U.S. Environmental Protection Agency
Region IX

Big River
Total Maximum Daily Load
for Sediment

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Approved by:

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Table of Contents

List of Figures

List of Tables

CHAPTER 1: INTRODUCTION

The Big River Total Maximum Daily Load (TMDL) for Sediment is being established in accordance with Section 303(d) of the Clean Water Act, because the State of California has determined that the water quality standards for the Big River are exceeded due to sediment. In accordance with Section 303(d), the State of California periodically identifies those waters that are not meeting water quality standards. In its latest Section 303(d) list, adopted through Resolution 98-45 on 23 April 1998, the North Coast Regional Water Quality Control Board (NCRWQCB) identified the Big River as impaired due to sediment.

In accordance with a consent decree (*Pacific Coast Federation of Fishermen's Associations, et al. v. Marcus*, No. 95-4474 MHP, 11 March 1997), 2001 is the deadline for establishment of this TMDL. Because the State of California will not complete adoption of a TMDL for the Big River by this deadline, EPA is establishing this TMDL, with assistance from NCRWQCB staff.

The primary adverse impacts associated with excessive sediment in the Big River pertain to the anadromous salmonid fishery. The water quality conditions do not adequately support several anadromous salmonid species present in the Big River and its tributaries, which has contributed to severe population declines. The populations of coho salmon (*Oncorhynchus kisutch*), chinook salmon (*O. tshawytscha),* and steelhead trout (*O. mykiss*) in this watershed are all listed as threatened under the federal Endangered Species Act.

The purpose of the Big River TMDL is to identify the total load of sediment that can be delivered to the Big River and its tributaries without causing exceedence of water quality standards, and to allocate the total load among the sources of sediment in the watershed. Although factors other than excessive sediment in the watershed may be affecting salmonid populations (e.g., ocean rearing conditions), this TMDL focuses on sediment in the watershed, the pollutant for which the Big River is listed under Section 303(d). EPA expects the NCRWQCB to adopt the TMDL and to develop an implementation strategy that will result in implementation of the TMDL in accordance with the requirements of 40 CFR 130.6. The load allocations, when implemented, are expected to result in the attainment of the applicable water quality standards for sediment for the Big River and its tributaries.

1.1. Information Sources

Information for this TMDL came from a variety of sources. Much of the analysis is summarized from an assessment of watershed conditions conducted by staff of the NCRWQCB (2001a, 2001b), and a sediment source analysis developed by Graham Matthews and Associates (GMA 2001), who conducted the analysis for EPA as a subcontractor to Tetra Tech, Inc. Primary sources of data for those studies were: the California Department of Fish and Game (CDFG), California Department of Forestry and Fire Protection (CDF), Jackson Demonstration State Forest (JDSF), U.S. Geological Survey (USGS), Mendocino Redwood Company, LLC (MRC) and its predecessor, Louisiana-Pacific, Inc. (LP), and Campbell Timberlands Management and its predecessor, Georgia-Pacific West, Inc. (Campbell/GP). CDFG provided historic aquatic surveys as well as some fish distribution and aquatic habitat data. CDF provided Timber Harvest Plan (THP) data. Some information in draft form was available for the JDSF portion of the watershed. USGS provided stream flow and topographic data. MRC provided substrate data in advance of the draft watershed analysis for their ownership. Campbell/GP provided qualitative assessments of watershed conditions through their 1997 Sustained Yield Plan. Most sources cited in this TMDL were originally cited in NCRWQCB (2001a, 2001b) and GMA (2001). Additional detail can be found in the two supporting documents.

1.2. Watershed Characteristics

The Big River drains a 181 mi^2 watershed located in the northern California Coast Range in western Mendocino County, entering the Pacific Ocean at the town of Mendocino, about 10 miles south of Fort Bragg. It drains primarily from the east to the west, sharing ridges with the Noyo and Caspar Creek watersheds to the north and the Albion River watershed to the south. Other than the town of Mendocino, there is relatively little human occupation in the watershed, with only scattered ranches and residences. Elevations within the Big River watershed range from sea level at the basin outlet to 2,725 feet.

The five largest property owners are private timber companies and a State-owned working forest: Together, MRC, Jackson State Demonstration Forest (which also extends into the Noyo Watershed), Pioneer Resources, Hawthorne Timber Company, and Weger Holdings own 83% of the watershed. Thirty-one property owners, with ownerships varying from 160 to 3,760 acres, own 14% of the watershed. These include smaller industrial and nonindustrial timberland owners, several ranches, and several public and quasi-public parcels. No other property owner owns more than 5% of the watershed. The remaining parcels are primarily residences (GMA 2001).

The Mediterranean climate in the watershed is characterized by a pattern of low-intensity rainfall in the winter and cool, dry summers with coastal fog. Mean annual precipitation varies from about 38 inches at Fort Bragg near the western margin of the watershed to over 50 inches at Willits to the east. Mean annual rainfall for the entire watershed is 56 inches, with portions receiving in excess of 65 inches at the higher elevations. Snowfall occurs occasionally in the higher elevations of the watershed and rarely accumulates. Snow is thus not considered to have any appreciable effect on the watershed hydrology. Only limited stream gauging records exist for the Big River watershed, having been collected by the USGS from 1961 to 1971.

The watershed’s topography is diverse along its length, varying from flat estuarine environments and uplifted marine terraces to rugged mountains with high relief in the eastern portion. It is characterized by narrow ridgelines separated by deeply incised inner gorges of the major river channels and streams draining the watershed. The western end of the drainage is distinguished by a drowned and filled estuary occupying a relatively narrow inner gorge, characterized by steep slopes that extend up to the flat coastal terraces (GMA 2001). Tidal influence extends upward from the mouth three miles in the winter and eight miles in the summer (NCRWQCB 2001a, 2001b). Moving upstream, mudflats become narrow floodplains (GMA 2001). The brackish and freshwater bogs and freshwater marshes are also noteworthy (NCRWQCB 2001a, 2001b).

The geology of the Big River watershed is primarily comprised of Coastal Belt Franciscan Complex. This portion of the Franciscan complex is relatively stable compared to the mélange terrane of the Central Belt, which is found only in the upper parts of the watershed. A small portion of Tertiary age sandstone is found in the Greenough Ridge - Montgomery Woods State Reserve area (GMA 2001).

History

The history of the Big River watershed is dominated by timber harvest. The following brief history has been compiled from Carranco and Labbe (1975), Andrews (1985, 1994), and Mendocino County Historical Society (1996), as described in GMA (2001). Logging began in the lower basin about 1852, around the time that the first mill was constructed in what was then known as Mendocino City. The mill was sited on the bluffs and an apron chute to load finished wood onto ships was constructed at the mill. Logs were kept in an enclosure at the mouth of the river, but this facility was continually being damaged by high river flows.

In 1854, a new mill was built on the flat east of the present Highway 1, and a railroad was eventually built to haul lumber to the loading point on the bluffs. This mill operated from 1855 to 1937, when it was shut down. It was the largest producer of lumber in Mendocino County until 1879. All logs were delivered to this mill by way of the river. The Mendocino Lumber Company used “river drives” of logs more extensively than any other timber operation on the North Coast, probably due to the ruggedness of the watershed. Some 27 splash dams have been documented (Jackson 1991, in GMA 2001) in the watershed. The first dams were built between 1860 and 1870, while the last dam was constructed in 1924. The dams varied in size and construction methods, but ranged to as tall as 40 feet. Many of the dams were designed to operate in a synchronized fashion to maximize the flow of water in downstream reaches. Known travel times for the water releases, accurate to the minute, were developed for the larger dams. The last operation of these dams occurred in 1937.

Logging operations in the watershed proceeded generally from the lower reaches in the early years, up as far as the Little North Fork and Two Log Creek by the 1870s, then gradually into the headwaters over a period of 40-80 years. Logging in the South Fork began about 1888 (Jackson 1991, in GMA 2001). A short railroad was constructed in the lower reaches of the watershed by the Mendocino Lumber Company, extending from the log dump to the Little North Fork. It operated from 1883 to 1936, although from 1883 to about 1900 it was operated only as a tramway, and not for hauling logs. In 1936, the railroad was shut down and replaced by truck transport. The log dump operated from 1901 to 1936. Pilings were placed almost continuously between the piers and the mill pond to assist in the transport of the logs to the mill.

The Caspar Lumber Company acquired ownership of extensive tracts of old growth near the turn of the century, and eventually extended the railroad into the South Fork Noyo via a tunnel from Hare Creek. From there, several remote logging areas were connected to the railroad with a series of inclines, the first built in 1915. In the late 1930s, the railroad was extended over a low pass from the south Fork Noyo into the North Fork Big River. A branch of the railroad into Two Log Creek was built in 1937, and in 1939, Camp 20 near the Dunlap Ranch at Chamberlain Creek opened. The area around Chamberlain Creek was harvested between 1940 and 1946, when the railroad was finally shut down. After harvesting much of the old growth, Caspar Logging Company sold 47,500 acres to create Jackson Demonstration State Forest (JDSF).

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

Planning Watersheds

The Big River watershed is divided into five Planning Watersheds (“PW”), corresponding generally to the CalWater California Watershed Map watersheds (Interagency California Watershed Mapping Committee 1999 in NCRWQCB 2001a, 2001b). These are shown in Figure 1 (frontispiece) and described in Table 1. The PWs range in size from 17.9 to 54.5 mi^2, and are generally divisions of the Big River mainstem and its associated main tributaries. The five PWs have been divided again into a total of 18 Sub-Watersheds (“SW”), ranging in size from 4.8 to 18.3 mi^2. The NCRWQCB has slightly different names for some SWs; these are noted on Table 1.

Table 1. Planning Watersheds

Planning Watershed Sub-Watershed	NCRWQCB Watershed Name and Major Tributaries		Approx. Size (mi^2)
Big River Headwaters (CalWater 113.3002)			**32.8**
Upper Mainstem Big River	NCRWQCB:	Rice Creek. Rice Ck, Valentine Ck.	12.6
Martin Creek	NCRWQCB:	Martin Creek.	9.3
Lower Mainstem Big River	NCRWQCB:	Russell Brook. Russell Brook, Pigpen Gulch.	11.0
North Fork Big (CalWater 113.3003)			**43.5**
Upper North Fork Big River	NCRWQCB:	Upper North Fork Big River	8.5
James Creek	NCRWQCB:	James Creek. James Creek, Sindel Gulch	7.0
Chamberlain Creek	NCRWQCB:	Chamberlain Creek. Chamberlain Ck, Park Gulch, Gulch Sixteen, Water Gulch.	12.3
East Branch North Fork	NCRWQCB:	East Branch North Fork	8.1
Lower North Fork Big River	NCRWQCB:	Lower North Fork Big River	7.7
Middle Big (CalWater 113.3004)			**17.9**
Middle Big River	NCRWQCB:	Two Log Creek (w/ Two Log Ck SW). Tramway Gulch, Blind Gulch, Kidwell Gulch, Peterson Gulch, Dietz Gulch.	13.1
Two Log Creek	NCRWQCB:	Two Log Creek (w/ Middle Big SW).	4.8
South Fork Big (CalWater 113.3001)			**54.5**
Upper South Fork Big River	NCRWQCB:	Leonaro Lake.	8.3
Middle South Fork Big River	NCRWQCB:	Dark Gulch. Montgomery Ck, Johnson Ck.	11.2
Daugherty Creek	NCRWQCB:	Daugherty Creek. Daugherty Creek, Snuffins Ck, Johnson Ck, Horsethief Ck, Gates Ck.	16.7
Lower South Fork Big River	NCRWQCB:	Mettick Creek. Mettick Ck, Halfway House Gulch, Boardman Gulch, Ramon Ck, Biggs Gulch, Kelly Gulch, Poverty Gulch.	18.3
Lower Big (CalWater 113.3004)			**32.5**
Lower Big River	NCRWQCB:	Mouth of Big River. Railroad Gulch, Wheel Gulch.	7.7
Little North Fork	NCRWQCB:	Berry Gulch. Thompson Gulch, Manly Gulch, Rocky Gulch.	12.5
Laguna Creek	NCRWQCB:	Laguna Creek.	5.1
Big River Estuary	NCRWQCB:	Mouth of Big River. Dry Dock Gulch.	7.2
TOTAL	**Big River Watershed**		**181 mi^2**

Source: GMA 2001 and NCRWQCB 2001a, 2001b.

1.3. Endangered Species Act Consultation

EPA initiated informal consultation with the National Marine Fisheries Service and the U.S. Fish and Wildlife Service (the Services) on this action, under Section 7(a)(2)of the Endangered Species Act (ESA). Section 7(a)(2) states that each federal agency shall ensure that its actions are not likely to jeopardize the continued existence of any federally-listed endangered or threatened species. EPA's consultation with the Services has not yet been completed. EPA believes it is unlikely that the Services will conclude that the Total Maximum Daily Load (TMDL) that EPA is establishing violates Section 7(a)(2), since the TMDL and load allocations are calculated in order to meet water quality standards, and water quality standards are expressly designed to "protect the public health or welfare, enhance the quality of water and serve the purposes" of the Clean Water Act, which are to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters." Additionally, this action will improve existing conditions. However, EPA retains the discretion to revise this action if the consultation identifies deficiencies in the TMDL or allocations.

1.4. Organization

This report is divided into seven chapters. Chapter 2 (Problem Statement) describes the nature of the environmental problem addressed by the TMDL. Chapter 3 (Water Quality Indicators) identifies specific stream and watershed characteristics to be used to evaluate whether the Big River is attaining water quality standards. Chapter 4 (Source Analysis) describes what is currently understood about the sources of sediment in the watershed. Chapter 5 (TMDL and Allocations) identifies the total load of sediment that can be delivered to the Big River and its tributaries without causing exceedence of water quality standards, and describes how EPA is apportioning the total load among the sediment sources. Chapter 6 (Implementation and Monitoring Recommendations) contains recommendations to the State regarding implementation and monitoring of the TMDL. Chapter 7 (Public Participation) describes public participation in the development of the TMDL.

CHAPTER 2: PROBLEM STATEMENT

This chapter summarizes how sediment is affecting the beneficial uses of the Big River and its tributaries associated with the decline of the cold water salmonid fishery. It includes a description of the water quality standards and salmonid habitat requirements related to sediment, and a qualitative assessment of existing instream and watershed conditions in the Big River basin.

2.1. Water Quality Standards

In accordance with the Clean Water Act, TMDLs are set at levels necessary to implement the applicable water quality standards. Under the Clean Water Act, water quality standards consist of designated uses, water quality criteria to protect the uses, and an anti-degradation policy. The State of California uses slightly different terms for its water quality standards (i.e., beneficial uses, water quality objectives, and a non-degradation policy). This section describes the State water quality standards applicable to the Big River TMDL, using the State's terminology. The remainder of the document simply refers to water quality standards.

