California Regional Water Quality Control Board
North Coast Region

Mattole River Watershed

Technical Support Document for the Total Maximum Daily Loads for Sediment and Temperature

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CONTENTS

FIGURES

TABLES

APPENDICES

COLOR FIGURES

EXPLANATION OF RIVER MILES

In this TSD, the NCRWQCB has reported river miles as the data was submitted or published. NCRWQCB staff recognize the potential confusion caused by different river mile reporting conventions, however it is not appropriate for the NCRWQCB to alter data submitted. River miles used in different sections of this TSD come from three different conventions:

(1) River miles measured on 1:100,000 scale USGS topographic maps are used by Watershed Sciences LLC to describe positions of thermal infrared data (Sections 2.5.2 and 4.1.3.3).
(2) River miles measured on 1:24,000 scale USGS topographic maps are used by NCWAP in determining miles of "blue line" watercourses (Table 1.4).
(3) The Division of Water Resources river mile convention (DWR, 1973) is used by the Mattole Salmon Group (Sections 1.2.4 and 2.5.2).

To show the correlation between these systems of river miles, NCRWQCB staff has created the table below which shows the position of the mouth of selected tributaries of the Mattole in each of the three river mile systems.

Conversion of River Miles

1:100k streams	1:24k "Blue Lines"	DWR 1973	Tributary
1.7	1.6	1.3	Stansberry Cr
3.9	3.8	2.8	Mill Cr (near estuary)
6.2	6.2	4.7	Lower NFK Mattole
9.7	9.6	7.8	Conklin Cr
13.6	13.6	11.7	Indian Cr
17.2	17.2	14.9	Squaw Cr
21.7	21.8	19.2	Pritchett Cr
29.1	29.3	25.5	Upper NFK Mattole
30.3	30.5	26.5	Honeydew Cr
35.0	35.3	30.4	Dry Cr
41.9	42.4	36.6	Sholes Cr
46.7	47.2	41.1	Mattole Cyn Cr
48.5	49.1	42.8	Bear Cr
53.6	54.4	47.4	Big Finley Cr
57.0	57.8	50.2	Nooning Cr
58.8	59.5	52.1	Bridge Cr
59.5	60.3	52.8	McKee Cr
60.9	61.7	54	Van Arken Cr
64.2	65.2	56.8	Gibson Cr
66.3	67.3	58.4	Thompson Cr
68.1	69.2	59.5	Dream Stream
69.4	70.6	60.8	McNasty Cr
70.3	71.4	61	Headwaters

CONVERSIONS OF UNITS USED ON THIS DOCUMENT

Temperature Conversion

Celsius	Fahrenheit
0	32
5	41
10	50
15	59
16	60.8
17	62.6
18	64.4
19	66.2
20	68
21	69.8
22	71.6
23	73.4
24	75.2
25	77
30	86

Fahrenheit = (9/5)*Celsius + 32
Celsius = (5/9)*(Fahrenheit -32)

Distance Conversion

Meters	Feet
1	0.30
2	0.61
3	0.91
4	1.22
5	1.52
10	3.05
20	6.10
30	9.14
40	12.19
50	15.24
60	18.29
70	21.34
80	24.38
90	27.43
100	30.48

Feet = 0.3048 * Meters
Meters = 3.28 * Feet

CHAPTER 1: INTRODUCTION

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. The State of California has determined that the water quality standards for the Mattole River are exceeded due to sediment and temperature. In accordance with Section 303(d), the State of California periodically identifies those waters that are not meeting water quality standards. In its latest Section 303(d) list, adopted through Resolution 98-45 on 23 April 1998, the North Coast Regional Water Quality Control Board (NCRWQCB) identified the Mattole River as impaired in regard to sediment and temperature. In accordance with a consent decree (*Pacific Coast Federation of Fishermen's Associations, et al. v. Marcus*, No. 95-4474 MHP, 11 March 1997), 2002 is the deadline for establishment of these TMDLs. Because the State of California will not complete adoption of a TMDL for the Mattole River by this deadline, EPA is establishing this TMDL, 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 first purpose of the Mattole River TMDLs is to estimate the assimilative capacity of the river by identifying the total loads of sediment and thermal inputs that can be delivered to the Mattole River and its tributaries without causing exceedence of water quality standards. The second purpose it to allocate the total loads among the sources of sediment and thermal loading in the watershed. Although factors other than excessive sediment and stream temperature in the watershed may be affecting salmonid populations (e.g., ocean rearing conditions), these TMDLs focus on sediment and stream temperature conditions in the watershed, the impairments for which the Mattole River is listed under Section 303(d). The NCRWQCB expects to adopt the TMDL and to develop an action plan (implementation strategy) to implement the TMDL in accordance with 40 CFR 130.6. The load allocations, when achieved, are expected to result in the attainment of the applicable water quality standards for sediment and stream temperatures for the Mattole River and its tributaries.

1.1 Information Sources

Information for this TMDL came from a variety of sources. Parts of the information are 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 North Coast Regional Water Quality Control Board 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 at University of California Davis consulted on aerial photo mapping and 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 Co. 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 (USGS). CDFG provided historical aquatic surveys as well as fish distribution and aquatic habitat data. Published scientific literature was used extensively and is referenced in the document.

1.2 Watershed Characteristics

1.2.1 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 (Figures 1.1, 1.2). Figures 1.3 to 1.8 summarize other geographic, climatic, and geologic information on the area.

1.2.2 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.

1.2.3 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 (Figure 1.3). The data summarized in Figure 1.3 represent the longest continuous data set available at the time this report was prepared. Snowfall occurs occasionally in the higher elevations of the watershed but rarely accumulates. Snow is not considered to have a significant effect on the watershed hydrology. USGS stream gaging records are available for the Mattole River at Petrolia for the periods 1911-1913 and 1950-2002.

1.2.4 Topography

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

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 miles 52.1 to 47.7 is a steep-sided canyon, known locally as the Grand Canyon of the Mattole, having steep cliffs, deep pools, 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 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 26.7 and river mile 5 (Figure 1.2) broadens to as wide as 1,500 feet. Many sections of both river and terraces, mostly bedrock terraces overlain by sand and gravel 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.

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.

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 part 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.

1.2.5 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 (Figure 1.4). 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.

Approximately half of the watershed is occupied by trees 12-24 inches in diameter at breast height (dbh). Approximately twenty percent of the watershed is covered with trees averaging greater than 24 inches dbh, and approximately eleven percent is covered by trees 6 to 11 inches dbh (NCWAP, 2002, p. 63). The distribution of tree sizes reflects the forest disturbance regime in the watershed. Large-scale timber extraction following World War II (described in section 1.4.2), wildfires, conversion of forestland to rangeland, and reversion of rangeland to forestland have all contributed to the abundance of relatively small trees.

1.2.6 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.

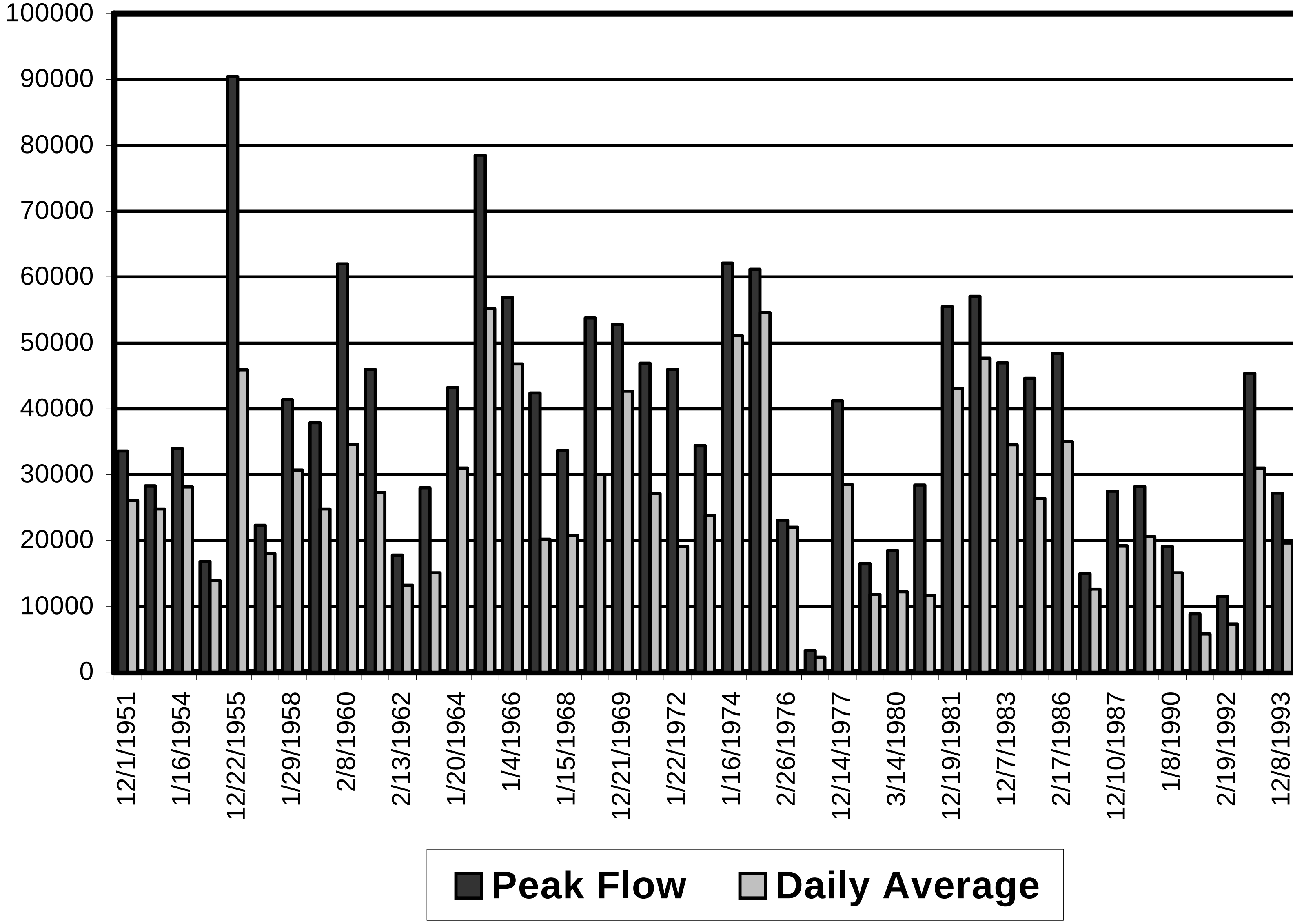

Figure 1.9. Annual instantaneous peak and daily mean flows at Petrolia, water years 1951 to 2001

The highest flows measured in each water year, as well as the highest daily mean flows, from water years 1951 to 2001 (a water year runs from October to September) are presented in Figure 1.8.

The figure illustrates the interannual hydrologic variability typical of the north coast of California. Notable high flows occurred in water years 1956, 1960, 1965, 1966, 1969, 1970, 1974, 1975, 1982, 1983, and 1995. Exceptionally dry years occurred in water years 1977, 1991, 1992, and 2001.

1.3 Geology

1.3.1 Tectonic Setting and Seismicity

The Mattole basin lies in a geologically and tectonically complex setting adjacent to the junction of the North American, Pacific, and Gorda plates, known as the Mendocino Triple Junction (MTJ). Because of active tectonic movements associated with this junction, the uplift rate in the Mattole basin is very high, and seismic activity is frequent. The Mattole basin area is being compressed from the southwest and northeast, and uplift occurs mostly along a series of thrust faults at depth. This activity originates not only along fault zones seen at the surface, but also in intraplate areas underlain by thrust faults (Dengler et al., 1992). Uplift associated with earthquakes is not uncommon.

Earthquakes serve as a periodic and unpredictable yet foreseeable triggering mechanism for landslides in a way unique in north coast basins. Tectonic effects including very high uplift rates and the orographic influence of high, steep mountains near the coast, combine to produce slopes that are in a precarious equilibrium. The added influence of frequent earthquakes generated at the MTJ creates a landslide-prone landscape unique in the region. For example, on April 25, 1992 the Cape Mendocino Earthquake of magnitude 7.1 originated at a depth of seven miles, effectively beneath Petrolia. The North American plate slipped up over the Gorda plate along a gently east-dipping thrust fault (Humboldt State University web site, http://humboldt.edu/~geodept/earthquakes/recent_eqks.html, accessed July 1, 2002). Intensity of the earthquake was determined to be IX on the Modified Mercali Scale (Figure 1.5), intense enough to damage structures designed to be earthquake resistant. At the same time, a stretch of coastline in the vicinity of Cape Mendocino was uplifted four to five feet. Within 18 hours, two aftershocks of magnitude 6.6 originated about 15 miles off shore within the Gorda plate. These earthquakes triggered several landslides in the Mattole watershed, as have earthquakes in the past.

1.3.2 Bedrock Geology

Bedrock underlying the Mattole watershed has been fractured, crushed, sheared, and faulted by intense tectonic activity, making the rock relatively weak and susceptible to erosion and mass wasting. All of the basement rocks in the area are part of the Franciscan Complex, which consists primarily of sedimentary rocks deposited offshore in a trench/continental-slope environment. As the Gorda plate has been overridden by the North American plate, these rocks have been "scraped off" the Gorda plate as it plunges beneath the North American plate, forming tectonic slices called terranes, each of which is bounded by major faults. 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 the argillite and is less sheared and weakened by tectonic deformation. Conglomerate occurs locally in the Franciscan unit along the divide between the Mattole and Eel Rivers. Each terrane has been subdivided into geologic units, each of which is more or less uniform in rock type, fracturing, and type of topography that it produces.

Tectonic deformation and shearing affect the softer argillite more than they affect the stronger and better-cemented sandstone. The difference in competence produced is shown dramatically in the landscape where erosion leaves isolated blocks of sandstone standing as large gray knobs above slopes underlain by less competent argillite. In areas where a large proportion of the bedrock is sandstone, slopes tend to be steeper, and landslides are less numerous, shallower, and smaller. Major shear zones, consisting of tectonically crushed and ground rock, are particularly susceptible to landsliding. Three such major shear zones cut through the Mattole watershed. The Petrolia Shear Zone follows the lower Mattole River valley. The King Range Thrust Fault is exposed along the east flank of the King Range. And the Cooskie Shear Zone crosses the King Range westward from the King Range Thrust Fault to the coast a short distance south of Punta Gorda (a map figure will be included).

1.3.3 Tectonic Uplift, Slope Stability, and Mass Wasting

Dense forest cover may also help to produce the very steep slopes in the Mattole watershed. Sidle and others (1985) concluded that very steep slopes on geologic units similar to those in the Mattole watershed would not have been able to form unless the slopes were stabilized by the protection of dense forest. The forest stabilizes the slope in four major ways: (a) a dense tangle of roots within the soil and penetrating down into fractured, weathered bedrock tends to hold the soil in place and stabilize the slope; (b) the large amount of water used by the vegetation keeps the water table lower than it would be without this water use; (c) the trees break the impact of falling rain so that surface erosion is minimized, and (d) duff on the ground absorbs water and prevents surface flow and attendant erosion. Thus, the forest itself may have a significant effect in shaping the landscape. Other studies that examine the contribution of roots to slope stability include Gray and Leiser (1982), Hammond and others (1992), and USFS (1994). For a discussion of the effect of rapid tectonic uplift on total erosion rates, see Appendix I.

1.3.4 Combined Geologic Units

In this TMDL study, the resistance of a geologic unit to mass movement such as landslides, debris slides, and soil creep is more important than the name, age, and composition of the unit. For the purposes of this report we have grouped bedrock geologic units into geomorphic terrains as developed by the California Geological Survey (NCWAP, 2002). These soft, moderate, and hard terrains are geomorphic units that have the greatest, intermediate, and least tendency toward slope failure by mass movement. The grouping of units is shown in Table 1.1, and the resulting derivative map is Figure 1.6.

The total area accounted for in Table 1.1 is 94 percent of the watershed. The remaining 6 percent is underlain by Quaternary deposits and bedrock units of very small extent.

The USGS has defined eight Quaternary units in the area, including stream and marine terrace deposits of ages ranging from Middle Miocene to Holocene and alluvial fan deposits (McLaughlin and others, 2000). These deposits generally form near-level surfaces and are affected by mass wasting and bank erosion primarily where rivers and streams cut laterally against them.

1.4 History, Land Use, and Water Use

1.4.1 Early Exploration and Commerce.

The first Western explorer into the valley was John Hill of Fort Humboldt, who wrote in 1854 of the tall grass and abundant wildlife in the area. During the next decade settlers moved into the valley to farm and raise cattle. These people 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 populations of the Mattole and Sinkyone peoples were nearly eliminated. Between 1865 and World War

II, oil, tanbark, and agricultural booms filled the valley repeatedly with new settlers who kept bottom lands cleared and in agricultural production. Upland forests were cleared

Table 1.1 Grouping of bedrock geologic units as Soft, Moderate, and Hard. Bedrock units from McLaughlin and others (2000). Grouping of units from NCWAP (2002), Appendix 1, p. 30-31.

Geomorphic Terrain	Bedrock Symbol	Name and Description of Bedrock Unit Within the Franciscan Complex	Per cent of area
Soft	cm1	Central Belt Melange -- mostly sheared meta-argillite and blocks of metasandstone	23
	Sp	Serpentinite	
	co1	Coastal Belt melange -- argillite, penetratively sheared	
Moderate	y1	Yager Terrane -- sheared and highly folded mudstone	34
	co2	Coastal Belt melange -- shattered sandstone and argillite	
	krk1	King Range Terrane -- melange and folded argillite, thin-bedded, highly folded	
Hard	y2	Yager Terrane -- mudstone, sandstone, and conglomerate, highly folded and broken	37
	y3	Yager Terrane -- sandstone, conglomerate, mudstone, highly folded, little-broken	
	co3	Coastal Terrane -- sandstone and argillite, broken	
	co4	Coastal Terrane melange -- sandstone and argillite, intact	
	krk2	King Range Terrane -- sedimentary rocks, highly folded and broken	
	krk3	King Range Terrane -- sedimentary rocks, highly folded, largely unbroken	
			94

for pasture by girdling and burning the trees that covered them. In addition, escaping homestead fires burned destructively into the forests, which at that time were of little value to settlers. In the lower Mattole, pasture and field crops occupied most river bottom flats until the middle of this century. A terrace known as Duncan Flat, a quarter of a mile from the mouth was the site of a pasture, with a dairy farm located across the river on the south bank. 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 (MRC, 1995).

1.4.2 Timber Harvest

The decades following World War II brought a timber boom to the Mattole watershed. During this short period, two of the most significant changes to the landscape took place – logging in almost every corner of the basin and the simultaneous construction of thousands of miles of logging roads. Analysis of aerial photos from the early 1940s through the mid-‘50s shows the sudden appearance of extensive networks of logging roads and skid trails – features that were absent in the 1942 pictures. Photos from the 1960s show an even greater increase in road density, and following the 1964 flood, widespread landsliding and channel aggradation are apparent. The amount of sediment mobilized during this period of less than two decades overwhelmed stream systems and severely upset any equilibrium that may have been established. As Douglas fir timber became valuable, wildfire was actively suppressed. At the same time, logged openings filled with brush and other early successional species, or with crowded stands of young growth that led to an increase in fuel loads. When ignited, these areas have produced intense, stand-replacing conflagrations (MRC, 1995).

Several factors promoted the post-war boom in timber harvest. In the post-war building boom Douglas fir became a major marketable commodity, supplementing the redwood that was being harvested throughout the north coast region. Improved roads into the Mattole watershed allowed better access for extraction of the resource and transport of the logs and lumber to market. The technology of tracked heavy equipment, developed during the war, transferred to the civilian world and evolved the tractors and other equipment that allowed large-scale harvest on the very steep slopes in the Mattole watershed (Figure 1.7).

The most intense harvesting, in terms of acres per year, took place in the period from 1945 to 1961 Table 1.2). However, the average figure of 4,288 acres per year for that 17-year period may be misleading. Residents interviewed remember very little logging going on before the landmark 1955 flood. Aerial photos, however, reveal some systematic logging, although not nearly as much as after 1955 (Fay Yee, CDF, spoken communication to D.A. Coates, 2002). Data are not presently available to determine the actual acreage logged between 1955 and 1961, but two sources indicate that the rate increased dramatically during that time. For this reason we must conclude that in some years between 1955 and 1961 the area logged considerably exceeded the 17 year average of 4,288 acres. Since 1974, rates of harvesting have decreased to a nearly stable level, a trend that is apparent in Table 1.2.

Table 1.2 Timber Harvest History in the Mattole River Watershed., modified from NCWAP (2002) Table 5.

Years Harvested	Interval, years	Total acres	Acres/year	Percent of area
1945-1961	17	72,897	4,288	38
1962-1974	13	21,141	1,626	11
1975-1983	9	6,948	772	4
1984-1989	6	4,150	692	3.5
1990-1999	10	7,866	786	4
2000-2001 part	2	583		

In many instances the timber was "mined" from the land with no regard for best management practices, cumulative effects, or long-range management. Responsible operations may have been conducted where the landowner had a say in the logging operation, but this was usually not the case. Most logging operations took place in remote areas, out of sight and out of mind (MRC, 1995).

The course of logging in the Mattole basin was strongly influenced by a changing tax structure. Gilligan (1966) summarized the history of taxes on standing timber as follows. Taxation of douglas-fir began in 1946 at the rate of $0.60/acre plus $0.10/acre land tax. By 1956, the timber tax had risen to $2.80/acre and the land tax to $0.22/acre. By 1961 the timber tax had been raised to $3.75/acre. These taxes on standing timber virtually forced some landowners to cut timber and provided strong incentive to others. Following logging, provided 70% or more of the timber was cut, the timber tax was dropped and only the land tax applied. Changes in this tax structure beginning in the 1970s essentially removed any tax incentive to cut timber.

The addition of unregulated logging in the 1940s and 1950s led to an overall regime shift in sediment production. The addition of logging and road construction to the devastating effects of extreme flood events swamped the river system with an enormous load of sediment that changed the form and functioning of the stream system. Some of these effects are still felt today in the form of elevated turbidities and fine sediment loads, filled pools, and aggraded reaches of the mainstem Mattole and tributaries.

During the timber boom, extremely heavy rainfall in 1955 and 1964 triggered erosion throughout the watershed from lands recently roaded and logged. High flows, heavily laden with bedload, filled main channels and washed over the deforested floodplain, sweeping away topsoil and carving a much wider channel. The river eliminated many acres of bottomland during these floods, including most of Duncan Flat, the last traces of which were washed away by 1970. The floodplain is a geologically dynamic area where terraces and river bars are alternately created and scoured away by high flows. But the events of 1955 and 1964 greatly accelerated that process, reflecting rates of sediment discharge vastly greater than those that prevailed before widespread logging. As a result, those terraces and floodplains presented a less stable environment for riparian vegetation and for floodplain agriculture; many acres were converted from productive soils to gravel bar and removed from agricultural production. During the period from 1955 to the present, high waters filled in the deep holes with gravel and swept away much of the riverbank vegetation (MRC, 1995).

Cattle and sheep grazing remains the principal use of the lower Mattole floodplain between river mile 1.7 and the confluence with the Lower North Fork at mile 4.5. In the mid-1970s, a large ranch was subdivided in the area, and the resulting small parcels attracted numerous new settlers to the area. As a result, the patterns of land ownership are more fragmented than in the past, and land uses are more varied. Locally, the river bar is treated as a commons and is used for small-scale gravel extraction, firewood cutting, hunting, and target practice. Fishing was formerly a major use of the estuary. Local inhabitants turned out each year during salmon runs to fish at the first riffles. That practice declined with the populations of fish, and was banned outright in 1991, when the state Fish and Game Commission prohibited fishing in the lowermost mile of the river to protect salmonids in response to requests from the Mattole Watershed Alliance (MRC, 1995).

1.4.3 New Settlers

Beginning in the 1960s a "back to the land" movement brought new settlers into the Mattole into subdivided land, generally on recently logged areas. Many of these people were interested in learning to rehabilitate and work their own land and to create an income. Local unemployment was estimated at 50 percent in 1999 (NCWAP, 2002), but much of the available work is seasonal so the actual unemployment is hard to calculate. In addition, the area is rumored to harbor a large underground economy of marijuana cultivation.

1.4.4 Water Rights

Water rights in the Mattole basin fall into five major categories; (a) domestic use, (b) industrial use, (c) irrigation use, (d) fire protection, and (e) a group of pre-1914 rights.

Thirty domestic use permits total 372 acre-feet per year (Table 1.2). Six of these permits are for five-and-a-half to seven months through the spring and summer, and the remainder allow water use throughout the year. Only one industrial use permit is active at present, for 1.1 acre-feet, and fire protection accounts for 35 acre-feet (Table 1.3). The biggest permitted use is for irrigation. Of 26 irrigation use permits, only four allow water use all year, and the rest restrict use to four to seven months from mid-spring to early fall.

The last group, pre-1914 rights, includes statements of water diversion and use, riparian water rights, stock ponds, and others. For the most part these are rights established by prior use rather than permits granted by application. The State Water Resources Control Board has records of these rights totaling 410.8 acre-feet per year (SWRCB, Water Rights Division, internal documents, July 2002). Registered water use permits and pre-1914 rights total 2,593 acre-feet per year.

The amount of water use permitted may not accurately indicate how much water is actually used. It is possible that not all the permitted water is used every year. Because extraction is not monitored, there is no way to know whether some permitted users are using more or less than their permits allow. At present, there is no way to know whether some users may be taking water illegally without any permit. In addition, the rumored underground industry of marijuana growing may consume a significant amount of water that is neither permitted nor accounted for.

<u>Table 1.3 Water permits in the Mattole River watershed</u>

Domestic Use

CFS	GPD	Months used	Days used	Gallons per year
	8400	12	365	3066000
	4500	12	365	1642500
	175	5-1;10-15 (5.5)	167	29225
0.083	53641	12	365	19578810
0.08	51702	12	365	18871142
0.08	51702	12	365	18871230
0.08	51702	12	365	18871230
	1000	12	365	365000
0.07	45239	5-1;10-31 (6)	182	8233505
	1800	12	365	657000
	3000	12	365	1095000
	50	5-1;11-1 (6)	183	9150
	100	5-1;11-1 (6)	183	18300
0.046	29729	5-1;12-1 (7)	215	6391735
	100	12	365	36500
	17000	12	365	6205000
	1000	12	365	365000
	550	12	365	200750
	200	12	365	73000
	450	12	365	164250
	1500	12	365	547500
	4000	12	365	1460000
	4090	12	365	1492850
	4090	12	365	1492850
	446	4-1;11-1 (7)	215	95890
	4500	12	365	1642500
	7200	12	365	2628000
	4300	12	365	1569500
	14400	12	365	5256000
	750	12	365	273750
Total gallons of domestic water per year =				121203168
Total acre-feet of **domestic** water per year =				372

Industrial

CFS	GPD	Months used	Days used	Gallons per year
	2000	10-1;4-1(6)	183	366000
Total gallons of industrial water use per year =				366000
Total acre-feet of **industrial** water use per year =				1.1

Irrigation Use

CFS	GPD	Months used	Days used	Gallons per Year
	8400	12	365	3066000
	4500	12	365	1642500
0.17	109866	5-15;11-15 (6)	182	19995656
0.083	53641	4-15;11-1(6.5)	198	10620834
0.08	51702	5-15;10-15 (5)	152	7858668
0.08	51702	5-15;10-15 (5)	152	7858704
0.08	51702	5-15;10-15 (5)	152	7858704
0.89	575182	6-1;10-1 (4)	152	87427676
0.12	77553	5-1;10-15 (5.5)	167	12951291
0.43	277897	5-1;10-1 (5)	152	42240338
0.035	22620	5-15;10-15 (5)	152	3438167
0.35	226195	5-15;10-15 (5)	152	34381670
0.07	45239	5-1;10-31 (6)	167	7554920
0.82	529943	5-1; 10-1 (10)	304	161102672
0.36	232658	6-1; 10-15 (4.5)	137	31874146
0.02	12925	5-15;10-1 (4.5)	137	1770725
	3000	12	365	1095000
	3900	6-15;11-30(5.5)	167	651300
0.046	29729	5-1;12-1 (7)	215	6391735
	17000	5-1;10-15 (5.5)	167	2839000
0.53	342524	6-1;11-1 (5)	152	52063648
0.066	42654	5-1;10-31 (6)	183	7805682
0.07	45239	5-1;11-30 (7)	215	9726385
	1400	6-1;10-1 (4)	122	170800
0.45	290822	5-1;10-31 (6)	183	53220426
	137	5-15;10-31(5.5)	167	22879
Total gallons of irrigation water per year =				575629525
Total acre-feet of **irrigation** water per year =				1766

Fire Protection

CFS	GPD	Months used	Days used	Gallons per Year
	550	12	365	200750
0.07	45239	5-1;11-30 (7)	215	9726394
	4000	12	365	1460000
Total gallons of fire protection water use per year =				11387144
Total acre-feet of **fire protection** water use per year =				35

Total gallons of permitted water use per year =	708585837
Total acre-feet of permitted water use per year =	**2174**

The fact that a large proportion of domestic and irrigation water use is permitted over the summer months is important to the hydrology of the fluvial system. This drawdown during the low-flow season may affect the summer flow of the Mattole and its major tributaries. However, the amount of water drawn out of the fluvial system for use is not necessarily lost to the system. An undetermined though probably small portion of this water returns to the system through infiltration and runoff.

1.5 Endangered Species Act Consultation

USEPA initiated informal consultation with the National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (the Services) on this action, under Section 7(a)(2)of the Endangered Species Act (ESA). Section 7(a)(2) states that each federal agency shall ensure that its actions are not likely to jeopardize the continued existence of any federally listed endangered or threatened species. USEPA's consultation with the Services has not yet been completed. Therefore, USEPA is establishing this TMDL subject to the results of the consultation. USEPA believes that it is unlikely that the Services will conclude that establishment of the TMDL violates Section 7(a)(2). This TMDL provides planning information which should assist the State and other interested parties in identifying appropriate implementation actions to reduce sediment loading. Any effects associated with implementation actions by other parties pursuant to State or local authorities are expected to be beneficial to listed salmonids. Additionally, USEPA believes that any effects associated with establishment of this TMDL by EPA, or any implementation actions by other parties, will either have no effect, or only beneficial effects, on any other listed species. Therefore, EPA believes that it is better both for water quality protection generally and for the at-risk species to establish this TMDL even though consultation has not been completed. However, EPA retains the discretion to revise this TMDL if the consultation identifies deficiencies in the TMDL that could potentially violate Section 7(a)(2) of the ESA.

USEPA believes it is unlikely that the Services will conclude that the TMDL that EPA is establishing violates Section 7(a)(2), since the TMDL and load allocations are calculated in order to meet water quality standards, and water quality standards are expressly designed to "protect the public health or welfare, enhance the quality of water and serve the purposes" of the Clean Water Act, which are to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters." Additionally, this action will improve existing conditions. However, USEPA retains the discretion to revise this action if the consultation identifies deficiencies in the TMDL or allocations.

1.6 NCWAP Subbasins

For this study, 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). Each subbasin is a division of the watershed of the Mattole River and its associated tributaries and is a combination of CALWATER 2.2a Planning Watersheds. 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 1.4

1.7 Organization

This report is divided into six chapters. Chapter 2 (Problem Statement) describes the nature of the environmental problems addressed by these TMDLs. Chapter 3 (Sediment) defines water quality indicators and targets for sediment contributions, sources of sediment, and sediment TMDL allocations. Chapter 4 (Temperature) examines sources of increased stream temperatures and Temperature TMDL and allocations. Chapter 5 (Implementation and Monitoring Recommendations) contains recommendations regarding implementation and monitoring of the TMDLs. Chapter 6 (Public Participation) describes public participation in the development of the TMDLs.

Table 1.4 Summary of attributes of subbasins in the Mattole River watershed. Table modified from NCWAP (2002), Table 3.

	Estuary	**Northern**	**Eastern**	**Southern**	**Western**	**Total**
Square Miles	2	98	79	28	89	296
Total Acres	1,326	62,857	50,794	17,640	57,144	189,761
Bureau of Land Management	385	277	2,412	1,442	25,506	30,022
Other Public Lands	0	220	668	342	0	1,230
Private Lands	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 (in.)	60	50-115	80-115	75-85	60-100	
Miles of Blueline Stream	71.4 Estuary and mainstem	69.4	49.9	27.5	85.6	303.4
Lowest elevation (ft.)	0	0	351	864	0	
Highest Elevation (ft.)	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	Warm summer temps; little canopy; good steelhead population only	High summer temps; large sediment load; little canopy; Steelhead and Coho	Favorable water temps; good canopy; good LWD supply; Steelhead, Coho, Chinook	Favorable temps in small tribs and upper parts of large tribs; good canopy; Steelhead, chinook; Coho	
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 qualitative assessment of existing instream and watershed conditions in the Mattole River basin.

This analysis is based on data that have been gathered by the Regional Water Board 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 (Summary of Water Quality Indicators and Targets) is based on the problems identified in this analysis. As additional data become available, such as through the North Coast Watershed Assessment Program (NCWAP) Limiting Factors Analysis, the TMDL and numeric targets can be modified by the NCRWQCB in the future.

2.1 Water Quality Standards

2.1.1 TMDL Defined

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 anti-degradation policy. The State of California uses slightly different terms for its water quality standards than does the USEPA (i.e., beneficial uses, water quality objectives, and a non-degradation 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 simply refers to water quality standards.

2.1.2 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).

In addition, 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.

2.1.3 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 TMDL

Parameter	Water Quality Objective
Suspended Material	Waters shall not contain suspended material in concentrations that cause nuisance or adversely affect beneficial uses.
Settleable Material	Waters shall not contain substances in concentrations that result in deposition of material that causes nuisance or adversely affect beneficial uses.
Temperature	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 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 Decline of Salmon and Steelhead

2.2.1 Large Historical Population.

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 (BLM 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 (USFWS) 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).

The DWR (1965) speculated that increases in siltation and debris jams following intensive logging that started in the early 1950s had caused a significant reduction in the size of anadromous fish runs since 1955. Prior to 1954, the Mattole River had an exceptionally good winter steelhead trout fishery. The fishery had deteriorated seriously since 1954. In fact, DWR (1965 in DFG, 2002) stated:

> It is sufficient to note here that the Mattole River was formerly one of the better king salmon (chinook salmon), steelhead (trout), and silver salmon (coho salmon) producers of the entire coast. Since 1950, excessive logging operations have taken place in the drainage, which has severely damaged the stream, primarily from siltation. The stream is still considered to have the potential to again be the major fish producer that it was historically if improved logging and land management principles are followed

2.2.2 Decline in Population

Over the past two to four decades, Mattole Salmon runs have declined sharply. Anecdotal evidence from as recently as the early 1970s indicates that salmon and steelhead were an important source of food for the people who lived there, and that fish returning to spawn were so numerous that they could be speared, snagged, or netted at numerous locations along the lower river. 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. As a result of these trend estimates, and other factors, the California Fish and Game Commission, acting on a recommendation from the Mattole Watershed Alliance, in August of 1991, banned the sport harvest of coho and chinook on the Mattole River. The Commission restricted the steelhead fishery by shortening the season (open January 1 to August 31) and limiting gear to artificial lures with barbless hooks. In addition, the estuary/lagoon, all Mattole tributaries, and the mainstem above Honeydew Creek are closed to sport fishing year-around (MRC, 1995).

Additionally, Nehlsen and others (1991) and Higgins and others (1992) both mention Mattole salmonid runs in their overviews of the risk of extinction of salmon runs in the Pacific and Northern California, respectively. They concluded that fall-run chinook salmon and coho salmon in the Mattole Basin had a high risk of extinction (DFG, 2002).

2.2.3 Threatened and Endangered Species

Declining numbers of salmonids led the National Marine Fisheries Service (NMFS, 2002) 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 Fishery Information Specific to the Mattole Watershed

Sections 2.3.1 through 2.3.7, contain summaries; of information presented in greater detail in the California Department of Fish and Games, Draft Assessment of Anadromous Salmonids and Stream Habitat Conditions of the Mattole River Basin (DFG, 2002).

2.3.1 California Department of Fish and Game Surveys

From 1950 to 1990 the California Department of Fish and Game conducted many stream surveys in the Mattole River watershed. Surveys in 1951 of Squaw Creek and Honeydew Creek both indicate thriving salmonid populations with high rates of natural reproduction. A stream survey of Bear Creek conducted in 1952 indicated that steelhead trout young-of-the-year were present in good numbers.

Out of 58 streams in the Mattole watershed surveyed in the 1960s, steelhead trout were found in 35, coho salmon were found in 10, and unidentified salmonids were found in 22. In June 1966, high densities of steelhead trout were estimated for the East Branch of the Lower North Fork Mattole River (500 per 100 feet of stream) and East Mill Creek (300 per 100 feet of stream). In the summer of 1966, coho salmon were found in East Mill Creek and Devil's Creek. In August 1966, steelhead trout density in McKee Creek was estimated at 300 per 100 feet of stream. In August 1966, steelhead trout density in Baker Creek was estimated at 100 per 100 feet of stream and coho salmon were found in Upper Mill Creek. A survey of Squaw Creek in August 1966 found approximately 150 steelhead trout per 100 feet of stream. In August 1965, coho salmon were found in Westlund Creek and Harrow Creek.

A survey of 24 streams in the 1980s showed a very different picture. Steelhead trout were found in 18 of the streams, rainbow trout were found in 4, chinook salmon were found in one, and unidentified salmonids were found in 10. Steelhead trout density in Baker Creek was estimated at 30-40 per 100 feet of stream in November 1982. The density of steelhead trout was estimated at 75-100 per 100 feet of stream in Jewett Creek in April 1981. Only eight steelhead trout were found by electrofishing along 650 feet of Bear Trap Creek in March 1981, and no salmonids were observed in Woods Creek in January 1981. A survey of Squaw Creek in March 1985 found 30 juvenile salmonids per 100 feet of stream, 115 redds, 24 adult steelhead trout, and two steelhead trout carcasses.

2.3.2 Bureau of Land Management Surveys

BLM conducted 24 stream surveys from 1972 to 1977. Observations include "few" juvenile steelhead or small salmonids in Anderson Creek and Baker Creek, and relatively abundant juvenile salmonids in Dry Creek and Bridge Creek. Sholes Creek had more than 100 steelhead trout per 100 feet of stream. The Sholes Creek report noted that this density of small fish exceeded that in any other tributary to the Mattole River surveyed by BLM. Interestingly, BLM noted that in 1965, only seven years earlier, Sholes Creek was severely impacted from logging abuse.

Salmonid densities of more than 50 fish per 100 feet of stream were recorded for Squaw Creek in August 1977, Honeydew Creek in July 1972, Bear Trap Creek in July 1972, the East Fork of Honeydew Creek in August 1972, and the West Fork of Honeydew Creek in July 1972.

