U.S. Environmental Protection Agency
Region IX

Navarro River
Total Maximum Daily Loads for Temperature and Sediment

Approved by:

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CHAPTER 1: INTRODUCTION

The Navarro River Total Maximum Daily Loads (TMDLs) for Temperature and Sediment are established by the U.S. Environmental Protection Agency (EPA) as required by Section 303(d) of the Clean Water Act. The primary purpose of the Navarro River TMDLs is to identify temperature and sediment loading allocations at levels which are necessary to implement water quality standards for temperature and sediment for the Navarro River and its tributaries. Increased sediment and summer temperatures are detrimental to native cold water fish, such as coho salmon and steelhead trout. Both species are listed as threatened under the federal Endangered Species Act.

These TMDLs are required under Section 303(d) of the Clean Water Act because the State of California has listed the Navarro as impaired due to both sediment and temperature in its list of impaired waters under Section 303(d). In accordance with a consent decree (*Pacific Coast Federation of Fishermen's Associations, et al. v. Marcus*, No. 95-4474 MHP, 11 March 1997), 31 December 2000 is the deadline for establishment of TMDLs for the Navarro River. Because the State of California will not complete adoption of TMDLs for the Navarro River by this deadline, EPA is establishing the Navarro River TMDLs, with assistance from staff from the North Coast Regional Water Quality Control Board (Regional Water Board).

The Navarro River TMDLs are based on the *Navarro River Watershed Technical Support Document for Sediment and Technical Support Document* (TSD) for Temperature (Regional Water Board, 2000a) and a technical addendum (Regional Water Board, 2000b) that was prepared in response to comments raised during the public comment period. The Regional Water Board staff compiled and analyzed existing data for the TSD and conducted original analysis. The TSD does not contain monitoring and implementation plans and has not been brought before the Regional Water Board for official action. EPA expects the Regional Water Board to adopt the TMDLs, once they have completed development of monitoring and implementation plans.

The Navarro River watershed is located in coastal southern Mendocino County, California, encompassing approximately 315 square miles (201,600 acres). The Navarro River flows through the coastal range, the Anderson Valley, and enters the Pacific Ocean about fifteen miles south of the town of Mendocino (Entrix 1998, as cited in Regional Water Board 2000a). The population of the watershed is about 3,500 people, with most living in and around the towns of Boonville, Philo, and Navarro (Entrix 1998, as cited in Regional Water Board 2000a). Three geologic formations comprise most of the Navarro River watershed: the Melange Unit of the Franciscan Assemblage, the Coastal Belt of the Franciscan Assemblage, and alluvial fill. Elevations in the basin range from sea level to about 3,000 feet. According to the State Water Resources Control Board, Division of Water Rights (Division of Water Rights), precipitation averages about 40.4 inches per year at Philo, with about 63 percent occurring between December 15 and March 31 (Division of Water Rights 1998, as cited in Regional Water Board 2000a).

Land-use in the watershed includes forestland (70%), rangeland (25%), and agriculture (5%) with a small percentage devoted to rural residential development (Entrix 1998, as cited in Regional Water Board 2000a). Timber harvesting began in earnest in the watershed during the mid-1800s following the gold rush. A second logging boom occurred from the later 1930s to the early 1950s, when large tracts of redwood-dominated forest in the mainstem Navarro River subwatershed were reharvested (Adams 1971, as cited in Regional Water Board 2000a). Douglas fir-dominated forest in the North Fork Navarro subwatershed was cut for the first time during this period (Adams 1971, as cited in Regional Water Board 2000a). Sheep and cattle have been grazed in the watershed since the 1870s. Today, commercial timber harvesting, viticulture, orchards, grazing, and tourism are the principal economic enterprises.

More information on the geology, vegetation, hydrology, land use, and other aspects of the Navarro River watershed can be found in the TSD (Regional Water Board 2000a).

EPA has initiated informal consultation with the U.S. 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 insure that an action authorized, funded, or carried out by such agency is not likely to jeopardize the continued existence of any endangered or threatened species.

EPA's consultation with the Services has not yet been completed. EPA believes that it is unlikely that the Services will conclude that the Total Maximum Daily Load (TMDL) that EPA is establishing violates Section 7(a)(2), since the load and wasteload allocations are calculated in order to meet water quality standards, and water quality standards are expressly designed to "protect the public health or welfare, enhance the quality of water and serve the purposes" of the Clean Water Act, which are to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters." Additionally, this action will improve existing conditions. However, EPA retains the discretion to revise this action if the consultation identifies deficiencies in the allocations requiring remedial action by EPA.

CHAPTER 2: PROBLEM STATEMENT

This chapter provides a description of the governing State water quality standards and their applicability to salmonids, sediment and temperature. The existing in-stream sediment and temperature problems in the Navarro are summarized, along with the literature on how these sediment and temperature increases affect salmonids. The sources of these problems are analyzed quantitatively in Chapters 3 - Temperature and 4 - Sediment.

2.1 Water Quality Standards

The water quality standards applicable to the Navarro River are contained in the *Water Quality Control Plan for the North Coast Region* (Basin Plan) as amended in 1996 (Regional Water Board 1996, as cited in Regional Water Board 2000a). The Basin Plan identifies beneficial uses for the Navarro River and the water quality objectives designed to protect those uses. The water quality objectives are intended to protect the most sensitive of the beneficial uses, in this case those associated with the Navarro River's salmonid fishery. The beneficial uses addressed in these TMDLs are: Commercial or Sport Fishing (COMM), Cold Freshwater Habitat (COLD), Estuarine Habitat (EST), Migration of Aquatic Organisms (MIGR), and Spawning, Reproduction, and/or Early Development (SPWN).

The Basin Plan (Regional Water Board 1996, as cited in Regional Water Board 2000a) identifies both numeric and narrative water quality objectives for the Navarro River. The objectives pertinent to the Navarro River TMDLs are narrative objectives, and they are listed in Table 2-1.

Table 2-1. Summary of Water Quality Objectives Addressed in the Navarro River TMDLs

Parameter	Water Quality Objective
Settleable Material	Waters shall not contain substances in concentrations that result in depositions of material that causes nuisance or adversely affect beneficial uses.
Sediment	The suspended sediment load and suspended sediment discharge rate of surface water shall not be altered in such a manner as to cause nuisance or adversely affect beneficial uses.
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 temperature of any COLD water be increased by more than 5EF above natural receiving water temperature.

In addition to water quality objectives, the Basin Plan (Regional Water Board 1996) includes two prohibitions specifically applicable to logging, construction, and other associated non-point 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 Coho and Steelhead

The beneficial uses identified above for the salmonid fishery are currently impaired. Freshwater habitat conditions in the Navarro River and its tributaries have degraded and are not adequate to support the beneficial uses. The degradation in freshwater habitat conditions has contributed to a dramatic decline in the populations of coho and steelhead from historical levels.

The number of coho in California (including the Navarro River and its tributaries) has dropped sharply since the 1940s. In the 1940s the number of adults returning to spawn apparently ranged between 200,000 and 500,000 fish per year (Brown et al. 1994, as cited in Regional Water Board 2000a). By the mid-1960s, the number statewide was estimated to have fallen to about 100,000 fish per year (Weitkamp et al. 1995, CDFG 1965, and California Advisory Committee on Salmon and Steelhead Trout 1988; all as cited in Regional Water Board 2000a), followed by a further decline to about 30,000 fish in the mid-1980s (Wahle and Pearson 1987, as cited in Regional Water Board 2000a). This is a decline from the 1940s to the 1960s of 50-80% and from the 1960s to 1980s of 70% for a total decline from the 1940s to the 1980s of 85-94%. From 1987 to 1991, an average of about 31,000 adult salmon returned to spawn, with hatchery populations making up 57% of the total (Weitkamp et al. 1995 and Brown et al. 1994; both as cited in Regional Water Board 2000a). Without the influence of hatcheries, the total decline from the 1940s to the early 1990s would have been 93-97%.

In December 1996, the NMFS listed the coho in the Central California Coast Evolutionarily Significant Unit (an area including the Navarro River and its tributaries) as a threatened species (i.e., they are likely to become endangered in the foreseeable future) under the federal Endangered Species Act.

The number of steelhead has also declined dramatically, and the NMFS listed steelhead in the Northern California Evolutionary Significant Unit (including the Navarro River and its tributaries) as threatened in June 2000a.

2.3 Salmonid Life Cycle and Habitat Requirements

Anadromous salmonids, including coho and steelhead, are born in freshwater streams where they spend one to several years feeding, growing, and hiding from predators. Once they are mature enough, they undergo a physiological change which allows them to swim out to the ocean where they spend the next one to several years. Subsequently, they return to the streams in which they were born and lay their eggs, beginning the life cycle again. Salmonids have different habitat requirements at different life stages. Table 2-2 describes the salmonid life cycle in more detail and outlines potential impacts to salmonids and their habitat. The TSD (Regional Water Board 2000a) describes a variety of requirements for temperature, sediment, and other parameters, including cover, stream flow, space, dissolved oxygen, barriers, and productivity of streams and food sources. The Navarro River TMDLs address the impairments to freshwater salmonid habitat related to sediment and temperature. However, salmonid populations may not fully recover until other factors (e.g., ocean rearing conditions) are addressed.

Table 2-2. Salmonid Life Cycle Stages and Potential Impacts to Salmonids and their Habitat

Life Cycle Stage	Potential Impacts to Salmonids and their Habitat	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-stream crossings - 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
Summer Rearing	- Elevated stream temperatures - Absence of or decline in the volume of rearing space (e.g., pools) - Absence of or decline in the amount of shelter - Absence of or decline in the amount of food - Disease	- Loss of or reduction in riparian vegetation, vegetation vigor, or complexity of community structure - Loss of or reduction in deep water habitat - Loss of or reduction in summer groundwater inflow - Loss of or reduction in summer intergravel flow - Delivery and/or remobilization of sediment to pools - Loss of or substantial reduction in instream structural elements (e.g., large woody debris) - Delivery and/or remobilization of fine sediment over aquatic macroinvertibrate habitat (e.g., gravels) - Increase in the types or ferocity of diseases (e.g., via release of hatchery-raised fish)
Winter Rearing	- Absence of or decline in off-channel habitat - Absence of or decline in-stream shelter (e.g., large woody debris) - Elevated peak flows - Increased stream flow velocities	- Disconnection of stream channel from floodplain - Removal or reduction of large woody debris and other structural elements in the stream channel - Modification of up-slope 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)

2.3.1. Temperature Requirements

Ambient water temperature is one of the most important factors affecting the success of salmonids and other aquatic life. With coho and steelhead, temperature influences growth and feeding rates; metabolism; development of embryos and juveniles; timing of life history events, such as upstream migration, spawning, freshwater rearing, and seaward migration; and food availability. Elevated temperatures can cause stress and lethality (Ligon et al. 1999, as cited in Regional Water Board 2000a). Temperature is such an important requirement that coho and steelhead are known as "cold water fish."

Coho and steelhead can be affected by both acute (short-term) and chronic (long-term) exposure to elevated stream temperatures. Chronic exposure is often defined in terms of the highest value of the 7-day moving average of temperatures. This is known as the Maximum Weekly Average Temperature (MWAT). Fish can withstand short-term exposure to temperatures higher than those required day in and day out without significant adverse effects, but there are maximum temperatures above which adverse effects are encountered after only short exposures.

The following ranges of values were derived in the TSD (Regional Water Board 2000a) from the available literature. The TMDL uses these values for comparison to MWAT values to characterize the quality of the cold water habitat in the Navarro (Table 2-3).

Table 2-3. Temperature Characterization Criteria

Descriptor	**Temperature Values**	
	Coho Salmon	Steelhead Trout
Good	<15EC (<59EF)	<17EC (<63EF)
Marginal	15E - 17EC (59E - 63EF)	17E - 19EC (63E - 66EF)
Poor/Unsuitable	>17EC (>63EF)	>19EC (>66EF)

In addition, to assess acute conditions, season hours above temperature thresholds of 18, 20, 22, 23, 24, and 25EC were evaluated.

2.3.2. Sediment Requirements

Coho and steelhead have a variety of requirements related to sediment. Sediments of the proper amount and size are needed for redd (salmon nest) construction, spawning, and embryo development. Excessive amounts of sediment can adversely affect salmonid habitat.

Too much sediment delivery to a stream can be a problem for coho and steelhead by filling pools. CDFG habitat data indicates that the better coho streams in Northern California (including the Navarro River watershed) have as much as 40% of their total habitat in primary pools (Flosi et al. 1998, as cited in Regional Water Board 2000a). Pools in first and second order streams are considered primary pools when they are 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 the same, except that maximum pool depth must be three feet or more.