The beneficial uses and water quality objectives for the Big River are contained in the *Water Quality Control Plan for the North Coast Region* (Basin Plan) as amended in 1996 (NCRWQCB 1996). The beneficial uses impaired by excessive sediment in the Big River are primarily those associated with the Big River's salmonid fishery, specifically: Commercial or Sport Fishing (COMM); Cold Freshwater Habitat (COLD); Estuarine Habitat (EST); Migration of Aquatic Organisms (MIGR); and Spawning, Reproduction, and/or Early Development (SPWN). The beneficial use of water related to rare, threatened, or endangered species (RARE) has been proposed for this basin as both federally-listed coho salmon and steelhead trout are found in the watershed (D. Leland NCRWQCB, letter to J. Parrish, US EPA, Oct. 22, 2001).

The Basin Plan (NCRWQCB 1996) identifies both numeric and narrative water quality objectives for the Big River. Those pertinent to the Big River TMDL are listed in Table 2.

Table 2. Water Quality Objectives Addressed in the Big River TMDL

Parameter	Water Quality Objective
Suspended Material	Waters shall not contain suspended material in concentrations that cause nuisance or adversely affect beneficial uses.
Settleable Material	Waters shall not contain substances in concentrations 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.
Turbidity	Turbidity shall not be increased more than 20 percent above naturally occurring background levels. Allowable zones of dilution within which higher percentages can be tolerated may be defined for specific discharges upon the issuance of discharge permits or waiver thereof.

In addition to water quality objectives, the Basin Plan (NCRWQCB 1996) includes two prohibitions specifically applicable to logging, construction, and other associated nonpoint source activities:

- The discharge of soil, silt, bark, sawdust, or other organic and earthen material from any logging, construction, or associated activity of whatever nature into any stream or watercourse in the basin in quantities deleterious to fish, wildlife, or other beneficial uses is prohibited; and

- The placing or disposal of soil, silt, bark, slash, sawdust, or other organic and earthen material from any logging, construction, or associated activity of whatever nature at locations where such material could pass into any stream or watercourse in the basin in quantities which could be deleterious to fish, wildlife, or other beneficial uses is prohibited.

2.2. Decline of Salmon and Steelhead

Some surveys have been conducted to estimate presence or absence of coho and steelhead in selected stream segments in the Big River watershed, but no information is available for chinook (the chinook population is likely extremely low). The NCRWQCB (2001a, 2001b) summarized what is known about salmonid populations on the Mendocino Coast. The following is abstracted from that summary.

There are only limited quantitative data from which to estimate the historic population size of coho and steelhead in the Big River watershed. In 1965, CDFG (1965, in NCRWQCB 2001a, 2001b) estimated 6,000 coho and 12,000 steelhead spawners and no chinook in the Big River. Similarly, Brown et al. (1994, in NCRWQCB 2001a, 2001b) estimated that there were 6,000 coho spawners in the Big River watershed in 1973. Although there are no quantitative data to estimate current population size, there is general agreement that the populations of both coho and steelhead have decreased substantially and continue to decline. Fish surveys in the last 25 years report either presence/absence, counts in a particular reach, or biomass in a particular reach. Although greatly reduced from historical levels, coho and steelhead are found throughout most of the basin. Coho have declined more significantly than steelhead.

It is believed that native California coho populations have declined by 80 to 90% from their numbers in the 1940s (Brown et al. 1994; Weitkamp et al. 1995; Clark 1988, as cited by Hassler et al. 1991, in NCRWQCB 2001a, 2001b). Steelhead populations also are in decline. Statewide, Brown et al. (1994, in NCRWQCB 2001a, 2001b) cited sources stating that there were approximately 200,000 to 500,000 coho spawning in the 1940s. They estimated that the statewide population had declined to about 100,000 fish in the 1960s and about 30,000 in 1984-1985. The NMFS status review of west coast steelhead concluded that steelhead stocks in the northern California ESU are very low relative to historic estimates, and recent trends are also downward (Weitkamp et al. 1995, NCRWQCB 2001a, 2001b).

The coho population was recently estimated at 4,950 fish in Mendocino County (Brown et al., 1994; Weitkamp et al. 1995, in NCRWQCB 2001a, 2001b). Adams et al. (1999, in NCRWQCB 2001a, 2001b) reported that coho are found in 51% of the streams in which they were historically present in California and 64% of the streams in Mendocino County in which they were historically present.

Declining numbers of salmonids led the National Marine Fisheries Service to list several populations under the federal Endangered Species Act. The populations of coho, chinook, and steelhead in the Big River and its tributaries have been listed as threatened (i.e., they are likely to become endangered in the foreseeable future). Coho in the Big River and its tributaries are included in the population known as the Central California Coast Evolutionarily Significant Unit (ESU), which was listed by NMFS as threatened in 1996. Chinook in the Big River and its tributaries are included in the California Coast ESU, which was listed as threatened in 1999. Steelhead in the Big River and its tributaries are included in the Northern California ESU, which was listed as threatened in 2000.

2.3. Fishery Information Specific to the Big Watershed

Various salmonid surveys have shown at least some coho presence in the following streams: Upper Big River, North Fork, Chamberlain Creek, East Branch North Fork, Bull Pen Gulch, Two Log Creek, Middle Big River, South Fork, Ramon Creek, North Fork Ramon Creek, Daugherty Creek, Berry Gulch, Little North Fork, Lower Big River (estuary), Water Gulch, Park Gulch, Arvola Gulch, and James Creek (NCRWQCB 2001a, 2001b).

CDFG Surveys. From 1983 to 1996, CDFG (unpublished 'h', in NCRWQCB 2001b) conducted 20 electroshocking surveys. During the 1980s, coho salmon were only found on three occasions: in Berry Gulch, Chamberlain Creek and Two Log Creek. All were young-of-year ("YOY") fish, with the highest density in Berry Gulch (0.31 fish/m^2). Steelhead were relatively more abundant and represented YOY and year-old age classes, but two-year steelhead were not observed in the surveys in the 1980s. Steelhead were found at all locations, except for Lower Gates Creek. Highest densities were observed in West Chamberlain Creek (2.25 fish/m^2). During surveys in the 1990s, coho salmon were only found on one occasion, in Berry Gulch (October 1995, all YOY fish). Steelhead were found at every location during these surveys, and all age classes were represented, although two-year steelhead were observed only twice (James Creek in 1993 and North Fork Big River in October 1996). CDFG also surveyed habitat characteristics in 41% of fish bearing streams in the watershed in 1995 and 1996 (NCRWQCB 2001a, 2001b). Data were collected according to Flosi and Reynolds (1994, in NCRWQCB 2001a, 2001b) protocol, which included pool frequency and depth and embeddedness.

CDF Surveys. The California Department of Forestry (CDF) electroshocked at 12 locations during the late summer and early fall, 1983 to 1989 (CDF 1989, in NCRWQCB 2001a, 2001b). CDF reported coho at one third of the stations: Berry Gulch, East Branch Little North Fork, Chamberlain Creek, and Two Log Creek. The highest density (0.32 fish/m^2) were in Berry Gulch in 1986, followed by Two Log Creek in 1983 (0.17 fish/m^2). Steelhead were reported at all locations, with the highest densities found at West Fork Chamberlain Creek and Chamberlain Creek (over 2 fish/m^2).

In its Draft Habitat Conservation Plan and Sustained Yield Plan for Jackson Demonstration State Forest, CDF (1999, in NCRWQCB 2001a, 2001b) reported that coho were present in 75% of streams in which they were expected, and steelhead were present in 64% of streams in which they were expected, based on gradient ($\leq$4% for coho and <8% for steelhead). In addition, coho were found in areas where they were not expected, including upstream segments of the East Branch Little North Fork and James Creek.

MRC Surveys. MRC reported fish data using electroshocking and snorkeling techniques from 1994-1996. The surveys were conducted over a three-year period to correspond with the coho life cycle. Although actual numbers or fish populations were not reported in the results, they did report that coho were present in 13 of the 58 sites (MRC 2000a, in NCRWQCB 2001a, 2001b), including three sites in the North Fork, two sites in Daugherty Creek, and one site each in the Upper Big River, East Branch North Fork, Bull Pen Gulch (tributary to East Branch North Fork), Two Log Creek, Middle Big River, South Fork, Ramon Creek, and North Fork Ramon Creek. Yearling coho were observed only once, in Daugherty Creek in 1996. All other coho that were observed were young-of-year fish. No coho were found at nine stations in the Headwaters PW, six stations in the North Fork Big PW, four stations in the Middle Big PW, and 25 stations in the South Fork Big PW. The same study found steelhead at 50 of the 58 stations. They were not reported in Steam Donkey Gulch, Dunlap Gulch, Quail Gulch, Tramway Gulch, Beaver Pond Gulch, No Name Gulch, Boardman Gulch, or Johnson Creek. In 145 sampling events conducted by MRC or its predecessor Louisiana-Pacific Corporation from 1994 to 1996, steelhead were observed in 130 sampling events. YOY steelhead were observed in 116 events, yearling were observed in 108, and two-year fish were observed in 101. Population numbers were fairly sparse (i.e., less than 40 individuals). There were no stations in which more than 400 individuals were counted. More than 40 individuals were counted at the Upper Big River, Middle Big River, East Branch North Fork, South Fork, Ramon Creek, Daugherty Creek and Gates Creek.

Georgia-Pacific Corporation. Georgia-Pacific Corporation ("G-P") collected salmonid population data at the lower Little North Fork and lower Two Log Creek from 1993 to 1996, as reported in its Sustained Yield Plan (G-P 1997, in NCRWQCB 2001a, 2001b). Coho densities were higher in the lower Little North Fork than in lower Two Log Creek. Steelhead densities were somewhat higher.

U.S. Fish and Wildlife Service. In 1973, U.S. Fish and Wildlife Service (USFWS, 1974, in NCRWQCB 2001) reported the number of juvenile coho salmon and steelhead observed from electroshocking surveys at ten sampling locations in July and October, including four locations on the Big River, one location on the South Fork, one location on the East Branch North Fork, three locations on the North Fork, and one location on Martin Creek. Coho were found at six of the ten stations: three of the four mainstem Big River locations, the South Fork, the East Branch North Fork, and Chamberlain Creek. The highest numbers of coho and steelhead observed were on the South Fork, below Daugherty Creek.

Nielsen et al. Nielson et al. (1990, in NCRWQCB 2001a, 2001b) included the South Fork Big River and seven tributaries (Ramon Creek, Mettick Creek, Anderson Creek, Daugherty Creek, Soda Creek, Gates Creek and one unnamed tributary) in a survey conducted during the 1989-1990 spawning season. During the entire survey period, the survey team observed only four live coho and 13 redds in Ramon Creek. Six redds were observed on Daugherty Creek. Surveyors assumed that the low numbers were due primarily to ongoing drought conditions.

Jones. Jones (2000, in NCRWQCB 2001a, 2001b) summarized several studies; chinook were reported only as strays, but coho and steelhead were believed to occur throughout the mainstem between 1958 and 1997. In 1966, juvenile steelhead were found in Two Log Creek (1966), coho and steelhead were found in East Branch North Fork, and juvenile coho and steelhead were found in South Fork. In 1967, juvenile coho and steelhead were found in the East Branch Little North Fork. Juvenile coho and steelhead were found in North Fork Big River in 1966, 1967 and 1974. In 1979, steelhead were found in Ramon Creek, Russell Brook, Martin Creek and Valentine Creek. In 1980, coho and steelhead were found in Arvola Gulch and James Creek. In 1981, coho and steelhead were found in Water Gulch and juvenile steelhead were found in Park Gulch. In 1983, coho and steelhead were found in Two Log Creek.

Hatchery Fish. While some hatchery fish were released into the Big River watershed up until the 1980s, and may have had some effect on the populations at that time, it is likely that most of the fish observed in the watershed today are of native origin (G. Bryant, NMFS, pers. comm., 2000, in EPA 2000b).

2.4. Salmonid Life Cycle and Water Quality Requirements

The Big River TMDL addresses sediment impairments to water quality. Salmonids are affected by a number of factors, some of which (e.g., ocean rearing conditions) occur outside of the watershed. This TMDL focuses on achievement of water quality standards related to sediment, which will facilitate, but not guarantee, population recovery.

Salmonids have a five-stage life cycle. Healthy habitat conditions are crucial for the survival of each life stage. First, adult salmonids lay their eggs in clean stream or lake gravels to incubate. Second, the eggs hatch into alevins, which depend upon the water flow through the gravel to survive and grow. Then the young fish (known as fry at this stage) emerge from the gravel and seek shelter in the pools and adjacent wetlands. Third, juvenile fish leave the stream or lake, migrate downriver, and reside in the estuary to feed and adjust to saltwater for up to a year before continuing onto the ocean. Fourth, juvenile fish mature in the ocean. And fifth, adult fish return to their home stream or lake to spawn. This cycle from freshwater spawning areas to the ocean and back defines Pacific salmonids as "anadromous." Most Pacific salmonids die after spawning: their total energies are devoted to producing the next generation, and their bodies help enrich the stream for that generation.

Salmonids have a variety of requirements related to sediment, which vary by life stage. Sediment of appropriate quality and quantity (dominated by gravels, without excess fine sediment) is needed for redd (i.e., salmon nest) construction, spawning, and embryo development. Excessive quantities of sediment or changes in size distribution (e.g., increased fine sediment) can adversely affect salmonid development and habitat.

To build the redd, the salmon needs an adequate supply of appropriately sized gravel, which varies by species but is generally around 64 mm (measured on the intermediate axis). The female salmon turns horizontally, parallel to the channel bed, and uses her tail fin to slap the gravel, moving it downstream. She then lays her eggs, while the male swims beside her to fertilize the eggs. The excavated area where the eggs have been deposited is then covered by the female using the same technique, moving the gravel onto the nest from just upstream. With adequate water flow, the process of moving the gravels also serves to clean some of the fine sediment out of the redd. Additional fine sediment may be deposited from winter flood flows, while the eggs are incubating.

Excessive fine sediment can reduce egg and embryo survival and juvenile salmonid development. Tappel and Bjornn (1983, in NCRWQCB 2001a, 2001b) found that embryo survival decreases as the amount of fine sediment increases. Excess fine sediment can prevent adequate water flow through salmon redds, which is critical for maintaining adequate oxygen levels and removing metabolic wastes. Deposits of these finer sediments can also smother and prevent the fry from emerging from the redds. Excess fine sediment can also cause gravels in the waterbody to become embedded; i.e., the fine sediment surrounds and packs in against the gravels, which effectively cements them into the channel bottom. Embeddedness can prevent the spawning salmon from building their redds.

Excessive fine or coarse sediment can also adversely affect the quality and availability of salmonid habitat by changing the morphology of the stream. It can reduce overall stream depth and the availability of shelter, and it can reduce the frequency, volume, and depth of pools. CDFG habitat data indicate that coho in Northern California tend to be found in streams that have as much as 40% of their total habitat in primary pools (Flosi et al. 1998). Pools in first- and second-order streams are considered primary pools when they are at least as long as the low-flow channel width, occupy at least half the width of the low-flow channel, and are two feet or more in depth. Primary pools in third-order and larger channels are defined similarly, except that pool depth should be three feet or more. Pools provide salmon with protection from predators, food supplies, and resting locations.

