U.S. Environmental Protection Agency
Region IX

Mattole River
Total Maximum Daily Loads
for Sediment and Temperature

Approved by:

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CHAPTER 1: INTRODUCTION

Overview of the TMDL program

The primary purpose of the Total Maximum Daily Load (TMDL) program in California's North Coast is to assure that salmon habitat in streams is protected from excess sediment and temperature increases. The TMDLs set maximum levels of pollutants, an important step in achieving water quality standards for the Mattole River and tributaries in Northern California. The major water quality problem, and the one addressed in this report, is the decline of salmon and steelhead populations. While many factors have been implicated in the decline of west coast salmon and steelhead, we are concerned here with two inland water quality considerations - increases to natural sediment and temperature patterns.

The Mattole River (along with many other watersheds in California and throughout the nation) has been put on a list of "impaired" or polluted waters. In this watershed, the listing leads to the TMDL, which determines the "allowable" amount of sediment and temperature. Development of measures to implement the TMDL is the responsibility of the State of California.

Background

The Mattole River Total Maximum Daily Loads (TMDLs) for sediment and temperature are 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 Mattole River are exceeded due to excessive sediment and temperature. In accordance with Section 303(d), the State of California periodically identifies "those waters within its boundaries for which the effluent limitations . . . are not stringent enough to implement any water quality standard applicable to such waters." In 1992, EPA added the Mattole River to California's 303(d) impaired water list due to elevated sedimentation and temperature. The North Coast Regional Water Quality Control Board (NCRWQCB) has continued to identify the Mattole River as impaired in subsequent listing cycles, the latest in 1998.

In accordance with a consent decree (*Pacific Coast Federation of Fishermen's Associations, et al. v. Marcus*, No. 95-4474 MHP, 11 March 1997), December 2002 is the deadline for establishment of these TMDLs. Because the State of California will not complete adoption of TMDLs for the Mattole River by this deadline, EPA is establishing these TMDLs, with assistance from NCRWQCB staff.

The primary adverse impacts associated with excessive sediment supply and elevated temperature in the Mattole River pertain to the anadromous salmonid fishery. The water quality conditions do not adequately support the several anadromous salmonid species present in the Mattole River and its tributaries, a situation that 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 Mattole River TMDLs is to identify the total amount (or load) of sediment and heat which can be delivered to the Mattole River and tributaries without causing exceedence of water quality standards, and then to allocate the total amount among the sources of sediment or heat in the watershed. Although factors other than excessive sediment and heat in the watershed may be affecting salmonid populations (e.g., ocean rearing conditions), these TMDLs focus on sediment and heat, the pollutants for which the Mattole River is listed under Section 303(d). EPA expects the NCRWQCB to develop implementation measures which will result in implementation of the TMDLs in accordance with the requirements of 40 CFR 130.6. The allocations, when achieved, are expected to result in the attainment of the applicable water quality standards for sediment and temperature for the Mattole River and its tributaries.

These TMDLs apply to the portions of the Mattole River watershed governed by California water quality standards. It does not apply to lands under tribal jurisdiction.

1.1. INFORMATION SOURCES

These TMDLs are based mostly on the Mattole River Watershed Technical Support Document (TSD) for Sediment and Temperature (NCRWQCB, 2002) prepared by NCRWQCB staff in support of TMDL development. The TSD contains additional information and analysis on many of the topics addressed in these TMDLs.

Information for the TSD came from a variety of sources. Information is summarized from the Mattole Watershed Synthesis Report produced by the North Coast Watershed Assessment Program (NCWAP, 2002) and sediment source investigations by Pacific Watershed Associates (PWA). The Mattole Restoration Council contributed information on environmental and habitat conditions and facilitated access to people in the Mattole community. The Mattole Salmon Group aided with historical information on salmonid populations and fish habitat conditions. Staff of the NCRWQCB researched sediment contributions and water temperature distribution and trends using field studies, reports from other government agencies, consulting reports, and published literature. Information Center for the Environment (ICE) at University of California Davis consulted on aerial photo mapping and geographic information system (GIS) mapping and data manipulation. Sanctuary Forest permitted access to its lands and facilitated access to other forestlands. Pacific Lumber Company permitted access to company lands and helped orient NCRWQCB staff in their investigations. Barnum Timber Company permitted access to company timberlands.

Other primary sources of data for these studies were: the Bureau of Land Management, Pacific Watershed Associates, California Department of Fish and Game (CDFG), California Department of Forestry and Fire Protection (CDF), and U.S. Geological Survey. CDFG provided historical aquatic surveys as well as fish distribution and aquatic habitat data. Published scientific literature was used extensively and is referenced in this document and the TSD.

1.2. WATERSHED CHARACTERISTICS

Area and Location

The Mattole River drains a 296 mi^2 watershed located in the northern California Coast Ranges, in western Humboldt County and northernmost Mendocino County. The river enters the Pacific Ocean about 30 miles south of Eureka and 290 miles north of the Golden Gate. It drains primarily northwestward to the area of Petrolia, whence it flows west to the Pacific. The watershed shares divides with the Eel River to the east, Bear River to the north, and small drainages leading to the Pacific on the west. ***Figure 1-1*** shows the general location of the Mattole River. ***Figure 1-2*** (located at the end of the document) provides information on the Mattole River watershed itself.

Population

The total resident population of the Mattole basin in the 2000 census was estimated at about 1,200, which is an overall density of four people per square mile (NCWAP, 2002). Three “post office” towns lie in the Mattole watershed: Whitethorn in the south end of the watershed, Honeydew near the middle, and Petrolia near the river mouth (Figure 1-2). Most of the population is centered near these towns.

Figure 1-1.

Climate

The Mediterranean climate in the watershed is characterized by a pattern of high-intensity rainfall in the winter and warm, dry summers with coastal fog primarily in the northern and western parts of the basin. Mean annual precipitation ranges from about 45 inches at the coast, near the mouth of the Mattole River, to about 110 inches in the King Range and the Honeydew area, and more than 115 inches on Rainbow Ridge, which forms the divide between the Mattole and the South Fork Eel River. Snowfall occurs occasionally in the higher elevations of the watershed but rarely accumulates.

Topography

The valley of the mainstem Mattole River can be described in three sections. The upper section extends from the head of the river at river mile 61 to a half mile downstream from the mouth of Eubanks Creek at river mile 42.8 (Figure 1-2). The uppermost two miles is typical mountain valley in this watershed; narrow and steep-sided, it has a steep gradient and very little flood plain. Continuing downstream, the valley bottom opens up to 600 to 1,000 feet wide and consists of floodplain and channel surmounted by river terraces in most areas. Parts of the terrace surfaces are used for grazing and hay cropping. From river mile 52.1 to 47.7 is a steep-sided canyon known locally as the Grand Canyon of the Mattole, having steep cliffs, deep pool, and falls as high as eight feet.

The middle section of the valley runs from river mile 42.8 to river mile 26.5, the mouth of Bear Creek (Figure 1-2). Through this reach, the channel, flood plain, and river terraces combined are generally less than 600 feet wide and rarely greater than 800 feet.

In the lower section of the valley, the valley bottom between river mile 26 and river mile 5 (Figure 1-2) broadens to as wide as 1,500 feet. Many sections of river terraces and marine terraces, mostly bedrock terraces overlain by river gravels capped by colluvium and alluvial fan deposits, stand 40 to 80 feet above the river. At Petrolia, river mile 5, the valley bottom opens up to almost a mile wide, before narrowing to a half mile near the mouth. In the downstream several miles of the valley, terraces generally are lower above the river than they are upstream.

Tributary valleys are mostly steep-sided and separated by sharp ridges. Lower reaches of the valleys of some larger tributaries, such as the North Fork Mattole River and Mattole Canyon Creek, broaden to 1,000 feet or wider. The upper parts of these valleys, however, generally fit the pattern of smaller tributaries; that is narrow, steep-sided valleys having extensive stretches of very steep-sided inner gorges.

Elevations in the Mattole watershed range up to 4,092 feet at the top of Kings Peak, between the Mattole River watershed and the coast, and higher than 3,600 feet on the divide to the east between the Mattole and the South Fork Eel River.

Vegetation

The Mattole watershed supports a mix of forestland and grassland. The majority of the watershed is covered with a mix of grasslands and conifer and hardwood forests. Grasslands occur throughout the watershed, but are most widespread in the northern half of the basin. Forested areas dominate the southern half of the basin and consist primarily of a mix of Douglas fir and tan oak with varying proportions of madrone, big-leaf maple, California bay laurel, canyon live oak, chinquapin, redwood, alder, and Oregon ash.

Large-scale timber extraction following World War II, wildfires, conversion of forestland to rangeland, and reversion of rangeland to forestland have all contributed to an abundance of relatively small trees.

Hydrology

The following is summarized and partly quoted from NCWAP, 2002, p. 53. Winter monthly stream flows in the Mattole River measured near Petrolia average between 1,710 and 4,170 cubic feet per second (cfs). Instantaneous peak flows measured on December 22, 1955 and December 22, 1964 were 90,400 and 78,500 cfs respectively. The Mattole River begins to overtop its banks at Petrolia when the discharge exceeds approximately 31,000 cfs. Summer and fall flows typically drop to as little as 28 cfs, and the minimum measured was 17 cfs (1977 and 2001). High winter rainfall on bedrock and other geologic units having low permeability and steep slopes contribute to the very flashy nature of runoff in the Mattole watershed. In addition, the runoff rate has been increased by extensive road systems and other land uses. High winter rainfall combined with rapid runoff on unstable soils delivers large amounts of sediment to tributaries and the Mattole River. This sediment is deposited in the lower gradient reaches of the system.

Geology

The Mattole basin lies in a geologically complex setting adjacent to the junction of the North American, Pacific, and Gorda tectonic plates, known as the Mendocino Triple Junction. Because of the active tectonic movements associated with this junction, the uplift rate in the Mattole basin is very high, and seismic activity is frequent. The intense tectonic activity has made the bedrock underlying the Mattole watershed relatively weak and susceptible to erosion and mass wasting. These rocks have been "scraped off" the Gorda plate as it plunges beneath the North American plate. Most of these rocks are argillite (sedimentary rock that is rich in clay - i.e., shale and mudstone). Some of the rock is sandstone, which is stronger than argillite and is less weakened by tectonic deformation. The difference is shown dramatically in the landscape where erosion leaves isolated blocks of sandstone standing as large gray knobs above slopes underlain by argillite.

History and Land Use

Between 1865 and World War II, oil, tanbark, and agricultural booms filled the valley repeatedly with new settlers who kept lands cleared and in agricultural productions. Early Western settlers found themselves competing with a population of Athapascan-speaking Mattole and Sinkyone peoples who already inhabited the valley. Within little more than a decade, the Mattole and Sinkyone peoples were nearly eliminated. The river channel was deep; octogenarian Russell Chambers remembers, as a small boy, numerous eighteen-foot-deep swimming holes. He recalls that his dad's horses had to swim their wagonloads of fenceposts across the river less than a mile from the mouth [Mattole Restoration Council (MRC), 1995].

The decades following World War II brought a timber boom to the watershed. The most intense harvesting, in terms of acres per year, took place from 1945 to 1961. Thousands of miles of logging roads were constructed.

Extremely heavy rainfall in 1955 and 1964 triggered erosion throughout the watershed from lands recently roaded and logged, causing a devastating increase in sediment delivery to streams in the watershed that changed the form and functioning of the stream system. The river eliminated many acres of bottomland during these floods. From 1955 to present, high waters filled in the deep holes with gravel and swept away much of the riverbank vegetation (MRC, 1995).

Beginning in the 1960s a "back to the land" movement brought new settlers into the Mattole. Local unemployment was estimated at 50% in 1999 (NCWAP, 2002), but much of the available work is seasonal, so actual unemployment is hard to calculate.

NCWAP Subbasins

For the TMDLs, the Mattole River watershed is divided into four major subbasins ranging from 28 mi^2 to 98 mi^2 corresponding to subbasins used in the NCWAP Mattole Watershed Synthesis Report (NCWAP, 2002 Figure 14). A fifth subbasin, the estuary (2 mi^2), is delineated because it contains environments different from those in the larger subbasins. A summary of the attributes of each subbasin is presented in Table 1-1.