2.3.3 Humboldt State University Surveys
According to archived accounts, historical levels of salmonid populations were very abundant. Many accounts of long-time residents describe excellent salmon fishing before 1950 (NCWAP, 2002). A much-anticipated annual event was the opening of the estuary/lagoon to the ocean, usually in October. Local residents would camp around the estuary and catch great numbers of salmon as the first of the runs migrated upstream. Humboldt State University students conducted field observations from 1984 –1992. Salmon populations decreased to the point that studies by Humboldt State University students documented no chinook over-summering in the estuary in 1988. Chinook had been found the previous three years. Dive observations since then indicate the presence of juvenile steelhead but not chinook.

2.3.4 Coastal Headwaters Association Surveys
Coho salmon were found in Eubanks Creek, and McKee Creek, and chinook salmon were seen in Grindstone Creek, Mattole Canyon Creek, and Eubanks Creek during carcass surveys. Chinook salmon were seen in Bridge Creek in December 1981, and coho salmon were found in Upper Mill Creek in 1982, Stanley Creek in the spring of 1982, and Baker Creek and Thompson Creek in September 1981. Coho salmon were found in (Lower) Bear Creek, Clear Creek, Indian Creek, Squaw Creek, and Honeydew Creek in August 1982. Interviews with local residents indicated that historically Woods Creek, Squaw Creek, Indian Creek, and Stansberry Creek supported runs of chinook salmon, coho salmon, and steelhead trout while Clear Creek and (Lower) Bear Creek supported runs of coho salmon and steelhead trout (MSG, 1982).

2.3.5 Redwood Sciences Laboratory Surveys
A 1995 survey found three coho salmon in Big Finley Creek in September but none in Little Finley Creek in August or September. In Eubanks Creek one coho salmon was found, but in an unnamed tributary between Little Finley Creek and Big Finley Creek none were found. Sixteen coho salmon were found in Yew Creek in September and October, but none were found in Ancestor Creek in August and October.

2.3.6 Mattole Salmon Group Surveys
MSG monitors fish population in the Mattole watershed through spawning surveys and downstream migrant trapping. As a part of their activities, MSG has conducted annual spawning surveys since the 1981-82 season to provide estimates of salmon escapement in specific index reaches and for extrapolation to basin-wide population levels. For the 1999-2000 season, basin-wide population of chinook salmon was estimated at 700 and coho salmon population at 300.

Since 1985, MSG has conducted trapping of downstream migrants in the lower mainstem Mattole near Mill Creek, at river mile (RM) 3.0, in the spring and early summer to monitor the timing of down-migration and to document the size of emigrating salmonid juveniles. The number of fish caught cannot be construed as a fish population estimate because of unknown trap efficiency and avoidance of the trap by fish at high flows. MSG data from 1995 to 2001 indicate that the majority of salmonids trapped are steelhead trout, followed by chinook salmon and coho salmon.

In 1997, MSG started another downstream migrant trap on Bear Creek 300 ft upstream from its confluence with the Mattole River in 1997. The confluence of Bear Creek and Mattole River is at RM 42.8. MSG data from the trap on Bear Creek also show that more steelhead trout are caught than chinook salmon and coho salmon. A third fish trap was placed on the mainstem Mattole River at Ettersburg in 2001(RM 42.9). This trap caught 1,923 chinook salmon, 6 coho salmon, 4,863 young-of-the-year steelhead trout, 541 steelhead trout one year plus, and 33 steelhead trout smolts.

2.3.7 Hatchery Fish

Between 1930 and 1981 the Mattole watershed was stocked with steelhead trout, coho salmon, and chinook salmon. During that time annual releases of steelhead trout varied between 2,690 and 105,000; a total of approximately 870,000 steelhead trout were released. In 1938, 1,000 coho salmon and 4,940 chinook salmon were released.

The Mattole Salmon Group (MSG) maintains and enhances the remnant runs of native fall-run chinook salmon and coho salmon in the Mattole Basin through a hatchbox program and a rescue-rearing program. The goal of these programs is to restore native salmon runs to self-sustaining levels that can be maintained without artificial propagation or other significant human intervention. MSG is part of the DFG Cooperative Trapping and Rearing Program. Beginning in 1981, MSG has trapped wild adult chinook and coho salmon in the Mattole Basin for use as broodstock. Eggs are obtained from females and fertilized. Fertilized eggs and alevin are incubated in hatchboxes. After emerging from gravels, fry are reared for 6 months before release.

2.4 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.

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.

2.4.1 Sediment and Related Salmonid Requirements

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 percent 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. Increases in sediment can also lead to subsurface flows, which completely eliminates habitat where it occurs. 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.

2.4.2 Turbidity and Suspended Sediment

The Mattole watershed is typical of North Coast watersheds in which bedrock geology produces mountains that are susceptible to storm-induced erosion events. Kelsey and others (1981) state that watersheds in “The California Coast Ranges between San Francisco and the Oregon border contain the most rapidly eroding, large-order, non-glaciated drainage basins of comparable size in the United States (Judson and Ritter, 1964). The combination of the underlying pervasively sheared and often folded Franciscan rocks (Bailey et al., 1964), recent uplift, and a distinctive climate accounts for the large sediment yields.” Suspended sediment and turbidity are elevated for periods of time during the high runoff, rainy season. There is inter-annual variation in the timing, duration, and levels of these factors.

It is generally accepted that the severity of effect of suspended sediment pollution on fish increases as a function of sediment concentration and duration of exposure (Newcombe and Jensen, 1996). The major impacts are summarized in Table 2.2. Suspended sediment data have been collected on a limited number of streams on the North Coast. Although the available regional suspended sediment data is limited, a distinctive trend has been identified in which turbidity and suspended sediment levels of managed streams are elevated for far longer than unmanaged streams following major rainfall events (Klein, 2002).

Survival of salmonid smolts is strongly a function of smolt size (Trush, 2001). Reduced smolt growth, caused by such impacts as increased chronic turbidity or elevated suspended sediment levels, decreases a smolt’s chance of returning to a watershed as a spawning adult, cumulatively jeopardizing population sustainability (Trush, 2001). A watershed with a healthy population of salmonids is capable of producing a size class distribution and abundance of salmonid smolts that can support a sustainable returning adult population. A watershed impacted by increased levels of turbidity and suspended sediment caused by anthropogenic impacts may not be able to produce a size class and distribution of salmonid smolts that can support a sustainable returning adult population (Trush, 2001). Even a small growth impairment may have highly significant implications for smolt survival and population sustainability (Trush, 2001).

Newcombe and Jensen (1996) developed measures of the severity of ill effect based on the suspended sediment concentration and the duration of exposure for juvenile salmonids, adult salmonids, eggs and larvae of salmonids, and non-salmonids based on a synthesis of previously collected data. However, the cumulative impact of successive stressful events on salmonid survival has not been clearly addressed in any study to date. Research to date is suitable for assessing discrete suspended sediment or turbidity events, but unsuitable for measuring the cumulative effect of multiple events over the course of a storm season.

Elevated levels of suspended sediment may have both acute and sublethal effects on salmonids (Meehan, 1991). Migrating salmonids avoid waters with high silt loads, or cease migration when such loads are unavoidable (Cordone and Kelley, 1961). Bell (1986) cited a study in which salmonids did not move in streams where the suspended sediment concentration exceeded 4,000 mg/L (as a result of a landslide). High turbidity in rivers may delay migration, but turbidity alone generally does not seem to affect the homing of salmonids very much.

It is reported that larger juvenile and adult salmon and trout appear to be little affected by the ephemeral high concentrations of suspended sediments that occur during most storms and episodes of snowmelt (Cordone and Kelley, 1961; as cited in Meehan, 1991: Sorenson et al., 1977). However, Bisson and Bilby (1982) reported that juvenile coho salmon avoided water with turbidities that exceeded 70 NTU (nephelometric turbidity units), which may occur in certain types of watersheds and with severe erosion. (Berg and Northcote, 1985, as cited in Meehan, 1991) reported that feeding and territorial behavior of juvenile coho salmon were disrupted by short-term exposures (2.5-4.5 days) to turbid water with up to 60 NTU. Turbidities in the 25-50 NTU range (equivalent to 125-275 mg/l of bentonite clay) reduced growth and caused more newly emerged salmonids to emigrate from laboratory streams, than did clear water (Sigler et al., 1984).

Barrett and others (1992) indicate that elevated turbidity had a consistent negative effect on reactive distance of feeding rainbow trout. They measured reactive distances of rainbow trout at different turbidities. Compared to reactive distance in ambient turbidity of four to six NTU, reactive distance was 80 percent at 15 NTU and 45 percent at 30 NTU.

Newcombe and Jensen (1996) indicate reduced short term feeding rates and feeding success when exposed to a suspended sediment concentration of 20 mg/l for three hours. They also report that juvenile and adult salmonids undergo major physiological stress and experience long-term reduction in feeding rates and feeding success when exposed to suspended sediment concentrations exceeding 148 mg/l for a duration of six days. Noggle (1978, cited in Meehan, 1991) reported that suspended sediment concentrations of 1,200 mg/L caused direct mortality of underyearling salmonids, while 300 mg/L caused reduced growth and feeding. Bozek and Young (1994) reported mortality of adult salmonids after peak suspended sediment concentrations of 9680 mg/L in a Yellowstone National Park stream.

Percent Fines <0.85 mm: As the percentage of fines increases in a total bulk core sample of a substrate, the survival to emergence of salmonids in that substrate decreases. Fines that impact embryo development are generally defined as particles that pass through a 0.85mm sieve. The 0.85mm cutoff is an arbitrarily established value based on the available sieve sizes at the time of the initial studies in this area.

The maximum percentage of fines that a bulk core sample can contain and still indicate a substrate that will ensure adequate embryo survival is not clearly established in the literature. For example, Cederholm and others (1981) found that coho salmon survival in a Washington stream was 30 percent at about 10 percent fines <0.85 mm in trough mixes and at 15 percent fines in natural redds. Koski (1966, as cited in Meehan, 1991), on the other hand, found that coho survival was about 45 percent on an Oregon stream when fines <0.85 mm were measured at 20 percent. This differs yet again from Tappel and Bjornn's (1983) work in Idaho and Washington which found that survival at 10 percent fines smaller than 0.85 mm varied from 20 percent to 80 percent as the amount of fines 9.5 mm or less varied from 60 percent to 25 percent. For example, Tappel and Bjornn (1983) predicted that a 70 percent steelhead embryo survival rate required no more than 11 percent fines < 0.85 mm and 23 percent fines < 9.50 mm. McNeil and Ahnell (1964) in their early work in Alaska found no more than 12 percent fines <0.85 mm in moderately to highly productive pink salmon streams.

In a broad survey of literature reporting percent fines in unmanaged streams (streams without a history of land management activities), Peterson and others (1992) found fines <0.85 mm ranging from 4 percent in the Queen Charlotte Islands to 28 percent on the Oregon Coast, with a median value for all the data of about 11 percent. Peterson and others (1992,) recommended the use of 11 percent fines < 0.85 mm as a target for Washington streams, because the study sites in unmanaged streams in Washington congregated around that figure. None of the data summarized by Peterson and others (1992) were from California.

Burns (1970) conducted three years of study in Northern California streams, including three streams he classified as unmanaged: Godwood and South Fork Yager Creeks in Humboldt County and North Fork Caspar Creek in Mendocino County. He found a range of values for fines < 0.8 mm in each of these streams: 17-18 percent in Godwood Creek, 16-22 percent in South Fork Yager Creek, and 18-23 percent in Caspar Creek. Data collection for this study began a few years following big storms in 1964 that many conclude caused extensive hillside erosion and instream aggradation, the results of which we still observe today.

2.4.3 Temperature and Related Salmonid Requirements

Temperature is one of the most important factors affecting the success of salmonids and other aquatic life. Most aquatic organisms, including salmon and steelhead, are poikilotherms, meaning their temperature and metabolism are determined by the ambient temperature of water. Temperature therefore 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).

Much of the information reported in the literature characterizes temperature requirements with terms such as "preferred" or "optimum" or "tolerable". Preferred temperatures are those that fish most frequently inhabit when allowed to freely select temperatures in a thermal gradient (McCullough, 1999). An optimum range provides for feeding activity, normal physiological response, and normal behavior (without symptoms of thermal stress) (McCullough, 1999). A tolerable temperature range refers to temperatures at which an organism can survive.

Most interpretations of water temperature effects on salmonids and, by extension, water temperature standards, have been based on laboratory studies. Many studies have also looked at the relationship of high temperatures to salmonid occurrence, abundance, and distribution in the field.

Table 2.2 Salmonid life cycle stages and potential impacts of suspended sediment on them.

Life Cycle Stage	Potential Impacts	Potential Sources of Impact
Migration	• Stop or impede access of adult fish to spawning grounds • Stop or impede access of fry to adequate shelter and food • Stop or impede access of juveniles to the estuary and/or ocean • Physical harm	• Low flow conditions • Sediment deltas or bars • Log or debris jams • Water supply dams • Poorly engineered or maintained road crossings (e.g., shotgun culverts) • Over-fishing • Predation
Spawning	• Absence of or reduction in appropriate substrate sizes • Substrate embedded or substantially embedded by fine sediment	• Mass wasting, including debris flows and stream bank failures • Gully erosion • Sheet and rill erosion • Drought • Loss or substantial loss of sediment storage capacity (e.g., removal or reduction in the availability of large woody debris)
Incubation	• Scouring or movement of redds • Suffocation or substantial entombment of redds	• Spring freshets • Elevated peak flows • Physical disturbance • Fine sediment delivery and/or remobilization
Emergence	• Substrate embedded or substantially embedded by fine sediment	• Fine sediment delivery and/or remobilization
Winter Rearing	• Absence of or decline in off-channel habitat • Absence of or decline in instream shelter (e.g., large woody debris) • Elevated peak flows • Increased stream flow velocities • Gill damage	• Disconnection of stream channel from floodplain • Removal or reduction of large woody debris and other structural elements in the stream channel • Modification of upslope hydrology (e.g., compacted soils, expanded surface drainage system, reduction in vegetation transpiration rate)
Ocean Rearing	• Physical harm • Absence of or decline in food supplies • Alteration of water temperatures	• Over fishing • Predation • Disease • Pollution • Climatic changes (e.g., greenhouse warming)

Literature reviews were conducted to determine temperature requirements for the various life stages of steelhead trout (*Oncorhynchus mykiss*) and coho salmon (*Oncorhynchus kisutch*). When possible, species specific requirements were summarized by four life stages: migrating adults, spawning, embryo incubation and fry emergence, and freshwater rearing. Results are summarized in Table 4.3. Some of the references reviewed covered salmonids as a general class of fish, while others were species specific.

It is useful to have measures of chronic and acute temperature exposures for assessing stream temperature data. An EPA document, *Temperature Criteria for Freshwater Fish: Protocol and Procedures* (Brungs and Jones, 1977) discusses development of criteria for assessing temperature tolerances of fish for several different life stages. Two measures of exposure are developed and applied: maximum weekly average temperature (MWAT) as a measure of chronic exposure and short-term maximum temperature as a measure of potentially lethal effects.

The Maximum Weekly Average Temperature (MWAT) is the maximum value of the mathematical mean of multiple, equally spaced, daily temperatures over a 7-day consecutive period (Brungs and Jones 1977). In different words, this is the highest value of the 7-day moving average of temperature. Brungs and Jones developed MWATs for the growth phase of fish life, as growth appears to be the life stage most sensitive to modified temperatures and it integrates many physiological functions. They also developed MWATs for spawning.

Sullivan and others (2000) review sub-lethal and acute temperature thresholds from a wide range of studies, incorporating information from laboratory-based research, field observations, and risk assessment approaches. The authors report calculated MWAT metrics for growth ranging from 14.3° C to 18.0° C (57.7° F to 64.4° F) for coho salmon, and 14.3° C to 19.0° C (57.7° F to 66.2° F) for steelhead trout. The risk assessment approach used by Sullivan and others (2000) suggest that an upper threshold for the MWAT of 14.8° C (58.6° F) for coho and 17.0° C (62.6° F) for steelhead will reduce growth 10 percent from optimum, and that thresholds for the MWAT of 19.0° C (66.2° F) for both coho and steelhead will reduce growth 20 percent from optimum.

While these thresholds relate to reduced growth, temperatures at sub-lethal levels also can effectively block migration, inhibit smoltification, and create disease problems (Elliot, 1981). Further, the stressful impacts of water temperatures on salmonids are cumulative and positively correlated to the duration and severity of exposure. The longer the salmonid is exposed to thermal stress, the less chance it has for long-term survival (Ligon et al., 1999).

Jobling (1981) reported that the upper lethal limit, that is the temperature at which death occurs within minutes, ranges from 27° C to 30° C (80.6 F to 86.0° F) for salmonids. Sullivan and others (2000) report acute threshold values, that is temperatures causing death or total elimination of salmonids from a location, that range from 21.0° C to 25.5° C (69.8° F to 77.9° F) for coho, and 21.0° C to 26.0° C (69.8° F to 78.8° F) for steelhead. The following paragraphs assess temperature requirements for various salmonid life stages.

2.4.4 Adult Migration

Salmon and trout respond to temperatures during their upstream migration (Bjornn and Reiser, 1991). Delays in migration have been observed in response to temperatures that were either too cold or too warm. Most salmonids have evolved with the temperature regime they historically used for migration and spawning, and deviations from the normal pattern can affect survival (Spence et. al., 1996).

Upstream migration of adult salmonids in the Mattole River occurs during a stream temperature transition period. Migration does not begin until the warmer summer period is waning, streamflows are increasing, and river temperatures are generally falling. Coho begin entering streams on the Humboldt Coast, including the Mattole River, in mid-October and may continue into February. Steelhead begin migrating in mid-November and continue through mid-March.

Bell (1986) notes migration temperatures for coho ranging from 7.2-15.6° C (45.0° F –60.1° F). Several sources cite 21° C (70° F) as a temperature at which migration or movement is delayed or movement is limited for coho and steelhead (Table 2.2).

2.4.5 Freshwater Rearing

Temperature affects metabolism, behavior, and survival of both juvenile fish as well as other aquatic organisms that may be food sources. In streams of the Northern California Coast, including the Mattole River, young chinook, coho and steelhead may rear in freshwater from one to four years before migrating to the ocean. Reported values of MWATs and short-term exposure maxima for juvenile rearing stages are presented in Table 2.3.

2.4.5.1 Freshwater Rearing – Chinook Specific

North Coast Watershed Assessment Programs watershed synthesis report for the Mattole River Watershed states that for chinook salmon the preferred spawning temperature is generally 52° F (11.1^{o} C) with low and high threshold temperatures of 42° F and 56° F (5.6^{o} C and 13.3^{o} C). Additionally stated, adults migrating upstream prefer water temperatures less than 60° F (15.6^{o} C), although, acceptable temperatures range from 57° F to 67° F (NCWAP, 2002).

2.4.5.2 Freshwater Rearing – Coho Specific

Reported estimates of the MWAT for growth range from 16.8-18.3° C (62.2-65.0° F). Brungs and Jones (1977) report maximum short-term temperatures 23.7° C (74.7° F). In an exhaustive study of both laboratory and field studies of temperature effects on salmonid and related species, McCullough (1999) concluded that upper short-term temperatures of approximately 22-24° C limit salmonid distribution, i.e., they totally eliminate salmonids from a location. McCullough (1999) also notes that changes in competitive interactions between fish species can lead to a transition in dominance from salmonids to other species at temperatures 2-4° C lower than the range of total elimination. In a study of coho presence and absence in the Mattole watershed, Welsh et al (2001) used logistic regression to determine an MWAT criterion of 16.8° C. The criterion correctly determined the presence or absence of coho in 18 of 21 streams. Welsh et al (2001) also reported that coho were found in all streams with an MWAT less than 14.5° C.

2.4.5.3 Freshwater Rearing – Steelhead Specific

Brungs and Jones (1977) reported that for steelhead the MWAT for growth is 19° C (66° F), and short-term maximum temperature is 23.9° C (75° F). The conclusions by McCullough (1999) would also apply to steelhead, with respect to limitations on distributions in the field. Nielsen and others (1994) studied thermally stratified pools and their use by steelhead in three North Coast rivers including the Middle Fork Eel River, Redwood Creek and Rancheria Creek Creek, located in the Mattole River watershed. In detailed observations of steelhead behavior in and near thermally-stratified pools, they noted behavioral changes including decreased foraging and increased aggressive behavior as pool temperature reached approximately 22° C. As pool temperature increased above 22° C (71.6° F), fish left the observation pools and moved into stratified pools where temperatures were lower. These observations would seem to be generally consistent with the results reported in McCullough (1999).

The MWAT is used as the primary statistical measure for interpretation of stream temperature conditions in the following summary of Mattole stream temperature data in the Mattole. The following ranges of values (Table 2.3, Table 2.4) are used for comparison to MWAT stream temperature values to characterize the temperature quality of surface waters in the Mattole River watershed.

Table 2.3 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)

Table 2.4 Temperature tolerances of coho salmon and steelhead trout at different life stages.

	COHO SALMON		STEELHEAD	
	Values - in °C (°F)	Reference	Values - in °C (°F)	Reference
Lower Lethal Temp.	1.7 (35) 0 (32)	Brett, 1952 Bell, 1986	0 (32)	Bell, 1986
Upper Lethal Temp.	25 (77) 23-25 (73.4-77) 24-25.8 (75.2-78.4)	Brett, 1952 Brungs and Jones, 1977 NMFS, 1997	27 (80.6) [d] 21 (69.8) [d] 23.9 (75) 24-26.7 (75.2-80)	Brungs and Jones, 1977 Brungs and Jones, 1977 Bell, 1986 McCullough, 1999
Preferred Temp.	12-14 (54-57)	Brett, 1952	13-19 (55.4-66.2) [d] 10-13 (50-55.4)	Brungs and Jones, 1977 Bell, 1986
Optimum	15 (59) 13.2 (55.8)	Brungs and Jones, 1977 NMFS, 1997	17-19 (62.6-66.2) [d] 7.2-14.4 (45-58)	Brungs and Jones, 1977 Bell, 1986
Upstream Migration	7.2-15.6 (45-60) 21.1 (70) migration delayed	Bell, 1986 Bell, 1986	21.1 (70) movement limited	McCollough, 1999
Spawning	Prefer:4.4-9.4 (40-49) >50% Survival: 2-11 (35.6-51.8) >50% Survival: 1.4-12.1 (34.5-53.8) MWAT for spawning: 10 (50)	Bell, 1986 Murray and McPhail, 1988 Murray et al., 1990 Brungs and Jones, 1977	Prefer: 3.9-9.4 (39-49) MWAT for spawning: 9 (48) [d]	Bell, 1986 Brungs and Jones, 1977
Incubation	4.4-13.3 (40-56) >50% Survival: 2-11 (35.6-51.8) >50% Survival: 1.4-12.2 (34.5-54) >50% Survival: <13.3 (56) Max short-term temp: 13 (55)	Bell, 1986 Murray and McPhail, 1988 Murray et al., 1990 Spence, 1996 Brungs and Jones, 1977	Prefer: 10 (50) Max short-term temp.: 13 (55) [d]	Bell, 1986 Brungs and Jones, 1977
Rearing	12.2-13.9 (54-57) MWAT for growth[c]: 18 (64) [a] 17.7-18.3 (63.8-65) [b] 16.8-17.4 (62.2-63.2) [b] Max short-term temp, (50% survival) 23.7 (74.7)	Brett, 1952 Brungs and Jones, 1977 Brungs and Jones, 1977 NMFS, 1997 Brungs and Jones, 1977	MWAT for growth[c]: 19 (66) [d] Max short-term temp, (50% survival) 23.9 (75) [d]	Brungs and Jones, 1977 Brungs and Jones, 1977

a: cited in reference
b: calculated from upper lethal & optimum temperatures from references as noted above
c: MWAT for growth = OT + (UUILT-OT)/3
d: values are for rainbow trout

MWAT=Maximum Weekly Average Temperature
OT=Optimum Temperature
UUILT=Ultimate Upper Incipient Lethal Temperature

2.5 Habitat Conditions in the Mattole River Watershed

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 a) poor quality habitat conditions for summer rearing and overwintering, b) excess sediment, c) lack of deep pools, d) fair to poor spawning gravels, e) low large woody debris (LWD) volume, f) low availability of canopy, g) high temperatures, and h) a lack of connection to off-channel habitat (NCRWQCB, 2001). Excess sediment is adversely impacting the number and volume of pools. Sediment is also causing moderate to high embeddedness of substrate and spawning gravels in the Mattole River watershed.

2.5.1 Sediment Conditions

The North Coast Watershed Assessment Program watershed synthesis report for the Mattole River watershed (NCWAP, 2002) states that excess sediment is adversely impacting the number and volume of pools. Sediment is also causing moderate to high embeddedness of substrate and spawning gravels in the basin. The report found that sediment is currently impacting the salmonid fisheries and other beneficial uses of water in the estuary and in the mainstem Mattole River up to the Southern Subbasin. Sediment also impacts the downstream, lower gradient reaches of Lower and Upper North Fork Mattole Rivers, and Blue Slide, Lower Bear, Honeydew, and Mattole Canyon Creeks. Data were insufficient for a conclusive analysis, but sediment may also be detrimentally impacting Squaw Creek.

Between 1941 and 1965 three major events took place. First, management activities, primarily logging and road-building, altered much of the upslope territory in the Honeydew Creek drainage basin, removing cover and disturbing the ground in ways that made the slopes susceptible to erosion and mass wasting. Then two catastrophic floods, in 1955 and 1964, mobilized huge amounts of sediment that overwhelmed the streams' ability to move it through the system. The floods on their own would have created a large influx of sediment, but management activities opened the way for increased mass movement and erosion during and following the flood events. Figure 2.1 shows the Honeydew Creek drainage basin in 1941, before major timber harvest. Figure 2.2 shows the same area in 1965 after major timber harvest and a major storm in 1964. In that interval, the valley bottoms were dramatically broadened and filled with sediment, which shows as light colored on the photos. Arrows on the figures show specific spots to compare.

Sediment conditions in the estuary are discussed in section 2.5.4. Additional discussion of sediment conditions as they relate to specific proposed numeric targets for water quality indicators is presented in Chapter 3.

2.5.2 Temperature Conditions

Water temperature is above acceptable limits and likely impacting the salmonid fisheries and other beneficial uses of water in the estuary and the mainstem of the Mattole River up to the Southern Subbasin near river mile 55. 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. Temperature is currently impacting the salmonid fisheries in many tributaries of the Mattole.

The majority of temperature data from continuously monitored sites reflect well-mixed conditions near the surface of the streams. These data characterize the overall temperature regime very well. However, discrete areas of colder water can be created by tributaries, groundwater seeps, intergravel flow, deep pools, and areas separated from currents by obstructions (Nielsen et al, 1994). Salmonids are able to access these pockets of colder water, called thermal refugia, as an avoidance strategy to survive during periods of elevated temperatures. The existence of these thermal refugia allows salmonids to persist in these reaches of otherwise poor or marginal habitat. Regional Board 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 August 9, 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).

Peak maximum temperatures in lower reaches of the mainstem Mattole river and the estuary have frequently exceeded the lethal, short term temperature extreme of 75° F (23.8° C) for salmonids (Table 2.6). Evidence for this was clear when a die-off of juvenile chinook was observed in 1987 in the estuary after a peak temperature of ~79° F (26.1° C) was measured (MSG, 1995). Habitat surveys conducted by the MRC (MRC, 1995) in lower river reaches and the estuary describe the lack of shelter, cover, and cold water refugia available for escape by salmonids during periods of high water temperature. Also, specific channel cross sections measured in the estuary by the MRC reveal a very shallow body of water, due to sediment aggradation. The shallow estuarine waters allow solar radiation to more fully penetrate the water column, possibly resulting in elevated water temperatures that are detrimental to populations of fish and other aquatic species.

Thermal infrared (TIR) images were used to derive point-in-time median temperatures for the mainstem and various tributaries to the Mattole River on July 19 and 20, 2001. Data were gathered between the hours of 2:23 and 4:03 p.m. on July 19, 2001. All flights and data collection were performed by Watershed Sciences under contract to the Regional Water Board (Watershed Sciences, 2002). The TIR charts are of particular interest because they provide an instant overview of median temperatures along the Mattole River longitudinal profile. Figure 2.4 shows the TIR longitudinal profile for the mainstem Mattole River from the estuary to the headwaters.

Particularly interesting are the frequent dips in temperatures shown in the Mattole River TIR profile (Figure 2.4). These localized drops in maximum temperatures show the influence of colder tributaries entering the warmer mainstem, 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^{o} C (6.7° F). Other notable mainstem temperature dips occur at river mile 36.7, where Westlund Creek lowers the mainstem temperature from 26.5^{o} C to 24.5^{o} C (79.7° F to 76.1° F), and Honeydew Creek at river mile 30.3, where the mainstem surface temperature is lowered from 26^{o} C to 24.4^{o} C (78.8° F to 75.9° F). Of fifteen tributaries detected entering the Mattole River, thirteen discharged cooler water into the mainstem while only two, the Lower and Upper North Fork Mattole Rivers, contributed warmer surface waters to the mainstem. Table 2.7 summarizes weekly average temperatures in the Mattole River from 1997 to 1999.

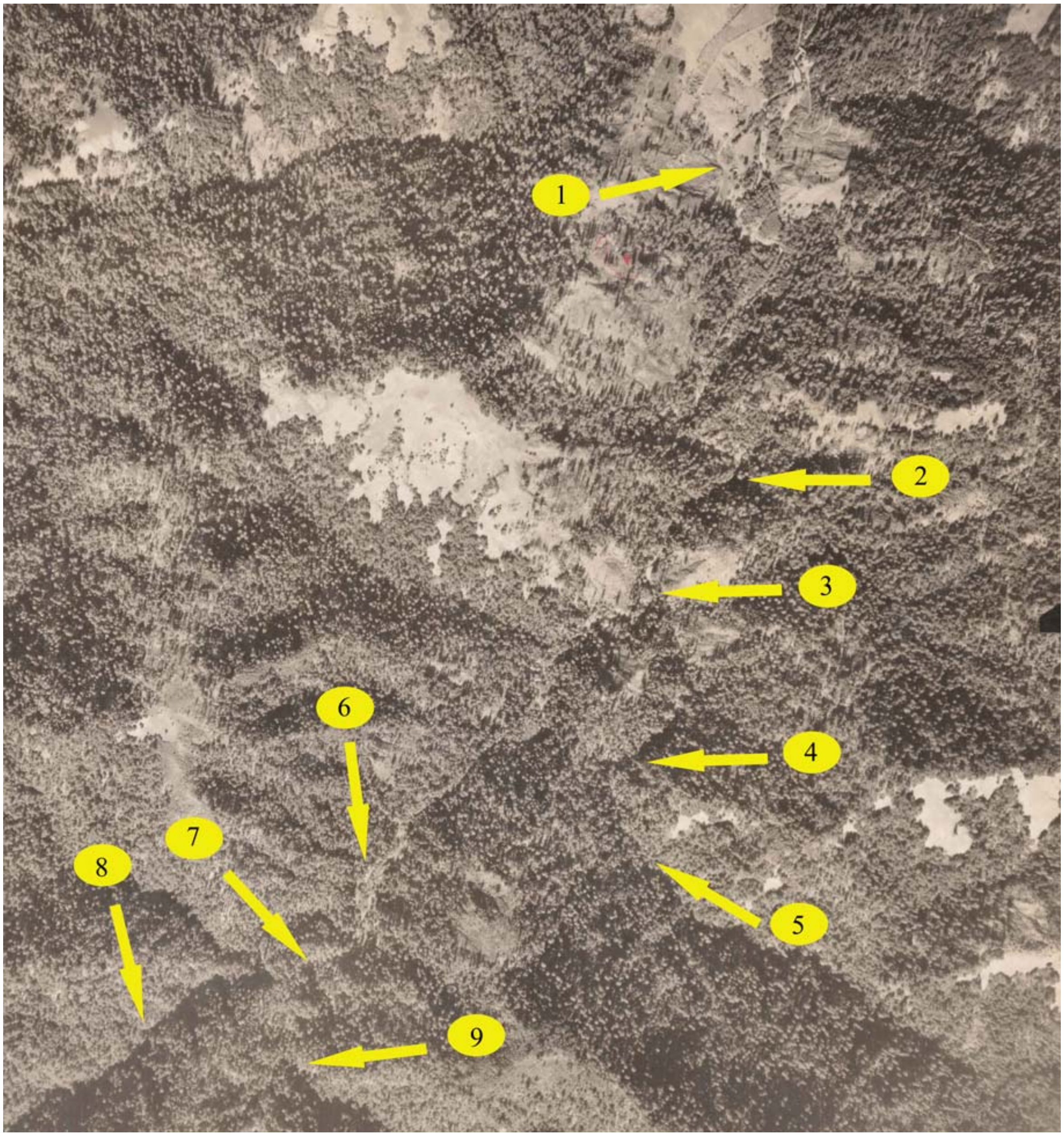

Figure 2.1 Aerial photograph of the area of Honeydew Creek taken in 1941. Arrows show points for comparison with 1965 photo in Figure 2.2.

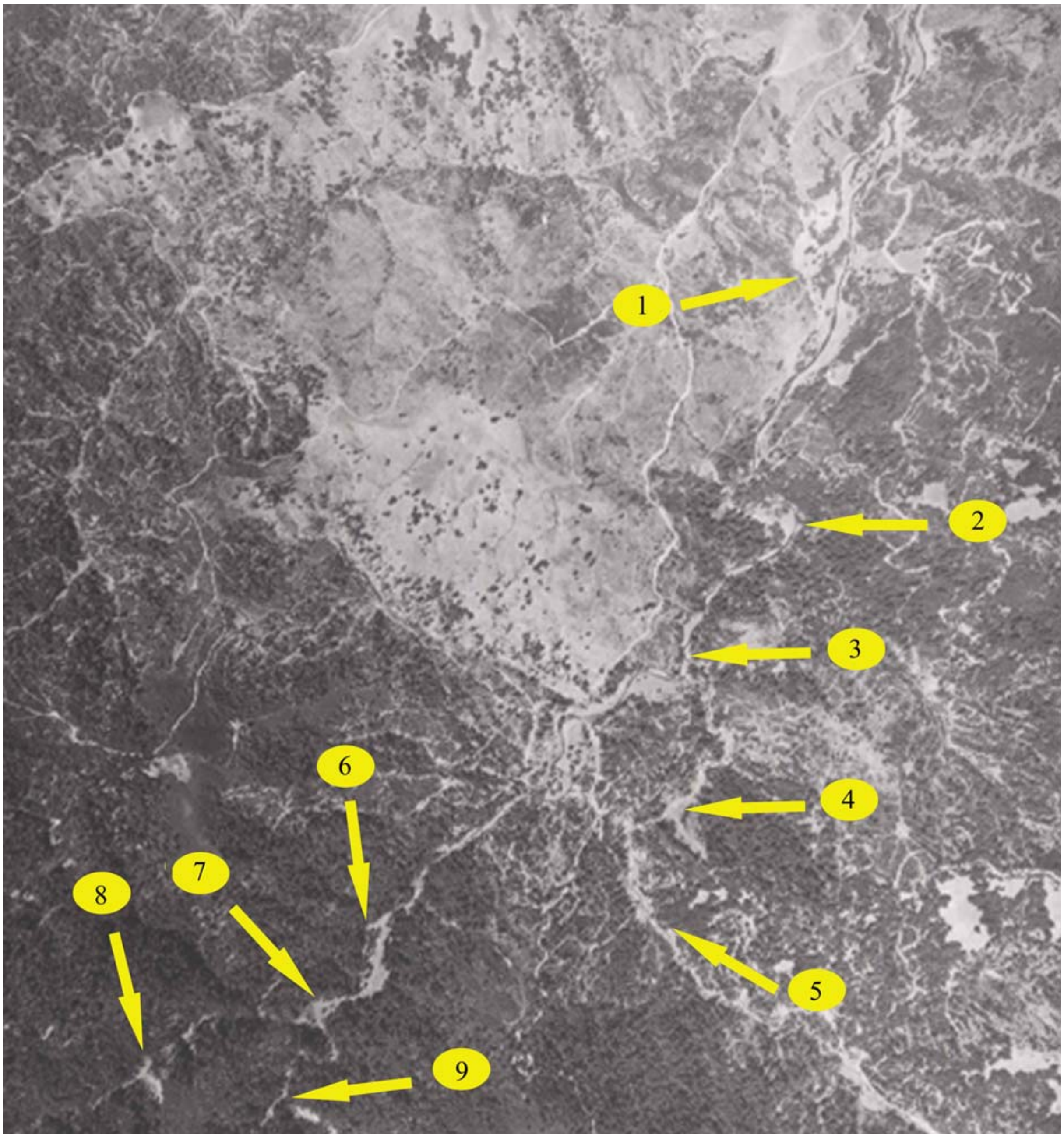

Figure 2.2- - Aerial photograph of the area of Honeydew Creek taken in 1965. Arrows show points for comparison with 1941 photo in Figure 2.1.

Table 2.5. Maximum weekly average temperatures, mainstem Mattole River, headwaters to the Pacific Ocean, 1996-2001. River mile identifiers are based on DWR (1973) convention.

River Mile	"Major" Upstream Watercourse	MWAT 1996		MWAT 1997		MWAT 1998		MWAT 1999		MWAT 2001		COHO	STEELHEAD
		°F	°C	°F	°C	°F	°C	°F	°C	°F	°C		
0.1	Estuary-Stansberry Cr					70.6	21.4	68.2	20.1			POOR	POOR
0.5	Estuary-Stansberry Cr (7ft deep)									73.4	23.0	POOR	POOR
0.5	Estuary-Stansberry Cr									70.7	21.5	POOR	POOR
1	Mill Cr					71.5	21.9	69.4	20.8			POOR	POOR
2.9	Lower NFK Mattole (surface)									72.2	22.3	POOR	POOR
2.9	Lower NFK Mattole (5-6ft deep)									67.3	19.6	POOR	POOR
3	Lower NFK Mattole					72.7	22.6	69.9	21.1	72.3	22.4	POOR	POOR
3.3	Lower NFK Mattole									68	20.0	POOR	POOR
3.5	Conklin Cr									71.5	21.9	POOR	POOR
6.2	Conklin Cr									72.4	22.4	POOR	POOR
6.2	Conklin Cr									72.3	22.4	POOR	POOR
14.5	Squaw Cr (surface)									72.9	22.7	POOR	POOR
14.5	Squaw Cr (5-6ft deep)									69.8	21.0	POOR	POOR
15.5	Pritchett Cr	73.6	23.1			73.9	23.3					POOR	POOR
25.2	Upper NFK Mattole									73.3	22.9	POOR	POOR
26.4	Honeydew Cr					71.7	22.1	69.8	21.0			POOR	POOR
40.6	Mattole Cyn Cr	75.8	24.3									LETHAL	LETHAL
42.9	Big Finley Cr			74.4	23.6			70	21.1	73	22.8	POOR	POOR
47.3	Big Finley Cr (surface)									66.6	19.2	POOR	POOR
47.3	Big Finley (9-10ft deep)									61.9	16.6	MARGINAL	GOOD
47.7	Nooning Cr					71.1	21.7					POOR	POOR
50.7	Bridge Cr	68.7	20.4	67.6	19.8	67.4	19.7	66.6	19.2			POOR	POOR
52.7	McKee Cr (5-7ft deep)									62.5	16.9	MARGINAL	GOOD
52.7	McKee Cr (surface)									64.9	18.3	POOR	MARGINAL
53.9	Van Arken Cr									65	18.3	POOR	MARGINAL
56.5	Gibson Cr			64.1	17.8	64.2	17.9	62.4	16.9			POOR	MARGINAL
56.7	Gibson Cr (surface)									61.7	16.5	MARGINAL	GOOD
56.7	Gibson Cr (5-6ft deep)									61.8	16.6	MARGINAL	GOOD
59.4	Dream Stream									57.9	14.4	GOOD	GOOD
60.8	McNasty Cr			64.1	17.8	60.8	16.0	60.1	15.6	58.5	14.7	MARGINAL	GOOD
61	Headwaters Lower	55.4	13.0									GOOD	GOOD
61.2	Headwaters-Upper	52.7	11.5									GOOD	GOOD

Table 2.6 Maximum summer temperatures, mainstem Mattole River, headwaters to the Pacific Ocean, 1996-2001. River mile identifiers are based on DWR (1973) convention.