Excessive sediment can affect other factors important to salmonids. Stream temperatures can increase as a result of stream widening and pool filling. The abundance of invertebrates, a primary food source for juvenile salmonids, can be reduced by excessive fine sediment. Large woody debris (LWD), which provides shelter, can be buried. Increased sediment delivery can also result in elevated turbidity, which is highly correlated with increased suspended sediment concentrations. Increases in turbidity or suspended sediment can impair growth by reducing availability or visibility of food sources, and the suspended sediment can cause direct damage to the fish by clogging gills.

2.5. Habitat Conditions in the Big River Watershed

In general, the most sensitive beneficial use in the Big River watershed – protection of the cold water fish species – is impaired by poor quality summer rearing and overwintering habitat conditions, excess sediment, lack of deep pools, fair to poor spawning gravels (primarily embeddedness), low large woody debris (LWD) volume, low availability of canopy, high temperatures, and a lack of connection to off-channel habitat (NCRWQCB 2001a, 2001b). Excess sediment is adversely impacting the number and volume of pools. Sediment is also causing moderate to high embeddedness of substrate and spawning gravels in the basin. Recently-increased road building and timber harvest activities may cause additional degradation in the future, although the impacts are not yet reflected in current stream habitat conditions.

The specific factors affecting the tributaries vary. In the Upper Big River, data are limited, but indicate degraded habitat and depressed populations. The North Fork Big River and Two Log Creek are particularly sensitive to disturbances because of the relatively high abundance of non-confined, low-gradient channels that are valuable for habitat. High sedimentation and erosion potential diminishes and further threatens the habitat value. Recent events, including blasting at a rock quarry in Two Log Creek in July 2000, resulted in 225 yds^3 of earthen material being deposited in the creek, some of which still remains following excavation. In addition, 80% of the watershed will have been harvested or has been proposed for harvesting in the last decade (D. Leland, NCRWQCB, letter to J. Parrish, US EPA, Oct. 22, 2001).

Throughout the South Fork Big River, pools are shallow and spawning gravels are embedded. Canopy cover is low and water temperatures are high. In Chamberlain Creek, stream channels are entrenched and have low volumes of LWD. Pool depths are shallow, and embeddedness is high. Sediment inputs are high and canopy cover is low. The Little North Fork contains valuable wetlands, leading to relatively high habitat complexity. The Little North Fork SW has relatively high amounts of LWD and canopy cover. Unfortunately, as with the rest of the watershed, it is adversely affected by high sediment input, substrate embeddedness and low pool volume. The Lower Big River also includes valuable estuarine habitat, whose value is diminished by sediment deposition and channel confinement. Natural and anthropogenic levee formation is fragmenting habitat by cutting off the lower river from the floodplain. Decreased access to adjacent off-channel habitat reduces sheltering, rearing and feeding areas for salmonids (NCRWQCB 2001a, 2001b).

Coho salmon and steelhead spawn and rear in the watershed; however, both species are present in very low numbers compared to historic levels and are continuing to decline. Steelhead are relatively more abundant and have more age classes represented than do coho. Chinook may also be present in the Big River, but in very low numbers.

2.6. Influence of Historic Harvest Practices on Channel Conditions

It is well known that historic logging practices, including the typical harvest sequence of falling, burning, yarding by Dolbeer donkey, and railroad transport, were highly destructive and have had long-term, pervasive effects on the stream channels of many watersheds. One of the most damaging logging practices in Mendocino County involved the construction and operation of artificial dams to transport logs downstream. This was a widely used practice in Mendocino County, particularly where difficult access precluded more reliable transportation methods (i.e., railroads), and has been documented in the Big River and Caspar Creek watersheds. In the Big watershed, at least 27 dam sites that were used in a synchronized fashion to transport logs downstream have been identified (Mendocino County Historical Society 1964, in GMA 2001).

During the winter, when the reservoirs behind the dams were full, the gates were tripped, timed so that a flash flood would move downstream, picking up tiers of logs that had been carefully stacked in channels downstream. These "log drives" could occur one or more times per winter. Before these log drives could be undertaken, however, the entire stream channel between the dam and the estuary had to be cleared of any obstructions that would interfere with the downstream movement of the logs, which involved cutting, burning, and blasting of boulders, large rocks, leaning trees, sunken logs or obstructions of any kind (Brown 1936, in GMA 2001). At a few sites in the Big River, logs were stored in the reservoir itself and released along with the water, but in most places they were stacked in tiers in downstream channels and entrained by the rising waters of the dam release (Jackson 1991, in GMA 2001). Jams of cut logs during such releases occurred occasionally in the Big River (Jackson, 1991, in GMA 2001), but were removed as quickly as possible. During certain periods and in certain locations, such as the Hellsgate reach of the Lower South Fork, logjams lasted for years, and prevented any of these logs from reaching the mill.

The geomorphic effect of logging dam operation and associated channel clearing on downstream channels must have been immense. The greatly increased peak flows, combined with the battering-ram effect of transport of thousands of logs, would likely have caused channel erosion and incision. Removal of all in-channel debris jams undoubtedly released a tremendous amount of sediment that had previously been stored behind these jams. In the Caspar Creek watershed, Napolitano (1996, 1998, in GMA 2001) concluded that the log drives resulted in channel incision, and the current entrenched condition indicates that valley fills have been converted from long-term sediment sinks (floodplains) to substantial sediment sources (terraces). Napolitano (1998, in GMA 2001) found this conversion to be a major change of trends in valley sediment storage and a pervasive alteration in the sediment budget for the basin. Furthermore, the channel has not recovered its previous morphology because jams in the channel are now less stable due to the more deeply entrenched geometry that concentrates stream energy. Comparison of old-growth to second-growth channels also shows that pools are much more frequent and their average depth is greater in the old-growth channels (Keller et. al. 1981, Montgomery et. al. 1995, in GMA 2001).

Although data do not exist to confirm explicitly that a similar sequence of events occurred in the Big River watershed, the current condition certainly resembles that in Caspar Creek, of a deeply entrenched stream system, in many places cut down to bedrock, lacking functional floodplains, and substantially depleted in large instream woody debris. Lack of instream log jams is allowing sediment delivered to the main channels to move through the system far more quickly, and ultimately reach the estuary in greater quantities, than historically occurred pre-disturbance. The recovery from these historic practices was hindered in relatively recent times by CDFG log jam removal programs, which were documented by MRC (1999, in NCRWQCB 2001a, 2001b), occurring through much of the channel system in the 1960s.

Changes at the Big River Mouth and Estuary

Historically, the estuary was used extensively as a mill pond for the transport and storage of logs. Quantitative data do not exist, but significant changes to the estuary likely occurred as a result. The Big River estuary is a drowned river valley, eroded by a terrestrial river, and later flooded by a rise in the sea level (Reneau 1981a, in GMA 2001). Wetlands in the lower reaches of tributaries suggest that the estuary may have extended further upstream in the past. In the JDSF assessment area, these wetlands are typically associated with tributary basins dominated by large deep-seated landslides and mass wasting, suggesting that older landslides or tributary debris flows caused deposition of valley fill in which the marshes developed (CDF 1999, in GMA 2001). Deposition of sediment in the estuary has resulted in substantial decreases in its width, filling of tidal sloughs, and rapid colonization of mudflats by salt marsh vegetation. Natural levees have built up, and extend at least two miles farther down the estuary now than they did 80 years ago The progression of river deposits down the estuary has apparently been greatly accelerated in the last 130 years, resulting in a great decrease in its biological productivity (Reneau 1981a, in GMA 2001).

Comparison of Historic and Recent Aerial Photographs

Alluvial valley reaches in river systems often act as “response reaches,” since they are areas of temporary (in a time frame of 10s to 100s of years) sediment storage that adjust their storage and the stream channel geometry traversing these areas in response to changes in streamflow and sediment discharge. Thus, large floods may cause the location to change, sometimes dramatically. Similarly, large influxes of sediment, whether derived in a single large storm or delivered chronically over a longer time period, may cause changes in channel form in these response reaches (GMA 2001).

GMA (2001) examined aerial photographs from 1936 (when available) or 1952, and compared them with 2000 photos for several randomly-selected locations in the watershed. This analysis revealed that there has been a substantial increase over the period in road density, an increase in tree density and height in some areas (and thus canopy closure in most riparian areas), little visible change in channel planform, and the return of many cleared areas in lower portions of the watershed to forest. In part, the increased height and canopy cover reflects the regeneration of the second-growth forest. The increased road density is clearly linked to the increase in timber harvest as the trees have matured. The following summarizes conditions in four of the PW. Grassland areas became more widespread in the upper portions of the watershed.

Lower Big River PW. Generally speaking, there is little change apparent in the lower reaches of the estuary. Further upstream, visible changes include channel narrowing by riparian vegetation encroachment onto what were formerly exposed alluvial deposits or former mudflat areas. The number of roads has noticeably increased, a modest amount of residential development has occurred, and the overall age and density of the forest stands appear to have increased. In one photo, the average width of the roads has increased along with increased numbers of turnouts and landings. Extensive areas of timber harvest were visible in some areas, along with a high density of skid trails. Areas that were sparsely vegetated in 1936 are quite dense by 2000.

North Fork PW. 1936 photos were not available; 1952 photos show that numerous roads were already present, and areas had been harvested, although one photo also showed an area that was mostly old growth in 1952. In many areas, tree height and density appeared to have substantially increased.

Headwaters and South Fork PW

One 1936 photo clearly showed the effects of the Comptche Fire in 1931, said to have been the sixth largest fire in the United States (Jackson 1991, in GMA 2001). Near the area of the fire, no roads were visible, but the South Fork Channel was extremely visible as a result of the fire. By 2000, a considerable road network had been developed. A photo near Martin Creek shows what appears to be old growth in 1952 and nearby active harvesting. The channel of Big River was highly visible in 1952, reflecting high sediment yields. By 2000, the channel is essentially not visible due to growth of vegetation, although a large number of roads and skid trails are evident. In contrast to other photo sets, one photo that includes Montgomery Woods State Reserve shows almost no changes between the 1952 and 2000 photos.

CHAPTER 3: WATER QUALITY INDICATORS

This chapter identifies water quality indicators. They are interpretations of the water quality standards expressed in terms of instream and watershed conditions. For each indicator, a target value is identified to define the desired condition for that indicator. EPA expects that these indicators, and their associated target values, will provide a useful reference in determining the effectiveness of the TMDL in attaining water quality standards, although they are not directly enforceable by EPA.

No single indicator adequately describes water quality related to sediment, so a suite of instream and watershed indicators is identified. Because of the inherent variability associated with stream channel conditions, and because no single indicator applies in all situations, attainment of the targets is intended to be evaluated using a weight-of-evidence approach. When considered together, the indicators are expected to provide good evidence of the condition of the stream and attainment of water quality standards.

Both instream and watershed indicators are appropriate to use in describing attainment of water quality standards. Instream indicators reflect sediment conditions that support salmonids. They relate to instream sediment supply and are important because they are direct measures of stream "health." Watershed indicators describe conditions that reflect protection against future degradation of water quality. These indirect measures of stream health support the anti-degradation policy by focusing on imminent threats to water quality that can be detected and corrected before the sediment is actually delivered to the stream. Watershed indicators are often easier to measure than instream indicators, and they identify conditions in the watershed needed to protect water quality.

Both instream and watershed indicators are set at levels associated with well-functioning stream systems. This TMDL contains both instream and watershed indicators in order to improve water quality in the short-term and long-term, by protecting from immediate and future threats of degradation. Watershed indicators reflect conditions in the watershed at the time of measurement, whereas instream indicators can take years or decades to respond to changes in the watershed, because linkages between hillslope sediment production and instream sediment delivery are complicated by time lags from production to delivery, instream storage, and transport through the system. Accordingly, watershed targets can potentially be achieved sooner than instream targets, and can serve as checks on the progress toward achievement of water quality standards.

In addition, both types of indicators are included to help ensure the attainment of water quality standards throughout the system. Watershed indicators tend to reflect local conditions, whereas instream indicators often reflect conditions from unknown locations upstream or up-basin as well as local conditions. Meeting target watershed conditions helps ensure that instream conditions will be met.

3.1. Summary of Water Quality Indicators and Targets

Table 3 lists the water quality indicators for the Big River TMDL and their respective target values. In several cases, targets are expressed as improving trends, since information on watershed processes is inadequate to develop appropriate thresholds.

Table 3. Water Quality Indicators and Targets

INDICATOR	TARGET	COMMENTS	PURPOSE	REFERENCES
Instream	Monitoring recommendations: annually (e.g., sediment substrate, embeddedness, V*, aquatic insect abundance) or periodically following large storms (thalweg profile, pool distribution, turbidity, LWD)			
Sediment Substrate Composition	≤ 14% < 0.85 mm ≤ 30% < 6.4 mm	McNeil (bulk) sample during low-flow period, at riffle heads in potential spawning reaches	Indirect measure of spawning support: improved quality & size distribution of spawning gravel	Burns 1970, CDF 1994, McHenry et al. 1994, Mangelsdorf & Lundborg 1998, Valentine 1997 (in EPA 1998b, EPA 1999).
Riffle Embeddedness	≤ 25% or improving (decreasing) trend toward ≤ 25%	Estimated visually at riffle heads where spawning is likely, during low-flow period	Indirect measure of spawning support; improved quality & size distribution of spawning gravel	Flosi et al. 1998, Mangelsdorf & Clyde 2000.
V*	< 0.21 (Franciscan) or < 0.10 (other)	Residual pool volume. Measure during low-flow period.	Estimate of sediment filling of pools from disturbance	Lisle & Hilton 1992, Knopp 1993, Lisle 1989 (in EPA 1999); Lisle & Hilton 1998.
Thalweg profile	increasing variation from the mean	Measured in deposition reaches during low-flow period.	Estimate of improving habitat complexity & availability	Trush 1999, Madej 1999 (in EPA 1999).
pool/riffle distribution & depth of pools	increasing trend toward >40% length in primary pools	Primary pools (>2' in low order, >3' in 3rd & higher order), measured low-flow period.	Estimate of improving habitat availability	Flosi et al. 1998.
Turbidity	≤ 20% above naturally occurring background	Measured regularly, continuously, or during storm flows. Future data may suggest a modified turbidity indicator.	Indirect measure of overall water quality, feeding/growth ability related to sediment, protection of water supplies	Basin Plan (NCRWQCB 1996).
Aquatic Insect Production	improving trends	EPT, Richness & % Dominant Taxa indices.	Estimate of salmonid food availability, indirect estimate of sediment quality.	Bybee 2000, Plafkin et al. 1989 (in EPA 1998b).
Large Woody Debris (LWD)	increasing distribution, volume & number of key pieces	Increasing number & volume of key pieces or increasing distribution of LWD-formed habitat.	Estimates improving habitat availability	Flosi et al. 1998.
Watershed	Monitoring recommendations: prior to winter			
Diversion potential & stream crossing failure potential	≤ 1% of crossings divert or fail in 100 yr storm	Measured prior to winter.	Estimate of potential for reduced risk of sediment delivery from hillslope sources to the watercourse	Weaver and Hagans 1994, Flanagan et al. 1998 (in EPA 1998a).
Hydrologic connectivity of roads	decreasing length of connected road to ≤ 1%	Measured prior to winter.	Estimate of potential for reduced risk of sediment delivery from hillslope sources to the watercourse	Ziemer 1998 (in EPA 1999); Flanagan et al. 1998, Furniss 1999 (in EPA 1998a).
Annual road inspection & correction	increasing proportion of road to 100%	Roads inspected and maintained, or decommissioned or hydrologically closed prior to winter. No migration barriers.	Estimate of potential for reduced risk of sediment delivery from hillslope sources to the watercourse	EPA 1998a.
Road location, surfacing, sidecast	decreasing length next to stream, increased % outsloped and hard surfaced roads	see text	Minimized sediment delivery	EPA 1998a.
Activities in unstable areas	avoid or eliminate	Subject to geological/geotechnical assessment to minimize delivery or show that no increased delivery would result	Minimized sediment delivery from management activities	Dietrich et al. 1998, Weaver and Hagans 1994, PWA 1998 (in EPA 1999).
Disturbed area	decrease	see text	Measure of chronic sediment	Lewis 1998 (in EPA 1999).