1.3. ENDANGERED SPECIES ACT CONSULTATION

EPA has initiated informal consultation with the National Marine Fisheries Service and the U.S. Fish and Wildlife Service on this action, under Section 7(a)(2) of the Endangered Species Act. 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 that it is unlikely that the Services will conclude that the Total Maximum Daily Loads (TMDL) that EPA is establishing violate Section 7(a)(2) since the TMDLs and 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 water." Additionally, this action will improve existing conditions. However, EPA retains the discretion to revise this action if the consultation identifies deficiencies in the TMDLs or allocations.

1.4. ORGANIZATION

This report is divided into chapters. Chapter 2 (Problem Statement) describes the nature of the environmental problems addressed by the TMDLs. Chapter 3 (Sediment) identifies specific stream and watershed characteristics to be used to evaluate whether the Mattole River is attaining water quality standards for sediment (water quality indicators and targets for sediment); describes what is currently understood about the sources of sediment in the watershed (sediment source analysis); and identifies the total load of sediment that can be delivered to the Mattole and its tributaries without causing exceedence of water quality standards, and describes how EPA is apportioning the total load among the sediment sources (sediment TMDL and allocations). Chapter 4 (Temperature) describes the water quality standards and the importance of shade; identifies specific targets for shade and thermally stratified pools (water quality indicators and targets for temperature); and identifies the loading capacity in terms of shade for the Mattole River and its tributaries, and describes how EPA is apportioning the necessary amounts of riparian shade (temperature TMDL and allocations). Chapter 5 (Implementation and Monitoring Measures) contains recommendations to the State regarding implementation and monitoring of the TMDL. Chapter 6 (Public Participation) describes public participation in the development of the TMDL.

Table 1.1. Summary of Attributes of Subbasins in the Mattole River Watershed [from NCWAP (2002), Table 3].

Attribute	***Estuary***	***Northern***	***Eastern***	***Southern***	***Western***	***Total***
Area (square miles)	2	98	79	28	89	296
Area (acres)	1,326	62,857	50,794	17,640	57,144	189,761
Bureau of Land Management (acres)	385	277	2,412	1,442	25,506	30,022
Other Public Lands (acres)	0	220	668	342	0	1,230
Private Lands (acres)	939	62,361	47,714	15,857	31,638	158,509
Principal Communities	Petrolia	Petrolia, Honeydew	Ettersburg, Thorn Junction	Thorn Junction, Whitethorn	Honeydew, Ettersburg	
Major Geologic Units	Quaternary deposits (sand, gravel)	Franciscan Coastal Terrane (argillite)	Franciscan Coastal Terrane (argillite)	Franciscan Coastal Terrane (sandstone)	Franciscan King Range Terrane (sandstone)	
Major Vegetation Units	Grassland, Hardwood Forest	Oak, Grassland, Douglas Fir, Hardwood Forest	Douglas Fir, Hardwood Forest	Douglas Fir, Hardwood Forest, Redwood Forest	Douglas Fir, Hardwood Forest	
Major Land Uses	Recreation	Ranching, Timber Production	Ranching, Timber Production	Rural Residential, Timber Production	Recreation	
Rainfall (inches)	60	50-115	80-115	75-85	60-100	
Length of Blueline Stream (miles)	71.4 Estuary and mainstem	69.4	49.9	27.5	85.6	303.4
Lowest elevation (feet)	0	0	351	864	0	
Highest Elevation (feet)	1,361	3,374	3,511	2,598	4,088	
Salmonid Habitat Conditions	High summer temps; large sediment load; lack of pool depth and cover	Good steelhead populations despite warm summer temps; little canopy	High summer temps; large sediment load; little canopy	Favorable water temps; good canopy; good LWD supply	Favorable temps in small tribs and upper parts of large tribs; good canopy	
Fish Species	Chinook salmon Coho salmon Steelhead trout Pacific lamprey Coastrange sculpin Prickly sculpin Threespine stickleback Surf smelt Redtail surfperch Walleye surfperch Staghorn sculpin Speckled sanddab Starry flounder	Chinook salmon Coho salmon Steelhead trout Pacific lamprey Coastrange sculpin Prickly sculpin Threespine stickleback	Chinook salmon Coho salmon Steelhead trout Pacific lamprey Coastrange sculpin Prickly sculpin Threespine stickleback	Chinook salmon Coho salmon Steelhead trout Pacific lamprey Coastrange sculpin Prickly sculpin Threespine stickleback Green sunfish	Chinook salmon Coho salmon Steelhead trout Pacific lamprey Coastrange sculpin Prickly sculpin Threespine stickleback	Chinook salmon Coho salmon Steelhead trout Pacific lamprey Coastrange sculpin Prickly sculpin Threespine stickleback Surf smelt Redtail surfperch Walleye surfperch Staghorn sculpin Speckled sanddab Starry flounder

CHAPTER 2: PROBLEM STATEMENT

This chapter summarizes ways in which increased sediment loads and elevated water temperatures have contributed to the decline of the cold water salmonid fishery. Increased sediment delivery is produced by management activities including road-related activities, forestry practices, and ranching. Temperature changes are produced by sediment delivery -- through processes such as channel aggradation and pool infilling -- as well as by other processes such as changes in riparian cover, increased solar heating, and changes in streamside microclimates. This chapter includes a description of the water quality standards and salmonid habitat requirements related to sediment and temperature and a generally qualitative assessment of existing instream and watershed conditions in the Mattole River basin.

This analysis is based on data that have been gathered by NCRWQCB staff and data contributed by landowners and organizations in the Mattole watershed. Because information about habitat parameters in some areas of the watershed is not available, conservative assumptions based on professional judgment were made regarding factors that potentially limit salmonid populations in the basin. The discussion in Section 3.1 (Water Quality Indicators and Targets for Sediment) is based on the problems identified in this analysis. As additional data become available, such as through the NCWAP Limiting Factors Analysis, the TMDL and numeric targets can be modified by the NCRWQCB in the future.

2.1. WATER QUALITY STANDARDS

In accordance with the Clean Water Act, a TMDL is set at a level necessary to implement the applicable water quality standards. Under the Clean Water Act, water quality standards define designated uses, water quality criteria to protect those uses, and an antidegradation policy. The State of California uses slightly different terms for its water quality standards than does the EPA (i.e., beneficial uses, water quality objectives, and a nondegradation policy). This section describes the State water quality standards applicable to the Mattole River TMDL, using the State's terminology. The remainder of the document generally refers simply to water quality standards.

Beneficial Uses

The beneficial uses and water quality objectives for the Mattole River are contained in the *Water Quality Control Plan for the North Coast Region* (Basin Plan) as amended in 1996 (NCRWQCB, 1996). These beneficial uses include:

1. Municipal and Domestic Supply (MUN)
2. Agricultural Supply (AGR)
3. Industrial Service Supply (IND)
4. Water Contact Recreation (REC-1)
5. Non-Contact Water Recreation (REC-2)
6. Commercial or Sport Fishing (COMM)
7. Cold Freshwater Habitat (COLD)
8. Estuarine Habitat (EST)
9. Wildlife Habitat (WILD)
10. Migration of Aquatic Organisms (MIGR)
11. 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, because federally-listed coho and chinook salmon and steelhead trout are found in the watershed (NCRWQCB, 2001a). Also, aquaculture (AQUA) in the watershed is foreseen in the Basin Plan (NCRWQCB, 1996) as a potential beneficial use.

Water Quality Objectives

The Basin Plan (NCRWQCB, 1996) identifies both numeric and narrative water quality objectives for the Mattole River. Those pertinent to the Mattole River TMDLs are listed in Table 2.1.

Table 2-1. Water Quality Objectives Addressed in the Mattole River TMDLs

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.
Temperature	The natural receiving water temperature of intrastate waters shall not be altered unless it can be demonstrated to the satisfaction of the NCRWQCB that such alteration in temperature does not adversely affect beneficial uses.
	At no time or place shall the temperature of any COLD water be increased by more than 5° F above natural receiving water temperature.
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. DECLINING POPULATIONS OF SALMON AND STEELHEAD

Anecdotal evidence provides a convincing case that salmonid runs in the Mattole Basin were large and have experienced a sharp decline since the mid 1950s. However, little quantitative historical data is available (Bureau of Land Management, 1996). Estimates of chinook and coho salmon, and steelhead trout populations in the Mattole Basin were made by the United States Fish and Wildlife Service in 1960. Spawning populations at that time were estimated to be 2,000 chinook salmon, 5,000 coho salmon, and 12,000 steelhead trout, while potential populations predicted were 7,900 chinook salmon, 10,000 coho salmon and 10,000 steelhead trout. The California Department of Water Resources (1965) reported that chinook salmon were able to access the Mattole River for 45 miles, while coho salmon and steelhead trout used several more miles of the river. Chinook salmon spawned mostly on the mainstem, though several tributaries including the North Fork of the Mattole River, Honeydew Creek, and Bear Creek also were spawning areas. Coho salmon and steelhead trout spawned mostly in smaller tributaries throughout the basin (DFG, 2002).

Local residents initiated consistent surveys of spawning pairs, carcasses and redds (gravel nests) in particular reaches of the river in the winter of 1981-82 (Coastal Headwaters Association, 1982), and have documented a decline to a barely viable salmon population in the late 1980s and early '90s. The Mattole Restoration Council (1995) stated, "For Mattole chinook, the data suggest that the number of spawners dropped from about 3,000 in 1981-82 to around 100 in the 1990-91 season, and recovered slightly to 500 in 1994-95". Coho populations suffered a similar abrupt decline, while steelhead populations have declined less dramatically.

A number of groups have conducted fish surveys in various streams in the watershed. A summary of this information is contained in the TSD.

Declining numbers of salmonids led the National Marine Fisheries Service (NMFS) to list several populations under the federal Endangered Species Act. The populations of coho, chinook, and steelhead in the Mattole River and its tributaries have been federally listed as threatened (i.e., they are likely to become endangered in the foreseeable future). Coho in the Mattole River and its tributaries are included in the population known as the Northern California/Southern Oregon Coasts Evolutionarily Significant Unit (ESU), which was listed by NMFS as threatened in 1997. Chinook in the Mattole River and its tributaries are included in the California Coast ESU, which was listed as threatened in 1999. Steelhead in the Mattole River and its tributaries are included in the Northern California ESU, which was listed as threatened in 2000.

2.3. SALMONID LIFE CYCLE AND HABITAT REQUIREMENTS

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 on to 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.

Requirements for Salmonids Related to Sediment

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 gravel 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) 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 pebbles on the surface, 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 food supplies, resting locations and protection from predators.

Excessive sediment can affect other factors important to salmonids. Stream temperatures can increase as a result of stream widening and pool filling. Excessive sediment can result in all flow being subsurface, completely eliminating salmonid habitat. 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 strongly correlated with increased suspended sediment concentrations. Increases in turbidity or suspended sediment can impair growth by reducing availability or visibility of food, and the suspended sediment can cause direct damage to the fish by clogging or eroding gills.

Requirements for Salmonids Related to Temperature

Temperature is one of the most important factors affecting the success of salmonids and other aquatic life. Temperature influences growth and feeding rates, metabolism, development of embryos and alevins, timing of life history events such as upstream migration, spawning, freshwater rearing, and seaward migration, and the availability of food. Temperature changes can also cause stress and mortality (Ligon et al., 1999).

Literature reviews were conducted by NCRWQCB to determine temperature requirements for the various life stages of steelhead trout and coho salmon. Results are presented in the TSD and summarized in Table 2-2.

Table 2-2. Summary of MWAT Temperature Tolerances of Coho Salmon and Steelhead

Descriptor	Coho Salmon	Steelhead
Good	<15 °C (<59 °F)	<17 °C (<63 °F)
Marginal	15°-17 °C (59-63 °F)	17°-19° C (63-66 °F)
Poor/Unsuitable	>17° C (63 °F)	>19° C (>66 °F)

The TSD evaluates temperature conditions in the Mattole River watershed using two measures of exposure. The maximum weekly average temperature (MWAT) is a measure of chronic exposure, and is the primary statistical measure for interpreting stream temperature conditions in the TMDL. The short-term maximum temperature is also used as a measure of potentially lethal effects.

