Phase 6: Regulatory Action Selection

Final Project Report

Pajaro River Total Maximum Daily Loads for Sediment (including Llagas Creek, Rider Creek, and San Benito River)

November 2005

Regional Water Quality Control Board
Central Coast Region

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Pajaro River Sediment TMDL

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1 INTRODUCTION

The following Project Report presents Sediment Total Maximum Daily Loads (TMDLs) for the Pajaro River including, Llagas Creek, Rider Creek, and the San Benito River. The Central Coast Regional Water Quality Control Board (Water Board) staff (staff) has prepared this report. Much of the information contained in this TMDL Project Report has been obtained from a document titled, "Technical Support Document for Establishment of a Suspended Sediment Total Maximum Daily Load for the Pajaro River Watershed," prepared by Tetra Tech, Inc., in May 2004 (Tetra Tech, 2004). The Tetra Tech document presents detailed information pertaining to suspended sediment characteristics of the Pajaro River watershed for the protection of fish habitat. In addition to addressing suspended sediment issues, staff has determined that numeric targets for streambed sediment characteristics are necessary to protect invertebrate, amphibian, and fish habitat. A discussion of streambed characteristics is also included in this Project Report. Together, the numeric targets for both suspended sediment and streambed sediment characteristics will protect the beneficial uses of the Pajaro River watershed.

This Project Report has been structured to present the elements necessary for establishing sediment TMDLs for the Pajaro River including, Llagas Creek, Rider Creek, and the San Benito River, beginning with a chapter that provides a description of the problem. Following chapters include a discussion of water quality standards, numeric targets, source analysis, sediment TMDLs, and concluding with a chapter that presents TMDL implementation, tracking and evaluation.

2 PROBLEM DESCRIPTION

This chapter contains a brief description of the geographic setting of the Pajaro River watershed and a presentation of the impairments related to each waterbody.

2.1 Geographic Setting

The Pajaro River watershed encompasses approximately 1,263 square miles (807,940 acres). It is about 60 miles southeast of San Francisco and Oakland and 120 miles southwest of Sacramento (Figure 2-1). The watershed is almost 90 miles in length and varies from 7 to 20 miles in width. The Pajaro River watershed drains into the Monterey Bay and is the largest coastal stream between San Francisco Bay and the Salinas River.

The watershed lies within Monterey, San Benito, Santa Cruz, and Santa Clara counties. The city of Watsonville is located in the watershed near the confluence of the Pajaro River with Monterey Bay. Major tributaries in the watershed are the San Benito River, Tres Pinos Creek, Santa Ana Creek, Pacheco Creek, Llagas Creek, Uvas Creek, and Corralitos Creek. The watershed is predominantly mountainous and hilly, and level lands are confined to the floodplains of the Pajaro River and its major tributaries (San Jose

State University, 1994). Elevations in the watershed range from sea level where the Pajaro River enters the Monterey Bay to over 4,900 feet in the headwaters of the San Benito River.

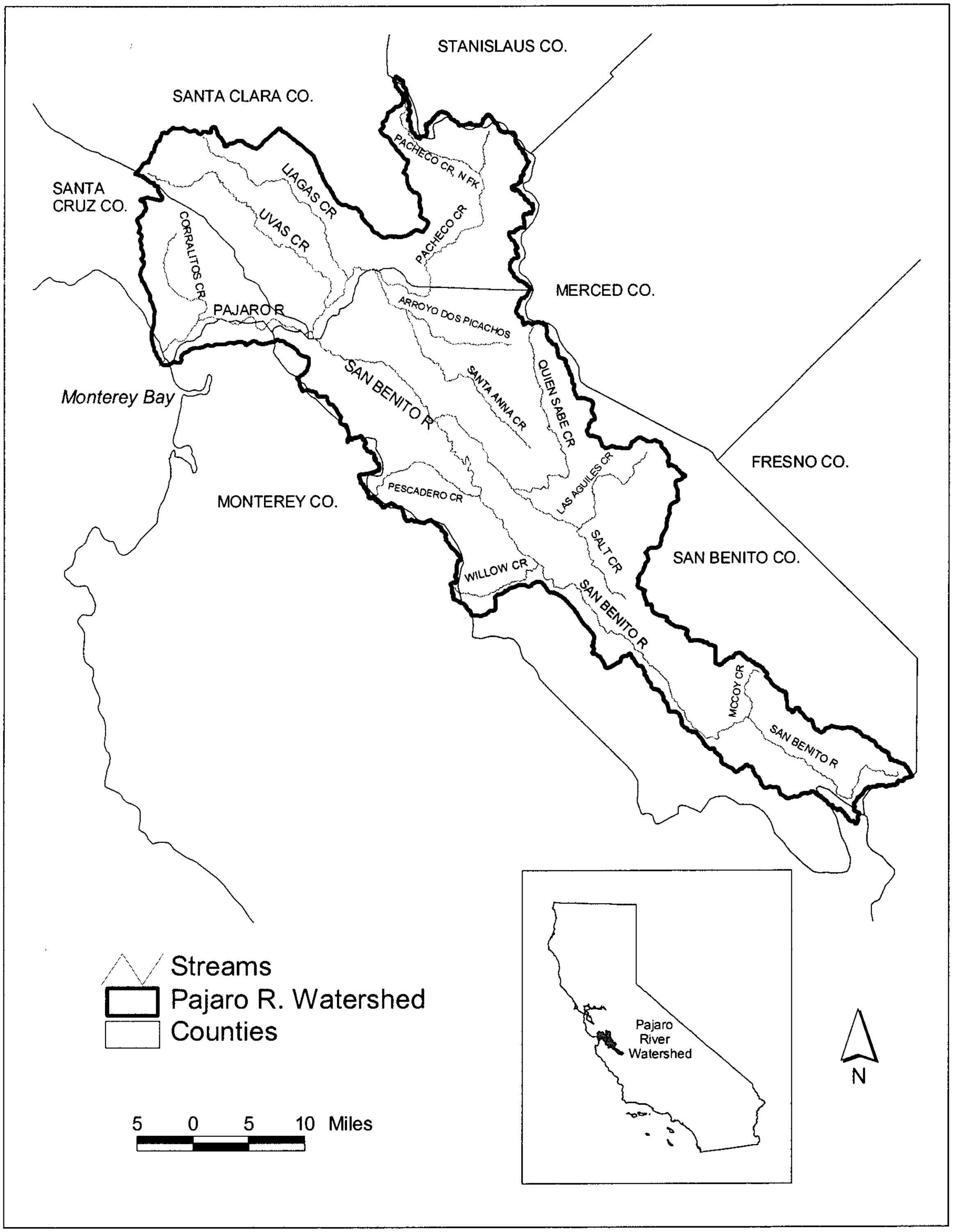


Figure 2-1. Location of the Pajaro River watershed.

2.2 Problem Statement

The Pajaro River was included on California's 1998 Section 303(d) list as impaired by sedimentation/siltation. Potential sources, as referenced on the list, were identified as agriculture, irrigated crop production, rangeland, agriculture-storm runoff, resource extraction, surface mining, hydromodification, channelization, habitat modification, removal of riparian vegetation, streambank modification, and channel erosion.

In addition to the Pajaro River, three additional waterbodies within the Pajaro River watershed are listed as impaired by sediment/siltation as summarized in Table 2-1 and depicted in Figure 2-2.

Table 2-1. Waterbodies on 1998 Section 303(d) List, Pajaro River Watershed

Waterbody	Cause	Source	Priority	Size
Pajaro River	Sedimentation/siltation	Sedimentation/siltation from agriculture, irrigated crop production, rangeland, agriculture-storm runoff, resource extraction, surface mining, hydromodification, channelization, habitat modification, removal of riparian vegetation, streambank modification, and channel erosion	Medium	32 miles
Llagas Creek	Sedimentation/siltation	Agriculture, hydromodification, habitat modification	Medium	16 miles
Rider Creek	Sedimentation/siltation	Agriculture, silviculture, construction/land development	Medium	1.8 miles
San Benito River	Sedimentation/siltation	Agriculture, resource extraction, nonpoint sources	Medium	86 miles

2.2.1 Pajaro River Sediment Impairment

The basis for including the Pajaro River on the 1998 Section 303(d) list is the report entitled *The Establishment of Nutrient Objectives, Sources, Impacts, and Best Management Practices for the Pajaro River and Llagas Creek* (San Jose State University, 1994), which compiled and collected turbidity data, measured in nephelometric turbidity units (NTU), at various locations in the watershed from the early 1950s through 1993. A summary and range of values are provided for turbidity data collected from the 1950s through 1991, while individual turbidity measurements are presented for data collected from 1992 through 1993 at seven stations in the watershed. Three of these stations were located along the Pajaro River and four were located along Llagas Creek. Pajaro River turbidity ranged from 0.4 to 240 NTU. California determined that the Pajaro River should be listed as impaired by sediment on the 1998 Section 303(d) list based on a qualitative assessment of turbidity data. The report did not specify which beneficial uses are impaired as a result of sedimentation/siltation.

2.2.2 Llagas Creek Sediment Impairment

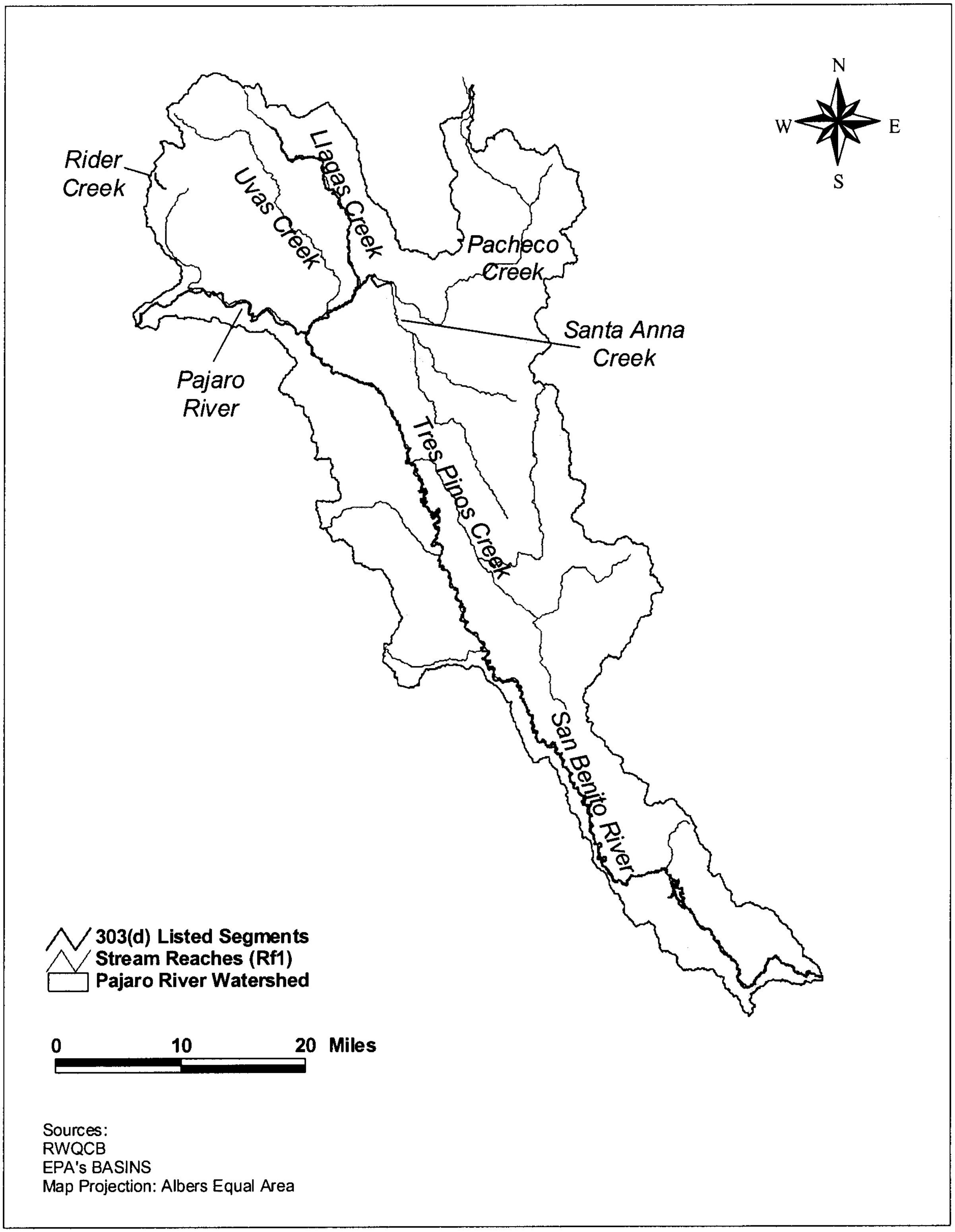
Four of the seven monitoring stations used during data collection activities for the San Jose State University study were located on Llagas Creek. Turbidity data were collected at the four stations from June 1992 through April 1993 and were used as the basis for listing Llagas Creek as impaired by sedimentation/siltation on the 1998 Section 303(d) list. Turbidity ranged from 1 to 120 NTU.

2.2.3 Rider Creek Sediment Impairment

Information in the *Rider Creek Sediment Management Plan, Santa Cruz County, California* (WRC Environmental, 1991) was used to justify listing Rider Creek on the 1998 Section 303(d) list as impaired by sediment/siltation. The report documented that "sediment export for the Rider Creek ... has been observed to bury portions of the Corralitos Creek [during baseflow conditions]... resulting in the loss of steelhead rearing habitat in Corralitos Creek." Sediment sources and export rates in the watershed were analyzed, and methods to reduce sedimentation were suggested.

2.2.4 San Benito River Sediment Impairment

Information in the *Qualitative and Quantitative Analysis of Degradation of the San Benito River* (Golder Associates, 1997) was used as the basis for listing the San Benito River as impaired due to sediments. The report concludes that the river is sediment-starved due to mining operations in the area, which have caused accelerated downcutting and increased headwater incision. The result is increased channel erosion and upward migration of streams and tributaries as the river seeks to reach equilibrium. The report also notes that channelization and low-flow road crossings are contributing factors. San Benito River was placed on the 303(d) list in 1998.



Sources:
RWQCB
EPA's BASINS
Map Projection: Albers Equal Area

Figure 2-2. Waterbodies on 1998 Section 303(d) List, Pajaro River Watershed.

3 WATER QUALITY STANDARDS

Water Quality Standards are comprised of the beneficial uses of water and the water quality objectives designed to protect those beneficial uses. The beneficial uses of water are described as either existing or potential. The water quality objectives are designed to protect the most sensitive of the beneficial uses. This section presents the beneficial uses and water quality objectives that are applicable to the Pajaro River watershed.

3.1 Beneficial Uses

The Water Quality Control Plan for the Central Coast Region (Basin Plan) establishes the beneficial uses shown in Table 3-1.