3.2. Instream Indicators

Sediment Substrate Composition

Target: < 14% fines < 0.85 mm, < 30% fines < 6.4 mm

The indicator and target selected represent adequate spawning, incubation, and emergence conditions relative to substrate composition. Excess fine sediment can decrease water flow through salmon redds. Sufficient water flow through the redd is critical for maintaining adequate oxygen levels and removing metabolic wastes. Deposits of these finer sediments can also prevent the hatching fry from emerging from the redds, resulting in smothering. Monitoring should be conducted by bulk sampling during low-flow periods at the heads of riffles, in potential spawning reaches. We recommend collecting and reporting the full range of sizes, but emphasize that the smallest size fraction is the most important indicator of the "fines" that are likely to clog and embed the spawning gravels. In addition, we recommend reporting the method by which the data is analyzed (e.g., size of total sample, measurements by dry weight v. wet volume), so that sources of uncertainty are known. Future indicators for permeability or turbidity may supplement or replace this indicator when additional information becomes available.

Conditions in the Watershed:

Very few data are available in the watershed. MRC collected McNeil samples (McNeil and Ahnell 1964) in September 2000, and reported the findings in terms of dry weight (MRC 1999). GMA collected McNeil samples in spring of 2001, reporting dry weight as well. Data are available for the size fractions <0.85 mm, and for <5.6 mm. The data are summarized for informational purposes in Table 4. Measured percentages of fine sediment <0.85 mm ranged from 3-22%, although all but two of the 16 sample locations from 2000/2001 had values within the target range of <14%. Two values from 1996 and 1997 in Two Log Creek also exceeded the target value. The highest values were found in the South Fork PW. MRC's samples for Ramon Creek ranged from 10% to as high as 22%, and those for Daugherty Creek ranged from 11-22%. Overall, the samples for which data are available are generally within the target range for the <0.85 mm size fraction. However, for the <6.4 mm size fraction,10 of the 16 sample locations exceed the target. Most of these are found in the South Fork PW, and the highest values are found in this PW. Several are also found in the North Fork and Lower Big Pws. All the samples within the Middle Big PW are within target values. From the limited data that are available, fine sediment appears to be impairing all but the Middle Big PW, particularly in the <6.4 mm size fraction.

MRC also began to collect some permeability data at its bulk sample sites. In the future, this may prove to be a more effective measure of the water quality than analysis of sediment substrate composition, since it directly measures the amount of water flow through the gravels, which is essentially what the bulk samples are representing indirectly. Table 4 also includes the MRC permeability rating (derived from the actual permeability rates) for four sites. The data generally appear to correlate logically with the bulk sample data, with very low permeability rates and survival ratings for the South Fork tributaries with high proportions of fine sediment, and the highest permeability/survivability rating for the Mainstem Big, which is generally within target values.

Table 4: Summary of Sediment Substrate Samples

PW Location	**Site No.**	**Year**	**Cumulative % Finer Than Size Fraction (mm)**			**Perm. Rating***
			0.85	**5.6**	**8**	
NF Big PW						
NF Big Above James (Upper NF SW)	GMA-NFBAJ 1&2	2001	3%	18%	18%	
NF Big Above Chamberlain (Lower NF SW)	GMA-NFBAC 1&2	2001	10%	**38%**	46%	
NF Big Above Big (Lower NF SW)	GMA-NFBAB 1&2	2001	7%	24%	31%	
East Fork North Fork Big (EF NF SW)	GMA-EFNFB 1&2	2001	11%	**32%**	38%	
East Branch North Fork Big	MRC-Tailout #3,5,6,7	2000	9-11%	25-**31%**		35%
Chamberlain Ck above NF Big	GMA-CANFB 1&2	2001	9%	**32%**	40%	
Middle Big PW-*SW*						
Big below SF Big (Middle Big SW)	GMA-BBSFA 1&2	2001	9%	24%	30%	
Big above Two Log (Middle Big SW)	GMA-BATL 1&2	2001	10%	27%	35%	
Two Log Creek (Campbell Timberland Mgmt)	Campbell Timberland Management (see note)	1996 1997	**17%** **20%**			
Mainstem Big	MRC-Tailout #1,2,3,6	2000	7-14%	20-29%		50%
South Fork Big PW - *Lower SF SW*						
SF Big above Daugherty (Middle SF SW)	GMA-SFBAD 1&2	2001	11%	**40**%	57%	
SF Big above Big (Lower SF SW)	GMA-SFBAB 1&2	2001	12%	**37**%	44%	
Ramon Crk (Lower SF SW)	MRC-Tailout #2,3,4,6	2000	10-**16%**	28-**31%**		12%
Lower SF Big	MRC-Tailout #1,2,4,6	2000	7-13%	19-**37%**		47%
Daugherty above SF Big (Daugherty SW)	GMA-DASFB 1&2	2001	8%	27%	32%	
Daugherty Ck	MRC-Tailout #1,2,4,5	2000	11-**22%**	19-**45%**		18%
Lower Big PW - *Lower Big SW*						
Big below Little North Fork (Lower Big SW)	GMA-BBLNFB 1&2	2001	**15%**	**35**%	45%	

Source: GMA 2001, GMA unpublished data and files, MRC unpublished data, except where noted for Two Log Creek (Campbell Timberland Management). Source for that data: D. Leland, letter to J. Parrish, Oct. 22, 2001. Data for GMA and MRC are reported as % dry weight. Source for Two Log Creek/Campbell Timberland data did not indicate how those data were reported.
GMA=Graham Matthews & Associates sampling data. MRC=Mendocino Redwood Company sampling data
Note: Bold numbers represent target exceedence. **Target values: ≤14% < 0.85mm / ≤30% <6.4mm**
*Permeability rating is based on %survival index (higher % suggests higher survival). MRC also reports standard error.

Riffle Embeddedness

Target: ≤25% or improving (decreasing) trend

Embeddedness is an indication of fine sediment that surrounds and packs in gravels. A heavily embedded riffle section may make spawning impossible. When constructing its redd, generally at a pool tail-out (i.e., the head of the riffle), the spawning fish slaps its tail against the channel bottom, which lifts unembedded gravels and removes some of the fine sediment. This process results in a pile of cleaner and more permeable gravel, which is more suited to nurturing the eggs. Embedded gravels do not generally lift easily, which can prevent spawning fish from building their redds. Flosi et al. (1998) suggest that gravels that are less than 25% embedded are preferred for spawning. This target should be estimated during the low-flow period, generally at riffle heads, in potential spawning reaches. Because this indicator is visually estimated, and thus subject to operator variability, it may be appropriate to substitute the use of pebble counts that also note embeddedness of individual pebbles that are counted.

Conditions in the Watershed:

CDFG (inventory reports, in NCRWQCB 2001a, 2001b, and D. Leland, letter to J. Parrish, Oct. 22, 2001) conducted surveys in the watershed from 1983 to 1998. The depth of embeddedness of cobbles in pool tail-outs was estimated as the percent of cobble that was surrounded or buried by fine sediment. The levels of embeddedness were generally very high. In the watershed, CDFG surveys show that a total of 2,809 pool tail-outs were measured; less than 10% were considered to be good spawning habitat quality for this parameter (i.e., less than 25% embedded). An additional 9% were considered unsuitable for spawning for various other reasons. In the South Fork PW, four reaches were measured: Gates Creek, Daugherty Creek, Snuffins Creek, and Soda Creek. Of the 505 total pool tail-outs measured, only 10% were less than 25% embedded. In the North Fork PW, eight reaches were measured: North Fork, Chamberlain Creek, East Branch North Fork, James Creek, North Fork James Creek, Soda Gulch, Water Gulch and West Chamberlain Creek. A total of 1,582 pool tail-outs were measured; only 12% were less than 25% embedded. Chamberlain Creek and James Creek were less embedded than some of the other reaches: 23% of tail-outs in Chamberlain Creek were good quality, with less than 25% embedded, and 18% of sites in James Creek were less than 25% embedded. Four reaches totaling 463 tail-outs in the Lower Big PW were measured (all in the Little North Fork SW): in the Little North Fork, Berry Gulch, Rocky Gulch and Thompson Gulch. On average, only 5% of the sample sites were less than 25% embedded. In the Middle Big PW, two reaches were measured: Railroad Gulch and Two Log Creek. Of the 75 total pool tail-outs measured in Railroad Gulch, only 5% were less than 25% embedded. In Two Log Creek, 184 pool tail-outs were measured; only 1% were less than 25% embedded.

V*

Target: <0.21 (Franciscan geology) or <0.10 (stable geology)

V* is a measure of the fraction of a pool's volume that is filled by fine sediment, and represents the in-channel supply of mobile bedload sediment (Lisle and Hilton 1992). It reflects the quality of pool habitat, since a lower filled pool volume reflects deeper, cooler pools offering protection from predators, a food source, and resting location. Lisle and Hilton (1992) also describe methods for monitoring, which should be conducted in low-flow periods. V* is not appropriate for large rivers, but in large river systems it is appropriate for tributaries.

Conditions in the Watershed: Very few data are currently available. KRIS (Klamath Resource Information System) indicates that V* in 1992 were reported to be 0.38 in Berry Gulch and 0.37 in Hare Creek (D. Leland, letter to J. Parrish, Oct. 22, 2001). These values are both very high.

Thalweg Profile

Target: increasing variation of elevation around the mean slope

Variety and complexity in habitat are needed to support fish at different times in the year or at different times in their life cycles. Both pools and riffles are utilized by fish for spawning, incubation of eggs, and emergence of the fry. Once fry emerge, they rest in pools and other slower-moving water, darting into faster riffle sections to feed where insects are abundant. Deeper pools, overhanging banks, or logs provide cover from predators. Measuring the thalweg profile is an indicator of habitat complexity.

Streambed elevations along a profile generally reflect the overall balance of sediment transport at that location. If sediment delivered to the channel is greater than the transport capacity of the channel (which is a function of flow and channel geometry), then the channel will aggrade or rise in elevation. When sediment loads are less than transport capacity, the channel will degrade or scour as long as suitably sized alluvial deposits (i.e. capable of being mobilized) are present on the channel bed (GMA 2001).

The thalweg is the deepest part of the stream channel at a given cross section. The thalweg profile is a plot of the elevation of the thalweg as surveyed along the length of the stream. The profile appears as a jagged but descending line, relatively flat at pool areas, and descending sharply at cascades. The comparison between the mean slope (i.e., the overall trend of the descending stream) and the details of the slope is a measure of the complexity of stream habitats. More variability in the profile indicates more complexity in stream habitat. Inadequate availability of pool-forming features, such as bedrock or LWD, can be revealed by this indicator of channel structure, particularly if information on channel features is included in the survey. Because the change in the profile will occur relatively slowly, and because not enough is yet known about channel structure to establish a specific number that reflects a satisfactory degree of variation, the target is simply an increasing trend in variation from the mean thalweg profile slope. The information is most useful if the water surface elevation is also surveyed at each thalweg point (to distinguish in the profile between individual pools). Comparisons among individual profiles over time or can be made visually if the plots are on the same scale. This indicator should be measured during the low-flow period every 5-10 years, after large storm seasons.

Conditions in the Watershed: No information is available.

Pool Distribution and Depth

Target: increasing inventory of reaches where length >40% pools

Pools generally account for more than 40% of stream length in streams with good salmonid habitat (Flosi et al. 1998). Frequent pools are important for providing food and shelter, and may also serve locally as refugia. This indicator should be measured during the low-flow period every 5-10 years, after large storm seasons. The data can be gathered simultaneously with a thalweg profile. Reported data should include length and depth of pools, and number of primary pools, usually defined as pools greater than two feet in depth in 1st and 2nd order streams, and greater than three feet in depth in 3rd and 4th order streams. Furthermore, additional information can be gathered during this process, without hindering the monitoring process greatly. For example, general habitat type can be noted. This may be particularly useful for determining the distribution of pool types, such as backwater pools, which can be indicative of overwintering habitats, or lateral scour pools, which tend to be heavily used by fish (Flosi et al. 1998).

Conditions in the Watershed:

CDFG (1998a, in NCRWQCB 2001a, 2001b) conducted surveys in the watershed in 1996 and 1997. Pools are too shallow in most of the basin to provide adequate rearing habitat for coho salmon. In the

South Fork PW, Daugherty Creek, Gates Creek, Johnson Creek, Snuffins Creek and Soda Creek were surveyed. Pools comprise 7-25% of the channel length, and average 21%; 2% of the channel length was dry (primarily in Johnson Creek). Mean pool depth was less than two feet, and was less than one foot in Johnson Creek, Snuffins Creek and Soda Creek. Pools were deeper, on average, in Daugherty Creek than in other areas of the South Fork PW. In the North Fork PW, pools were more frequent. The East Branch North Fork, Soda Gulch, James Creek and North Fork James Creek were surveyed. Pools averaged 31% of stream channel length. Pool lengths ranged from 16% to 41% (North Fork SW). Mean pool depth was less than two feet in length, and less than 0.9 feet in Soda Gulch and North Fork James Creek. Chamberlain Creek SW was tallied separately; surveyed tributaries included Lost Creek, Water Gulch and its unnamed tributary, West Chamberlain Creek, Chamberlain Creek and Gulch 16. Pools averaged 29% of the survey length, and ranged from 22% to 39% (the highest value in Water Gulch). Mean pool depth was less than 1.25 feet throughout the SW, and was less than one foot in Lost Creek, Water Gulch, Water Gulch tributary, and Gulch 16. Little North Fork PW channel surveys included Berry Gulch, an unnamed Berry Gulch tributary, Little North Fork, Manly Gulch, and Rocky Gulch. Pool frequencies ranged from quite low (8% in Rocky Gulch) to greater than adequate (53% in Little North Fork), averaging 38%. Average pool depth, however, was fairly low (less than 1.5 feet, except in the Berry Creek tributary, where the backwater pools averaged 2.3 feet). Two Log Creek and Railroad Gulch were also surveyed (in the Middle Big PW). Two Log Creek was composed primarily of dry channel (74%). Only 7% was composed of pools, and the average depth was less than 0.6 feet. In Railroad Gulch, pools made up 35% of the stream length, but average depth was less than 0.8 feet. Mean depth of backwater pools was 2 feet.