Excessive fine sediment can smother redds, reducing egg and embryo survival. The redd construction process can reduce the amount of fine sediments and organic matter in the pockets where eggs are deposited (Meehan 1991, McNeil and Ahnell 1964, Ringler 1970, Everest et al. 1987; as cited in Regional Water Board 2000a). However, if fine sediments are being transported in a stream either as bedload or in suspension, some of them are likely to be deposited in the redd. Tappel and Bjornn (1983, as cited in Regional Water Board 2000a) found that embryo survival decreases as the amount of fine sediment increases.

The summer or winter carrying capacity of the stream for fish declines when fine sediments fill the interstitial spaces of the substrate used by fish for shelter. Newly emerged fry can occupy the voids of substrate made up of 2-5 cm diameter rocks, but larger fish need larger (>7.5 cm diameter) substrates in order to occupy the voids. In a laboratory stream experiment, Crouse et al. (1981, as cited in Regional Water Board 2000a) found that growth of juvenile coho was related to the amount of fine sediments in the substrate. Density of juvenile steelhead and chinook salmon (*Oncorhynchus tshawytscha*) in summer and winter were found to be reduced by more than half when enough sand was added to fully embed the large cobble substrate (Bjornn et al. 1977, as cited in Regional Water Board 2000a).

The addition of fine sediments to stream substrates as a result of watershed disturbances and erosion may reduce the abundance of invertebrates, a primary food source for juvenile salmonids, as well.

2.4. Temperature Problems in the Navarro River and its Tributaries

Monitoring in the Navarro has found many locations where stream temperatures are higher than suitable for salmonids. Existing literature and research provides information on the sources of human-caused stream temperature increases.

Regional Water Board staff analyzed available data to determine the extent to which various factors are affecting stream temperatures in the Navarro and its tributaries. They reviewed data on temperature collected continuously at 66 locations in the watershed by the Mendocino County Water Agency or the Louisiana-Pacific Corporation. Of the 66 locations, 29 are located on main stream channels and 37 are located on smaller tributaries. Locations tend to be concentrated in forested areas and along the main stream channels.

Regional Water Board staff made several general observations. Current stream temperatures tend to be lowest in small tributary streams. Temperatures tend to be highest in locations on the main streams of Anderson, Indian, and Rancheria Creeks, and on the Navarro. The active channels are wider than natural in many reaches with high stream temperatures. Riparian vegetation in some of these reaches is sparse.

Maximum weekly average temperatures (MWAT) values were calculated for all locations to determine the extent of current problems. The results are presented in Figure 2-1. Most locations monitored are considered poor/unsuitable for both coho and steelhead, using the criteria identified in Table 2-3. At many locations, stream temperatures are high enough to be lethal to salmonids on many days during the summer months. Data for the entire watershed were used to generate Figure 2-1. The TSD (Regional Water Board 2000a) also describes current temperature conditions in each of the major subwatersheds.

The data were also evaluated to determine when the MWATs occurred. As described in Figure 2-2, the MWAT most frequently occurred between July 16 and July 31, with the average date being July 22.

A variety of activities and events, both human-induced and natural, can affect stream temperatures (Coutant 1999, as cited in Regional Water Board 2000a). During summer, direct solar radiation is the primary source of heat energy input to streams (Brown 1970, Brown 1980, Beschta et al. 1987, Beschta 1997, Coutant 1999, Oregon Department of Environmental Quality 1999, Sinokrot and Stefan 1993, Sullivan et al. 1990; all as cited in Regional Water Board 2000a). Activities described in the TSD

Figure 2-1. Frequency Distribution of Site-Averaged MWAT Values
Navarro Watershed, 1995-1999

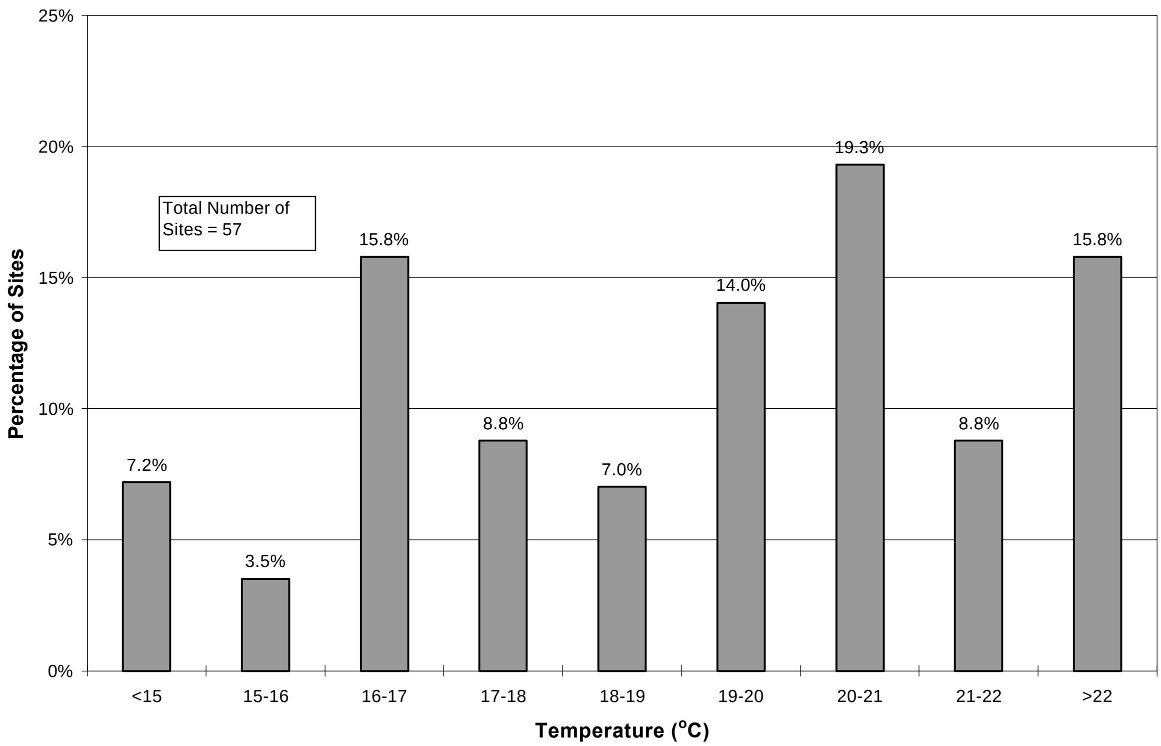
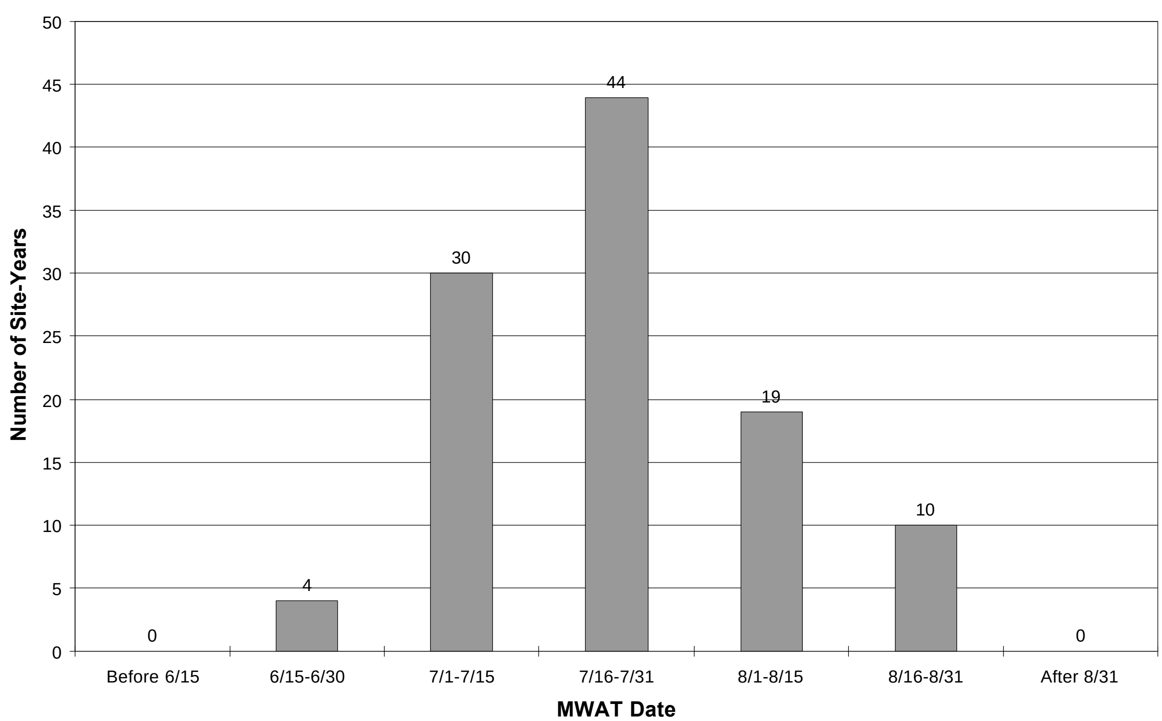


Figure 2-2. Frequency Distribution of MWAT Dates
Navarro Watershed, 1995-1999



(Regional Water Board 2000a) that can affect stream temperatures include those that decrease streamside (riparian) vegetation, reduce stream flow, or change channel morphology.

2.5. Sediment Problems in the Navarro River and its Tributaries

Sediment problems in the Navarro River and its tributaries are assessed by subwatershed (see Figure 2-3) below. Overall, these conditions indicate that excessive amounts of coarse and fine sediment are causing decreased habitat quality for salmonids. Additional details are presented in the TSD (Regional Water Board 2000a).

In the North Fork Navarro Basin, analysis of the in-stream data indicates salmonid habitat conditions, in general, have been degraded. The data suggests management activity has resulted in reduction of both the quantity and quality of pool habitat. In 1996, Entrix (1998, as cited in Regional Water Board 2000a) found excessive deposition of fine sediments in pools and riffles in all reaches surveyed, as well as evidence of aggradation in the lower North Branch of the North Fork, and concluded that chronic fine sediment deposition and loss of large woody debris are adversely affecting stream reaches throughout the entire Navarro River watershed. Gravel samples evaluated by Mendocino Redwood Company (Surfleet 2000, as cited in Regional Water Board 2000a) and Roger Foott Associates (1990, as cited in Regional Water Board 2000a) indicate that gravel quality may also be a problem in the North Fork. The data indicates that on the whole, the suitability of gravels found in the North Fork is marginal for spawning.

The Mainstem Navarro River Basin is also adversely impacted by sediment. Data from CDFG surveys (CDFG 1998, as cited in Regional Water Board 2000a) indicate that the quantity and quality of pool habitat in the tributary systems of the Mainstem Navarro River Basin are deficient. Entrix (1998, as cited in Regional Water Board 2000a) reported that deposition of fine sediments in pools was widespread in Mill Creek, the largest tributary in the basin, and in general, accumulation of fine sediments was very high compared to most other stream reaches surveyed. They also reported evidence of accelerated bank erosion, which may explain the elevated fine sediment deposition, while CDFG (1998, as cited in Regional Water Board 2000a) noted that several road crossings were adding sediment and suggested that the road system be treated to reduce sediment yield. Deposition of fine sediments has also affected the quality of spawning gravels in the Mainstem Navarro River Basin.

For the Rancheria Creek Basin, information in the recent past is slim. CDFG crews surveyed the entire length of Rancheria Creek and most major tributaries in 1962, and with the exception of the upper reaches of Camp Creek, every stream survey indicated intense degradation due to recent logging. CDFG data from 1996 for the lower reaches of Rancheria Creek indicates that these streams have at least partially recovered from the destruction of the 1960s.

In the Anderson Creek Basin, Entrix (1998, as cited in Regional Water Board 2000a) surveyed two reaches of Con Creek, a tributary to Anderson Creek. They concluded that fine sediment deposition and accelerated bank erosion had occurred in both reaches. They analyzed aerial photos of unconfined reaches of Anderson Creek and concluded that evidence of present-day aggradation was strong, based on changes in active channel width, sediment storage in gravel bars, and cross-sections at bridges.

The Indian Creek Basin also demonstrates impacts from sediment. Entrix (1998, as cited in Regional Water Board 2000a) surveyed a 1.5-mile stretch of the North Fork of Indian Creek in 1996. They concluded that coarse sediment deposition and persistent channel aggradation has occurred; that fine sediment deposition did not appear to be prevalent; and that there is moderate to strong evidence of wood loss. The stream survey also noted evidence of historical bank erosion problems that dated back fifteen to thirty years.