The values in Table 2-2 are to be compared to MWAT values for specific locations. For example, a specific location on a river would have marginal temperature conditions for coho and good temperature conditions for steelhead, if the MWAT for that location was 16EC.

WHAT IS MWAT?

Because temperatures in streams fluctuate daily and seasonally, it is useful to summarize this detailed variability with a summary measurement. To summarize summer stream temperatures in this TMDL (and other TMDLs in California's North Coast), we use the Maximum Weekly Average Temperature (MWAT), a widely used summary measurement. MWAT is calculated here as the maximum value of the 7 day running average of all monitored temperatures (temperature monitors often make hourly measurements).

Readers should note that the term MWAT is not used consistently by researchers and agencies. For example, the State of Oregon uses MWAT which is calculated as the maximum week of the daily maximum. In addition, the term MWAT is occasionally

2.4. HABITAT CONDITIONS IN THE MATTOLE RIVER WATERSHED

The Mattole River TMDLs address sediment and temperature 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. These TMDLs focus on achievement of water quality standards related to sediment and temperature, which will facilitate, but not guarantee, population recovery. In general, the most sensitive beneficial uses in the Mattole River watershed – those related to propagation and rearing of the cold-water fish species – are impaired by several factors including those related to sediment and temperature.

Sediment Conditions

Evaluation of sediment conditions in the Mattole watershed found adverse conditions for salmonid spawning and rearing in most locations. Possibly most commonly noted is the filling of the estuary with sediment. The North Coast Watershed Assessment Program watershed synthesis report for the Mattole River watershed (NCWAP, 2002) found that sediment from the upper watershed, through periodic flooding, has reduced the volume of the Mattole River estuary and altered the physical and biological functioning of the estuarine ecosystem and adjacent wetlands. The NCWAP report found that sediment is a problem in other locations as well, including the mainstem Mattole River (up to the Southern Subbasin) and the downstream, lower gradient, reaches of Lower and Upper North Fork Mattole Rivers and Blue Slide, Lower Bear, and Mattole Canyon Creeks. Data were insufficient for a conclusive analysis, but sediment may also be detrimentally impacting Squaw Creek.

Some stream habitat data has been evaluated. Measurements of embeddedness (which reduces the ability of salmon to spawn and eggs to hatch) have been taken throughout the basin. Data were available for 46 streams that represented all four subbasins. Several samples were taken at each location. Only three streams had good sediment habitat conditions (defined as 25% of samples with 0-25% embeddedness). Measurements of pool depth and pool frequency throughout the basin show very few deep pools - an indicator of excess sediment. Of the 46 streams with measurements, very few (Eubanks and the Mattole headwaters) had frequent deep (>2 feet) pools. Another measurement of sediment, V* (which is the amount of fine sediment filling pools), was taken at eight locations. Of these locations, one was in good condition, and the other seven were marginally worse than suggested good conditions.

Temperature Conditions

Elevated water temperatures are impairing salmonid habitat in many locations in the watershed. Water temperatures have been measured to be above stressful, even lethal, limits in most locations in the estuary, mainstem, and lower downstream areas. In the upper, headwater reaches temperatures have been measured to be adequate for rearing salmonids.

Temperatures found in the estuary and the mainstem of the Mattole River up to the Southern Subbasin (near river mile 55) are near lethal. The present highly-impacted state of the estuarine habitat is likely limiting the production of salmonids in the Mattole River. In fact, extensive studies, led by Humboldt State University from 1985-92, found that chinook juveniles were suffering lethal impacts during summer rearing in the estuary. In response, the Mattole Salmon Group (MSG) initiated a rescue trapping and rearing program, which has had limited success (NCWAP, 2002).

Temperature extremes are also affecting the lower-gradient downstream reaches of Lower and Upper North Fork Mattole Rivers, and Honeydew, Blue Slide, Lower Bear, Mattole Canyon, and Squaw Creeks. In the upper reaches of these large tributaries, however, temperatures are within optimal conditions for salmonids. Fish presence data compiled by the California Department of Fish and Game and the Mattole Salmon Group appear to confirm this conclusion.

The TSD contains detailed temperature information on streams throughout the watershed. Data from temperature monitors is presented for the mainstem and specific tributaries in all four major subbasins. Data from thermal infrared images is also presented, providing an instant overview of temperatures along the mainstem and several tributaries. The thermal infrared results show localized drops in temperatures, which reflect the influence of colder tributaries entering the warmer mainstem, or influxes of cooler groundwater.

Salmonids can use areas of cooler water, when they are present, as an avoidance strategy to survive during periods of elevated temperatures. Discrete areas of colder water, called thermal refugia, can be created by tributaries, groundwater seeps, intergravel flow, deep pools, and areas separated from currents by obstructions (Nielsen et al, 1994). The existence of these thermal refugia allows salmonids to persist in these reaches of otherwise poor or marginal habitat. NCRWQCB staff observed great quantities (estimated to be greater than 1000 juveniles 3-7” long) of steelhead trout occupying thermal refugia at the mouth of Squaw Creek on the afternoon of 9 August 2001. At that time, the mainstem of the Mattole was 27 °C (80.6 °F), while Squaw creek was 22 °C (71.6 °F). The previous day, staff observed adult summer steelhead occupying thermal refugia offered by a groundwater seep between Nooning and Eubanks Creeks at a time when the water surface was 21 °C (69.8 °F), while the temperature at depth was 16 °C (60.8 °F).

CHAPTER 3: SEDIMENT

This chapter presents information specific to the sediment TMDL for the Mattole River. The first section of this chapter identifies water quality indicators, which are proposed as interpretations of the water quality standards and used to evaluate stream conditions. The second section presents the results of the sediment source analysis. The third section presents the calculation of the TMDL, which is the total loading of sediment which the Mattole River and its tributaries can receive without exceeding water quality standards, and apportions the total among the sources of sediment.

3.1. WATER QUALITY INDICATORS AND TARGETS FOR SEDIMENT

This section identifies water quality indicators for sediment. The turbidity indicator is a numeric water quality objective in the Basin Plan. The remaining indicators 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. It is expected 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 as indicators.

No single indicator adequately describes water quality with relation to sediment; instead, 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 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 progress toward attainment of water quality standards.

Both instream and watershed indicators are appropriate to use in evaluating 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 antidegradation policy by focusing on imminent threats to water quality that can be detected and corrected before the sediment is 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. Linkages between hillslope sediment production and instream sediment delivery are complicated by time lags between production and delivery, instream storage, and transport through the system. Accordingly, watershed targets potentially can 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 target conditions will be met.

The water quality indicators for the Mattole River are summarized in tables. Table 3-1 lists the instream water quality indicators for the Mattole River TMDL and their respective target values. Table 3-2 lists the watershed indicators and targets. In several cases, targets are expressed as improving trends, because information on watershed processes is inadequate to develop appropriate thresholds. Detailed descriptions of the indicators and targets are contained in the TSD.

3.2. SEDIMENT SOURCE ANALYSIS

This section summarizes the results of the sediment source analysis, the purpose of which is to identify the various sediment delivery processes and sources in the watershed and to estimate the sediment yield from those sources.

The natural setting of the Mattole watershed, along with accelerated sediment delivery caused by human activities, has resulted in the delivery of high sediment loads to streams. The natural setting of the Mattole basin is characterized by high rainfall amounts averaging 60-115 in/yr with extremes of 212 in/yr in 1983 and 57 in/yr in 1991 (MRC, 1995). The Mattole watershed is located in a tectonically active area with some of the highest rates of crustal deformation, surface uplift, and seismic activity in North America (Merritts, 1996). Sources of sediment delivery to aquatic habitat include natural erosion processes as well as those influenced by human activities, such as road construction, operation and maintenance, timber harvest activities, and livestock grazing. As described below, the estimated rate of sediment delivery to streams in the Mattole River watershed is 8000 tons/mi^2/yr.

3.2.1. Sediment Source Analysis Analytical Methods

A combination of methods was used to estimate the amount of sediment being delivered to streams from the various sources of sediment. Aerial photo analysis, existing GIS data, published literature, watershed analysis studies in the Mattole, field measurements in the Mattole, and existing watershed analysis methodologies were all used depending upon the sediment source estimated. Each of the sediment source categories is briefly described below, along with a summary of methods used to derive the estimates. The TSD provides more detailed information on the sediment delivery processes and analysis methods.

Key pieces of information developed for this TMDL underlie most of the analysis. The NCRWQCB staff conducted field surveys in various locations in the watershed, representing a range of geologic conditions. A total of 16 roads and 22 streams were surveyed. In addition, ICE, under contract to the NCRWQCB, conducted an aerial photo analysis of five subwatersheds for large, visible landslides (>10,000 square feet in surface area). The results were then used to estimate conditions in the four major subbasins. The 1984-2000 period was analyzed, because forestry operations in this period were subject to the California Forest Practice Rules. In addition, the density of roads in each of the four major subbasins was estimated from data on three subwatersheds provided by ICE combined with a scaling factor.

Natural Mass Wasting: Natural mass wasting is mass wasting (landslides, debris flows, etc.) that is not associated with human causes. The estimate of natural mass wasting was attained by combining an estimate of natural large landslides (from the ICE aerial photo analysis) and an estimate for natural smaller landslides. The estimate for smaller landslides was based on data on the rate and size of smaller landslides from the road and stream field surveys, extrapolated to the four major subbasins. Note that earthflow delivery has been incorporated into the stream bank erosion estimate.

Stream Bank Erosion: The sediment delivered to stream channels from stream banks was estimated by combining information on literature values for soil creep with an estimate of the extent of hillslopes

Table 3-1. Summary of Instream Indicators and Targets for Sediment

INDICATOR	TARGET	COMMENTS	PURPOSE	REFERENCES
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; NCRWQCB, 2000; Valentine, 1995.
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, NCRWQCB, 2001b.
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; Lisle & Hilton, 1999.
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.
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.
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.
Monitoring recommendations: annually (e.g., sediment substrate, embeddedness, V*, aquatic insect abundance) or periodically following large storms (e.g., thalweg profile, pool distribution, turbidity, LWD)				

Table 3-2. Summary of Watershed Indicators and Targets for Sediment

INDICATOR	TARGET	COMMENTS	PURPOSE	REFERENCES
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.
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; Flanagan et al., 1998; Furniss et al., 2000.
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		Minimized sediment delivery	EPA, 1998a.
Activities in unstable areas	Avoid or eliminate	Subject to geological/geotechnical assessment to minimize or show that no increased delivery would result	Minimized sediment delivery from management activities	Dietrich et al., 1998; Weaver and Hagans, 1994; PWA, 1998.
Disturbed area	Decrease		Measure of chronic sediment input	Lewis, 1998.
Monitoring recommendations: prior to winter				

subject to bank failure (including earthflow processes), then extrapolating by stream density (from GIS) to each of the four major subbasins.

Road Related Mass Wasting: Road related mass wasting was estimated by combining estimates of large landslides (from the aerial photo analysis) with measured volumes for smaller features (from the road surveys), then extrapolating to the four major subbasins using the ICE road density information.

Road-Stream Crossing Failures: Sediment delivery associated with roads crossing streams (including outlet erosion, stream diversions, and washouts) is additional road related mass wasting that was not estimated during the road surveys. These estimates were derived from a study of the Sanctuary Forest extrapolated by the number of road/stream crossings and the failure rate.

Road Related Gullying: Sediment delivery associated with gullies caused by road runoff was estimated from the road surveys and extrapolated using ICE road density information.

Road Related Surface Erosion: Sediment delivery of eroded road surface materials was estimated using road density information from the NCWAP report and information from the road surveys, using Washington State Watershed Analysis Manual methods.

Skid Trail Related Erosion: Sediment delivery from skid trails was estimated by combining information on large mass wasting features associated with skid trails (from the ICE aerial photo analysis) with the rate and size of smaller mass wasting features (from the road surveys), then extrapolating to the four major subbasins using stream density information.

Other Harvest Related Delivery: Sediment delivery associated with landings or other harvest related delivery not accounted for elsewhere was estimated from the ICE aerial photo analysis combined with estimates of surface erosion from human-caused landslides that continue to deliver sediment because they remain unvegetated.