Table 3-1. Beneficial uses for 303(d) Listed Streams in the Pajaro River Watershed

Beneficial Use	**Waterbody Name**			
	Pajaro River	**Llagas Creek**	**Rider Creek**	**San Benito River**
Municipal and domestic supply	●	●	●	●
Agricultural supply	●	●		●
Industrial	●	●		●
Groundwater recharge	●	●	●	●
Water contact recreation	●	●	●	●
Non-contact water recreation	●	●	●	●
Wildlife habitat	●	●	●	●
Cold fresh water habitat	●	●	●	
Warm fresh water habitat	●	●		●
Migration of aquatic organisms	●	●	●	
Spawning, reproduction, and/or early development	●	●	●	●
Rare, threatened, or endangered species		●		
Freshwater replenishment	●			●
Commercial and sport fishing	●	●	●	●

3.2 Water Quality Objectives

The Basin Plan contains general objectives for all inland surface waters, enclosed bays, and estuaries. General objectives applicable to the Pajaro River watershed impairments, including suspended materials, settleable material, sediment, and turbidity, are listed in Table 3-2.

Table 3-2. Applicable General Objectives

Parameter	General Objective
Suspended materials	Waters shall not contain suspended material in concentrations that cause nuisance or adversely affect beneficial uses.
Settleable materials	Waters shall not contain settleable material in concentrations that result in deposition of material that causes nuisance or adversely affects beneficial uses.
Sediment	The suspended sediment load and suspended sediment discharge rate of surface waters shall not be altered in such a manner as to cause nuisance or adversely affect beneficial uses.
Turbidity	Waters shall be free of changes in turbidity that cause nuisance or adversely affect beneficial uses. Increases in turbidity attributable to controllable water quality factors shall not exceed the following limits: Where natural turbidity is between 0 and 50 Jackson turbidity units (JTU), increases shall not exceed 20 percent; Where natural turbidity is between 50 and 100 JTU, increases shall not exceed 10 JTU; Where natural turbidity is greater than 100 JTU, increases shall not exceed 10 percent. Allowable zones of dilution within which higher concentrations will be tolerated will be defined for each discharge in discharge permits.

The general objective for turbidity is of limited use in developing TMDLs because Jackson Turbidity Units are the antiquated unit for measuring turbidity and the majority of recent turbidity data (from 1990 to the present) were measured in NTU. No known conversion between the two measures is currently available.

With the exception of the turbidity objective, no numeric water quality criteria relating to sedimentation/siltation impairments are available. However, excessive sedimentation has caused an exceedance of the narrative, general water quality objective for sediment because sediment load and rate have interfered with the beneficial uses of these waterbodies including, fish and wildlife (COLD, MIGR, and SPWN).

4 NUMERIC TARGETS

This section describes the two categories of numeric targets that have been selected for the Pajaro River Watershed Sediment TMDLs, suspended sediment concentration and streambed characteristics. Together, the suspended sediment and streambed numeric targets are designed to protect the beneficial uses of the Pajaro River watershed.

Since only narrative water quality objectives exist to protect beneficial uses, numeric targets that interpret or translate the narrative objectives were developed. Of the beneficial uses in the Pajaro River watershed, those related to cold and warm water habitat including spawning, migration, and rearing would require the most stringent sediment limits[1]. The targets have therefore been selected in an effort to be most protective of these uses. Data on steelhead trout and local warm water fish communities (e.g., threespine stickleback, pikeminnow, prickly sculpin, sucker, California roach, speckled dace, carp, and Sacramento blackfish) in the Pajaro River watershed were assembled in an effort to identify sediment characteristics considered to be protective of those species.[2] Because the sediment requirements of cold water species such as steelhead are more stringent than those for warm water fishes, target selection focuses on cold water species.

It is important to keep in mind that the numeric targets for the Pajaro River watershed are *targets*, not water quality objectives. They are meant to express the goals we hope to eventually achieve through improved land management and restoration. They are not, however, standards upon which regulatory action will be taken, and therefore are not themselves enforceable. Landowners, land managers and the public should view the numeric targets as guideposts which serve to assist groups in evaluating the success of their work.

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[1] Benthic invertebrates for example, could require even more stringent limits, but information regarding such requirements is not available at this time.

[2] Steelhead trout (*Oncorhynchus mykiss*) in the Pajaro River are at high risk for extinction. There has been a substantial decline in steelhead population over the past 30 years in the South-Central California Coast Region, which includes the Pajaro River. It is estimated that steelhead numbers in the Pajaro River have decreased from more than 1,000 in the 1960s to less than 100 in 1991 (NOAA 1996). Reasons for the decrease in population size include minor habitat blockages such as small dams and impassable culverts, as well as forestry practices and dewatering due to irrigation and urban water diversions.

4.1 Numeric Targets for Suspended Sediment

Suspended sediment numeric targets have been structured to incorporate the Severity of Ill Effects framework within the dynamic system of the Pajaro River watershed (Tetra Tech). In general, the Severity of Ill Effects provides a metric by which to estimate suspended sediment concentration and duration that may result in deleterious effects upon fish. To represent the dynamic hydrologic and sediment delivery mechanisms of the Pajaro River watershed, a watershed model was developed to evaluate various sediment loading conditions. Together, the Severity of Ill Effects and the conditions represented by the watershed model are used to establish the numeric targets. Methods used to develop suspended sediment numeric targets are discussed in greater detail in the following sections.

4.1.1 Severity of Ill Effects

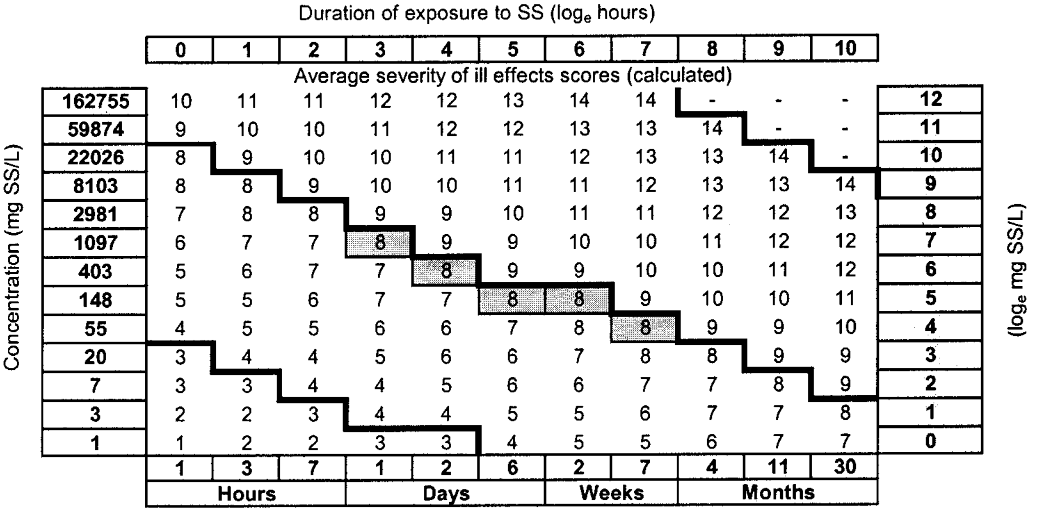
The framework for expressing suspended sediment targets is based on the work of Newcombe and Jensen, as contained in their article, "Channel Suspended Sediment and Fisheries: A Synthesis for Quantitative Assessment of Risk and Impact"(Newcombe and Jensen, 1996). Based on their meta-analysis of eighty (80) published and adequately documented reports on fish responses to suspended sediment, Newcombe and Jensen created a semi-quantitative index, the "Severity of Ill Effects" (SEV) scale. The SEV scale defines qualitative fish response data to various sediment concentration-duration scenarios and is represented in Table 4-1.

Table 4-1. Severity-of-Ill Effects Scale

SEV		**Description of Effect**
Nil effect	0	No behavioral effect
Behavioral effects	1	Alarm reaction
	2	Abandonment of cover
	3	Avoidance response
Sublethal effects	4	Short-term reduction in feeding rates; short-term reduction in feeding success
	5	Minor physiological stress; increase in rate of coughing; increased respiration rate
	6	Moderate physiological stress
	7	Moderate habitat degradation; impaired homing
	8	Indications of major physiological stress; long-term reduction in feeding rate; long-term reduction in feeding success; poor condition
Lethal and paralethal effects	9	Reduced growth rate; delayed hatching; reduced fish density
	10	0-20% mortality; increased predation; moderate to severe habitat degradation
	11	>20%-40% mortality
	12	>40%-60% mortality
	13	>60%-80% mortality
	14	>80%-100% mortality

Source: Newcombe and Jensen, 1996

Expression of the suspended sediment numeric targets is based on Newcombe and Jensen's predicted regression model for juvenile and adult salmonids[1]. This model is one of six they developed and best represents the species and life cycles observed in the Pajaro River system. For visualization, Figure 4-1 presents the predicted dose/response matrix for the model.



Concentration (mg SS/L)	0	1	2	3	4	5	6	7	8	9	10	($\log_e$ mg SS/L)
	Duration of exposure to SS ($\log_e$ hours) Average severity of ill effects scores (calculated)											
162755	10	11	11	12	12	13	14	14	-	-	-	**12**
59874	9	10	10	11	12	12	13	13	14	-	-	**11**
22026	8	9	10	10	11	11	12	13	13	14	-	**10**
8103	8	8	9	10	10	11	11	12	13	13	14	**9**
2981	7	8	8	9	9	10	11	11	12	12	13	**8**
1097	6	7	7	8	9	9	10	10	11	12	12	**7**
403	5	6	7	7	8	9	9	10	10	11	12	**6**
148	5	5	6	7	7	8	8	9	10	10	11	**5**
55	4	5	5	6	6	7	8	8	9	9	10	**4**
20	3	4	4	5	6	6	7	8	8	9	9	**3**
7	3	3	4	4	5	6	6	7	7	8	9	**2**
3	2	2	3	4	4	5	5	6	7	7	8	**1**
1	1	2	2	3	3	4	5	5	6	7	7	**0**
	1	**3**	**7**	**1**	**2**	**6**	**2**	**7**	**4**	**11**	**30**	
	Hours			**Days**			**Weeks**		**Months**			

Figure 4-1. Predicted dose/response matrix for model.

For a given sediment dose (concentration and duration), the matrix shows the corresponding SEV score as predicted by the regression model. For example, a suspended sediment concentration of 8,103 mg/L for a period of 2 days would be expected to produce an SEV of 10. The SEV cell values are separated by diagonal terraced lines denoting thresholds of sublethal effects (lower left) and lethal effects (middle diagonal) with reference to the four response categories listed in Table 4-1. Grey boxes surrounding SEV-8 in the 1 day to 7-week range highlight the area of focus for this study. The selection of SEV-8 is further described in following paragraphs. Axes are shown in logarithmic (top and right side) and absolute (bottom and left side) terms. The concentration and duration values shown in the matrix are the median values of the range of concentrations and durations associated with a predicted SEV. The range of logarithmic values represented by a row or column is approximately the value ±0.49999 in log units. The absolute value ranges are obtained by calculating the antilog values of the log ranges. For example, the suspended sediment concentration of 1,097 mg/L is representative of the range from approximately 665 mg/L to approximately 1,808 mg/L as shown in Table 4-2.

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[1] The regressions, fit to the data, produced predictive models of the form

$z = a + b(\log_e x) + c(\log_e y)$, Where:

z = calculated severity of ill effect,
x = an estimate of exposure duration, and
y = concentration of the suspended sediment (mg SS/L).

For Juvenile and Adult Salmonids, intercept (a) = 1.0642, slope of $\log_e x$(b) = 0.6068, and slope of $\log_e y$(c) = 0.7384.

Table 4-2. Concentration Ranges for Predicted SEV[a]

Absolute Value Concentration (SS mg/L)	$\log_e$ Concentration (SS mg/L)	$\log_e$ Concentration Range (SS mg/L)	Absolute Value Concentration Range (SS mg/L) [b]
162755	12	11.50001 - 12.4999	98716.75 – 268310.45
59874	11	10.50001 - 11.4999	36315.86 – 98716.75
22026	10	9.50001 - 10.4999	13359.86 – 36315.86
8103	9	8.50001 - 9.4999	4914.81 – 13359.86
2981	8	7.50001 - 8.4999	1807.86 – 4914.81
1097	7	6.50001 - 7.4999	665.07 – 1807.86
403	6	5.50001 - 6.4999	244.69 – 665.07
148	5	4.50001 - 5.4999	90.01 – 244.66
55	4	3.50001 - 4.4999	33.11 – 90.00
20	3	2.50001 - 3.4999	12.18 – 33.11
7	2	1.50001 - 2.4999	4.48 – 12.18
3	1	0.50001 - 1.4999	1.64 – 4.48

[a] Based on Juvenile and Adult Salmonids Model ; [b] Values are rounded

As expected, the dose matrix shows regular increases of response severity with increasing doses. For example, a sediment concentration between 665 and 1,808 mg/L that lasts for at least a 24-hour period (1 day) might be expected to elicit a physiological response categorized as an '8' on the SEV scale, producing major physiological stress in fish (See Figure 4-1). This would be classified as ranking in the sublethal range. Longer exposure durations of the same concentrations are predicted to elicit increasingly deleterious effects. Theoretically, the SEV scores within the dose/response matrix allow for estimating the minimum concentrations and durations that might be expected to trigger sublethal and lethal effects in fish and provide a potential mechanism through which a numeric suspended sediment target can be expressed for the Pajaro River watershed sediment TMDL.

Table 4-3 shows the SEV-8 threshold combinations of sediment concentrations and duration based on the selected regression model.

For discussion, this report refers to the combination of sediment concentration and duration as the sediment 'exposure'. Exposure category refers to the combination of paired sediment concentrations and durations. The first column of Table 4-3 lists exposure categories and their related maximum concentrations as predicted from Figure 4-1. Conditions listed as Categories A through E, outlined in bold, are the focus of this study. The sediment concentration value listed in the second column is the maximum value within the range of concentrations associated with a given exposure category. The associated range is shown in the fourth column.

Table 4-3. Regression Model SEV-8 Thresholds

Exposure Category	SEV-8 Threshold		Concentration Range (SS mg/L)	log e Concentration (SS mg/L)
	Maximum Concentration (SS mg/L)	Duration (days)		
A	1808	1	665.14--1807.86	7
B	665	2	244.69--665.07	6
C	244	6	90.01--244.66	5
D	244	14	90.01--244.66	5
E	90	49	33.11--90.01	4
F	33	120	12.18--33.11	3
G	12	330	4.48--12.18	2

Note: Based on SEV level 8, Group 1 model.

The range of SEV-8 exposures can be used as numeric targets. For example, to meet the SEV-8 threshold, exposure category A indicates that water column sediment concentrations should not exceed 1,808 mg/L for more than one day. To satisfy the threshold for exposure category B, water column sediment concentrations should not exceed 665 mg/L for more than two days. The range of concentration values associated with each exposure category is derived from the corresponding log $_e$ range (See Table 4-2). The SEV-8 thresholds presented in Table 4-3 represent a range of ideal conditions, based on predictive models developed using laboratory-derived fish response data. The laboratory-derived data do not explicitly account for fish behavior under environmental conditions, (e.g. the ability to find short term refuge from increased sediment concentrations of an acute nature).