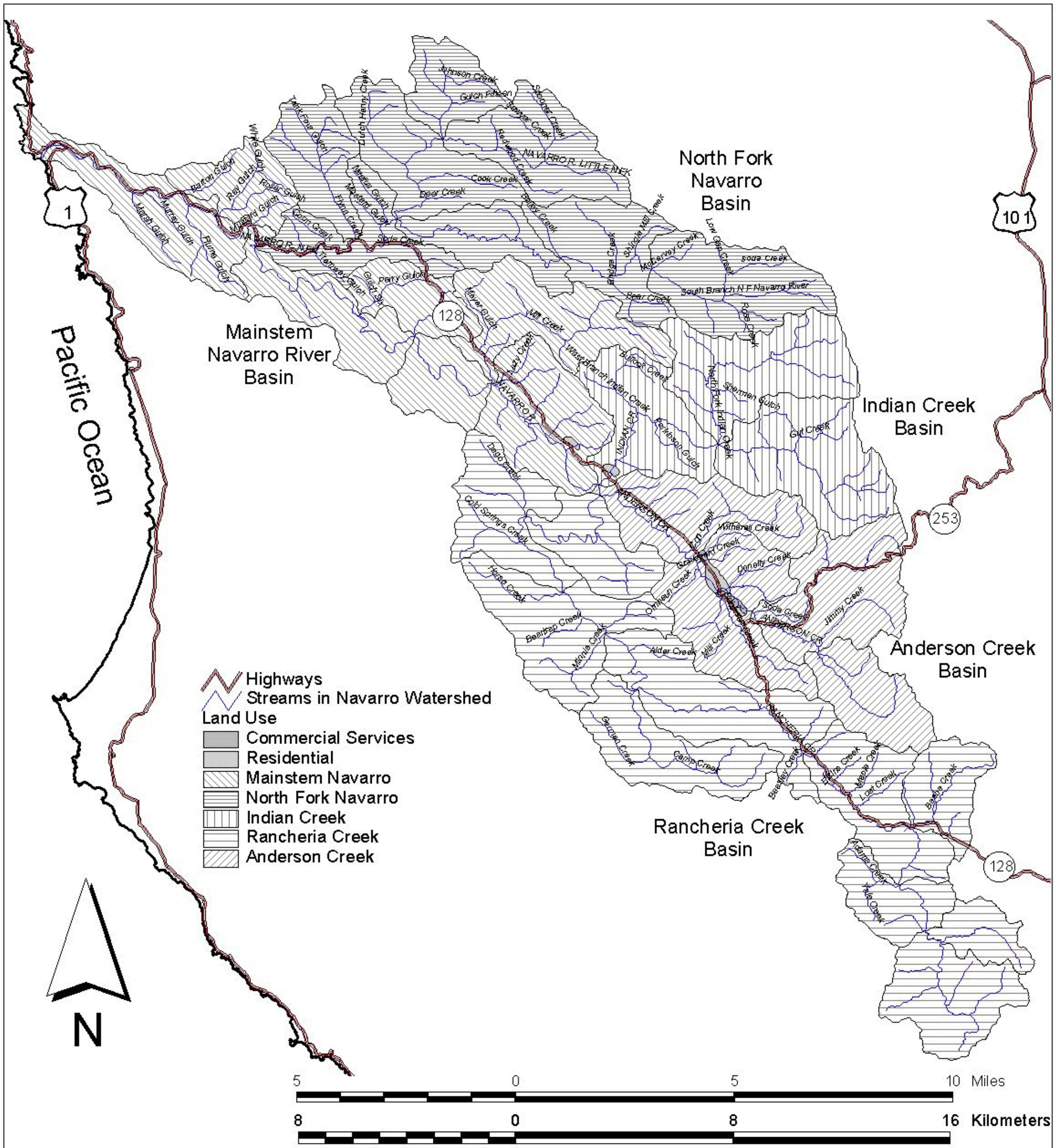


FIGURE 2-3
Navarro River Watershed TMDL Planning Areas and Sub-watersheds

Navarro River Watershed
August 2000

CHAPTER 3: TEMPERATURE

This analysis for the Navarro TMDL finds that natural stream temperatures have been increased. This temperature increase has led to decreased suitable habitat for salmonids. Therefore, actions to reduce heat inputs are warranted in order to implement State water quality standards.

This chapter contains a summary of the evaluation of different factors and conditions that could be the source of stream temperature increases, including those recommended by public comments. We conclude that shade very clearly plays an important role in stream temperature in the Navarro - in all locations and under all hydrological conditions. The chapter sets shade levels needed to meet water quality standards for temperature including the legally required loading capacity and allocations.

Scope of Temperature TMDLs and reduced summer flows & salmonid habitat

While the scope of this TMDL is limited to temperature, EPA notes that reductions in flow may adversely affect salmonid habitat in other ways (e.g. connectivity between refugia, estuarine conditions, food production, access to cover, stream dewatering).

The Division of Water Rights is working with NMFS to address all habitat concerns of flow and listed species. The Division of Water Rights has been conducting increased enforcement, permitting and other activities in the Navarro.

The chapter also summarizes the significance of reduced flow on stream temperature and beneficial uses. The magnitude of temperature changes due to flow is smaller than changes due to shade. The geographic extent of adverse effects from flow on temperature cannot be determined, but is also smaller than shade. Site specific conditions were found that buffer stream temperatures in some locations, and that adversely affect stream temperatures in other locations. Given that the data needed for extrapolation was not available, we cannot derive reliable conclusions about the flow/temperature relationship on a watershed scale. The significance of flow as a determinate on summer temperature in the basin is a source of uncertainty. Because flow can be important in certain circumstances, EPA is providing a margin of safety by setting an instream target which states: "The quantity of flow diverted from the Navarro in the summer is not increased, unless it can be shown that such an increase does not adversely affect beneficial uses." USEPA does not allocate flow among users. This is the responsibility of the State.

3.1. Determining the Sources of Increased Stream Temperature in the Navarro and their Significance

There are no known point sources of heat to the Navarro or its tributaries. Therefore, the source analysis focused on non-point sources. During the public comment period, many commentors criticized the draft TMDL for not adequately taking into consideration reduce flow as an influence on stream temperature. EPA and the Regional Water Board agreed with the commentors that more analysis of the effect of flow on stream temperature was appropriate. Thus, in response to the many comments concerning flow, Regional Water Board staff conducted additional modeling and data review. They prepared a technical addendum to the TSD describing the additional analyses (Regional Water Board, 2000b). The results of both the original and additional modeling and analysis are discussed below. The additional modeling changed some of our conclusions from the draft TMDL.

Many likely factors were analyzed for their effects on stream temperature in the Navarro watershed, including stream side vegetation changes (shade) and reduced flow. Two approaches were used: SSTEMP modeling and regression analysis. The SSTEMP model was the primary tool used to analyze the relative importance of factors affecting stream temperature in the Navarro. The SSTEMP model has been used for many years nationwide and EPA considers it a reliable analytical tool. The TSD (Regional Water Board 2000a) presents the results of the initial modeling. The TSD addendum (Regional Water Board 2000b) discusses the additional and revised SSTEMP modeling conducted in response to public recommendations and concerns that more stream reaches needed to be analyzed in order to account for the importance of flow to stream temperature. Regression analysis based on monitored stream reaches in the Navarro was also conducted and is described in the TSD (Regional Water Board 2000a).

3.1.1. Results Show Shade has Significant Effects on Temperature

The modeling and regression analyses indicate that shade is clearly affecting temperature. Combining this with GIS information, EPA finds that improvements in shade are needed to meet the State's water quality standard "natural stream temperatures...shall not be altered....unless such a alteration does not adversely affect beneficial uses."

The results of the SSTEMP modeling demonstrate that shade has consistent and significant effects on water temperature. Figure 3-1, shows that increasing shade from 5% to 80% can lower stream temperatures by 3-5°C (about 5.4-9°F) depending upon site specific groundwater conditions. The resulting decrease in temperature results in improved rearing habitat. Figure 3-1 shows that temperatures can move from unsuitable conditions (21-24°C or 69.8-75.2°F) to more suitable conditions (18-20°C or 64.4-68°F) by improving shade. To put this into the context of the State's water quality standard, the natural receiving water temperature (suitable conditions) was affected at levels that adversely affect beneficial uses (by moving to unsuitable conditions for salmonids.)

Extrapolating the modeled reach to the watershed, the GIS information on current riparian conditions indicates that significant improvements in shade can be achieved throughout the watershed. These improvements in shade will lead to clear improvements in stream temperatures for salmonids. Not only will temperatures decrease once shade is improved, but the reductions will be sufficient to make a large portion of the Navarro good cold water habitat. Figure 3-2 illustrates this point where the tributaries turn largely blue (best habitat) with improved shade. Regression analysis conducted for the TSD (Regional Water Board 2000a) also confirms the importance of shade. Later sections of this chapter determine the loading capacity and allocations for shade.

3.1.2. Results Show the Effect of Water Diversions on Temperature is Limited to Certain Circumstances and thus Adverse Effects on Beneficial Uses are Uncertain

The effect of flow on temperature is more complex and dependant upon site specific conditions. (Additionally, recall that reduced flows can have negative effects on fish beyond temperature effects.) Using available monitoring information on two reaches of the mainstem Navarro (including a losing reach recommended by public comments), Regional Water Board staff conducted SSTEMP analysis of both existing and theoretical conditions. This analysis is based on the best information available on permitted summer diversions. The actual amount of water diverted would also include riparian rights, pre-1914 and illegal diversions. However, no information is available to determine the amount of these diversions.

Only a subset of the known and theoretical conditions modeled showed that decreasing flow resulted in an increase in stream temperature. Several considerations are appropriate when contemplating whether conclusions can be drawn regarding an adverse effect on beneficial uses.

Insert Figure 3-1 here.

Figure 3-1 Effect of Shade and Flow on Stream Temperature: Neutral, Losing, and Gaining Reaches of the Navarro