River Mile	"Major" Upstream Watercourse	MAX 1996		MAX 1997		MAX 1998		MAX 1999		MAX 2001	
		°F	°C	°F	°C	°F	°C	°F	°C	°F	°C
0.1	Estuary-Stansberry Cr	83	28			73	23	76	24		
0.5	Estuary-Stansberry Cr									79	26
0.5	Estuary-Stansberry Cr (7ft deep)									82	28
1	Mill Cr	83	28			78	26	79	26		
2.9	Lower NFK Mattole (surface)									83	28
2.9	Lower NFK Mattole (5-6ft deep)									76	24
3	Lower NFK Mattole	79	26	78	26	81	27	81	27		
3.3	Lower NFK Mattole									72	22
3.5	Lower NFK Mattole									82	28
6.2	Conklin Cr									81	27
7.5	Conklin Cr									80	27
14.5	Squaw Cr	80	27							83	28
14.5	Squaw Cr									73	23
15.5	Pritchett Cr	82	28	85	29	80	27	80	27		
25.2	Upper NFK Mattole									82	28
26.4	Honeydew Cr	78	26	78	26	78	26	81	27		
40.6	Mattole Cyn Cr	81	27	81	27						
42.9	Big Finley Cr	72	22	82	28	82	28	82	28	79	26
47.4	Big Finley Cr (surface)									72	22
47.4	Big Finley Cr (9-10ft deep)									64	18
47.7	Nooning Cr	73	23	73	23	80	27	80	27		
50.7	Bridge Cr	76	24			65	18				
52.7	McKee Cr (5-7ft deep)									64	18
52.7	McKee Cr									70	21
53.9	Van Arken Cr	57	14	64	18	60	16			69	21
56.5	Gibson Cr	62	17	68	20	67	19				
56.7	Gibson Cr (5-6ft deep)									65	18
56.7	Gibson Cr									66	19
59.4	Dream Stream									63	17
60.8	McNasty Cr			68	20	62	17	62	17		
61	McNasty Cr	57	14							64	18
61.2	Headwaters-Upper	53	12	60	16						

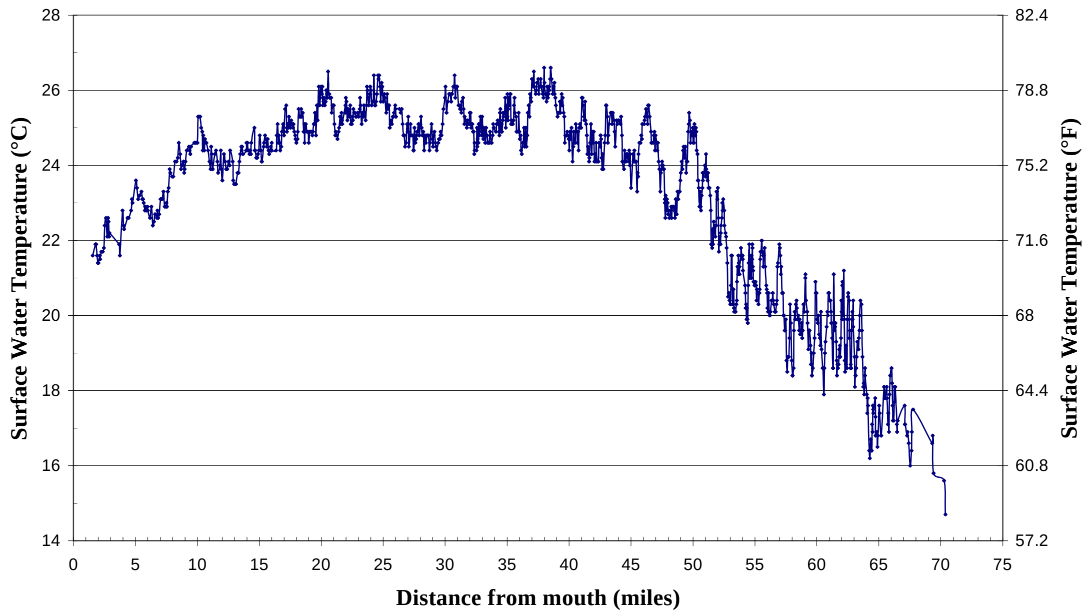

Figure 2.4 Temperatures of the Mattole River, headwaters to estuary July 19, 2001, from thermal infrared imagery

Table 2.7 Maximum weekly average temperatures of the Lower North Fork Mattole River and the Upper North Fork Mattole River from 1997-1999. River mile identifiers are based on DWR (1973) convention.

Tributary	River Mile*	MWAT 1997		MWAT 1998		MWAT 1999		MWAT 2000		MWAT 2001		COHO	STEEL-HEAD
		°F	°C	°F	°C	°F	°C	°F	°C	°F	°C		
Lower NFK Mattole River	4.7 + 0.5			69.7	20.9							POOR	POOR
Lower NFK Mattole River US	4.7 + 9.0							65.0	18.3			POOR	MARGINAL
Sulphur Cr	4.7 + 10.5							65.5	18.6	64.4	18.0	POOR	MARGINAL
Upper NFK Mattole River	25 + 2.0	70.1	21.2	71.1	21.7	69.8	21.0					POOR	POOR
Upper NFK Mattole US	25 + 4.5							69.4	20.8	67.8	19.9	POOR	POOR

*River mile indicates distance of the confluence of the tributary from the mouth of the Mattole River; the + indicates the distance upstream the thermograph was located from the confluence of the tributary to the Mattole mainstem. Records were available in summary form from the MSG and as complete data sets from PALCO.

TIR temperature surveys were used to derive point-in-time maximum surface water temperatures for the Upper North Fork Mattole River and two of its larger tributaries, Rattlesnake Creek and Oil Creek, on July 20, 2001. The Lower North Fork Mattole River and a single tributary, the East Branch, Lower North Fork were also surveyed on the same date.

Figure 2.5 represents maximum surface temperatures for the Lower North Fork Mattole River. There is a large spike in surface temperatures from approximately river mile 6.8 to 5.8 that coincides with the confluence of the East Branch Lower North Fork River, a tributary that was considerably warmer than the mainstem Lower North Fork.

Figure 2.5 Temperatures in Lower North Fork Mattole River mouth, to 12 miles upstream, July 20, 2001.

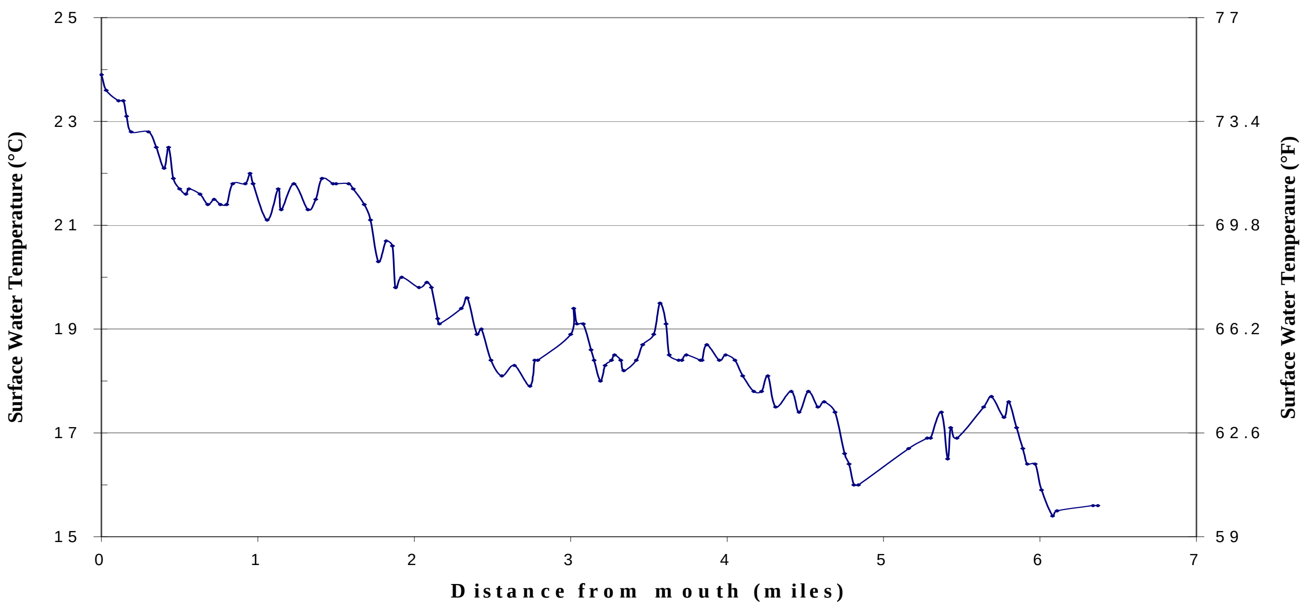

Figure 2.6 Temperatures of East Branch Lower North Fork Mattole River from Lower North Fork to 6.4 miles upstream, July 20, 2001.

Eastern Subbasin: Temperature records were available for Westlund, Mattole Canyon, Blue Slide, and Eubanks Creeks in this subbasin. Tables 2.7 and 2.8 show that all MWATs calculated were above the range for good coho temperature conditions. Eubanks, Middle, and Westlund Creeks provide fair temperature conditions for coho in at least some years. Juvenile coho salmon were not detected in any of the four tributaries during Welsh's study (Welsh, et al., 2001). All monitored sites provided at least marginal habitat for steelhead, except Blue Slide Creek and Mattole Canyon Creek sites. Middle and Eubanks Creeks provide good steelhead temperature conditions.

Table 2.8 Maximum weekly average temperatures from 1996 through 2001 for various tributaries to the Mattole River in the Eastern subbasin. River mile identifiers are based on DWR (1973) convention.

Tributary	River Mile*	MWAT 1997		MWAT 1998		MWAT 1999		MWAT 2001		COHO	STEEL-HEAD
		°F	°C	°F	°C	°F	°C	°F	°C		
Dry Cr	30.4 +0.1							65.5	18.6	POOR	MARGINAL
Middle Cr	31.3 +0.2							61.5	16.4	MARGINAL	GOOD
Westlund Cr	31.7+0.1			67.9	19.9	63.1	17.3	62.5	16.9	POOR	MARGINAL
Mattole Cyn Cr	41.1+0.1			73.3	22.9	71.3	21.8	70.8	21.6	POOR	POOR
Upper Mattole Cyn Cr (surface)	41.1 +3.1							70.7	21.5	POOR	POOR
Upper Mattole Cyn Cr (8 ft deep)	41.1 +3.1							65.2	18.4	POOR	MARGINAL
Blue Slide Cr	42.0+0.1	69.1	20.6	70.8	21.6	68.2	20.1			POOR	POOR
Eubanks Cr	47.7+0.1					61.1	16.2	59.7	15.4	MARGINAL	GOOD

*River mile indicates location of the confluence of the tributary from the Mattole River mouth; the + indicates distance upstream the thermograph is located from the confluence of the tributary to the Mattole mainstem.

Peak Maximum summer temperatures are extremely high in Mattole Canyon Creek. All of the maximum temperatures measured in Dry, Grindstone, and Mattole Canyon Creeks, exceeded the critical peak lethal temperature threshold of 75° F (23.9° C) and, thus, are poor habitat for salmonids (Table 2.9).

Table 2.9 Maximum summer temperatures for eight tributaries in the Eastern subbasin from 1996-2001. River mile identifiers are based on DWR (1973) convention as submitted by MSG.

Tributary	River Mile*	MAX 1996		MAX 1997		MAX 1998		MAX 1999		MAX 2000		MAX 2001	
		°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C
Dry Cr	30.4+0.1									88.0	31.1	73.3	22.9
Middle Cr	31.3+0.2									64.4	18.0	68.3	20.2
Westlund Cr	37.1+0.1							67	19	69.5	20.8	68.4	20.2
Westlund Cr (upstrm)	31.7+1.0									66.9	19.4		
Grindstone Cr	39.0+0.1									78.1	25.6		
Mattole Cyn Cr	41.1+0.1	88	31			80	27	84	29			84.1	28.9
Mattole Cyn Cr-upstrm	41.1+3.1											81.6	27.6
Mattole Cyn Cr-upstrm (8ft)	41.1+3.1											68.4	20.2
Blue Slide Cr	42.0+0.1			79	26	78	26			74.4	23.6		
Eubanks Cr	47.7+0.1	70	21			68	20	67	19	67.8	19.9	68.1	20.1

*River mile indicates distance of the confluence of the tributary from mouth of the Mattole River. Plus sign (+) indicates distance upstream from the confluence where the thermograph is located. Records were available in summary form from the MSG.

Southern Subbasin: Southern subbasin MWATs, depicted in Table 2.10, range from 55.4° to 65.0° F (13.0° C to 18.3° C) Seven of the nine streams show MWATs indicating good temperature conditions for coho in at least some years, though it should be noted that Dream Stream does not provide rearing habitat for salmonids. Fish population data collected by the DFG and the MSG indicate that most of these tributaries support coho, chinook, and steelhead populations and are some of the most highly productive salmonid streams of the Mattole River subbasins (Coastal Headwaters Association, 1983; CDFG, 1986; Gary Peterson, MSG, oral communication to Elmer Dudik, NCRWQCB, 2001).

Table 2.10 Maximum weekly average temperatures from 1996 through 2001 for various tributaries to the Mattole River in the Eastern subbasin. River mile identifiers are based on DWR (1973) convention as submitted by MSG.

Tributary	River Mile*	MWAT 1996		MWAT 1997		MWAT 1998		MWAT 1999		MWAT 2001		COHO	STEEL-HEAD
		°F	°C	°F	°C	°F	°C	°F	°C	°F	°C		
Bridge Cr	52.1 + 2.0	63.9	17.7			65.0	18.3	59.8	15.4	60.9	16.1	MARGINAL	GOOD
Van Arkin	54 + 0.1			60.1	15.6	60.8	16.0	59.9	15.5	58.9	14.9	MARGINAL	GOOD
Baker Cr	57.6 + 0.1	61.3	16.3	60.9	16.1	61.3	16.3			58.6	14.8	MARGINAL	GOOD
Yew Cr	58.4 + 0.4	61.5	16.4	60.3	15.7	60.7	15.9	58.7	14.8	57.6	14.2	MARGINAL	GOOD
Thompson Cr	58.4 + 0.6	62.3	16.8	61.8	16.6	62.5	16.9			60.6	15.9	MARGINAL	GOOD
Helen Barnum Cr	58.7 + 0.1									56.4	13.6	GOOD	GOOD
Lost River Cr	58.8 + 0.5	60.3	15.7			60.9	16.1			58.4	14.7	MARGINAL	GOOD
Dream Stream	59.5 + 0.01									55.4	13.0	GOOD	GOOD
Ancestor Cr	60.8 + 0.2									56.7	13.7	GOOD	GOOD

*River miles and distances upstream in tributaries, if applicable, are listed after the watercourse name; otherwise temperature locations are within 0.1 mile from the confluence with the Mattole mainstem.

Southern subbasin MWATs, represented in table 2.11, represents maximum summer temperatures in selected tributaries in the Southern subbasin. None of these tributaries had maximum summer temperatures that exceeded the critical peak lethal temperature threshold of 75° F (23.9° C) established for salmonid survival, however, Bridge Creek approached the 75° F (23.9° C) threshold with a peak summer temperature of 72° F (22.2° C) during 1998.

Table 2.11 Maximum summer temperatures for nine tributaries, Southern sub-basin from 1996-2001. River mile identifiers are based on DWR (1973) convention as submitted by MSG.

Tributary	River Mile*	MAX 1996		MAX 1997		MAX 1998		MAX 1999		MAX 2000		MAX 2001	
		°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C
Bridge Cr	52.1+1.0	68	20			72	22	62	17	68.7	20.4	69.5	20.8
Van Arken Cr	54.0+0.01									64.5	18.1	62.2	16.8
Baker Cr	57.6+0.1	64	18	65	18	65	18	63	17			68.7	20.4
Yew Cr	58.4+0.2	66	19	63	17	65	18	62	17	64.2	17.9	61.6	16.4
Thompson Cr	58.4+0.2	67	19	64	18	65	18	65	18	68.7	20.4	66.1	18.9
Lost River Cr	58.8+0.01	61	16	61	16	65	18	59	15			61.2	16.2
Helen Barnum Cr	58.8+0.1											58.1	14.5
Dream Stream	60.4+0.1	57	14	57	14							57.3	14.1
Ancestor Cr	60.8+0.5	57	14	59	15							60.1	15.6

*River mile indicates locations of the confluence of the tributary from the Mattole River mouth, the + indicates distance uptream the thermograph is located from the confluence of the tributary to the Mattole mainstem. Records were available in summary form from the MSG.

Western Subbasin: The tributaries in the western subbasin where data describing temperature conditions exist are Squaw, Honeydew, Bear, Mill, Stansberry, Big Finley, Clear, Saunders, and Nooning Creeks.

In the upper reaches of both Honeydew Creek and Bear Creek and their tributaries, MWATs indicate marginal to poor temperature conditions for coho salmon, and good to marginal for steelhead. By the time Bear Creek and Honeydew Creek reach their confluences with the mainstem, MWATs increase to produce poor or lethal temperature conditions for both species.

Of the remaining western subbasin tributaries, only Mill, Stansberry, and Nooning Creeks have had MWATs in the range considered good for coho. Saunders, Woods, Big Finley, Mill, Stansberry, and Nooning Creeks all have had MWATS in the range considered good for steelhead. Welsh and others (2001) found that Mill Creek was the only stream in the Western subbasin that had populations of juvenile coho salmon.

Squaw Creek had MWATS in the range considered poor for steelhead and coho in three out of four years. In 1999 the Squaw Creek MWAT was in the marginal range for steelhead at the site approximately 0.1 mile upstream from its confluence with the Mattole River.

Tables 2.12 and 2.13 and Figures 2.7, 2.8, and 2.9 visually illustrate the above discussions concerning temperature relationships in the Western subbasin.

Table 2.12 Maximum weekly average temperatures for various tributaries to the Mattole River, Western subbasin, 1996 through 2001. River mile identifiers are based on DWR (1973) convention as submitted by MSG.

Tributary	River Mile*	MWAT 1996		MWAT 1997		MWAT 1998		MWAT 1999		MWAT 2001		COHO	STEEL-HEAD
		°F	°C	°F	°C	°F	°C	°F	°C	°F	°C		
Stansberry Creek	1.3 + 0.1					63.5	17.5	58.2	14.6			MARGINAL	GOOD
Mill Creek Lower	2.8 + 0.5	57.7	14.3					58.4	14.7	57.7	14.3	GOOD	GOOD
Clear Cr	6.1 +0.2									59.1	15.1	MARGINAL	GOOD
Squaw Ck	15.0 + 0.1	69.1	20.6	69.5	20.8	70.0	21.1	63.5	17.5			POOR	POOR
Saunders Cr	19.9 +0.3									60.1	15.6	MARGINAL	GOOD
Woods Cr	24.1 +0.1									60.8	16.0	MARGINAL	GOOD
Honeydew Cr	26.6 + 0.5			68.9	20.5	68.9	20.5	71.9	22.2			POOR	POOR
Honeydew Cr LwrUS	**26.5 + 3.2					62.9	17.2					POOR	MARGINAL
Honeydew Cr Mid-US	**26.5 + 4.2					62.6	17.0					POOR	MARGINAL
HoneyDew Upper-US	**26.5 + 4.8					63.9	17.7					POOR	MARGINAL
Honeydew US Lower EFK	26.5+3.0+0.2					64.0	17.8					POOR	MARGINAL
HoneyDew WFK	26.5+4.2+0.2					62.6	17.0					POOR	MARGINAL
Honeydew US Upper EFK	26.5+4.5+0.3					61.1	16.2					MARGINAL	GOOD
Bear Creek MS	42.8 + 0.01									70.1	21.2	POOR	POOR
Bear Creek MS (A)	42.8 + 0.6			67.8	19.9	71.0	21.7	70.1	21.2	69.4	20.8	POOR	POOR
Bear Creek MS (B)	42.8 + 0.6					71.5	21.9					POOR	POOR
Bear Creek upstrm	42.8 + 5.0			64.7	18.2							POOR	MARGINAL
N Bear Ck Main	42.8 + 6.6	64.7	18.2									POOR	MARGINAL
Bear Ck NFK	42.8 + 5.1	60.0	15.6	69.5	20.8					60.9	16.1	POOR	MARGINAL
Bear Ck SFK	42.8 + 5.1	64.2	17.9							61.5	16.4	POOR	MARGINAL
Big Finley Creek	47.4 + 0.1							60.3	15.7	59.2	15.1	MARGINAL	GOOD
Nooning Creek	50.2 + 0.01									57.8	14.3	GOOD	GOOD

*River miles and distances upstream in tributaries, if applicable, are listed after the watercourse name, otherwise temperature locations are within 0.1 mile from the confluence with the Mattole mainstem.

Table 2.13 Maximum summer temperatures for various tributaries to the Mattole River, Western subbasin, 1996-2001. River mile identifiers are based on DWR (1973) convention as submitted by MSG.

Tributary	River Mile*	MAX 1996		MAX 1997		MAX 1998		MAX 1999		MAX 2000		MAX 2001	
		°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C
Stansberry Cr	1.3+0.1			65	18	62	17	62	17				
Mill Cr	2.8+0.5	57	14	64	18	61	16	68	20			59.3	15.2
Clear Cr	6.1+0.2									62.2	16.8		
Squaw Cr	15+0.1	77	25	74	23	75	24	72	22				
Squaw Cr-upstr	15+2.0			67	19								
Woods Cr	24.1+0.1									67.4	19.7		
Honeydew	26.6+0.5	76	24	80	27	80	27	79	26				
Bear Cr	42.8+0.6	68	20	76	24	78	26			71.1	21.7	76.8	24.9
Bear Cr, upstr	42.8+5.0	71	22	72	22								
NFK Bear Cr	42.8+5.1			74	23	72	22					66.6	19.2
SFK Bear Cr	42.8+5.1	69	21	69	21							65.4	18.6
Little Finley Cr	46.7+0.1	72	22	72	22								
Big Finley Cr	47.5+0.1					63	17	61	16			61.8	16.6
Nooning Cr	50.2+0.01											61.2	16.2

*River mile indicates locations of the confluence of the tributary from the Mattole River mouth, the + indicates distance upstream the thermograph is located from the confluence of the tributary to the Mattole mainstem

The critical peak lethal temperature threshold of 75° F (23.9° C) established for salmonid survival was exceeded in Squaw Creek during 1996 and equaled in 1998. It was exceeded all years in Honeydew Creek, and in Bear Creek during 1997, 1998, and 2001. All of these peak maximum temperature exceedences were measured within 0.6 miles from each stream's confluence with the Mattole River. The upstream reaches of Bear Creek did not exceed the maximum 75° F (23.9° C) lethal temperature threshold during any of the years of record, although the North Fork Bear Creek was close at 74° F (23.3^{o} C). A peak maximum summer temperature of 67° F (19.4 ^{o} C) was recorded in Squaw Creek in 1997 at a location two miles upstream from the confluence with the Mattole.

TIR temperature imaging surveys were used to derive point-in-time median temperatures for Bear Creek, Honeydew Creek, and Squaw Creek on July 20, 2001. Bear Creek was flown from the Mattole River to the confluence of the North and South Forks, a distance of approximately 6.9 miles. Honeydew Creek was surveyed for approximately 5.7 miles upstream from the Mattole River, and Squaw Creek was surveyed upstream from the mouth to the headwaters, a distance of approximately 11.7 miles (Watershed Sciences, 2002).

Figure 2.7 shows the TIR-derived temperature profile for the mainstem of Bear Creek flown from 1:55 to 2:11 p.m., on July 20, 2001. In general, surface maximum temperatures increase relatively rapidly from the forks at approximately mile 6.9, to mile 6.1, then fluctuate between approximately 63° F and 66° F (17.2^{o} C to 18.9^{o} C) until river mile 1.4. From mile 1.4 to approximately mile 0.9, the surface temperature spikes rapidly upward from approximately 65° F (18.3^{o} C) to a maximum 70° F (21.1 ^{o} C).

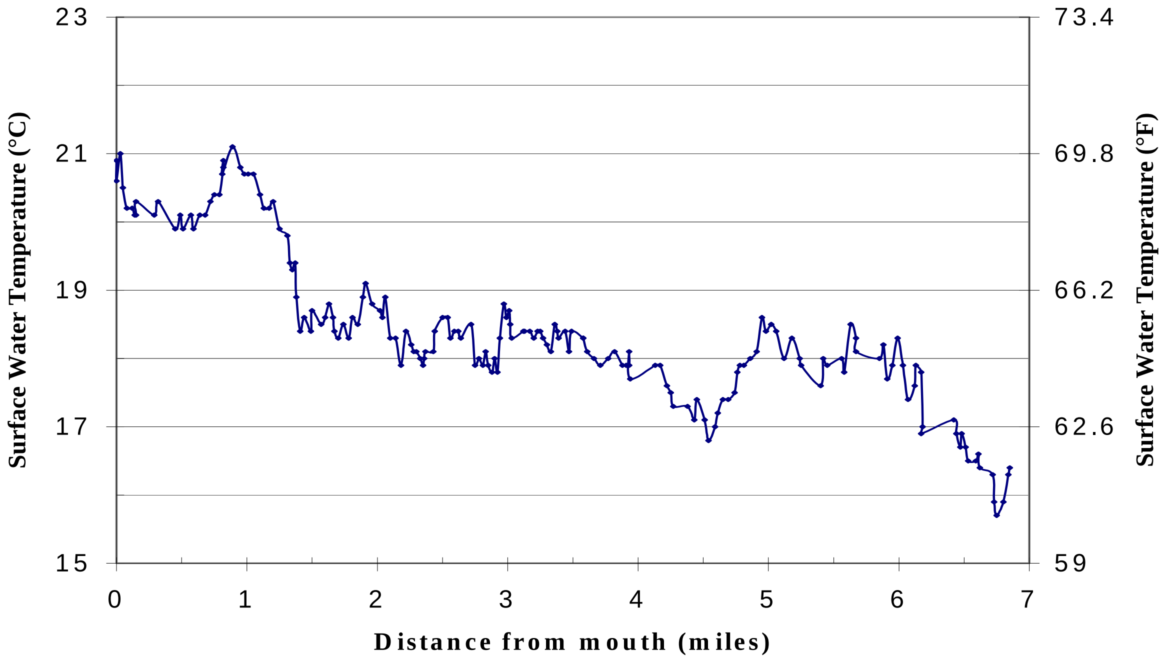

Figure 2.7 Surface temperatures of Bear Creek from mouth to North and South Forks, July 20, 2001, from thermal infrared imaging.

Honeydew Creek temperatures in the TIR profile gradually increase from 57.6° F (14.2 °C) at the upstream end, reaching a maximum near 71° F (21.7 °C) approximately 0.5 miles from the mouth (Figure 2.8).

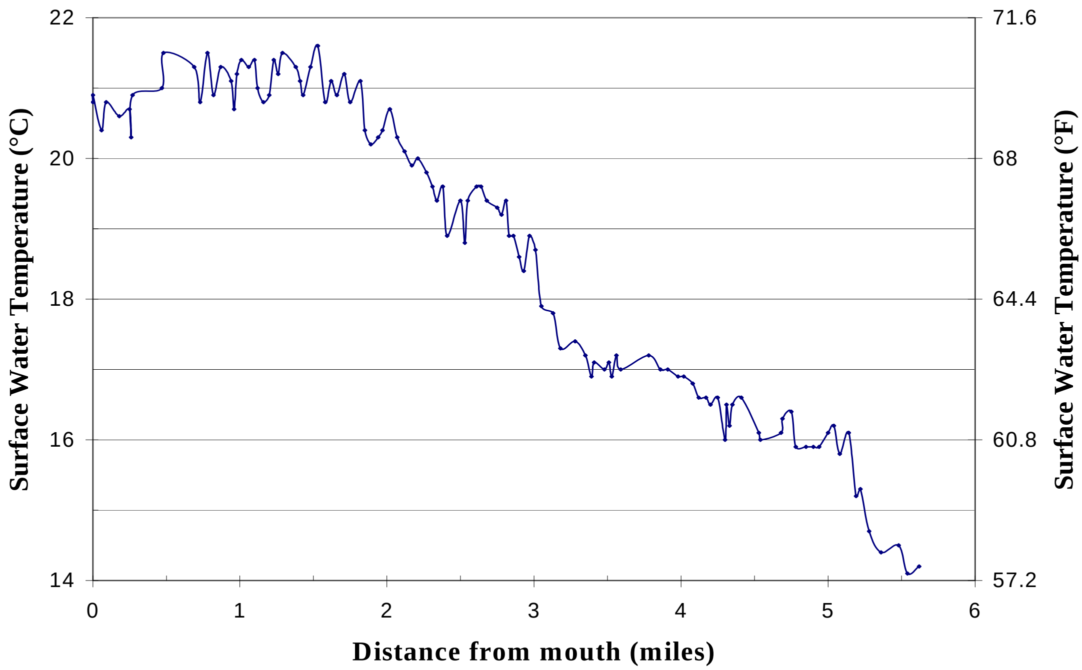

Figure 2.8: Surface temperatures of Honeydew Creek, from Mouth to approximately 5.6 miles upstream, July 20 2001, from thermal infrared imaging

Squaw Creek temperatures increase from 55.6° F (13.1 ^{o} C) at the upstream end of the survey to 66.7° F (19.3 ^{o} C) just upstream from the confluence with the Mattole (Figure 2.9).

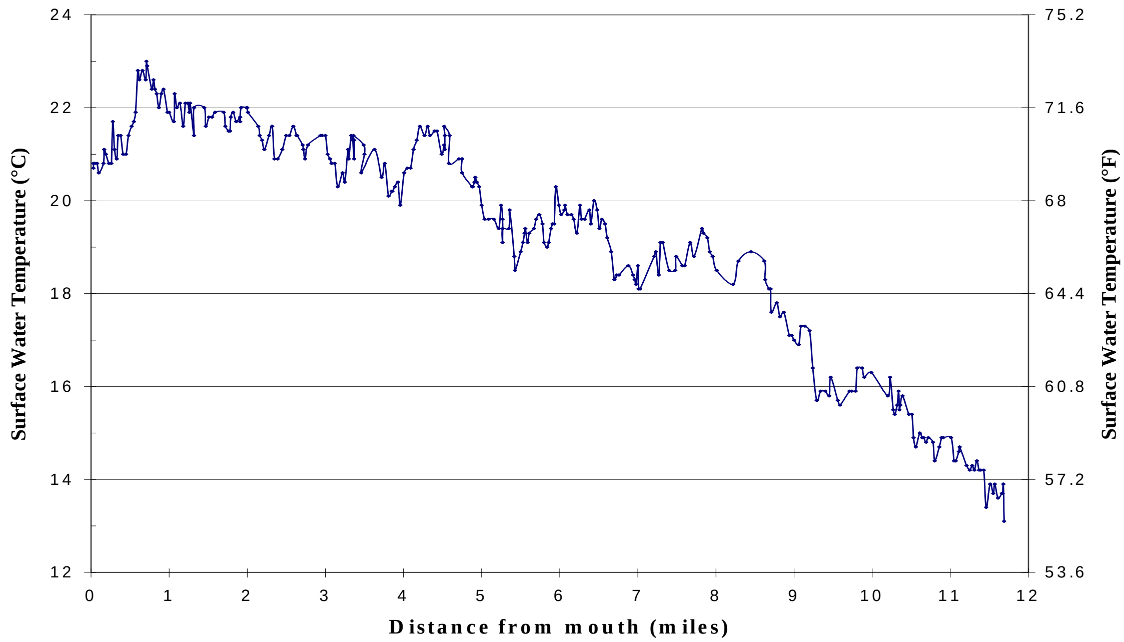

Figure 2.9 Surface temperatures of Squaw Creek, mouth to 11.7 miles upstream, July 20, 2001

2.5.3 Oxygen and Chemical Pollutants.

Although data were gathered inconsistently spatially, temporally, and volumetrically, it does not appear that water chemistry and basic physical parameters, such as pH, specific conductance, and dissolved oxygen are impacting the salmonids or other vertebrate species, macroinvertebrates, and floral constituents in the Mattole River watershed. Some evidence suggests that dissolved oxygen may approach anoxic levels in deeper pools in the estuary; further sampling is needed to confirm or refute this finding (NCWAP, 2002).

Water quality in the estuary varies seasonally depending on river discharge and is also highly dependent on periodic sand bar closure between the river and the Pacific Ocean. The MRC estuary assessment, Dynamics of Recovery (1995), and other research projects mention possible drops in dissolved oxygen leading to anoxic conditions associated with the growth and decay of extensive algal mats during bar closure and low river discharges (MRC, 1995; Young, 1987; Zedonis, 1992). Anoxic pockets may develop in association with the bacterial decomposition of the algal mats in deeper, stagnant pools. Similar conditions have been documented in the Russian River estuary during periods of mid- to late-summer bar closures of the river mouth (Goodwin, 1993). Anoxic conditions in the Russian River were typically associated with pools as deep as 35 to 40 feet. The Mattole estuary did not appear to be deeper than 12 feet at any location (MRC, 1995). To ascertain if anoxic pockets do develop in association with bar closure, a rigorous sampling procedure that includes depth integrated sampling at the locations of specific pools and transects would be necessary (NCWAP, 2002).

2.5.4 Conditions in the Mattole River Estuary

The following discussion of Mattole estuary conditions is largely summarized, paraphrased, and in some places quoted from the Mattole River Draft Report (NCWAP, 2002, p. 3-5). NCRWQCB staff have contributed data toward that section, reviewed the document, and found no significant disagreement with the data or findings.

Estuaries are critical habitats for all anadromous salmonids. Estuaries afford the environment of transition between freshwater and saltwater environments during the seaward migration of juveniles and the spawning run of the adults. Estuaries serve also as a nursery for juveniles, and as such function well only when they can provide abundant food, diverse habitat, relative security from predators, and water of suitable temperature.

In the Mattole River estuary, large volumes of sediment transported from throughout the watershed during the episodic flood events have reduced the volume and depth of water. The impacts include changes in the biologic functioning of the estuary and adjacent wetlands and elevated summer water temperatures. NCWAP concluded that the present highly impacted state of the estuary probably is limiting the production of salmonids in the Mattole River. Studies by Humboldt State University from 1985 to 1992 and current studies by the Mattole Salmon Group support these conclusions.

Estuary subbasin issues include:

- Current sediment and temperature impacts have been shown to be deleterious to rearing of salmonids.
- Estuary pool habitats, including water depth, cover, temperature, and substrate embeddedness appear unsuitable for salmonids in their critical summering stage.
- The uplands that drain into the Mattole River have moderate to very high production of sediment as the result of landsliding and management activities.
- Since 1984, conditions in the estuary have shown slight improvement after the deleterious effects produced by land use and floods before 1965.

In summary, conditions of depth, cover, temperature, and biological functioning of the estuary are a function of processes and conditions throughout the watershed. Therefor, the estuary conditions, and the ability of the estuary to support a large salmonid population, are not likely to improve dramatically until sediment influx from the watershed decreases.

CHAPTER 3: SEDIMENT

The sediment analysis for the Mattole River Watershed examines water quality indicators as they relate to numeric targets and determines sources of sediment, the sediment total maximum daily load (TMDL), and sediment load allocations. The water quality indicators are subdivided into watershed indicators and instream indicators, both of which are used in evaluating attainment of water quality standards. Watershed indicators express hillslope conditions that reflect protection against continuing and future degradation of water quality. Instream indicators express conditions that support salmonids. Because no single indicator adequately represents watershed processes, a suite of indicators is used.

Sources of sediment include natural erosion processes and human activities such as road construction, operation and maintenance, timber harvest, and livestock grazing. The sediment total maximum daily load (TMDL) is equal to the loading capacity of the stream. Therefore, the TMDL is an estimate of the maximum rate of sediment delivery to the stream without exceeding applicable water quality standards. USEPA regulations stipulate that a margin of safety is to be allowed in determining the loading capacity and allocating the TMDL to various sediment sources in the watershed. Thus the TMDL sediment load allocation equals the sum of all load allocations (for non-point sources) plus a margin of safety.

3.1 Water Quality Indicators and Numeric Targets for Sediment

This section identifies water quality indicators. With the exception of turbidity, these indicators are interpretations of the water quality standards expressed in terms of two categories, instream conditions 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 and implementation measures in attaining water quality standards, although they are not directly enforceable as indicators. The turbidity target is an enforceable numeric water quality objective in the Basin Plan.

No single indicator adequately describes water quality with relation to sediment; instead, a suite of both 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. Experience shows that, when considered together, the indicators provide good evidence of the condition of the stream and progress toward attainment of water quality standards.

Instream indicators reflect sediment conditions that support salmonids. They relate to quantity and size distribution of sediment and are important because they are direct measures of stream "health."

Watershed indicators describe conditions that reflect either predictors of or protection against future degradation of water quality. These indirect measures to protect stream health support the State Water Resources Control Board Resolution No. 68-16: *Statement of Policy with Respect to Maintaining High Quality of Waters in California,* which is incorporated into the Basin Plan in Appendix 3 and is commonly known as the "anti-degradation policy." Watershed indicators focus 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 identify conditions that are needed in the watershed to protect water quality.

Target values of both instream and watershed indicators are set at levels associated with well-functioning stream systems. Watershed indicators reflect processes in the watershed at the time of measurement, and may respond relatively quickly to induced changes. Instream indicators reflect present conditions, but these conditions can take years or decades to respond to changes in the watershed. Time lags between production and delivery, instream storage, and times and processes of transport through the system complicate linkages between hillslope sediment production and instream sediment delivery. 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 conditions will be met.