By employing the method described above, the suspended sediment numeric targets are contained within the Newcombe and Jensen framework of severity of ill effects. The selection of SEV-8 as the basis for establishing numeric target conditions, as opposed to SEV-7 for example, was based on the following information:

- Staff acknowledges that the SEV-8 level is at the upper threshold of sublethal effects; however, the lethal effects (0-10% mortality) that are predicted by the Newcombe and Jensen begin at the SEV-10 level. The SEV-8 level prevents the lethal effects associated with excessive sediment concentration and duration.
- Staff acknowledges the potential that suspended sediment concentrations associated with the SEV-8 level may periodically induce some form of ill effect (stress) upon fish; however stress, even under natural conditions, is inherent in most ecological systems. Staff assumes that most species have evolved or have adapted to (e.g., behavioral adaptations such as avoidance) natural occurrences of stress within their domain, in this case suspended sediment concentration and duration within the Pajaro River system. It is staff's intent to ensure that beneficial uses are protected and that the sediment-related stress imposed upon fish within the Pajaro River system are reflective of the conditions in which fish have adapted.

- As Newcombe and Jensen state in their journal article, it was "assumed for modeling purposes that the severity-of-ill-effects (SEV for "severity") scale represents proportional differences in true effects." Because of this model assumption, staff does not interpret the distinction between various SEV levels to be absolute.
- Data used to develop the Newcombe and Jensen SEV model was derived from a multitude of laboratory studies, primarily conducted with laboratory fish stocks of the Pacific Northwest. Staff has made the assumption that results from a majority of these studies may be overly conservative when compared to the environmental and ecological conditions of the Pajaro River system. Data and/or studies regarding suspended sediment concentrations and duration and the resulting effect upon fish is not available for the Pajaro River. Therefore staff will propose a site specific monitoring program that will be aimed at better defining sediment-related impacts to salmonids within the Pajaro River watershed.
- Staff made the assumption that data used to derive the SEV model equations is inherently conservative because it was primarily provided from laboratory studies of fish stocks that have adapted to waters of naturally low turbidities in more ecologically stable regions.
- Suspended sediment concentrations were evaluated for conditions that represent little anthropogenic disturbance (see Section 4.1.2). Under these conditions, maximum concentrations within the various exposure categories are occasionally exceeded. This data has led staff to assume that the Pajaro River system maintains a relatively high sediment production rate under relatively undisturbed conditions and that establishing a lower SEV exposure level may be unrealistic.
- The Idaho Department of Environmental Quality (IDEQ) evaluated numeric targets under high and low flow condition for the Blackfoot River Sediment TMDL using the SEV scale. When compared to the SEV scale it was found that their targets were within the SEV-8 range (high and low flow) for all salmonid groups (groups 1, 2, and 3), at SEV-11 (high flow) and SEV-12 (low flow) for eggs and larvae of salmonids and nonsalmonids (group 4), and at SEV-9 (high flow) to SEV-10 (low flow) for adult freshwater nonsalmonids (group 6). Though these levels may have lethal or paralethal effects on the fish community (according to the Newcombe and Jensen prediction models), IDEQ made the decision to accept the recommend targets, subjected to change as new information on natural concentrations of suspended sediment, effects of duration exposure on fish, or support of beneficial uses at proposed targets becomes available.

In summary, staff acknowledges that a certain degree of uncertainty exists with the application of the Newcombe and Jensen SEV (severity of ill effects) model to the Pajaro River system. The specific responses of salmonids to suspended sediment concentrations within the Pajaro River watershed are not currently known. It is also not known whether the relatively erosive geology of the Pajaro River watershed has resulted in a salmonid population that is more or less tolerant of suspended sediment. Staff has identified these uncertainties as evidence for establishing the Margin of Safety. Furthermore, the adaptive management approach will require the review of additional data pertaining to suspended sediment and streambed characteristics numeric targets, the effects of sediment upon salmonids and their habitat, as well as an evaluation of implementation measures.

4.1.2 Watershed Model

Given the nature of sedimentation in the Pajaro River watershed, episodic extremes in sediment concentrations are expected due to storm events and loading from all sediment sources. To understand the frequency of these expected events, and to assess the validity of using the SEV-8 thresholds in the Pajaro River watershed, it is necessary to evaluate how the system behaves under natural conditions. Unfortunately, a local reference watershed that would provide these insights is unavailable, therefore a calibrated computer model, the Soil and Water Assessment Tool (SWAT), was used to derive an approximation of sediment loading conditions (see Section 6.1 for SWAT model description). Through the use of a computer modeling program, various sediment loading conditions were analyzed (Tetra Tech, 2004). These conditions included the following two (2) loading scenarios:

- Scenario 1: A representation of existing load conditions by which the model was calibrated and initial load conditions were evaluated,
- Scenario 2: A representation of TMDL conditions where model variables were adjusted to represent load reductions of controllable anthropogenic sources. These load reductions amounted to a 100% decrease in road erosion in basins 3, 15, and 20; an 80% decrease of sediment from cropland, fallow field, and mines; a 60% decrease from orchards and pastureland; and, a 20% decrease from rangeland. After these reductions, loading rates from the anthropogenic sources are comparable to loading rates from shrubland and grassland areas.

To establish the numeric targets, modeled results for both Scenario 1 (existing conditions) and Scenario 2 (TMDL conditions) are compared to the SEV-8 conditions. The results of these comparisons are the Numeric Targets as represented in Table 4-4. It is important to note that the numeric targets contained in Table 4-4 include occasional exceedences that were observed during the 15-year modeling period. In simple terms, the numeric targets are the direct comparison of both existing conditions and TMDL load reduction conditions to the SEV-8 level of exposure. The same model results for both Scenario 1 (existing conditions) and Scenario 2 (TMDL conditions) were used to develop the TMDL load allocation tables (Appendix A, Tables 1 through 9).

Because sediment-loading characteristics vary according to geographic location within the Pajaro watershed, discrete targets are specified for specific subwatershed areas. A total of seven (7) targets were developed for the Pajaro River Sediment TMDL, one for each major subwatershed. Each target is a number of occurrences that can last up to a specified duration, during which a suspended sediment concentration is allowed to persist. The targets encompass a range of conditions that account for modeled exposures for the duration and concentrations expected under load reduction conditions (Table 4-4).

To illustrate how numeric targets are to be applied, consider exposure category B for the Upper Pajaro (Table 4-4). Exposure category B represents a 2-day duration with a suspended sediment concentration range from 244 to 665 mg/L. The numeric target, representing load reductions from controllable anthropogenic sources, indicates that this exposure may occur on 3 occasions within a 15-year period.

To summarize, several categories of concentration/durations are specified as the numeric target for each major subwatershed in the Pajaro watershed. By specifying a range of categories, the numeric targets take into account the inherent variability of the Pajaro River system.

Table 4-4. Numeric Targets for Suspended Sediment [a]

Major Subwatershed [b] (Subbasin numbers)	Exposure Category	Duration (Days)	Maximum Concentration of Exposure Category Range (mg/L)	Numeric Targets		Existing Conditions	
				Number of Instances Greater than Max Conc.	Maximum Duration of Instances (days)	Number of Instances Greater than Max Conc.	Maximum Duration of Instances (days)
Tres Pinos (16, 18, 19)	A	1	1808	15	22	24	25
	B	2	665	42	44	46	45
	C	6	244	36	51	39	60
	D	14	244	20	51	21	60
	E	49	90	5	108	6	109
San Benito (15, 17, 20, 21)	A	1	1808	9	9	23	10
	B	2	665	30	21	39	28
	C	6	244	29	35	33	44
	D	14	244	14	35	16	44
	E	49	90	2	60	5	66
Llagas (5, 23)	A	1	1808	0	0	0	0
	B	2	665	0	1	8	8
	C	6	244	9	15	16	16
	D	14	244	1	15	3	16
	E	49	90	0	28	0	30
Uvas (11, 22)	A	1	1808	1	3	8	3
	B	2	665	12	8	20	8
	C	6	244	12	15	15	15
	D	14	244	1	15	1	15
	E	49	90	0	18	0	29
Upper Pajaro (1, 2, 9, 10)	A	1	1808	0	1	5	4
	B	2	665	3	3	21	8
	C	6	244	2	9	10	15
	D	14	244	0	9	1	15
	E	49	90	0	33	0	33
Corralitos (3 (including Rider Creek), 4, 7)	A	1	1808	0	1	1	2
	B	2	665	0	2	22	10
	C	6	244	8	11	25	29
	D	14	244	0	11	9	29
	E	49	90	0	36	1	60
Mouth of Pajaro (6, 8, 12, 13, 14, 24)	A	1	1808	0	1	8	8
	B	2	665	0	2	37	25
	C	6	244	8	11	26	75
	D	14	244	0	11	15	75
	E	49	90	0	36	10	185

[a] Targets based on a 15-year model run for the period from 1986 to 2000.

[b] Major subwatersheds of the Pajaro River. The numbers in parenthesis correspond to the subbasins depicted in Figure 6-1 (page 29) and the subbasins identified in TMDL Tables 1-9 in the Appendix.

4.2 Numeric Targets for Streambed Characteristics

This section describes streambed numeric targets. The streambed numeric targets described herein are to be used in conjunction with suspended sediment targets to protect the beneficial uses of the Pajaro River watershed.

Numeric targets for four streambed parameters are established for the Pajaro River Watershed (Table 4-5). These parameters include: pool volume, median gravel size diameter (D_{50}), and the percent fine material for both fine fines and for coarse fines within spawning gravels. The foundation for establishing these numeric targets is discussed below and is consistent with targets established in other sediment TMDLs within the Central Coast region (i.e., Morro Bay).

Table 4-5. TMDL Targets for Streambed Characteristics

Pajaro River Watershed Streambed Sediment	
Parameter	**Numeric Target**
Residual Pool Volume	V* (a ratio) = Mean values ≤ 0.21 Max values ≤ 0.45
Median Diameter (D_{50}) of Sediment Particles in Spawning Gravels	D_{50} = Mean values ≥ 69 mm Minimum values ≥ 37 mm
Percent of *Fine* Fines (< 0.85 mm) in Spawning Gravels	Percent fine fines $\leq 21\%$
Percent of *Coarse* Fines (< 6.0 mm) in Spawning Gravels	Percent coarse fines $\leq 30\%$

Streambed sediment characteristics are being used as numeric targets for the Pajaro River watershed to ensure that sediment accumulation in pools, or fines around gravels do not degrade invertebrate, amphibian, and fish habitat. While there are several factors contributing to the decline in steelhead and other organisms' habitat, including low flows, competition with non-native species, and fish barriers, sedimentation of these habitats is a significant factor. These numeric targets were developed with specific consideration for the steelhead. However, achieving these numeric targets is expected to support a broader spectrum of beneficial uses, including: COLD, MIGR, SPWN, WARM, BIOL, RARE, WILD, and COMM.

These numeric targets will be evaluated as part of the TMDL Monitoring Plan to ensure the target's applicability to the Central Coast and to verify that the targets provide protection of beneficial uses, hence attainment of water quality objectives as part of the TMDL. The stream locations in which these numeric targets apply will also be evaluated as part of the TMDL Monitoring Plan.

4.2.1.1 Pool Volume

Parameter: Residual Pool Volume (V*).

Numeric Target: ≤ 0.21 (mean) and ≤ 0.45 (max).

V* gives a direct measurement of the impact of sediment on pool volume. It is the ratio of the pool volume filled in with fine, mobile sediment, to the total scour pool volume. Overwintering habitat requirements for salmonids include deeper pools, undercut banks, side channels, and especially large, unembedded rocks that provide shelter for fish against the high flows of winter. In some years, such as water years 1983, 1992, 1995, floods may make overwintering habitat the critical factor in steelhead production. In most years, however, if the pools have sufficient larger boulders or undercut banks to provide summer rearing habitat for yearling steelhead, then these elements are sufficient to protect them against winter flows.

Pool habitat is the primary habitat for steelhead in summer. The deeper the pool the more value it has. Fish biologists working in coastal streams in Santa Cruz County found that densities of yearling steelhead are usually regulated by water depth and the amount of escape cover that exists during low-flow periods of the year (July-October). In most small coastal streams, availability of this habitat provided by depth and cover appears to determine the number of smolts produced by the smaller streams (Alley, 1998, pp. 15, 16).

Discussion: This parameter is being selected as appropriate because of its strong correlation with upslope disturbances (Knopp, 1993, p. 23). It minimizes bias to the maximum extent practicable and its variance in a reach of stream has been shown to be low enough to provide precise estimates of mean values with a reasonable amount of effort (Lisle, 1993). Conclusive data on V* are not available for the Pajaro River watershed, therefore numeric targets of 0.21 mean values and 0.45 maximum values are proposed based on V* data collected by Knopp (1993) in 60 streams on California's north coast. Knopp found that in reference streams (those having no human disturbance for the past 40 years or more) the V* mean measured 0.21 or less and the maximum measured 0.45 or less. These values represent the average of six separate pools. V* measurements exhibited a trend of increasing accumulations of fine sediments with increasing upslope disturbance, indicating that V* results were affected by upslope disturbance. Knopp found that V* results may take upwards of 40 years before mitigation of current disturbance is positively reflected (Garcia River Sediment TMDL,USEPA, 1998, p.20).

Staff recognize the conditions in the north coast contrast sharply with those in the Central Coast and may modify these values as V* data for the Central Coast Region become available. Staff also assumes that these targets will address the MIGR beneficial use. Since V* reflects sediment aggradation of pools, staff presume that as sediments are reduced in pools, other migration areas within the stream channel will improve.

4.2.1.2 Median Diameter (D50) of Sediment Particle in Spawning Grounds

Parameter: Median diameter (D_{50}) of sediment particle from riffle crest surfaces of spawnable gravels in major tributaries.

Numeric Target: ≥ 37 mm (minimum for a reach); ≥ 69 mm (mean for a reach); with an approximately normal distribution of grain size.

Discussion: The D_{50} is the median value of the size distribution in a sample of surface pebble counts. It is a measure of the central tendency of the whole sample, and thus is one of several indicators of how "fine" or "coarse" the sample is overall. As discussed below for the percent fines targets, both amount and size of fine and coarse sediments can impact salmonid life stages. These targets are expected to ensure the protection of spawning habitat for species including steelhead.

The D_{50} indicator is selected for the Pajaro River Watershed because it is sensitive to sediment inputs, and it is relatively easy to obtain data from pebble counts. In a study that evaluated the relationship between hillslope disturbance and various instream indicators, Knopp (1993) found a clear trend of decreasing particle sizes in the riffles with increasing hillslope disturbance. Moreover, Knopp found a statistically significant difference in average and minimum D_{50} values when comparing reaches in undisturbed and less disturbed watersheds with reaches in moderately and highly disturbed watersheds.

The targets are based on Knopp's findings (1993) concerning D_{50} levels in north coast watersheds that were relatively undisturbed. Staff determined that because Knopp found the D_{50} to be a discriminating indicator (that is, an indicator capable of distinguishing between watersheds that are more or less disturbed as a result of prior management), this indicator and its associated targets identified in Knopp's study are appropriate.

4.2.1.3 Percent of Fine Fines in Spawning Gravels

Parameter: Percent fines < 0.85 mm in spawning gravels.

Numeric Target: ≤ 21 percent by dry weight using McNeil Bulk Sampler.