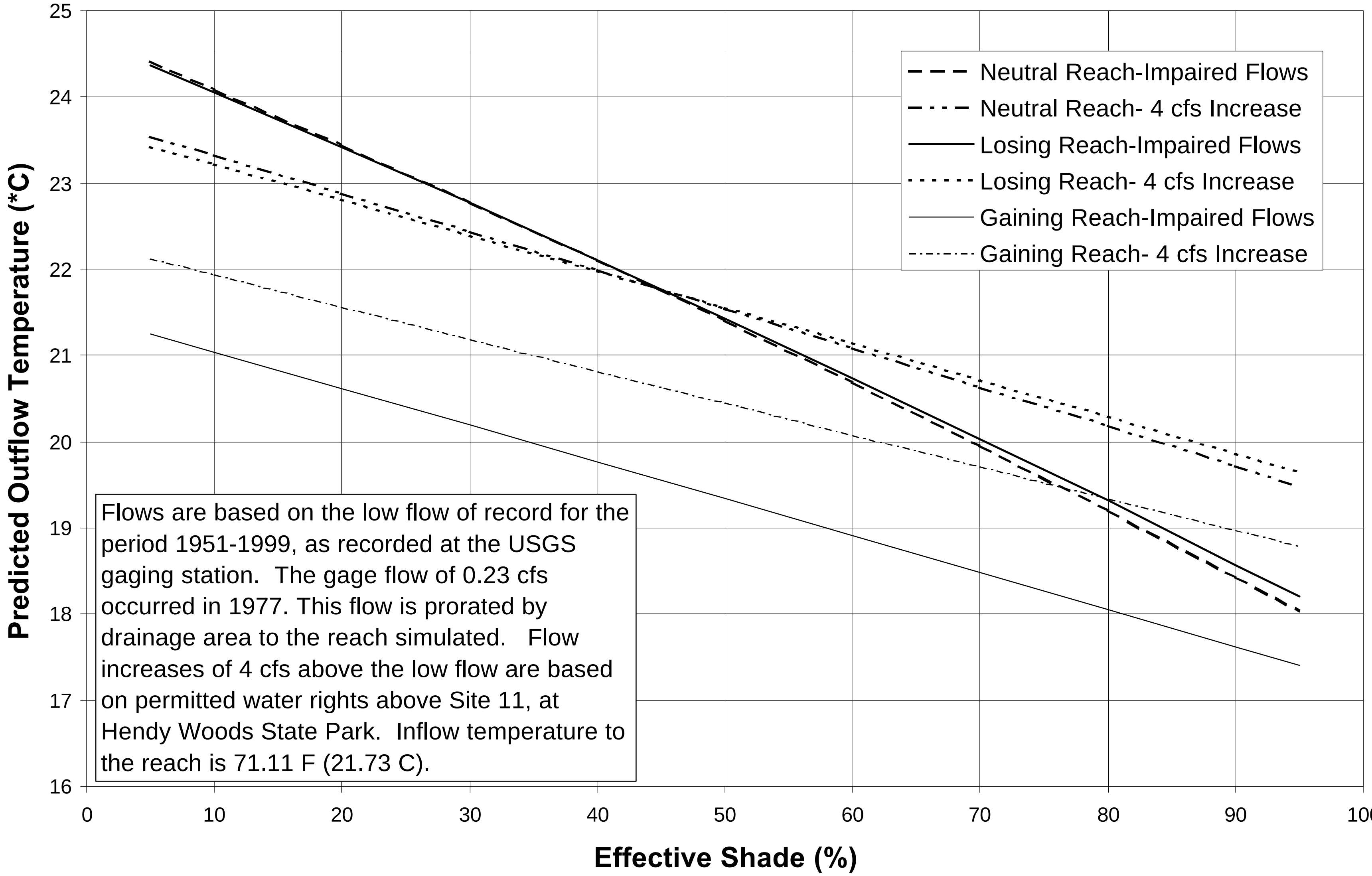
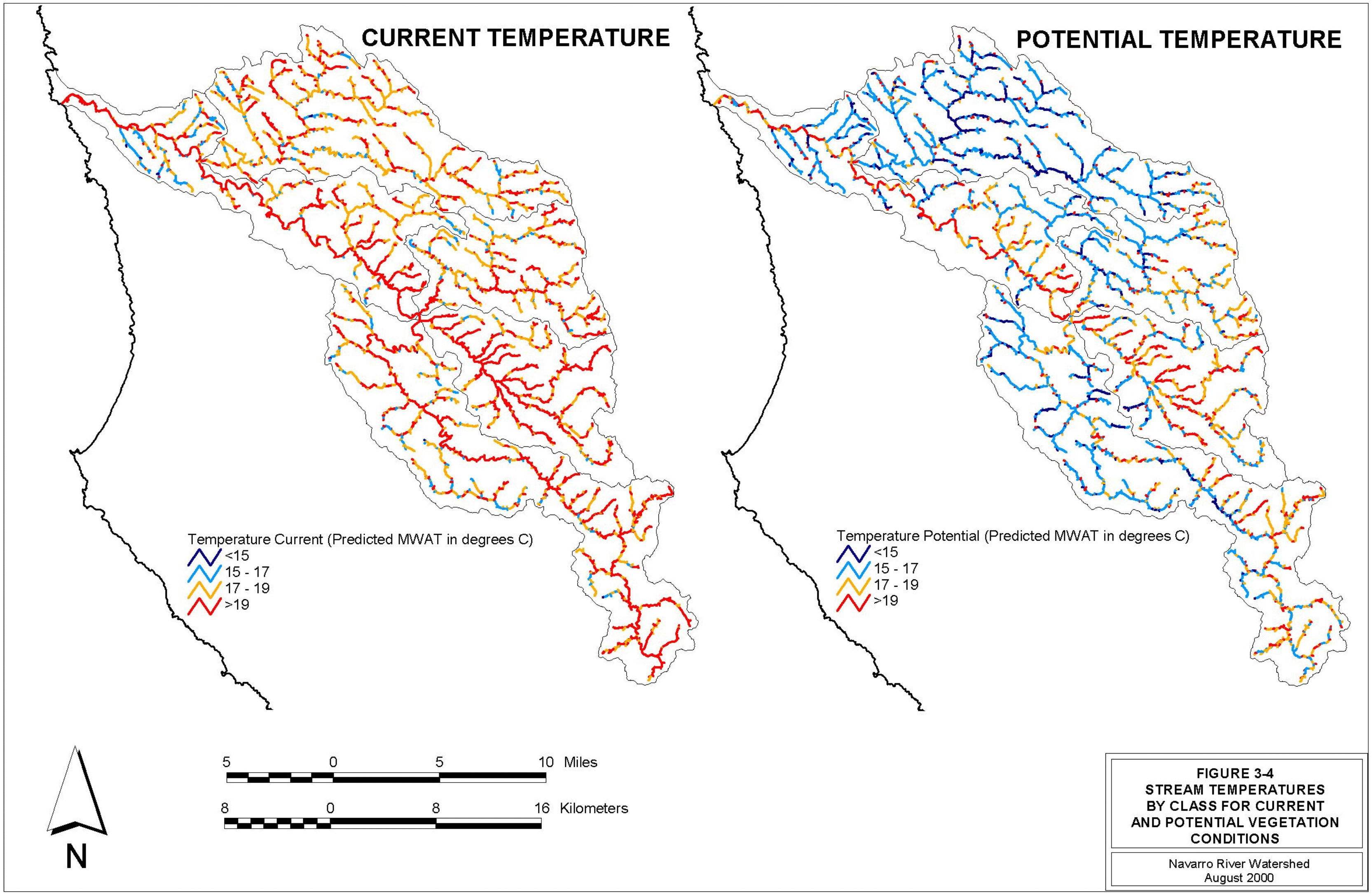


Figure 3-2: Stream Temperatures by Class for Current and Potential Vegetation



1) Flow has the greatest effect in very dry years in the modeled reach. Effects in dry years, despite their historical infrequency, often have the most biological significance. Each part of a salmon's life cycle and each year class must have available habitat. While the amount of habitat varies naturally, decreasing habitat during the worst natural conditions can lead to population effects. Therefore, adverse effects are possible if many locations are affected during dry years.

2) Flow is a more important factor in reducing stream temperatures under poor shade conditions. This could be important because the areas with the least potential to be improved by shade (e.g. Anderson Creek and parts of the mainstem Navarro) commonly are the same areas with diversions. Again, adverse effects are possible if many locations are affected by poor shade conditions.

3) The magnitude of the effect of flow reductions on temperature is smaller than the effect related to shade in the modeled reach. In that reach, even the largest temperature effect from increased flows only reduces the temperature 1°C (about 1.8°F) to approximately 23°C (73.4°F) - unsuitable conditions for salmonid rearing. We do not know with much certainty how much changing poor conditions to worse conditions adversely affects fish.[2] The second portion of the State's water quality standards states "At no time or place shall temperature of any COLD water be increased by more than 5°F above the natural receiving water temperature." This portion of the State temperature standards, which provides a clear guide for circumstances that are not frequent or geographically widespread, is met for the modeled stream reaches because the largest increase in temperature from flow was 1EC (about 1.8°F). EPA notes that the second part of the standard is less protective than the first, more general part in this case.

4) The geographic extent of temperature changes is also uncertain. An especially important unknown is the existence of groundwater as an important buffer on site specific stream temperatures. Streams which are being increased by inflow of groundwater are known as "gaining" streams. For example, in the stream segment of Hendy Woods to Mill Creek during 1995 and 1996, where cold groundwater is entering the stream, increasing surface flow does not decrease stream temperature. It is unknown how many streams with diversions in the Navarro are buffered by this groundwater factor, during what water year types or what seasons, nor it is known how much groundwater pumping has affected this cold water input. It is known that the opposite temperature effect occurs in the stream segment upstream of this segment, from the confluence of Rancheria Creek and Indian Creek (where the Navarro begins) to Hendy Woods, where cold groundwater is NOT entering the stream. Adding surface flow to the upstream stretch from Hendy Woods decreases water temperatures. The TSD addendum (Regional Water Board, 2000b) also analyzed streams without any groundwater factors.

In conclusion, the modeling suggests that increases in stream temperatures are possible from diversions in the Navarro - but at levels where effects on salmonids are not clear. These small temperature increases, if they occur over large areas, have the potential to adversely affect beneficial uses. As described above, the geographic extent of these temperature changes is not known. EPA recommends further monitoring in a variety of stream reaches to determine the extent and significance of the temperature problems caused by flow. This TMDL does not allocate flow among users. Flow issues are being addressed in other forums, specifically the Division of Water Rights is working with NMFS to address concerns for listed species from all problems related to flow. Given that flow can adversely affect stream temperatures, albeit to an uncertain extent, the TMDL sets an instream target of "The quantity of flow diverted from the Navarro in

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[2] The MWAT measurement does not fully capture all the rearing habitat of salmonids. Salmonids utilize stream reaches with high temperatures by using cold pockets of water (refugia formed by pools, often near groundwater seeps) during hot periods of the day and then feeding when conditions cool during the day. A study of Rancheria Creek in the Navarro (Nielsen et al. 1994) documented the physical and biological mechanisms.

the summer is not increased, unless it can be shown that such an increase does not adversely affect beneficial uses."

3.2. Targets and Goals

To repeat the State's water quality standard for temperature:

> "The natural receiving water temperature of intrastate waters shall not be altered unless it can be demonstrated...that such an alteration 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

In the context of TMDLs, targets are defined in order to more precisely interpret water quality standards. They provide indicators of watershed health, and represent habitat and related conditions necessary or adequate for the achievement of water quality standards. They can be used to compare existing conditions to target conditions, to provide an evaluation framework for analyzing monitoring data collected in the future (and making changes to the TMDL and implementation measures), and to assist in evaluating whether land management and restoration activities are effective in improving temperature conditions in the watershed.

For the Navarro River temperature TMDL, we are setting numeric targets by estimating the "natural" water temperatures for the watershed. This is done by estimating the natural level of shade for streams in the watershed and calculating the resulting water temperatures using a GIS model. These water temperatures are the numeric targets for the Navarro River temperature TMDL. In addition, a target condition related to flow is set.

The GIS model was used to determine the potential amount of shade that would be present if the vegetation near streams was fully mature. The GIS model, developed by Regional Water Board staff (Regional Water Board 2000a), calculates the percent of possible solar radiation received at each location along the Navarro River and its tributaries, considering sun position, topography, stream location and orientation, the unvegetated channel width, the distribution of vegetation types in the watershed, and the adjusted potential height of mature vegetation (dependant on vegetation type). The results are expressed in terms of effective shade, which accounts for the fact that shade varies by time of day. Effective shade is the percent reduction of potential solar radiation delivered to the water surface. For example, if the combination of topography and vegetation at a specific location blocks 3/4 of the potential solar radiation from reaching the stream, the effective shade for that location would be 75%.

In addition, in response to public comment and because of the potential impact of flow on stream temperature, we are also including a target for flow and temperature. We emphasize that this target does not represent an allocation of flow among users; rather, it describes what we consider to be conditions necessary for watershed health. It is based on the guidelines of NMFS and CDFG that are in use by the Division of Water Rights (CDFG, NMFS, 2000) and the evidence that stream temperatures can be increased, under certain circumstances, by summer diversions.

The following are the targets for the Navarro watershed:

Temperature: Temperature conditions in the Navarro should show the general pattern illustrated in Figure 3-2. Good or suitable habitat conditions for cold water fish (<17°C [62.6°F] as measured MWAT) should exist in most tributaries. Streams that cannot support ambient suitable conditions (e.g., mainstem Navarro, Anderson and lower Rancheria) will provide improving conditions for pool refugia and connectivity between refugia through sufficient natural surface and groundwater flow.

Flow and Temperature: The quantity of flow diverted from the Navarro in the summer is not increased, unless it can be shown that such an increase does not adversely affect beneficial use. The NMFS guidelines provide details of the documentation required for summer diversions.

3.3. Loading Capacity, TMDL, and Linkage Analysis

The loading capacity for the Navarro temperature TMDL is the cumulative total of adjusted potential shade levels from individual streams. The piecharts of Figure 3-3 and 3-4 summarize the modeling results for the watershed as a whole. Table 3-1 provides the same information in a different format. The total loading of a pollutant that a water body can assimilate while still meeting water quality standards is the loading capacity. While heat (radiant solar energy) is the pollutant of concern, this TMDL focuses on effective shade as a surrogate for heat, because effective shade is inversely and directly proportional to heat, and it is readily measured in the field or calculated using mathematical models. Therefore, the loading capacity of the Navarro River for temperature is defined in terms of the amount of effective shade possible along the Navarro River and its tributaries when riparian vegetation is in its adjusted potential condition.