Turbidity

Target: <20% above naturally occurring background levels

Turbidity is a measure of the ability of light to shine through water (higher turbidity indicating more material in the water that blocks the light). Although turbidity levels can be elevated by both sediment and organic material, in the Big River watershed, stream turbidity levels are highly correlated with suspended sediment (GMA 2001). High turbidity in the stream affects fish by reducing visibility, which may result in reduced feeding and growth. Elevated suspended sediment, particularly over a long period, may also result in direct physical harm, for example, by clogging gills. This indicator should be measured during storm flows, particularly during the winter. Although determinations of background levels are sometimes problematic, it is reasonable to measure levels upstream and downstream of a management activity to compare changes in the turbidity levels that are likely attributable to that activity. Information should include both magnitude and duration of elevated turbidity levels.

The NCRWQCB has been working on developing a more descriptive indicator of turbidity, which could supplement or substitute for this indicator once it is sufficiently developed. The work may result in a more precise definition of background levels, or a target related to level and duration of exposure, or a downward shift in the turbidity/discharge relationship.

Conditions in the Watershed:

GMA (2001) collected turbidity and suspended sediment samples at 10 sites in the Big watershed during the 2000 and 2001 water years. However, the data were collected primarily to establish a relationship with suspended sediment concentration, in order to estimate sediment discharge in the watershed, and the turbidity data were not continuously collected. Therefore, there is no information on duration, which is a major factor both in determining turbidity impacts and in differences over background levels. Table 5 summarizes the data that were collected. The highest measurement was 811 NTU, and the average throughout the watershed was 72 NTU. These levels appear to be significantly elevated. However, no data on background levels were collected, so a clear determination as to whether target levels are met or by how much they are exceeded cannot be made. NCRWQCB staff suggest that even the average values are above values the literature report as creating adverse conditions; behavioral impacts may be observed in values as low as 10 NTU, based on a summary review of literature, primarily from the Pacific Northwest (D.Leland, NCRWQCB, letter to J. Parrish, US EPA, Oct. 22, 2001). The lowest values were in Chamberlain Creek above the North Fork and the East Fork North Fork Big above the North Fork Big River (average 39-52 NTU, maximum 66-114 NTU). The highest maximum values (average 171-178 NTU, maximum 777-811 NTU) were found in the South Fork Big River near Dougherty Creek.

Table 5: Summary of Turbidity Values Winter 2000 and 2001

Sample Site	Number of Samples	Average Value (NTU)	Maximum Value (NTU)
ALL	90	72	811
Big R ab. SF Big R	7	58	240
Chamberlain Ck ab. NF Big R	13	39	114
Daugherty Ck ab. SF Big R	9	52	158
EF of NF Big R ab. NF Big R	7	32	66
NF Big R ab. Chamberlain Ck	17	52	214
SF Big R ab. Daugherty Ck	9	171	811
SF Big R bl. Daugherty Ck	8	178	777
SF Big R ab. Big R	7	95	382

Source: GMA 2001, unpublished data

Aquatic Insect Production

Target: improving trends in EPT, % dominant taxa and species richness indices

Benthic macroinvertebrate populations are greatly influenced by water quality and are often adversely affected by excess fine sediment. This TMDL recommends that several indices be calculated, following the CDFG Water Pollution Control Laboratory Stream Bioassessment Procedures (1996, in Mangelsdorf & Clyde 2000).

1) EPT Index. The EPT Index is an indicator of the number of species divided by the total number of taxa found within the orders Ephemeroptera, Plecoptera, and Trichoptera (EPT), more commonly known as mayflies, stoneflies and caddisflies. These organisms require higher levels of water quality and respond rapidly to improving or degrading conditions (EPA 1998b; Bjornn et al. 1997, in Bybee 2000).

2) Percent Dominant Taxa. This index is calculated by dividing the number of organisms in the most abundant taxa by the total number of organisms in the sample. Collections dominated by one taxa generally represent a disturbed ecosystem.

3) Richness Index. This is the total number of taxa represented in the sample. Higher diversity can indicate better water quality.

Conditions in the Watershed: No information is available.

Large Woody Debris (LWD)

Target: increasing distribution, volume and number of key pieces, or increasing distribution of LWD-formed habitat

California coastal streams are especially dependent on the presence of LWD to provide ecological functions, such as sediment metering and sorting, pool formation, and shelter. Large pieces of woody debris in streams influence the physical form of the channel, the movement of sediment, the retention of organic matter and the composition of the biological community (Bilby and Ward 1989). LWD can be instrumental in forming and stabilizing gravel bars (Bilby and Ward 1989; Lisle 1986 in EPA 1999), or in accumulating fine sediment, which keeps it from clogging spawning areas (Zimmerman et al. 1967, Megahan 1982, in Bilby and Ward 1989). LWD can also form pools by directing or concentrating flow in the stream in such a way that the bank or bed is scoured, or by impounding water upstream from the obstruction (Lisle and Kelsey 1982, in EPA 1999). LWD plays a more significant role in routing sediment in small streams than in large ones (Bilby and Ward 1989). This indicator should be measured during the low-flow period, and should report the number and volume of key pieces or the distribution of LWD-formed habitat. The target is designed to be flexible, depending on the type of descriptor that an overall monitoring finds most useful for assessing stream and watershed conditions. The description of a "key piece" should be related to a size that is important for salmonid use in the stream. EPA encourages the NCRWQCB to specify the description in its monitoring plan.

Conditions in the Watershed:

The operation of logging dams probably contributed to the current degraded condition of the Big River watershed, which is largely depleted in LWD. Lack of instream log jams is allowing sediment delivered to the main channel to move through the system far more quickly and ultimately reach the estuary in greater quantities than prior to disturbance (NCRWQCB 2001a, 2001b). CDF recorded log jam removal in Jackson Demonstration State Forest (and, apparently, in some watersheds adjacent to JDSF) in the 1950s, 1960s, 1980s and 1990s, which probably hindered recovery. Most of the LWD removal occurred in lower-gradient channels, which reduced the amount of LWD-stored sediment, reduced pool frequency and depth, and converted the habitat type in the channel. LWD removal was documented in Tramway Gulch, Two Log Creek, Berry Gulch, East Branch Little North Fork, Big River Laguna, James Creek, Chamberlain Creek, Water Gulch, East Branch North Fork, and North Fork Big River. Documented LWD removal is highest in the James Creek SW, with 86% of its Class I streams having been subject to LWD removal. This is followed by Chamberlain Creek SW, with removal in greater than 50% of its stream length. LWD removal was lowest in the Lower Big River PW, with only 2% of its stream length having been altered (CDF 1999, in NCRWQCB 2001a, 2001b).

3.3. Watershed Indicators

Stream Crossings with Diversion Potential or Significant Failure Potential

Target: <1% of all stream crossings divert or fail as a result of a 100-year or smaller flood

Most roads, including skid trails and railroads, cross ephemeral or perennial streams. Crossings are built to capture the stream flow and safely convey it through, under, or around the roadbed. However, stream crossings can fail, adding sediment from the crossing structure (i.e., fill) or from the road bed directly into the stream. Stream crossing failures are generally related to undersized, poorly placed, plugged, or partially plugged culverts. When a crossing fails, the total sediment volume delivered to the stream usually includes both the volume of road fill associated with the crossing and sediment from collateral failures such as debris torrents that scour the channel and stream banks. Diversion potential is the potential for a road to divert water from its intended drainage system across or through the road fill, thereby delivering road-related sediment to a watercourse. The potential to deliver sediment to the stream can be eliminated from almost all stream crossings by eliminating inboard ditches, outsloping roads, or installing rolling dips (M. Furniss, pers. comm., in EPA 1998a). Generally, less than 1% of stream crossings have conditions where modification is inappropriate because it would endanger travelers or where modification is impractical because of physical constraints (D. Hagans, pers. comm., 1998, in EPA 1998a).

Stream crossings with diversion potential or significant failure potential are high risks for sediment delivery to streams in the Big River watershed. Although there are no data for the Big River watershed regarding the current rate of stream diversions or stream crossing failures, or the quantities of sediment delivered to watercourses from these processes, sediment from stream diversions and other sources associated with haul road and skid trail crossings have been estimated to contribute from 25-38% of the overall sediment budget in some other North Coast basins (e.g., Rolling Brook, a tributary of the Garcia River, and Redwood Creek in Redwood National Park, and Navarro River (EPA 1998b, EPA 2000a)).

Conditions in the Watershed: No information is available.

Hydrologic Connectivity

Target: decreasing length to ≤1%

A hydrologically connected road drains water directly to the stream, which increases the intensity, frequency, and magnitude of flood flows and suspended sediment loads in the adjacent stream. This can destabilize the stream channel, with a devastating effect on salmonid redds and growing embryos (Lisle 1989, in Mangelsdorf and Clyde 2000). 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, and Weaver and Hagans 1994, in EPA 1998). The reduction of road densities and the reconstruction of roads to reduce the miles of inboard ditches, for example, can reduce the amount of water that is directly delivered to watercourses, including any associated sediment load.

Conditions in the Watershed: No information is available.

Annual Road Inspection and Correction

Target: increasing proportion to 100%

EPA's analysis indicates that in watersheds with road networks that have not experienced excessive road-related sedimentation, roads are either (1) regularly inspected and maintained; (2) hydrologically maintenance free (i.e., they do not alter the natural hydrology of the stream); or (3) decommissioned or hydrologically closed (i.e., fills and culverts have been removed and the natural hydrology of the hillslope has largely been restored). If not, they are potentially large sources of sediment (D. Hagans, pers. comm., 1998, in EPA 1998). 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. This target calls for an increase in the proportion of roads that are either (1) inspected annually and maintained prior to winter, (2) hydrologically maintenance free, or (3) decommissioned or hydrologically closed, until all roads in the Big River watershed fall into one of these categories.

Conditions in the Watershed: No information is available.

Road Location, Surfacing, Sidecast

Target: decreasing road length next to streams, increasing proportion outsloped or hard surfaced roads

This indicator is intended to address the highest risk sediment delivery from roads not covered in other indicators. Roads located in inner gorges and headwall areas are more likely to fail than roads located in other topographic locations. Other than ephemeral watercourses, roads should be removed from inner gorge and potentially unstable headwall areas, except where alternative road locations are unavailable and the road is clearly needed. Road surfacing and use intensity directly influence sediment delivery from roads. Rock surfacing or paving is appropriate for frequently used roads. Sidecast on steep slopes can trigger earth movements, potentially resulting in sediment delivery to watercourses. 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, in EPA 1998).

This target calls for several things: (1) elimination of roads alongside inner gorge areas or in potentially unstable headwall areas, unless alternative road locations are unavailable and the road is clearly needed; (2) road surfacing, drainage methods, and maintenance are appropriate to their use patterns and intensities; and (3) pulled back or stabilized sidecast or fill on steep (i.e., greater than 50%) or potentially unstable slopes that could deliver sediment to a watercourse.

Conditions in the Watershed: The lengths of roads by surface type are listed in Table 6.

Table 6. Existing Road Types

Planning Watershed Sub-watershed	**Miles of Indicated Road Type**			**Total (mi)**	**Road Density (mi/mi^2)**
	Paved	**Rocked**	**Native**		
Headwaters PW	**0**	**25.52**	**208.26**	**233.78**	**7.13**
Upper Mainstem Big SW	0	2.28	80.49		6.75
Martin Ck SW	0	17.58	49.21		7.20
Lower Mainstem SW	0	5.66	76.56		7.51
North Fork Big PW	**10.25**	**36.17**	**242.58**	**288.99**	**6.64**
Upper North Fork Big SW	0.62	13.10	46.14		7.08
James Creek SW	5.65	1.73	44.12		7.40
Chamberlain Creek SW	0	1.74	62.18		5.21
East Branch North Fork Big SW	0	11.79	41.59		6.62
Lower North Fork SW	3.98	7.81	48.55		7.80
Middle Big PW	**2.17**	**23.79**	**128.24**	**154.20**	**8.64**
Middle Big River SW	0	18.01	260.44		8.85
Two Log Creek SW	2.17	5.78	192.27		8.06
South Fork Big PW	**17.49**	**38.67**	**51.75**	**316.60**	**5.81**
Upper South Fork Big SW	3.89	0	71.98		4.12
Middle South Fork Big SW	5.85	0.46	32.62		5.17
Daugherty Creek SW	6.47	16.14	35.92		6.54
Lower South Fork Big SW	1.28	22.07	1031.78		6.31
Lower Big PW	**10.28**	**45.96**	**192.27**	**248.49**	**7.65**
Lower Big SW	1.25	10.30	51.75		8.23
Little North Fork SW	2.79	9.78	71.98		6.79
Laguna Creek SW	2.09	6.31	32.62		8.09
Big River Estuary	4.15	19.26	35.92		8.22
TOTAL BIG WATERSHED	**40.18**	**170.10**	**1,031.78**	**1242.10**	**6.86**
% of Total	3%	14%	83%	100%	

Source: GMA 2001

Activity in Unstable Areas

Target: avoid or eliminate, unless detailed geologic assessment by a Certified Engineering Geologist concludes there is no additional potential for increased sediment loading

Unstable areas are those areas that have a high risk of landsliding, and include: steep slopes, inner gorges, headwall swales, stream banks, existing landslides, and other locations identified in the field. Because of the high risk of landsliding inherent in these features, any activity that might trigger an erosional event should be avoided, if possible, and kept to a minimum if unavoidable. Such activities include road building, harvesting, yarding, terracing for vineyards, etc. Analysis of chronic landsliding in the Noyo River basin indicated that landslides observed on aerial photographs largely coincide with predicted chronic risk areas including steep slopes, inner gorges and headwall swales (Dietrich et al. 1998, in EPA 1999). Several other studies have shown that landslides are larger or more common in some harvest areas, particularly in inner gorges (GMA 2000, in EPA 2000). Weaver and Hagans (1994) also suggest methods for eliminating or decreasing the potential for road-related sediment delivery.

Conditions in the Watershed: No information is available. However, GMA (2001) noted that the Lower and Middle Big PW have about one-third of their area in lower-gradient slopes (less than 30%). The North Fork, South Fork and Headwaters PW are steeper, with 32-38% of their slopes steeper than 50%. The Upper Mainstem Big SW has noticeably steeper slopes than the other SW, with nearly half of its slopes exceeding 50%, and 18% of slopes exceeding 70%. In addition, it is important to note the existence of Central Belt mélange terrane in the central portion of the eastern margin of the watershed: this bedrock geology is significantly less stable than other areas of the watershed.