3.1.1 Summary of Water Quality Indicators and Targets for Sediment

Table 3.1 lists the water quality indicators for the Mattole River TMDL and their respective target values. In several cases, targets are expressed as improving trends, because information on watershed processes is inadequate to develop appropriate thresholds.

3.1.2 Sediment Indicators-Instream

3.1.2.1 *Sediment Substrate Composition*
Target: ≤ 14% fines < 0.85 mm, ≤ 30% fines < 6.4 mm
The indicator and target selected represent adequate spawning, incubation, and emergence conditions relative to substrate composition. Excess fine sediment can decrease water flow through for salmon redds. Sufficient water flow through for the redd is critical for maintaining adequate oxygen levels and removing metabolic wastes. Deposits of these finer sediments can also prevent the hatching fry from emerging from the redd, thus smothering them. Monitoring should be conducted by bulk sampling during low-flow periods at the heads of riffles in potential spawning reaches. We recommend collecting and reporting the full range of sizes, but emphasize that the smallest size fraction is the most important indicator of the “fines” that are likely to clog and embed the spawning gravels. In addition, we recommend reporting the method by which the data is analyzed (e.g., size of total sample, measurements by dry weight, wet volume), so that sources of uncertainty are known. In the future, when additional information becomes available, other indicators for permeability or turbidity may supplement or replace this indicator.

Conditions in the Mattole Watershed
DFG collected data on percent fines in the upper Mattole and Lost Man Creek (Preston, 1991). Results generally indicate percent fines <0.85 mm at levels above the target of 14%. DFG also collected data on fine sediment at several locations in the northern subbasin from 1991-1995. Results were not available for review or summary here, but are expected to be included in the final KRIS Mattole product when it becomes available.

3.1.2.2 *Riffle Embeddedness*
Target: ≤25% or improving (decreasing) trend
Embeddedness is a measure of the degree to which cobbles and pebbles are embedded in the finer-grained substrate. A heavily embedded riffle section may make spawning impossible. When constructing its redd, generally at a pool tail-out (i.e., the head of the riffle), the spawning fish slaps its tail against the channel bottom, which lifts unembedded gravels and removes some of the fine sediment. This process results in a pile of cleaner and more permeable gravel, which is more suited to nurturing the eggs. Embedded gravels do not generally lift easily and can prevent spawning fish from building their redds. Flosi and others (1998) suggest that gravels less than 25% embedded are preferred for spawning. This target should be estimated during the low-flow period, generally at riffle heads, in potential spawning

reaches. Because this indicator is estimated visually and subject to operator variability, it may be appropriate to substitute the use of pebble counts that note individual pebble embeddedness.

Conditions in the Mattole Watershed
The NCWAP Mattole Synthesis Report expresses riffle embeddedness as cobble embeddedness at pool tail crests. Data are available for each subbasin (not including the estuary).

- In the northern subbasin, embeddedness was measured in seven streams (NCWAP, 2002, Fig.65). Sulphur Creek showed 32% of the samples with embeddedness in the 0-25% range, the lowest, most desirable category. All other streams showed less than 10% of the samples with embeddedness of 0-25%.
- In the eastern subbasin, 14 streams were sampled. None showed more than 16% of the riffles sampled in the 0-25% embeddedness category (NCWAP, 2002, Fig 81). Ten streams showed no embeddedness values in this low category.
- In the southern subbasin, of 12 streams sampled (NCWAP, 2002, Fig. 97), only Baker Creek (42%) shows more than 15% of samples in the 0-25% category. Seven streams show no samples in this category.
- In the western subbasin, 13 locations were sampled (NCWAP, 2002, Fig. 113). Nine out of 13 locations showed few or no samples in the 0-25% category. The samples from the Bear Creek drainage (4 locations) showed 18-52% in this category. Bear Creek shows the highest percentage of embeddedness in the 0-25% category of any location reported in the watershed.

Only a few areas in the watershed have more than 20% of the sampled sites in the lowest category (0-25%), and many areas show no values of 25% or lower, the value recommended by Flosi and others (1998) as preferred for spawning gravels. High embeddedness values of pool tail gravels in the Mattole in general indicate poor instream sediment conditions.

3.1.2.3 *V**

Target: <0.21 (Franciscan geology) or <0.10 (stable geology)
V* (pronounced vee-star) is a measure of the fraction of a pool's volume that is filled by fine sediment and represents the in-channel supply of mobile bedload sediment (Lisle and Hilton, 1992). V* reflects the quality of pool habitat, because a lower filled pool volume reflects deeper, cooler pools that offer protection from predators, a food source, and a resting location. Lisle and Hilton (1992) also describe methods for monitoring, which should be conducted in low-flow periods. V* is not an appropriate measure for large rivers, but in large river systems it is appropriate for tributaries. The target value of V* <.21 is adopted from Knopp's (1993) study as applied in the TMDL for the Garcia River in which V* values from six pools from the index yes and index no reaches were averaged to calculate a numeric mean V* ≤0.21, and the highest V* value for an individual pool was V* ≤0.45.

Conditions in the Mattole Watershed
Very few data are currently available. Knopp (1993) presents results of V* analysis for a number of North Coast locations, including several in the Mattole. He calculated an average V* for the number of pools sampled per reach using a weighting factor for that reach. The study was based on the methodology used by Hilton and Lisle (1993). Results for reach-average V* values were well above the TMDL target for Baker Creek (0.51) and Yew Creek (0.45) (both in the southern subbasin), slightly above the target for the North Fork of Bear Creek (0.25) (western subbasin) and Mill Creek (0.24) (southern subbasin), and below the target for the West Fork of Honeydew Creek (0.10) (western subbasin).

Table 3.1 Water quality indicators and targets

INDICATOR	TARGET	COMMENTS	PURPOSE	REFERENCES
Instream	Monitoring recommendations: annually (e.g., sediment substrate, embeddedness, V*, aquatic insect abundance) or periodically following large storms (thalweg profile, pool distribution, turbidity, LWD)			
Sediment Substrate Composition	≤ 14% < 0.85 mm ≤ 30% < 6.4 mm	McNeil (bulk) sample during low-flow period, at riffle heads in potential spawning reaches	Indirect measure of spawning support, improved quality and size distribution of spawning gravel	Burns, 1970; CDF, 1994; McHenry et al., 1994; NCRWQCB, 2000a; 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 and 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.
Watershed	Monitoring recommendations: prior to winter			
Diversion potential & stream crossing failure potential	≤ 1% of crossings divert or fail in 100 yr storm	Measured prior to winter.	Estimate of potential for reduced risk of sediment delivery from hillslope sources to the watercourse	Weaver and Hagans, 1994; Flanagan et al., 1998.
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	see text	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	see text	Measure of chronic sediment input	Lewis, 1998.

The Mattole Salmon Group (MSG) collected V* measurements along eight stream reaches in different parts of the Mattole watershed during 2000. MSG methods also were based on Hilton and Lisle (1993) and therefore are comparable to Knopp's (1993) results when used in stream reaches in the Mattole River watershed which have similar hydrologic and geologic characteristics.

The MSG reported V* value in Bridge Creek was 0.04. The values in seven other creeks (Mill, Conklin, Squaw, Westlund, Middle, and Honeydew Creeks, and the mainstem Mattole River) ranged from 0.22 to 0.27, all somewhat higher than the target value of 0.21.

3.1.2.4 *Thalweg Profile*

Target: increasing variation of elevation around the mean slope

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

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

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

Conditions in the Mattole Watershed

We are not aware of any recent thalweg profile survey on the Mattole River.

3.1.2.5 *Pool Distribution and Depth*

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

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

Conditions in the Mattole Watershed.
The NCWAP Mattole Watershed Synthesis Report (NCWAP, 2002) presents data by subbasin for habitat categories by stream survey length (including pool habitat) and for pool depths by stream survey length (presented as a percentage of total survey length). The reported figures do not include stream order for the surveyed streams, so it is not possible to directly compare these data to the indicator targets. For purposes of this discussion, the stream survey length occupied by pools greater than two feet deep is used for comparison.

Northern Subbasin. Data from seven streams presented by NCWAP (2002) show total pool habitat ranging from 16 percent to as low as 2 percent of total stream length. Pools greater than two feet deep occupy from zero to approximately 13 percent of total survey length. Pool conditions in none of the northern subbasin streams surveyed meet pool indicator targets. Conditions are best in Oil, Rattlesnake, and Devils Creeks, and worst in Conklin Creek.

Eastern Subbasin. Data presented by NCWAP (2002) from 14 streams show pool habitat ranging from five to 33 percent of total stream length. Pools greater than two feet deep occupy three percent or less of total survey length in five surveyed streams, but as much as 25 percent in Eubanks Creek. Pool conditions in none of the eastern subbasin streams surveyed meet pool indicator targets. Conditions are best in Eubanks, McKee, and Harrow Creeks. Conditions are worst in Middle, North Fork Four Mile, Fire, a tributary to Gilham, and Little Grindstone Creeks, where pools greater than two feet deep occupy less than three percent of survey length.

Southern Subbasin. Data presented by NCWAP (2002) from 12 streams show pool habitat in the range of 10 to 43 percent of total stream length. Pools greater than two feet deep occupy from four percent of stream survey length in Anderson Creek to as high as 31 percent in the Mattole headwaters. Except in the headwaters of the Mattole River, conditions in none of the southern subbasin streams surveyed meet pool frequency indicator targets. Conditions in none of the southern subbasin streams surveyed meet pool depth indicator targets. Conditions are best in Mattole headwaters and are worst in Anderson and Helen Barnum Creeks. Conditions in parts of this subbasin may reflect bedrock controls on pool depth.

Western Subbasin. Data presented in the NCWAP synthesis report from 13 streams show pool habitat in the range of 12 to 36 percent of stream length. Pools greater than two feet deep occupy from eight to 36 percent of total survey length. Pool conditions in none of the western subbasin streams surveyed meet pool indicator targets. Conditions are best in Bear, South Fork Bear, a tributary to Bear, East Fork Honeydew, and Squaw Creeks, and are worst in Mill and Jewett Creeks.

3.1.2.6 *Turbidity*

Target and Enforceable Water Quality Standard: <20% above naturally occurring background levels.
Turbidity is a measure of the ability of light to shine through water (higher turbidity indicating more material that blocks light in the water). Although turbidity levels can be elevated by both sediment and organic material, in the Mattole River watershed, stream turbidity levels are strongly correlated with suspended sediment (GMA, 2001). High turbidity in the stream affects fish by reducing visibility, which may result in reduced feeding and growth. Elevated suspended sediment, particularly over a long period, may also result in direct physical harm, for example by clogging gills. Turbidity should be measured

during storm flows, particularly during the winter. Although determinations of background levels are sometimes problematic, it is reasonable to measure levels upstream and downstream of a management activity to compare changes in the turbidity levels that may be attributed to that activity. Information should include both magnitude and duration of elevated turbidity levels.

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

Conditions in the Watershed
Groups in the watershed have attempted turbidity sampling at or near the USGS stream gage location on the Mattole River at Petrolia. It is not known whether any results have been generated from this effort.

3.1.2.7 *Aquatic Insect Production*
Target: improving trends in EPT Index, percent dominant taxa, and species richness indices
Benthic macroinvertebrate populations are greatly influenced by water quality and are often adversely affected by excess fine sediment. This TMDL recommends that several indices be calculated, following the California Salmonid Stream Restoration Manual (Flosi, et al., 1998).

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

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

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

The use of macroinvertebrate conditions to assess water quality is an area of active interest at present. EPA is supporting research to develop macroinvertebrate indices suitable for use in the Mattole. DFG also continues to work in this area. It would be appropriate to evaluate the indices proposed above with any newly developed indices with respect to suitability for use in the Mattole.

Conditions in the Mattole Watershed
The NCWAP Mattole Synthesis Report (NCWAP, 2002) summarizes macroinvertebrate data collected by BLM and PALCO at 21 locations in the watershed. Data were interpreted according to a number of indices assessing diversity, richness, composition, tolerance/intolerance, and other factors. The NCWAP summary, after assigning qualitative descriptors to the results for each index value, characterized conditions for each location sampled. Overall conditions generally were described as fair to good or good.

3.1.2.8 *Large Woody Debris (LWD)*
Target: increasing distribution, volume, and number of key pieces, or increasing distribution of LWD-formed habitat
California coastal streams are especially dependent on the presence of LWD to provide ecological functions such as sediment metering and sorting, pool formation, and shelter. Large pieces of woody debris in streams influence the physical form of the channel, the movement of sediment, the retention of organic matter, and the composition of the biological community (Bilby and Ward, 1989). LWD can be instrumental in forming and stabilizing gravel bars (Bilby and Ward 1989; Lisle 1989), or in accumulating fine sediment, which keeps it from clogging spawning areas (Zimmerman et al., 1967; Megahan, 1982 *in* Bilby and Ward, 1989). LWD can also form pools by directing or concentrating flow in the stream in such a way that the bank or bed is scoured, or by impounding water upstream from the obstruction (Lisle and Kelsey, 1982). LWD plays a more significant role in routing sediment in small streams than in large ones (Bilby and Ward, 1989).

This indicator should be measured during the low-flow period. Reporting should include the number and volume of key pieces or the distribution of LWD-formed habitat. The target is designed to be flexible, depending on the type of descriptor that an overall monitoring project finds most useful for assessing stream and watershed conditions. The description of a "key piece" should be related to a size that is important for salmonid use in the stream. EPA encourages the NCRWQCB to specify the description in its monitoring plan.

Conditions in the Mattole Watershed
The NCWAP Mattole River Synthesis Report (2002, Appendix D, p. 99-100) has the following to say about recent history:

> In the late 1970s, DFG perceived that LWD accumulations, caused by timber harvest activities and flood events, presented a problem of instream barriers to salmonid movement. This perception led to wood removal projects supervised by the DFG in many California streams. Large woody debris was removed in about 71 stream miles in the Mattole Basin during the 1980's (Table 30). A total of 56,960 cubic feet of wood was removed. This is equivalent to 445 logs 2 feet x 40 feet. This activity likely had adverse impacts on salmonid habitat conditions. No wood was removed in the Estuary or Northern Subbasin: however, the amount of wood removed in the Eastern, Western, and Southern Subbasins was recorded.
>
> A total of 1,024 cubic feet of wood was removed in the eastern subbasin (Table 31). This is equivalent to 8 logs 2 feet x 40 feet. In the southern subbasin, a total of 36,800 cubic feet of wood was removed (Table 32). This is equivalent to 294 logs 2 feet by 40 feet. Lastly, a total of 19,136 cubic feet of wood was removed in the western subbasin (Table 33). This is equivalent to 153 logs 2 feet by 40 feet. No wood was removed from the estuary or Northern Subbasin.
>
> The wood removal program was carried out as late as 1992. Since that time apparently DFG has allowed LWD to accumulate in its natural manner.

3.1.3 Sediment Indicators-Watershed
The following sections on sediment indicators in the Mattole River watershed contain reported conditions taken from several publicly funded watershed inventories, including those for the Sanctuary Forest (PWA, 2001), Mill Creek (PWA, 2000), Honeydew Creek (BLM, 1996), Bear Creek (BLM, 1995), and the Mattole Estuary (MRC, 1995).

According to the analysis conducted by BLM, widespread logging in the Mattole River watershed that occurred from 1950 to 1970 was done with little regard to placement of roads or skid trails, or to protection of watercourses. Logging operations commonly used stream channels as transportation corridors, with some logging roads located in the inner gorge areas of the watershed (BLM, 1995).

Field observations in the BLM (1995) report for the Honeydew Creek Watershed reveal that most of the roads and skid trails were constructed with almost no drainage structures. This report concluded that the corresponding disruption to the natural drainage patterns in the watershed resulted in the majority of road prisms, skid trails, and stream crossings washing out with the floods of 1955 and 1964. Both floods generated a huge number of slides, mainly within the inner gorges of streams (BLM, 1996). This report went on to state that although many new slides occurred in the unentered portions of the watershed, landslide density was greater in the managed landscape. This appeared to be due to activated slides caused by the extensive road and skid trail system, failing within the inner gorges, and flood waters destabilizing the toes of slopes (BLM, 1996).

A report prepared by Pacific Watershed Associates (PWA, 2001) for the Sanctuary Forest notes that virtually all future road-related erosion sites in the upper Mattole watershed are expected to come from three sources: 1) the failure of road and landing fills (landsliding), 2) erosion at or associated with stream crossings, and 3) road surface and ditch erosion (PWA, 2001). PWA reported that permanently decommissioning (closing) or "storm proofing" could accomplish treatments along these unstable and/or high yield roads (upgrading).

3.1.3.1 *Stream Crossings with Diversion Potential or Significant Failure Potential*
Target: <1% of all stream crossings divert or fail as a result of a 100-year or smaller flood
Most roads, including skid trails and railroads, cross ephemeral or perennial streams. Crossings are built to capture the stream flow and safely convey it through, under, or around the roadbed. However, stream crossings can fail, adding sediment from the crossing structure (i.e., fill) or from the roadbed directly into the stream. Stream crossing failures are generally related to undersized, poorly placed, plugged, or partially plugged culverts. When a crossing fails, the total sediment volume delivered to the stream usually includes both the volume of road fill associated with the crossing and sediment from collateral failures such as debris torrents that scour the channel and stream banks. Diversion potential is the potential for a road to divert water from its intended drainage system across or through the road fill, thereby delivering road-related sediment to a watercourse. The potential to deliver sediment to the stream can be eliminated from almost all stream crossings by eliminating inboard ditches, outsloping roads, or installing rolling dips (M. Furniss, pers. comm., in USEPA 1998a). Generally, less than one percent of stream crossings have conditions where modification is inappropriate because it would endanger travelers or where modification is impractical because of physical constraints (D. Hagans, pers. comm., 1998, in USEPA 1998a).

Conditions in the Mattole Watershed
BLM stated in their watershed analysis for Bear Creek that stream crossings with diversion potential or significant failure potential are high risks for sediment delivery to streams in the Mattole River watershed (BLM, 1995). BLM additionally reported that Kings Peak Road located in the Bear Creek Watershed contains relief structures such as inboard drains that are inadequate and too widely spaced, allowing extremely long uninterrupted inboard ditch reaches (BLM, 1995). This report goes on to state that some of numerous stream crossings with large fills have deteriorating culverts. King Range Road within the Bear Creek watershed was reported by BLM in 1995 to contain three major stream crossings that exhibit large volumes of fill material and which have the potential to deliver fine sediments to adjacent streams.

The Queen Peak Mine main access road, in the Bear Creek watershed, is located in extremely steep terrain. There are stream crossings along the road that have inadequate or poorly installed culverts, one of which is noted as being "shotgunned" (BLM, 1995).

According to BLM, Chemise Mountain Road in the riparian zone of the upper South Fork Bear Creek may be the greatest contributor of fine sediments in the watershed. Most of the culverts along this road appear to be undersized, and there are not enough culverts to effectively drain the ditch system along the road. Therefor, the culverts are prone to clogging with storm debris during major runoff events (BLM, 1995).

BLM's watershed analysis for the King Range Road in the Honeydew Creek watershed reveals 11 major stream crossings and 24 to 30 ditch-relief culverts which have the potential for catastrophic failure of the road prism (BLM, 1996). The vast majority of these stream crossings and, in some cases, entire road prisms have failed in the last 30 years.

BLM (1996) reported that past harvesting operations in the Bear Trap Creek area accessed timber, as in other harvested areas, by constructing haul roads and skid trails from the ridges down into, and up from, the bed of the creek. These roads were constructed with almost no drainage structures. As a result, the majority of the road prisms, skid trails, and stream crossings in Bear Trap Creek washed out in the floods of the 1960s and 1970s.

In the Thompson Creek watershed, Pacific Watershed Associates (2001) recommended treatment for 174 stream crossings, of which 51 are currently diverted and 77 have diversion potential. PWA estimated total future erosion and sediment delivery from these stream-crossing sites at approximately 19,056 yds^3 if erosion prevention measures are not undertaken. They also estimated that approximately one third of the total future sediment yield from stream crossings would result from erosion associated with abandoned unculverted stream crossings (PWA, 2001).

3.1.3.2 *Hydrologic Connectivity*
Target: decreasing length of hyrologically connected roads to $\leq$1%
A hydrologically connected road drains water directly to the adjacent stream, which increases the intensity, frequency, and magnitude of flood flows and suspended sediment loads in the stream. This process can destabilize the stream channel and produce a devastating effect on salmonid redds and growing embryos (Lisle, 1989). The hydrologic connectivity can be reduced by outsloping roads, creating road drainage that mimics natural drainage as much as possible, and other factors (M. Furniss, pers. comm., 1998, and Weaver and Hagans, 1994). The reduction of road densities and the reconstruction of roads to reduce the miles of inboard ditches, for example, can reduce the amount of water that is directly delivered to watercourses, as well as associated sediment load.

Conditions in the Mattole Watershed
The study conducted by BLM on Kings Peak Road within the Bear Creek watershed found that this road has an extensive inboard ditch system, is insloped, and exhibits a nearly continuous outboard berm. The ditches collect and concentrate surface runoff from large upslope areas and from the road, discharging it downslope through the major drainages into Bear Creek. Many of the culverts where reported as being "shotgunned" and initiating more erosion downslope. As Kings Peak Road runs along the ridgeline it diverts some water that would have drained to the ocean side of the ridge into the Bear Creek drainage (BLM, 1995). The modified drainage configuration provides an efficient mechanism for the direct delivery of fine road sediments into Bear Creek.

The sediment source inventory for South Fork Bear Creek (Horn, 1992) identifies three major sediment problems with the road: (1) Large quantities of fine sediment are washed off the road by winter rains into inboard ditches and transported directly into the stream channel, (2) Culverts have deteriorated by aging, rusting through, and leaking, causing erosion of the fill beneath the culvert and threatening to wash out the road prism, and (3) Fill materials across existing unstable soils are failing and in some cases are threatening to enter the stream channel.

Results from BLM for the analysis of geomorphic mapping have shown that 89 percent of the King Range Road length is drained by inboard ditch features, and that 41 percent of the road length had actively eroding cutbanks that contribute sediment to the ditch in the form of ravel cones, rockfalls, debris avalanches, and other shallow translational slides (BLM, 1996).

Bear Trap West Road exhibits extensive gullying and rill erosion for almost its entire 2-mile length within BLM lands. The inboard ditch is incising in some areas and failing in others. There are no cross drains and the road is presently in worse hydrologic condition than the majority of abandoned roads (BLM, 1996).

In the Thompson Creek Watershed, Pacific Watershed Associates reported that 13.45 miles of the 24.12 miles of roads (54 percent) identified are hydrologically connected and currently deliver sediment and/or runoff to streams (PWA, 2001).

3.1.3.3 *Annual Road Inspection and Correction*
Target: increasing proportion to 100%
EPA's analysis indicates that in watersheds with road networks that have not experienced excessive road-related sedimentation, roads are either (1) regularly inspected and maintained; (2) hydrologically maintenance free (i.e., they do not alter the natural hydrology of the stream); or (3) decommissioned or hydrologically closed (i.e., fills and culverts have been removed and the natural hydrology of the hillslope has largely been restored). Roads that do not meet one of these conditions are potentially large sources of sediment (D. Hagans, pers. comm., 1998, cited in USEPA, 1998a). In general, road inspection should be done annually and could in most cases be accomplished with a windshield survey. The areas with the greatest potential for sediment delivery should be corrected before the onset of winter conditions. This target calls for an increase in the proportion of roads that are either (1) inspected annually and maintained before winter, (2) hydrologically maintenance free, or (3) decommissioned or hydrologically closed, until all roads in the Mattole River Watershed fall into one of these categories.

Conditions in the Mattole Watershed
Within Bear Creek watershed are five arterial gravel roads and one paved road (Shelter Cove Road). BLM is responsible for maintaining King Range Road, Saddle Mountain Road, and Paradise Ridge Road. Humboldt County is responsible for maintaining Shelter Cove Road, Chemise Mountain Road, and Horse Mountain Road (BLM, 1995). Humboldt County maintenance responsibilities also include Kings Peak Road, which is located in the Bear Creek watershed and maintained at least once per year. Culverts on King Range Road receive winter maintenance and are relatively effective (BLM, 1995). Maintenance for Chemise Mountain Road is reported to include occasional "graveling" of the road with aggregate. Wilder Ridge Road is a county-maintained road that has stabilized over the years. It has been surfaced with chip-seal over nearly its entire length (BLM, 1996).

The portion of Smith-Etter Road that climbs to the top of Bear Trap Ridge is boggy and easily rutted during wet periods (BLM, 1996). BLM has applied rock to some sections in an attempt to harden these areas, but generally the problem persists.

For other areas of the Mattole River Watershed, where specific road maintenance information is not available, BLM reports that all roads managed by BLM receive annual maintenance (BLM, 1997).

The northernmost 3.5 miles of King Range Road was successfully decommissioned by heavy equipment during the summer and fall of 1995 and 1996. This included recontouring of the entire length, and the excavation of 22 stream crossings. The project removed approximately 186,500 cubic yards of soil material that would have been potentially delivered to the streams (MRC, 1998).

3.1.3.4 *Road Location, Surfacing, Sidecast*

Target: decrease road length next to streams and increase proportion of out-sloped or hard surfaced roads

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

This target calls for several things: (1) elimination of roads alongside inner gorge stream reaches or in potentially unstable headwall areas, unless alternative road locations are unavailable and the road is clearly needed, (2) road surfacing, drainage methods, and maintenance should be appropriate to the road's use patterns and intensities, and (3) sidecast or fill on slopes of greater than 50 percent grade, or potentially unstable slopes that could deliver sediment to a watercourse, should be stabilized or regraded to 50 percent grade or less.

Conditions in the Watershed

Chemise Mountain Road lies directly in the riparian zone of the upper South Fork Bear Creek and may be the greatest contributor in the watershed of large amounts of fine sediments transported by winter runoff (BLM, 1995). BLM concluded that the location and system of ditches associated with the road completely disrupts the natural drainage network and concentrates sediment-laden runoff, a situation that is aggravated by private driveways with inadequate culverts, which are in some instances collecting and discharging runoff directly onto Chemise Mountain Road. Elements of Recovery (MRC, 1989) recommends (1) paving the entire length of this county road, (2) elimination of diversions caused by the road, (3) enlarging roadside culverts associated with driveways, (4) education programs for residential driveway maintenance, (5) outsloping the roads, and (6) adding water bars and other improvements.

3.1.3.5 *Activity in Unstable Areas*

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

Unstable areas are those areas that have a high risk of landsliding, and include steep slopes, inner gorges, headwall swales, stream banks, existing landslides, and other locations identified in the field. Because of the high risk of landsliding inherent in these features, any activity that might trigger an erosional event should be avoided, if possible, and kept to a minimum if unavoidable. Such activities include road building, timber harvesting, yarding, terracing for vineyards, etc. Analysis of chronic landsliding in the Noyo River basin indicated that landslides observed on aerial photographs largely coincide with predicted chronic risk areas including steep slopes, inner gorges, and headwall swales (Dietrich et al., 1998).

Several other studies have shown that landslides are larger or more common in some harvest areas, particularly in inner gorges (GMA, 2001). Weaver and Hagans (1994) also suggest methods for eliminating or decreasing the potential for road-related sediment delivery.

Conditions in the Watershed
Analysis of activities in unstable areas was not conducted for this report.

3.1.3.6 *Disturbed Area*

Target: decrease, or decrease in disturbance index
The areal extent of disturbed areas is an indication of increased sediment loads and particularly chronic sediment discharges that are not associated with large storms or floods. Studies in Caspar Creek (Lewis, 1998) indicate that there is a statistically significant relationship between disturbed areas and the corresponding suspended sediment discharge rate (Lewis, 1998; and Mangelsdorf and Clyde, 2000). In addition, studies in Caspar Creek indicate that clear cutting causes greater increases in peak flows (and, by extension, increased suspended sediment loads) than does selective harvest (Ziemer 1998). As with the "hydrologic connectivity" target, increases in peak flows, annual flows, and suspended sediment discharge rates negatively affect the potential survivability of salmonid eggs in redds (Lisle, 1989,).

Available information is not sufficient to identify a threshold below which effects on the Mattole River watershed would be insignificant. Accordingly, the target calls for a reduction in the amount of disturbed area or in the disturbance index. In this context, "disturbed area" is defined as the area covered by urban development or management-related facilities of any sort, including: roads, landings, skid trails, firelines, harvest areas, animal holding pens, and agricultural fields (e.g., pastures, vineyards, orchards, row crops, etc.). The definition of disturbed area is intentionally broad to include managed agricultural areas, such as pastures and harvest areas, where the management activity (e.g., logging or grazing) results in removal of vegetation sufficient to significantly reduce rainfall interception and other soil protection functions. Agricultural fields or harvest areas in which adequate vegetation is retained to perform these ecological functions are not considered disturbed areas. Dramatic reductions in the amount of disturbed area can be made by reducing road densities, skid trail densities, clearcut areas, and other management-produced bare areas.

Conditions in the Mattole Watershed
Early logging in the watershed was done at smaller scale and generally on gentler slopes than post-1950 logging, and did not significantly impact the watershed. During the 1950s, technology and the demand for Douglas-fir logs allowed logging operations to exploit steep terrain. The access roads, skid trails, and stream crossings employed during these operations resulted in huge sediment inputs into Bear Creek (BLM, 1995). Though a high percentage of the sediments from these sources has already entered the stream, significant amounts remain.

According to Thomas Dunklin, the Lower East Fork drainage of Honeydew Creek has the most extensive network of abandoned roads, except for the High Prairie Creek drainage (BLM, 1996).

3.2 Sources of Sediment

The unstable geology, extreme slopes, changes in vegetation, and high precipitation rates along the North Coast of California, including the Mattole watershed, make streams in the region susceptible to elevated sediment loading from both natural and anthropogenic sources.

3.2.1 Summary and Conclusions

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 rainfall peaks ranging from a high of 212 in/yr. in 1983 to a low of 57 in/yr. in 1991 (MRC, 1995). The Mattole watershed is dominated by Franciscan Complex geology, which 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.

The estimated current rate of sediment delivery for the entire watershed is 8,000 tons/mi^2/yr. To do the analysis, we used the four subbasins, north, east, west, and south, defined by NCWAP (2000). The east subbasin had the largest estimated sediment delivery, 9,500 tons/mi^2/yr, followed by the north subbasin at 8,200 tons/mi^2/yr, the west subbasin at 7,800 tons/mi^2/yr, and the south subbasin at 4,400 tons/mi^2/yr. The watershed total of 8,000 tons/mi^2/yr (see Table 3.2) was an area weighted average of the subbasin totals, summed for the entire watershed. Greater subbasin totals reflect differences in extent of geologic units (e.g. more soft and moderate units in the north versus hard units in the south) and reflect the road densities of the subbasins (south-9.1 mi/mi^2, west-6.2 mi/mi2, east-6.0 mi/mi^2, and north-3.0 mi/mi^2). These factors along with slope largely influence the subbasin totals. Stream densities are similar in the four subbasins (south-4.2 mi/mi^2, west-4.2 mi/mi^2, east-4.1 mi/mi^2, and north-4.4 mi/mi^2), and they are not a significant factor in explaining differences among the subbasins. Approximately 36 percent (2,900 tons/mi^2/yr) of the total estimated sediment delivery (8,000 tons/mi^2/yr) is attributed to natural erosional processes, and 64 percent is attributed to human activity (harvest activity 1,400 tons/mi^2/yr, and road related erosion 3,700 tons/mi^2/yr).

The estimated total sediment delivery for the Mattole watershed (8,000 tons/mi^2/yr) is larger than the sediment load for Redwood Creek (4,750 tons/mi^2/yr), and over three times the estimated sediment load for the Van Duzen River (2,232 tons/mi^2/yr) (PWA, 1999; EPA, 1999c). Though the Mattole values are high, they are comparable to values derived from comparable sediment studies conducted in other rapidly tectonically uplifting regions. Sediment yields in the San Gabriel Mountains, California on granitic and metamorphic terrane were 5,173 tons/mi^2/yr (Bull, 1978; 1979; 1991). Drainage basins in the rugged

Table 3.2 Natural and Management-Related Sediment Yields in the Mattole Watershed

Sediment Source	Estimated Sediment Delivery			(tons/mi^2/yr)	
	North	East	South	West	Entire Watershed
Natural Mass Wasting	3,700	1,600	1,600	2,100	2,400
Stream Bank Erosion	790	270	170	360	460
Natural Erosion Total	4,500	1,900	1,800	2,500	2,900
Road-Related Mass Wasting	2,000	5,900	450	2,100	2,900
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
Skid-Trail Related Erosion	590	700	760	850	710
Other Harvest Related Delivery	600	110	130	1500	700
Road Erosion Total	2,500	6,800	1,700	2,900	3,700
Harvest Activity Erosion Total	1,200	840	910	2,400	1,400
Erosion Total for All Sources	8,200	9,500	4,400	7,800	8,000

Seaward Kaikoura Range of New Zealand have characteristics similar 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 slopes and high rainfall (1,200-2,000 mm or 47-78 in./yr.) (Bull, 1991). Sediment yield rates for this area range from 7,759-10,346 tons/mi^2/yr (Thompson and McArthur, 1969; O'Loughlin and Pierce, 1982).

The categories in Table 3.2 are defined as follows:

Natural Mass Wasting: Mass wasting (landslides, debris flows, etc.) not influenced by human activities. Note that earthflow delivery has been incorporated into the stream bank erosion estimate. This estimate was generated from the aerial photo analysis and field measurement of road and stream survey plots.

Stream Bank Erosion: Sediment delivered to stream channels by soil creep and earthflow processes. Estimate was generated from the aerial photo analysis and field measurements of stream survey plots.

Road-Related Mass Wasting: Mass wasting (landslides, debris flows, etc.) originating from roads. Estimate was generated from aerial photo analysis and road survey field measurements.

Road-Stream Crossing Failures: Sediment delivery associated with erosion caused by stream crossings, including outlet erosion, stream diversions, and washouts. This is almost certainly an underestimate due to the fact that stream crossings are often repaired after failure, and in some cases repaired after repeated failures. This estimate was generated from the aerial photo analysis and independent studies.

Road-Related Gullying: Sediment delivery associated with gullies caused by road runoff. Estimate was generated from the aerial photo analysis and field measurements of road survey plots.

Road-Related Surface Erosion: Sediment delivery of eroded road surface materials. Estimate was generated from the aerial photo analysis and field measurements of road survey plots.

Skid Trail-Related Erosion: Sediment delivery by mass wasting (landslides, debris flows, etc.) originating from skid trails. This estimate was generated from the aerial photo analysis and field measurement of road and stream survey plots.

Other Harvest-Related Delivery: Sediment delivery from mass wasting features and surface erosion associated with landings, trails, and areas not accounted for elsewhere. This estimate was generated from the aerial photo analysis and field measurement of stream surveys plots.

Caution should be exercised when interpreting the results presented above. The numbers may not add up to exact quantities because of rounding to two significant figures. The estimated sediment delivery numbers are based on the best available data and on professional judgement. The source analysis and the findings presented in Chapter 3 support the following points:

1. Salmonid habitats have been significantly degraded as a result of excess sediment loads, particularly fine sediments.

2. Sediment delivery in the Mattole River watershed has been dramatically increased by human activities, especially harvest-related activity and the construction and existence of roads.

3. Most human-induced sediment yield, particularly that related to roads and preventable effects of timber harvest activities, can be curtailed by changes in operating practices.

3.2.2 Natural Sources

Soil mass movements, especially landslides, are a significant component of hillslope sediment transport to stream channels in mountainous regions (Meehan, 1991). Some mass wasting processes such as debris slides and debris flows tend to yield sediment episodically. Other mass wasting processes such as slumping, soil creep, and earthflows tend to yield sediment more gradually, although these processes may be both gradual and episodic (Selby, 1993; National Research Council, 1996).

Natural mass wasting may add substantial quantities of sediment and organic debris to the stream channel, altering aquatic habitat for many years. Effects include rapid increases in bed and suspended-sediment loads, shifts and redistribution of existing channel-bed sediments, aggradation, and partial or complete blocking of the channel by debris.

Surface erosion results from the detachment of particles from the hillslope surface (Meehan, 1991). The process usually results in the delivery of fine sediment through channelized erosion from rillwash and gullying, overland flow transport, or gravitational movement of dry particles (Selby, 1993). In an undisturbed watershed, surface erosion is generally low. However, effects can vary from year to year because surface erosion usually results from intense rainstorms or excess surface flows after natural processes, such as landslides or wildfires, expose or loosen soil.

Natural Sources in the Mattole Watershed

Much of the Franciscan Complex bedrock underlying the Mattole watershed consists of sedimentary and meta-sedimentary rocks that have been tectonically broken, sheared and folded, making them relatively weak, easily weathered, and inherently susceptible to landslides. Three geologic formations are found in the watershed, Quarternary (recent) fluvial and surficial deposits, Franciscan Complex, and Wildcat Group (McLaughlin, et al., 2000). Sandstone, argillite and conglomerate dominate the rocks in these geologic formations. For the purposes of this report, mapped geologic units (McLaughlin, et al., 2000) have been combined into hard, moderate, and soft bedrock units and recent deposits (Figure 1.6).

Table 3.3 Distribution of Soft, Moderate, and Hard Geologic Units in the Mattole Watershed

Geologic Units in square miles	North	East	South	West	Estuary	Total
Quaternary Deposits (Recent)	12.2	3.6	2.0	6.9	2.0	26.7
Soft Geologic Units	39.2	14.9	0.0	15.9	0.0	70.0
Moderate Geologic Units	24.8	30.0	0.1	24.1	0.0	79.0
Hard Geologic Units	21.7	30.5	25.9	42.0	0.0	120.1
Totals	97.9	79.0	28.0	88.9	2.0	295.8

(Data from NCWAP, 2002)

These units are based on topographic expression, differences in lithology, and structural conditions of the rock. The “hard” units are dominated by relatively intact sandstone, which form sharp-crested ridges with steep slopes and well-incised drainages. The “soft” units consist of melange, clay-rich rocks that are highly sheared and fractured, that forms rounded, lumpy and irregular topography with gentle slopes and poorly developed sidehill drainages. The “moderate” units are rocks with lithology and structural conditions intermediate between intact sandstone and melange and form irregular topography lacking well-incised sidehill drainages (Mclaughlin et al., 2000).

The slope classes and their relative amounts (Figure 1.8 and Table 3.4) indicate the steep topography of the Mattole watershed. Twenty two percent of the Mattole watershed (64.48 mi^2) has slopes steeper than 60 percent and 83 percent of the watershed (244.10 mi^2) has slopes steeper than 25 percent. The steepness of the terrain coupled with moderately to highly erodible geologic material and high rainfall (60-115 in./yr.) creates a perfect environment for high rates of sediment delivery.