3.2.2. Sediment Source Analysis Results

A summary of the results of the sediment source analysis for 1984-2000 is presented in Table 3-3. Results are presented for each of the four major subbasins as well as the watershed as a whole (based on an area-weighted average of the results for the four subbasins). The results for the subbasins reflect differences in geology, road density, and the steepness of slopes.

The total estimated current rate of sediment delivery for the entire watershed is 8000 tons/mi^2/yr, with approximately 36% attributed to natural erosional processes and 64% attributed to human activity. The total is larger than the estimated sediment load for Redwood Creek (4750 tons/mi^2/yr), and more than three times the estimated sediment load for the Van Duzen River (2232 tons/mi^2/yr) (EPA, 1998b; EPA, 1999a). Though the Mattole values are high, they are comparable to values derived from sediment studies conducted in other rapidly tectonically uplifted regions. Sediment yields in the San Gabriel Mountains, California, were estimated to be 5173 tons/mi^2/yr (Bull, 1978; 1979; 1991). Drainage basins in the rugged Seaward Kaikoura Range of New Zealand have similar characteristics to the Mattole watershed. The Seaward Kaikoura Range is underlain by folded and faulted massive to medium graywacke sandstone and argillite, and it has steep drainage basin slopes with high rainfall amounts (1200-2000 mm or 47-78 in./yr) (Bull, 1991). Estimated sediment yield rates for this area range from 7759-10346 tons/mi^2/yr (Thompson and McArthur, 1969; O'Loughlin and Pierce, 1982).

Table 3-3. Mattole Watershed Sediment Source Analysis Results

Sediment Source	Estimated Sediment Delivery 1984-2000 (tons/mi²/yr) North (98 mi²)	East (79 mi²)	South (28 mi²)	West (89mi²)	Entire Watershed
Natural Erosion Sources					
Natural Mass Wasting	3700	1600	1600	2100	2400
Stream Bank Erosion	790	270	170	360	460
Subtotal (Natural Sources)	**4500**	**1900**	**1800**	**2500**	**2900**
Sources Associated with Human Activity					
Road-related Sources					
Road Related Mass Wasting	2000	5900	450	2100	2900
Road-Stream Crossing Failures	50	40	160	40	50
Road Related Gullying	100	190	290	200	170
Road Related Surface Erosion	360	670	780	560	540
Subtotal (Road Sources)	*2500*	*6800*	*1700*	*2900*	*3700*
Timber Harvest-related Sources					
Skid Trail Related Erosion	590	700	760	850	710
Other Harvest Related Delivery	600	110	130	1500	700
Subtotal (Harvest Activity)	*1200*	*840*	*910*	*2400*	*1400*
Subtotal (Human Activity)	**3700**	**7600**	**2600**	**5300**	**5100**
TOTAL	**8200**	**9500**	**4400**	**7800**	**8000**

Note: numbers have been rounded to two significant figures, so columns may not add exactly. The sediment delivery numbers are based on the best available data and professional judgment, as described in the TSD.

3.3. SEDIMENT TMDL AND ALLOCATIONS

3.3.1. Sediment TMDL

This TMDL is set equal to the loading capacity of the Mattole River. 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 Mattole River watershed without exceeding applicable water quality standards. We are assuming that there can be some increase above the natural amount of sediment and not adversely affect fish. We postulate this because fish populations were thriving throughout the North Coast when there was some sediment from human activities. For the Mattole River, the sediment TMDL is set equal to 125% of natural sediment delivery, based on our past experience determining TMDLs for other North Coast watersheds.

EPA used a reference time period to calculate the TMDL for the Noyo River (EPA 1999b). The TMDL for the Noyo River was set at the estimated sediment delivery rate for the 1940s. Because salmonid populations were substantial during this time period, which was assumed to be a quiescent period between the logging of old growth at the turn-of-the-century and logging of second growth in the middle of the 20th century, we postulated that there could be increases above the natural amount of sediment and still maintain healthy watershed conditions. Analysis of sediment sources during this period indicates that there was about one part human induced sediment delivery for every four parts natural sediment delivery (i.e. a 1:4 ratio).

We reached similar results in the TMDL analysis for the Trinity River (EPA 2001). For that TMDL EPA used reference streams within the watershed to calculate TMDLs for all the subwatersheds of the Trinity. Again, the reference streams were subwatersheds in which there was some management and healthy watershed conditions. As with the Noyo, it appeared that in these watersheds fish populations could be supported under TMDLs set at a level equivalent to a 1:4 ratio.

Based on these analyses, we have determined that setting the TMDL at 125% of natural sediment delivery is appropriate for the Mattole. This can also be expressed as a 1:4 ratio. Using the estimated natural sediment delivery rate of 2900 tons/mi^2/yr, the TMDL for the Mattole River (rounded to two significant figures) is:

$$\text{TMDL} = \text{Loading Capacity} = (125\%) \times (2900\ \text{tons/mi}^2/\text{yr}) = 3600\ \text{tons/mi}^2/\text{yr}.$$

The ratio approach has several potential advantages. Stillwater Sciences (1999) indicates that looking at the ratio of human to natural sediment sources can detect the effects of land use changes better than an average annual sediment loading alone, because the ratio may vary with hydrology less than the annual sediment load. The ratio could be measured periodically and provide an indication of progress toward meeting sediment reduction goals. The ratio may also be less dependant upon spatial and hydrologic variability.

The approach taken focuses on sediment delivery, rather than a more direct measure of salmonid habitat (i.e. instream conditions). Sediment delivery can be subject to direct management by landowners (for example, roads can be well maintained), whereas instream conditions (pool depth, percent fines) are subject to upstream management that may not be under the control of local landowners. While it would be desirable to be able to mathematically model the relationship between salmon habitat and sediment delivery, these tools are not available for watersheds with landslides and road failure hazards. Sediment movement is complex both spatially and temporally. Sediment found in some downstream locations can be the result of sediment sources far upstream; instream sedimentation can also be the result of land management from decades past. Nevertheless, management activities can clearly increase sediment delivery and instream habitat can be adversely affected by increased sediment inputs. Therefore, it is reasonable to link increases in sediment delivery to decreased stream habitat quality.

The approach also implies that salmon populations can be self-sustaining even with the yearly variation of natural rates of erosion observed in the 20th century. Although the sediment delivered to the streams varied, salmon adjusted to the natural variability by using the habitat complexity created by the stream's adjustments to the naturally varying sediment loads.

3.3.2. 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:

TMDL = sum of the wasteload allocations for individual point sources
+ sum of the load allocations for nonpoint sources
+ sum of the load allocations for background sources.

The margin of safety in this TMDL is not added as a separate component of the TMDL, but rather is incorporated into conservative assumptions used to develop the TMDL, as discussed in Section 3.3.3. As there are no point sources of sediment in the Mattole River watershed, the wasteload allocation for point sources is set at zero.

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 sources of sediment. The load allocations for nonpoint sources reflect professional judgment as to 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).

For the Mattole River TMDL, source categories that are more controllable receive load allocations based on a higher percentage reduction from current levels. For example, road stream crossing failures are more readily controlled than road related mass wasting. Therefore, the load allocation for road stream crossing failures is based on a loading reduction of 94%, whereas the load allocation for road related mass wasting is based on a loading reduction of 82%.

The load allocations for the Mattole River TMDL are presented in Table 3-4. The allocations clarify the relative emphasis and magnitude of erosion control programs that need to be developed during

Table 3-4. Load Allocations for Sediment

Source Category	Load Allocation (tons/mi²/day)	Current Loading Estimate (tons/mi²/day)	Reduction Needed (%)
Natural Erosion Sources			
Natural Mass Wasting	2400	2400	0%
Stream Bank Erosion	460	460	0%
Subtotal (Natural Sources)	**2900**	**2900**	**0%**
Sources Associated with Human Activity			
Road-related Sources			
Road Related Mass Wasting	520	2900	82%
Road-Stream Crossing Failures	3	50	94%
Road Related Gullying	10	170	94%
Road Related Surface Erosion	27	540	95%
Subtotal (Road Sources)	*560*	*3700*	*85%*
Timber Harvest-related Sources			
Skid Trail Related Erosion	70	710	90%
Other Harvest Related Delivery	70	700	90%
Subtotal (Harvest Activity)	*140*	*1400*	*90%*
Subtotal (Human Activity)	**700**	**5100**	**86%**
TOTAL	**3600 (= TMDL)**	**8000**	**55%**

Note: current loading estimates have been rounded to two significant figures, so that column may not add exactly.

implementation. The 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. 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 expect each square mile within a particular source category to necessarily meet the load allocation; rather, EPA expects the average for the entire source category to meet the load allocation for that category.

3.3.3. 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 into conservative assumptions used to develop the TMDL, or added as an explicit separate component of the TMDL.

EPA is incorporating an implicit margin of safety into the Mattole River TMDL. As stated in the TSD, the estimate of sediment delivery from natural sources is an underestimate. This provides a margin of safety, because the TMDL is based on the estimated natural sediment delivery rate.

3.3.4. Seasonal Variation and Critical Conditions

The TMDL must describe how seasonal variations were considered. Sediment delivery in the Mattole River watershed inherently has considerable annual and seasonal variability. The magnitudes, timing, duration, and frequencies of sediment delivery fluctuate naturally depending on intra- and inter-annual storm patterns. Since the storm events and mechanisms of sediment delivery are largely unpredictable year to year, the TMDL and load allocations are designed to apply to the sources of sediment, not the movement of sediment a across the landscape, and to be evaluated on a ten-year rolling average basis. EPA assumes that by controlling the sources to the extent specified in the load allocations, sediment delivery will occur within an acceptable range for supporting aquatic habitat, regardless of the variability of storm events.

The TMDL must also account for critical conditions for stream flow, loading, and water quality parameters. Rather than explicitly estimating critical flow conditions, this TMDL uses indicators which reflect net long term effects of sediment loading and transport for two reasons. First, sediment impacts may occur long after sediment is discharged, often at locations far downstream of the sediment source. Second, it is impractical to accurately measure sediment loading and transport, and the resulting short term effects, during the high magnitude flow events that produce most sediment loading and channel modifications.

CHAPTER 4: TEMPERATURE

Summary

This chapter presents a TMDL for temperature developed in terms of shade. Section 4.1 provides EPA's interpretation of the water quality standards for temperature, and explains why shade is used as a surrogate for heat in this TMDL. Section 4.2 describes water quality targets. Section 4.3 presents the TMDL and allocations.

4.1. INTERPRETING THE WATER QUALITY STANDARDS FOR TEMPERATURE

This temperature TMDL is calculated so as to attain the applicable water quality standards. The Basin Plan identifies the following two temperature objectives for surface water:

> "The natural receiving water temperature of intrastate waters shall not be altered unless it can be demonstrated to the satisfaction of the Regional Water Board that such an alteration in temperature does not adversely affect beneficial uses."

> "At no time or place shall the temperature of any COLD <i.e. water with a beneficial use of cold freshwater habitat> water be increased by more than 5 EF above natural receiving water temperature."

In considering the first objective, EPA and NCRWQCB staff have examined whether alterations from natural temperature conditions would adversely affect beneficial uses - that is, cold water fish.   Stream temperature conditions in many locations in the Mattole River watershed are less than ideal for salmonids under natural conditions, so any increase in stream temperatures above natural conditions would adversely affect beneficial uses. Therefore, EPA concludes that the TMDL should be set at the level necessary to attain natural temperature conditions.

As we have concluded that no alterations of natural conditions are appropriate for the first objective, it is clear that the first objective is more stringent than the second. Therefore, this TMDL is calculated to meet the first objective.

4.1.1. Shade as a Surrogate for Heat

This TMDL generally focuses on shade as a surrogate for the heat entering the stream. While the actual pollutant is heat (i.e., solar radiant energy), effective shade is the surrogate, because it is a more useful measure for making land management decisions. Essentially, effective shade is the converse of solar radiant energy; it is the reduction in solar radiant energy resulting from topography and vegetation. Effective shade can be readily measured in the field, and it can be calculated using mathematical equations. Additionally, shade is the factor affecting stream temperatures in the Mattole that is most likely to be altered from natural conditions (the Mattole does not have discharges of cooling water from industries, and it does not have dams, though some water is diverted, primarily for irrigation).