This value is derived from published, peer-reviewed literature (Kondolf, 2000) since no data currently exists for this parameter within the Pajaro River Watershed. Staff determined this to be a legitimate numeric target for spawning areas with the Pajaro River watershed, since the impact to developing steelhead should be similar regardless of geographic location. The value of 21 percent was derived using research values for the base percentage of fines (14 percent) and multiplying it by a factor (1/0.67) to account for fine sediment removal that occurs when the redd (nesting gravels) is constructed. The value of 14 percent was used in the Garcia River Sediment TMDL (USEPA, 1998, p. 16) and is also referenced by Kondolf (2000, p. 271). Kondolf suggests that survival rates would be around 50 percent where fines less than approximately 1 mm make up 14 percent of the total redd gravel.

The factor used to account for the fines removal during redd construction was taken from Kondolf (2000, p. 268). It was derived using linear regression for data collected from eleven sites. Kondolf found that there was a linear relationship between the percent < 1 mm in the undisturbed gravel, and the percent < 1 mm (represented by "y") in the redd gravel. The following equation represents this relationship:

Equation A:

$$y = 0.67\,x$$

Where:
X = percent < 1 mm in the undisturbed gravel
Y = percent < 1 mm in the redd gravel

In order to go from a desired gravel condition to an initial gravel condition Equation A must be rearranged to:

Equation B:

$$x = y/0.67$$

The Numeric Target in potential spawning gravels then, is:

$$21\% = 14/0.67$$

<u>Discussion</u>: "Once the eggs are laid and fertilized, the spawners cover the redds with material from upstream, including clean gravels and cobbles. The interstitial spaces between the particles allow for water to flow into the interior cavity where dissolved oxygen, needed by the growing embryos, is replenished. Similarly, the interstitial spaces allow water to flow out of the interior cavity carrying away metabolic wastes. However, fine particles either delivered to the stream or mobilized by storm flow can get into those interstitial spaces, blocking the flow of oxygen into the redd, and the movement of metabolic wastes out of it. The reduced permeability into and out of the redd results in a reduction in the rate of embryo survival.

"Research on this subject has concluded that as the percentage of fines increases as a proportion of the total bulk core sample, the survival to emergence (i.e., out of the gravel) decreases. Fines that impact embryo development are generally defined as particles that pass through a 0.85 mm sieve" (Garcia River Sediment TMDL, USEPA, 1998, p. 16).

Monitoring of fine sediment for compliance with this target will be conducted using a McNeil bulk sampler applied directly to potential spawning substrates. The Monitoring Plan will identify sampling protocols. This numeric target will be evaluated as part of the TMDL Monitoring Plan to ensure the target's applicability to the Pajaro River Watershed and to verify that the targets show attainment of the TMDL.

4.2.1.4 Percent of Coarse Fines in Spawning Gravels

Parameter: Percent fine sediment particles < 6 mm in spawning gravels.

Numeric Target: ≤ 30 percent by dry weight using a McNeil Sampler.

This value is taken from Kondolf (2000, p. 271). Staff determined this is a legitimate numeric target for potential and existing spawning areas of the Pajaro River Watershed, since the impact to developing steelhead from fines should be similar for steelhead regardless of geographic location. The grain size of 6 mm was chosen because it falls between the values cited by Kondolf (3.35 mm and 6.35 mm) associated with the value of 30 percent used as the numeric target. No factor accounting for removal of coarser fines during redd construction was applied to this value, as was done for the percent fines less 0.85 mm, because the data is more variable, and therefore less dependable, than similar data for fines less than 0.85 mm.

Discussion: Sedimentation has been identified as one of the principal factors in determining the survival rate from deposition to hatching of eggs, and the survival rate from hatching to emergence from the gravel (Shapovalov and Taft, 1954, p. 155). The coarser fines, > 0.85 mm and < 6.5 mm, can impede emergence of fry from the redd thereby reducing survival rates for fry. Bjornn, et al (1977) have recommended using the percentage of fine sediment in selected riffle areas as an indicator of the "sediment health" of streams. Bjornn (1969) and McCuddin (1977) found that survival of steelhead embryos were reduced when fines (6.44 mm) made up 20-25 percent or more of the substrate.

Monitoring of fine sediment for compliance with this target will be conducted using a McNeil bulk sampler directly applied to potential spawning substrates.

5 SOURCE ANALYSIS

This section briefly describes the sources of sediment in the Pajaro River watershed. These sources have been identified in earlier reports that include: the *Pajaro River Watershed Water Quality Management Plan*, completed in 1999 by Applied Science and Engineering for the Association of Monterey Bay Area Governments (ASE, 1999); the *Establishment of Nutrient Objectives, Sources, Impacts, and Best Management Practices for the Pajaro River and Llagas Creek,* completed in 1994 by San Jose State University (SJSU, 1994); *Technical Memorandum No. 1.2.4, Task: Collection and Analysis of Sediment Data*, completed in 2002 by Raines, Melon, and Carella, Inc., for the Pajaro River Watershed Flood Prevention Authority (RMC, 2002); *Rider Creek Sediment Management Plan, completed in 1991 by* WRC Environmental, for the Santa Cruz County Planning Department (WRC Environmental, 1991); *Lower Pajaro River Enhancement Plan*, completed in 2002 by Fall Creek Engineering, Inc. for the Santa Cruz County Resource Conservation District (FCE, 2002); and, *Upper Pajaro River Sediment Assessment*, completed in 2004 by Fall Creek Engineering, Inc.for the Monterey Bay Sanctuary Foundation (FCE, 2004).

5.1 Nonpoint Sources

Sediment sources within the Pajaro River watershed were primarily identified as nonpoint in nature, meaning that the origination is from multiple sources over a relatively large area. These nonpoint sources include agricultural operations, silviculture, urban land use, rangeland and grazing activities, sand and gravel mining operations, streambank erosion, roads, and natural erosion processes such as landslides. Section 6.2 provides additional information regarding nonpoint sources related to land use and the methods for allocation.

5.1.1 Agriculture

Agricultural runoff from cropland, orchards, and pasture often contribute pollutant loads and sediment to a waterbody when eroded soils are washed into the stream. Irrigated agricultural areas in the Lower Pajaro River watershed result in increased erosion rates that contribute to excess sedimentation (ASE, 1999). There do not appear to be significant efforts to control erosion from cropland in the watershed (RMC, 2002). In addition, in the Lower Pajaro, farmed row crops often come right to the edge of the streams and drainage ditches adjacent to roads (RMC, 2002) and encroachment of croplands has reduced the coverage of riparian vegetation along many of the stream reaches (ASE, 1999). Cropland in the watershed is often tilled just a few feet from the upper terraces of the major surface waters, and irrigation ditches and rows are often oriented such that they provide direct runoff pathways to surface waters (SJSU, 1994).

5.1.2 Silviculture

Silviculture, especially timber harvesting, can be a significant nonpoint source of sediment to waterbodies. Unimproved roads in steep upper watershed areas associated with timber harvest practices are accelerating erosion and sedimentation throughout the watershed. Forest roads are considered the major source of erosion in silvicultured areas. Forest roads account for nearly 90 percent of the total sediment load from forestry operations in the watershed (ASE, 1999).

Timber harvesting occurs primarily in the upper watershed areas of Santa Cruz and Santa Clara counties.

5.1.3 Urban/Residential

Sediment from urban and residential sources can be carried into streams through surface runoff and through erosion from unpaved areas and disturbed sites. Paved roads are potential sources of sediment in populated areas. The majority of the paved roads in the watershed are included in the urban and transportation land use categories of the MRLC land use coverage (Table 6-1). Urban development in the valley regions of the watershed has resulted in the reduction of riparian vegetation along stream reaches (ASE, 1999). In rural residential areas, farm animal and livestock boarding, primarily equine, often result in low amounts of residual vegetation, compacted soil, and riparian encroachment that lead to high potential runoff and erosion rates (FCE, 2004).

5.1.4 Streambank Erosion

The loss of riparian vegetation has left many streambanks unvegetated, causing accelerated erosion from steep and unstable banks (ASE, 1999). Channelization and channel-clearing activities associated with flood-control measures have altered and reduced the amount of riparian habitat mainly along the lower Pajaro River and Tres Pinos Creek. Streams and channels within Llagas Creek and Uvas Creek watersheds are in varying states of disequilibrium leading to accelerated bank loss, channel incision, and sedimentation (FCE, 2004). Within the lower Pajaro River, substantial stream and waterway hydromodification are causing severe bank erosion in many manmade and natural waterways (FCE, 2002).

5.1.5 Sand and Gravel Mining

Sand and gravel mining along the San Benito River has caused significant channel degradation in the watershed (ASE, 1999). The riverbed has become highly degraded and is in a state of disequilibrium. The river is deeply incised in several areas with steep erodible banks and active headcutting. These conditions result in accelerated erosion and sedimentation to the river.

5.1.6 Rangeland/Grazing

Grazing practices in the Pacheco, Tres Pinos, and San Benito watersheds have reduced coverage of riparian habitat along many of the stream reaches in these areas (ASE, 1999); however, grazing appears to be well managed in the majority of the watershed (RMC, 2002).

5.1.7 Roads

Unpaved off-road vehicle trails have been found to contribute to erosion and sedimentation in the Pajaro River watershed. Unsurfaced roads are a potential major source of erosion. There are two publicly owned off-highway recreational areas in the Pajaro River watershed: Hollister Hills State Vehicular Recreation Area and the Clear Creek Management Area. Hollister Hills encompasses 114 miles of dirt roads and trails and is in the Bird Creek watershed. The Clear Creek Management Area, in the upper portions of the San Benito River, is extensively used for vehicular off-road recreation. Studies of erosion and sedimentation in this area have estimated that the erosion rates from the roads alone are more than 25 times the rate from undisturbed soils (PTI 1993).

Sand sediment export form the Rider Creek watershed during the summer months has been observed to bury portions of the Corralitos Creek channel. The sand load inundation has been observed to result in the loss of steelhead rearing habitat in Corralitos Creek. The main sources of sediment production are road cut debris slides, road cut soil block glides, improper road drainage facilities, graded surfaces, and dirt road features (WRC Environmental, 1991).

5.1.8 Landslides/Natural Erosion

Soils and topography in the Pajaro River watershed contribute to naturally high rates of erosion and sediment production. The Pajaro River watershed lies along one of California's most active fault zones, the San Andreas fault, and many landforms in the watershed are highly unstable (ASE, 1999). Most of the steep upper watershed areas have active landslides or are prone to landslides. Landslides are major and primarily uncontrollable sediment sources in the watershed.

5.2 Point Sources

5.2.1 Urban/Residential Areas

In 1990, the U.S. Environmental Protection Agency (USEPA) developed rules establishing Phase I of the NPDES storm water program, designed to prevent harmful pollutants from being washed by storm water runoff into Municipal Separate Storm Sewer Systems (MS4s), or from being dumped directly into the MS4s and then discharged from the MS4s into local waterbodies. Phase II of the rule extends coverage of the NPDES storm water program to certain small municipalities with a population of at least 10,000 and/or a population density of greater than 1,000 people per square mile. A small MS4 is defined as any MS4 that is not a medium or large MS4 covered by Phase I of the NPDES Storm Water Program. There are no large or medium MS4s in the Pajaro River watershed, but there are small MS4s.

The cities in the Pajaro River watershed that are designated as small MS4s are Watsonville, Hollister, Gilroy, and Morgan Hill. As such, these cities are required to develop and implement stormwater management plans that address water quality related issues. Urban and residential land uses within designated urban boundaries for each municipality are therefore assigned a wasteload allocation, while urban and residential land uses outside designated urban boundaries will receive load allocations.

6 SEDIMENT TMDLS

This chapter describes the process used for determining sediment loads and load allocations (Tetra Tech, 2004).

6.1 Load Analysis

To determine existing sediment loads a dynamic watershed model was used to consider time-variable nonpoint source contributions from twenty-four (24) watersheds using the Soil and Water Assessment Tool (SWAT) model (Neitsch et al., 2002). The SWAT model operates in conjunction with a geographic information system (GIS), where a majority of SWAT input data is contained and analyzed.

Establishing the relationship between the in-stream water quality targets and source loading is a critical component of TMDL development. The SWAT model was applied to the Pajaro River watershed to determine existing sediment loads and evaluate optimal TMDL load reductions. The SWAT model was configured for the Pajaro River watershed and was used to simulate the watershed as a series of hydrologically connected subwatersheds. Configuration of the model involved subdivision of the Pajaro River watershed into modeling units, followed by continuous simulation of flow and water quality for these units using meteorological, land use, and stream data. The specific pollutant modeled was sediment.

GIS land use data used to configure the Pajaro River watershed SWAT model was obtained from the Multi-Resolution Land Characterization (MRLC) database and subsequently grouped into SWAT land use categories. The MRLC is a consortium of federal government agencies acting together to acquire satellite imagery for various environmental monitoring programs. One program that resulted from the MRLC effort is the National Land Cover Data (NLCD) program, which used images acquired from LANDSAT's Thematic Mapper sensor, as well as ancillary data sources, to produce a national land cover data set. The MRLC land use data used for this load analysis is representative of years between approximately 1988 to 1994. Table 6-1 shows the MRLC land uses and subsequent SWAT land uses that were used for the model. Landslide prone areas are represented by the barren and bare rock/sand/clay MRLC land use categories. Generally, roads are accounted for in the Pajaro River watershed SWAT model via the High-Intensity Commercial/Industrial/Transportation land use from MRLC. This coverage does not provide an accurate representation of road densities, especially unpaved roads, for areas of the watershed where roads and unpaved roads are known to contribute significantly to sediment loading (Clear Creek, Hollister Hills, and Corralitos and Rider Creeks). To better represent the loading from Corralitos and Rider Creek areas, additional road density information was obtained from the U.S. Census Bureau's Tiger 2000 roads coverage. Additional study data provided estimates of road mileage specifically in the Clear Creek and Hollister Hills areas (ASE, 1999).

Table 6-1. Modeled Land Use Categories

MRLC Code	**MRLC Description**	**SWAT LAND USE**
83	Small Grains	AGRC
80	Herbaceous Planted/Cultivated	AGRL
82	Row Crops	AGRR
33	Transitional	BTRS
84	Bare Soil (Fallow)	FALW
41	Deciduous Forest	FRSD
42	Evergreen Forest	FRSE
40	Natural Forested Upland	FRST
43	Mixed Forest	FRST
32	Quarries/Strip Mines/Gravel	MINE
0	Unclassified	NOCL
60	Non-Natural Woody	ORCD
61	Planted/Cultivated (orchard)	ORCD
81	Pasture/Hay	PAST
85	Urban/Recreation Grasses	PAST
50	Natural Shrubland	RNGB
51	Deciduous Shrubland	RNGB
52	Evergreen Shrubland	RNGB
53	Mixed Shrubland	RNGB
70	Herbaceous Upland Natural/Semi Natural	RNGE
71	Grassland/Herbaceous	RNGE
30	Barren	ROCK
31	Bare Rock/Sand/Clay	ROCK
12	Perennial Ice/Snow	SNOW
23	High Intensity Commercial/Industrial/Transportation	UCOM
22	High Intensity Residential	URHD
21	Low Intensity Residential	URLD
20	Developed	URMD
10	Water	WATR
11	Open Water	WATR
91	Woody Wetlands	WETF
90	Wetlands	WETL
92	Emergent Herbaceous Wetland	WETN

For subbasins with significant road-related sediment contributions, roads were assumed to be evenly distributed throughout the subbasin. The total area of paved and unpaved roads in subbasins 3, and the total area of unpaved roads in subbasins 15, and 20 (see modeled subbasins in Figure 6-1) were calculated based on length and width estimates.[3] The percentage of the subbasin covered by roads was calculated and assumed to be evenly distributed throughout the predominant land use type, either forest or rangeland depending on the watershed. Based on the estimated percentage of roads, the USLE C factor for the predominant land use was increased to reflect the additional loading potential. The SWAT model was run using the normal C values for the predominant land use and again using the updated C values for the predominant land use. Sediment contribution from roads was then determined based on the difference in loading rates between the normal C value run and the updated C value run. Table 6-2 provides a summary of the C values used in each area. Roads in the Clear Creek area are estimated to comprise approximately 1 per cent of the area; in Hollister Hills, 1.1 per cent; and in Rider Creek, .07 per cent..