Disturbed Area

Target: decrease, or decrease in disturbance index

The aerial extent of disturbed areas is an indication of increased sediment loads, and particularly chronic sediment discharges that are not associated with large storms or floods. Studies in Caspar Creek (Lewis, 1998, in EPA 1999) indicate that there is a statistically significant relationship between disturbed areas and the corresponding suspended sediment discharge rate (Lewis 1998; J. Lewis pers. comm. w/ A. Mangelsdorf, in EPA 1999). In addition, studies in Caspar Creek indicate that clear cutting causes greater increases in peak flows (and, by extension, increased suspended sediment loads) than does selective harvest (Ziemer 1998, in EPA 1999). As with the “hydrologic connectivity” target, increases in peak flows, annual flows, and suspended sediment discharge rates negatively affect the potential survivability of ova in redds (Lisle 1989, in EPA 1999).

Available information is insufficient to identify a threshold below which effects on the Big River watershed would be insignificant. Accordingly, the target calls for a reduction in the amount of disturbed area or in the disturbance index. In this context, “disturbed area” is defined as the area covered by urban development or management-related facilities of any sort, including: roads, landings, skid trails, firelines, harvest areas, animal holding pens, and agricultural fields (e.g., pastures, vineyards, orchards, row crops, etc.). The definition of disturbed area is intentionally broad to include managed agricultural areas, such as pastures and harvest areas, where the management activity (e.g., logging or grazing) results in removal of vegetation sufficient to reduce significantly important rainfall interception and soil protection functions. Agricultural fields or harvest areas in which adequate vegetation is retained to perform these ecological functions can be excluded from consideration as disturbed areas. Dramatic reductions in the amount of disturbed area, then, can be made by reducing road densities, skid trail densities, clearcut areas, and other management-induced bare areas.

Conditions in the Watershed: GMA (2001) defined a relative disturbance index for current conditions as the product of SW road density, the percent of SW area harvested in the 1989-1999 period, and the volume (tons) of landslides mapped in the 1989-1999 period. Data are not sufficient at this time for EPA to develop a disturbance index, but the NCRWQCB may develop information in the future either to strengthen this index, or determine an alternate disturbance index to represent chronic sediment inputs.

CHAPTER 4: SOURCE ANALYSIS

The purpose of the sediment source analysis is to identify the various sediment delivery processes and sources in the watershed and to estimate sediment delivery from those sources. This analysis is largely abstracted from GMA (2001). Detail on the methods and results can be found in that report.

4.1. Summary of Results

GMA estimated sediment delivery to streams in the watershed from 1921-2000 (see Table 7). The quantity of sediment delivered typically varied with the amount of timber harvest, with an average 944 t/mi^2/yr over the 80-year study period. In earlier periods, timber harvest was very intensive, and harvest practices generally caused more erosion than today. Sediment production in the watershed was greatest in the 1937-1952 period (1,686 t/mi^2/yr). Most of the timber stock was depleted by the 1950s, and sediment production was lower during the periods of 1966-1978 (594 t/mi^2/yr) and 1979-1988 (618 t/mi^2/yr), because the second-growth timber stocks were not mature enough to harvest. In the 1989-2000 period, harvesting activity increased and the quantity of roads increased, with over a third of the roads in the watershed being built in the last two decades. However, sediment generation did not increase in the current period (600 t/mi^2/yr), possibly due in part to improved road building and timber harvest practices. The contribution from road-related surface erosion has continued to increase, and sediment generation from harvest-related and road-related landslides in the current period has increased compared to the 1966-1978 period, although it has not reached the levels from the periods prior to 1966. The landsliding rates have declined overall since 1965, while surface erosion rates, primarily from roads, have steadily increased.

The sediment delivery rates in Table 7 can be grouped into background and management-related categories. With a long-term average background rate of 315 t/mi^2/yr, the background sediment inputs over the study period comprise about a third of the total. Management inputs averaged two-thirds of the total over the long term, but have been as high as 81% in 1937-1952. The contribution of management inputs in the current period is just over half of the total. Road-related sediment, from surface erosion and landslides combined, has been increasing in both absolute quantity and as a proportion of the total sediment during the study period. The contribution was as low as 6 t/mi^2/yr in the 1921-1936 period (1% of total sediment, all from surface erosion), although this figure is probably low due to the unavailability of aerial photographs for the eastern portion of the watershed. It has increased to 181 t/mi^2/yr in the current period (24% of the total).

4.2. Analysis Methods and Results

Existing data were compiled from a variety of sources, including data collection and air photo analysis in the Big River watershed. MRC is in the process of preparing a Watershed Assessment for their lands within the watershed, and information on substrate quality was made available for this analysis in advance of the draft. Some information was also available from Georgia-Pacific Corporation from their Sustained Yield Plan. CDF provided a Draft Sustained Yield Plan and Habitat Conservation Plan (CDF 1999, in GMA 2001). Similar sediment source analyses have been conducted for similar basins such as the Noyo, Ten Mile, Albion , Navarro (Entrix et al. 1998, in GMA 2001) and Garcia Rivers (PWA, 1997, in GMA 2001), and information from those analyses were used where appropriate. GIS data were

TABLE 7

BIG RIVER WATERSHED SEDIMENT SOURCE ANALYSIS

Preliminary Sediment Budget -- Sediment Input Summary -- Average Annual Unit Area Rates

		INPUTS													
									SURFACE EROSION						
STUDY PERIOD	NO. OF YEARS	BKGRND LANDSLIDES (t/mi2/yr)	TOTAL MGMT LANDSLIDES (t/mi2/yr)	HARVEST RELATED LANDSLIDES (t/mi2/yr)	ROAD RELATED LANDSLIDES (t/mi2/yr)	SKID TRAIL LANDSLIDES (t/mi2/yr)	GRASSLAND LANDSLIDES (t/mi2/yr)	TOTAL LANDSLIDES (t/mi2/yr)	BKGRND (t/mi2/yr)	SKID TRAIL (t/mi2/yr)	ROAD (t/mi2/yr)	FLUV/BANK EROSION (t/mi2/yr)	TOTAL NON-MGMT INPUTS (t/mi2/yr)	TOTAL MGMT INPUTS (t/mi2/yr)	TOTAL INPUTS (t/mi2/yr)
1921-1936	16	175	284	284	0	0	0	459	75	16	6	65	315	306	621
		28%	46%	46%	0%	0%	0%	74%	12%	3%	1%	10%	51%	49%	100%
1937-1952	16	179	1,336	847	364	3	122	1,515	75	8	23	65	319	1,367	1,686
		11%	79%	50%	22%	0%	7%	90%	4%	0%	1%	4%	19%	81%	100%
1953-1965	13	203	915	341	397	94	83	1,118	87	22	46	75	365	983	1,348
		15%	68%	25%	29%	7%	6%	83%	6%	2%	3%	6%	27%	73%	100%
1966-1978	13	194	148	48	52	34	14	342	83	33	64	72	349	245	594
		33%	25%	8%	9%	6%	2%	58%	14%	6%	11%	12%	59%	41%	100%
1979-1988	10	131	295	81	149	31	34	426	56	13	74	49	236	382	618
		21%	48%	13%	24%	5%	6%	69%	9%	2%	12%	8%	38%	62%	100%
1989-2000	12	159	214	92	88	7	27	373	68	7	93	59	286	314	600
		27%	36%	15%	15%	1%	5%	62%	11%	1%	16%	10%	48%	52%	100%
	80	19%	60%	33%	19%	3%	5%	79%	8%	2%	5%	7%	33%	67%	100%
1921-2000	80	175	566	313	178	26	48	741	75	16	47	65	315	629	944

Source: GMA 2001

Notes:

-- Background landsliding based on long-term background rate of 315 tons/mi2/yr (see text). After subtraction of creep (75 t/mi2/yr) and fluvial erosion (65 t/mi2/yr), this leaves 175 t/mi2/yr for landsliding. For periods from 1953 to present, rate was adjusted by the ratio of the estimated sediment transport in that period to the long term sediment transport rate to provide an approximation of the hydrology characterizing each period (see text).

-- All landslides mapped were management-related except1937-52 (4 t/mi2/yr); actual background landslides were assumed to be not mappable (too small, under canopy, etc), so were not visible for mapping.

-- Landsliding values developed from aerial photographs taken at the end of each budget period

-- Harvest related landslides include harvest areas estimated at <20years old, >20years old, and those from clear cut areas, and skid trail sources.

-- Road related landslides include those associated with cut and fill failures, landings, and in the early periods, those associated with railroads

-- Grassland related landslides are those observed in un-forested areas, which may be grazed areas, areas currently maintained as grasslands, or areas cleared during early harvests which have since regrown.

-- Surface erosion from roads and skid trails for the 1979-1988 period is probably low; some sediment listed in the 1989-2000 period was probably generated in the 1979-1988 period (see text)

-- Background surface rates (comprised of creep, surface erosion by sheetwash and rilling, and deep-seated landslide components) based on work of Roberts and Church (1986, in GMA 2001) and Cafferata/Stillwater Sciences (pers. Comm. 1999, in GMA 2001). Rate used is 75 tons/mi2/yr, but is adjusted in 1953-2000 periods by the hydrologic factor similar to background landslides.

-- Skid road estimates based on measured harvest areas on the 1936, 1952, 1965 & 1978 aerial photographs, delineated into 3 classes of skid road density. Harvest areas after 1988 are computed from CDF GIS coverages.

-- Road erosion computed from measured road miles in 1936, 1952, 1965 and 1978 aerial photographs. Roads after 1988 based on CDF GIS coverage developed from THPs, corrected to GMA 2000 aerial mosaic.

-- Bank erosion is based on a rate of 0.005 tons/ft/yr for Class 1 and Class 2 channels, based on adjustment of average rates developed by MRC (1999) for their lands in the Noyo River watershed. This category includes bank erosion and smaller streamside mass movements under the canopy and generally not visible on aerial photography. Rate used is 66 tons/mi2/yr with adjustments in the 1953-2000 period to reflect period hydrology, similar to background landslides and background surface erosion.

-- Numbers are rounded, so slight discrepancies may occur.

obtained from CDF Coast-Cascade GIS, Mendocino County, MRC (ownership, landslides, roads), and Campbell Timberland (ownership).The sediment source analysis involved three primary components: (1) evaluation of the dominant geomorphic processes that deliver sediment to the various stream channels in the Big River watershed through limited field reconnaissance, review of existing data, and consultation with those who are familiar with basin conditions; (2) measurement of various parameters, such as landslide size/type/associated land use, road length and harvest areas from sequential aerial photography and existing data bases; and (3) selection of factors to complement or modify the photo-based measurements where other data or information exist, or to estimate conditions where no data exist, thus allowing computation of results. The approach was primarily an indirect, office-based approach.

GMA investigated sources of sediment with this approach for a budget period of 1921 to 2000. This information provides a history of sediment production and delivery to the watercourse during this century, as well as an idea of how the different PW and SW were affected, and which sources have been more or less prevalent. GMA’s report (GMA 2001) describes in detail the methods used to develop their data.

Historic Watershed Activities

As described in Chapter 2, the Big River watershed was heavily logged in the beginning of the century. These early practices were fairly intensive, and produced a considerable amount of sediment. Harvest rates decreased in the 1950s through the 1970s, as the timber stock was fairly well depleted, then increased sharply in the 1980s, accompanied by increased road-building. Methods were unregulated until after 1973, when the California Forest Practice Act was passed (the Z’berg-Nejedly Forest Practice Act of 1973, which established Forest Practice Rules (FPRs) intended to protect resources while allowing for sustainable timber harvest). During the most recent period, harvest methods and road construction methods were relatively less destructive and produced less sediment on a unit basis, but the significant increases in harvest rates have resulted in steady increases in sediment, particularly in road-related sediment production.

Time Period of Analysis

Historic aerial photographs were available for 1936 (partial coverage, only of the western half of the watershed), 1952, 1965, 1978, 1988, and 2000. GMA assumed that features observed in the 1936 photographs covered approximately a 16-year period (i.e., no earlier than 1921), generally similar to the length of the subsequent 1936-1952 period. Thus, the sediment budget covers an 80-year period, extending from 1921 to 2000. Sediment source data were developed for all six of these time intervals, capturing different periods of sediment- producing events, including both the largest storms this century (water years 1938, 1956, 1965, 1974, 1993) and changes in harvest practices and road building techniques.

Hydrology and Geomorphology

GMA analyzed precipitation and streamflow data, extending the relatively short period of record for the Big River by correlating the existing data with the longer record available for the Noyo River to generate synthetic data. They installed monitoring stations to collect streamflow, turbidity and some suspended sediment data during the 1999-2000 and 2000-2001 winters. GMA also compared 1936 or 1952 aerial photos of randomly selected locations within each PW to 2000 photos of the same location, to generalize about large-scale watershed changes over the period.

Streamflow data collected in the basin by the USGS are limited to a single gage: South Fork Big River near Comptche, located on the South Fork Big River at Orr Springs Road, just downstream from the confluence of the Middle South Fork and Daugherty Creek. The gage measured streamflow from 36 of the 56 mi^2 of that SW, including the wetter upper watershed areas, from October 1960 to September 1971.

The 1952 and 1988 air photos reflect periods of relatively little geomorphic change in the watershed, due in part to low water years and, in the case of the 1988 photos, a period of drought. The photo years prior to 1978 reflect intensive timber harvest with no regulation, while 1988 and 2000 reflect timber harvest under the California Forest Practice Act. The effects of precipitation and flood flows in harvested areas were greater prior to the FPRs. Considerable lengths of roads and skid trails had been built, and the railroad had been constructed and was operational in the earlier photos. Most of these were adjacent to the stream channels. Effects of precipitation and flood flows were less pronounced in the 2000 air photos, probably reflecting both the FPRs and the fact that many of the landslides had already been triggered in earlier years.

Mass Wasting

Mass wasting sources were determined by sequentially analyzing aerial photographs for each of the six periods, classifying the landslides into categories related to timber harvest, roads, skid trails, grasslands and background categories, categorizing the landslides by type, estimating the proportion of the features that delivered sediment to streams, and estimating the volume of sediment delivered for each feature. Very few background landslides were detected in the aerial photograph analysis, even in the small area of old growth in Montgomery State Reserve, possibly due to a combination of widespread harvest activity beginning earlier than photographs are available, and the inability to detect small landslides at the photo scale; thus, background landsliding rates were estimated based on a review of other studies (see next section).

In earlier periods, erosion rates were highest in the Middle and South Fork Big PW. In 1921-1936, 43% of the sediment delivery from landslides occurred in the Middle Big PW, which is in line with the extent of disturbance in that PW during that period and the immediately preceding period. Virtually all of the landslide sediment delivery in that PW came from the Middle Big SW, while Two Log Creek SW produced almost nothing. In contrast, the Middle Big PW produced very little during the 1937-1952 period, while the South Fork and North Fork PW were the major contributors for the period. During this period, Chamberlain Creek and the Upper South Fork Big SW each produced over 20% of the landslide sediment delivery total for the period.

The 1937-1952 period represents 47% of the total volume of sediment from landslides over the entire 80-year study period; the 1953-1965 period produced 26% of the entire amount. By contrast, the 1966-1978 period produced only 4% of all the landslides, despite several large storms. The South Fork PW continued to be the largest landslide sediment producer in each period from 1953 through 1988, although the overall quantity diminished: In the 35 years since 1966, only 17% of the overall landslide sediment delivery has occurred. However, it is clear that the South Fork has produced nearly twice as much on a per-unit basis than any other PW, comprising nearly half the erosion for the watershed in the recent period. Middle and Lower Big PWs, which have also seen significant increases in the last two periods, comprise about a quarter of the watershed-wide erosion. The Upper Big SW, where harvest rates declined significantly, only produces about 5% of the total.