The TSD evaluates the importance of shade to stream temperatures using the computer simulation model SSTEMP, a public domain model currently supported by the U.S. Geological Survey. SSTEMP combines information on shade, hydrology, stream geometry, meteorology, and time of year to predict stream temperatures. NCRWQCB staff used SSTEMP to examine the relative importance of the various factors affecting stream temperatures, and the impact that the loss of stream shade has on the stream temperature regime of the Mattole River watershed.

Sensitivity Analysis

To evaluate the relative importance of the various factors affecting stream temperatures, NCRWQCB staff conducted a sensitivity analysis using SSTEMP. In this analysis, one parameter at a time was varied (+/- 10%), while holding the others constant. This was done for two locations. Upper Eubanks Creek was modeled to represent smaller streams in the watershed, and the Mattole mainstem from Bundle Prairie to the Mattole Grange was modeled to represent mainstem habitats.

Total shade is clearly the parameter of most concern for smaller streams, which make up most of the stream network in the watershed. When the results for Upper Eubanks Creek are ranked by effect on mean stream temperature, air temperature is the most important parameter, with total shade second. When the results are ranked by effect on maximum stream temperature, total shade is the most important parameter and air temperature is second. Total shade has a significant influence on both mean and maximum temperatures. Also, it is readily affected by human activities, whereas air temperature is not.

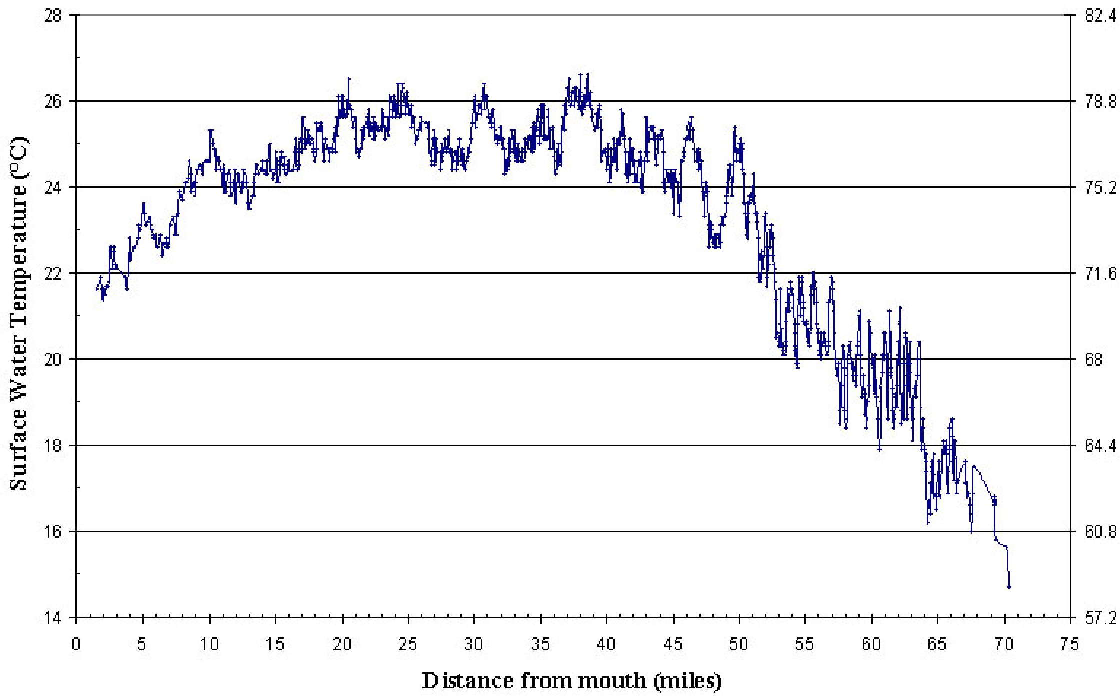
Shade is a factor, but not as important, for mainstem locations. Shade has a moderate direct effect on maximum temperatures, but relatively little direct effect on mean temperatures. The modest influence of shade on mainstem reaches is not surprising, because channels can be too wide for even tall trees to provide shade, especially when streams are overwidened due to excessive sediment delivery. However, shade is still relevant to mainstem habitats in two additional ways. First, riparian shade along mainstem locations can have an indirect affect on stream temperatures, because riparian conditions can influence local air temperature, wind speed, relative humidity, and ground temperature (i.e., shady locations are typically cooler, less windy, and more humid than open areas). Second, the temperature of water flowing into mainstem reaches has a moderately large effect on mainstem temperatures, so shade conditions along upstream reaches and tributaries effect mainstem temperatures.

The effect of tributaries on mainstem temperatures can be seen in the results of the thermal infrared images collected by Watershed Sciences under contract to the NCRWQCB during development of the TSD. Figure 4-1 shows the thermal infrared longitudinal profile for the mainstem Mattole River from the estuary to the headwaters on 19 July 2001. As discussed in the TSD, the frequent dips in mainstem temperatures show the influence of colder tributaries or influxes of groundwater. For example, between river mile 48 and 50, where Bear and Blue Slide Creeks enter the river, mainstem surface temperatures dropped approximately 3.7 EC (6.7 EF).

Reach Level Simulation of Stream Temperatures

The impact of changes in effective shade on stream temperatures was evaluated for twelve reaches of streams in the Mattole watershed using SSTEMP. Stream temperatures were simulated for current and adjusted potential riparian vegetation conditions. The shade associated with adjusted potential riparian vegetation (i.e., adjusted potential shade) was calculated using either potential tree heights reduced by 10% (to account for natural events, such as fire, landslides, and windthrow) or existing tree heights, whichever was greater. The results of the model are presented in Table 4-1.

Figure 4-1. Temperatures of the Mattole River on 19 July 2001 (from Thermal Infrared Imagery)



The results of the stream temperature simulations demonstrate the impact that changes in shade conditions have on stream temperatures. The results show that an increase in effective shade from current to adjusted potential conditions results in a significant decrease in stream temperatures where the two shade conditions are significantly different. In the mainstem, the potential for effective shade is not great, and shade does not appear to be a limiting factor. In smaller stream reaches, however, shade is shown to be a significant factor governing stream temperature conditions.

4.1.2. Importance of Sediment

Although this temperature TMDL focuses on shade, there is another crucial factor related to temperature and fish habitat in the Mattole -- sediment. EPA anticipates that implementing the sediment TMDL will result in narrowing and deepening of stream channels, which should improve temperature conditions. Sediment control in the watershed is also important for temperature because excess sediment adversely affects the formation and maintenance of deep pools. Pools can provide important thermal refugia for salmonids. Stratified pools can provide a much needed refuge in hot periods of the day and at the hottest times of the year. Also, flood damage related to sediment can affect riparian vegetation. Thus, sediment control is important for temperature by its influence on stream width, the frequency and depth of pools, and flood damage to riparian vegetation.

Thus, in order to fully achieve natural temperature conditions, as required by the applicable water quality standard (see above), it is necessary to reduce both the amount of heat entering the waterbody (by increasing shade), which is the goal of this temperature TMDL, and the amount of sediment entering the waterbody, which is the goal of the sediment TMDL.

Table 4-1. Modeled and Measured Daily Average Stream Temperatures

Reach	Current Effective Shade (%)	Adjusted Potential Effective Shade (%)	Measured Temperature (EC [EF])	Simulated Current Temperature (EC [EF])	Simulated Potential Temperature (EC [EF])
Mattole Mainstem, Big Finley to Bear Creeks	27	36	23.7 [74.7]	22.8 [73.0]	22.1 [71.8]
Mattole Mainstem, Bundle Prairie to Mattole Grange	14	16	22.1 [71.8]	23.1 [73.6]	23.0 [73.4]
Mattole Mainstem, Mattole Grange to Petrolia Gauge	14	16	22.8 [73.0]	23.4 [74.1]	23.2 [73.8]
Grindstone Creek	74	82	20.2 [68.4]	18.9 [66.0]	18.1 [64.6]
Upper Eubanks	77	85	16.9 [62.4]	16.8 [62.2]	15.1 [59.2]
Nooning Creek	65	80	14.8 [58.6]	17.7 [63.9]	15.9 [60.6]
Woods Creek	71	73	16.5 [61.7]	19.6 [67.3]	19.4 [66.9]
Baker Creek	76	85	17.0 [62.6]	16.3 [61.3]	15.3 [59.5]
Yew Creek	67	86	15.1 [59.2]	17.4 [63.3]	15.2 [59.4]
South Fork Bear Creek, Wailaki Campground to Queens Mine Road	48	83	No data available	20.3 [68.5]	16.8 [62.2]
Bear Creek, Confluence of South and North Forks to Mouth	44	54	18.1 [68.5]	18.8 [65.8]	17.9 [64.2]
Lower North Fork Mattole, above East Fork	62	77	19.2 [66.6]	19.8 [67.6]	18.4 [65.1]

4.2. WATER QUALITY INDICATORS AND TARGETS FOR TEMPERATURE

This section identifies water quality indicators for temperature. The indicators 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. It is expected 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.

For the temperature TMDL, we are identifying two indicator parameters: (1) the amount of effective shade at stream locations throughout the watershed and (2) the extent of thermally stratified pools. When considered together, the indicators are expected to provide good evidence of the condition of the stream and progress toward attainment of water quality standards.

Effective Shade

Target: adjusted potential shade conditions from riparian vegetation

The target shade conditions are those that result from achieving the natural mature vegetation conditions that occur along stream channels in the watershed, approximated as adjusted potential shade conditions as described in the previous section. For this TMDL, target conditions for adjusted potential shade are estimated using two approaches, one based on modeling of the watershed, the second based on field observations and effective shade curves. The first approach generates maps of the watershed, which are useful in evaluating the extent to which the watershed as a whole has the necessary amounts of effective shade. The second approach is more suited to assessing the adequacy of shade conditions at a specific location.

Maps of the watershed were generated using RIPTOPO, a GIS model developed by the Information Center for the Environment at U.C. Davis. It was used to estimate stream shade values throughout the watershed, based on vegetation conditions, topography, stream geometry, and sun position. The target conditions for effective shade using RIPTOPO are presented in Figure 4-2, which is located at the end of this document. Figure 4-2 displays the estimated amounts of adjusted potential effective shade for locations throughout the watershed for adjusted potential riparian vegetation conditions. For comparison purposes, the estimated current effective shade conditions are presented in Figure 4-3, also located at the end of this document. Note that shade conditions can be improved in many locations in the watershed.

The second approach involves the estimation of adjusted potential shade for a specific location based on field observations and effective shade curves. The effective shade curves were developed by the NCRWQCB using SHADE, an Excel-based spreadsheet developed by the Oregon Department of Environmental Quality. Effective shade curves are presented for various vegetation types found in the Mattole watershed: Oak Woodland (Figure 4-4), Klamath Mixed Conifer and Ponderosa Pine Forest (Figure 4-5), Douglas Fir and Mixed Hardwood-Conifer Forest (Figure 4-6), and Redwood Forest (Figure 4-7). Observations of vegetation type, channel width, and stream direction (i.e., north-flowing) can be used in conjunction with the appropriate effective shade curve to estimate the adjusted potential shade condition for a specific location. For example, take the case of a stream flowing west through a redwood forest with a channel 32 meters wide. Using Figure 4-7 (for redwood forest) and the line connecting the triangles (for a west flowing stream), the effective shade value corresponding to a channel width of 32 meters is about 85%.

Thermally Stratified Pools

Target: increased volume of thermally stratified pools

The results of the RIPTOPO modeling show that in the lower reaches of the mainstem Mattole River effective shade is low (< 20%) even under mature riparian vegetation conditions. The low potential for effective shade in these reaches is due to the low height of trees relative to the width of the stream channel. These reaches have high stream temperatures due to the cumulative effects of stream heating processes upstream. In reaches where stream temperatures are stressful or lethal to salmonids, such as in the mainstem Mattole, thermal refugia (e.g., cold water provided by stratified pools, groundwater, intra-gravel exchange) are important habitat elements and may be more important than local shade in supporting suitable stream temperatures. Observations by NCRWQCB staff of ten miles of mainstem Mattole River reaches indicate that thermal refugia are important habitat features for salmonids in the Mattole River. Observations in these reaches, as well as thermal infrared imagery and literature describing effects of sediment loads on channel features, indicate that the volume of thermal refugia is dependent on sediment load.