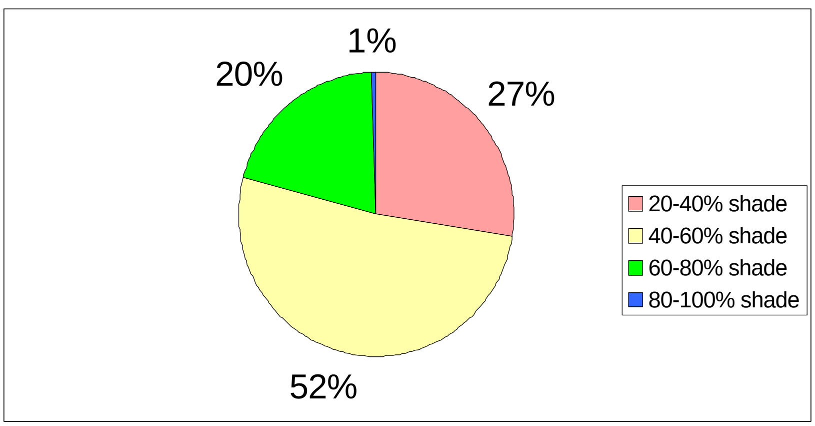
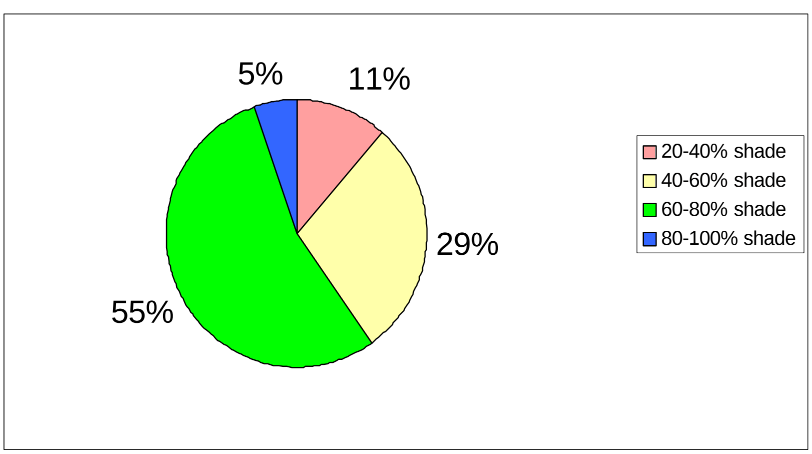


Figure 3-3. Percentage of Streams in the Watershed having Specified Amounts of Effective Shade with Current Vegetation

Figure 3-4. Percentage of Streams in the Watershed having Specified Amounts of Effective Shade with Adjusted Potential Vegetation

Table 3-1. Total Length of Streams in the Watershed having Specified Amounts of Effective Shade (Loading Capacity and TMDL for Temperature)

Amount of Effective Shade (%)	**Stream Length (miles [km])**		**% of Total**		**% Shadier (cumulative)**	
	Current Vegetation Conditions	*Adjusted Potential Conditions*	Current Vegetation Conditions	*Adjusted Potential Conditions*	Current Vegetation Conditions	*Adjusted Potential Conditions*
0 - 10	0 [0]	*0 [0]*	0.0	*0.0*	100.0	*100.0*
10 - 20	0 [0]	*0 [0]*	0.0	*0.0*	100.0	*100.0*



20 - 30	58 [93]	*16 [25]*	10.9	*2.9*	89.1	*97.1*
30 - 40	89 [142]	*43 [69]*	16.5	*8.1*	72.6	*89.0*
40 - 50	132 [211]	*74 [119]*	24.6	*13.9*	48.0	*75.1*
50 - 60	145 [232]	*81 [130]*	27.0	*15.2*	20.9	*59.9*
60 - 70	84 [134]	*125 [200]*	15.6	*23.4*	5.3	*36.5*
70 - 80	25 [40]	*166 [265]*	4.6	*31.0*	0.7	*5.5*
80 - 90	3 [5]	*29 [47]*	0.6	*5.5*	0.0	*0.0*
90 - 100	0 [0]	*0 [0]*	0.0	*0.0*	0.0	*0.0*
Total*	**535 [856]**	***535 [856]***				

*Columns were summed before rounding, so totals listed may not equal the sum of the rounded column entries.

The GIS model described in Section 3.2 was used to calculate effective shade values for the Navarro River and its tributaries for July 22, the date that, on average, is the hottest of the year in the watershed Effective shade values were calculated for both current and adjusted potential vegetation conditions.

The results are described in Table 3-1, which identifies the length of streams in the watershed that would have specific amounts of effective shade, under current and under adjusted potential shade conditions. It also identifies the percentage of stream length in the watershed that has more than the specified amount of effective shade. For example, under current riparian vegetation conditions, 84 miles (134 km, or 15.6%) of the streams in the watershed have between 60% and 70% effective shade, and 5.3% of the streams in the watershed have more than 70% shade. However, under adjusted potential vegetation conditions, 125 miles (200 km; or 23.4%) of streams in the watershed would have between 60% and 70% effective shade, and 36.5% of the streams in the watershed would have more than 70% effective shade.

The results for adjusted potential vegetation are the amounts of effective shade needed to meet applicable water quality standards for temperature. When streams in the watershed have at least this much shade, it is expected that the temperature targets identified in Section 3.2 will be met. Thus, the values for adjusted potential conditions in Table 3-1 constitute the loading capacity, and therefore the TMDL, for temperature for the Navarro River and its tributaries.

3.4. Load Allocations

Effective shade requirements are set as the legally required load allocations for the Navarro temperature TMDL. The effective shade requirements vary by vegetation type, stream width and stream orientation. This approach has several advantages. First and foremost, field verification and site specific conditions can be factored into any implementation scheme. Many public comments were concerned that modeling results would be used without field verification. EPA reiterates our recommendation that field verification be factored into any implementation measures developed by the Regional Water Board. Second, effective shade can be readily measured and monitored when a full monitoring protocol is developed by the Regional Water Board.

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. Allocations for point sources are known as wasteload allocations. Those for non-point sources are known as load allocations. As there are no known point sources of heat into the Navarro River and its tributaries, the wasteload allocation for point sources is set at zero. Thus, the TMDL for temperature for the Navarro River and its tributaries is divided 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 heat, the establishment of load allocations equates to the identification of the effective shade requirement for any specific streamside location.

The method used to calculate effective shade needs for the watershed as a whole is not appropriate for determining the requirements (i.e., load allocations) for specific stream reaches. As described in Section 3.3, the GIS model was used to calculate effective shade conditions under adjusted potential vegetation conditions for all streams in the watershed, with the aggregated values representing the loading capacity for the Navarro River and its tributaries. However, it is not accurate enough to use a GIS map to determine the amount of effective shade needed at a specific stream location during implementation. Therefore, the Regional Water Board developed a means of determining the necessary effective shade value for any given stream reach, based on conditions found in the field at that location.

The Regional Water Board developed effective shade curves in the TSD (Regional Water Board 2000a), which correlate vegetation type, stream direction (e.g., north), and active (i.e., unvegetated) channel width with effective shade. The effective shade curves were developed using an Excel-based spreadsheet developed by the Oregon Department of Environmental Quality for TMDL applications. Effective shade curves are presented for various vegetation types: Redwood Forest (Figure 3-5), Douglas Fir and Mixed Hardwood-Conifer Forest (Figure 3-6), Klamath Mixed Conifer Forest and Ponderosa Pine Forest (Figure 3-7), and Oak Woodland (Figure 3-8). For example, take the case of a stream flowing west through a redwood forest with a channel 32 meters wide. Using Figure 3-5 (for redwood forest) and the line connecting the triangles (for a west flowing stream), the effective shade value corresponding to a channel width of 32 meters is about 85%.

The effective shade value corresponding to conditions for a particular stream reach is the load allocation for that location. The difference between current shade conditions and the load allocation constitutes the increase in effective shade needed to meet water quality standards at that location. The shade values derived from GIS model, which use more aggregated data than the field approach suggested here, when related by modeling into stream temperatures result in the target stream temperatures in Table 3-1.

Figure 3-5. Effective Shade vs. Channel Width, Redwood Forest

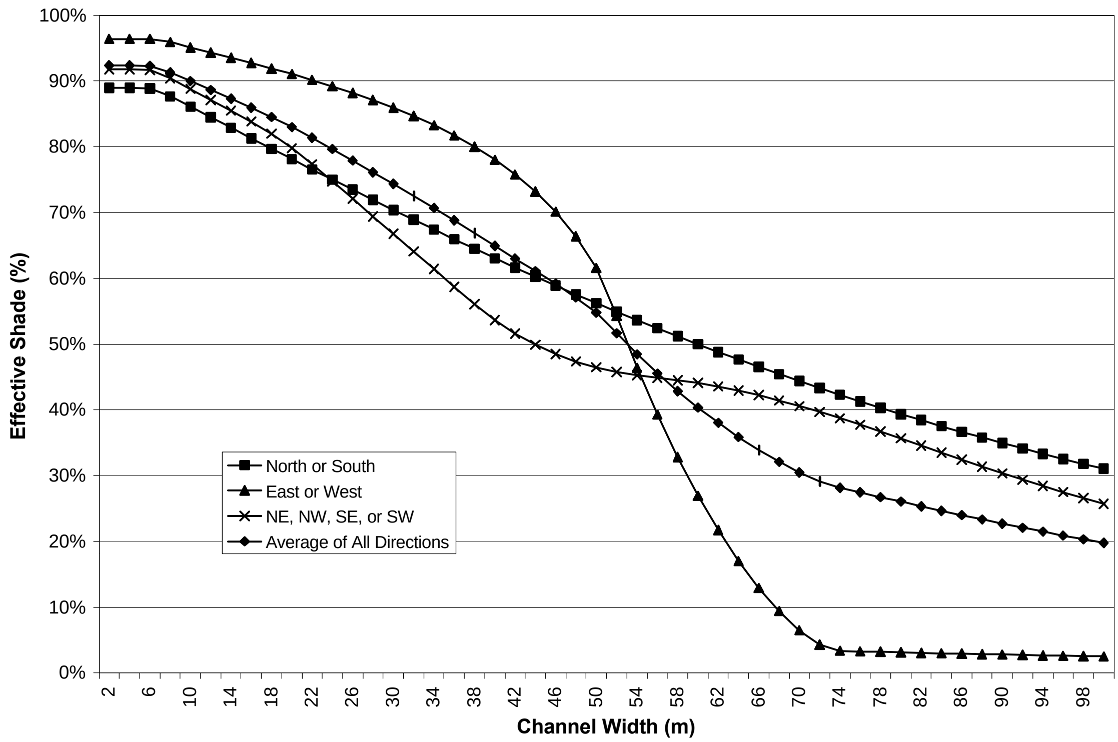


Figure 3-6. Effective Shade vs. Channel Width, Douglas Fir Forest and Mixed Hardwood-Conifer Forest

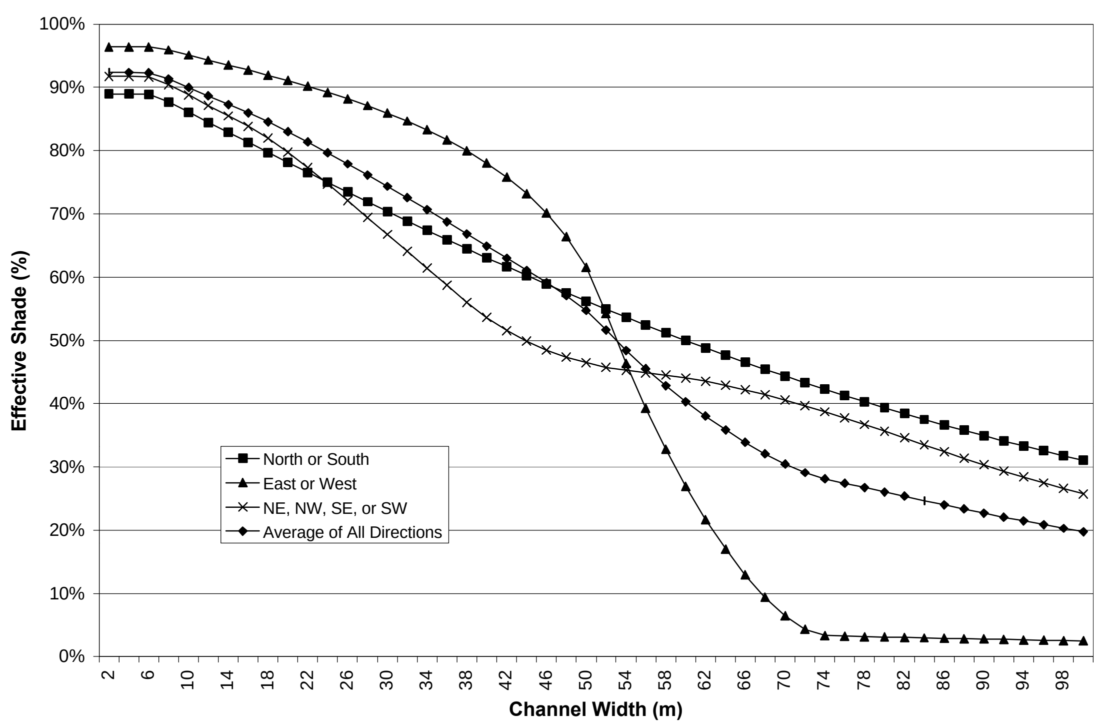


Figure 3-7. Effective Shade vs. Channel Width, Klamath Mixed Conifer Forest and Ponderosa Pine Forest