Determination of Background Loading

As with many other watersheds in the North Coast, determination of a background landsliding rate was difficult. No information on background landsliding rates could be developed from GMA's investigation of aerial photographs, because the earliest aerial photography is from 1936, and intensive human disturbance in the watershed significantly pre-dates those photographs. Thus, few landslides were mapped that were clearly associated with background conditions. However, GMA reviewed various studies of the Caspar Creek watershed as well as long-term sediment yield within the Big River watershed. Data from the South Fork Caspar Creek during 1968-1998 and the North Fork Caspar Creek during 1978-1989 are most representative of unmanaged sediment yields. Depending upon the bulk density factor selected to convert available volume data (in cubic yards) to mass (in tons), the range is from 239-411 t/mi^2/yr, with the most reasonable values ranging from about 250 to 325 t/mi^2/yr, and the higher values being more likely. Based on this information, GMA estimated long-term background sediment yield at 315 t/mi^2/yr. GMA attributed approximately 65 t/mi^2/yr of this to fluvial erosion and 75 t/mi^2/yr to hillslope creep, based on literature values. The remainder, 175 t/mi^2/yr, GMA attributed to background landsliding. For Table 7, GMA adjusted the rates for each period using sediment yield estimates for the period, to reflect whether the periods were relatively wet or dry periods.

Surface Erosion

Surface erosion estimates were categorized as background creep, skid trail/harvest related, and road/railroad related. Background creep was estimated from literature values (see section above).

Skid Trails and Harvest. Surface erosion estimates from skid trails and harvest were developed by estimating the aerial extent and type of harvest for each time period. There is considerable variation in estimates from the literature on sediment production and delivery to stream channels from skid trails. Since skid trails are generally not linked as directly to stream channels as roads typically are, drainage practices (proper installation of water bars, etc.) are of primary importance in determining whether significant sediment production and delivery will occur. Since extensive field surveys to determine these site-specific characteristics were not possible, harvest areas were identified on the historic aerial photographs and assigned a high, medium, or low rating regarding the density of skid trails. Erosion factors were assigned by time period of construction, as well as by density, with the earlier periods assumed to produce more sediment relative to newer construction due to better construction practices, and the amount of erosion assumed to be highest during the period immediately following construction.

Harvest rates were high in the watershed in the early part of the century, and have generally increased over the study period: 10% of the watershed was harvested in 1921-1936, 8% in 1937-1952, 14% in 1953-1965, 21% in 1966-1978, 17% in 1979-1988, and 38% in 1989-2000. Although some of the harvest attributed to the current period may have occurred in the previous decade, it still holds that 55% of the watershed has been harvested in the last two decades. Total harvest in the watershed for the 80-year period from 1921 to 2000 was 126,141 acres, or 109% of the total watershed area, reflecting that some areas have been harvested several times. This does not include harvesting that occurred prior to 1921, which was likely to have been extensive. There are some notable differences amongst the SW. For example, only 13% of the Upper South Fork Big SW has been harvested since 1921(reflecting extensive brush and grassland in the SW), while 188% of the East Branch North Fork has been harvested during the study period.

All harvest areas in the 1936 photos were assumed to have a high density of skid trails. In 1952 and 1965 the majority of harvesting still used a high density of skid trails. By 1988 no harvest areas were mapped as high density, which may reflect changes in the Forest Practice Rules. For 2000, areas that were mapped were all assigned low skid trail density, along with a number of new harvest categories from the CDF database, including clear cuts, narrow clear cuts, and cable cuts. In the current period, harvest rates obtained from the THP history were primarily partial cuts, with some clear-cutting, and only very small amounts were tractor logged. Typically, few if any skid trails were seen on these areas, as much effort was apparently spent to obliterate the skid trails developed during harvest operations.

Throughout the study period, landslides and surface erosion from skid trails accounted for an average of 5% of the sediment generated, with the highest rates in 1953-1965, 1966-1978, and 1979-1988 (9%, 12% and 7%, respectively, of the total sediment load). The current load is estimated at 14 t/mi^2/yr, only 2% of the total sediment load.

Road Surface Erosion. Surface erosion from roads and railroads was estimated by developing a road construction history and a harvest history, and applying erosion rates based on surface type and estimated use intensity. The method used to estimate sediment production from roads is based on a procedure developed by Reid (1981, in GMA 2001) for industrial timber roads and associated use and sediment production in the Clearwater (Washington) basin. This procedure was also recently undertaken on the Navarro River, Noyo River and Ten Mile River watersheds. Although its use has limitations in that the similarity between the Mendocino watersheds and the Clearwater basin is unknown, it provides the best practical method for this TMDL, because any other method would require more extensive development of site-specific information than could be undertaken in this analysis.

Because of revegetation over time, probably not all haul roads were mapped. Furthermore, their importance could be misinterpreted because of lack of use, being overgrown, or being incorporated into harvest units and lost in a maze of skid trails. Some error also exists in combining the GMA and CDF data bases, because the CDF data base is based on Timber Harvest Plans, which did not always include new roads that were not part of the harvest area. GMA corrected the CDF data base using GIS coverage developed from the aerial photograph analysis, and adjusted for roads that were only vaguely defined in the CDF database. Road segments that were not coded to a specific year in the CDF data base were assigned by GMA to the 1989-2000 period, which probably resulted in an overestimate of roads constructed in the current period, and an underestimate of roads in the 1979-1988 period.

There are currently 1,242 miles of roads in the Big River watershed, which translates to a basinwide road density of 6.86 mi/mi^2. The highest road densities in the basin are found in the Middle and Lower Big River, Estuary, Laguna Creek and Two Log Creek SWs(8.85, 8.23, 8.22, 8.09 and 8.06 mi/mi^2, respectively). Native surface roads were 83% of the total, followed by rocked roads at 14%, and paved at only 3%.

The road construction and railroad history largely mirrors the history of timber harvest through the watershed. Only 5% were constructed by 1936, another 40% added during the next two decades, with rates dropping off slightly in 1966-1978 and 1979-1988. Over a third of the roads were constructed in the last two time periods, with a quarter built in the most recent decade. (As noted earlier, some of the road construction in the last decade may have actually occurred in earlier time periods, particularly the 1979-1988 period.) However, it is still evident that, even accounting for that potential overestimate, considerable quantities of new roads were constructed recently, with the greatest mileage added to the Lower Big, Headwaters and South Fork Pws. The fastest rate of construction, relative to watershed size as well as to construction rates over the duration of the study period, have been in the Middle Fork PW.

Although the roads constructed in the last two periods tend to generate less sediment on a unit basis than those constructed in the earlier part of the century (many of the newer roads are ridgetop roads, and drainage practices have improved significantly since the Forest Practice Rules have been enacted), surface erosion from roads has increased from a low of 6 t/mi^2/yr in the 1921-1936 period, up to 93 t/mi^2/yr during the last decade. In fact, road surface erosion accounted for only 1% of the total sediment inputs in the earlier period, but accounts for 16% today. This appears to be related to the sheer quantity of roads. Together with increased surface erosion from skid trails, this accounts for 100 t/mi^2/yr in the 1989-2000 period, which is considerably higher than the long-term average of 63 t/mi^2/yr.

Fluvial Erosion

Numerous studies have indicated that fluvial erosion, whether from road diversions and washouts, road drainage-induced gullies, natural gullies, bank erosion or small streamside landslides, can be a major component of the watershed sediment sources. Unfortunately, quantification of these components requires considerable field investigation, typically as part of a comprehensive road inventory process, in order to develop reliable information. GMA used values from previous work in other coastal watersheds with similar geology to develop estimates for bank erosion/small streamside mass wasting.

This approach involved modification of unit area values of fluvial erosion rates developed for the Noyo and Albion Rivers, which had been extrapolated from preliminary data for two analysis units from MRC (C. Surfleet, pers. comm. 1999, in GMA 2001), and bank erosion rates from USDA (1972, in GMA 2001). However, because GMA’s limited field observations suggested that most of the channels in the Big River watershed are incised and moderately stable, and the rates would be significantly lower than those in other watersheds, the rate was adjusted downward. Separating fluvial erosion into background and management-related sources is problematic. Since most fluvial erosion is probably due to background sources, GMA assigned fluvial erosion to background.

CHAPTER 5: TMDL AND ALLOCATIONS

The purpose of this chapter is to determine the total loading of sediment which the Big River and its tributaries can receive without exceeding water quality standards, and to apportion the total among the sources of sediment.

5.1. TMDL

This TMDL is set equal to the loading capacity of the stream. It is the estimate of the total amount of sediment, from both natural and human-caused sources, that can be delivered to streams in the Big River watershed without exceeding applicable water quality standards.

For North Coast sediment TMDLs, EPA has used three general approaches for deriving the loading capacity: (1) a comparison with a reference time period; (2) a comparison with a reference stream; and (3) the estimated needed improvement from existing loading rates. The approach used in a particular TMDL depends on the availability of data and the characteristics of the specific watershed. For the Big River TMDL, data were not available to determine either an appropriate reference period within the watershed or an appropriate local reference stream. The TMDL is set using a similar approach used for the South Fork Eel, Navarro and Ten Mile River TMDLs. This approach uses information on sediment delivery during healthier aquatic conditions from a similar watershed, then applies the sediment delivery information to the Big River.

The TMDL sets the total sediment loading capacity at 125% of background sediment delivery. This level is adequate to protect aquatic habitat, which is the most sensitive of the beneficial uses. Information from the Noyo River watershed was used to develop this figure. Specifically, salmonids were still abundant during the 1933-1957 period in the Noyo River watershed, so the corresponding sediment delivery during this period must have allowed salmonid habitat of suitable quality to persist. In the Noyo River, the total sediment delivery during this period included human-caused sediment and natural background sediment. The amount of total sediment was estimated to be 125% of the background sediment (EPA 1999).

This ratio is then applied to the natural background sediment levels estimated for the Big River in the sediment source analysis. Given the proximity of the Noyo River to the Big River, as well as their similarities in climate, geology, vegetation, and land use history, EPA concludes that this approach is reasonable.

Using the long-term background rate of 315 t/mi^2/yr, as determined in Chapter 4, the modified approach results in a loading capacity for the Big of 315 t/mi^2/yr x 125%, or 393 t/mi^2/yr.

The TMDL for the Big River and its tributaries, which is set equal to loading capacity, is 393 tons/mi^2/yr.

Given the hydrologic variability typical of the Northern California Coast Ranges, EPA expects the TMDL to be evaluated as a ten-year rolling average. Load allocations are expressed as an average over the entire watershed; however, the NCRWQCB may determine in the future that its implementation measures could benefit by a distinction among the different Planning Watersheds.

5.2. Allocations

In accordance with EPA regulations, the loading capacity (i.e., TMDL) is allocated to the various sources of sediment in the watershed, with a margin of safety. That is, the TMDL equals the sum of: all waste load allocations (for point sources), load allocations (for nonpoint sources and background), and a margin of safety.

Table 8 shows the TMDL and allocations for the Big River watershed. Because there are no significant individual point sources of sediment in the Big River watershed, the wasteload allocation for point sources is set at zero. The margin of safety is not added as an explicit component of the TMDL, but rather is incorporated implicitly through conservative assumptions used to develop the TMDL, as discussed in Section 5.3. Thus, the TMDL for sediment for the Big River and its tributaries is apportioned among the categories of background and nonpoint sources of sediment identified in the source analysis (see Chapter 4), as load allocations. In other words:

TMDL = loading capacity = nonpoint sources + background = 393 t/mi^2/yr.

Approximately 20% of the current loading (78 t/mi^2/yr) is allocated to management-associated nonpoint sources (management-related landsliding, skid-trail surface erosion and road surface erosion). Background sources comprise 80% of the load allocation (315 t/mi^2/yr), including non-management landsliding, soil creep, and fluvial erosion.

The TMDL and load allocations are expressed in terms of yearly averages (tons/mi^2/yr). They could be divided by 365 to derive daily loading rates (tons/mi^2/day), but EPA is expressing them as yearly averages, because sediment delivery to streams is naturally highly variable on a daily basis, and because sediment effects occur over longer time periods. In fact, EPA expects the load allocations to be evaluated on a ten-year rolling average basis, because of the natural variability in sediment delivery rates. In addition, EPA does not necessarily expect each square mile within a particular source category to meet the load allocation; rather, EPA expects the average for the entire source category to meet the load allocation for that category.

TABLE 8:
TMDL AND LOAD ALLOCATIONS

Source Category	TMDL Load Allocation t/mi^2/yr	Current Load Estimate t/mi^2/yr 1989-2000	% of Total Current Loading[1]	Loading Reduction Needed	% of Total TMDL Alloc.[2]
LOAD ALLOCATIONS FOR NONPOINT SOURCES (MANAGEMENT-ASSOCIATED LOADS)	**78**	**314**	**50%**	**75%**	**20%**
TOTAL MANAGEMENT LANDSLIDING	63	214	34%	71%	16%
Harvest	29	92	15%	68%	7%
Grasslands	9	27	4%	67%	2%
Roads	20	88	14%	77%	5%
Skid Trails	5	7	1%	29%	1%
SKID TRAILS SURFACE EROSION	3	7	1%	57%	1%
ROAD SURFACE EROSION	12	93	15%	87%	3%
Total Road-Related Sediment (Surface Erosion and Landslides)	32	181	29%	82%	8%
Total Skid Trail-Related Sediment (Surface Erosion and Landslides)	8	14	2%	43%	2%
LOAD ALLOCATIONS FOR BACKGROUND (NON MANAGEMENT-ASSOCIATED LOADS)[3]	**315**	**294**	**48%**	**0%**	**80%**
NON-MANAGEMENT LANDSLIDING	175	175	29%	0%	45%
SOIL CREEP (Background Surface Erosion)	75	75	12%	0%	19%
FLUVIAL EROSION	65	65	10%	0%	17%
TOTALS	**393**	**629**	**100%**	**38%**	**100%**

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[1] Proportion of current loading that is associated with each source category.
[2] Proportion of TMDL allocation for each source category.
[3] Based on an estimate of long-term background loading rate.