To increase the extent of thermal refugia, a target of an increased volume of thermally stratified pools is set. Thermally stratified pool volume can be expected to increase as existing stratified pools become deeper and shallow pools become deep enough to stratify in response to reduced sediment supply.

Figure 4-4 . Effective Shade vs. Channel Width, Oak Woodland Tree Height=20m

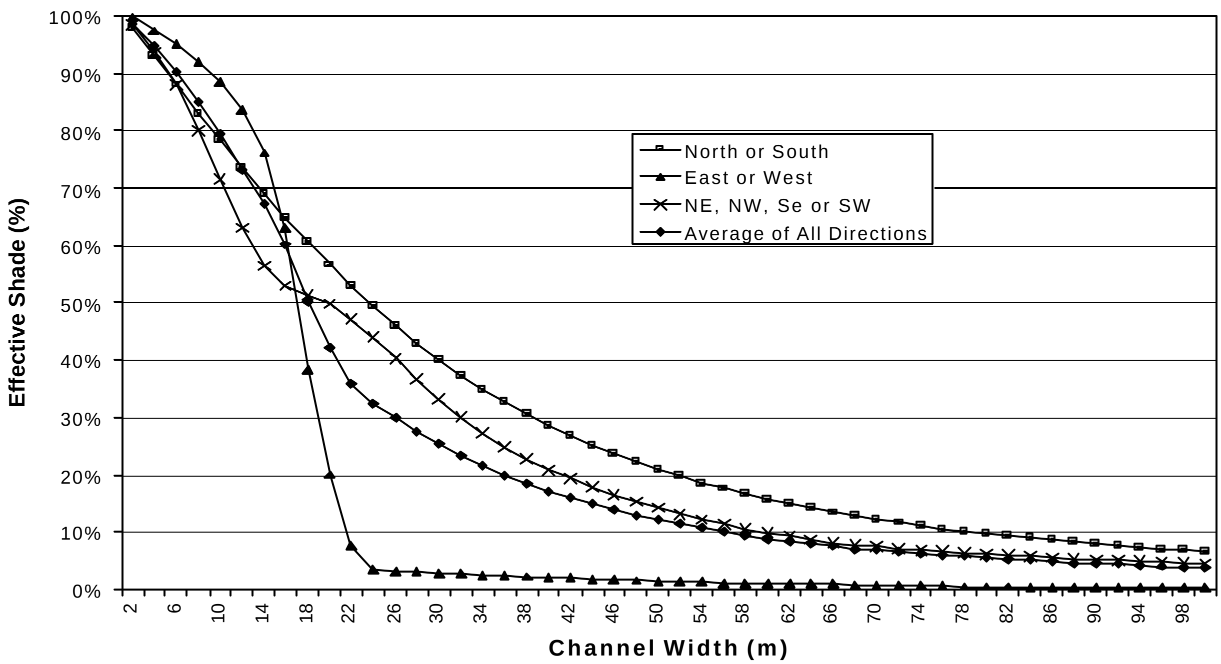


Figure 4-5 . Effective Shade vs. Channel Width, Klamath Mixed Conifer Forest and Ponderosa Pine Forest, Tree Height=35m

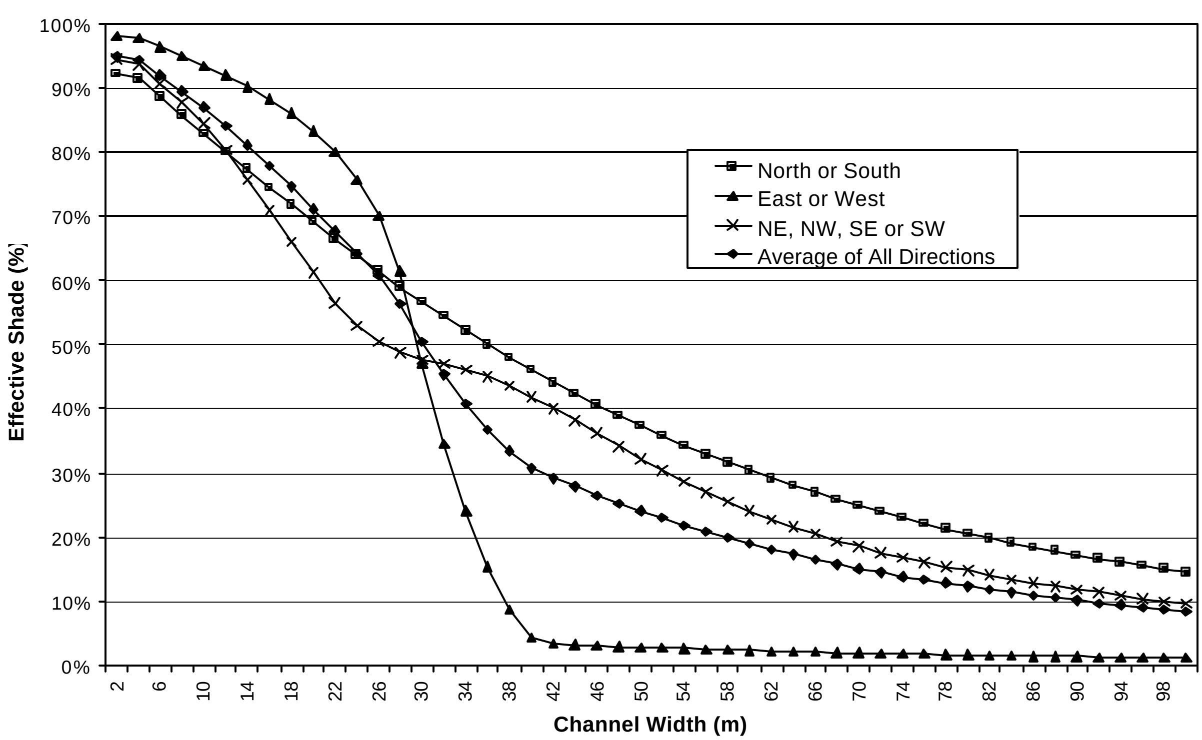


Figure 4-6. Effective Shade vs. Channel Width, Douglas Fir Forest and Mixed Hardwood-Conifer Forest, Tree Height=40m

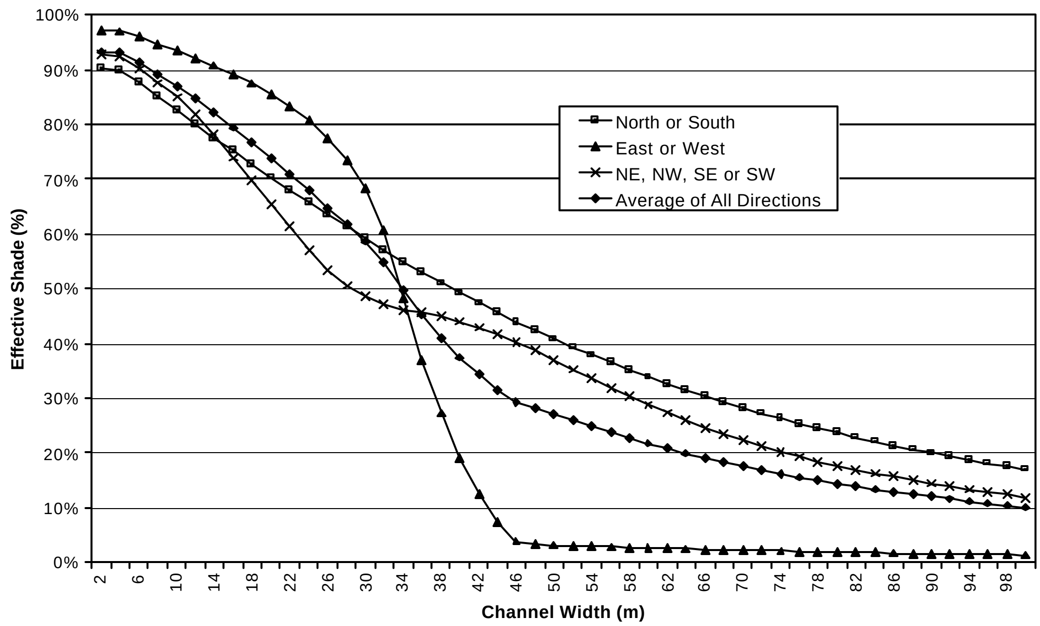
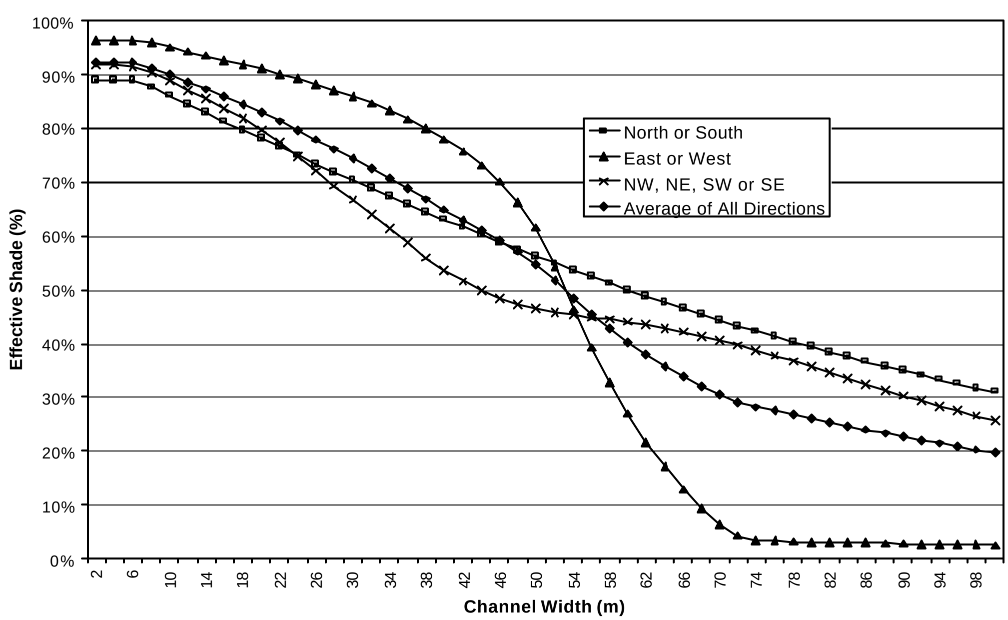


Figure 4-7. Effective Shade vs. Channel Width, Redwood Forest Tree Height=63m



4.3. TEMPERATURE TMDL AND ALLOCATIONS

4.3.1. Temperature TMDL

The loading capacity (i.e., the TMDL) is the total loading of the pollutant that the river can assimilate and still attain water quality standards for temperature. The loading capacity provides a reference for calculating the amount of pollutant reduction needed to meet water quality standards.

In this TMDL, the actual pollutant is heat (i.e., solar radiant energy), but effective shade is used as a surrogate, because it is a more useful for making land management decisions. Effective shade is the reduction in solar radiant energy resulting from topography and vegetation. Effective shade is not the amount of stream in shadow or the amount of the stream surface shaded from direct sunlight (think of entering a deep forest; although you are in 100% shadow or sheltered from direct sunlight, some amount of light remains - it is not totally dark). It is possible to relate heat load to effective shade and to relate effective shade to temperature conditions. Effective shade can be readily measured in the field, and it can be calculated using mathematical equations.

For this temperature TMDL, the loading capacity is the adjusted potential effective shade on the mean date of the MWAT for the watershed. Figure 4-8 shows the results of the RIPTOPO model for current and adjusted potential shade aggregated into cumulative frequency curves for the entire set of stream reaches included in the analysis. These curves show the percent of the stream length in the watershed that is shadier than a given shade value. For example, about 47% of the stream length has 70% or more effective shade with current vegetation conditions, whereas about 70% of the stream length would have 70% or more effective shade with adjusted potential shade conditions. The curve for adjusted potential conditions is the TMDL for temperature for the Mattole River and its tributaries. The same information is presented as a bar chart in Figure 4-8.

4.3.2. Allocations

In accordance with EPA regulations, the loading capacity (i.e. TMDL) is allocated to the various sources of heat in the watershed, with a margin of safety. That is:

TMDL = sum of wasteload allocations for individual point sources,
+ sum of the load allocations for nonpoint sources, and
+ sum of the load allocations for background sources.