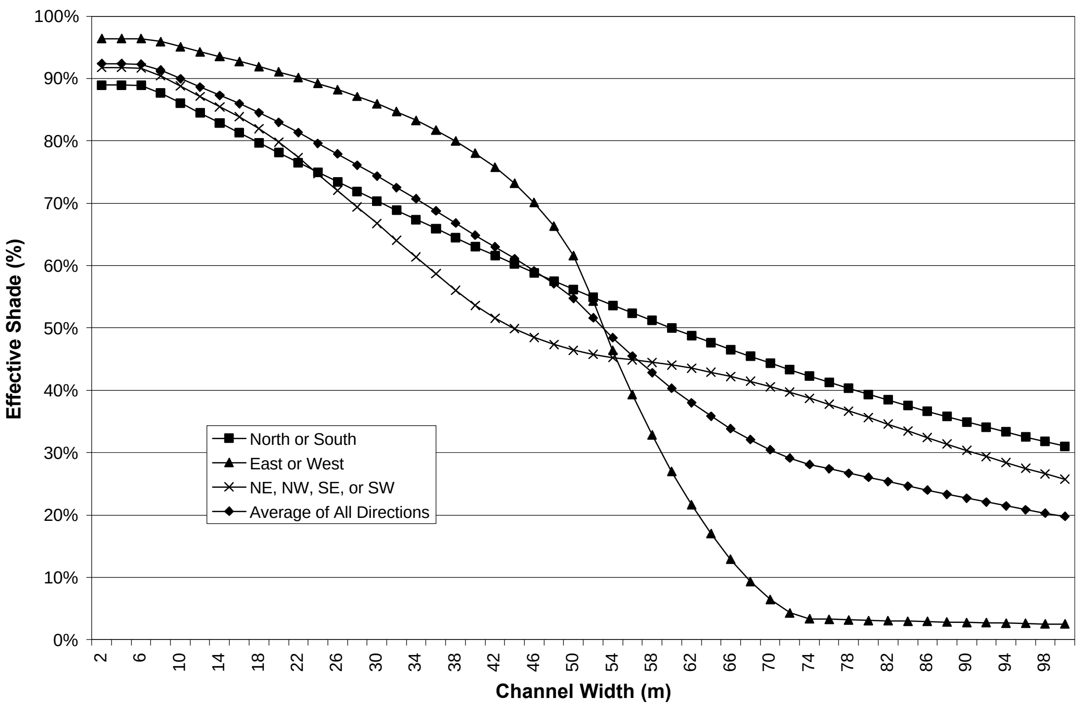
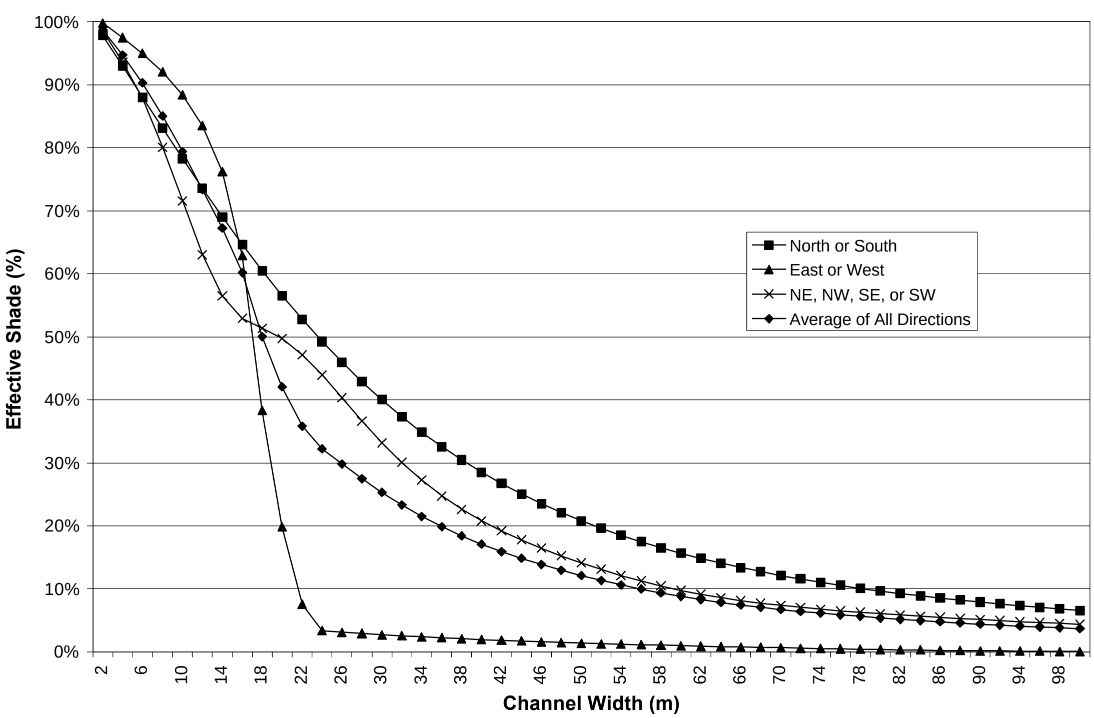


Figure 3-8. Effective Shade vs. Channel Width, Oak Woodland



3.5. Margin of Safety, Seasonal Variation, and Critical Conditions

As required by the Clean Water Act and its implementing regulations, EPA includes in TMDLs a margin of safety to deal with uncertainty. The margin of safety can be implicitly incorporated into conservative assumptions used in calculating loading capacities, waste load allocations, and load allocations. For this TMDL, several conservative assumptions concerning shade were made that account for uncertainties in the analysis and provide 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.

- 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, which can provide areas of cooler water for fish. These changes were not accounted for in the analysis.

- Potential shade estimates were adjusted (reduced) by 10% to allow for the effects of natural factors which reduce shade, such as fires and storms. The actual amount of reduction may be more, so the use of 10% results in conservative load allocations.

- The Navarro River TMDLs for temperature and sediment are based on separate analyses. 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 would tend to result in lower stream temperatures overall and in more lower-temperature pool habitat. Improvements in stream temperature that may result from reduced sedimentation were not considered in the analysis.

- While the potential shade conditions used to calculate the loading capacity assume that the occurrence of site potential vegetation 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, as was done in the analysis, does not account for channel narrowing that may occur as a result of reduced sediment loads.

A major source of uncertainty is how much reduced flow is affecting stream temperatures in the Navarro. While the available evidence cannot determine the geographic extent or frequency of adverse effects, the effects are not expected to occur throughout the watershed. However, a margin of safety is provided by the target related to flow and temperature " The quantity of flow diverted from the Navarro in the summer is not increased, unless it can be shown that such an increase does not adversely affect beneficial uses."

The TMDL must also account for critical conditions and seasonal variations. In this case, the analysis is based on the most critical conditions (i.e., the period of highest stream temperatures). The temperature analysis for flow was also based on the lowest flow recorded. Seasonal variations were also accounted for analyzing the monitoring data and then focusing on the period of highest temperatures in the summer period and using the 50 year record of varying stream flow.

CHAPTER 4: SEDIMENT

This chapter identifies numeric targets for in-stream and surrounding watershed conditions that are needed to meet applicable water quality standards for sediment. It contains an evaluation of the sources of sediment, including the relative contribution of natural and human-caused sediment sources. It establishes the maximum amount of sediment that the system can tolerate and still attain water quality standards and allocates this amount among the various source categories. It concludes with a description of the margin of safety, critical conditions, and seasonal variation associated with the sediment TMDL.

4.1. Numeric Targets

The applicable water quality objectives for sediment for the Navarro River and its tributaries are listed in Table 2-1. The in-stream targets identified below are based on the Regional Water Board staff's interpretation of these objectives, specifically how increased sediment delivery causes nuisance and adversely affects beneficial uses (Regional Water Board 2000a). These targets are in-stream sediment conditions which reflect good conditions for cold water fishery species present in the Navarro and its tributaries. They are indicators of in-stream sediment supply and stream "health."

In addition, hillslope targets (i.e., targets applying to the hillslopes adjacent to streams) are identified as a means of evaluating the degree to which sediment production problems, and the associated risk of future delivery to streams (and, thus, overall watershed and future in-stream health), are addressed.

Of course, the ultimate indicator of success is that of increasing returns of adult salmonids. However, since other processes beyond freshwater quality are significant, fish populations alone cannot be used as the gauge for determining decreasing impairment due to effects of sedimentation (i.e., desirable freshwater habitat conditions may be attained before salmonid populations recover).

Because of the inherent variability associated with stream channel conditions, it is appropriate to evaluate the attainment of the in-stream numeric targets based on a weight-of-evidence approach. No single parameter may be indicative of the health of the stream, but when considered together, the parameters are expected to provide a good indication of the condition of the stream.

The targets are divided into short-, mid-, and long-term categories, depending on how long it is expected to take for the target parameter to respond to changes.

4.1.1 Short-term Numeric Targets and Indicators

Short-term targets are for in-stream and up-slope parameters that respond relatively quickly (a few years). Short-term in-stream targets are expected to respond quickly to changes in sediment delivery to streams. (For instance, V* surveys are expected to respond to changes in the supply of fine sediments soon after those changes occur.) Similarly, changes in short-term targets for up-slope parameters are expected to result quickly in reductions of sediment production. (For example, decreases in the hydrologic connectivity between roads and streams are expected to decrease the delivery of road-related surface erosion soon after implementation.) Though the targets are called short-term targets (because they can be attained relatively quickly), they apply over the life of the TMDL.

V* # 15%: Lower-order Streams

V* (pronounced "vee-star") is a measure of the fraction of a pool's volume that is filled by fine sediment and is representative of the in-channel supply of mobile bedload sediment (Lisle and Hilton 1992, as cited in Regional Water Board 2000a). Lisle and Hilton (1999, as cited in Regional Water Board 2000a) demonstrated the usefulness of the parameter by comparing annual sediment yields of select streams with their average V* values. The comparison indicated that V* was well correlated to annual sediment yield. Lisle and Hilton also demonstrated that V* values can quickly respond to changes in sediment supply. V* values in French Creek, a tributary to the Scott River, decreased to approximately one-third the initial value soon after an erosion control program focusing on roads was implemented. A study of more than sixty streams in the Franciscan geology of Northern California found that a mean V* value of 21% represented good stream conditions (Knopp 1993, as cited in Regional Water Board 2000a). Knopp's study was conducted after a period of drought that many believe had affected the results. Lisle and Hilton (1999, as cited in Regional Water Board 2000a) reported that V* values for Elder Creek, an undisturbed tributary of the South Fork Eel River in Coastal Belt Franciscan Geology, averaged only 9%. Therefore, the numeric target for V* in the Navarro and its tributaries is the average of 21% and 9%, which is 15%. The V* target applies to lower-order streams as a short-term indicator. It does not apply to higher-order streams on a short-term basis, because higher-order streams are not expected to be as responsive to changes in short-term sediment delivery, due to the high amounts of fine sediments currently stored as in-stream deposits.

Fine Sediment Volume of the Active Bed Matrix: Decreasing Trend

The fine sediment volume of the matrix material of the active bed is the volume of fine sediment in the subsurface of gravel bars. It is included as a method of tracking trends of in-stream fine sediment storage. The parameter is also intended to aid in interpretation of V* trends, and eventually as a means of describing changes in sediment supply. Volumes should be measured as described in Lisle and Hilton (1999, as cited in Regional Water Board 2000a). No particular value is set as a target, only a decreasing trend in the volume stored.

Percent Fines # 0.85 mm: # 14%

The percent fines # 0.85 is defined as the percentage of subsurface fine material in pool tail-outs # 0.85 mm in diameter. This parameter is chosen as one of two surrogate measurements of spawning gravel suitability. The numeric target for this parameter is 14% based on the average of values reported for unmanaged streams in the studies by Peterson et al. (1992, as cited in Regional Water Board 2000a) and Burns (1970, as cited in Regional Water Board 2000a).

Percent Fines # 6.4 mm: # 30%

The percent fines #6.4 mm is defined as the percentage of subsurface fine material in pool tail-outs # 6.4 mm in diameter. This parameter is chosen as the second of two surrogate measurements of spawning gravel suitability. The numeric target for this parameter is 30% based on Kondolf's (2000, as cited in Regional Water Board 2000a) summary of information reported in various studies.

Hydrologic Connectivity of Roads: # 10%

Hydrologic connectivity of roads, defined as the proportion of road length draining to a stream, is chosen as an indicator of sediment yield. Hydrologic connectivity is both an easily determined and easily correctable parameter that can result in immediate reductions in sediment yields associated with road surface erosion when treated. Hydrologic connectivity data from forty miles of roads in the Navarro watershed collected by Pacific Watershed Associates showed hydrologic connectivity was 56%. The target value of 10% is based on Regional Water Board staff's best professional judgment of what amount of reduction is possible (Regional Water Board 2000a).

Diversion Potential: < 1%

Diversion potential is defined as the potential for a stream to be diverted out of its channel as a result of a plugged stream crossing. Like hydrologic connectivity, diversion potential is easily identifiable and correctable. This parameter is chosen as an indicator of risk of sediment delivery. The condition in itself is not a sediment contributor, but is a condition that greatly elevates the consequences of stream crossing failure. The numeric target is the elimination of diversion potential at all stream crossings except those that cannot be corrected without compromising safety, which are expected to comprise approximately 1% of all stream crossings.