Table 3.4 Slope Classes in the Mattole Watershed

North (N), East (E), South (S), and West (W) Subbasins									Watershed	
Slopes	N mi^2	N %	E mi^2	E %	S mi^2	S %	W mi^2	W %	mi^2	%
0-10%	6.48	7	2.53	3	1.95	7	4.60	5	15.56	5
11-25%	10.34	11	11.21	14	3.71	13	8.47	10	33.74	12
26-60%	59.35	61	53.14	67	16.08	57	51.05	57	179.62	61
61-100%	20.71	21	11.73	15	6.17	22	23.84	27	62.45	21
101-290%	1.11	1	0.39	0	0.08	0	1.04	01	2.63	1
Totals	98.00		79.00		28.00		89.00		294.00	

Note: The Mattole River estuary (approximately 2 square miles) was not included in this analysis.
(Data supplied by UC Davis ICE)

A confounding factor in sediment production is the effect of vegetation on slope stability. Very steep slopes in terrains similar to those in the Mattole watershed would not have been able to form unless the slopes were stabilized by the protection of dense forest (Sidle, 1985). The forest stabilizes the slope in four major ways: a) a dense tangle of roots within the soil and penetrating down into fractured, weathered bedrock tends to hold the soil in place and stabilize the slope; b) the large amount of water transpired by the vegetation keeps the water table lower than it would be without this water use; c) the trees break the impact of falling rain so that surface erosion is minimized, and d) duff on the ground absorbs water and prevents surface flow and attendant erosion. Thus the forest itself may have a significant effect in shaping the landscape. Undoubtedly, the removal of forest canopy, e.g., timber harvest and conversion to rangeland, in areas of high erosion potential has had a dramatic effect on sediment production within the watershed. Further compounding sediment production has been the increased road construction both for timber harvest activities and for rural homes.

The high natural rate of erosion in the Mattole watershed ranks it among the most prolific California watersheds in the amount of sediment it discharges into the Pacific Ocean (MRC, 1995). In 1967, the discharge of suspended sediment alone in the Mattole River was estimated to be 16,370 tons/mi^2/yr. (Kennedy and Malcolm, 1977). Sediment discharge was probably near the historical high during this period, due to the nature of land use practices and the destabilizing effects of the 1964 flood. Rates from the Eel River during the same time were 9,426 tons/mi^2/yr. (Curtis and Lee, 1973), while tributaries to the Pacific Ocean averaged 157 tons/mi^2/yr. (Kennedy and Malcolm, 1977). Recent measurements at the Petrolia gaging station (See Figure 1.1) for 2000 and 2001 averaged 705 tons/mi^2/yr. suspended sediment and 80 tons/mi^2/yr. bedload (USGS, 2002). These recent values may reflect a number of factors, including reduced river volumes from lower rainfall years, accumulation of sediment in the upstream reaches of the watershed, and/or lower sediment delivery rates compared to past years.

Accurately measuring the speed at which sediment is transported from source to sea is extremely difficult considering the complexity of watershed processes. In many drainage basins, large amounts of sediment are transported episodically in large rainfall/flood events. However, studies in the Redwood Creek basin (Madej, 1999) may serve as a model to provide a quantitative estimate of sediment movement in the Mattole basin. The Redwood Creek basin is similar in area and lies about 60 miles north of the Mattole. In Redwood Creek large bedload slugs or waves move downstream at an average of 700 to 1,700 meters

(0.43 to 1.05 miles) per year. At the rate of transport in Redwood Creek reported by Madej, bedload would move through the entire length of the 62-mile-long Mattole mainstem in 59 to 144 years.

3.2.3 Management-Related Sources

Management-related sources of sediment include road construction, operation, and maintenance, timber harvest, livestock management, and fire history. The intensity of these activities since 1950, in conjunction with the extreme water years of 1955 and 1964, has introduced enormous amounts of sediment to the Mattole River and its tributaries. The natural sediment sources have been more than doubled by management-related sources (see Table 3.2). This increased sediment load has contributed to high and chronic suspended sediment and turbidity conditions, similar to those described in the Redwood Creek TMDL for Sediment (USEPA, 1998c), and apparently are instrumental in depressing salmonid populations.

3.2.3.1 *Road Construction*
Road construction, maintenance, and operation are a major source of erosion and sedimentation on most managed forest and ranch lands (Weaver and Hagans, 1994). The construction of roads increases the potential for surface erosion and slope instability by increasing the area of bare soil exposed to rainfall and runoff, obstructing stream channels, over-steepening hillslopes, and altering surface and subsurface flow pathways. Road ditches concentrate storm runoff and increase its erosive power to form rills and gullies, the pathways of sediment delivery to streams.

Culverted stream crossings often fail during storm events causing massive fill wash-outs and stream diversions. Stream crossing failures occur when the hydraulic capacity of the culvert is exceeded because of either obstruction of the inlet or inadequate hydraulic capacity. Stream crossing fill material is often washed into watercourses when water is impounded behind the road fill prism until it floods over and erodes the road fill, or the fill becomes saturated and fails catastrophically (Furniss et al., 1998). In some instances, stream crossing failures divert streams out of their channels and down the roadway, which often leads to gullies, landslides and other stream crossing failures (Furniss et al., 1998; Weaver, et al., 1995). In addition, road fill prisms can act as hydraulic barriers to subsurface flow, which acts to increase pore pressure locally, reducing material strength, and often causing landsliding.

The practice of cutting up-slope banks and side-casting soil during road grading also increases the likelihood of landsliding by eliminating cover and disturbing native soils. Cutbanks related to road construction often fail and deliver sediment and other debris to watercourses. Cutbank failures can also plug inside ditches causing erosion of the road surface. In addition, roads built on steep or unstable slopes may exacerbate soil mass movements, by increasing slope weight and decreasing slope support, as well as by altering groundwater pressures (Meehan, 1991).

Conditions in the Watershed
Road sediment delivery to the waterways is a major source of sediment in the Mattole basin. Road construction dramatically increased after 1950 with the accelerated timber harvest. This led to building more haul roads, skid trials, stream crossing fills, and creating other slope disturbances associated with logging on steep slopes. Perhaps of equal concern today has been the construction of more rural residential roads, which have intensified road networks and road densities in the watershed. There are approximately, 3,310 miles of active and abandoned roads in the Mattole basin (Perala et al., 1993). The county maintains about 100 miles of road, and about 25 miles are maintained by the BLM. About 385 miles of active roads are maintained at various levels, leaving 2,800 miles of abandoned roads, which are neither managed nor maintained. These old roads still contribute “legacy” sediment to the system. Roads

contribute sediment not only through surface runoff, but also through road-construction-related failures such as cut and fill failures, gullies, and landslides.

3.2.3.2 *Timber Harvest*

Timber harvest is another human activity that affects erosion and slope stability. The quality of management planning and implementation strongly influences sediment production from forest-harvesting activity (Meehan, 1991; Cafferata and Spittler, 1998). Timber harvest activities such as clearcutting and construction of landings and skid trails can increase erosion and sedimentation (Meehan, 1991; Lewis, 1998). These activities increase exposure of bare surfaces to rainfall and runoff, modify surface water flow pathways, and therefore increase the potential for surface erosion. In addition, they create steepened slopes in both cuts and fills. Removal of vegetation associated with logging has been shown to increase peak stream flow and reduce lag between high precipitation events and high stream flow events (Ziemer, 1998), which can lead to bank erosion downstream. Vegetation removal and soil compaction associated with timber harvest can reduce the factor of safety on hillslopes and increase susceptibility to mass wasting by elevating pore pressures and decreasing root strengths (Keppler and Brown, 1998; Abe and Ziemer, 1991).

Conditions in the Watershed

Historically, timber harvest activities, in particular clear-cutting and road building, have caused more widespread erosion than any other land use practice (MRC, 1989). More than 91 percent of the original coniferous forests in the Mattole River watershed have been harvested at least once (MRC, 1989). Before World War II, logging was small scale, but shortly after the war, logging activity intensified. The harvest rate exceeded 5,000 acres per year up to 1962, by which time over 60 percent of the coniferous forest in the watershed had been logged, and by 1974 approximately 80 percent had been cut. Since that time, the annual harvest rate dropped to 800 acres per year from 1974 to 1989, and has been dropping ever since. Most of this logging was done before the state required replanting after harvest, and many previously forested sites are still unstocked. It was not until 1975 that landowners in California were required to replant after timber harvest. Before that, vast acreage was cut and left unstocked, only to be taken over by brush. Undoubtedly, the reduction in forest canopy has dramatically affected the Mattole's hydrology by reducing canopy interception, depleting forest litter and soil organic matter, reducing soil water holding capacity, and altering basin wide evapotransporation. All these changes have increased surface runoff and potentially increased sediment delivery to the streams.

3.2.3.3 *Livestock Management*

Livestock grazing has the potential to increase rates of sediment delivery. Livestock grazing may lead to indirect sediment delivery by changing the structure and composition of riparian vegetation and through other processes:

- Grazing can affect the riparian environment by changing, reducing, or eliminating vegetation, and by actually eliminating riparian areas through channel widening, channel aggrading, or lowering of the water table (Platts, 1991).
- Reduction of vegetative cover by intense grazing can lead to increased surface erosion by exposing soils to rainsplash, increasing runoff velocities, decreasing infiltration rates, and reducing soil strength provided by roots (Bauer and Burton, 1993; Selby, 1993).
- Riparian zones are often grazed more heavily than upland zones because they have flatter terrain, more water, more shade, and more succulent vegetation (Platts and Nelson, 1985; Platts, 1991).
- Livestock can cause direct sediment delivery by collapsing stream banks, wearing trails at watercourse crossings, and breaking down soils where confined livestock operations (e.g. feeding areas and corrals) are near streams.
- Overgrazing can lead to reduction in the strength and cohesion of streambanks, which then leads to bank erosion, higher width-to-depth ratios, or downcutting.

- In general, grazed areas along stream channels contain more fine sediment, streambanks are more unstable, banks are less undercut, summer water temperatures are higher than in streams in ungrazed areas, and salmonid populations are reduced (Armour, 1977; Benke and Zarn, 1976; Platts, 1983).

Conditions in the Watershed
The coastal prairie of Humbolt County is a grassland dominated by perennial native grasses (Barbour and Major, 1995). Four major factors contributed to dramatic changes of the pristine coastal prairie: (a) the elimination of annual fires, (b) an increase in grazing pressures, (c) the introduction of highly competitive, exotic species, and (d) cultivation (Barbour and Major, 1995). The use of fire by Native Californians created nutrient-rich ash, removed thatch, stimulated new growth, and prevented woody plants from establishing (Barbour, et al., 1993). All this changed in the nineteenth century, as European settlers introduced domesticated livestock with high-density year-round grazing, controlled fires, with some plowed and farmed grassland. At this time, native perennial grasses were displaced by introduced weeds and intensified year-round grazing by livestock (Barbour, et al., 1993). Two factors contributed to increased erosion rates at this time. More soil was left without adequate cover, which made it more susceptible to wind and water erosion, and the annual grasses have small and shallow root systems, so that they stabilize soil less than the larger and deeper root systems of the native perennial grasses. With increased grazing pressure, native perennial species diminished and introduced annual species proliferated (Barbour and Major, 1995). However, with improved grazing practices, native perennial grasses can recover and replace introduced annual species.

Livestock grazing has consisted almost entirely of cattle and sheep ranching, -and brush and timberland were converted to grasslands in order to supplement existing pastures. This type of conversion would seem to have increased grassland acreage over the years, but this is not the case. The Mattole Restoration Council created digital GIS maps of grassland coverage representing the distribution of grasslands in the Mattole River watershed coverage for the 1950s and 1990s (MRC, 2002). In the 1950s approximately 40,850 acres of grassland (21.5% of the watershed) were apparent, and in the 1990s approximately 25,680 acres of grassland (13.5% of the watershed) were apparent. These results show that grasslands have been lost in the Mattole watershed in this period, possibly due to fire suppression, the cessation of sheep grazing, and disturbance of the soil that has allowed conifers to gain a foothold. These grasslands are important economically, particularly for cattle and sheep ranching, and other agricultural operations.

The effect of livestock grazing on estimated sediment delivery rates has not been quantified in the Mattole watershed. However, it is believed that the displacement and loss of perennial grasses by introduced annual grasses to the watershed, the grassland areas may have led to reduced soil water holding capacity and soil cohesion. Additionally, intensive livestock grazing may compact soil over natural conditions, and thereby decrease soil water holding capacity and lead to more potentially erosive runoff. This study did not address the effects of livestock grazing on sediment delivery to streams within the Mattole watershed. Quantifying the effects of livestock grazing on sediment delivery is an area for further investigation. Because no estimate of sediment delivery produced by livestock grazing is included in our calculations, we believe that the estimated total management-related sediment contribution is less than what is actually occurring.

3.2.3.4 *Fire History and Sediment Loading (Natural & Anthropogenic)*
The burning of forests may dramatically increase sediment loading to streams (Meehan, 1991; Robichaud, 2000). However, the degree to which wildfires and prescribed burns affect erosion and sediment delivery varies greatly, depending on site characteristics and burn intensity (Robichaud, 2000). Wildfires expose bare mineral soil to increased runoff and surface erosion. In addition, fire increases the potential for landslides after the event due to the decay of anchoring and reinforcing root systems, as well as by alteration of soil and hydrologic characteristics (National Research Council, 1996).

Conditions in the Watershed
Up until the 1950s, the most widespread use of the watershed appears to have been grazing (NCWAP, 2002). The deliberate conversion of pre-existing brush and timberland to range land is indicated by the amount of grassland (40,850 acres, MRC, 2002) and the fires (17,000 acres) burned between 1950 and 1959 (NCWAP, 2002). The use of fires as a management tool has continued as a way to convert brush and timberland to range land, to eliminate logging slash, and to control weeds. Undoubtedly, the prescribed burns have led to increased erosion and potential sediment delivery to streams.

3.2.4 Analytical Methods and Results

3.2.4.1 *Sediment Source Analysis Methods*
A combination of methods was used to determine sediment source amounts and delivery rates, using published literature, supporting watershed analysis studies, field measurements, and aerial photo analysis. These methods include: 1) estimation of bulk density of eroded materials, 2) aerial photo analysis of selected planning watersheds for mass wasting features by the Information Center for the Environment (ICE, Department of Environmental Science and Policy, UC Davis), an analysis that includes mass wasting quantification methods and extrapolation of mass wasting, and 3) field measurements of selected road and stream surveys by NCRWQCB staff.

Bulk Density of Eroded Material
In order to convert volume of eroded sediment to tons, a representative material was chosen for bulk density calculations. The Hugo Soil Series, a gravelly sandy clay loam, was used for calculations of tonnage, since it is one of the most commonly found soil series in the watershed (MRC, 1989). Natural vegetation associated with Hugo soils is mixed conifer-hardwood forest of Douglas fir, coast redwood, tanoak, and madrone. The bulk density of the fine earth fraction (< 2mm) is 1,600 kg/cubic meter (USDA, 2002), and the bulk density of the coarse fragments (> 2mm) is assumed to be 2,650 kg/cubic meter (average bulk density of continental rock). The eroded material is assumed to consist of 80% soil (< 2mm) and 20% rock (> 2mm), which yields a value of 2.00 US tons per cubic meter or 1.53 US tons per cubic yard of eroded material.

Aerial Photo Analysis
The Regional Water Board contracted with ICE to provide an aerial photo analysis of recently active mass wasting features and road systems in the Mattole watershed. For this purpose, recently active mass wasting features are defined as those that exhibit signs of movement discernible from sequential sets of aerial photos at a 1:24,000 scale. A geologist with experience in aerial photo interpretation in the Mendocino coastal area performed the aerial photo analysis. By nature, aerial photo analysis includes subjective factors that rely on the judgment and experience of the interpreter.

Temporally discrete mass wasting features (landslides > 10,000 sq. ft.) were identified on aerial photographs and digitized as polygons into an Arc-GIS coverage for five planning watersheds in the Mattole River Watershed. Mapping was done for Rainbow Ridge, Cow Pasture Opening, Dry Creek, Squaw Creek, and Bridge Creek planning watersheds using a Topcon MS-3 mirror stereoscope with a 4x magnifier. The photo sets used were: 1941/1942-CVL, black and white, 1:20,000; 1965-CVL, black and white, 1:20,000; 1984-WAC, black and white, 1:31,680; 1996-WAC, black and white, 1:24,000; and 2000-WAC, black and white, 1:24,000. Mass wasting features were digitized on 1993 USGS digital orthogonal quadrangle photos allowing the status of stereo photo mapped features to be determined in 1993 as well as each photo year.

Each feature identified on a photo was categorized as (a) appeared, static-less than ~20% re-vegetated, (b) re-vegetated –20-80% re-vegetated, (c) healed-greater than ~80% re-vegetated, or (d) enlarged.

The management association for each landslide was identified as (a) natural, (b) in a recognizable harvest unit, not associated with a road or skid road, (c) cutbank, (d) fill, (e) both cutbank and fill, (f) road related, or (g) intersects skid/tractor road.

In all planning watersheds, about 90 percent of features first appear in 1965 or 1984. This timing is likely a result of high intensity ground-based timber harvest of the late 40s or early 50s through the 70s and large storm events of 1955, 1964, 1974, and 1983. However, the different planning watersheds have responded differently. For example, despite heavy management, the Bridge Creek planning watershed has far fewer large discrete features than the average for the Mattole river watershed. It is likely that the dominant sediment input in this unit is from surface erosion of the extremely dense logging roads and skid trails (almost every creek and hillslope were tractored from valley bottom to ridge before 1980). Most likely the mobilized sediment was finer-grained material than would be present in deeper discrete landslide features. Additionally, this unit appears in 1996 and 2000 photos to have recovered despite the heavy rains of 1993, 1995 and 1997.

Large, deeper discrete landslides characterize both Cow Pasture Opening and Rainbow planning watershed. These units had the least high intensity, pre-1980, ground-based timber harvest, on the order of 25 percent of the planning watersheds.

The Squaw Creek planning watershed was devastated by sediment delivery, and it remains in relatively poor condition. High intensity ground-based timber harvest, poor road construction, and unstable geology (Cooskie shear zone) have led to the mobilization of considerably more material than in other planning watersheds. Much of the forested area in this unit has not re-grown or has been converted to range. This unit has experienced so much erosion and extensive complex mass movement that usual mapping techniques (i.e., aerial photo interpretation which poorly renders detection of features under the current forest canopy or features smaller than 30 meters) are likely to underestimate sediment production.

The Dry Creek planning watershed saw the highest delivery of sediment associated with road use, prior to 1965. Many of the roads are slow to recover and continue to be visible today. Additionally, no erosion was identified in this planning watershed with respect to natural processes for the 1984 to 2000 period.

In all five planning watersheds, roads were identified on the 1996 photo set and added to a GIS layer created by CDF, NCWAP. Roads were also identified on 1965 and 1984 photos (on acetate overlays) but not digitized due to time constraints. The 1996 identified roads are estimated to be less than half of roads present on earlier photo sets. Road densities in the earlier photo sets were determined using the photos directly. Roads identified are assumed to support wheeled vehicle traffic (haul roads, county roads, jeep 'trails') and have been cut into the hillslope where necessary. Identifying roads in the Bridge Creek unit was particularly difficult due to the extremely high density of skid trails. Frequently, an apparent cut and fill road across the hillslope would turn up or down slope apparently too steep or tight for log trucks or anything but high-clearance 4wd vehicles or tracked equipment. This type of feature was not identified as part of the road network unless it was connected to the wheeled vehicle road network. Again, this high density of cut and fill skid roads before 1980 likely led to the mobilization of large amounts of fine-grained sediment that was not associated with large discrete failures.

Mass Wasting Quantification Methods

Regional Board staff quantified mass wasting volumes and rates for all features identified from 1984 to present, as well as surface erosion for the unvegetated landslides prior to 1984 (see Figure 3.1, Index of

Planning Watersheds). The volumes for the mass wasting (landslides) for Rainbow Ridge (Figure 3.2), Cow Pasture Opening (Figure 3.3), Dry Creek (Figure 3.4), Bridge Creek (Figure 3.5), and Squaw Creek (Figure 3.6) planning watersheds were determined using an average depth of 1.5 meters. This was based on experience in north coast watersheds, limited observations in the Mattole of typical slide depths, the areas in meters of the mapped polygons, and the estimated percentage of sediment delivery (from ICE coverage) for all visible features. Only landslides that have not healed, or those less than 80 percent re-vegetated were analyzed. All healed slides, those greater than 80 percent re-vegetated, were not included. Next, all features delineated in the 1984 to present period were quantified for sediment delivery, and the quantities were averaged over the 18-year delivery period. All features delineated in 1996 to present were quantified for sediment delivery, and the quantities were averaged over the 6-year delivery period. All features delineated in 2000 photos were quantified for sediment delivery, and quantities were averaged over the 2-year delivery period. Then, all delivery rates from 1984, 1996, and 2000 aerial photos were added together to produce the mass wasting (landslide) sediment source category.

Mass wasting features delineated in 1965 and 1941 photos were not included, because the majority of sediment delivery form these landslides to waterways would have occurred before 1984. However, surface erosion as a source of sediment will continue to occur on these slides. Subsequently, the Revised Universal Soil Loss Equation (RUSLE) (USDA, 1996) was applied to the five planning watersheds analyzed by ICE. Of the landslides in 1941 and 1965 photos, only those that have not healed (less than 80 percent re-vegetated) were included. All healed slides (greater than 80 percent re-vegetated) were not included. It is assumed that 50 percent of the landslide was soil and 50 percent was rock. Therefore, the landslide areas were reduced by 50 percent before using RUSLE to calculate surface erosion (soil loss). The estimated delivery rates for landslides and surface erosion are presented in Table 3.5.

Mass Wasting Extrapolation Methods

Effectively applying these estimated sediment delivery rates across the entire Mattole watershed required specific assumptions. The assumed values of sediment contribution by landslides and surface erosion that were used best-reflected land management practices, slope, and vegetation. Regional Board staff identified specific planning watersheds for aerial photo analysis within each NCWAP watershed for its representative characteristics of that watershed. The sediment delivery rates were calculated for the specific planning watersheds, which were then applied to their corresponding NCWAP watershed on an area to area basis.

Table 3.5 Landslide and Surface Erosion Sediment Delivery in five planning watersheds in $t/mi^2/yr$

ICE Watershed	NCWAP Subbasin	Landslides > 10,000 square feet				Surface	
		Natural	Road	Skid Trail	Harvest	Erosion	Total
Rainbow Creek &Cow Pasture	North	2117	1881	189	475	10	4672
Dry Creek	East	0	5578	160	0	24	5762
Bridge Creek	South	0	0	133	0	35	168
Squaw Creek	West	539	1746	392	1306	52	3976

Landslide data supplied by ICE at UC Davis

The estimated sediment delivery rate calculated for Dry Creek representing the east NCWAP watershed, was the highest. Rainbow and Cow Pasture Opening representing the northern NCWAP watershed had the next highest estimated rate of sediment delivery. The Bridge Creek rates were applied for the south NCWAP watershed, and Squaw Creek rates were applied for the west NCWAP watershed. Regional Board staff considered these rates a reasonable approximation for the NCWAP watersheds considering the geology, slopes, and land management practices in the respective areas.

Further analysis of the ICE landslide data for Cow Pasture Opening, Rainbow Ridge, Squaw Creek, Dry Creek, and Bridge Creek planning watersheds are presented in Figures 3.7 and 3.8. Figure 3.7 shows the total number of landslides first appearing in each photo year in each planning watershed. The landslide occurrences were highest in the 1965 and 1984 photos, which reflects the intense land use in the 60s, 70s and 80s. Dry Creek had the most landslides, which reflects its soft and moderate geologic units and steep slopes, while Bridge Creek had the least landslides, which reflects its lower average slopes (compared to Squaw Creek) and geology dominated by hard units. The decline in landslide occurrences in the 1996 and 2000 photos reflects the lower intensity of land use, especially timber harvest activity.

Figure 3.8 portrays the same landslide occurrence data in a different manner. The total visible, first visible, and healed landslides are shown for each photo year for all five planning watersheds combined. The 'First Visible' designation shows the number of landslides that were first visible in each respective photo year. All the data from Figure 3.7 is graphed as the first visible "wedge" in Figure 3.8. The 'Total Visible' "wedge" shows all the visible landslides, the cumulative landslide count, which is all the first occurring landslides plus the landslides from previous years that are still visible. The healed landslides have been subtracted form the total visible and portrayed in the healed "wedge". Despite the reduction of newly occurring landslides, or first visible landslides, in the 1996 and 2000 photo years, the total visible landslides have not dropped significantly in numbers in the 1996 and 2000 photo years. Most of the sediment delivery from former landslides, those that first occurred in 1941, 1965, and 1984, has undoubtedly been delivered to the stream network in previous years and would not be relevant to current sediment delivery budgets. Nevertheless, many of the former landslides, whose "legacy" sediment is already in the stream network, are not healed and apparently are still delivering sediment today. The low number of landslides that were designated in this study as healed verifies this continuing sediment delivery. In other words, the landslides of the past are still influencing sediment delivery today.

The weighted averages used to calculate sediment delivery for landslides > 10,000 square feet that were derived from the ICE aerial photo analysis may not accurately estimate current sediment delivery for all the NCWAP subbasins. The averages that were derived tend to lower estimated rates for the extreme or higher sediment delivery areas, although these averages have not included landslide data from before 1984. Surface erosion or soil erosion was accounted for in the 1965 and 1941 photos on visible, partially vegetated landslides. Current surface erosion from the visible landslides on the 1984, 1996, and 2000 photos, was not accounted for in the estimated sediment delivery. The unaccounted surface erosion and the use of representative planning watersheds for NCWAP watersheds may contribute to an underestimate of what is actually being delivered.

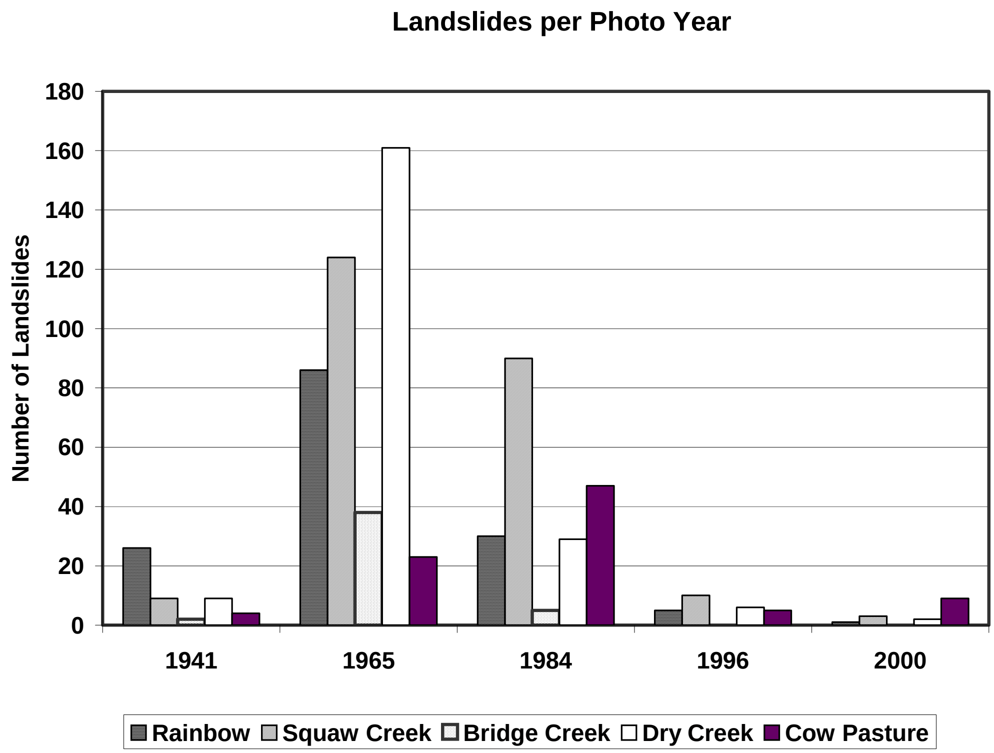

Figure 3.7 First appearance of landslides per photo year analyzed, by planning watershed

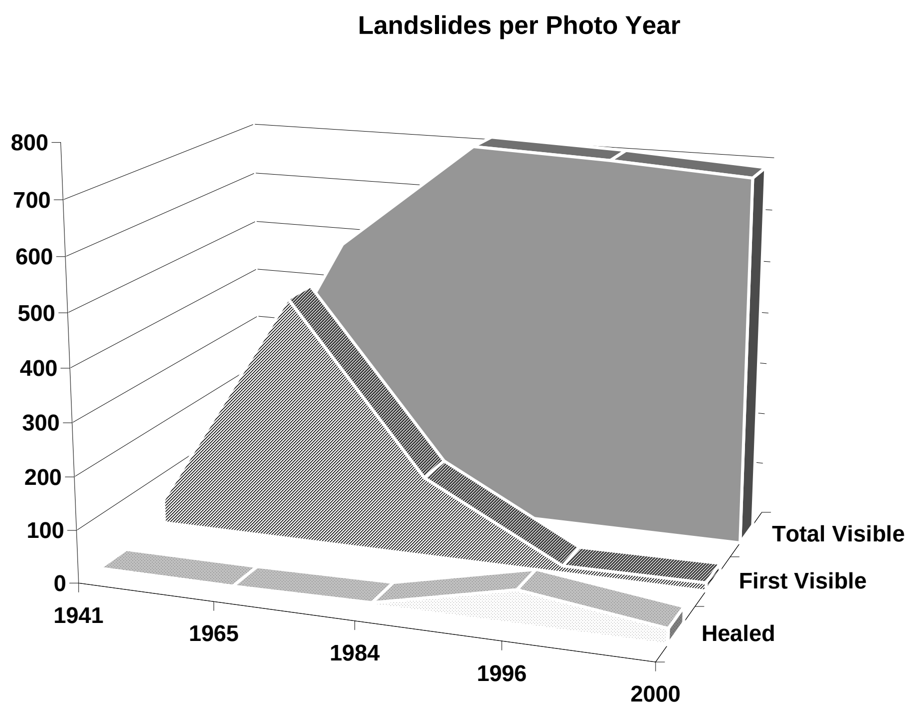

Figure 3.8 Total number of landslides per photo year analyzed in the Rainbow Ridge, Squaw Creek, Bridge Creek, Dry Creek, and Cow Pasture Opening planning watersheds combined.

Field Measurements
Regional Water Board staff conducted field investigations of randomly selected 1000-foot road survey plots and 1000-meter stream survey plots. However, restricted access to desired surveyed sites along with time constraints limited field investigation efforts. Field survey data for streams, roads, and their associated erosional features were gathered between March 2002 and September 2002. Erosional features < 10,000 square feet were classified as translational/rotational slides, debris slides, debris torrents, gullies, active earthflows, stream bank erosion, road bank failures, and natural erosion. The source of the erosional feature was identified where possible, with the rate entered into the appropriate category (see Table 3.5). The road and stream surveys, though limited in number, provide the most accurate sediment delivery estimate available for this report.

Road Surveys. Field investigations for 54 selected 1000-foot survey segments, and associated erosional features, were conducted on different geologic units in each of the NCWAP subbasins (north, east, south, west). Using the Washington Forest Practices Board's, Standard Methodology for Conducting Watershed Analysis, field survey data were described. Sediment delivery amounts were calculated per mile for road-related surface erosion, road-related mass wasting, road-related gullying, and natural erosion. Road densities were calculated for each of the NCWAP subbasins using road density data from the NCWAP Mattole Watershed Synthesis Report (2002) created by CDF. These road densities were used to calculate road-related surface erosion. NCWAP road densities were adjusted with ICE road coverage data (2002) to reflect more current delivery for erosional features other than surface erosion.

Table 3.6 Road Densities and Stream Densities in NCWAP Subbasins

Area	NCWAP Road Density	ICE Road Density	ICE Stream Density
	mi/mi^2	mi/mi^2	mi/mi^2
North	2.3	3.00	4.4
East	4.6	6.00	4.1
South	7.0	9.10	4.2
West	4.8	6.20	4.2

Stream Surveys. Field investigations for 22 selected 1000-meter survey segments, with observations of erosional features, were conducted on different geologic units in each of the NCWAP subbasins (north, east, south, west). Using stream survey forms developed by the Regional Water Board staff, stream erosion data were recorded (reach, stream bank height, percent rock and percent soil of stream banks, percent of sediment actively eroding along stream banks), as well as on all sediment delivery features greater than five cubic meters. Sources of sediment delivery were categorized as skid-trial erosion, harvest-related delivery, and natural erosion. Sediment delivery amounts per mile of stream were calculated for each of the NCWAP subbasins (north, east, south, west) and for the entire watershed using ICE (2002) GIS coverage. The stream densities used in this calculation are in Table 3.5.

3.2.4.2 *Sediment Source Analysis*

Natural Mass Wasting
Sediment delivery by natural mass wasting was estimated using stream surveys, road surveys, and aerial photo analysis. Natural landsliding rates were estimated for each of the NCWAP subbasins for roads and streams. From the aerial photo analysis, the rate of sediment contribution from natural landsliding was estimated in each of the NCWAP subbasins. For each subbasin this was added to estimated sediment contribution rates from roads and streams to yield total sediment rates (rounded to two significant figures). The watershed total is an area weighted average.

Table 3.7 Sediment Contribution Rates from Natural Mass Wasting

Area	Roads-t/mi2/yr	Streams-t/mi2/yr	Aerial Photos-t/mi2/yr	Total-t/mi2/yr
North	41	1,576	2117	3,700
East	83	1,477	0	1,600
South	126	1,511	0	1,600
West	86	1,490	539	2,100
Watershed				2,400

Stream Bank Erosion

The fluvial erosion of bank materials was estimated based on estimates of soil and earthflow creep rate and drainage density. This method assumes that the rate of stream bank erosion is in equilibrium with the rate of soil production and delivery from hillslopes adjacent to the channels. This assumption is consistent with field observations that in general stream banks are neither actively retreating nor encroaching on the stream channel. Measurements of drainage density, streambank height, and streambank composition made as part of the stream surveys were used to estimate the extent of streambank areas susceptible to bank erosion.

Regional Board staff reviewed literature reporting measurements of soil creep in sheared graywacke sandstone and mudstone units of the Franciscan Complex (Lehre, 1987; Swanston, 1981; Swanston et al, 1995; Ziemer, 1984). Creep rates in the Franciscan Complex were assumed to be 1.6 mm/year, the average of the values reported by Swanston (1981) and Lehre (1987). That rate is within the ranges suggested by the Washington Forest Practices Board (1997) (1-2 mm/year), and Selby (1993) (0.5-2 mm/year). For units of the Franciscan Complex, the value above was adjusted to incorporate delivery rates associated with earthflows. The general rate of earthflow creep was estimated to be 122 mm/year, based on measurements of earthflows reported by Swanston and others (1995). In order to adjust this rate to reflect the geologic units, the estimated extent of hillslopes undergoing progressive failure, including earthflows and complex landslides, was estimated to be 30 percent in the north, 25 percent in the east, 20 percent in the west, and 10 percent in the south.

Regional Board staff then developed a weighted average creep rate for the central belt units by assuming the weighted averages for streambanks that were adjacent to earthflows and soil creep. This process resulted in an estimated overall soil and earthflow creep rate for each subbasin. These rates are applied to the stream survey information and stream densities of each sub-watershed, to calculate sediment rates for the NCWAP subbasins. These rates are rounded to two significant figures and appear in Table 3.8. The watershed total is an area weighted average.

Table 3.8 Rates of Sediment Contribution from Stream Bank Erosion

Area	Creep Rate	Yearly Rate	Stream Density	Totals
	mm/yr	t/mi/yr	mi/mi^2	t/mi^2/yr
North	38	179	4.41	790
East	32	66	4.13	270
South	14	41	4.23	170
West	26	81	4.17	360
Watershed				460

The dependence on rates derived from studies in other watersheds and the weighted estimates applied to each NCWAP subbasin, may lead to some inaccuracies. Measurements obtained from within the Mattole watershed may provide more accurate sediment delivery numbers.

Road-Related Mass Wasting

Sediment delivery rates from road related mass wasting were estimated using rates derived from the road surveys and aerial photo analysis. Rate was determined for each NCWAP subbasin using road density in the subbasin multiplied by subbasin total road related sediment (tons/mi/yr). From the aerial photo analysis the total sediment delivery rates were estimated and added to the total road related sediment to produce the total sediment contribution rate (rounded to two significant figures) presented in Table 3.9. The watershed total is an area weighted average.

Table 3.9 Sediment Contribution from Road-Related Mass Wasting

Area	Road Density	Sediment Contribution	Roads	Aerial Photos	Totals
	mi/mi^2	t/mi/yr	t/mi^2/yr	t/mi^2/yr	t/mi^2/yr
North Subbasin	3.00	49.4	148	1881	2,000
East Subbasin	6.00	49.4	296	5578	5,900
South Subbasin	9.10	49.4	450	0	450
West Subbasin	6.20	49.4	306	1749	2,100
Mattole Watershed					2,900

Road-Stream Crossing Failures

The sediment delivery rate and percentages of road-stream crossing failures were derived form Pacific Watershed Associates' watershed study of the Sanctuary Forest area (PWA, 2001). The sediment delivery rate was 16 tons per year per stream crossing with 52 percent of the stream crossings exhibiting failure. We applied these numbers across the forested portion of the NCWAP subbasins to estimate the sediment contribution from road-stream crossings in the forested areas(see Figure 1.4). The road-stream crossings with the watershed averages are presented in Table 3.10 (rounded to two significant figures). The watershed total is an area weighted average.

Table 3.10 Sediment Contribution from Road-Stream Crossing Failures

NCWAP Subbasin	Road-Stream Crossings	Percent Failures	Sediment Delivery Rate t/yr/crossing	Totals t/mi^2/yr
North	539	52	16	50
East	318	52	16	40
South	542	52	16	160
West	569	52	16	40
Watershed				50

Road-Related Gullying

Road-related gullying and its sediment delivery rates were estimated using rates derived from the road surveys and ICE road densities per subbasin. The estimated sediment delivery rates for gullying for each of the NCWAP subbasins for roads (rounded to two significant figures) are presented in the table below. The watershed total is an area weighted average.

Table 3.11 Sediment Contributions from Road-Related Gullying

Area	Road-Density mi/mi^2	Average Delivery t/mi/yr	Totals t/mi^2/yr
North Subbasin	3.00	32.3	100
East Subbasin	6.00	32.3	190
South Subbasin	9.10	32.3	290
West Subbasin	6.20	32.3	200
Mattole Watershed			170

Road Related Surface Erosion

Road related surface erosion and the resulting sediment delivery rates were estimated using rates derived from the road surveys and applying the Washington State Department of Natural Resources, WATERSHED ANALYSIS MANUAL, WAC 222-22. The total road-related surface erosion rates were partitioned into rates for the road tread (40 percent of the total), and rates for the cutslope, ditch, and fillslope (60 percent of the total). The basic erosion rates used were high on highly weathered sedimentary parent material with an age greater than two years. The appropriate road tread surfacing factors used were those for paved roads, gravel greater than 6 inches, gravel two to six inches, and native soil surface as appropriate. The traffic/precipitation factors used were those for moderate or light traffic with 1,200 mm to 3,000 mm of precipitation. The appropriate correction factors for ground cover density were used for cut and fill slopes. The values for road tread erosion (tons/acre/yr) and cutslope, ditch, and fill slope erosion (tons/acre/yr) were converted to tons/mi/yr from acquired data, and combined to yield total road related surface erosion. The estimated sediment delivery rates for road related surface erosion for each of the NCWAP subbasins (rounded to two significant figures) are presented in Table 3.12. The watershed total is an area weighted average.

