Rogers, D.W. 1970. South Fork Trinity River spring-run king salmon survey, 1970. Memo to Assoc. Fish Biologist, CDFG, 8/18/70, 1 p. (available at Trinity County library, Weaverville).

Rogers, D.W. 1971. South Fork Trinity River spring-run king salmon spawning stock survey. Memo to Don LaFaunc (available at Trinity County library, Weaverville).

Rogers, D.W. 1974. Spring-run king salmon survey on the South Fork Trinity River, 1974. Memo to Don LaFaunce, (available at Trinity County library, Weaverville).

Swanston, D.N., R.R. Ziemer, and R.J. Janda. 1983. Influence of climate on progressive hillslope failure in Redwood Creek Valley, Northwest California, Open-file report 83-259, Us. Geol. Survey, Menlo Park, CA, 49 pp. In Raines 1998.

USDA Forest Service (USFS). 1994. Butter Creek Watershed Analysis, Hayfork Ranger District, Shasta-Trinity National Forests, Klamath Province. December 10. 182 p. plus appendices.

USDA Forest Service (USFS). 1990. South Fork Trinity River watershed and fisheries monitoring 1990 progress repo National Forest).

USDA Forest Service (USFS). 1991. Annual progress report for South Fork Trinity River watershed & fisheries moni (Shasta-Trinity National Forest).

USDA Forest Service (USFS) and US Bureau of Land Management and cooperating agencies. 1994. Final supplemental environmental impact statement on management of habitat for late successional and old growth forest related species within the range of northern spotted owl: Vol. 1, and Record of Decision. US Govt. Printing office, Washington DC.

USDA Forest Service (USFS). 1995. Grouse Creek Watershed Analysis, Version 1.0. October.

USDA Forest Service (USFS). 1996. Lower Hayfork Creek Watershed Analysis. Hayfork Ranger District, South Fork Management Unit, Shasta-Trinity National Forest. March 29. 156 p.

USDA Forest Service (USFS) and South Fork Coordinated Resource Management Plan. 1998a. East Fork/Smoky Cre South Fork Trinity River. Shasta Trinity National Forest, Hayfork Ranger District. March.

USDA Forest Service (USFS). 1998b. Lower South Fork Trinity River Watershed Analysis (Draft). Eureka: Six Rivers National Forest. May 4.

USDA River Basin Planning Staff (Briggs et. al). 1972. Water, land and related resources, north coastal area of California and portions of southern Oregon. Appendix No. 2: Sediment yield and land treatment, Klamath, Trinity and Smith River Basins, Russian River, Mendocino, Coastal and Clear Lake Basins. June.

USDA River Basin Planning Staff. 1972. Water, land and related resources, north coastal area of California and portic Main report. September.

U.S. Environmental Protection Agency. 1991. Guidance for Water Quality-based Decisions: The TMDL Process, EPA 440/4-91-001.

U.S. Environmental Protection Agency. 1998. South Fork Trinity River/Hay fork Creek Sediment TMDLs Comment Responsiveness Summary. December.

U.S. Forest Service (USFS). 1991. and 1990 monitoring plans.

Washington Forest Practices Board. 1995. Board Manual: Standard methodology for conducting watershed analysis. Version 3.0. In Raines 1998.

Weaver W. E. and D. K. Hagans. 1994. Handbook for forest and ranch roads: a guide for planning, designing, constructing, reconstructing, maintaining and closing wildland roads. Prepared for the Mendocino County Resource Conservation District, Ukiah, CA in cooperation with the California Department of Forestry and Fire Protection and the USDA Soil Conservation Service. 149 pages + appendices.

Wilson, C.E. and T.J. Mills. 1992. Life history, distribution, run size and angler harvest of steelhead in the South Fork Trinity River Basin. in Annual report, Trinity River basin salmon and steelhead monitoring project, 1989-1990 season, California Dept. of Fish and Game, Inland Fisheries Division, Sacramento. June.

11. GLOSSARY

Aggradation	To fill and raise the elevation of the stream channel by deposition of sediment.
Anadromous	Refers to aquatic species which migrate up rivers from the sea to breed in fresh water.
Areas of instability	Locations on the landscape where land forms are present which have the ability to discharge sediment to a watercourse.
Baseline data	Data derived from field based monitoring or inventories used to characterize existing conditions and used to establish a database for planning or future comparisons.
Beneficial Use	Uses of waters of the state that may be protected against quality degradation including, but not limited to, domestic, municipal, agricultural and industrial supply; power generation; recreation; aesthetic enjoyment; navigation; and the preservation and enhancement of fish, wildlife and other aquatic resources or preserves.
Controllable source	Any source of sediment with the potential to enter a water of the State which is caused by human activity and will respond to mitigation, restoration, or altered land management.
CRMP	Coordinated Resources Management Plan. In this document, refers to the organization of SFTR stakeholders working together to identify solutions to protect the SFTR basin
Debris torrents	Long stretches of bare, generally unstable stream channel banks scoured and eroded by the extremely rapid movement of water-ladened debris, commonly caused by debris sliding or road stream crossing failure in the upper part of a drainage during a high intensity storm.
Deep seated landslide	Landslides involving deep regolith, weathered rock, and/or bedrock, as well as surficial soil. Deep seated landslides commonly include large (acres to hundreds of acres) slope features and are associated with geologic materials and structures.
Drainage structure	A structure or facility constructed to control road runoff. These structures include but are not limited to fords, inside ditches, water bars, outsloping, rolling dips, culverts or ditch drains.
Flooding	The overflowing of water onto land that is normally dry.
Fry	A young juvenile salmon after it has absorbed its egg sac and emerged from the redd.
Interstices	The space between particles (e.g. space between sand grains).
Inner gorge	A geomorphic feature formed by coalescing scars originating from mass wasting and erosional process caused by active stream erosion. The feature is identified as that area of stream bank situated immediately adjacent to the stream, having a slope generally over 65% and being situated below the first break in slope above the channel.
Inside ditch	The ditch on the inside of the road, usually at the foot of the cutbank.
Landslide	Any mass movement process characterized by downslope transport of soil and rock, under gravitational stress by sliding over a discrete failure surface-- or the resultant landform.
Large woody debris	A piece of woody material having a diameter greater than 30 cm (12 inches) and a length greater than 2 m (6 feet) that is located in a position where it may enter the watercourse channel.
Mass wasting	Downslope movement of soil mass under force of gravity-- often used synonymously with "landslide." Common types if mass soil movement include rock falls, soil creep, slumps, earthflows, debris avalanches, debris slides and debris torrents.