Stream Crossings with High Risk of Failure: # 1%

Risk of stream crossing failure is related to the size and configuration of the crossing. The NMFS stream crossing guidelines (NMFS 2000, as cited in Regional Water Board 2000a) include a requirement that rural stream crossings have the hydraulic capacity to accommodate the 100-year flood flow. Flanagan et al. (1998, as cited in Regional Water Board 2000a) have described other factors that increase risk of failure, such as culvert slope, width, and inlet basin configuration. The numeric target for stream crossings is stream crossing with a high risk of failure will be reduced to 1%. This will not apply to stream crossings that cannot be corrected without compromising safety.

4.1.2. Mid-term Numeric Targets and Indicators

Mid-term targets are for parameters that are expected to improve as a result of restoration activities, but only after storm events of sufficient frequency and magnitude have occurred. This may take a decade or more.

V* # 15%: Higher-order Streams

The fraction of a pool's volume filled with fine sediment, V*, should be monitored in higher-order streams to evaluate the effectiveness of restoration efforts. This parameter is considered a mid-term target due to the amount of fine sediment currently existing in the channels of the Navarro and its tributaries.

Residual Pool Depth: 2 feet for First and Second Order Channels, 3 feet for Higher-order Channels

Residual pool depth is defined as the maximum depth of a pool minus the maximum depth of its riffle crest (i.e., the depth of the pool at the point of zero flow). Flosi et al. 1998, as cited in Regional Water Board 2000a, indicates that the better coho streams have as much as 40 percent of their total length in primary pools. The numeric target for residual pool depth is an average of no less than two feet for first and second order channels and three feet for third and greater channels.

Stream Crossing Failures: Decreasing Trend

The objective of this parameter is to assess the degree to which stream crossing improvements are effective in reducing the delivery of sediments. Although high-risk stream crossings can be treated in a short time period, the effectiveness of those treatments will not be known until large storm events test their adequacy.

Since large storm events are infrequent, it is unlikely that the effectiveness of stream crossing treatments can be assessed until at least a decade has passed.

Thalweg Variability: Increasing Trend

Thalweg variability is defined as the deviation of the thalweg (the deepest part of the channel) from the average channel slope. It is chosen as a surrogate measure of channel complexity. As the sediment load decreases and the frequency and depth of pools increases (thereby improving habitat for fish), the thalweg profile develops more dramatic variation around the mean profile slope. No specific numeric value is set as the target, only an increasing trend.

4.1.3. Long-term Numeric Targets and Indicators

Long-term targets and indicators are for parameters which are dependent on infrequent hydrologic events. Targets related to pools and landslides are identified which may not respond to changed land-management practices for decades. The proportion of pools may not change, regardless of reductions in sediment delivery, until a large flood occurs which reconfigures the entire stream channel. Likewise, a decrease in road-related landslides may not be apparent for decades, because landslides are often triggered only by major rainfall events.

Proportion of Stream Length in Pools: 40%

Habitat data from all sub-watersheds indicate that pool frequency may be a factor limiting the rearing capacity of streams in the Navarro watershed. Frequent pools are necessary summer rearing habitat for salmonids, particularly coho. CDFG data indicates that the better coho streams have as much as 40 percent of their total length in primary pools (Flosi et al. 1998, as cited in Regional Water Board 2000a).

Road-related Landslides: Decreasing Trend

Appropriate location, design, construction, and maintenance of roads are expected to result in a reduction in the rate of road-related landslides.

4.1.4. Additional Targets and Indicators

We have added the following targets as recommended by NMFS. We encourage the Regional Water Board to work with NMFS and others to define monitoring protocols and establish priorities, during the preparation of the monitoring and implementation measures.

Aquatic Insect Production: Improving Trends

Benthic macroinvertebrate populations are greatly influenced by water quality and can be adversely affected by excess fine sediment. The target is for improving trends in three indicators: the EPT Index, the Percent Dominant Taxa, and the Richness Index. The EPT Index is the number of species of mayflies, stoneflies, and caddisflies in a sample. These insects generally require high water quality and respond rapidly to improving or degrading conditions. The Percent Dominant Taxa indicator is calculated by dividing the number of organisms in the most abundant taxa by the total number of organisms in the sample. Collections dominated by one taxa generally represent a disturbed ecosystem. The Richness Index is the total number of taxa represented in the sample. Higher diversity can indicate better water quality. Target conditions are expressed as improving trends, because appropriate thresholds have not been developed.

Backwater Pools: Increasing Trend

Backwater pools are used by salmonids as overwintering habitat. In particular, they provide shelter from high storm flows. We are specifying the target as a trend, rather than a specific number, in part because no standard methodology is available at this time.

Large Woody Debris: Increasing Trend

Large woody debris (LWD) affects the storage, routing and sorting of sediment, as well as channel for and other aquatic habitat conditions such as cover, pool depths and distribution, temperature and bank stability (Lisle 1986, Bilby and Ward, 1989). We are specifying the target as a trend, rather than a specific number, in part because no standard methodology is available at this time.

Unstable Areas: Avoid activities that trigger erosion

Features such as steep slopes, headwall swales, inner gorges, and streambanks inherently have a high risk of landsliding. The target is to avoid any activity that might trigger an erosional event in unstable areas (e.g., road building, harvesting, yarding, or terracing for vineyards). For example, a detailed geological assessment could be performed by a certified engineering geologist to show there is no potential for increased sediment delivery to a watercourse as a result.

Road Location, Surfacing, and Sidecast: Prevent sediment delivery

Targets to prevent sediment delivery from road location, surfacing, and sidecast because these road-related conditions pose a high risk of sediment delivery. For example, for road location, roads in inner gorge areas or in potentially unstable headwall areas could be removed, unless alternative road locations are unavailable and need for road is clearly justified. For road surfacing, roads should have surfacing, drainage methods and maintenance appropriate to their use patterns and intensities. To prevent sediment delivery from sidecast, fill on steep (greater than 50%) or potentially unstable slopes, that could deliver sediment to a watercourse slopes, could be pulled back or otherwise stabilized.

Road Maintenance: Prevent Sediment Delivery

The target is that every road should prevent sediment delivery. For example, roads can be inspected and the areas with the greatest potential for sediment delivery to a watercourse can be corrected annually prior to winter, or the road could be decommissioned or hydrologically closed or disconnected (i.e., fills and culverts removed, natural hydrology of hillslope largely restored).

4.2. Source Analysis

The purpose of the sediment source analysis is to identify the various erosion processes in the Navarro watershed and to estimate the sediment yield from those sources in a way that allows them to be compared to each other. The approach taken focuses on rates of sediment yield that have occurred in the recent past (i.e., past twenty years).

The estimated rates are based on studies performed in the Navarro watershed, studies performed in nearby watersheds, interpretation of aerial photographs, and other published literature relating to sediment yield processes. A significant amount of information, including estimates of sediment yield from hillslope and streamside processes, came directly from the Navarro Watershed Restoration Plan (Entrix et al. 1998, as described in Regional Water Board 2000a). Data describing current conditions of rural roads were provided to Regional Water Board staff by Danny Hagans of Pacific Watershed Associates. Information pertaining to sediment yield on industrial forestlands was taken from the Albion Watershed Analysis (Mendocino Redwood Company 1999, as cited in Regional Water Board 2000a) and the Garcia Watershed Analysis (Louisiana-Pacific Corporation 1998, as cited in Regional Water Board 2000a). Regional Water Board staff (Regional Water Board 2000a) compared aerial photographs for the entire watershed taken in 1996 to photographs taken in 1984 to quantify sources of erosion (e.g., landslides and gullies) and their associated land uses, to provide information on roads, and to quantify the location and extent of lands under cultivation. In response to comments, Regional Water Board reviewed and revised the acreage of vineyards (Regional Board, 2000b.) The revision resulted in increased estimates of sediment production from vineyard erosion.

The results of the sediment source analysis are presented in Table 4-1. Human-caused sources account for about 40% of the total sediment yield of the Navarro watershed. Road-related sources dominate other anthropogenic sources, reflecting the dominant land uses in the watershed, specifically timber production and ranching, which use a vast network of roads. Vineyards, which occupy only about 2 percent of the watershed, have the potential to cause locally significant deleterious impacts.

Table 4-1. Results of Sediment Source Analysis (1984-1996)

Sediment Source	Estimated Average Yield (tons/mi^2/yr)						
	Anderson	Indian	Main-stem	North Fork	Rancheria	Entire Watershed	
Shallow Landslides	180	210	150	160	200	180	Natural: 1170
Deep-Seated Landslides	0	0	250	0	130	90	
Gullies	550	270	60	30	380	250	
Bank Erosion	80	60	40	50	70	60	
Inner Gorge / Streamside Delivery	1180	400	510	280	670	590	
Road-Stream Crossing Failures	100	80	140	160	130	130	Human-caused: 775 (Roads: 620)
Road-related Mass Wasting	90	80	140	150	110	120	
Road-related Gullying	90	90	150	150	110	120	
Road-related Surface Erosion	220	210	320	210	250	250	
Skid Trail Erosion	10	20	50	70	30	40	

Vineyard Erosion	120	0	180	5	5	55	
Management-related Mass Wasting	60	70	50	50	60	60	
Totals	2680	1490	2040	1315	2145	1945	

4.3. Linkage Analysis, Loading Capacity, and TMDL

The purpose of the linkage analysis is to estimate the extent of reductions in sediment sources needed to attain applicable water quality standards in the Navarro River and its tributaries. The loading capacity is the estimate of the total amount of sediment, from either natural or human-caused sources, that can be delivered to streams in the Navarro watershed without exceeding applicable water quality standards. In the case of the Navarro and its tributaries, the loading capacity is based on an analysis of the amount of human-caused sediment delivery that can occur in addition to natural sediment delivery without causing adverse impacts to coho and steelhead.

This approach entailed estimating a sediment delivery rate for the watershed at a period when salmonids were abundant and comparing this to an estimated rate of natural sediment delivery. There are no sediment delivery data for the Navarro watershed at a time when salmonids were abundant. Therefore, data for a nearby watershed, the Noyo River watershed, was used in this analysis. Salmonids were abundant in the Noyo and its tributaries during the 1930s - 1950s period, so the corresponding sediment yield during this period must have been sufficiently low to allow salmonid habitat of suitable quality to persist. In the Noyo River Total Maximum Daily Load for Sediment, the total sediment yield during this period was estimated at 470 tons/mi^2/yr and the natural sediment yield was estimated at 370 tons/mi^2/yr (EPA 1999, as cited in Regional Water Board 2000a). Thus, the anthropogenic load during this period was roughly 25% of the natural load (or, equivalently, 20% of the total load).

This 25% factor is applied to the Navarro, because of the proximity of the Noyo to the Navarro, as well as their similarities in vegetation, climate, geology, and land use history. Because of the differences between the two watersheds, we do not use the actual delivery amounts from the Noyo in setting the TMDL; rather, we use the ratio of natural/anthropogenic. Thus, the loading capacity of the Navarro and its tributaries for sediment is the estimated natural sediment delivery rate plus 25%. Multiplying 1170 tons/mi^2/yr by 1.25 equates to approximately 1463 tons/mi^2/yr. Therefore, 1463 tons/mi^2/yr is the TMDL for sediment for the Navarro River and its tributaries. Given the hydrologic variability typical of the Northern California Coast Ranges, EPA expects the TMDL to be evaluated as a ten-year rolling average.

4.4. Load Allocations

In accordance with EPA regulations, the loading capacity (i.e., TMDL) must be allocated to the various sources of sediment in the watershed. As there are no known point sources of sediment into the Navarro River and its tributaries, the wasteload allocation for point sources is set at zero. Thus, the TMDL for sediment for the Navarro River and its tributaries is divided among the categories of nonpoint sources of sediment identified in the source analysis, as load allocations, with a margin of safety.

The load allocations are calculated by applying different percentage reductions from the current sediment delivery rates by category of human-caused sources. The total allowable human-caused sediment yield equals the loading capacity (1463 tons/mi^2/yr) minus the natural sediment yield (1170 tons/mi^2/yr), which equates to 293 tons/mi^2/yr. The analysis indicates that the current human-caused sediment yield is 775 tons/mi^2/yr, therefore reductions are needed. In response to concerns that the equal reduction of 60% proposed would reward those that discharge more sediment, EPA and the Regional Water Board revised the method of calculating allocations. Instead, best professional judgement of Regional Water Board staff on the ease or difficulty of reducing sediment from sources was used. These percentages are given in Table 4-2 with the resulting allocations. For example, reducing road surface erosion has well known best management practices and thus this category was reduced 80%. Conservation practices for vineyards - cover crops, contouring, filter strips and sediment traps - are well known and successful. Considering this and Regional Water Board's observations that current practices are generally poor, EPA is now specifying an allocation for vineyards based on a reduction of 80% from current estimated levels. Mass wasting is more difficult to predict and avoid, so we are specifying a reduction of 40% (Regional Board, 2000b.)