Table 6-2. USLE[1] C values used in determining road-related loading

		Rangeland	Forest
USLE C factor		0.006	0.001
USLE C factor for subbasins with roads	Clear Creek	0.0124	0.0075
	Hollister Hills	0.0124	0.0075
	Rider/Corralitos area	0.0065	0.0015

[1] The Universal Soil Loss Equation (USLE) is an empirical model developed by Wischmeier and Smith (1978) to estimate soil erosion from fields. The equation is defined mathematically:

$$A = R \cdot K \cdot L \cdot S \cdot C \cdot P$$

where, A is soil loss in tons per acre, R is a rainfall-erosivity index, K is a soil erodibility index, L represents slope length, S is the slope steepness factor, C is a land cover management factor, and P is a supporting practices factor.

To represent loadings and resulting concentrations of sediment in the impaired waterbodies, the Pajaro River watershed was divided into 24 subwatersheds. Subdivision of the watershed enables the model to reflect differences in hydrology and evapotranspiration for different land covers, crops, and soil groups. The 24 modeled subwatersheds, shown in Figure 6-1, represent physical hydrologic boundaries. The division was based on GIS elevation data, stream data, and locations of monitoring stations.

Each delineated subwatershed was further subdivided using a soils/land use overlay process to generate Hydrologic Response Units (HRUs). An HRU consists of a unique combination of land use/land cover, soil, and land management practice characteristics, and thus represents areas of similar hydrologic response. Individual land parcels included within an HRU are expected to possess similar hydrologic and load generating characteristics and can thus be simulated as a unit. These soil/land use combinations are

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[3] Total unpaved road length estimates were obtained from study data (Clear Creek and Hollister Hills) or the US Census Bureau Tiger roads coverage (Corralitos Creek and Rider Creek subwatersheds). Road widths are assumed to be 2-3 meters.

then assigned appropriate curve numbers and other physical and chemical parameter values.

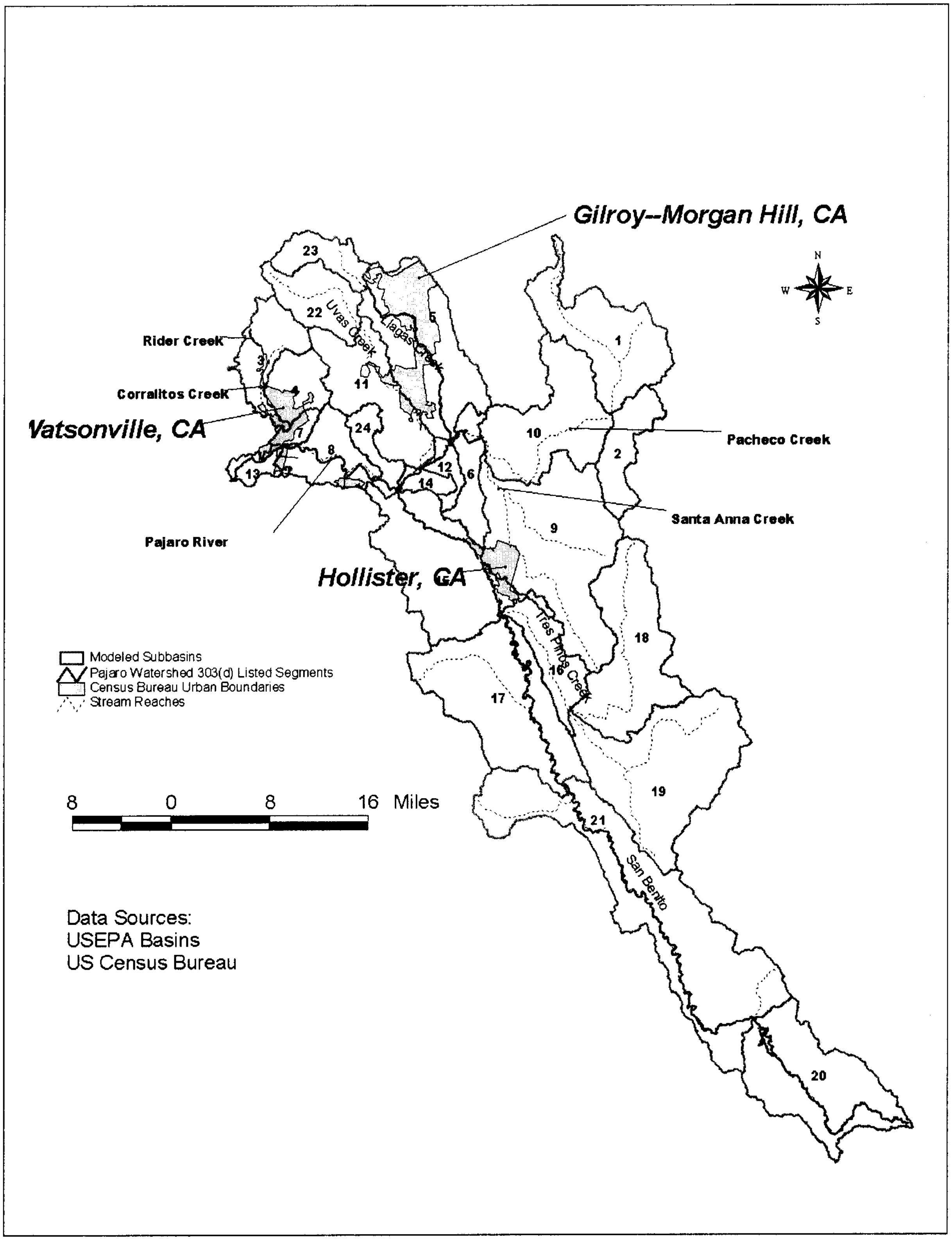

Figure 6-1. Modeled subbasins in the Pajaro River watershed.

Soils associated with a given land use within a subwatershed were only included if they represent at least 10 percent of the area in that land use in a subwatershed. No threshold was set for urban land use because densely developed areas may occupy a small area of the watershed but can have significant pollutant contributions. 644 individual HRUs were simulated in the Pajaro River watershed.

After the model was configured, calibration was performed for the Pajaro River watershed. Calibration refers to the adjustment or fine-tuning of modeling parameters to ensure that model output matches observed data as closely as possible. It is typically a two-phase process: hydrology calibration is performed first, followed by water quality calibration.

Hydrology is the first model component calibrated because estimation of sediment contributions relies heavily on flow prediction. The hydrology calibration involves a comparison of model results to in-stream flow observations at selected locations and the subsequent adjustment of hydrologic parameters. The Pajaro River watershed SWAT model was calibrated at three locations (Corralitos Creek, Clear Creek, and Pajaro River at Chittenden) for which sufficient flow and limited sediment data were available. For water quality calibration, suspended sediment concentration data were compared to model output. Suspended sediment concentration data are considered more representative of in-stream sediment conditions than TSS data (Gray et al., 2000).

After calibration, model parameters were validated. Model validation refers to the testing of calibration adequacy through application of parameters to an independent data set (without further adjustment). In this case, the calibrated model parameters were used to simulate a time period other than the calibration period for each calibration location. Model outputs were analyzed to determine whether the model predictions for the validation period are accurate when compared to observed data. After validation, the calibrated data set containing parameter values for modeled sources and pollutants was then applied to the entire watershed. Time periods selected for calibration and validation were dependent upon availability of observation data.

Results of the hydrology calibration and validation process indicated good agreement for each of the three calibration locations. The monthly and weekly slope equations for modeled flow vs. observed flow are presented in Table 6.3.

Table 6-3. Slope Equations for Flow Calibration Sites

Calibration Site and Water Year	Monthly	Weekly
Corralitos 1982	$y = 1.0662x + 3.0486$; $R^2 = 0.9584$	$y = 1.1336x + 0.1912$; $R^2 = 0.9635$
Corralitos 1993	$y = 1.0024x + 3.6139$; $R^2 = 0.9717$	$y = 1.0024x + 3.6139$; $R^2 = 0.958$
Clear Creek 1995	$y = 0.868x + 0.7489$; $R^2 = 0.9609$	$y = 0.6942x + 2.8211$; $R^2 = 0.7416$
Clear Creek 2001	$y = 0.902x + 0.5769$; $R^2 = 0.9458$	$y = 0.9244x - 0.66$; $R^2 = 0.9309$
Pajaro River at Chittenden 1983	$y = 1.3062x - 47.284$; $R^2 = 0.9634$	$y = 1.1485x + 69.687$; $R^2 = 0.8416$
Pajaro River at Chittenden 1995	$y = 0.9562x - 87.484$; $R^2 = 0.9235$	$y = 1.0081x - 108.67$; $R^2 = 0.8007$

Limited suspended sediment data were available for the three calibration locations. To assist in sediment calibration of the SWAT model, the U.S. Army Corps of Engineer's FLUX program was used to estimate sediment loads. The FLUX regression method provides load estimates from sample concentration data and continuous flow records. The regression equations were used to create "synthetic" suspended sediment data points to represent "observed" concentrations for the SWAT model to be calibrated to. Following model calibration, modeled sediment loads were compared to regression sediment loads on an annual basis to determine if these estimates are within reason. Figures 6-2 through 6-4 represent annual sediment loads of the SWAT model and FLUX regression estimates. The SWAT model was calibrated using the FLUX estimates then compared to local watershed studies to establish reasonable estimates of sediment loads (Tetra Tech, 2004). Following this annual load calibration the SWAT model was used to estimate the daily suspended sediment concentrations.

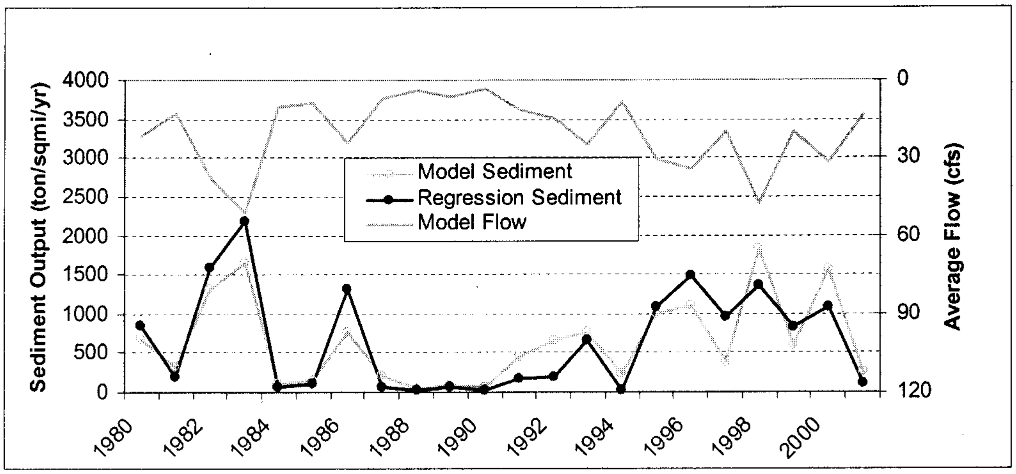

Figure 6-2. SWAT Modeled vs. FLUX regression-generated annual sediment load, Corralitos Creek at Freedom.

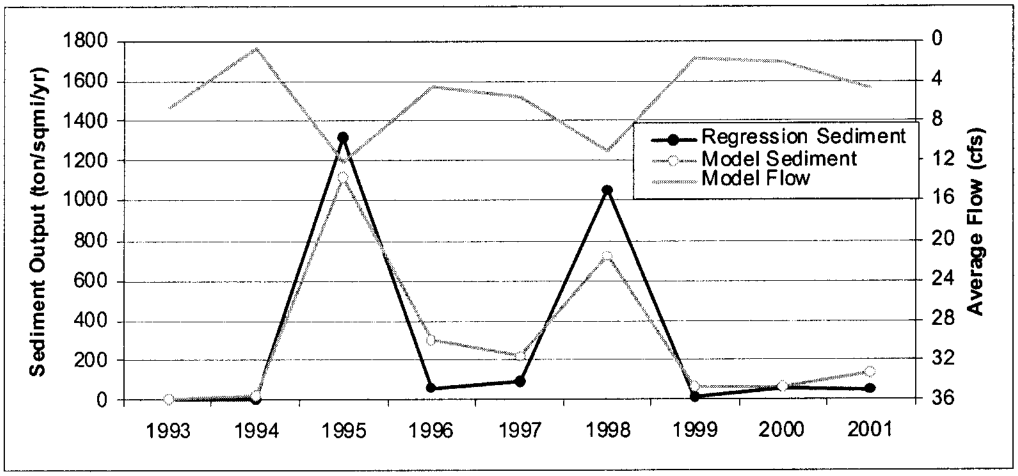

Figure 6-3. SWAT Modeled vs. FLUX regression-generated annual sediment load, Clear Creek.

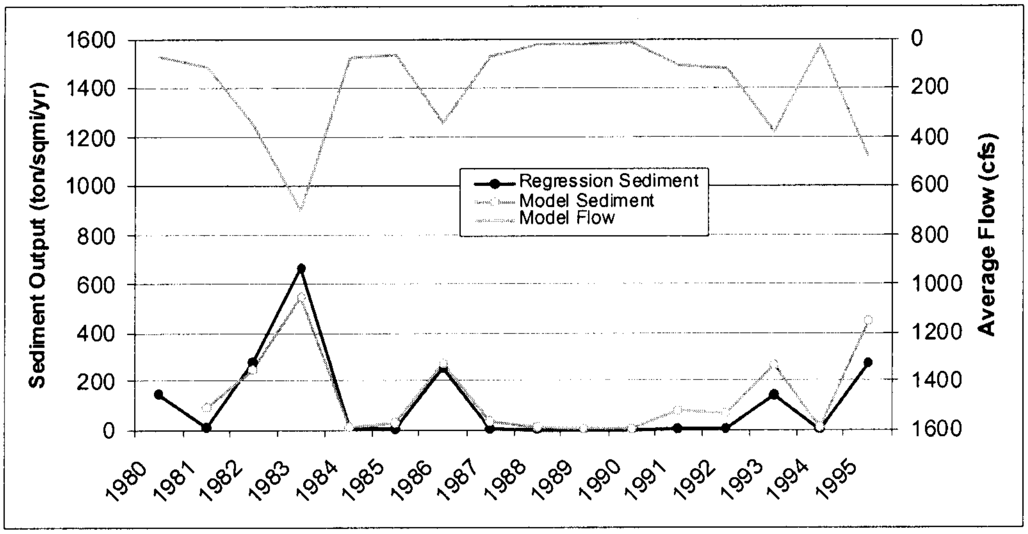

Figure 6-4. SWAT Modeled vs. FLUX regression-generated annual sediment load, Chittenden.