Table 3.12 Sediment Delivery Rates from Road-Related Surface Erosion

Area	Road Densities mi/mi^2	Average Delivery t/mi/yr	Totals t/mi^2/yr
North Subbasin	2.30	156	360
East Subbasin	4.60	146	670
South Subbasin	7.00	111	780
West Subbasin	4.80	117	560
Mattole Watershed			540

Skid Trail Related Sediment Delivery

Mass wasting related to skid trails and the resulting sediment delivery rates were estimated using rates derived from the stream surveys and aerial photo analysis. Stream survey analysis yielded an average rate for skid trial related delivery of 153 tons per stream mile. This figure was applied to the stream density of each subbasin. The aerial photo analysis yielded rates, which were combined with the skid trail volumes, were adjusted for the percentage of forested area in each NCWAP subbasin (rounded to two significant figures), and are presented in Table 3.13. The watershed total is an area weighted average.

Table 3.13 Sediment Delivery Rates from Skid Trail Related Erosion

Area	Stream Density	Skid Trail Rates	Skid Trail Volumes	From Aerial Photos	Forested Area	Totals
	mi/mi^2	t/mi/yr	t/mi^2/yr	t/mi^2/yr		t/mi^2/yr
North Subbasin	4.4	153	673	189	0.68	590
East Subbasin	4.1	153	631	160	0.88	700
South Subbasin	4.2	153	645	133	0.98	760
West Subbasin	4.2	153	637	330	0.88	850
Mattole Watershed						710

Other Harvest Related Delivery

Other harvest related sediment delivery rates were estimated using estimated sediment delivery rates for mass wasting features and surface erosion derived from the stream surveys and aerial photo analysis. These sediment delivery rates are associated with features not accounted for elsewhere, such as landings, estimated surface erosion from unvegetated landslides in harvested areas from the 1965 and 1941 photos, and landslides of less than 10,000 square feet in harvested areas not directly identified with previously discussed sediment sources. The estimated sediment delivery rates for each of the NCWAP subbasins (rounded to two significant figures) are presented in Table 3.14 the table below. The watershed total is an area weighted average.

Table 3.14 Sediment Delivery from Other Harvest Related Activities

Area	Stream Density	OH Rates	OH Volumes	Aerial Photos	Soil Erosion	Totals
	mi/mi^2	t/mi/yr	t/mi^2/yr	t/mi^2/yr	t/mi^2/yr	t/mi^2/yr
North Subbasin	4.4	22	97	475	10	600
East Subbasin	4.1	22	90	0	24	110
South Subbasin	4.2	22	92	0	35	130
West Subbasin	4.2	22	92	1306	52	1500
Mattole Watershed						700

3.2.4.3 *Sediment Source Analysis Results*

The primary objectives of the Mattole River Watershed TSD for Sediment are to identify and quantify sources of sediment delivery in a way that allows a relative comparison of those sources, to estimate the sediment loading capacity for the watershed, and to provide information required for non-point source planning and implementation. The broad watershed-scale overview of sources of sediment delivery in the Mattole River watershed presented in this TSD is intended to guide landowners, land managers, and resource protection agencies in the protection of water quality in the Mattole River watershed. The sediment source analysis and load allocations should not be used for site-specific land management prescriptions or for any other purpose other than that for which they are intended.

The results of the sediment source analysis are presented in Table 3.5. Natural sediment yield accounts for approximately 36% of the total sediment delivery in the Mattole watershed while human-caused sediment delivery accounts for 64% of the sediment delivery in the watershed, or an amount greater than the natural load. The analysis shows that harvest activities and road-related processes are the dominant sources of sediment delivery in the watershed.

It is important to note that although the analysis estimates only sediment delivery from 1984 to present, and sediment contribution from landslides greater than 10,000 square feet from 1965 and 1941 photo analysis, many of the pre-1984 management activities continue to contribute to sediment delivery. While conducting aerial photo analysis and road and stream surveys, Regional Board and ICE staff observed many legacy problems associated with management practices pre-dating the Z'Berg-Nejedly Forest Practices Act.

The total natural sediment delivery in the watershed is estimated to be 2,900 tons/mi^2/yr (Table 3.2).

3.3 Sediment TMDL and Allocations

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

3.3.1 TMDL

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

To determine North Coast sediment TMDLs, EPA has used four general approaches to derive the loading capacity: (1) a comparison with a reference time period; (2) a comparison with a reference stream; (3) the estimated needed improvement from existing loading rates, based on a comparison between current and target instream conditions; and (4) a combination and modification of the first two approaches, based on the results of TMDL analysis on other North Coast watersheds. The approach used in a particular TMDL depends on the availability of data and the characteristics of the specific watershed. For the Mattole River TMDL, the fourth method was used. Data were not available to determine either an appropriate reference period within the watershed or an appropriate local reference stream. The TMDL is set using field surveys (road and stream), aerial photo analysis of selected subbasins, and selected data from professional studies in order to formulate sediment delivery information for the Mattole River.

The sediment loading capacity was derived from the Noyo River Sediment TMDL (USEPA, 1999) and the Redwood Creek Sediment TMDL (USEPA, 1998c). Both watersheds exhibited similar characteristics to the Mattole River watershed such as climate, geology, vegetation, land use history, and geographic proximity. The Noyo River analysis was based on a comparison with a reference time period, while the Redwood Creek analysis was based on reference streams.

The Noyo River TMDL sets the total sediment loading capacity at 125 percent of background sediment delivery (USEPA, 1999), using a reference time period. This level is estimated to be adequate to protect aquatic habitat, which is the most sensitive of the beneficial uses. Specifically, salmonids were still abundant during the 1933-1957 reference time period in the Noyo River watershed, so the sediment delivery during that period must have allowed salmonid habitat of suitable quality to persist. In the Noyo River, the total sediment delivery during the 1933-1957 period included both human-caused sediment and natural background sediment. This sediment source analysis indicated about one part human-induced sediment delivery for every four parts natural sediment delivery.

The Redwood Creek TMDL (USEPA, 1998c) had the highest estimated sediment load (4750 tons/mi^2/yr) of any North Coast river for which USEPA has established sediment TMDLs to date. Regional Water Board staff reassessed information from this TMDL and determined that 30-40% was attributed to natural background sources. The background rate was set at an average of 35% or 1600 tons/mi^2/yr. This was compared to the estimated sediment load for the watershed of approximately 1960 tons/mi^2/yr, based on a weighted average of three reference streams in the watershed. Reference streams were used for estimating historical watershed loading rates, which had not been influenced by excessive human caused erosion. These reference streams exhibited physical characteristics believed to be associated with well-functioning cold water aquatic habitat, and protective of salmonid habitat. Therefore, based on information in the Redwood Creek TMDL, the estimated reference sediment load for the watershed is about 118% of natural background.

Using the ratio approach has several potential advantages. Stillwater Sciences (1999) indicated that the ratio of natural sediment sources to human sediment sources can detect the effects of land use changes better than an average annual sediment load alone. This is because the ratio may vary with hydrology less than the annual sediment load. The ratio may be less dependent upon spatial and hydrologic variability, and it could be used to measure progress toward meeting sediment reduction goals.

The Mattole River sediment TMDL was based on findings from the Noyo River Sediment TMDL and the Redwood Creek Sediment TMDL. The total estimated sediment loading capacity was set at 125 percent of background sediment delivery, which is equivalent to using a 1:4 ratio (or that natural sediment delivery must be at least 80% of total sediment delivery). Using the long-term background rate of 2,900 t/mi^2/yr as determined earlier, this approach yields a loading capacity for the Mattole River watershed of 2,900 t/mi^2/yr x 125%, or 3,600 t/mi^2/yr (rounded to two significant figures). This sediment contribution rate in the Mattole River watershed will require a reduction of approximately 55 percent (from 8,000 t/mi^2/yr to 3,600 t/mi^2/yr; see Table 3.6).

The TMDL for the Mattole River and its tributaries, which is set equal to loading capacity, is 3,600 tons/mi^2/yr, expressed as a 10-year rolling annual average.

While load allocations are expressed as an average over the entire watershed; the NCRWQCB may determine in the future that implementation measures could benefit by a distinction among the different planning watersheds.

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, the TMDL equals the sum of: all waste load allocations (for point sources), load allocations (for nonpoint sources and background), and a margin of safety.

Table 3.15 shows the TMDL, load allocations, and required reductions for the Mattole River watershed. It expresses the allocations in terms of the percentage reductions needed from the estimates of current levels described in this analysis. The load allocations pertain to the entire Mattole River watershed, whereas implementation actions may be focused at a smaller scale. Because there are no significant individual point sources of sediment in the Mattole River watershed, the waste load allocation for point sources is set at zero. The margin of safety is not added as an explicit component of the TMDL, but rather is incorporated implicitly through conservative assumptions used to develop the TMDL, as discussed in Section 3.2. Thus, the TMDL for sediment for the Mattole River and its tributaries is apportioned among the categories of background and nonpoint sources of sediment identified in the source analysis, as load allocations. In other words:

TMDL = loading capacity = nonpoint sources + background = 3,600 t/mi^2/yr.

Twenty percent of the loading capacity (700 t/mi^2/yr) is allocated to management-associated nonpoint sources (road related mass wasting, road-stream crossing failures, road related gullying, road related surface erosion, skid trail erosion, and other harvest related activity). Background sources compose 80 percent of the loading capacity (2,900 t/mi^2/yr), including natural mass wasting and stream bank erosion.

The TMDL and load allocations are expressed in terms of yearly averages (tons/mi^2/yr) (Table 3.15). These load allocations could be divided by 365 to derive daily loading rates (tons/mi^2/day), but they are expressed as yearly averages, because daily sediment delivery to streams is naturally highly variable, and because sediment effects occur over longer time periods. For that reason, Regional Water Board staff recommend that the load allocations be evaluated as a ten-year rolling average. In addition, Regional Water Board staff do not expect each square mile within a particular source category to meet the load allocation; but rather that the average for the entire source category will meet the load allocation for that category.

Determination of Allocations

The load allocations for nonpoint sources reflect Regional Water Board staff's best professional judgment of how effective best management practices are in controlling these sources. For example, techniques are available to greatly reduce sediment delivery from roads (Weaver and Hagans, 1994); therefore, the load allocation for road-related sediment (including road-related gullying, and surface erosion) reflects a reduction of about 90-95 percent from the estimate of the current loading rate. Other road related mass wasting features, which are greatly influenced by their geologic terrane, maybe more difficult to control so a loading reduction of 80-85 percent may be a more realistic target.

Estimates that 95 percent of road-stream crossing failures are controllable (Hagans, et al., 1986), are reflected by a reduction of 90-95 percent from the current estimated loading rate. Furthermore, because road-related sediment accounts for the largest component of management-related sediment of the current loading (64 percent of 5,100 t/mi^2/yr), efforts to reduce sediment from roads are expected to be highly effective in reducing sediment overall.

The best conservation and land management measures to control sediment associated with landsliding in timber harvest areas are expected to be about as effective as those to control road-related sediment. Therefore, the load allocations for sediment delivery from timber harvest, such as skid trail related erosion and other harvest-related delivery reflect 85-90 percent reductions from the estimate of the current loading.

TABLE 3.15 Sediment TMDL and Load Allocations

Source Category	TMDL Load Allocation $t/mi^2/yr$	Current Load Estimate $t/mi^2/yr$ 1984-2002	% of Total Current Loading[1]	Loading Reduction Needed	% of Total TMDL Alloc.[2]
LOAD ALLOCATIONS FOR NONPOINT SOURCES (MANAGEMENT-ASSOCIATED LOADS)	**700**	**5,100**	**64%**	**86%**	**20%**
ROAD RELATED MASS WASTING	520	2,900	33%	82%	10%
ROAD STREAM CROSSING FAILURES	3	50	1%	94%	1%
ROAD RELATED GULLYING	10	170	3%	94%	1%
ROAD RELATED SURFACE EROSION	27	540	11%	95%	2%
SKID TRAIL RELATED EROSION	70	710	14%	90%	3%
OTHER HARVEST RELATED DELIVERY	70	700	14%	90%	3%
LOAD ALLOCATIONS FOR BACKGROUND (NON-MANAGEMENT-ASSOCIATED LOADS)[3]	**2,900**	**2,900**	**36%**	**0%**	**80%**
NATURAL MASS WASTING	2,400	2,400	85%	0%	67%
STREAM BANK EROSION	460	460	15%	0%	13%
TOTALS	**3,600**	**8,000**	**100%**	**55%**	**100%**

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

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 through conservative assumptions used to develop the TMDL, or added as an explicit separate component of the TMDL (EPA, 1991). In this TMDL, we employed conservative assumptions, as described below.

Targets
Water quality targets were chosen that consider several factors for the protection of water-quality related to sediment. These include:

- Selecting a wide range of targets that are both directly descriptive of good water quality conditions (instream targets) and supportive of anti-degradation policies (watershed targets)
- Selecting conservative water quality targets where the scientific literature supports them
- Making conservative assumptions for targets, where data are sparse, regarding which limiting factors are potentially affecting salmonids
- Making conservative assumptions with respect to the nature of the relationship between hillslope sediment production and in-stream effects.
- Including targets for watershed conditions (hillslope and roads) that will limit additional sediment delivery into the water bodies

As existing in-stream data are limited, the targets represent the optimal conditions for beneficial use support for salmonids, because beneficial uses associated with the cold water fishery are the most sensitive beneficial uses.

Source Analysis
Conservative assumptions were made in the source analysis to account for uncertainty that tended to under-estimate sediment delivery. In general, the methods used resulted in attributing less of the observed sediment loads to natural sources than is actually taking place. For example, only mass wasting features < 10,000 square feet that were 15 years old or less were included in the road and stream survey calculations for sediment delivery. Additionally, in the aerial photo analysis, only mass wasting features > 10,000 square feet that were first observed in the 1984 photos or more recently (1993, 1996, 2000) were included in sediment delivery calculations. Many of the older mass wasting features (pre-1984) that may still be contributing sediment to the fluvial system were not completely accounted for in this TMDL. Only estimated surface erosion rates for the older mass wasting features (pre-1984) were accounted for, not there potential delivery volumes. The cumulative impacts of road construction, operation, and maintenance, logging, conversion of forest to grassland, and widespread burning, all considered in conjunction with the large storms of the 1950s and 1960s, contributed enormous amounts of sediment to the fluvial system (MRC, 1995). This "legacy effect" sediment or sediment that is still in storage throughout the Mattole watershed was not considered as part of the current estimated sediment budget.

3.3.4 Seasonal Variation and Critical Conditions

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

The TMDL must also account for critical conditions for stream flow, loading, and water quality parameters. This TMDL does not explicitly estimate critical flow conditions because sediment impacts may occur long after sediment is delivered to the streams, often at locations far downstream of the sediment source. Rather, the approach used in this TMDL is to use indicators, which reflect net long-term effects of sediment loading and transport.

CHAPTER 4: TEMPERATURE

4.1 Sources of Increased Stream Temperatures

The water bodies in the Mattole River watershed are included on the 303(d) list as impaired for temperature. Because there are no known point sources of heat input to the streams of the Mattole watershed, temperature loads from point sources are not considered further in this document.

Because temperature is a measure of the heat energy per unit volume of a material, elevated stream temperatures equate to increases in heat energy derived from solar radiation and other sources. However, the main source of increased energy entering a stream is from sunlight. As more sunlight reaches a stream it raises the water temperatures. The source of increased stream temperature is excessive solar heat energy delivered to streams and is the pollutant targeted in this TSD.

This TMDL uses effective shade as an inverse surrogate measure to determine addition of solar heat energy. Effective shade is the shade from topography and vegetation that blocks solar radiation from reaching streams. The following equation relates effective shade and solar radiation inputs at a location:

Actual Solar Radiation Input = Potential Solar Radiation Input - Effective Shade

The narrative water quality objective for temperature (Section 2.1.3) states that the natural receiving water temperature of intrastate water shall not be altered. To meet this objective, solar radiation inputs and effective shade for this TSD will be those that result in no alteration of natural receiving water temperatures.

4.1.1 Summary

In evaluating the influence of human activities on stream temperatures, the areas adjacent to streams, that is the riparian corridors, are most critical. It is near the streams that a change of conditions can allow increased sunlight to reach streams directly and raise temperatures. Human activity upslope of stream channels, however, can have an impact on both sediment delivery and runoff characteristics within the riparian corridor, and in that way may influence local air temperatures.

The source analysis focuses on natural and management-related (non-point) controls on solar radiation inputs to streams. There are no known point sources of heat to the Mattole or its tributaries. This section looks at factors affecting stream temperatures in the critical summer low-flow periods. Those factors include streamside shading, stream flow, the width and depth of wetted stream channels, and microclimate influences as possible controls related to management activities to account for observed stream temperatures. The summer low-flow periods are most critical because during those times solar radiation inputs are the greatest and increases in solar radiation have the greatest effect on stream temperatures.

Two models were used to explore stream heating processes and land use impacts. SSTEMP, a public domain model currently supported by the US Geological Survey, was used to evaluate the effects of stream heating mechanisms in the Mattole River watershed and to investigate the role that land use impacts have had on stream temperatures. A Geographic Information System (GIS) model developed by the Information Center for the Environment (ICE) at UC Davis, RIPTOPO, was used to estimate effective shade under various vegetation conditions, based on vegetation characteristics, topography, stream geometry, and sun position.

The results of the SSTEMP modeling analysis show that changes in channel geometry and riparian conditions can increase or decrease stream temperatures. Specifically, increases in solar radiation inputs to streams result in elevated stream temperatures. Changes in microclimate associated with removal of riparian vegetation can also lead to increased stream temperatures. Microclimate alteration due to reduction of riparian vegetation is not readily predictable, although the phenomenon has been well documented. Changes in channel morphology, such as increased stream width and decreased channel topographic complexity, can also lead to increased stream temperatures.

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 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 (cold water havens provided by stratified pools, groundwater, intra-gravel exchange, etc.) are important habitat elements and may be more important than shade in supporting suitable stream temperatures. Observations along 10 miles of mainstem Mattole River reaches indicate that thermal refugia are important habitat features for salmonids in the river. Observations in the same reaches, as well as thermal infrared imagery and literature describing effects of sediment loads on channel features, indicate that the volume of thermal refugia depends on sediment load.

4.1.2 Temperature Sources: Stream Heating Processes

Water temperature is a measure of the total heat energy contained in a volume of water. Stream temperature is the product of a complex interaction of heat exchange processes. These processes include heat gain from direct solar (short –wave) radiation, both gain and loss of heat through long-wave radiation, convection, conduction, and advection, and heat loss from evaporation (Brown 1980; Beschta et al. 1987; Sinokrot and Stefan 1993; Theurer et al., 1984).

- Net direct solar radiation reaching a stream surface is the difference between incoming radiation and reflected radiation, reduced by the fraction of radiation that is blocked by topography and stream bank vegetation (Sinokrot and Stefan, 1993). At a given location, incoming solar radiation is a function of position of the sun, which in turn is determined by latitude, day of the year, and time of day. During the summer months, when solar radiation levels are highest and streamflows are low, shade from streamside forests and vegetation can be a significant control on direct solar radiation reaching streams (Beschta et al., 1987).

- Long-wave radiation emitted from the water surface can cool streams. Heat exchange via long-wave radiation at a stream surface is a function of the difference between air temperature and water surface temperature (Sinokrot and Stefan, 1993; ODEQ, 2000). During the course of a 24-hour period, heat leaving and heat entering a stream via long-wave radiation generally balance (Beschta, 1997; ODEQ, 2000).

- Evaporative heat losses are a function of the vapor pressure gradient above the stream surface and wind conditions (Sinokrot and Stefan, 1993). Evaporation tends to dissipate energy from water and thus tends to lower temperatures. The rate of evaporation increases with increasing stream temperature. Air movement (wind) and low vapor pressures (dry air) increase the rate of evaporation and accelerate stream cooling (ODEQ, 2000).

- Convection describes heat transferred between the air and water via molecular and turbulent motion. Heat is transferred from areas of warmer temperature to areas of cooler temperature. The amount of heat transferred by this mechanism is generally considered low (Brown 1980; Sinokrot and Stefan, 1993).

- Conduction is the means of heat transfer between the stream and its bed. In shallow streams, solar radiation may be able to warm the streambed (Brown, 1980). Bedrock or cobbles on the streambed may store heat and conduct heat back to the water if the bed is warmer than the water (ODEQ, 2000). Likewise, water can lose or gain heat as it passes through subsurface sediments during intra-gravel flow through gravel bars and meanders. Bed conduction is a function of the thermal conductivity of the bed and the temperature gradient within the bed (Sinokrot and Stefan, 1993). A streambed that has absorbed radiant energy during the day will conduct that energy back to the stream at night.

- Advection is heat transfer through the lateral movement of water as stream flow or groundwater. Advection accounts for heat added to a stream by tributaries or groundwater. This process may warm or cool a stream depending on whether a tributary or groundwater entering the stream is warmer or cooler than the stream.

Each of the heat fluxes discussed above can be represented by mathematical equations. By adding the values of the fluxes for a particular location, the net of the heat fluxes associated with all of these processes can be calculated (Theurer et al., 1984). The net heat flux represents the change in the water body's heat storage. The net change in storage may be positive, leading to higher stream temperatures, negative, leading to lower stream temperatures, or zero such that stream temperature does not change.

4.1.3 Analytical Methods and Results

The approach taken to develop the Mattole River Temperature TMDL involved the use of computer simulation models to investigate stream heating processes. Two separate models were used. The first model, RIPTOPO, was developed and used by ICE at UC Davis to estimate stream shade values throughout the watershed. The second model, SSTEMP, was used to evaluate the relative importance of the various factors that combine to produce the observed stream temperatures, and to evaluate what impact loss of stream shade has had on the stream temperature regime. The SSTEMP model is intended for application to a segment or reach of a stream or river (Bartholow, 1999).

Considerable data is available on the spatial and temporal distribution of stream and air temperature in the Mattole watershed. Other parameters, including the wetted widths of streams, active channel widths, stream shade values, and flow rates necessary for stream temperature modeling are scarce. Given the lack of data in some areas, many parameters were estimated based on relationships developed from existing data. The following sections describe the data requirements of the models, how the data was developed, and the results of the modeling exercises.

4.1.3.1 Stream Shade Simulation

Because stream shade is a major factor in the temperature dynamics of streams, information describing current and natural stream shade conditions is important in evaluating the influence of management on stream temperatures. The Regional Board contracted with ICE at UC Davis to provide shade estimates, which ICE developed with the RIPTOPO GIS model. The RIPTOPO model uses information describing vegetation characteristics, topography, stream geometry, and sun position at any given point in the watershed to calculate the percent of total possible sun intercepted by vegetation and topography.

Vegetation Height and Characteristics: As a key step in the RIPTOPO model development, input on the vegetation type, height, and extent is required for both potential and current vegetation conditions. Vegetation information was developed from available GIS coverages, literature on occurrence and characteristics of particular tree species, field observations in the watershed, and review of historical and recent aerial photos.

The California Existing Vegetation GIS dataset was the primary source of distributed (watershed-scale) vegetation information. Particularly useful database fields included the vegetation classification by Wildlife Habitat Relationships (WHR) type and tree size classes (classified into diameter at breast height [dbh] ranges). In the GIS dataset, WHR types were identified on a polygon basis. A polygon is a closed shape defining an area of similar characteristics. To describe potential vegetation height conditions, the mature tree heights (Table 4.2) for hardwoods and conifers by vegetation class (WHR type) were combined with derived percent conifer and percent hardwood values to calculate polygon-specific potential vegetation heights. For current vegetation conditions, an additional step was performed. Each polygon in the GIS coverage has an associated dbh class. Using the conversions in Table 4.1, dbh information was converted to estimated current vegetation heights for each polygon.

A summary of tree species occurring in the Mattole watershed was compiled from published reports (Griffin and Critchfield, 1972) and field observations, and is presented in Table 4.2. For each species, reported heights of mature trees were compiled from a variety of sources (Burns and Honkala, 1990; Fowells, 1965; Hickman, 1993; Munz and Keck, 1968; Sudworth, 1908; Whitney, 1998). For each tree species, a mature tree height considered to be representative of tree heights in riparian areas of the north coast of California was selected from the compiled values. In addition, estimated tree heights associated with dbh classes were developed (Burns and Honkala, 1990; Fowells, 1975) for later use in characterizing current vegetation height conditions, as seen in Figure 4.1. Next, key tree species associated with the Klamath Region Vegetation Mapping Project habitat database vegetation types were identified.

Table 4.1
Summary of Tree Species and Mature Height Estimates for Near-Stream Vegetation Characterization

Tree Name		**Mature Heights**									**Selected Value**	
		Sudworth		Whitney	Burns and Honkala		Munz		Jepson Manual			
Common	Latin	Typical (ft)	Extreme (ft)	(ft)	(ft)	(m)	(ft)	(m)	(ft)	(m)	(ft)	(m)
Conifers												
Grand fir	*Abies grandis*	150-200	250-275	100-200	140-200	43-61	40-295	12-90	<240	<73	190	58
Ponderosa pine	*Pinus ponderosa*	125-140	150-200		130	40	50-230	15-70	<225	<68	130	40
Douglas fir	*Pseudotsuga menziesii*	180-190	200	80-200	250	76	<230	<70	<220	<67	190	58
Redwood	*Sequoia sempervirens*	190-280	300-350	200-325	300	91	165-330	50-100	<380	<115	280	85
Hardwoods												
Bigleaf maple	*Acer macrophyllum*	60-80		30-70			15-100	5-30	15-100	5-30	70	21
California buckeye	*Aesculus californica*	10-20	25-50	25			23-40	7-12	12-40	4-12	35	11
White alder	*Alnus rhombifolia*	50-75		70			35-115	10-35	<115	<35	70	21
Red alder	*Alnus rubra*	60-90		40-100	100-130	30-40	50-80	15-25	<80	<25	80	24
Pacific madrone	*Arbutus menziesii*	60-80		20-80	110	34	16-130	5-40	<130	<40	110	34
Oregon ash	*Fraxinus latifolia*	60-75		80			35-80	10-25	<80	<25	75	23
Tanoak	*Lithocarpus densiflorus*	50-75	80-85	50-80	150	46	65-150	20-45	<100	<30	90	27
Black cottonwood	*Populus trichocarpa*		80-125		70-200	20-60		40-60				
Blue oak	*Quercus douglasii*	30-40	60-75				20-65	6-20	20-65	8-20	60	18
Oregon oak	*Quercus garryana*	50-60	75-90	30-70	70		25-65	8-20	25-65	8-20	65	20
California black oak	*Quercus kelloggii*	50-75	80-85	30-80	82	25	35-80	10-25	<80	<25	80	24
Goodding's black willow	*Salix gooddingii*	25-50	60-80				35-65	10-20	<100	<30	60	18
Pacific willow	*Salix lucida ssp.lasiandra*	25-30	40-50	20-50			20-50	6-15	<30	<10	40	12
California bay	*Umbellularia californica*	30-40	60-80	40-80	100	30	100-150	30-45	<150	<45	110	34

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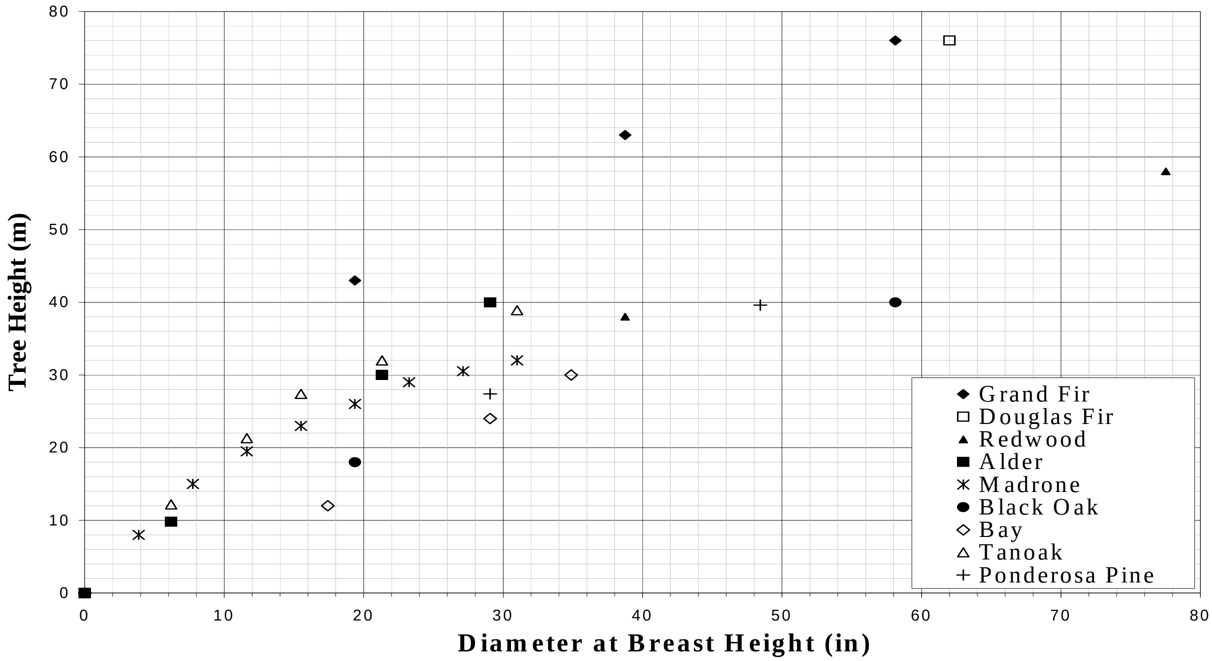

Figure 4.1 Relation of Tree Height to Diameter at Breast Height

Examples of vegetation types are redwood forest, Douglas fir forest, and mixed hardwood-conifer forest. For each vegetation type, height values were developed for each dbh class for groupings of conifers and hardwoods. Results are presented in Table 4.2.

Table 4.2
Summary of Tree Heights by Vegetation Class and DBH Conversions

DBH (in)	**Tree Height (m)**											
	CPC	DFR		MHW	COW	MHC		JPN		RDW		MRI
	CON (100%)	CON (80%)	HW (20%)	HW (100%)	HW (100%)	CON (30%)	HW (70%)	CON (80%)	HW (20%)	CON (80%)	HW (20%)	HW (100%)
1-6	4	14	5	5	5	10	5	4	4	8	5	5
6-11	8.7	24	12	12	12	18	12	10	9	14	12	9.7
11-24	13.3	31	21	21	21	31	21	20	17	25	23	14.3
>24	18	42	31	31	31	42	31	27	27	36	34	19
>36		56	35	35	35	56	35	40	34	58	34	
Potential	18	56	35	35	35	56	35	40	24	80	27	19

Vegetation Types:

CPC	Closed-Cone Pine/Cypress	JPN	Jeffrey/Ponderosa Pine
DFR	Douglas Fir	RDW	Redwood
MHW	Mixed Hardwood	MRI	Montane Riparian
COW	Coastal Oak Woodland	CON	Conifer
MHC	Mixed Hardwood-Conifer	HW	Hardwood

Topography: Topographic coverage was developed using 10m Digital Elevation Model (DEM) input acquired from the U.S. Geological Survey. The DEM was used to develop the network and aspect of streams in the watershed in addition to the topography of the watershed.

Vegetation Extent: The underlying stream network was developed from USGS topographic data. The unvegetated channel was defined using bankfull width, centered on the centerline of the stream channel. Bankfull widths were assigned using a relationship for the Mattole watershed (Figure 4.2) developed with techniques and equations described in Leopold, Wolman, and Miller (1964) from data collected by NCRWQCB staff. Bankfull width is a characteristic of all stream channels and corresponds to the top width of a stream flowing under bankfull conditions. In the simplest of channels, bankfull flow is the greatest flow the channel can accommodate before flooding occurs. Bankfull water levels correspond to the height of incipient flooding, submerged point bars, changes in bank slope, differences in substrate, and often differences in vegetation (Leopold, 1994).

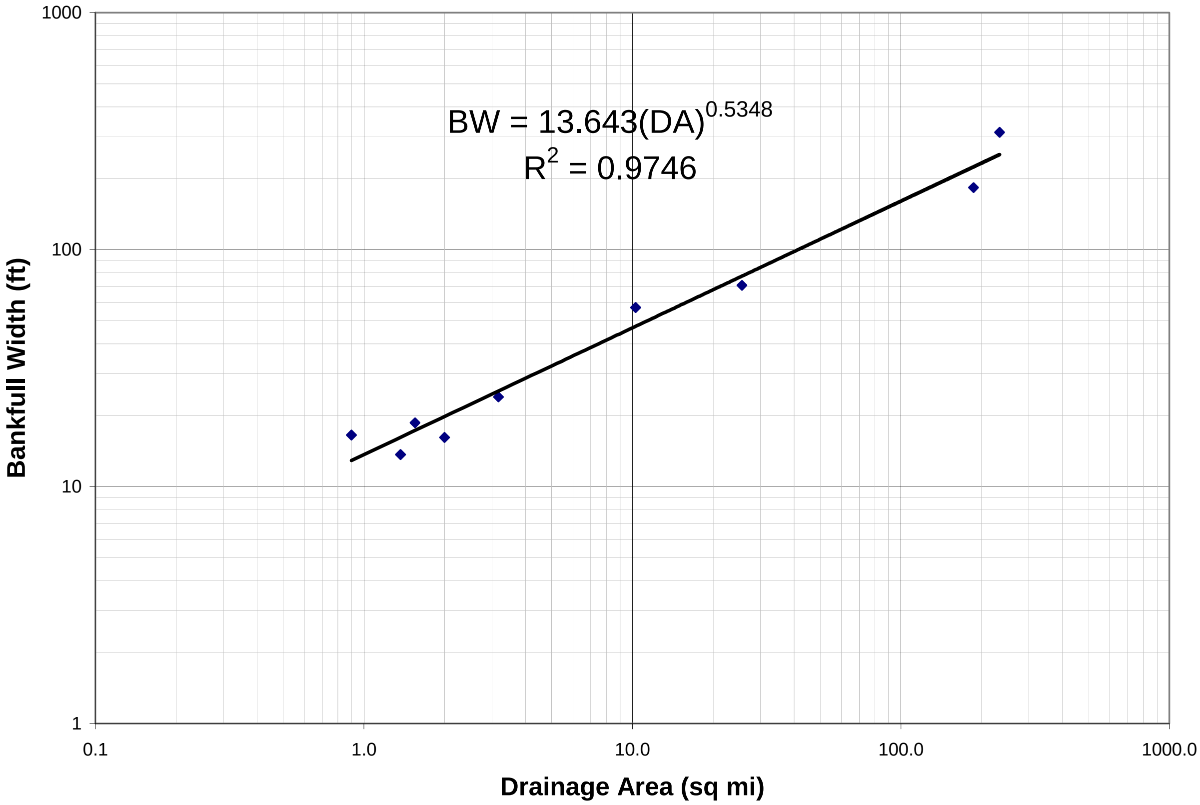

Figure 4.2 Bankfull Width (BW) vs. Drainage Area (DA) in the Mattole River Watershed

Sun Track for Mean MWAT Date: The GIS model uses sun position in calculating shading produced by topography and vegetation. Equations presented in Boes (1981) were used to calculate hourly solar azimuths and altitudes for July 23, the date believed to be the mean MWAT for the watershed at the time of the development of the shade estimates. (Since the shade estimates were developed, the true mean MWAT date was found to have been July 30. The difference of seven days is not believed to be significant, given the fact that suntracks do not change substantially over the course of a week at this time of year.)

The values were then used as input to the ArcInfo HILLSHADE module, which calculates shade at any point given the surrounding topography and vegetation. A HILLSHADE simulation was run for each hour of the MWAT date. The results then were weighted to reflect variations in solar intensity during the day, using the solar radiation intensity distribution for July from the Solar Pathfinder sun path diagram for a horizontal collector at 37-43°N latitude. These results were summed to develop watershed-scale portrayals of shade conditions.

Stream Shade Modeling Results: Results of the GIS effective shade calculations are presented in Figures 4.3, 4.4, and 4.5 (appended to the end of the document). Figure 4.3 presents the estimated current shade conditions along the stream network. Figure 4.4 presents the potential shade conditions along the stream network. Figure 4.5 presents the difference between the potential and current shade conditions along the stream network, and the locations and magnitude (on a percentage basis) where current shade is less than potential shade. This figure is useful in highlights locations where opportunities for improving shade conditions (and reducing solar loads) exist. Figure 4.5 supports the following general conclusions:

- The greatest differences between the estimated current and potential effective shade values are along the reaches of major tributaries (Bear, Mattole Canyon, Squaw, Blue Slide Creeks, Lower North Fork, and Upper North Fork and others) and the upper mainstem of the Mattole river.
- Effective shade should not be expected to increase along the lower reaches of the Mattole River, where trees are not able to provide substantial shade.
- Some reaches of small tributaries throughout the Mattole River watershed show substantial differences (>15 percent) between estimated current shade and potential effective shade.

4.1.3.2 Stream Temperature Simulation

The dynamics of stream heating processes are complex and non-linear. The degree to which a change in one factor will affect stream temperature depends on the values of other factors. Regional Board staff used the SSTEMP model to evaluate the importance and interaction of the relevant factors acting on stream temperatures in the Mattole River watershed. Stream temperature modeling is a well developed area of investigation and has been used extensively throughout the world to understand stream heating processes. The model was used to identify which factors affect stream temperatures the most and to evaluate the potential change in stream temperatures that could be expected under mature riparian conditions.

Model Inputs

The parameters that go into the SSTEMP model are summarized in Table 4.3.

Stream Flow Estimation: A relationship between stream flow and drainage area was developed from flow measurements made by CDFG and NCRWQCB staff. This relationship allows estimation of stream flow at a site as a proportion of the stream flow reported at the Petrolia gage, based on the drainage areas upstream of the site and the gaging station. Figure 4.6 shows the stream flow – drainage area relationship that was developed. The coefficient of determination (R^2, the fraction of the variance explained by the regression) of the relationship shown is misleading. Although the relationship generally fits the data well over the range of the data, a high degree of variation shows in the small drainage area region where most of the data were gathered. Despite the variation in stream flows seen in the data, the stream flow – drainage area relationship provides an adequate basis for estimating stream flow in a stream-temperature-modeling context given the relative insensitivity of stream temperatures to stream flow, as described in the sensitivity analysis section below.