Table 4-2. Load Allocations

Sediment Source	**Current Load (tons/mi^2/yr) and percent load reduction**	**Load Allocation (tons/mi^2/yr)**
Natural Sources		
Shallow Landslides	180 (0%)	180
Deep-seated Landslides	90 (0%)	90
Gullies	250 (0%)	250
Bank Erosion	60 (0%)	60
Inner Gorge / Stream-side Delivery	590 (0%)	590
Subtotal	*1170*	*1170*
Anthropogenic Sources		
Road-Stream Crossing Failures	130 (50%)	65
Road-related Mass Wasting	120 (43%)	69
Road-related Gullying	120 (65%)	42
Road-related Surface Erosion	250 (80%)	50
Skid Trail Erosion	40 (50%)	20
Vineyard Erosion	55 (80%)	11
Management-related Mass Wasting	60 (40%)	36
Subtotal	*775*	*293*
Totals	1945	1463

The load allocations are expressed in terms of watershed average tons/mi^2/yr. They could be divided by 365 to derive daily loading rates (tons/mi^2/day), but EPA is expressing them as yearly averages, because sediment delivery to streams is naturally highly variable on a daily basis. In fact, EPA expects the load allocations to be evaluated on a ten-year rolling average basis, because of the variability in sediment delivery rates. In addition, the allocations are intended to apply on an average basis for the entire source category, even though the allocations are expressed in terms of square miles. In other words, EPA does not expect that each square mile within a particular source category will meet the load allocation; rather, EPA expects the average for the entire source category to meet the load allocation for that category.

4.5. Margin of Safety, Seasonal Variation, and Critical Conditions

Section 303(d) requires that TMDLs include a margin of safety to account for uncertainties. The margin of safety can be incorporated into conservative assumptions used to develop the TMDL, or added as separate quantitative component of the TMDL. The Navarro River sediment TMDL incorporates an implicit margin of safety based on conservative assumptions employed in the source analysis. The following examples illustrate the conservative assumptions which constitute the margin of safety.

- A conservative estimate of erosion rates for vineyards was used to address the uncertainty related to the lack of data on vineyard erosion processes.

- A conservative estimate of the rate of road gullying was used to address the uncertainty associated with the lack of data describing sediment delivery associated with road-related gullies.

- A conservative assumption that all unpaved rural roads are unsurfaced was used to address the uncertainty in the estimate of road surface erosion resulting from the lack of information on the proportion of unpaved rural roads that are rock surfaced.

- A conservative assumption that the entire contribution of bank erosion and inner gorge processes is natural was used to address the uncertainty associated with the relation of accelerated sediment yield, increased in-channel storage, and the resulting increased vulnerability of stream banks and inner gorge hillslopes. In fact, there is likely to be some decrease in bank erosion and inner gorge sediment delivery as restoration activities decrease up-slope erosion sources.

- Overall, the use of 125% of natural is a conservative assumption. Although salmonids can likely thrive in less than pristine conditions (which would be 100%) and there were healthy populations during the period of the 1940s (represented by 125% of natural) it is likely that the actual level that is the “maximum allowable” is greater than 125%. Therefore the use of 125% is a conservative assumption.

The TMDL must also account for critical conditions and seasonal variation. Sediment delivery to streams is an inherently seasonal phenomenon, with a disproportionate amount of erosion taking place in association with the winter rainy season. Sediment delivery is also variable on an annual basis, with considerably more sediment production occurring in years with large storms. To account for this normal inter-seasonal and inter-annual variability, the TMDL and load allocations are expressed as ten year rolling averages. Similarly, the approach used in this TMDL is to identify indicators that are reflective of the net effects over multiple years.

CHAPTER 5: IMPLEMENTATION AND MONITORING RECOMMENDATIONS

The main responsibility for water quality implementation and monitoring resides with the States. EPA expects the State to develop and submit implementation measures to EPA (as part of revisions to the State water quality management plan) when it adopts and submits the TMDLs for temperature and sediment. The State implementation and monitoring measures for temperature and sediment should contain provisions for ensuring that the load allocations in the TMDLs will in fact be achieved. These provisions may be non-regulatory, regulatory, or incentive-based, consistent with applicable laws and programs, including the State's recently upgraded non-point source control program. In addition, the measures should include a public participation process and appropriate recognition of other relevant watershed management processes, such as local source water protection programs, state programs under Section 319 of the Clean Water Act, or State continuing planning activities under Section 303(e) of the Clean Water Act.

EPA encourages the State and landowners to work together to implement fully the implementation and monitoring measures. EPA intends to review the implementation and monitoring measures and to play an active role in assessing whether the measures will ensure that the load allocations are met.

Specific monitoring recommendations for temperature include a focused, coordinated monitoring study by the State of California (including CDFG, Division of Water Rights and Regional Water Board) that studies the flow and temperature patterns of areas with current diversions. This would reduce the uncertainty regarding the spatial extent of possible temperature problems from flow and estimates of all diversions.

Implementation for temperature should include a program to continue to field test the temperature allocations (effective shade targets) and possible studies on averaging and monitoring techniques for shade.

CHAPTER 6: PUBLIC PARTICIPATION

EPA regulations require that TMDLs be subject to public review (40 CFR 130.7). EPA provided public notice of the draft Navarro River temperature and sediment TMDLs by placing a notice in the Santa Rosa Press Democrat, Anderson Valley Advertiser, and Mendocino Beacon, newspapers of general circulation in the Navarro River watershed. EPA held an informal public meeting on Tuesday, 3 October 2000, and together with the Regional Water Board described the draft TMDLs and answered clarifying questions regarding the draft TMDLs. The meeting was held at the Apple Hall Dining Room at the Mendocino County Fairgrounds in Boonville. EPA prepared a written response to all written comments on the draft TMDLs received by EPA through the close of the comment period (16 October 2000). Comments were received from eighteen persons. In response to comments, the Regional Water Board conducted additional modeling on flow and additional research on vineyard acreage. A technical addendum was prepared and the draft TMDL has been revised.

The EPA draft TMDLs are based in large part on the TSD prepared by Regional Water Board staff (Regional Water Board 2000a). Regional Water Board staff provided for public participation in the development of the TSD through both meetings, presentations and a newsletter as described in the TSD (Regional Water Board 2000a). In addition, all materials were accessible on the web.

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Glossary

Aggradation	To fill and raise the elevation of the stream channel by deposition of sediment.
Anadromous	Refers to aquatic species which migrate up rivers from the sea to breed in fresh water.
Areas of instability	Locations on the landscape where land forms are present which have the ability to discharge sediment to a watercourse.
Beneficial Use	Uses, as designated in the Basin Plan, of waters of the state that may be protected against quality degradation including, but not limited to, domestic, municipal, agricultural and industrial supply; power generation; recreation; aesthetic enjoyment; navigation; and the preservation and enhancement of fish, wildlife and other aquatic resources or preserves.
Basin Plan	The *Water Quality Control Plan, North Coast Region-- Region 1.*
CDFG	The California Department of Fish and Game.
Debris torrents	Long stretches of bare, generally unstable stream channel banks scoured and eroded by the extremely rapid movement of water-laden debris, commonly caused by debris sliding or road stream crossing failure in the upper part of a drainage during a high intensity storm.
Deep seated landslide	Landslides involving deep regolith, weathered rock, and/or bedrock, as well as surficial soil. Deep seated landslides commonly include large (acres to hundreds of acres) slope features and are associated with geologic materials and structures.
Division of Water Rights	The Division of Water Rights at the California State Water Resources Control Board.
Drainage structure	A structure or facility constructed to control road runoff, including (but not limited to) fords, inside ditches, water bars, outsloping, rolling dips, culverts or ditch drains.
Effective Shade	The percent reduction of potential solar radiation delivered to the water surface. It is the amount of shade, averaged to account for daily and seasonal cycles.
Embeddedness	The degree that larger particles (boulders, rubble or gravel) are surrounded or covered by fine sediment. It is usually measured in classes (<25%, 25-50%, 50-75%, and >75%) according to percentage of random large particles that are covered by fine sediment.
EPA	The United States Environmental Protection Agency.
Flooding	The overflowing of water onto land that is normally dry.
Fry	A young juvenile salmon after it has absorbed its egg sac and emerged from the redd.
Gaining reach	A stream or reach of a stream the flow of which is being increased by inflow of groundwater
GIS	Geographic Information System.
Inner gorge	A geomorphic feature formed by coalescing scars originating from mass wasting and erosional process caused by active stream erosion. The feature is identified as that area of

	stream bank situated immediately adjacent to the stream, having a slope generally over 65% and being situated below the first break in slope above the channel.
Inside ditch	The ditch on the inside of the road, usually at the foot of the cutbank.
Landslide	Any mass movement process characterized by downslope transport of soil and rock, under gravitational stress by sliding over a discrete failure surface-- or the resultant landform.
Large woody debris	A piece of woody material having a diameter greater than 30 cm (12 inches) and a length greater than 2 m (6 feet) located in a position where it may enter the watercourse channel.
Losing reach	A stream or reach of a stream that is losing water by seepage into the ground.
Mass wasting	Downslope movement of soil mass under force of gravity-- often used synonymously with "landslide." Common types if mass soil movement include rock falls, soil creep, slumps, earthflows, debris avalanches, debris slides and debris torrents.
MWAT	Maximum Weekly Average Temperature.
NMFS	The United State National Marine Fisheries Service.
Numeric targets	A numerical expression of the desired in-stream or hillslope environment. For each pollutant or stressor addressed in the problem statement, a numeric target is developed.
Redd	A gravel nest or depression in the stream substrate formed by a female salmonid in which eggs are laid, fertilized and incubated.
Regional Water Board	Regional Water Quality Control Board, North Coast Region.
Sediment	Fragmented material that originates from weathering of rocks and decomposed organic material that is transported by, suspended in, and eventually deposited by water or air.
Sediment delivery	Material (usually referring to sediment) which is delivered to a watercourse channel by wind, water or direct placement.
Sediment discharge	The mass or volume of sediment (usually mass) passing a watercourse transect in a unit of time.
Sediment erosion	The group of processes whereby sediment (earthen or rock material) is loosened, dissolved and removed from the landscape surface. It includes weathering, solubilization and transportation.
Sediment source	The physical location on the landscape where earthen material resides which has or may have the ability to discharge into a watercourse.
Sediment yield	The sediment yield consists of dissolved, suspended and bed loads of a watercourse channel through a given cross section in a given period of time.
Shallow seated landslide	A landslide produced by failure of the soil mantle on a steep slope (typically to a depth of one or two meters; sometimes includes some weathered bedrock). It includes debris slides, soil slips and failure of road cut-slopes and sidecast. The debris moves quickly (commonly breaking up and developing into a debris flow) leaving an elongated, concave scar.

Skid trail	Constructed trails or established paths used by tractors or other vehicles for skidding logs. Also known as tractor roads.
Steep slope	A hillslope, generally greater than 50% that leads without a significant break in slope to a watercourse. A significant break in slope is one that is wide enough to allow the deposition of sediment carried by runoff prior to reaching the downslope watercourse.
Stream	See watercourse.
Stream order	The designation (1,2,3, etc.) of the relative position of stream segments in the drainage basin network. For example, a first order stream is the smallest, unbranched, perennial tributary which terminates at the upper point. A second order stream is formed when two first order streams join. Etc.
Sub-basin	A subset or division of a watershed into smaller hydrologically meaningful watersheds. For example, the North Fork Navarro River watershed is a sub-basin of the larger Navarro River watershed.
Tail-out	The lower end of a pool where flow from the pool, in low flow conditions, discharges into the next habitat unit.
Thalweg	The deepest part of a stream channel at any given cross section.
Thalweg profile	Change in elevation of the thalweg as surveyed in an upstream-downstream direction against a fixed elevation.
TMDL	Total Maximum Daily Load.
TSD	Technical Support Document.
Unstable areas	Characterized by slide areas, gullies, eroding stream banks, or unstable soils. Slide areas include shallow and deep seated landslides, debris flows, debris slides, debris torrents, earthflows and inner gorges and hummocky ground. Unstable soils include unconsolidated, non-cohesive soils and colluvial debris.
V*	A numerical value which represents the proportion of fine sediment that occupies the scoured residual volume of a pool. Pronounced "V-star."
Watercourse	Any well-defined channel with a distinguishable bed and bank showing evidence of having contained flowing water indicated by deposit of rock, sand, gravel, or soil.
Waters of the state	Any ground or surface water, including saline water, within the boundaries of the state.
Watershed	Total land area draining to any point in a watercourse, as measured on a map, aerial photo or other horizontal plane. Also called a basin, drainage area, or catchment area.
Water quality criteria	Limits or level of water quality constituents or characteristics which are established for the reasonable protection of beneficial uses of water or the prevention of nuisance within a specific area.
Water quality objective	Water quality criteria as described in the Basin Plan.
Water quality standard	Consist of the beneficial uses of water and the water quality objectives as described in the Basin Plan.