The calibrated SWAT model was used to simulate flow and estimate sediment loading within the Pajaro River watershed for the period 1986 to 2000. A loading scenario reflective of reductions in anthropogenic sediment sources was also developed and is presented as the TMDL for each subbasin. For the TMDL conditions, model variables were adjusted to represent load reductions of controllable anthropogenic sources. These load reductions amounted to a 100% decrease in road erosion in basins 3, 15, and 20; an 80% decrease of sediment from cropland, fallow field, and mines; a 60% decrease from orchards and pastureland; and, a 20% decrease from rangeland. After these reductions, loading rates from the anthropogenic sources are comparable to loading rates from shrubland and grassland areas.

6.2 Total Maximum Daily Loads and Allocations

The TMDL is the sediment loading that would be expected if all the land uses were similar to more natural conditions as a result of optimal reductions in anthropogenic sources. The allocations are based on assigning greater load reductions to crops, orchards, unpaved roads, mines, and pasture land uses because they have the highest existing sediment loading. Rangeland and urban land uses were assigned load reductions to a lesser degree because they have lower existing sediment loads relative to the other land uses mentioned above. A set of sediment TMDLs are established for each of the seven (7) major subwatersheds as represented in Table 6-5. The TMDLs and load allocations for each of the seven (7) major subwatersheds are a composite of the twenty-four (24) subbasins that are included in Appendix A, Tables 1 through 9. These TMDLs are based on land use source categories that are described in the following paragraphs.

The names of land use source categories represented in TMDL Tables 1 through 9 in the Appendix differ slightly from the land use names indicated in the Source Analysis (Section 5). Table 6-4 provides a cross-reference for names of the land use source categories that appear in Appendix Tables 1-9 and the source categories identified the Source Analysis.

Table 6-4. Sediment Source and Load Reductions Categories Based on Land Use.

Sediment Source Category (Section 5)	Land Use (Tables 1 to 9 in Appendix)
Agriculture	Crop Orchard Fallow
Sand/Gravel Mining	Mine [1]
Rangeland/Grazing	Pasture Range
Roads	Unpaved Roads (San Benito River subwatershed only). Paved and Unpaved Roads (Corralitos and Rider Creek subwatersheds only)
Landslides/Natural Erosion	Forrest and Barren
Urban/Residential Areas	Urban [2]

[1] This land use includes sand and gravel mining and other types of mining (i.e., metals), however the bulk of the sediment impact is believed to be from sand and gravel mining operations.

[2] Included as both point source (NPDES stormwater) and nonpoint source.

The Source Analysis in Section 5 included silviculture and streambank erosion source categories. These two source categories were not specifically evaluated as part of the Tetra Tech load analysis because of insufficient data. However, a portion of sediment loading from timber harvest roads is included for the Corralitos Creek and Rider Creek subwatersheds, to the extent that these roads are represented in the U.S. Census Bureau's Tiger 2000 roads coverage. Load and load allocations for streambank and streambed erosion was not conducted due to limitations of the SWAT model. Therefore, staff assumes that the sediment loads from stream erosional processes are contained within the load allocations and waste load allocations of nearby land uses.

With exception to the roads and barren source categories, Table 6-5 represents the modeled load and waste load allocations based on source category and major subwatershed.

The TMDL load allocations for the roads source category within the San Benito River and Corralitos Creek wathersheds is based on Tetra Tech's assumption that road-related sediment production is 100% controllable. This assumption would result in a load allocation of zero. However, staff changed the percent reduction from 100% to 90% because studies have shown that control measures are only capable of 27-96% reductions, based on a variety of site conditions (Burroughs and King, 1989). This change in reduction is reflected in the load allocations assigned to roads as represented in Table 6-5. Due to this change, staff reduced the load allocated to background sources, as represented by the Barren land use, to balance the total load allocation for each respective watershed.

The quantitative results should not be assumed to explicitly represent amounts of sediment reductions expected by any one of the individual implementing parties. The expectation is that all parties implementing and reporting appropriate management practices to reduce sediment will meet these allocations. Staff will track implementation progress and numeric targets to determine attainment of the TMDLs in lieu of quantifying sediment load reductions explicitly.

Table 6-5. Load Allocations Based on Land Use Source Category and Major Subwatershed.

		Land Use Source Category							
Major Subwatershed (Subbasin numbers)	Allocations[1] (LA/WLA)	Crop, Fallow, and Orchard	Forest [2]	Pasture and Range	Urban Lands [3]	Roads	Barren [2]	Sand and Gravel Mining	Total Load
Tres Pinos (16, 18, 19)	LA	477	352	41085	312		11551		53,778
	WLA				1				
San Benito (15, 17, 20, 21)	LA	1971	2083	19863	327	1180	14128	27	39,679
	WLA				100				
Llagas (5, 23)	LA	596	326	6978	354		144		9,185
	WLA				787				
Uvas (11, 22)	LA	946	989	12454	280		369		15,177
	WLA				139				
Upper Pajaro (1, 2, 9, 10)	LA	4114	1228	37664	356		425	3	43,951
	WLA				161				
Corralitos (3,4) (including Rider Creek)	LA	3544	4536	2427	443	79	73	2	11,389[4]
	WLA				284				
Mouth of Pajaro (6, 7, 8, 12, 13, 14, 24)	LA	3047	58	3055	383		500	35	7,268[4]
	WLA				191				

Notes:

[1] Annual load allocations (LA) and waste load allocations (WLA) expressed in metric tones (1 metric ton equals 1,000 kilograms). Allocations are the portion of a receiving water's loading capacity attributed to one of its existing or future pollution sources. Load allocations are assigned to nonpoint sources or to natural background levels and wasteload allocations are assigned to point sources.

[2] Forest includes loads from natural sources and from timber harvesting operations; Barren includes loads from natural sources only.

[3] Load allocations for urban lands outside of NPDES Phase 2 urban boundaries. Waste load allocations for urban lands within NPDES Phase 2 urban boundaries.

[4] Number rounded.

6.3 Margin of Safety

There are two methods for incorporating the MOS (USEPA, 1991):

1. Implicitly incorporate the MOS using conservative model assumptions to develop allocations.
2. Explicitly specify a portion of the total TMDL as the MOS and use the remainder for allocations.

For the Pajaro River watershed sediment TMDLs, an implicit MOS was incorporated in the following manner:

- The use of a multiple-year simulation period (1986 to 2000) enabled the consideration of multiple hydrologic conditions and included seasonality and critical conditions (see Section 6.5).
- The exposure category methodology incorporates a range (rather than a finite value) of suspended sediment concentrations and durations of exposure associated with a given response level.
- The exposure category methodology was uniquely applied to each subwatershed as opposed to the application across one "gross" watershed.
- The use of a calibrated model minimizes the uncertainty of loading relationships.
- An uncertainty remains in determining whether and to what degree suspended sediment concentrations from the San Benito River is transported directly into the Pajaro River. Due to this uncertainty, a conservative approach was chosen whereby suspended sediment numeric targets protective of COLD and MIGR beneficial uses of the Pajaro River were applied to the San Benito River. The San Benito River maintains WARM and SPAWN beneficial uses among others.

The land use data used to develop the SWAT model may not accurately reflect current land use conditions within the Pajaro River watershed. In addition, water quality (suspended sediment) calibration was conducted using synthetic data derived from regression analysis. The monitoring plan will be designed to minimize the uncertainty of these issues.

6.4 Linkage

This linkage analysis examines the relationship between sediment loadings and numeric targets identified in previous sections. The linkages addressed are identified in the Table 6-6. Improved linkage may be realized through evaluation of monitoring data collected to measure progress toward each target.

Table 6-6 Linkage Analysis

This TARGET	is LINKED	to the LOADING to:
Rider Creek, Llagas Creek, San Benito River, and Pajaro River Suspended Sediment Concentrations	←→	Rider Creek, Llagas Creek, San Benito River and Pajaro River from Major Tributaries
Rider Creek, Llagas Creek, San Benito River, Pajaro River Residual Pool Volume		
Rider Creek, Llagas Creek, San Benito River, and Pajaro River Median Gravel Diameter		
Rider Creek, Llagas Creek, San Benito River, and Pajaro River Percent *Fine* fines		
Rider Creek, Llagas Creek, San Benito River, and Pajaro River *Coarse* fines		

6.4.1 Suspended Sediment Concentration

The Soil and Water Assessment Tool (SWAT) was applied to the Pajaro River watershed to link sediment sources to in-stream indicators, determine existing sediment loads, and evaluate optimal TMDL load reductions (TetraTech). The SWAT model is capable of predicting water quantity, water quality, and sediment yields from large, complex watersheds with variable land uses, elevations, and soils. Hydrology in SWAT is based on the water balance equation. Overland flow runoff volume is computed based on the Natural Resources Conservation Service curve number method. Curve numbers are a function of hydrologic soil group, vegetation, land use, cultivation practice, and antecedent moisture conditions. SWAT accounts for sediment contributions from overland runoff through the Modified Universal Soil Loss Equation, or MUSLE (Williams, 1975), which provides increased accuracy, compared to the original USLE method, when predicting sediment transport and yield. The suspended sediment numeric targets are linked to watershed loading through analysis of the total and land use specific sediment loads for each simulated condition. Available monitoring data provided a limited picture of instream sediment values (with respect to the target) because they are based on monthly or greater sampling frequencies. The Pajaro River watershed SWAT Model allows for evaluating the selected target by providing a way to analyze sediment concentrations over continuous and extended periods of time. Figure 6-5 summarizes the numeric target development process and its linkage to overall watershed loading.

Please note that the SWAT model does not directly address numeric targets relating to streambed characteristics. This TMDL analysis assumes reduction in sediment load will reduce suspended sediment concentrations and improve streambed characteristics (i.e., pool volume and spawning habitat).

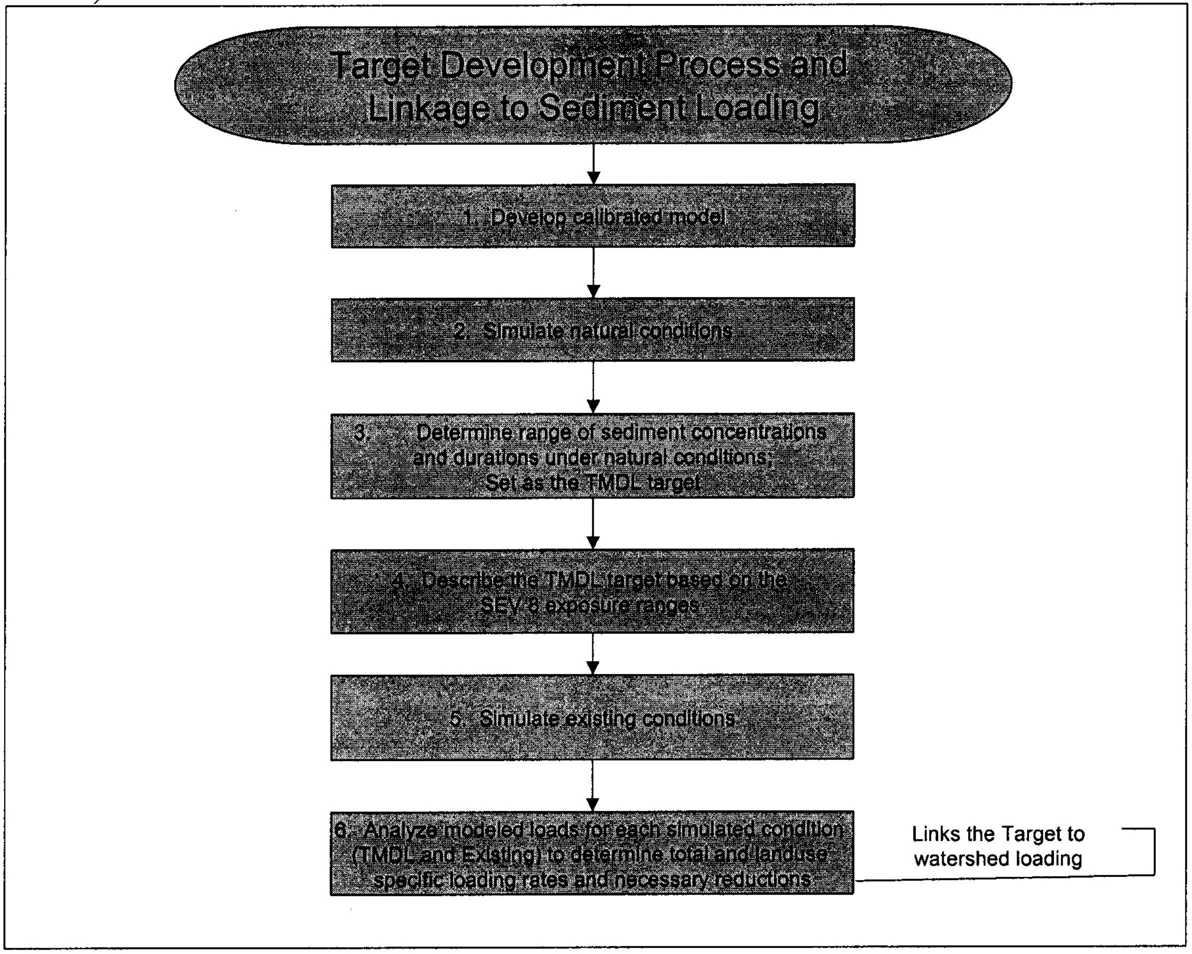

Figure 6-5. SWAT Model Linkage to Suspended Sediment Loading

6.4.2 Streambed Characteristics

Knopp's (1983) study of northern California coastal streams demonstrated that sediment generated from upslope disturbance had a measurable effect on the structure of the aquatic environment (p.40). He identified a statistical link between watershed disturbance and several in-stream sediment indicators, including residual pool volume (V*) and median gravel diameter (D_{50}). This linkage is the basis for selecting the four stream substrate targets.

Calculating the actual loading that would attain the desired substrate conditions as expressed in the targets, will require data that are not currently available. As the TMDL Monitoring Plan is implemented staff will evaluate the data collected and make necessary modifications to the substrate targets.

6.5 Seasonality and Critical Conditions

Sediment concentration data for the Pajaro River watershed show that the largest loading of sediment to the watershed typically occurs during the winter months at high-flow periods (Tetra Tech 2004). Sediment loading in some portions of the watershed is also extremely sporadic in nature. For example, over a 10-year period, a disproportionately large amount of loading, 80 percent, might be delivered in one wet year, with 20 percent delivered over the course of the remaining dry years. Such disproportionate loading is determined by many factors, including topography, land use, geology, and soils. The relative unpredictability of loading especially in geologically active portions of the watershed, adds to modeling uncertainty. To ensure that the model would simulate the widest possible range of loading scenarios, a long-term simulation period covering a variety of hydrologic and rainfall conditions was used. By calibrating the model to observations over long periods, it is assumed that such variability is captured. Seasonal hydrologic and source loading was inherently considered through the use of a continuous-flow simulation (estimating flow over a period of several years). Therefore, the TMDL and allocations developed by the model account for seasonality.