Determination of Allocations

In addition to ensuring that the sum of the load allocations equals the TMDL, EPA considered several factors related to the feasibility and practicability of controlling the various nonpoint source sediment sources. The allocations are intended to be a guide for the NCRWQCB in implementing the TMDL, and for landowners in continuing their programs of sediment reduction. The load allocations for nonpoint sources reflect our best professional judgment of how effective best management practices are in controlling these sources. For example, techniques are available for greatly reducing sediment delivery from roads (Weaver and Hagans 1994); therefore, the load allocation for road-related sediment (including both road-related landsliding and road-related surface erosion) reflects a reduction of about 82% from the current estimate of the current loading rate. Furthermore, since road-related sediment accounts for the largest component of management-related sediment of the current loading (29%), efforts to reduce sediment from roads are expected to be highly effective in reducing sediment overall. Landslides are generally more difficult to control; thus, a greater reduction is expected from surface erosion (87%) than from landslides (77%) related to roads. The best conservation and land management measures to control sediment associated with landsliding in timber harvest and grassland areas are expected to be somewhat less effective than those to control road-related sediment; therefore, the load allocations for mass wasting from timber harvesting and grassland areas reflect 68% and 67% reductions, respectively, from the estimate of the current loading. Sediment from skid trail landsliding and surface erosion is a fairly small contribution overall (comprising only 2% of current loading), so somewhat lesser reductions are called for. Skid trails are expected to remain a relatively insignificant source of sediment, whereas the overall contribution from roads is expected to be reduced significantly, from 29% of the current load, to 8% of the allocated load. Similarly, the overall contribution from timber harvest and grasslands areas is expected to be reduced by about half, from 15% for harvest areas to 7%, and from 4% for grasslands areas to 2%.

5.3. Margin of Safety

The margin of safety is included to account for uncertainties concerning the relationship between pollutant loads and instream water quality and other uncertainties in the analysis. The margin of safety can be incorporated through conservative assumptions used to develop the TMDL, or added as an explicit separate component of the TMDL (EPA 1991). In this TMDL, we employed conservative assumptions, as described below.

Targets

Water quality targets were chosen that consider several factors for the protection of water quality related to sediment. These include: selecting a wide range of targets that are both directly descriptive of good water quality conditions (instream targets) and supportive of anti-degradation policies (watershed targets); selecting conservative water quality targets where the scientific literature supports them; making conservative assumptions for targets, where data are sparse, regarding which limiting factors are potentially affecting coho salmon; making conservative assumptions with respect to the nature of the relationship between hillslope sediment production and in-stream effects; and including targets for watershed conditions (hillslope and roads) that will limit additional sediment delivery into the water bodies. Because existing in-stream data are limited, the targets represent the optimal conditions for beneficial use support for salmonids, which is the most sensitive beneficial use.

Source Analysis
Conservative assumptions were made in the source analysis to account for uncertainty, as described by GMA (2001). In general, the assumptions resulted in attributing more of the observed sediment loads to management activities than is actually taking place. For example, the factor used to convert landslide volume to mass (1.48) was on the high end of literature values, which ranged from about 0.8 to 1.5 (G. Matthews, pers. comm., 2001). Similarly, for surface erosion from roads and skid trails, the overall lengths of roads and skid trails is somewhat overestimated, as described in GMA (2001), and some older roads may have been abandoned or hydrologically closed, thus producing less sediment than was estimated. (The small amount of fluvial erosion that may have been caused by management activity was assigned to background, but was more than adequately compensated for by additional conservative assumptions in the background rate determined in the sediment source analysis). These conservative approaches reduce the amount estimated for background sources. Because the determination of loading capacity and TMDL was derived as a percentage of background, the amount available for load allocations is thus reduced.

TMDL and Load Allocations
EPA determined that historical loading rates analyzed for the study period in this basin were not appropriate to use as a reference period within the basin. No data were available that suggested a period during which water quality standards were apparently being met. Because the watershed was intensively harvested even by 1921, a loading capacity and TMDL was selected that is lower than the sediment loading rates estimated for any periods within the basin between 1921-1999. Because background loading from fluvial erosion is assigned entirely to non-management causes, no allocation is made for management-caused bank erosion, which essentially functions as a margin of safety for that particular source.

5.4. Seasonal Variation and Critical Conditions

The TMDL must describe how seasonal variations were considered. Sediment delivery in the Big River watershed and its effects on beneficial uses are inherently variable on an annual and seasonal basis. For this reason, the TMDL and load allocations are designed to apply to the sources of sediment, not to the movement of sediment across the landscape, and they are to be evaluated on a ten-year rolling average basis.

The TMDL must also account for critical conditions for stream flow, loading, and water quality parameters. This TMDL does not explicitly estimate critical flow conditions because sediment impacts may occur long after sediment is delivered to the streams, often at locations far downstream of the sediment source. Rather, the approach used in this TMDL is to use indicators which reflect net long term effects of sediment loading and transport. Critical conditions are also influenced by high flow events (i.e., significant floods), which we considered by bracketing our analysis periods to show the effects of major storm periods or droughts.

CHAPTER 6: IMPLEMENTATION AND MONITORING RECOMMENDATIONS

The main responsibility for water quality management and monitoring resides with the State. EPA fully expects the State to develop and submit implementation measures to EPA as part of revisions to the State water quality management plan, as provided by EPA regulations at 40 CFR. Sec. 130.6.

The State implementation measures should contain provisions for ensuring that the load allocations in the TMDL (see Chapter 5) will in fact be achieved. These provisions may be non-regulatory, regulatory, or incentive-based, consistent with applicable laws and programs, including the State's recently-upgraded nonpoint source control program.

Furthermore, the State implementation and monitoring plans should be designed to determine if, in fact, the TMDL is successful in attaining water quality standards. To assist in this effort, the Big River TMDL contains water quality indicators (see Chapter 3) as well as load allocations. Both the indicators and load allocations can assist in interpreting water quality standards, but they were developed using independent approaches, because the relationship between land management practices and the effects on water quality related to sediment is highly complex. Given the complexities, EPA recommends that the State consider both approaches to implement and evaluate the success of the TMDL in attaining water quality standards.

In addition, the State's implementation plan should include a public participation process and appropriate recognition of other relevant watershed management processes, such as local source water protection programs, State programs under Section 319 of the Clean Water Act, or State continuing planning activities under Section 303(e) of the Clean Water Act.

It is clear from the available data that reducing sediment from roads should be the highest priority in terms of sediment reduction. This will be the most cost-effective means of achieving the TMDL. This could include reducing the overall mileage of roads through decommissioning unused roads and upgrading existing roads to reduce sediment delivery to streams. Correction of small landslides to prevent delivery will also assist in efforts to achieve the TMDL.

The data base of information describing the watershed could also be increased through additional monitoring. EPA encourages the State and landowners to work together to fully implement the implementation and monitoring measures, as specified by the State.

CHAPTER 7: PUBLIC PARTICIPATION

EPA regulations require that TMDLs be subject to public review (40 CFR 130.7). EPA provided public notice of the draft Big River sediment TMDL by placing a notice in the Mendocino Beacon and Santa Rosa Press-Democrat, newspapers of general circulation in the Big River watershed. EPA prepared a written summary of responses to all written comments on the draft TMDL received by EPA through the close of the comment period, October 22, 2001.

EPA maintained an email mailing list of interested persons to provide notification of issues relating to the Big River TMDL. Occasionally, this included items of interest on the watershed not directly related to the TMDL. EPA also responded to comments and concerns that we received during the development process. EPA provided notification of its meetings and activities also to local radio stations and newspapers.

EPA and its consultant, Graham Matthews and Associates, met with MRC, Campbell Timberland Management, Inc., and members of the Big River Watershed Alliance.

EPA held an informational meeting on the development of Big and Albion River TMDLs at the Mendocino Community Center on February 15, 2001. This was also coordinated with the Big River Watershed Alliance.

EPA also participated in the Mendocino County Board of Supervisors/Joint Planning Commission meeting on March 15, 2001, to present information on TMDLs generally, and the Big and Albion Rivers particularly.

An informal meeting to discuss the Public Review Draft TMDL was held on October 3, 2001, at the Mendocino Community Center. Formal written comments were received until October 22, 2001.

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Glossary

Active channel	The area of the stream channel that is usually wetted.
Aggradation	Elevated stream channel bed resulting from deposition of sediment.
Anadromous	Refers to aquatic species which migrate up rivers from the sea to breed in fresh water, undergoing a physiological change to allow them to adjust from freshwater to saltwater to freshwater conditions.
Bankfull	The average annual flood , generally with a frequency interval of once every 1.5-2.3 years. Also, the channel form that accommodates the bankfull flow.
Bankfull channel	The area of the stream channel that contains the bankfull flow. Also, the area of the channel that appears to hold an average annual flood.
Basin Plan	The Water Quality Control Plan, North Coast Region-- Region 1.
Beneficial Use	Uses of waters of the state designated in the Basin Plan as being beneficial. Beneficial uses that may be protected against quality degradation include, but are 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.
Cable Yarding	Yarding of cut timber accomplished by dragging cut timber up a hillslope from the cut area to a ridgetop landing.
CDF	California Department of Forestry and Fire Protection.
CDFG	California Department of Fish and Game.
CDWR	California Department of Water Resources.
cfs	Cubic feet per second: a measure of water flow.
Debris torrents	Long stretches of bare, generally unstable land areas or stream channel banks scoured and eroded by the extremely rapid movement of water-laden debris, commonly caused by debris sliding or road stream crossing failure in the upper part of a drainage during a high intensity storm.
Decommission	Closing and obliterating all traces of a road and restoring the land to its natural contours and drainage patterns.
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.
Degradation	Lowering of the channel bed resulting from scour during flood flows.
Diversion potential	The potential for a road to divert water from its intended drainage system across or through the road fill, thereby delivering road-related sediment to a watercourse
Drainage structure	A structure or facility constructed to control road runoff, including (but not limited to) fords, inside ditches, water bars, outsloping, rolling dips, culverts or ditch drains.
Dolbeer Donkey	The first machine used to haul cut timber to a landing area. It replaced animal hauling teams.

Electroshocking	A sampling technique for fish surveys that uses electrical current to stun fish in the water, allowing them to be measured and released.
Embeddedness	The degree that larger stream bed sediment particles (boulders, rubble or gravel) are surrounded or covered by fine sediment. It is usually visually estimated in classes (<25%, 25-50%, 50-75%, and >75%) according to percentage of random large particles that are covered by fine sediment.
EPA	The United States Environmental Protection Agency.
Erosion	The group of processes whereby sediment (earthen or rock material) is loosened, dissolved, or removed from the landscape surface. It includes weathering, solubilization, and transportation.
ESU	Evolutionarily Significant Unit, used by NMFS to identify a distinctive group of Pacific salmon or steelhead for purposes of the federal Endangered Species Act.
Flooding	The overflowing of water onto land that is normally dry.
FPR	Forest Practice Rules, defined by the Z'berg Nejedly Forest Practice Act of 1973, as amended.
FWS	The United States Fish and Wildlife Service
Fry	A young juvenile salmon after it has absorbed its egg sac and emerged from the redd.
GIS	Geographic Information System.
Headwall Swale	A topographical depression in the headwaters area of a watercourse or head of a landslide area; often a potentially unstable boggy area where moisture tends to collect.
Hydrologically closed road	Generally referring to roads that are closed to further use, with natural flow conditions restored (e.g., removing stream crossing fill), though the road itself may not be revegetated or obliterated.
Hydrologically connected road	A road with drainage that is directed toward a watercourse.
Hydrologically maintenance-free road	A road constructed so that there is no possibility of connecting the road drainage to the watercourse with the potential of failure, such as stream crossing failure.
Inner gorge	A geomorphic feature generally identified as the area of stream bank 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.
JDSF	Jackson Demonstration State Forest.
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 generally having a diameter greater than 30 cm (12 inches) and a length greater than 2 m (6 feet) located in a position where it may enter the watercourse channel.
Low-Flow Channel	The part of the stream that is occupied by water during the periods of lowest flow, generally in late summer or early fall.

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.
MRC	Mendocino Redwood Company.
NCRWQCB	North Coast Regional Water Quality Control Board.
NMFS	The United State National Marine Fisheries Service.
NTU	Nephelometric Turbidity Units, a standard measure of turbidity.
Pool Tail-out	The downstream end of a pool, where the main current narrows, forming a “tail.” AKA riffle head
Primary Pool	A pool that is at least as long as the low-flow channel width, and occupies at least half the width of the low-flow channel and, for 1st and 2nd order streams, is at least 2 ft or more in depth; and for 3rd order and higher streams, is at least 3 ft or more in depth. (Flosi et al. 1998)
PW	Planning Watershed.
Reach	The stretch of water visible between bends in a river or channel.
Redd	A gravel nest or depression in the stream substrate formed by a female salmonid in which eggs are laid, fertilized and covered with gravel for a period of incubation.
Refugia	Habitat areas that are of best quality and can contribute to full support of the species.
Regional Water Board	The California Regional Water Quality Control Board, North Coast Region.
Riffle	A gravelly or rocky shoal or sandbar lying just below the surface of a stream, or the stretch of choppy water caused by such a shoal or sandbar.
Riffle Head	The beginning (i.e., upstream end) of a riffle (aka pool tail-out).
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 delivery	Sediment 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 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 total amount of sediment (dissolved, suspended, and bed load) passing through a given cross section of a watercourse channel in a given period of time.
Shallow -seated landslide	A landslide produced by failure of the soil mantle on a steep slope (typically to a depth of one or two meters; sometimes includes some weathered bedrock). 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.
Sidecast	Fill from road construction cuts that is deposited to the side of the road.

Skid trail	Constructed trails or established paths used by tractors or other vehicles for skidding logs. Also known as tractor roads.
Steep slope	A hillslope, generally with a gradient greater than 50%, that leads without a significant break in slope to a watercourse.
Stream	See watercourse.
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. A third order stream is designated when two 2nd- order streams join.
SW	Sub-watershed
Tail-out	The lower end of a pool where flow from the pool, in low flow conditions, discharges into the next habitat unit, usually a riffle. Location where spawning generally occurs.
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.
THP	Timber Harvest Plan
TMDL	Total Maximum Daily Load, as defined under section 303(d) of the Clean Water Act, and regulations at 40 CFR Section 130.
Tractor Yarding	Yarding of cut timber using a tractor.
TSD	Technical Support Document.
Turbidity	A measure of the degree of light that can pass through water. High turbidity (low light transmissivity) can be caused by suspended fine sediments or organic material.
Unstable areas	Locations on the landscape which have a higher than average potential to erode and discharge sediment to a watercourse, including slide areas, gullies, eroding stream banks, or unstable soils. Slide areas include shallow and deep seated landslides, debris flows, debris slides, debris torrents, earthflows, 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, as described by Lisle and Hilton (1992). Pronounced "V-star."
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 ground or surface water, 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 criteria	Numeric or narrative criteria established under the Clean Water Act to protect the designated uses of a water.
Water Quality Indicator	An expression of the desired instream or watershed environment. For each pollutant or stressor addressed in the problem statement, an indicator and target value is developed.
Water quality objective	

	A State Basin Plan term equivalent to the Clean Water Act's water quality criteria. Water quality criteria are limits or levels of water quality constituents or characteristics established for the reasonable protection of beneficial uses of water or the prevention of nuisance within a specific area.
Water quality standard	A Clean Water Act term which includes the designated uses of a water, the water quality criteria established to protect the designated uses, and an anti-degradation policy.
Yarding	Collection of cut timber at a landing area.
Yearlings	Fish that hatched in the previous year (i.e., one-year-olds).
Young-of-Year	Fish that hatched in the current season.
WY	Water Year. October 1 - September 30. E.g., WY1999 = October 1, 1998 through September 30, 1999.