Numeric targets	A numerical expression of the desired instream environment. For each stressor or pollutant addressed in the problem statement of the Strategy , a numeric target is developed based on the numeric or narrative State water quality standards which are needed to recovered the impaired beneficial use.
Permanent drainage structure	A road drainage structure designed and constructed to remain in place following active land management activities while allowing year round access on a road.
Planning Watershed	The uniform designation and boundaries of sub basins within a larger watershed. These Watersheds are described by the California Department of Forestry as Cal Water Watersheds.
Redd	A gravel nest or depression in the stream substrate formed by a female salmonid in which eggs are laid, fertilized and incubated.
Sediment	Fragmented material that originates from weathering of rocks and decomposed organic material that is transported by, suspended in, and eventually deposited by water or air.
Sediment budget	An accounting of the sources, movement, storage and deposition of sediment produced by a variety of erosional processes, from its origin to its exit from a basin.
Sediment delivery	Material (usually referring to sediment) which is delivered to a watercourse channel by wind, water or direct placement.
Sediment discharge	The mass or volume of sediment (usually mass) passing a watercourse transect in a unit of time.
Sediment erosion	The group of processes whereby sediment (earthen or rock material) is loosened, dissolved and removed from the landscape surface. It includes weathering, solubilization and transportation.
Sediment source	The physical location on the landscape where earthen material resides which has or may have the ability to discharge into a watercourse.
Sediment yield	The sediment yield consists of dissolved, suspended and bed loads of a watercouse channel through a given cross-section in a given period of time.
SFTR	South Fork Trinity River.
Shallow seated landslide	A landslide produced by the failure of the soil mantle (typically to a depth of one or two meters, sometimes includes some weathered bedrock), on a steep slope. It includes debris slides, soil slips and failure of road cut-slopes and sidecast. The debris moves quickly (commonly breaking up and developing into a debris flow) leaving an elongated, concave scar.
Skid trail	Constructed trails or established paths used by tractors or other vehicles for skidding logs. Also known as tractor roads.
Smolt	A young salmon at the stage at which it migrates from fresh water to the sea.
Steep slope	A hillslope, generally greater than 50% that leads without a significant break in slope to a watercourse. A significant break in slope is one that is wide enough to allow the deposition of sediment carried by runoff prior to reaching the downslope watercourse.
Stream	See watercourse.
Stream class	The classification of waters of the state, based on beneficial uses, as required by the Department of Forestry in Timber Harvest Plan development. See definitions for Class I, Class II, Class III, and Class IV for more specific definitions.
Stream order	The designation (1,2,3, etc.) of the relative position of stream segments in the drainage basin network. For example, a first order stream is the smallest, unbranched, perennial tributary which terminates at the upper point. A second order stream is formed when two first order streams join. Etc.
Sub basin	A subset or division of a watershed into smaller hydrologically meaningful Watersheds. For example, the North Fork South Fork Trinity River is a sub basin of the larger South Fork Trinity River watershed.

Swale	A channel-like linear depression or low spot on a hillslope which rarely carries runoff except during extreme rainfall events. Some swales may no longer carry surface flow under the present climatic conditions.
Thalweg	The deepest part of a stream channel at any given cross section.
Thalweg profile	Change in elevation of the thalweg as surveyed in an upstream-downstream direction against a fixed elevation.
Unstable areas	Characterized by slide areas, gullies, eroding stream banks, or unstable soils. Slide areas include shallow and deep seated landslides, debris flows, debris slides, debris torrents, earthflows and inner gorges and hummocky ground. Unstable soils include unconsolidated, non-cohesive soils and colluvial debris.
V*	A numerical value which represents the proportion of fine sediment that occupies the scoured residual volume of a pool.
Watercourse	Any well-defined channel with a distinguishable bed and bank showing evidence of having contained flowing water indicated by deposit of rock, sand, gravel, or soil.
Waters of the state	Any surface water or groundwater, including saline water, within the boundaries of the state.
Watershed	Total land area draining to any point in a watercourse, as measured on a map, aerial photo or other horizontal plane. Also called a basin, drainage area, or catchment area.
Water quality objective	Limits or level of water quality constituents or characteristics which are established for the reasonable protection of beneficial uses of water or the prevention of nuisance within a specific area.
Water quality standard (WQS)	Consist of the beneficial uses of water and the water quality objectives as described in the Water Quality Control Plan for the North Coast Region.