7 TMDL IMPLEMENTATION, TRACKING AND EVALUATION

Implementation, implementation tracking, and TMDL evaluation activities are necessary to assure that the TMDLs will be successful. In addition, staff is recommending a Land Disturbance Prohibition for the Central Coast Regional Water Quality Control Board (Water Board) to consider and adopt as a Basin Plan Amendment. This section describes these activities and the proposed land disturbance prohibition.

7.1 Implementation

Implementation activities will be required to achieve sediment load reductions such that numeric targets are met. This section describes the various regulatory mechanisms, implementation methods, and parties that are responsible for the implementation as related to controllable sediment sources from crop, fallow, orchard, forest, pasture, rangeland, hydromodification, and urban land use activities, as well as roads, and sand and gravel mining operations.

The key regulatory mechanisms staff will rely upon include NPDES permits for stormwater discharges, waste discharge requirements for sand and gravel mining operations, waiver of waste discharge requirements for irrigated agriculture and timber harvest activities, and individual or cooperative nonpoint source pollution control programs for all other discharge types.

Nonpoint source implementation programs are required for all nonpoint source discharges pursuant to the Policy for the Implementation and Enforcement of the Nonpoint Source Pollution Control Program (NPS Policy), dated May 20, 2004. The NPS Policy requires all current and proposed nonpoint source discharges to be regulated under Waste Discharge Requirements (WDRs), waivers of WDRs, a basin plan prohibition, or some combination of these administrative tools. The Pajaro River Sediment TMDL will use the Pajaro River Watershed land disturbance prohibition to control nonpoint source discharges of sediment. To comply with the Pajaro River Watershed land disturbance prohibition, nonpoint source dischargers are required to either submit documentation that their activity does not cause sediment discharge within the watershed or submit a NPS Implementation Program that is consistent with the NPS Policy. The NPS Policy specifies that each NPS Implementation Program must include the following key elements:

Key Element 1: An NPS Implementation Program must explicitly acknowledge the beneficial uses and water quality requirements the programs are designed to protect and meet;

Key Element 2: The NPS Implementation Program shall include a description of the management practices (MPs) and other program elements that are expected to be implemented, along with an evaluation program that ensures proper implementation and verification;

Key Element 3: The Implementation Program shall include a time schedule and quantifiable milestones, should the Water Board so require;

Key Element 4: The Implementation Program shall include sufficient feedback mechanisms (e.g. reporting, inspection, monitoring, etc.) so that the Water Board, dischargers, and the public can determine if the implementation program is achieving its stated purpose(s), or whether additional or different MPs or other actions are required; and,

Key Element 5: Each Water Board shall make clear, in advance, the potential consequences for failure to achieve an NPS control implementation program's stated purposes.

7.1.1 Crop, Fallow, and Orchard Lands

Landowners and operators of crop, fallow, and orchard lands, where irrigated agricultural activities are conducted, will implement agricultural management measures and perform monitoring and reporting pursuant to the Conditional Waiver of Waste Discharge Requirements for Discharges from Irrigated Lands and the Monitoring and Reporting Program, Order No. R3-2004-0117 conditional waiver.

7.1.2 Forest Lands

Landowners and operators of timber lands, where timber harvest activities are conducted, will implement timber harvest management measures and perform monitoring and reporting pursuant to the General Conditional Waiver of Waste Discharge Requirements for Timber Harvest Activities and the Monitoring and Reporting Program, Order No. R3-2005-0066.

7.1.3 Pasture and Range Lands

Owners and operators of pasture and range lands, where grazing activities occur, must comply with the land disturbance prohibition.

Within one year following approval of the TMDLs by the Office of Administrative Law, the Executive Officer will notify the owners and operators of pasture and range lands of the prohibition and conditions for compliance with the prohibition. The Executive Officer will review and approve, or request modification of, the Nonpoint Source Pollution Control Implementation Program (Program) or documentation submitted in compliance with the prohibition within six months of the submittal date. Should the Program or documentation require modification, or if a party fails to submit a Program or documentation, the Executive Officer may issue a civil liability complaint pursuant to section 13268 or 13350 of the CWC, or alternatively, propose individual or general waste discharge requirements to assure compliance with the prohibition.

7.1.4 Urban Lands

Urban lands include the small communities of Watsonville, Hollister, Gilroy, and Morgan Hill (cities), rural properties throughout the watershed with farm animals or livestock boarding (rural properties), and roads throughout the watershed. These lands do not include unpaved roads in San Benito River watershed, and paved and unpaved roads within the Corralitos Creek and Rider Creek subwatersheds (See Roads below).

The cities must obtain a Municipal Separate Storm Sewer System (MS4) permit. Their Storm Water Management Programs must include specific actions to reduce sediment discharges pursuant to Clean Water Act Section 402(p)(3)(B) and Section D of State Board Order No. 2003-005, NPDES General Permit No. CAS000004 for Storm Water Discharges from Small Municipal Separate Storm Sewer Systems. The cities will then describe the actions taken as part of their annual report. If necessary, the Regional Board's Executive Officer can require more stringent sediment controls. This is an existing requirement and an on-going activity.

Owners and operators of rural properties and roads must comply with the land disturbance prohibition.

Within one year following approval of the TMDLs by the Office of Administrative Law, the Executive Officer will notify the owners and operators of rural properties and roads of the prohibition and conditions for compliance with the prohibition. The Executive Officer will review and approve, or request modification of, the Program or documentation submitted in compliance with the prohibition within six months of the submittal date. Should the Program or documentation require modification, or if a party fails to submit a Program or documentation, the Executive Officer may issue a civil liability complaint pursuant to section 13268 or 13350 of the CWC, or alternatively, propose individual or general waste discharge requirements to assure compliance with the prohibition.

7.1.5 Roads

Within one year following approval of the TMDLs by the Office of Administrative Law, the Executive Officer will notify the owners and operators of unpaved roads within the San Benito River watershed and paved and unpaved roads within the Corralitos Creek and Rider Creek watersheds of the prohibition and conditions for compliance with the prohibition. The Executive Officer will review and approve, or request modification of, the Program or documentation submitted in compliance with the prohibition within six months of the submittal date. Should the Program or documentation require modification, or if a party fails to submit a Program or documentation, the Executive Officer may issue a civil liability complaint pursuant to section 13268 or 13350 of the CWC, or alternatively, propose individual or general waste discharge requirements to assure compliance with the prohibition.

7.1.6 Sand and Gravel Mining Operations

Within six months following approval of the TMDLs by the Office of Administrative Law and pursuant to Section 13263(e) of the CWC, Regional Board staff will review existing waste discharge requirements (WDRs) for sand and gravel mining operations and revise or require activities to: 1) assess cumulative impacts, including fluvial geomorphic impacts, upon the beneficial uses of the San Benito River; 2) mitigate the impacts identified; and 3) monitor the effectiveness of mitigation activities. One year following approval of the TMDLs by the Office of Administrative Law, pursuant to Section 13267 of the CWC, the Executive Officer will require owners and operators of sand and gravel mining operations to submit a plan to assess cumulative impacts, including fluvial geomorphic impacts, upon the beneficial uses of the San Benito River. The Executive Officer will comply with the requirements of section 13267 when issuing the orders. Regional Board staff will encourage sand and gravel mining operators to conduct the cumulative impacts assessment cooperatively.

7.1.7 Streambank Erosion

Owners and operators of properties where hydromodification activities occur must comply with the land disturbance prohibition.

Within one year following approval of the TMDLs by the Office of Administrative Law, the Executive Officer will notify the owners and operators of pasture and range lands of the prohibition and conditions for compliance with the prohibition. The Executive Officer will review and approve, or request modification of, the Program or documentation submitted in compliance with the prohibition within six months of the submittal date. Should the Program or documentation require modification, or if a party fails to submit a Program or documentation, the Executive Officer may issue a civil liability complaint pursuant to section 13268 or 13350 of the CWC, or alternatively, propose individual or general waste discharge requirements to assure compliance with the prohibition.

7.2 Proposed Pajaro River Watershed Land Disturbance Prohibition

The Pajaro River Watershed Sediment TMDLs propose to add the following land disturbance prohibition to Chapter 4 in VIII.E.1, Land Disturbance Prohibitions:

> The controllable discharge of soil, silt, or earthen material from any grazing, farm animal and livestock, hydromodification, road, or other activity of whatever nature into waters of the State within the Pajaro River watershed is prohibited.
>
> The controllable discharge of soil, silt, or earthen material from any grazing, farm animal and livestock, hydromodification, road, or other activity of whatever nature to a location where such material could pass into waters of the State within the Pajaro River watershed is prohibited.
>
> The above two prohibitions do not apply to any discharge regulated by existing National Pollutant Discharge Elimination System permits, Waste Discharge Requirements or waivers of Waste Discharge Requirements.

The above two prohibitions do not apply to any grazing, farm animal and livestock, hydromodification, or road activity if the owner or operator:

i. Submits a Nonpoint Source Pollution Control Implementation Program, consistent with the *Policy for Implementation and Enforcement of the Nonpoint Source Pollution Control Program, May 20, 2004*, that is approved by the Executive Officer, or

ii. Demonstrates there is no activity that may cause soil, silt, or earthen material to pass into waters of the state within the Pajaro River watershed, as approved by the Executive Officer.

This Land Disturbance Prohibition takes effect three years following approval by the U.S. Environmental Protection Agency.

7.3 Implementation Time Frame

Staff anticipates that this TMDL will be implemented in 45 years. This is based on the time required for implementing parties to conduct additional assessments, establish programs, implement BMPs, for staff to develop a TMDL Monitoring Plan, to allow for an adequate period of time to observe a positive response in numeric target parameters, and to gather necessary data in order to demonstrate that numeric targets are met.

7.4 Implementation Tracking and TMDL Evaluation

Evaluation will be based on the reporting of implementation actions and monitoring described in the previous section. Staff will review data and reports every three years to determine compliance with the TMDL.

If the executive officer determines that additional reporting or monitoring is needed from the implementing parties he shall request it pursuant to Section 13267 of the California Water Code. For the NPDES stormwater permits for the MS4 municipalities, if the executive officer determines additional reporting or monitoring is needed he shall request it pursuant to Section 13383 of the California Water Code. Should the update or revision of waste discharge requirements necessitate a report of waste discharge, the executive office shall request it pursuant to Section 13260 of the California Water Code.

Evaluating the implementation progress and monitoring results related to the numeric targets will determine TMDL compliance. The numeric targets, not actual loads or reductions in loads, will be measured, as they are a more direct indicator of beneficial use protection. They provide a more comprehensive method in which to evaluate progress regarding load reductions and the attainment of water quality objectives and protection of beneficial uses.

Initially, staff will rely on site assessments, photo-documentation and annual reporting that are currently required by the Agricultural Waiver Program for Irrigated Agriculture; on monitoring and reporting by municipalities for the Stormwater Program; on site assessment, mitigation and monitoring plans required for sand and gravel mining activities; and nonpoint source implementation plans. Additional monitoring to determine TMDL compliance will build upon theses efforts as appropriate.

No monitoring program exists at this time to measure sediment numeric targets. In cooperation with implementing parties, staff will develop a monitoring program for this TMDL that is consistent with other sediment TMDLs and regional sediment monitoring programs. However, such a program will be complex to design and implement. Such a program will be labor-intensive because it will require ongoing measurements of sediment, streamflow, and streambed characteristics at many stations throughout the Pajaro River watershed. Success of the monitoring program will depend on careful design and implementation by personnel with appropriate expertise in the collection and analysis of this data. Staff anticipates the development of a monitoring program will take approximately five years. In addition, funding sources need to be identified during this initial period. While this will be a complex challenge, staff believes that this type of monitoring is necessary to determine beneficial use impacts of sediment and compliance with the TMDL.

In addition, as part of the TMDL progress and compliance evaluation, staff will evaluate forthcoming information pertaining to Pajaro River watershed sediment-related impacts to fisheries and fish habitat conditions. It is anticipated that this future information will be made available by other agencies or will be provided as results from specific research projects.

7.5 Cost of Implementation

Porter-Cologne requires that the Water Board take "economic considerations", into account when requiring pollution control requirements (Public Resources Code, Section 21159 (a)(3)(c)). The Water Board must analyze what methods are available to achieve compliance and the costs of those methods."

Staff identified a variety of costs associated with implementation of this TMDL. These fall into three broad categories: 1) Planning or Program Development Actions (e.g., establishing nonpoint source implementation programs, conducting assessments); 2) Implementation of management practices for permanent to semi-permanent features (e.g., sediment basins, stream restoration projects, grass filter strips) and for routine operation and maintenance practices; and 3) TMDL Monitoring.

7.5.1 Cost of Trackable Implementation Actions

Anticipating the costs of planning or program development actions with any accuracy is challenging for several reasons. Many of the actions, such as review and revision of policies and ordinances by a governmental agency, could incur no significant costs beyond the program budgets of those agencies. However, other actions, like the establishment of nonpoint source implementation programs and assessment workplans to identify restoration needs, do carry discrete costs. Cost estimates are further complicated by the fact that some implementation actions are necessitated by other regulatory requirements (e.g., Phase II Storm water) or are actions anticipated regardless of TMDL adoption. Therefore assigning all of these costs to TMDL implementation would be inaccurate. For example, Phase II Storm water program implementation costs could run as high as $51,000 for a community with a population of 65,000, based on preliminary estimates developed by staff. These programs would include many components that address sediment management in the watershed, such as: public education, a storm water ordinance, and good housekeeping (erosion control, vegetation, storm drain maintenance, and agency staff training for municipal facilities). The City of Watsonville's (population 38,000) Basic Urban Runoff Program costs were $33,750 and the program will likely result in substantial reductions in sediment loading in storm water flows.

The following urban cost estimates are based on costs estimated by the City of Watsonville for implementing stormwater regulations (personal communication, Jennifer Bitting; RWQCB, September 2003):

Table 7-1. Annual Cost Estimate for Implementation of Stormwater Management Plan, City of Watsonville

Control Measure	**Activities**	**Total Cost**
Public Education and Outreach	Brochures, advertising through media and businesses	$16,000
Public Participation	Stormdrain stenciling, community clean-ups	$3,750
Stormwater Ordinance	Draft to approval	$2,100
Illicit discharge and detection	Program development, mapping, determining sources, correction	$3,750
Pollution prevention/Good-Housekeeping	Training, clean-up activities	$1,900
Construction site runoff control	Education and training	$2,400
Post-construction runoff control	Education and training	$2,400
Permitting and reporting requirements	Development of good-housekeeping procedures	$700
Estimated Annual Program Costs		$33,750 per year
Per-capita program annual costs		$0.89/person
Street sweeping annual cost per-capita		$3.42
Total per-capita annual cost		$4.31

Using the estimated per-capita annual cost for the City of Watsonville, annual costs for the Cities have been estimated as:

Watsonville: 38,000 (population) x $4.31 (total per-capita annual cost) = $163,780 per year.
Gilroy: 41,460 (population) x $4.31 (total per-capita annual cost) = $178,693 per year.
Morgan Hill: 33,556 (population) x $4.31 (total per-capita annual cost) = $144,626 per year.
Hollister: 34,413 (population) x $4.31 (total per-capita annual cost) = $148,320 per year.