Table 4.3
SSTEMP model input requirements

Hydrology		Meteorology	
	Segment Inflow *		Air Temperature*
	Inflow Temperature		Relative Humidity*
	Segment Outflow *		Wind Speed *
	Accretion (Groundwater) Temperature*		Ground Temperature *
			Thermal Gradient (j/m2/s/c)*
Geometry			Possible Sun (%)*(a measure of cloud cover)
	Latitude (°)		Dust Coefficient *
	Segment Length		Ground Reflectivity (%)*
	Upstream Elevation		
	Downstream Elevation	Shade*	
	Width's A Term (a measure of width-to-depth ratio) *		
	Manning's n *	Time of Year (mm/dd)	

* Input parameter that was varied as part of the sensitivity analysis.

Figure 4.6. Relationship Between Stream Flow and Drainage Area, Mattole River Watershed

Stream Width Estimates: To estimate wetted channel widths under low flow conditions, a relationship between mean wetted channel width and drainage area was developed from California Department of Fish and Game's (CDFG) habitat typing data. The mean channel widths of individual habitat units, weighted by the length of the habitat unit, were averaged over 30 bankfull widths for each of seven reaches. Bankfull widths were estimated based on the relationship between bankfull width and drainage area developed for the shade analysis described above. Habitat typing data was used only from streams where habitat typing data was continuous (not randomly sampled). These streams are Squaw, Rattlesnake, Green Ridge, Vanauken, Oil, and Devils Creeks. The relationship developed is shown in Figure 4.7. Although the relationship provides only a relatively crude estimate of channel width, length-weighted low-flow channel width and drainage area correlate well, given that width varies with flow and is influenced by sediment and other site-specific morphologic conditions.

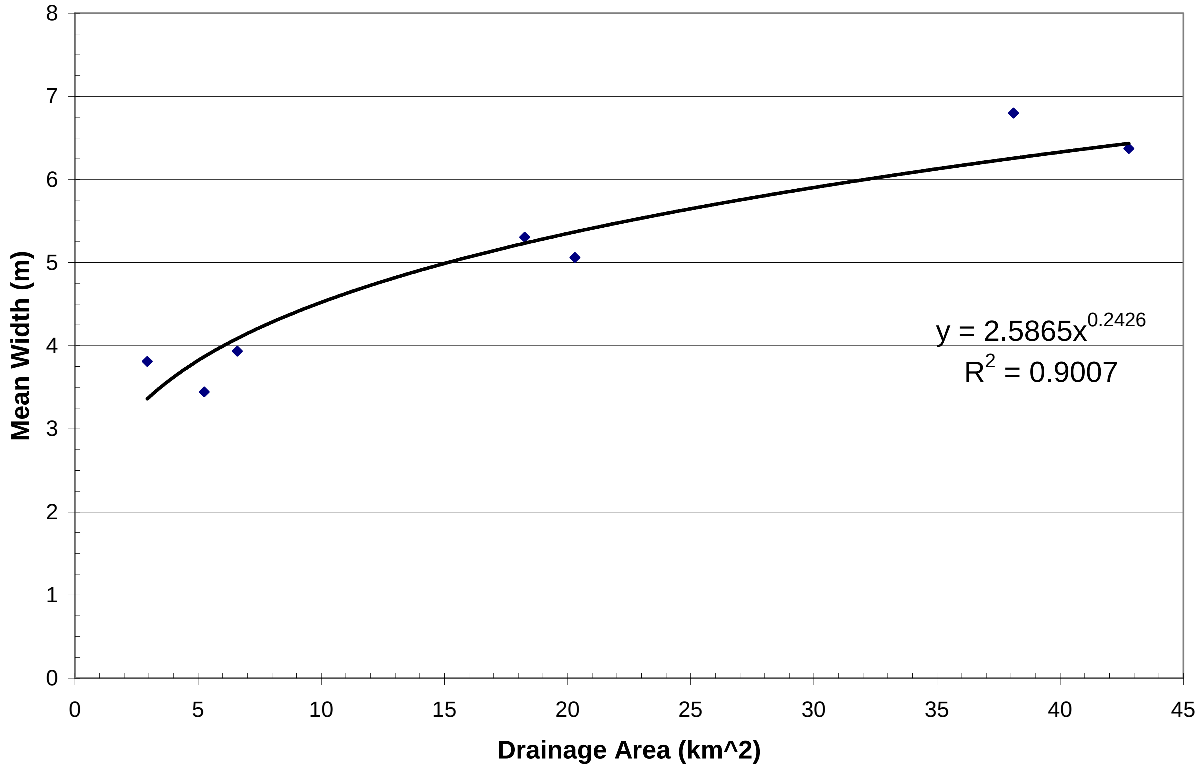

Figure 4.7. Mean Low Flow Width vs. Drainage Area, Weighted by Length of Habitat Unit

Ground and Groundwater Temperature: Ground and groundwater temperatures were assumed to be equal to the mean annual air temperature except in Eubanks Creek, where water temperature data collected at the headwaters was used. Air temperature, humidity, and wind speed data were available from a private weather station operated in the lower Thompson Creek watershed from 9/1/2000 – 4/1/2001.

Sensitivity Analysis

Sensitivity analysis is a technique that can be used to understand the influences that various stream geometry, meteorological, and hydrological conditions have on stream temperature (Bartholow, 1989). The primary uses for sensitivity analysis in this report are to rank parameters and their interactions according to effects on predicted stream temperatures, and to identify the most important management-related parameters.

The sensitivity analysis approach used in this analysis is based on varying the value of one parameter while holding others constant. The approach uses the SSTEMP model to estimate the magnitude of effects that meteorological and stream conditions have on stream temperatures by using reasonable values of these parameters under different scenarios (Table 4.4). This approach investigates the effect an individual parameter has on stream temperatures in reaches of both small (drainage area = 1.8 $mi.^2$) and large (drainage area = 202 mi^2) stream channels. Upper Eubanks Creek (Figure 1.2) was chosen to represent low order streams in the Mattole watershed, the Mattole mainstem from Bundle Prairie to the Mattole Grange was chosen to represent mainstem habitats.

Table 4.4 Summary of parameters and initial values used for SSTEMP sensitivity analysis

Parameter	Units	Reference Value		
		Eubanks Creek	Bundle to Grange	Dependence
Air Temperature	°C (°F)	19.9 (67.8)	19 (66.2)	+
Total Shade	%	77	14	-
Relative Humidity	%	60	60	+
Accretion Temperature	°C (°F)	11.6 (52.9)	12.4 (54.3)	+
Width's A Term	Dimensionless	11.54	11.54	+
Width's B Term	Dimensionless	0.243	0.243	-
Segment Outflow	Cms	0.0166	1.104	-
Possible Sun	%	90	90	+
Ground Temperature	°C (°F)	11.6	12.4 (54.3)	+
Manning's n	Dimensionless	0.035	0.035	-
Wind Speed	m/s	1	1	-
Thermal Gradient	Joules/m^2/sec/°C	1.65	1.65	-
Dust Coefficient	Dimensionless	5	5	-
Ground Reflectivity	%	25	25	+
Segment Inflow	Cms	0.0003	0.851	+
Inflow Temperature	°C (°F)	11.6 (52.9)	22.6 (72.7)	+

Note: Sensitivity analysis performed using SSTEMP sensitivity analysis function. Parameters were varied +/- 10% from the Initial Value.

Note: Dependence column indicates temperature was (+) directly dependent or (-) inversely dependent on the parameter.

The input parameters used for the sensitivity analysis of individual parameters are marked with an asterisk in Table 4.3. The values of the parameters were varied individually +/- 10% from the initial conditions. The initial conditions and ranges of variation are presented in Table 4.4.

Sensitivity Analysis Results: Results of the sensitivity analysis are presented in Figures 4.8 and 4.9. The results indicate that the sensitivity of daily mean stream temperature to changes in factors influencing stream temperatures depends on the size of the stream being analyzed.

Of the factors that determine stream temperatures, shade and flow can be directly affected by management activities. Air temperature, relative humidity, wind speed, ground temperature, width-to-depth ratio, Manning's n, and ground reflectivity can be indirectly affected by management activities. Shade, air temperature, wind speed and relative humidity interact with one another to create microclimates associated with riparian corridors, and thus have a direct effect on stream temperatures. In the Mattole River watershed, while these conditions are demonstrated to be important, data are not sufficient to quantify the effect management has had or can have on microclimates.

Mainstem Mattole River: In the mainstem reach, mean stream temperature was most sensitive to air temperature. Mean stream temperature is somewhat sensitive to segment inflow, segment outflow (in this case a measure of groundwater contribution), relative humidity, inflow temperature, and possible sun.

Mean stream temperature is insensitive to the other parameters tested, including groundwater temperature, total shade, thermal gradient, and ground reflectivity. Sensitivities of maximum daily stream temperatures to changes in parameters in the mainstem reach are similar to the sensitivities of daily mean stream temperatures described above.

Smaller streams: In smaller streams, where spawning and rearing of salmonids takes place, mean stream temperature is most sensitive to air temperature, and is also sensitive to total shade and relative humidity. Mean stream temperature is somewhat sensitive to groundwater temperature and stream geometry (width's A term). Mean stream temperature is not sensitive to the other parameters tested, including flow and wind speed. When the results are ranked by effect on the maximum stream temperature estimated by the model, total shade is the most important parameter, and air temperature also is important. Maximum temperature is somewhat sensitive to relative humidity and possible sun (a measure of cloud cover), and is relatively insensitive to the remaining parameters including wetted channel width and flow, ground temperature, thermal gradient, dust coefficient, and ground reflectivity.

Given the results of the sensitivity analysis, a logical question to ask is, "Why are smaller streams more sensitive to changes in effective shade than larger streams?" The answer lies in the stream geometry. The ability of vegetation to provide shade to a stream channel is a function of the width and orientation of the channel. As streams become wider, taller trees are required to shade the channel. In smaller streams like Eubanks Creek, vegetation is able to consistently provide more shade than it can provide in larger, wider channels. In larger streams, if the wetted channel runs along the bank in an area of tall trees, there is likely to be substantial shade provided by those trees. However, given the fact that low-flow wetted channels shift or braid within the confines of their active channel, it is unlikely that substantial shade will be provided throughout a lengthy reach.

The parameters to which mean or maximum temperatures are very sensitive or somewhat sensitive include total shade, air temperature, wind speed, relative humidity, possible sun, width-to-depth ratio as measured by width's A term, and flow (Figures 4.8 and 4.9).

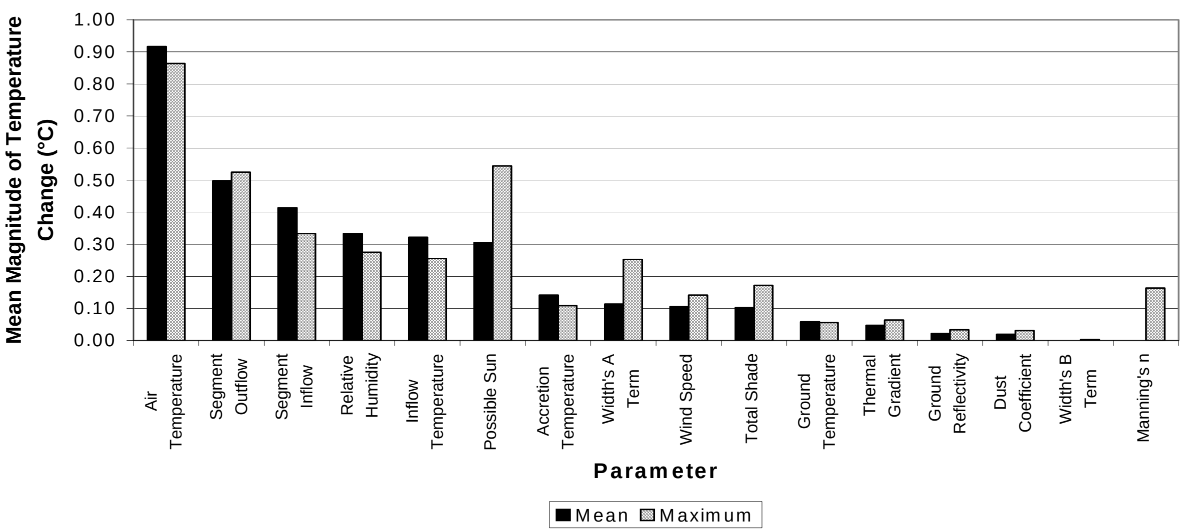

Figure 4.8 Sensitivity Analysis of SSTEMP to +/- 10% Variation of Each Parameter, Mattole Mainstem from Bundle Prairie to the Grange Reach Simulation, Sorted by the Effect on Mean Temperature

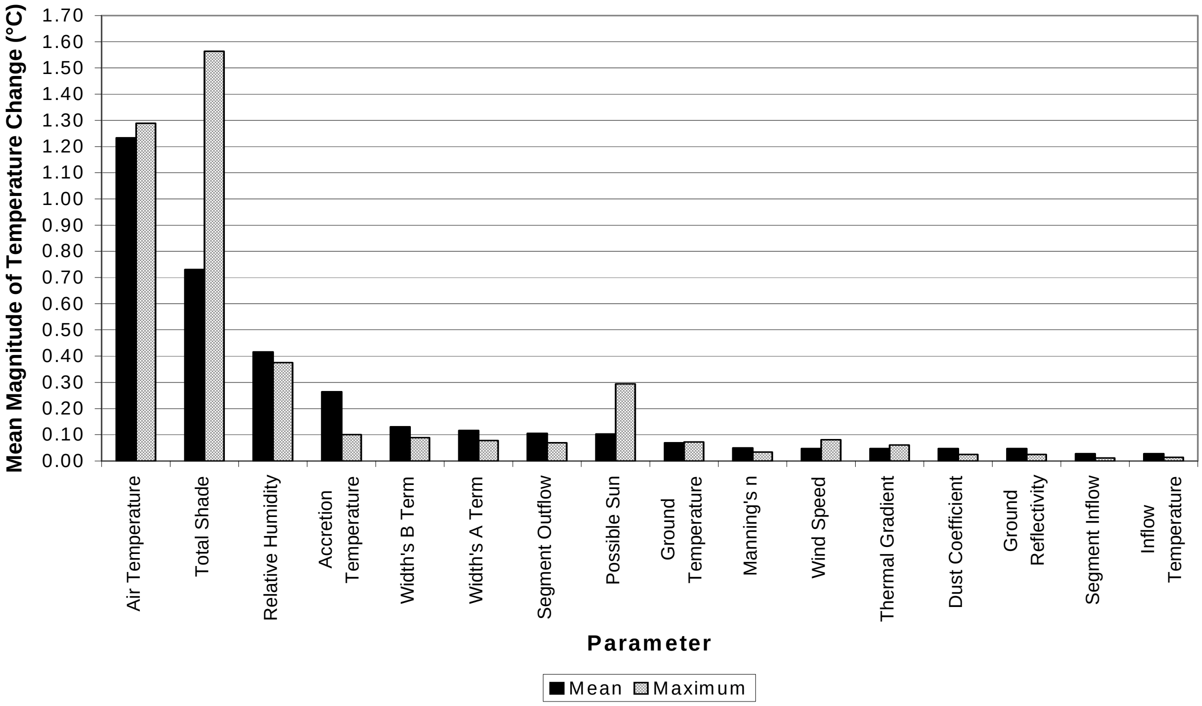

Figure 4.9: Sensitivity Analysis of SSTEMP to +/- 10% Variation of Each Parameter, Upper Eubanks Creek Simulation, Sorted by the Effect on Mean Temperature

Total shade reflects circumstances of topography, vegetation, channel orientation, sun angle, and channel conditions in and near streams. The presence, type, height, and density of vegetation near streams all affect the nature and quantity of streamside shade. Channel width, or width's A term, can change in response to changes in sediment loads transported by a stream or river; increased sediment loads often lead to wider, shallower channels. The model results indicate that wider, shallower channels affect estimated temperatures in smaller streams by increasing mean temperatures and diurnal fluctuations.

While air temperature, wind speed, relative humidity, and ground temperature would not be subject to management measures on a regional basis, values of these parameters may reflect local conditions near streams. In particular, these parameters can indirectly reflect or be affected by changes in riparian vegetation conditions. These parameters would vary together and balance one another to a certain extent. For example, a shaded streamside area generally has lower air temperatures, lower wind speeds and higher relative humidity than an open area. The net of these changes is lower temperatures in more shaded areas. Possible sun is of lesser importance in the Mattole than other parameters and is not influenced by management measures.

Results indicate that while changes in flow have little effect on mean temperatures, they have a modest effect on diurnal fluctuations in temperature as shown by the model's estimated maximum temperature. This is because stream temperature is a manifestation of heat energy present in the water. Stream temperature can be thought of as a concentration of heat energy, an amount of energy per unit of water volume. At low flows there is a smaller volume of water so an addition of heat energy from external conditions has a greater effect on a stream at low flow than a stream at high flow. For this reason, smaller streams, which have lower flows, are more responsive to external conditions than reaches of large streams. A relatively small change in stream flow in a small stream has little effect on stream temperature because the stream temperature is still dominated by local site conditions. A relatively small change in stream flow in a large stream, which has a larger volume of water, has little effect on stream temperature because a large amount of heat energy is required to change the concentration of heat energy in a large volume of water. Therefore, the temperature of the water entering the reach dominates the stream temperature. In short, as flow rates increase the temperature of the water is more resistant to change.

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 the SSTEMP model. The reaches are listed in Table 4.5. Stream temperature monitoring sites that could be simulated as a single reach were chosen for evaluation. Stream temperatures were simulated for current shade conditions, as well as mature riparian conditions. Mature riparian shade conditions were approximated by using potential tree height values for the tree species present. To account for natural events such as fire, landslides, and wind-throw that would reduce effective shade under ideal conditions, potential shade conditions were reduced from ideal conditions by 10 percent. In cases where a reduction of 10 percent from full potential shade conditions resulted in shade estimates less than the estimated current shade, the potential shade value was set equal to the estimated current shade. The resulting shade conditions are referred to as adjusted potential shade.

Air and ground temperatures from the nearest data source were used as approximations for the two parameters. Wind speed values of 0.6 meters per second and relative humidity values of 60 percent were used for all scenarios, except Nooning Creek where local relative humidity data was available. All input data for each simulation scenario is provided in Appendix II.

Table 4.5 Modeled and Actual Daily Average Stream Temperatures of Modeled Reaches

Reach	Current Effective Shade (%)	Adjusted Potential Effective Shade (%)	Measured Temperature (^oC) (^oF)	Simulated Current Temperature (^oC) (^oF)	Simulated Potential Temperature (^oC) (^oF)
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	22.873.0	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

Temperatures predicted by the model for current conditions are within 0.7^{o}C (1.3 ^{o}F) of the measured temperatures in five of the 12 reaches modeled (upper Eubanks Creek, Baker Creek, Bear Creek, Lower North Fork Mattole, and Mattole mainstem at Petrolia). The difference between predicted and measured temperatures for Grindstone Creek and the Mattole mainstem reaches from Big Finley to Bear Creeks and Bundle Prairie to the Mattole Grange, range from 0.9^{o}C to 1.3^{o}C (1.6 ^{o}F to 2.3 ^{o}F). Yew, Nooning, and Woods Creeks were off by 2.3^{o}C, 2.9^{o}C and 3.1^{o}C (4.1 ^{o}F, 5.2 ^{o}F, and 5.6 ^{o}F), respectively.

Differences between measured and predicted current water temperatures in Grindstone Creek and the Mattole mainstem reaches from Big Finley to Bear Creek and Bundle Prairie to the Mattole Grange are most likely the result of wind speed and humidity assumptions that do not match site conditions. When the wind speed and humidity values were adjusted within the bounds of reasonable values, the differences were greatly reduced. In Nooning and Woods Creeks other conditions, such as ground water inputs, may be a factor.

The results of the stream temperature simulations demonstrate the impact that changes in shade conditions have on stream temperatures. The simulations show that an increase in effective shade from current to adjusted potential shade 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.

The results of the modeling exercise are consistent with the conclusions reached by Regional Board staff in their analysis of the Navarro River watershed (NCRWQCB, 2000b), as well as conclusions reached by Stillwater Sciences (USEPA, 1999a) in their analysis of streams in the South Fork Eel River. Stillwater's modeling analysis demonstrated that streamside shade significantly affects stream temperatures in the subbasins that were modeled. Their analysis further showed that maintaining shade in class II streams (non-fish-bearing streams with aquatic habitat), in particular, is important for maintaining natural temperatures of class I (fish-bearing) streams.

Effects of Forest Practices: The California Forest Practice Rules stream canopy requirements for waterbodies with threatened or endangered salmonids differ for class I and class II streams. For class I streams, defined as streams with fish always or seasonally present or streams that provide water for domestic use, foresters are required to retain at least 85 percent stream canopy within 75 feet of the stream, with 65 percent retained in the next 75 feet. Additionally, 25 percent of the existing conifer overstory must be composed of conifer species and the 10 largest diameter conifers along any 330 foot stretch of stream must be left. For class II streams, defined as streams providing aquatic habitat for nonfish aquatic species, foresters are required to retain 50 percent of the total canopy, with retention of 25 percent of the existing overstory conifer (Ch. 14 CA Code of Regulations, Section 916, available online at: http://cdf.ca.gov/ResourceManagement/pdf/FPR200201.pdf).

The California Forest Practice Rules allow for reduction of stream canopy, as much as 50 percent in some cases. Although stream canopy and effective shade are different measures of riparian characteristics, effective shade is dependent on stream canopy, thus large reductions of stream canopy result in large reductions in effective shade in most cases. The Basin Plan's water quality objective for temperature states that temperatures of intrastate waters shall not be altered unless it can be shown that such an alteration does not impact beneficial uses. Our analysis in the Mattole River watershed has determined that reductions of stream shade cause increases in stream temperature. Therefore, the California Forest Practice Rules do not ensure that water quality objectives set in the Basin Plan will be met.

4.1.3.3. Impacts of Sediment on Stream Temperature

While participating in the 2001 Mattole summer steelhead surveys on August 7, 8, and 9, Regional Board staff observed stream conditions of approximately 10.2 miles of the 60.4 miles of Mattole mainstem habitat (river miles 0-1.3, 14.9-19.9, and 47.4 to 51.3). Thermal refugia were mapped and described as part of the surveys. Observations suggested that the quantity of thermal refugia is impacted by sediment conditions. In particular, many of the thermally stratified pools observed in the river mile 14.9-19.9 reach of the Mattole had large volumes of silt, sand, and fine gravel covering the bottoms of the pools. Although the depth of these fine sediments could not be determined, it is reasonable that a lower sediment load would result in greater pool depths and larger pool volumes, which would increase the size of thermal refugia.

Other observations included intra-gravel flow seeps in areas of higher streambed complexity (e.g. back-watered side channels, prominent riffle-pool morphology, etc.). These observations are consistent with thermal infrared images showing pockets of water cooler than water in the main channel created by the same types of features (Figures 4.10-4.13).

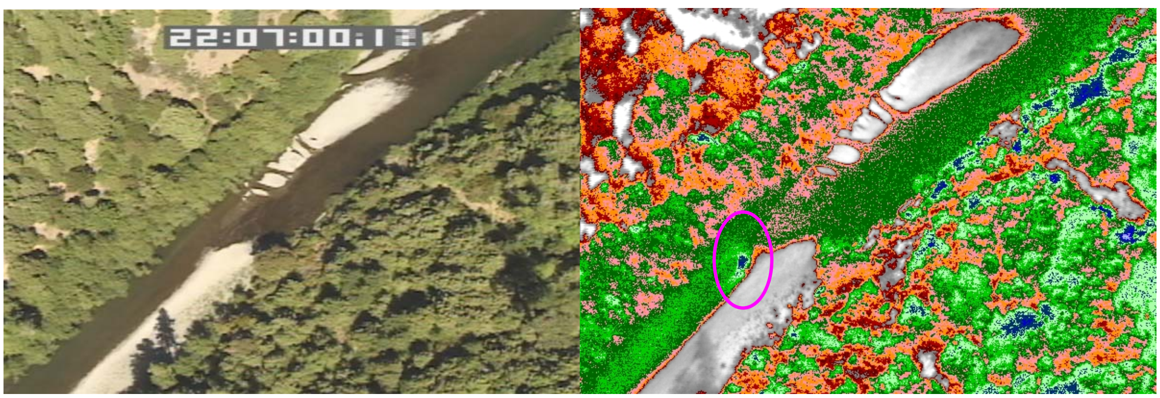

Figure 4.10: Cold water seep created by intra-gravel flow at bottom of riffle at river mile 35.5, Mattole River

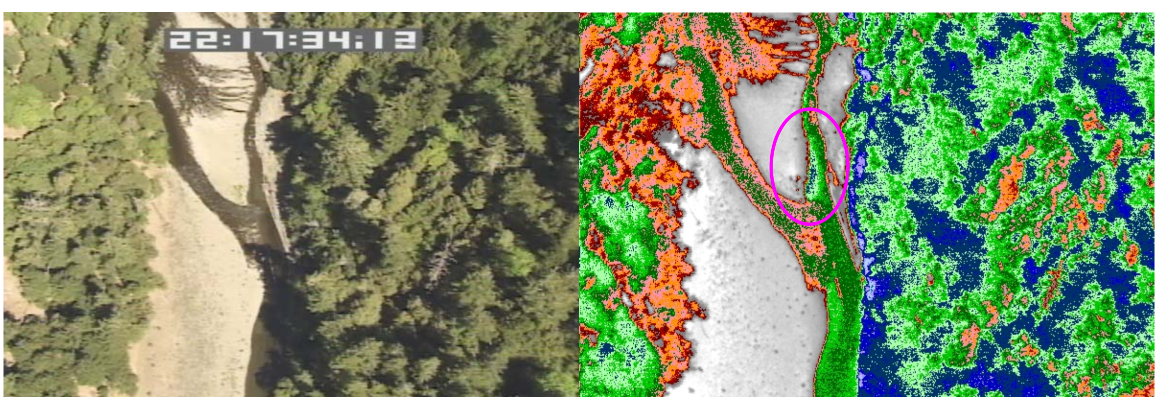

Figure 4.11: Cold water seep created by intra-gravel flow at bottom of riffle at river mile 43, Mattole River

Thermal imagery temperature scale bar (^{0}C):

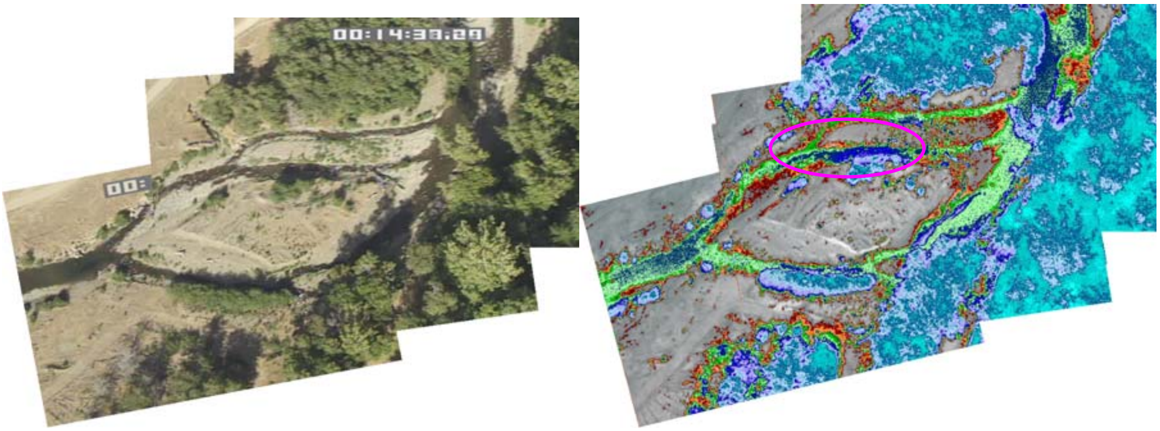

Figure 4.12: Cold water seeps created by intra-gravel flow at bottom of riffle 0.2 miles up the East Branch Lower North Fork Mattole River

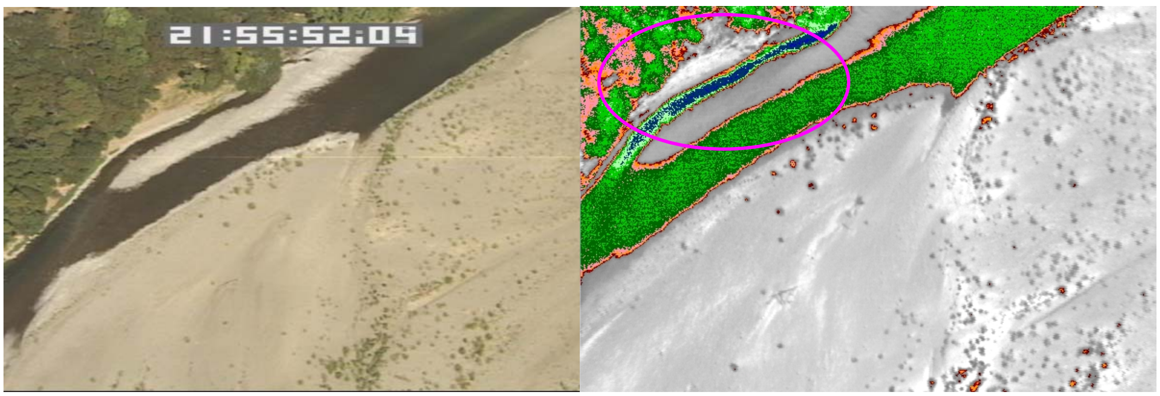

Figure 4.13 Cold water pocket in backwatered side channel at river mile 27.7, Mattole River

Thermal imagery temperature scale bar (^{0}C):

Although the observations of stream temperatures related to sediment conditions are not quantitative or definitive, they are consistent with trends documented in published literature. Several papers describe effects of sediment on stream channel morphology and stream channel characteristics related to thermal refugia and intra-gravel flow. In a study of stream channel geometry at twelve gauging stations throughout northwest California, Lisle (1982) described bars becoming smaller, pools filling, and riffle gradients becoming more gentle in response to increases in sediment supply. Vaux (1968) demonstrated that exchange of intra-gravel flow with surface waters is dependent on longitudinal profiles and gradients of the stream surface. Wondzell and Swanson (1999) similarly demonstrated that simplification of stream channel geometry decreases intra-gravel exchange rates and suggested that loss of pool-step sequences related to channel disturbances could result in decreased exchange.

Additional evidence of sediment-stream temperature interactions was observed in aerial photos. Large decreases in stream canopy in reaches of streams downstream of large sediment inputs were found throughout the watershed. The Honeydew Creek aerial photos presented in Section 2.5.1 (Figures 2.1 and 2.2) illustrate the substantial stream widening and loss of riparian vegetation coinciding with large sediment inputs. In the 1965 image stream widening and riparian loss is most pronounced in the depositional areas.

4.1.3.4 Conclusions
The sensitivity analysis results indicate that air temperature, total shade, and relative humidity are the three most important parameters influencing stream temperatures in tributary reaches of the Mattole River. In the mainstem reaches of the Mattole River, air temperature is the most important factor influencing the overall stream temperature distribution, while flow conditions, relative humidity, and the temperature entering a reach are also important.

Observations of 10 miles of mainstem Mattole reaches indicate that thermal refugia are important habitat features for salmonids. Observations in the same 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.

Shade is of greatest concern for this TMDL because management affects it and changes in shade can alter stream temperatures from natural levels. Shade can be directly related to solar radiation inputs that affect stream temperatures. Stream temperatures also are sensitive to air temperature, and in some circumstances relative humidity and wind speed, which in turn are subject to change as a result of management of streamside vegetation.

The results of the stream temperature modeling analysis show that changes in channel geometry and riparian conditions can increase or decrease stream temperatures. Specifically, increase in solar radiation inputs to streams results in elevated stream temperatures. Changes in microclimate associated with removal of riparian vegetation can also lead to increased stream temperatures. However, the degree of microclimate alteration due to reduction of riparian vegetation is not readily predictable, although the phenomenon has been well documented. Changes in channel morphology, such as increased stream width and decreased topographic complexity of the channel, can also lead to increased stream temperatures.

The stream temperature modeling analysis demonstrates that changes in solar radiation inputs alone can lead to significant changes in stream temperatures, especially in small streams. Furthermore, the modeling analysis demonstrates that an increase in stream shade from current conditions to those that could be expected for mature vegetation conditions will lead to significant improvements in stream temperature. Where prior management has decreased stream shade, water quality standards are not being met (see Section 2.1.3).

The results of the shade modeling analysis indicate that significant improvements in stream shade are possible. Currently, 434 stream miles of the 1652 stream miles in the Mattole river watershed are in the 75-85 percent stream shade class. If riparian vegetation were allowed to achieve mature conditions, 816 stream miles would be expected to be in the 75-85 percent stream shade class (Table 4.6), an improvement of 88 percent.

In summary, this analysis demonstrates that stream shade is a major factor affecting stream temperatures. Other effects of management activities, such as changes in stream geometry and microclimate, can also impact stream temperatures. Stream temperatures in many places in the Mattole River watershed are elevated above natural background stream temperatures. Achievement of TMDL targets is expected to significantly increase the length of streams in temperatures suitable for salmonids during the summer juvenile rearing period.

From a management standpoint, the analysis leads to four conclusions:

1. Where removal of riparian vegetation, or vegetation that provides shade to a stream, has caused stream temperatures to be elevated from natural receiving water temperatures, the Basin Plan's water quality objective for temperature is not being achieved.
2. The protections set forth in the California Forest Practice Rules do not ensure compliance with water quality objectives contained in the Basin Plan.
3. The recovery of riparian vegetation from past disturbances is expected to be the most important factor in lowering stream temperatures toward natural levels where they would meet Basin Plan objectives.
4. Increased sediment delivery resulting from upslope disturbances can increase stream temperatures. Where this situation is occurring, the Basin Plan objective for temperature is not being met.

4.2 Temperature TMDL and Allocations

This section presents the temperature TMDL and load allocations. The starting point for the analysis is the equation that describes the Total Maximum Daily Load:

$$\text{TMDL} = \Sigma\text{WLAs} + \Sigma\text{LAs} + \text{Natural Background}$$

where Σ = the sum, WLAs = waste load allocations, and LAs = load allocations. Waste load allocations are contributions of a pollutant from point sources while load allocations are contributions from management-related non-point sources.

In this analysis, natural effective shade is estimated by first calculating potential effective shade based on fully mature trees growing along the bankfull channel of the streams. This potential shade is then reduced by 10 percent to account for natural effects such as fire, windthrow, and earth movements that would reduce the actual riparian area vegetation below the site potential. If reducing the potential shade by 10 percent resulted in less shade than the estimated current shade values, the natural effective shade was set equal to the estimated current shade condition. This modified condition is taken to represent natural vegetation, and is referred to in this document as adjusted potential vegetation. The target water temperatures are those that result from achieving the adjusted potential vegetation conditions in the watershed.

Figure 4.14 shows the results for adjusted potential shade and current shade aggregated into cumulative frequency curves for the entire set of stream reaches included in the analysis. These curves are analogous to curves such as grain size distribution curves that show the percent of the grain size sample that is finer than a given grain diameter. In this case, the curves show the percent of the stream length in the watershed that is shadier than a given shade value. Table 4.6 presents in tabular form the same information as Figure 4.14. Table 4.6 constitutes the TMDL for temperature for the watershed.

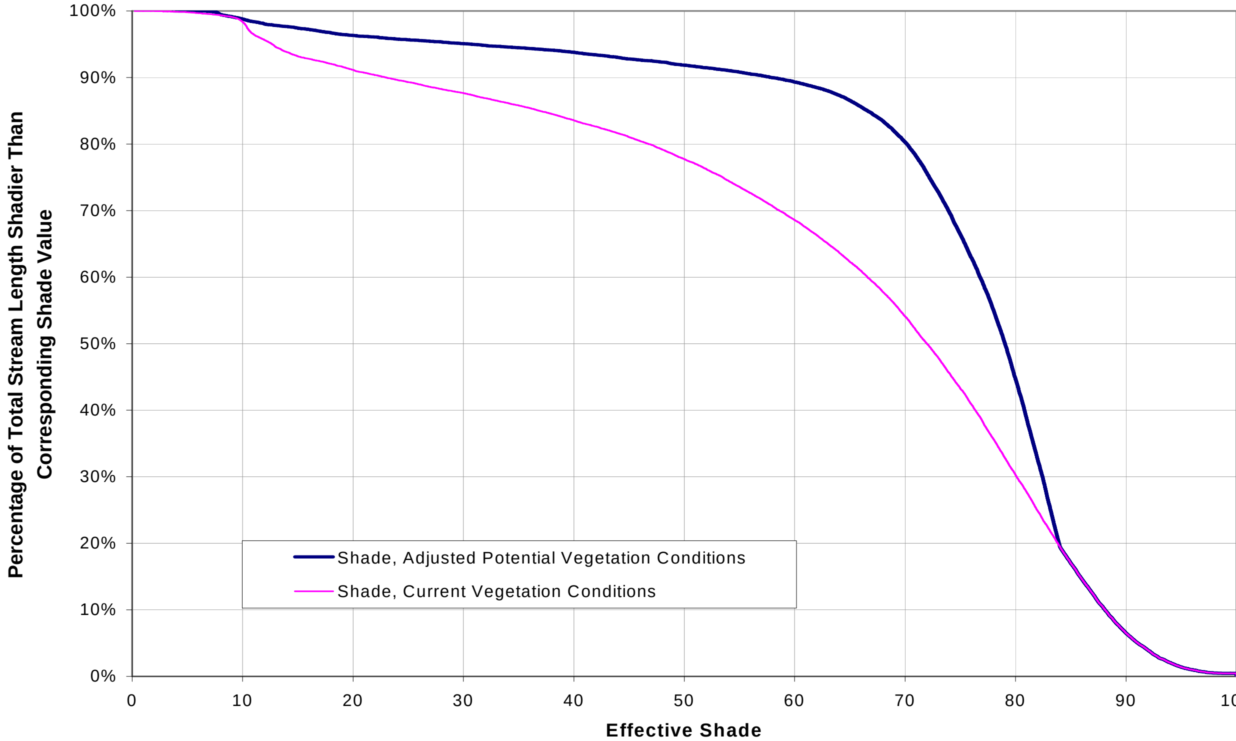

Figure 4.14 Shade Exceedance Curves for Current and Adjusted Potential Vegetation Conditions

Table 4.6 Summary of Stream Lengths in Shade Classes for Current and Potential Vegetation Conditions

Shade Class	**Stream Length - Current Vegetation Conditions**						**Stream Length - Potential Vegetation Conditions**					
(%)	By Class			Cumulative			By Class			Cumulative		
	(miles)	(km)	% of Total	(miles)	(km)	% Shadier	(miles)	(km)	% of Total	(miles)	(km)	% Shadier
0	3.1	5.0	0.2%	0.0	0.0	100.0%	0.1	0.2	0.0%	0.0	0.0	100.0%
10	109.5	176.2	6.6%	27.3	43.9	98.3%	42.4	68.2	2.6%	20.1	32.4	98.8%
20	64.1	103.2	3.9%	146.4	235.6	91.1%	28.9	46.5	1.7%	60.8	97.8	96.3%
30	57.9	93.2	3.5%	204.1	328.4	87.6%	19.8	31.9	1.2%	81.1	130.5	95.1%
40	78.4	126.2	4.7%	271.5	437.0	83.6%	27.8	44.8	1.7%	102.5	164.9	93.8%
50	123.5	198.8	7.5%	367.7	591.7	77.7%	32.7	52.7	2.0%	134.4	216.3	91.9%
60	186.2	299.6	11.3%	519.2	835.6	68.6%	70.3	113.2	4.3%	176.4	283.9	89.3%
70	314.5	506.1	19.0%	758.3	1220.3	54.1%	332.7	535.4	20.1%	325.5	523.8	80.3%
80	433.5	697.7	26.2%	1151.9	1853.8	30.3%	815.9	1313.1	49.4%	913.9	1470.7	44.7%
90	257.9	415.0	15.6%	1544.2	2485.2	6.5%	257.9	415.0	15.6%	1544.2	2485.2	6.5%
100	23.2	37.3	1.4%	1651.8	2658.3	0.0%	23.2	37.3	1.4%	1651.8	2658.3	0.0%
Total	1651.8	2658.3					1651.8	2658.3				

Note: For "By Class", shade class is given value +/- 5%. For "Cumulative", length with shade less than given value is represented.