The margin of safety in this TMDL is not added as a separate component of the TMDL, but rather is incorporated into conservative assumptions used to develop the TMDL, as discussed below. As there are no point sources of heat in the Mattole River watershed, the wasteload allocation for point sources is set at zero.

The RIPTOPO model was used to calculate effective shade conditions along the stream segments in the watershed, assuming adjusted potential tree heights. The results, as presented in Figure 4-2 (which is located at the end of this document) are the load allocations for nonpoint and background sources.

Figure 4-8. Cumulative Frequency Curves for Effective Shade

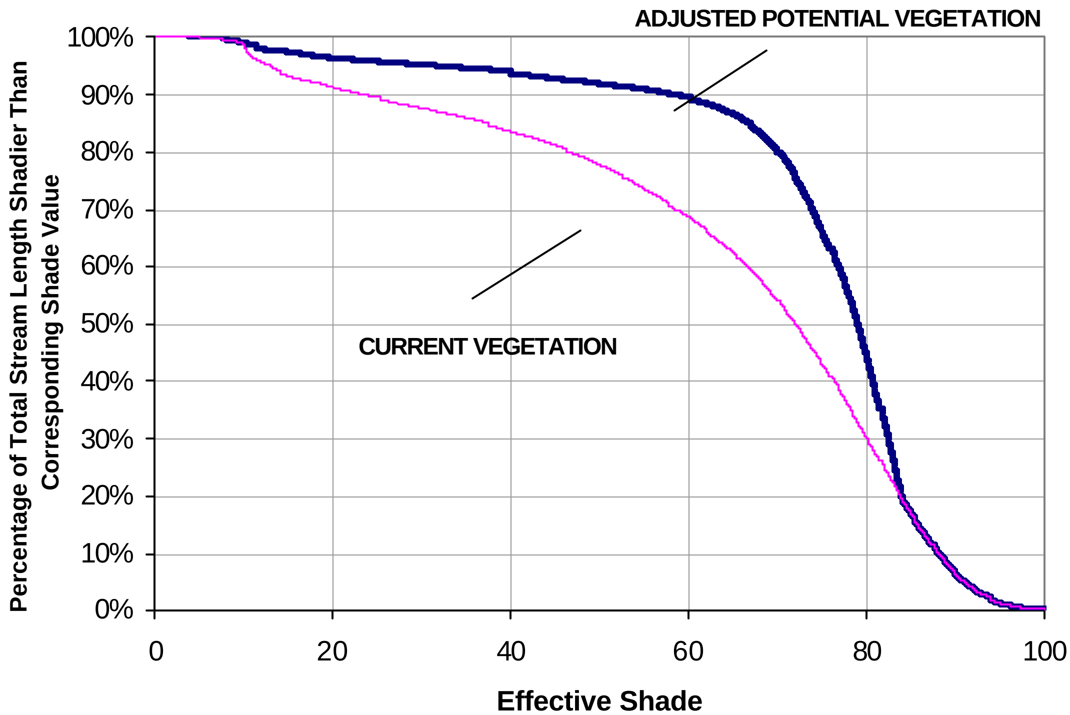
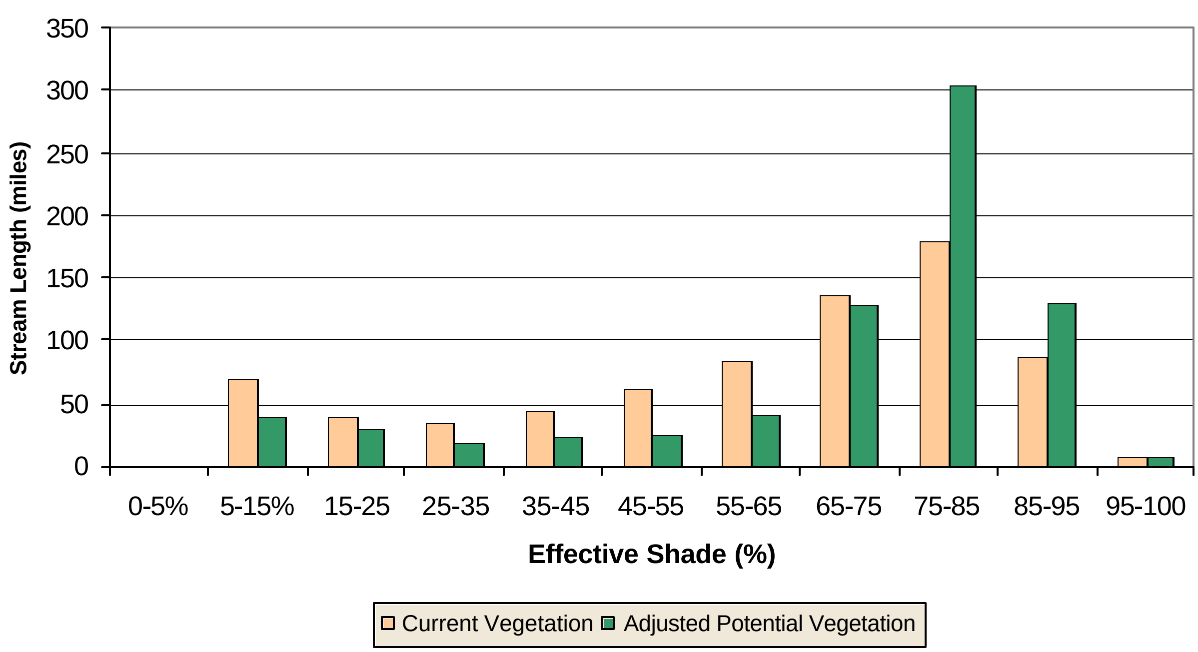


Figure 4-9. Distribution of Effective Shade



4.3.3. 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 into conservative assumptions used to develop the TMDL, or added as an explicit separate component of the TMDL.

EPA is incorporating an implicit margin of safety into the Mattole River temperature TMDL. Table 4-2 identifies the uncertainties in the TMDL and the adjustments or assumptions that were made to account for the uncertainty to ensure that the beneficial uses will be protected.

4.3.4. Seasonal Variation and Critical Conditions

The TMDL must account for seasonal variation and critical conditions. In the Mattole watershed, the summer period is the period when stream temperatures are most likely to have adverse impacts on beneficial uses (young salmonids growing in the streams before migrating to the ocean). To account for seasonal variations and critical conditions, the analysis is based on the MWAT (i.e., the maximum weekly average of the 7 day running average of all monitored temperatures).

Table 4-2. Uncertainties in Mattole River Temperature TMDL

Uncertainty	Adjustment to Account for Uncertainty
Effect of implementing the sediment TMDL on stream channel width:depth ratios	Implementing the sediment TMDL will result in a narrowing and deepening of stream channels, thus improving temperature conditions. This effect was not quantified, but provides an implicit margin of safety.
Effect of implementing the sediment TMDL on frequency and depth of pools	Implementing the sediment TMDL will result in more frequent and deeper pools, which can provide thermal refugia for salmonids. This effect was not quantified, but provides an implicit margin of safety.
Effect of implementing the sediment TMDL on extent of riparian vegetation	Implementing the sediment TMDL will reduce the impact of floods on riparian vegetation, thus improving temperature conditions. This effect was not quantified, but provides an implicit margin of safety.
Effect of larger riparian vegetation on stream microclimates	Implementing the temperature TMDL will result in larger riparian vegetation. Larger vegetation will tend to create microclimates that will lead to improvements in stream temperatures. These effects were not accounted for in the temperature analysis, but provide an implicit margin of safety.
Effect of larger riparian vegetation on large woody debris	Implementing the temperature TMDL will result in larger riparian vegetation. Larger vegetation will increase the potential for contributions of large woody debris to streams. Increases in large woody debris benefit stream temperatures and associated cool water habitat by increasing channel complexity, including the number and depth of pools, which can provide areas of cooler water for fish. These changes were not accounted for in the analysis, but provide an implicit margin of safety.

CHAPTER 5: IMPLEMENTATION AND MONITORING MEASURES

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 C.F.R. Sec. 130.6.

The State implementation measures should contain provisions for ensuring that the load allocations in the TMDLs 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 nonpoint source control program.

Furthermore, the State implementation and monitoring plans should be designed to determine if, in fact, the TMDLs are successful in attaining water quality standards. To assist in this effort, the Mattole River TMDLs contain water quality indicators as well as load allocations.

Both the indicators and load allocations are essentially extensions of the water quality standards, but for sediment they were developed using independent approaches. Different approaches were used because the relationship between land management practices and the effects on water quality related to sediment is highly complex, with factors such as highly variable seasonal and interannual precipitation and landscape response to disturbance, and complexities in geology and sediment routing mechanisms from watershed sources to and through streams. Given the complexities, EPA believes that using two approaches for sediment provides a better basis for evaluating the success of the TMDL in attaining water quality standards.

For temperature, targets are identified not only for effective shade, but for thermally stratified pools. Implementation measures should recognize the importance of sediment control for attaining water quality standards for temperature as well as sediment.

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

In the TSD, NCRWQCB staff conclude that it is clear from the available data that reducing sediment from roads, timber harvesting, and associated management activities should be the highest priority in terms of sediment reduction, and that increasing streamside shade should be the highest priority in terms of temperature reductions. Reducing sediment loads could be achieved by reducing the overall mileage of roads through decommissioning unused roads, upgrading existing roads to reduce sediment delivery to streams, and changes in forestry practices. Correction of small landslides to prevent delivery will also assist in efforts to achieve the TMDL. Increasing streamside shade could be accomplished by limiting tree removal in stream buffer areas, and by restoring riparian buffers where possible.

NCRWQCB staff also conclude in the TSD that the data base of information describing the watershed in terms of sediment delivery, instream conditions, and temperature could also be increased through additional monitoring. The NCRWQCB hopes to work cooperatively with landowners to fully put into practice the implementation and monitoring measures, as specified in amendments to the Basin Plan.

CHAPTER 6: PUBLIC PARTICIPATION

EPA regulations require that TMDLs be subject to public review (40 CFR 130.7). EPA provided public notice of the draft Mattole River sediment and temperature TMDLs in several ways. A legal notice was placed in the Eureka Times-Standard and Humboldt Beacon, newspapers of general circulation in the Mattole River watershed. In addition, NCRWQCB staff compiled a mailing list of persons interested in the Mattole River TMDLs during development of the TSD, based in part on expressions of interest in response to a mailing to all boxholders in the watershed, and meetings with residents. NCRWQCB mailed notices to about 30 persons on the mailing list and to 300 landowners. In addition, the public comment period was announced in the Mattole Restoration Council newsletter distributed in early November.

EPA and NCRWQCB held two informational public meetings in the watershed during the public comment period on the draft TMDLs. The first meeting was held on the evening of 12 November 2002 at the Mattole Grange in Petrolia, and the second was held on the evening of 13 November 2002 at the Whitethorn Grange in Whitethorn. At the meetings, staff from EPA and the NCRWQCB gave presentations explaining the content of the draft TMDLs and TSD and answered questions from the public. No recordings or transcipts of the meetings were made, but NCRWQCB staff took notes on major comments.

EPA has prepared a comment responsiveness summary for all written comments on the draft TMDLs received through the close of the comment period, 25 November 2002. The major comments from the informational public meetings were also included. For each comment, the responsiveness summary includes a summary of the comment and EPA's response to the comment.

REFERENCES

Bull, W. B., 1978, Geomorphic tectonic activity classes of the south front of the San Gabriel Mountains, California: U. S. Geological Survey Contracts Report 14-08-001-G-394; Office of Earthquakes, Volcanoes, and Engineering, Menlo Park, California, 59 p.

Bull, W. B. 1979, Threshold of critical power in streams: Geological Society of America Bulletin, v. 90, p.453-464.

Bull, W. B. 1991, Geomorphic Responses to Climatic Change. Oxford University Press, New York, New York, 1991, p. 227-234, 275-246.

Bureau of Land Management, 1996, Honeydew Creek Watershed Analysis, U.S. Department of the Interior, Bureau of Land Management, Arcata, CA. November, 1996. 89 p. plus appendices.