4.2.1 Development of Pollutant Load Capacity and Surrogate Measures

Loading capacity is an estimate of the assimilative capacity of a water body for the pollutant of concern. For the Mattole temperature TMDL analysis, loading capacity refers to the adjusted potential effective shade conditions and associated solar loading that result in no alteration of natural stream temperatures. The TMDL equation becomes:

TMDL = Loading Capacity = Adjusted Potential Effective Shade

The loading capacity estimate uses a GIS model developed as part of the Mattole River temperature TMDL analysis (and described in Section 4.1.3) to describe potential shade conditions that reflect fully mature natural vegetation throughout the watershed. The GIS model also was used to estimate current effective shade conditions. The difference between current and adjusted potential effective shade is the amount of effective shade increase and reduced solar loading that is required to restore beneficial uses.

Under the TMDL framework, and in this document, identification of the ‘loading capacity’ is a required step. The loading capacity represents the total loading of a pollutant that a water body can assimilate and still meet water quality objectives so as to protect beneficial uses. The loading capacity provides a reference for calculating the amount of pollutant reduction needed to bring a water body into compliance with standards. For this temperature TSD, the loading capacity is expressed as effective shade on the mean date of the MWAT for the watershed. Effective shade is an inverse surrogate for solar radiant energy load. The percentage of effective shade represents a percentage reduction of the possible radiant energy load reaching the streams of the watershed during critical temperature periods, as represented by the suntrack of July 23.

To use the loading capacity and to be able to compare it to current conditions, a surrogate measure of loading capacity is proposed. EPA regulations (40 CFR §130.2(i)) allow for the use of other appropriate measures (surrogate measures) to allocate loads for conditions "when the impairment is tied to a pollutant for which a numeric criterion is not possible…" (EPA 1998c). There are no numeric criteria for radiant heat loads. However, it is possible to relate heat load to effective shade (that shade resulting from topography and vegetation that reduces the heat load reaching a stream) and to relate effective shade to temperature conditions. Effective shade can be readily measured in the field and also can be calculated using mathematical equations.

4.2.2 Load Allocations

In accordance with EPA regulations, the TMDL (i.e., loading capacity) for a water body is to be allocated among the various sources of the targeted pollutant, with a margin of safety. The sum of the load allocations for individual locations in the watershed is equivalent to the loading capacity for the watershed as a whole. Allocations for point sources are known as wasteload allocations. Those for non-point sources are known as load allocations. There are no known point sources of heat into the Mattole River and its tributaries, thus the wasteload allocation for point sources is set at zero. The TMDL for temperature for the Mattole River and its tributaries is distributed among the non-point sources of heat in the watershed, with a margin of safety. In this case, with the non-point sources being sunlight at the various streamside locations in the watershed, and with effective shade being used as a surrogate for solar energy, the establishment of load allocations equates to the identification of the effective shade requirement for any specific streamside location. Site-specific adjusted potential shade is set as the legally required load allocation for the Mattole temperature TMDL. The load allocations for this TMDL are the shade provided by topography and natural mature vegetation conditions that occur at a site, approximated as adjusted potential shade conditions as described in Section 4.1.3. The distribution of adjusted potential shade values presented in Figure 4.4 is the TMDL load allocation.

4.3 Temperature and Temperature-Related Indicators and Numeric Targets

4.3.1. Temperature

Unlike sediment conditions, stream temperature is a directly measurable water quality parameter and requires no indicator for interpretation of the water quality standard related to temperature.

4.3.2. 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 Section 4.1.3. The distribution of adjusted potential shade values is presented in Figure 4.4. A second approach to identifying the potential shade conditions at a site is detailed below.

To determine potential shade conditions provided by riparian vegetation for a particular stream reach in the watershed requires correlation of vegetation type, stream aspect, and active (unvegetated) channel width with effective shade. These relationships are functions of vegetation type, channel geometry, topography, and solar position.

Two models used to predict shade given channel characteristics as input were tested for use in estimating potential shade on a reach-by-reach basis. ODEQ (2000) has developed an Excel-based spreadsheet that allows calculation of effective shade as a function of vegetation height, stream aspect, active channel width, stream buffer width and buffer density. The spreadsheet is based on equations presented by Boyd (1996) and expanded for TMDL applications. USGS (Bartholow, 1999) also has a shade model. The two models were tested using observations of channel characteristics at sites where Solar Pathfinder measurements were taken. Results are presented in Figure 4.15. The ODEQ spreadsheet, named

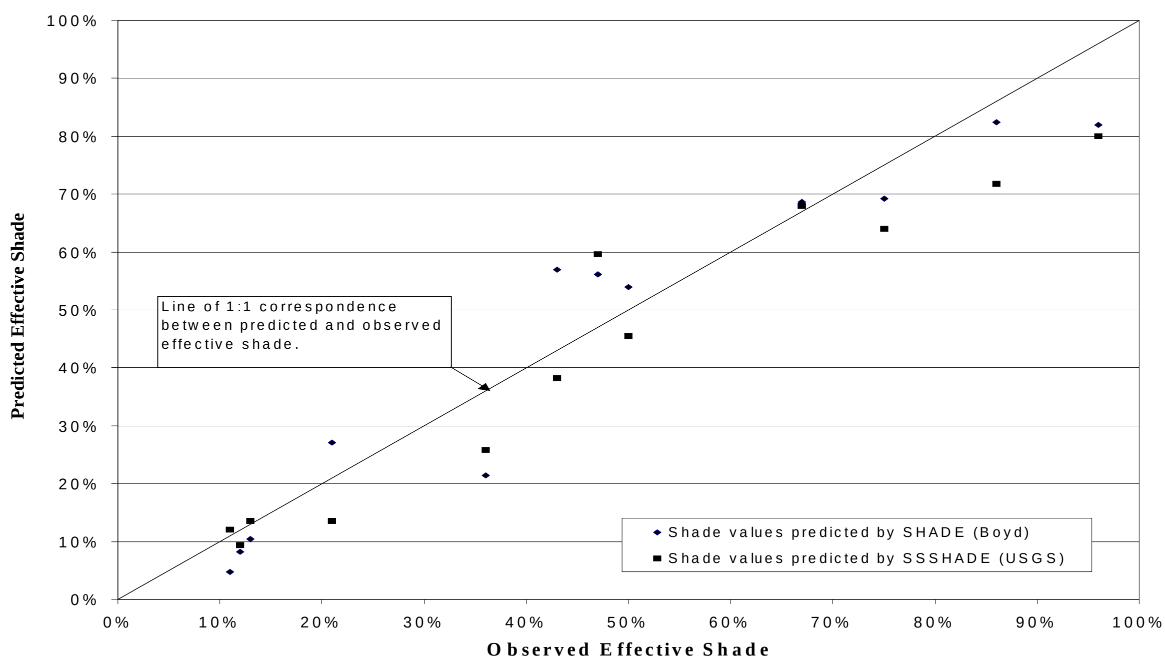

Figure 4.15: Predicted Effective Shade vs. Observed Effective Shade, July sun track

SHADE, was selected for use in developing target shade curves for different vegetation types occurring along riparian corridors of the Mattole River and its tributary streams because it is better adapted for TMDL applications and has been approved as part of a temperature TMDL (ODEQ 2000).

Effective shade targets for the vegetation classes occurring in the watershed were set at 90% of the potential vegetation height for the class (Table 4.1). Effective shade curves are presented for redwood (RDW) forest (buffer height of 63m), Douglas Fir (DFR) and Mixed Hardwood-Conifer (MHC) forest (40m), Klamath Mixed Conifer (KMC) and Ponderosa Pine (PPN) forest (35m), and Oak Woodland (20m) (Figures 4.16, 4.17, 4.18 and 4.19) as an indicator of riparian conditions relative to a potential condition. Buffer widths are assumed to be 30m.

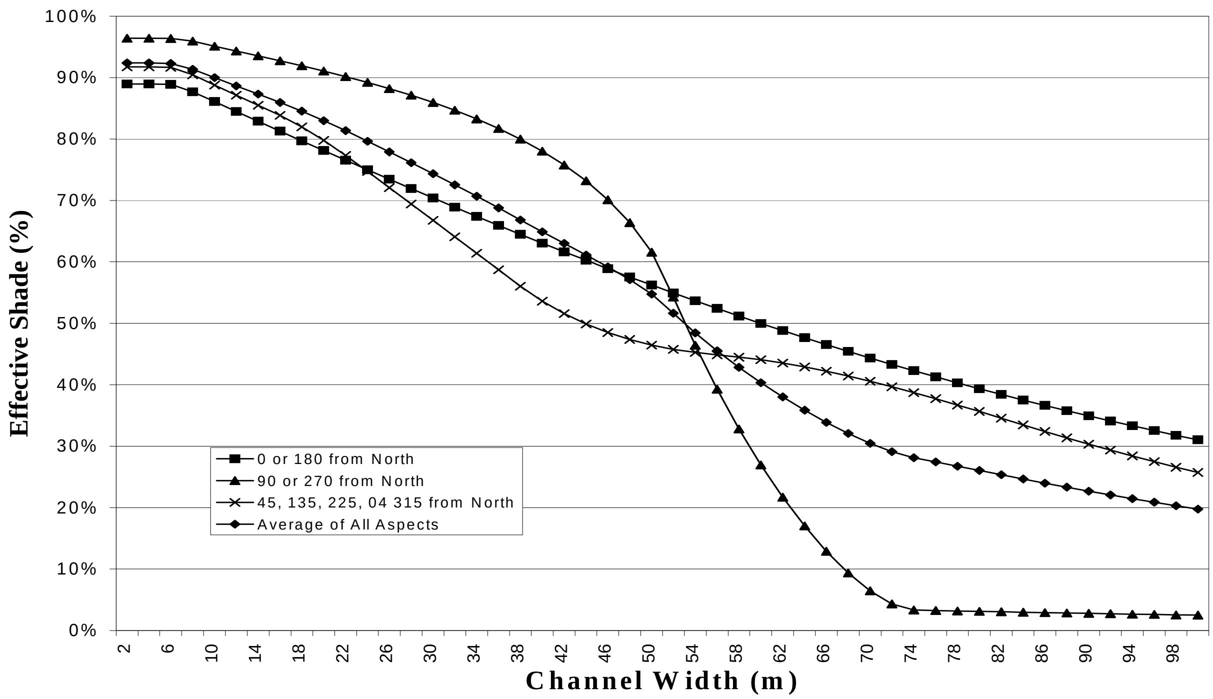

Figure 4.16: Effective Shade vs. Channel Width, Redwood Forest (RDW), Buffer Height = 63m

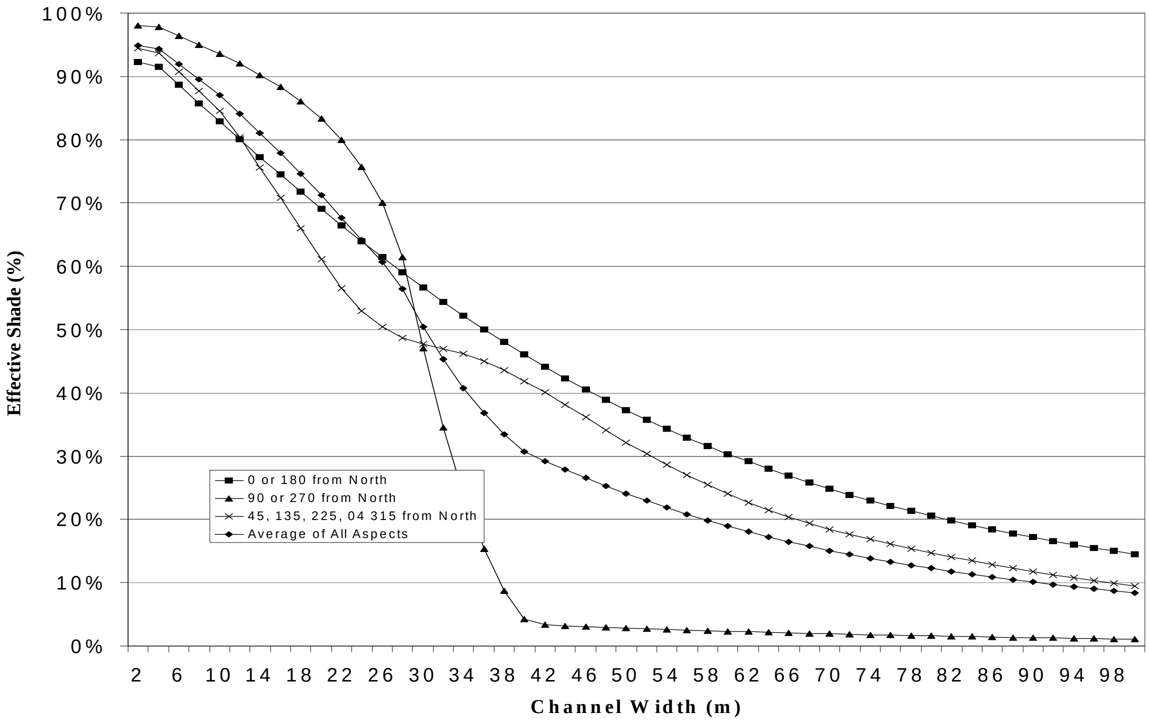

Figure 4.17 Effective Shade vs. Channel Width, Douglas Fir Forest (DFF) and Mixed Hardwood – Conifer Forest, Buffer Height = 40m

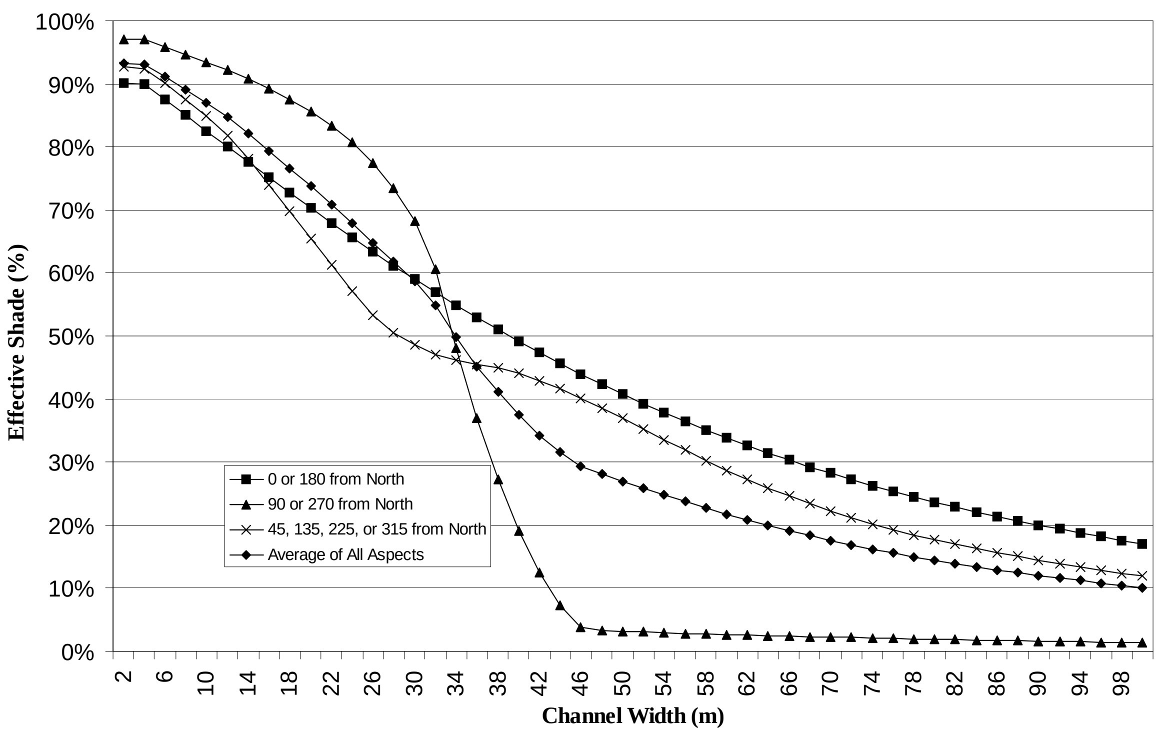

Figure 4.18 Effective shade vs. channel width, Klamath Mixed Conifer Forest (KMC) and Ponderosa Pine Forest (PPN), buffer height =35m

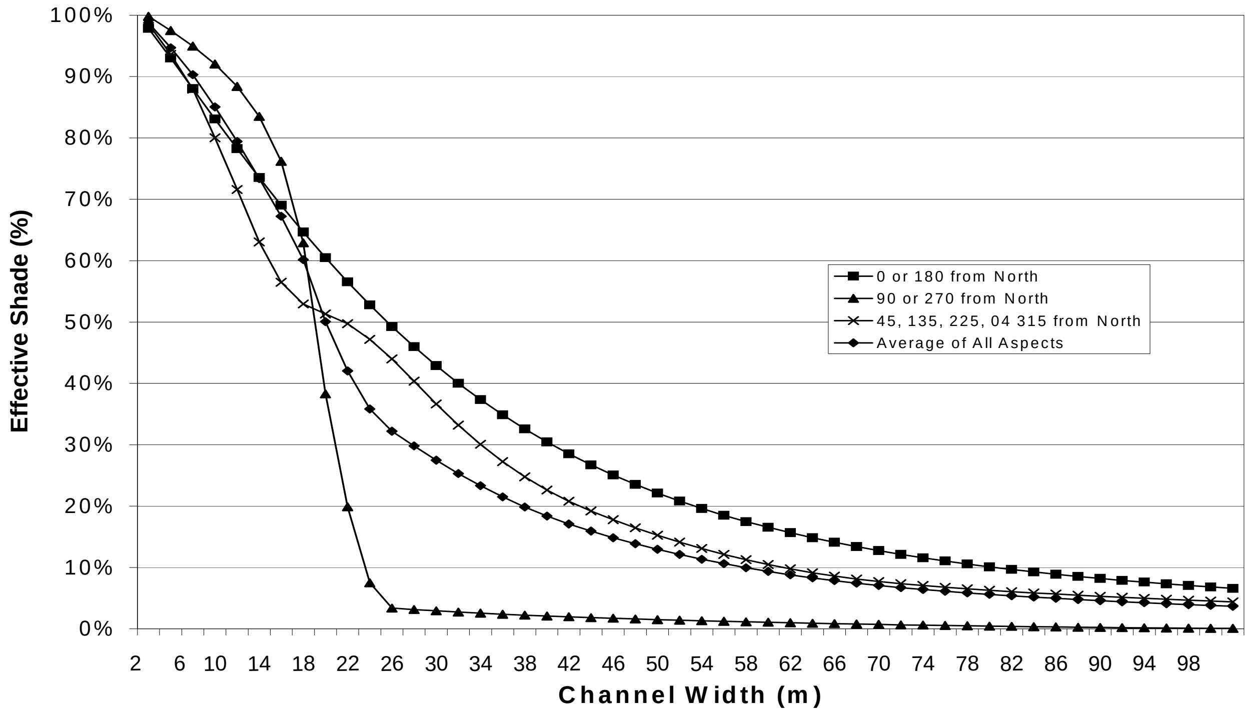

Figure 4.19: Effective shade vs. channel width, Oak woodland, buffer height =20m

4.3.3 Thermally Stratified Pools

Target: Increased volume of thermally stratified pools

The target condition is an increased volume of thermally stratified pools. Regional Board staff observed that in the summer of 2001 pools became thermally stratified at an approximate depth of six feet. The depth and degree of stratification is partly a function of stream flow and is expected to vary depending on site conditions. 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.

4.4 Margins of Safety & Seasonal Variation

The Clean Water Act Section 303(d) and the associated regulations at 40 CFR §130.7 require that TMDLs include a margin of safety that takes into account any lack of knowledge concerning the relationship between the pollutant loads and the desired receiving water quality. The margin of safety is often implicitly incorporated into conservative assumptions used in calculating loading capacities, waste load allocations, and load allocations (EPA 1991). The margin of safety may also be incorporated explicitly as a separate component in the TMDL equation. For this TSD analysis, conservative assumptions were made that account for uncertainties in the analysis.

- This report analyzes temperature and sediment separately. Some improvements in stream temperature that may result from reduced sedimentation are not calculated explicitly. Reduced sediment loads could be expected to lead to increased frequency and depth of pools and to reduced wetted channel width/depth ratios. These changes tend to result in lower stream temperatures overall and in more lower temperature pool habitat. These changes are not accounted for in the analysis and provide a margin of safety.

- While the potential shade conditions used to calculate the loading capacity assume that the occurrence of potential vegetation at a site extends to the bankfull channel width, the effective shade curves can be applied to either current channel widths or to projected bankfull widths. Application of the curves to current channel conditions does not account for channel narrowing that may occur as a result of reduced sediment loads. These effects constitute a margin of safety.

- The effects of changes to streamside riparian areas toward mature trees will tend to create microclimates that will lead to improvements in stream temperatures. These effects were not accounted for in the temperature analysis and provide a margin of safety.

- Changes in streamside vegetation toward larger, mature trees will increase the potential for contributions of large woody debris to the 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. These changes were not accounted for in the analysis and provide a margin of safety.

With respect to seasonal variations in stream temperatures, the analysis takes the most extreme heating conditions as measured by the 7-day running average of temperatures as constituting a limiting condition for salmonid survival with respect to temperature.

CHAPTER 5. IMPLEMENTATION AND MONITORING RECOMMENDATIONS

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

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

Furthermore, the State implementation and monitoring plans are expected be designed to determine if, in fact, the TMDL is successful in attaining water quality standards. In support of this effort, this document contains water quality indicators (see Chapter 3) as well as load allocations. Both the indicators and load allocations interpret water quality standards, but they were developed using independent approaches, because the relationships between land management practices and the effects on water quality as related to sediment and temperature are highly complex.

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

It is clear from the available data that reducing sediment from roads, 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.

The data base of information describing the watershed in terms of sediment delivery, instream coniditons, and temperature could also be increased through additional monitoring. The Regional Water Board 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 is providing public notice of the draft Mattole River sediment and temperature TMDLs by placing a notice in the Eureka Times-Standard and Humboldt Beacon newspapers. EPA will prepare a written summary of responses to all written comments on the draft TMDL and draft Technical Support Document received through the close of the comment period, date TBD.

EPA and the Regional Board maintain a mailing list of interested persons to provide notification of issues relating to the Mattole River TMDLs. The Regional Board has sent out a newsletter to all mailboxholders in the watershed. EPA and the Regional Board have responded to comments and concerns received during the development process. EPA also will provide notification of its meetings and activities to local radio stations and newspapers.

Regional Board staff were guests on a public affairs news program broadcast by KMUD in Redway, CA, on July 16, 2001, to discuss the TMDL process in general and as the process applies to the Mattole watershed.

Regional Board staff held two informational meetings on the development of the Mattole River TMDLs at the Mattole Grange, on May 8, 2002, and at the Whitethorn Grange, on May 9, 2002.

Meetings to discuss the Public Review Draft TMDL and TSD will be held in October, in Petrolia and in Whitethorn or another upper watershed location. Comments at the meeting as well as formal written comments received through the end of the public comment period will be considered during preparation of final TMDL and TSD documents.

Glossary

Active channel	The area of the stream channel that is seasonally inundated, and often scoured free of perennial vegetation.
Aggradation	Elevation of the stream bed resulting from deposition of sediment.
Anadromous	Refers to aquatic species that migrate up rivers from the sea to breed in fresh water, undergoing a physiological change to allow them to adjust from freshwater to saltwater to freshwater conditions.
Bankfull	The discharge at which channel maintenance is most effective over time, generally with a frequency interval of once every 1.5-2.3 years. Also, the channel form that accommodates the bankfull flow.
Bankfull channel	The stream channel that contains the bankfull flow.
Basin Plan	Water Quality Control Plan for the North Coast Region (Region 1).
Beneficial Use	Use of waters of the state designated in the Basin Plan as being beneficial. Beneficial uses that may be protected against quality degradation include, but are not limited to: domestic, municipal, agricultural, and industrial supply; power generation; recreation; aesthetic enjoyment; navigation; and the preservation and enhancement of fish, wildlife and other aquatic resources or preserves.
Cable Yarding	Yarding of cut timber accomplished by dragging or suspending cut timber up a hillslope from the cut area to a ridgetop landing.
CDF	California Department of Forestry and Fire Protection.
CDFG	California Department of Fish and Game.
CDWR	California Department of Water Resources.
cfs	Cubic feet per second: a measure of water flow.
Decommission	Closing and obliterating a road and restoring the land to its natural contours and drainage patterns.
Degradation	Lowering of the channel bed resulting from scour during flood flows. Also, lowering or degrading of quality.

Diversion potential
The potential for a road to divert water from its intended drainage.

Drainage structure
A structure or facility constructed to control road runoff, including (but not limited to) a ford, inside ditch, water bar, outslope of the road, rolling dip, culvert, and ditch drain.

Electroshocking
A sampling technique for fish surveys that uses electrical current to stun fish in the water, allowing them to be measured and released.

Embeddedness The degree that larger streambed sediment particles (boulders, rubble, or gravel) are surrounded or covered by fine sediment. Embeddedness is usually estimated visually in classes (<25%, 25-50%, 50-75%, and >75%) according to percentage of random large particles that are covered by finer sediment.

EPA United States Environmental Protection Agency.

Erosion The group of processes whereby sediment (earth rock material) is loosened, dissolved, or removed from the landscape surface. It includes weathering, dissolution, and transportation.

ESU Evolutionarily Significant Unit, used by NMFS to identify a distinctive group of Pacific salmon or steelhead for purposes of the federal Endangered Species Act.

Flooding Overflowing of water onto land that is dry most of the time.

FPR Forest Practice Rules, defined by the Z'berg Nejedly Forest Practice Act of 1973, as amended.

FWS United States Fish and Wildlife Service

Fry A young juvenile salmon after it has absorbed its egg sac and emerged from the redd. Word is singular or plural.

GIS Geographic Information System.

Headwall swale
Topographic depression in the headwaters area of a watercourse or head of a landslide area; often a potentially unstable area where moisture tends to collect.

Hydrologically closed road

Generally refers to a road that is closed to further use and has natural flow conditions restored (e.g., stream crossing fill removed), although the road itself may not be revegetated or obliterated.

Hydrologically connected road
Road with drainage that is collected and directed toward a watercourse.

Hydrologically maintenance-free road
A road constructed so that drainage of the road is self-maintaining..

ICE — Information Center for the Environment at UC Davis.

Inner gorge — A geomorphic feature; generally a steep-walled inner part of a valley immediately adjacent to the stream, having a slope generally over 65%, and lying below less steep upper valley sides.

Inside ditch — Ditch on the side of the road toward the hill slope, 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 combination of surfaces -- or the resultant landform.

Large woody debris
Woody material generally having a diameter greater than 30 cm (12 inches) and a length greater than 2 m (6 feet) located in watercourse or in a position where it may enter a watercourse.

Low-Flow Channel
The part of a stream that is occupied by water during the periods of lowest flow, generally in late summer or early fall.

Mass wasting — Downslope movement of soil mass under force of gravity, often used synonymously with "landslide." Common types if mass movement include rockfall, soil creep, slump, earthflow, debris avalanche, and debris slide.

MRC — Mattole Restoration Council

MSG — Mattole Salmon Group

NCRWQCB — North Coast Regional Water Quality Control Board, aka Regional Board, Regional Water Board, California Regional Water Quality Control Board, North Coast Region.

NMFS — National Marine Fisheries Service.

NTU — Nephelometric Turbidity Units, a standard measure of turbidity.

Pool Tail-out The downstream end of a pool, where the main current narrows, forming a "tail." aka riffle head.

Primary Pool A pool that is at least as long as the low-flow channel width, and occupies at least half the width of the low-flow channel and, for 1st and 2nd order streams, is at least 2 ft or more in depth; and for 3rd order and higher streams, is at least 3 ft or more in depth. (Flosi et al. 1998).

PW Planning Watershed.

Reach Limited stretch of a stream considered for a specific purpose.

Redd A gravel nest or depression in the stream substrate, created by a female salmonid, in which eggs are laid, fertilized, and covered with gravel for a period of incubation.

Refugia Habitat areas that allow refuge from poor habitat conditions.

Regional Water Board
California Regional Water Quality Control Board, North Coast Region.

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 (aka pool tail-out).

Sediment Fragmented material that originates from weathering of rocks and decomposed organic material that is transported by water, as bedload, suspended load, or dissolved load, and eventually deposited.

Sediment delivery
Sediment delivered to a watercourse..

Sediment source
The physical location on the landscape where earth material has or may have the ability to discharge into a watercourse.

Sediment yield The quantity of sediment, expressed by weight or volume, produced from a unit area in a unit time.

Sidecast Fill from road construction or grading that is deposited to a hillside below a road.

Skid trail Constructed trails or established paths used by tractors or other vehicles for skidding logs. Also known as tractor roads.

Smolt A young salmon at the stage intermediate between the parr and the grilse, when it becomes covered with silvery scales and first migrates from fresh water to the sea.

Smoltification	Suite of physiological, morphological, biochemical and behavioural changes, including development of the silvery color of adults and a tolerance for seawater, that take place in salmonid parr as they migrate downstream and enter the sea
Stream	See watercourse.
Stream order	The designation (1,2,3, etc.) of the relative position of stream segments in the drainage basin network. For example, a first order stream is the smallest, unbranched, perennial tributary which terminates at the upper point. A second order stream is formed when two first order streams join. A third order stream is designated when two 2^{nd}- order streams join.
SW	Sub-watershed
Tail-out	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	Elevation profile surveyed along the length of the stream and centered on the water surface over the deepest part of the stream.
THP	Timber Harvest Plan
TMDL	Total Maximum Daily Load, as defined under section 303(d) of the Clean Water Act, and regulations at 40 CFR Section 130.
Tractor Yarding	Yarding of cut timber using a tractor.
TSD	Technical Support Document.
Turbidity	A measure of the amount of light that can pass through water. High turbidity (low light transmissivity) can be caused by suspended fine sediments or organic material.
Unstable area	Location on the landscape that has a higher than average potential to erode or otherwise fail and discharge sediment to a watercourse. Includes slide areas, gullies, eroding stream banks, and unstable soils. Slide areas include landslides of all sizes and depths, debris flows, debris slides, earthflows, inner gorges, and hummocky ground. Unstable soils include unconsolidated, non-cohesive soils and colluvial debris.
V*	A numerical value that represents the proportion of fine sediment that occupies the scoured residual volume of a pool, as described by Lisle and Hilton (1992). Pronounced "Vee-star."

Watercourse — Any well-defined channel having a distinguishable bed and bank and showing evidence of having contained flowing water as indicated by deposit of rock, sand, gravel, or soil.

Waters of the state
All ground and surface waters, including saline waters, 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 body.

Water Quality Indicator
Factor or condition that determines or expresses the quality of water in terms of the instream or watershed environment. For each pollutant or stressor addressed in the problem statement, an indicator and target value of that indicator is developed.

Water quality objective
A State Basin Plan term equivalent to the Clean Water Act's water quality criteria. Water quality criteria are limits or levels of water quality constituents or characteristics established for the reasonable protection of beneficial uses of water or the prevention of nuisance within a specific area.

Water quality standard
A Clean Water Act term which includes the designated uses of a water, the water quality criteria established to protect the designated uses, and an anti-degradation policy.

Yarding — Collecting of cut timber at a landing area.

Yearling — Fish that hatched during the previous year (i.e., one-year-old).

Young-of-Year — Fish that hatched in the current season.

WY — Water Year. October 1 - September 30. E.g., WY1999 = October 1, 1998 through September 30, 1999.

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Appendix I.

Tectonic Uplift and Mass Wasting in the Mattole Watershed.

The Mattole watershed is unique on the West Coast in that it sits virtually atop a major junction of three tectonic plates, each of which is moving with relation to the other two. This junction of the North American Plate, the Gorda Plate, and the Pacific Plate is known as the Mendocino Triple Junction (MTJ). The Gorda Plate is subducting beneath the North American Plate, or conversely, the North American Plate is overriding the Gorda Plate. Whichever way you want to look at it, the convergence of the two plates is several centimeters per year and results in continued rapid uplift. These processes produce many strong earthquakes in the region.

Field evidence and history of the area show that the land in the Mattole basin is extremely prone to landsliding, rapid soil creep, and other types of mass movement (See the landslide map by the California Geological Survey in NCWAP, 2002). The underlying rock is highly fractured and sheared as discussed in the body of this report, and slopes are mostly very steep. This raises interesting questions. How is it that a region of weak rocks has very steep slopes? If erosion is rapid, why is the area not eroded much flatter? Part of the answers lie in the rapid uplift of the region during recent geologic time. Rapid uplift is offset by rapid erosion so that the uplift supplies a constantly regenerating source of sediment, which is the subject of this TSD.

Through the last two million years or longer, the Mattole River region has been uplifted very rapidly by geologic standards. McLaughlin and others (2000) summarized what is known of the age of river terraces and marine terraces in the Mattole area. They noted that isotopic ages of an uplifted marine terrace that extends from the area of Point Delgada, at Timber Cove, northward almost to the mouth of the Mattole River, show an uplift rate of 2-4 mm/year averaged over the past 45 thousand years (Lajoie and others, 1982). Merrits and Vincent (1989, Fig. 6 b) show the same range of uplift in that area, with about two thirds of that coastline uplifting at 2-3 mm/year and a small area uplifting 4mm/year. That coastline lies just to the west of the Mattole River watershed west of the King Range (See Figure 1.2 in the text of the TSD), and the uplift rate probably is similar to uplift rates in at least the western portion of the Mattole Basin.

To the east of the Mattole River watershed, the uplift rate around Garberville appears to be about 1 mm/year (Bickner, 1985; Merrits and Bull, 1989: Merrits and Vincent, 1989; and Merrits et al., 1994). The eastern part of the Mattole watershed is closer to Garberville, and may have an uplift rate lower than two mm/year. Based on these rates of uplift to the east and west, it is reasonable to assume an average uplift rate in the Mattole of about 2mm/ year over the past 45,000 years.

The uplift rate discussed here is an average over an extended time; it is not a steady process. In many cases uplift and subsidence happen very quickly in association with earthquakes. At the time of the 1992 Cape Mendocino earthquake and its aftershocks, areas along the coast west of the Mattole watershed were uplifted as much as 1.4 meters, and some areas inland subsided as much as 0.4 meters. The distribution of these level changes is shown in Figure A.1. Dealing with uplift over many thousands of years, we have to assume that many sudden changes over limited areas, such as happened in 1992, go into producing the average uplift of 2mm per year in the region.

Approximately 90 m of uplift occurred in 45,000 years, or about 300 feet. In 45,000 years, the Mattole River has removed from the basin a quantity of sediment equal in volume to the area of the watershed and 300 feet deep.

Two millimeters per year does not sound like much, so let's examine what this means to the river system in the long term. For the purpose of this experiment, we will make two simplifying assumptions:

a) The average rate of uplift in the Mattole for the past 45,000 years has been about two mm/year, as discussed above.

b) With this rapid uplift, erosion and mass wasting have balanced uplift so that the steepness of topography and the amount of relief have stayed about the same, that is, the mountains are just about as steep and high as the weak, fractured rock can hold up. The mountains are being eroded as fast as they are being uplifted.

With the mountains wearing away as fast as they are rising, how much sediment is generated? One inch is 25.4mm, so if the land uplifts 2mm each year, then it takes only about 13 years to uplift one inch (25.4mm per inch divided by 2mm per year = 13 years to uplift one inch). If the rate of uplift and the rate of erosion are balanced in the long term, then an average of one inch of soil and rock is removed from the whole Mattole basin, mountains and valleys alike, every 13 years. This comes to about eight inches of downwasting per century for the whole watershed.

The area of the Mattole basin is about 300 square miles, so each century a layer averaging eight inches thick and 300 square miles in area is removed by erosion. Each square mile is 640 acres, so the area of the watershed is 300 square miles x 640 acres per square mile = about 200,000 acres. Eight inches is two thirds of a foot, so now we are talking about two thirds of 200,000 or 130,000 acre-feet of sediment generated in the Mattole each century. Divide that figure by 100 years per century and we have 1,300 acre-feet of sediment per year on the average. Other ways to picture that quantity are a square bin 416 feet on a side (four acres in area) filled to a depth of 325 feet; or 2,100,000 cubic yards; or 210,000 dump truck loads per year; or 3,400,000 tons of sand and gravel and silt. The yield per acre would be about 10 cubic yards per year. One cubic yard of landslide material, assuming 80% soil and 20% gravel, weighs about 2.00 tons, so the landscape as a whole sheds about 20 tons per acre per year. . The 20 tons/acre/yr equates to 12, 800 tons/square mile/year. This quantity is very similar to the amount that Bull found in the Kaikoura Range in New Zealand, as discussed in the text of this TSD.

That estimate is built on broad assumptions, some of which are listed above. In addition, we all know that the sediment generated from one year to another varies greatly even in natural conditions as quantity is affected by draught years and by the occasional huge storm. But we are discussing here averages over the long term. All considered, we believe that the average real natural sediment generation is about what is calculated above.

This sediment that is generated has only one place to go. It is washed down the hillsides into the small streams, into bigger streams, into the Mattole River, down the river, and across the bar into the ocean. The high floods in the river are extremely important in this process of transporting sediment through the stream system and out to the ocean. In the natural regime, without management of the landscape, sediment contribution to the stream system tends to be episodic, linked to major storm events and earthquakes that produce slope failures. In this scheme, the streams can move a lot of the sediment through the system and out to the ocean, clearing out a lot of excess load and restoring better stream conditions and water quality between major storms and earthquakes. The country heals itself as the saying goes. On the other hand, when management is contributing a large and steady flow of additional sediment between the major natural events, and causing additional sediment contribution associated with these events, the stream system does not get a chance to clear out sediment and restore itself to the extent that it does without management.

Keep that picture in mind as you examine other parts of this report that discuss in more detail how this sediment is generated and transported and how human activities add more sediment to the stream system.