Burns, J.W., 1970, Spawning bed sedimentation studies in north California streams. California Fish and Game, v. 56, no. 4, p. 253-279.

Bybee, J. R., 2000, Letter addressed to Janet Parrish, U.S. Environmental Protection Agency region IX, San Francisco, from National Marine Fisheries Service, southwest Region, Santa Rosa. 1 DEC 00.

California Department of Fish and Game, 2002, Assessment of anadromous salmonids and stream habitat conditions of the Mattole River basin, 194 p. Appendix D *in* North Coast Watershed Assessment Program Mattole River Draft Report. 19 JUL 02.

California Department of Forestry and Fire Protection, 1994, Coho salmon habitat impacts: Qualitative assessment technique for Registered Professional Foresters (Draft No. 2): Prepared for the Board of Forestry. Sacramento, CA.

California Department of Water Resources, 1965, North Coastal area investigation, Appendix C, Fish and Wildlife, Dept. of Water Resources Bulletin, No. 36. California Dept. of Water Resources.

Coastal Headwaters Association, 1982, Mattole Survey Program, first annual report, August 1981 - August 1982. Unpublished report prepared under contract to the California Department of Fish and Game, Sacramento, California, by Coastal Headwaters Association, Whitethorn, California. 50 p. plus appendices.

Dietrich, W.E., Real de Asua, R., Coyle, J., Orr, B., and Trso, M., 1998, A validation study of the shallow slope stability model, SHALSTAB, in forested lands of Northern California: Prepared for Louisiana-Pacific Corporation, Calpella, CA, 29 JUN 98.

Flanagan, S.A., Furniss M.J., Ledwith T.S., Thiesen S., Love, M., Moore, K., and Ory, J., 1998, Methods for inventory and environmental risk assessment of road drainage crossings. U.S. Department of Agriculture, Forest Service. Research Paper No. 9877-1809-SDTDC. DEC 1998.

Flosi, G., Downie, S., Hopelain, J., Bird, M., Coey, R., and Collins B., 1998, California salmonid stream habitat restoration manual, Third edition. California Department of Fish and Game. JAN 1998.

Furniss, M.J., Flanagan, S.A., and McFadin, Bryan, 2000, Hydrologically-connected roads: An indicator of the influence of roads on chronic sedimentation, surface water hydrology, and exposure to toxic chemicals: Stream Notes, Stream Systems Technology Center, USDA Forest Service, Rocky Mountain Research Station, Fort Collins, CO, JUL 00, 3 p.

Knopp, C., 1993, Testing indices for cold water fish habitat, final report for the North Coast Regional Water Quality Control Board. California Regional Water Quality Control Board, North Coast Region. AUG 93.

Lewis, J., 1998, Evaluating the impact of logging activities on erosion and suspended sediment transport in Caspar Creek Watersheds. In Proceedings of the Conference on Coastal Watersheds: The Casper Creek Story, 6 MAY 98. USDA Forest Service Gen. Tech. Rep. PSW-GTR-168.

Ligon, F., A. Rich, G. Rynearson, D. Thornburgh, and Trush, W., 1999. "Report of the Scientific Review Panel on California Forest Practice Rules and Salmonid Habitat." Prepared for the Resources Agency of California and the National Marine Fisheries Service, Sacramento, CA.

Lisle, T.E., 1989, Sediment transport and resulting deposition in spawning gravels, north coast California. Water Resources Research, v. 25, no. 6, p. 1303-1319.

Lisle, T.E, and Hilton, S., 1992, The volume of fine sediment in pools: An index of the supply of mobile sediment in stream channels. Water Resources Bulletin, v. 8, no. 2, p. 371-383.

Lisle, T.E., and Hilton, S., 1999, Fine bed material in pools of natural gravel-bed channels: Water Resources Research, vol. 35, no. 4, p. 1291-1304. Available online at: http://www.rsl.psw.fs.fed.us/projects/water/Lisle99WR35_4.pdf

Madej, M. A., 1999, Time, space, and rates of change in channel monitoring. *in* Using stream geomorphic characteristics as a long-term monitoring tool to assess watershed function: a workshop: Co-sponsored by Fish, Forests, and Farm Communities Forum; Forest Science Project; and the Americorps Watershed Stewards Program. Edited by Ross N. Taylor, M.S. Arcata, CA.

Mattole Restoration Council, 1995, Dynamics of Recovery; A plan to enhance the Mattole estuary. Mattole Restoration Council, Petrolia, California. FEB 95.

McHenry, M.L., Morrill, D.C., and Currence, E., 1994, Spawning gravel quality, watershed characteristics and early life history survival of coho salmon and steelhead in five north Olympic peninsula watersheds. Port Angeles, WA. 59 p.

Merrits, D.J. 1996, The Mendocino triple junction: Active faults, episodic coastal emergence and rapid uplift. Journal of Geophysical Research, v. 101, no. B3, p. 6051-6070.

Nielsen, J.L., Lisle, T.E., and Ozaki, V., 1994, Thermally stratified pools and their use by steelhead in northern California streams: Transactions of the American Fisheries Society, v. 123, p. 613-626.

North Coast Regional Water Quality Control Board (NCRWQCB), 1996, Water Quality Control Plan for the North Coast Region (Basin Plan). As amended, through 23 MAY 96.

North Coast Regional Water Quality Control Board (NCRWQCB), 2000, Reference Document for the Garcia River Watershed Water Quality Attainment Action Plan for Sediment. (Revision to 12/09/97 Garcia River Watershed Water Quality Attainment Strategy for Sediment) 21 SEP 00.

North Coast Regional Water Quality Control Board (NCRWQCB), 2001a, California Department of Fish and Game's Natural Diversity Database, 2001 in the Staff Report for the Proposed Amendment to the Water Quality Control Plan for the North Coast Region to Revise Section 2, Beneficial Uses with Respect to the RARE, MIGR, and SPWN Beneficial Uses, 22 MAY 01.

North Coast Regional Water Quality Control Board (NCRWQCB), 2001b, Assessment of aquatic conditions in the Mendocino Coast hydrologic unit. Chapter 4: Ten Mile River. 7 SEP 01.

North Coast Regional Water Quality Control Board (NCRWQCB), 2002, Mattole River Watershed Technical Support Document for Sediment and Temperature, DEC 02.

North Coast Watershed Assessment Program (NCWAP), 2002, Mattole River watershed synthesis report (draft). State of California, Resources Agency. Sacramento, California. 306 p. plus appendices.

O'Loughlin, C. L. and Pearce, A. J., 1982, Erosion processes in the mountains, *in* J. M. Soons, and M. J. Selby *eds*., Landforms of New Zealand: Aukland, Longman Paul, pp67-79.

Pacific Watershed Associates, 1998, Sediment source investigation for the lower Eel River (draft). Prepared for U.S. Environmental Protection Agency, San Francisco, CA. JAN 98.

Plafkin, J.L., Barbour, M.T., Porter, K.D., Gross, S.K., and Hughes R.M., 1989, Rapid bioassessment protocols for use in streams and rivers: benthic macroinvertebrates and fish. US Environmental Protection Agency. EPA/440/4-89/001. Washington D.C.

Stillwater Sciences, 1999, South Fork Eel TMDL: sediment source analysis, prepared for Tetra Tech, Inc., 3 AUG 99.

Tappel, D.T., and Bjornn, T.C.,1983, "A New Method of Relating Size of Spawning Gravel to Salmonid Embryo Survival". North American Journal of Fisheries Management. Vol 3, Pp. 123-135.

Thompson, P. A., and MacArthur, R. S., 1969, Major river control, drainage and erosion control scheme for Kaikoura: Marlborough Catchment Board Report.

Trush, B., 1999, Know your X's and Y's. In Using stream geomorphic characteristics as a long-term monitoring tool to assess watershed function: a workshop. Co-sponsored by Fish, Farm, Forests, and Farm Communities Forum; Simpson Timber company; National Marine fisheries Service, Environmental Protection Agency; Forest Science Project; and the Americorp Watershed Stewards Program. Edited by Ross N. Taylor, M.S. Arcata, CA.

U. S. Environmental Protection Agency, 1998a, South Fork Trinity River and Hayfork Creek Sediment Total Maximum Daily Loads.

U. S. Environmental Protection Agency, 1998b, Redwood Creek Sediment Total Maximum Daily Load.

U.S. Environmental Protection Agency, 1999a, Van Duzen River and Yager Creek Total Maximum Daily Load for Sediment.

U.S. Environmental Protection Agency, 1999b, Noyo River Total Maximum Daily Load for Sediment.

U.S. Environmental Protection Agency, 2001, Trinity River Total Maximum Daily Load for Sediment.

Valentine, B.E. 1995, Stream substrate quality for salmonids: guidelines for sampling, processing, and analysis. Appendix B of Aquatic Field Protocols Adopted by the Fish, Farm, and Forest Communities (FFFC) Technical committee, Version 1.1 compiled by R.N. Taylor, OCT 96.

Weaver, W. E., and Hagans, D.K., 1994, Handbook for Forest and Ranch Roads: A Guide for Planning, Designing, Constructing, Reconstructing, Maintaining and Closing Wildland Roads. Prepared for the Mendocino County Resource Conservation District, Ukiah, CA, in cooperation with the California Department of Forestry and Fire Protection and the USDA soil Conservation Service. 149 pages plus appendices.

Ziemer, R.R. 1998, Flooding and Stormflows, *in* Ziemer, R. R., technical coordinator. Proceedings of the conference on coastal watersheds: the Caspar Creek story, 6 May 1998; Ukiah, California. General Tech. Rep. PSW GTR-168. Albany, California: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture, p. 24.

GLOSSARY

Adjusted potential shade	The shade associated with either potential tree heights reduced by 10% (to account for natural events, such as fire, landslides, and windthrow) or existing tree heights, whichever is greater.
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.
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.
Basin Plan	The Water Quality Control Plan, North Coast Region-- Region 1.
CDF	The California Department of Forestry and Fire Protection.
CDFG	The California Department of Fish and Game.
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.
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.
Effective Shade	The reduction in solar radiant energy resulting from topography and vegetation.
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, a term 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.
Fry	A young juvenile salmon after it has absorbed its egg sac and emerged from the redd.
GIS	Geographic Information System.
ICE	Information Center of the Environment at University of California at Davis.
Inner gorge	A geomorphic feature generally identified as that area of stream bank situated immediately adjacent to the stream, having a slope generally over 65% and being situated below the first break in slope above the channel.
Inside ditch	The ditch on the inside of the road, usually at the foot of the cutbank.
Landslide	Any mass movement process characterized by downslope transport of soil and rock, under gravitational stress by sliding over a discrete failure surface-- or the resultant landform.
LWD	Large woody debris; a piece of woody material having a diameter greater than 30 cm (12 inches) and a length greater than 2 m (6 feet) located in a position where it may enter the watercourse channel.
Mass wasting	Downslope movement of soil mass under force of gravity-- often used synonymously with "landslide." Common types if mass soil movement include rock falls, soil creep, slumps, earthflows, debris avalanches, debris slides and debris torrents.
MRC	Mattole Restoration Council.
MWAT	Maximum Weekly Average Temperature is the maximum week of the 7 day running average of all monitored temperatures.
NCRWQCB	The California Regional Water Quality Control Board, North Coast Region.
NCWAP	North Coast Watershed Assessment Program.
NMFS	The United State National Marine Fisheries Service.
Pool Tail-out	The downstream end of a pool, where the main current narrows, forming a "tail."
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.
Riffle	A reach of stream characterized by an increased water velocity resulting from a drop in elevation, usually shallow.
Riffle Head	The beginning (i.e., upstream end) of a riffle (also known as a pool tail-out).
Riparian	The area adjacent to streams.
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	Material (usually referring to sediment) which is delivered to a watercourse.
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.
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.
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.
Thermal refugia	Relatively cool areas in streams where fish can go to minimize stress due to warm water.
Thermally stratified pools	Areas in streams where the water is still and deep enough to form two layers: a warmer layer on top and a relatively cooler layer at the bottom.
TMDL	Total Maximum Daily Load.
TSD	Technical Support Document (NCRWQCB, 2002).
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 antidegradation policy.

Figure 1-2.

Figure 4-2.

Figure 4-3.