Estimated costs for compliance with the conditional waiver for irrigated agriculture includes a one time cost between $0 (funded) to $160 (unfunded) for education and farm water quality plan development. Water quality monitoring costs are estimated between $55 (10 acres, low threat) to $2,200 (1,000 acres, high threat). Estimated costs for a variety of agricultural nonpoint source management practices are included in Section 7.5.2.

Costs for developing implementation programs and plans will vary widely among the type and geographic extent of the pollution source. In addition, leveraging opportunities, where multiple implementing parties may develop a coalition, may be explored to reduce (share) costs associated with development and preparation of implementation programs or plans. Estimated costs for developing these programs and plans are provided in Table 7-2. Staff estimated these costs based on approximate time staff spends on similar scale projects. Also included are estimated annual costs for maintaining the program, conducting monitoring activities, and annual reporting.

Table 7-2. Estimated Costs for Implementation Programs and Plans

Implementation Action	**Implementation Plan Development [1] 1 Person Year (PY) = $100,000**		**Implementation Annual Cost [2] 1 Person Year (PY) = $100,000**		**Implementing Party**
Nonpoint Source (NPS) Implementation Program					
Option 1 Develop Watershed-wide NPS Implementation Program for the following NPS categories: Pasture and range lands Rural properties Roads Hydromodification.	3.0 PY per NPS Category	$1,200,000	2.5 PY per NPS Category	$1,000,000	Coalition of NPS dischargers in cooperation with third-party representative, organization, or government agency.
Option 2 Develop Individual NPS Implementation Program for the following source categories: Pasture and range lands Rural properties Roads Hydromodification.		$500-$3,000	0.01PY	$1,000	Individual owner/operator
Implementation Plans					
Develop Regional Implementation Plan for Sand and Gravel Mining. Option 1	5.0 PY	$500,000	2 PY	$200,000	Coalition of dischargers in cooperation with third-party representative, organization, or government agency
Develop Individual Implementation Plan for Sand and Gravel Mining. Option 2		$50,000 - $100,000	1 PY	$100,000	Individual owner/operator

Notes:

[1] Estimated costs for implementation plan development.

[2] Estimated annual costs for program management, monitoring, and reporting. Annual costs for Sand and Gravel Mining does not include any mitigation or monitoring activities.

7.5.2 Cost of Management practices

There is a wide range of discrete costs and a variety of potential measures that are associated with on-the-ground BMP implementation. The most significant factor is the uncertainty surrounding the number sites that necessitate, and are suitable for, various types of management measures. For example, it is not reasonable to assume that streambank restoration, protection, or fencing measures are appropriate for every stream reach within the Pajaro River watershed. Instead, it would be more appropriate for each implementing party to determine which management practice to employ based on site-specific characteristics and the nature of the problem. In most cases, additional assessment will be required to identify which management practices are best suited to address site specific erosion and sediment control. Because of this uncertainty, saff is providing unit costs for a variety of proven management practices.

BMP costs for erosion and sediment control on agricultural lands (including range and pasture), urban lands, roads, and streambanks are included in Table 7-3. Labor, materials, and land values all have bearing on the final cost of implementation, and are all subject to market conditions throughout the period of implementation.

The basis for the estimates presented here was derived from a variety of sources identified in Table 7-3. Staff used local and recent examples where possible and provided a range of costs, when available, to demonstrate how costs could vary.

Table 7-3 Basis for Calculating Cost of BMP Implementation.

TREATMENT STRATEGY	APPLICABLE SOURCE CATEGORY [1]	TREATMENT MEASURE	TECHNIQUE	$/unit	PRICE RANGE		SOURCE
					Low $/unit	High $/unit	
Disperse/Slow Runoff	A, RG, R	Grass-lined Swales	Permanent seeding	812/mi	2,500/ac	7,000/ac	SCC, 2001, p. 55
	A, RG, R	Rolling Dips + Water Bars	Ripping, slash scattering, and waterbar installation				USEPA, 1993, p. 3-57.
			$20/dip; $12.50/bar				(USEPA, 1993, p. 3-85)
	A, RG, R	Water Bar	Keyed into road base 6"-8"	227/bar			FCE, 2002
	A, RG, R	Vegetated Road Cover	Labor, fertilizer, seed	574/ac			FCE, 2002
Soil Stabilization	RG, R	Pave roads with compacted gravel/decomposed Granite.	Crushed rock to 5cm and large stone to 20cm depth.		3,218/mi	14,481/mi	USEPA, 1993, p. 3-46.
	RG, R	Stabilize roadcuts and sidecast with vegetation.	Grass, hydroseed with mulch		321/mi	1,228/mi	USEPA, 1993, pp. 3-46, 3-56.
	U	Install vegetated filter strips in drainage paths and/or in flow dispersion areas.			4,500/ac	48,000/ac	USEPA, 1993, p. 4-80.
	A	Cover crop	Disc and seed broadcast	143/ac			FCE, 2002
	A	Edge of field vegetative filter strip	Shaping, disc, seed broadcast	447/ac			FCE, 2002
Sediment Retention	A	Sediment Basin	For 10 acres of strawberries	3,717/basin			FCE, 2002
	U	Install vegetated filter strips.			4,500/ac	48,000/ac	USEPA, 1993, p. 4-80.
	U	Install sediment retention basins.	$1,000/drainage acre for <50K cu. ft. capacity; $550/drainage acre for >50K cu. ft. capacity.				USEPA, 1993, p. 4-78.
	U	Install catch basins at inlets or culvert discharge points, control outflow by dispersion and/or energy dissipation.			700/ac	900/ac	USEPA, 1993, p. 4-78
	U	Mulch and plant vegetation on exposed soils.			800/ac	1,500/ac	SCC, 2001, p. 68.
Grazing Management	RG	Livestock Exclusion	Permanent livestock exclusion		2,474/mi	4,015/mi	USEPA, 1993, Table 2-25
	RG	Water development for grazing management	Water pipeline		0.35/ft	1.62/ft	USEPA, 1993, Table 2-24
	RG	Forage Improvement Re-establishment	Planting		83/ac	195/ac	USEPA, 1993, Table 2-24

Notes:

[1] Applicable source categories for implementation of the various treatment measures include agriculture (A), rangeland and grazing (RG), urban (U), hydromodification (H), roads (R), and wetlands, riparian areas, and vegetated treatment systems (WRV).

Table 7-3 (cont'd). Basis for Calculating Cost of BMP Implementation

TREATMENT STRATEGY	APPLICABLE SOURCE CATEGORY [1]	TREATMENT MEASURE	TECHNIQUE	$/unit	PRICE RANGE		SOURCE
					Low $/unit	High $/unit	
Streambank Protection	H, WRV	Vegetative stabilization of streambanks	Bank grading, installation of riprap and sediment traps in deep gullies, planting of trees and willows		2,527/ac	5.94/ft	USEPA, 1993
	H, WRV	Biotechnical Bank Stabilization	Vegetative rip-rap		60/ft	100/ft	FCE, 2002
	H, WRV	Biotechnical Bank Stabilization	Willow wattles/facines		45/ft	75/ft	FCE, 2002
	H, WRV	Biotechnical Bank Stabilization	Bank Reshaping w/ vegetation		25/ft	50/ft	FCE, 2002
Wetland/Stream Restoration	H, WRV	Streambank Restoration Project	Design, permitting, installation, and monitoring for 2,500 cubic yards rough grading, 1,700 linear feet vegetative rip-rap toe protection, 5,100 linear feet facines.	176,500/ project			FCE, 2002
	H, WRV	Wetland and Riparian Habitat Restoration	Planning, design, permitting, installation, and monitoring for 45 acres wetland restoration and 3,000 linear feet stream restoration	2,895,200/ project			FCE, 2002

Notes:

[1] Applicable source categories for implementation of the various treatment measures include agriculture (A), rangeland and grazing (RG), urban (U), hydromodification (H), roads (R), and wetlands, riparian areas, and vegetated treatment systems (WRV).

Sources:
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SCC, 2001: Santa Cruz County, 2001. Draft Santa Cruz County Manual of Erosion Control Standards. Prepared by Salix Applied Earthcare, Redding, CA.
FCE, 2002: Fall Creek Engineering, 2002. Lower Pajaro River Enhancement Plan, Prepared for Santa Cruz County Resource Conservation District.

8 PUBLIC PARTICIPATION

During the course of TMDL development, staff initiated a public participation process that has provided valuable contributions for this Project Report. A Pajaro River TMDL Advisory Committee comprised of staff and watershed stakeholders was formed in February 2001. Initial efforts of the Advisory Committee were focused on development of the nutrient TMDL; however, the committee extended their commitment to assist in development of the current sediment TMDL. A summary of meeting dates and activities is provided in Table 8-1. Staff prepared and distributed the Preliminary Project Report along with references to the Advisory Committee in August 2004. In August 2004 an Advisory Committee meeting was held where staff presented highlights of the sediment TMDL report and questions and comments from the committee were received. The comments received were incorporated into this Project Report where appropriate.

Table 8-1 Summary of Public Participation Activities

Date	**Activity**	**Notes**
May 2003	Advisory Committee Meeting	EPA contractor TetraTech presented the scope of their modeling project. Also, Monterey Bay Sanctuary Foundation contractors presented the Upper Pajaro River Sediment Assessment project.
August 2004	Mailing of Preliminary Project Report to Advisory Committee	Hard copy mailing to committee members.
August 2004	Advisory Committee Meeting	Staff presented highlights of the Preliminary Project Report and received comments from the committee
December 2004	Provide web-based access to Special Studies Report	Staff posted a web link on Region 3 TMDL website to provide stakeholder access to the Upper Pajaro River Sediment Assessment. The report is available on the Monterey Bay National Marine Sanctuary website.

Staff anticipates that additional public participation activities will be conducted as the Pajaro River Sediment TMDL moves forward. These additional will be described in future versions of this document.

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APPENDIX A: TMDL TABLES BY SUBBASIN

Table 1 - TMDLs for San Benito River Subwatershed

Modeled Subbasin	LANDUSE	AREA (sq mile)	Existing Sediment Load Rate (t/sq mile/yr)	TMDL Sediment Load Rate (t/sq mile/yr)	% Contribution to Sediment Load [1]	Existing Sediment Load (t^2)	TMDL Sediment Load (t^2)	% Reduction	LA	WLA
15	Unpaved Road	0.96	559	-	0%	535	-	100%	-	0
	Crop	4.73	636	130	7%	3,011	616	80%	616	0
	Forest	16.23	3	3	0%	41	41	0%	41	0
	Mine	0.10	205	42	0%	20	4	79%	4	0
	Orchard	1.61	184	73	1%	296	118	60%	118	0
	Pasture	13.31	961	391	61%	12,788	5,211	59%	5,211	0
	Range	46.19	34	27	15%	1,549	1,250	19%	1,250	0
	Barren	1.13	867	867	11%	980	980	0%	980	0
	Urban	2.55	120	120	4%	306	306	0%	207	100
	Wetland	0.27	-	-	0%	-	-	0%	-	0
	Subtotal	*87.08*	*224*	*98*	100%	*19,526*	*8,527*	*56%*	*8,527*	*100*
17	Crop	3.88	1,212	273	10%	4,703	1,059	77%	1,059	0
	Fallow	0.50	319	64	0%	160	32	80%	32	0
	Forest	25.90	0	0	0%	8	8	0%	8	0
	Mine	0.12	866	175	0%	101	20	80%	20	0
	Orchard	0.33	267	107	0%	89	36	60%	36	0
	Pasture	9.05	1,061	424	35%	9,603	3,838	60%	3,838	0
	Range	60.16	33	27	15%	2,003	1,608	20%	1,608	0
	Barren	2.07	2,096	2,096	40%	4,345	4,345	0%	4,345	0
	Urban[3]	0.20	170	170	0%	34	34	0%	34	0
	Wetland	0.02	0	0	0%	0	0	0%	0	0
	Subtotal	*102.24*	*206*	*107*	100%	*21,046*	*10,980*	*48%*	*10,980*	*0*
21	Crop	0.30	1,094	259	1%	327	77	76%	77	0
	Fallow	0.08	408	83	0%	33	7	80%	7	0
	Forest	38.55	21	21	8%	800	800	0%	800	0
	Orchard	0.02	448	179	0%	8	3	60%	3	0
	Pasture	1.59	2,635	1,053	17%	4,193	1,676	60%	1,676	0
	Range	116.54	36	29	33%	4,181	3,345	20%	3,345	0

	Barren	6.26	660	660	41%	4,131	4,131	0%	4,131	0
	Urban*	0.08	1,029	1,029	1%	80	80	0%	80	0
	Wetland	0.03	0	0	0%	0	0	0%	0	0
	Subtotal	*163.46*	*84*	*62*	100%	*13,754*	*10,119*	*26%*	*10,119*	*0*
20	Unpaved Road	0.60	18,700	-	0%	11,264	-	100%	-	0
	Crop	0.02	662	142	0%	10	2	78%	2	0
	Fallow	0.15	674	143	0%	101	21	79%	21	0
	Forest	32.02	271	39	12%	8,668	1,234	86%	1,234	0
	Mine	0.04	728	75	0%	26	3	90%	3	0
	Orchard	0.00	230	92	0%	0	0	60%	0	0
	Pasture	0.08	499	200	0%	39	16	60%	16	0
	Range	48.51	148	60	29%	7,158	2,919	59%	2,919	0
	Barren	4.49	1,305	1,305	58%	5,852	5,852	0%	5,852	0
	Urban^3	0.07	86	86	0%	6	6	0%	6	0
	Wetland	0.09	-	-	0%	-	-	0%	-	0
	Subtotal	*86.06*	*385*	*117*	100%	*33,125*	*10,053*	*70%*	*10,053*	*0*
TOTAL	Unpaved Road	1.56	7,564	-	0%	11,799	-	100%		
	Crop	8.92	902	197	4%	8,051	1,754	78%		
	Fallow	0.73	402	82	0%	294	60	80%		
	Forest	112.71	84	18	5%	9,516	2,082	78%		
	Mine	0.25	586	109	0%	147	27	81%		
	Orchard	1.96	200	80	0%	393	157	60%		
	Pasture	24.04	1,108	447	27%	26,623	10,740	60%		
	Range	271.40	55	34	23%	14,893	9,122	39%		
	Barren	13.95	1,097	1,097	39%	15,308	15,308	0%		
	Urban	2.90	147	147	1%	427	427	0%		
	Wetland	0.41	0	0	0%	0	0	0%		
	TOTAL	***438.83***	***199***	***90***	100%	***87,451***	***39,679***	***55%***		

[1]: based on existing load; [2]: metric tones; [3] Occurs outside a designated "urban boundary"; therefore associated load is LA

Table 2 - TMDLs for Tres Pinos Creek Subwatershed

Modeled Subbasin	LANDUSE	AREA (sq mile)	Existing Sediment Load Rate (t/sq mile/yr)	TMDL Sediment Load Rate (t/sq mile/yr)	% Contribution to Sediment Load ^{1}	Existing Sediment Load (t^2)	TMDL Sediment Load (t^2))	% Reduction	LA	WLA
16	Crop	0.8	638	154	6%	537	130	76%	130	0
	Fallow	0.5	155	31	1%	78	15	80%	15	0
	Forest	0.6	1	1	0%	1	1	0%	1	0
	Orchard	0.9	168	67	3%	149	60	60%	60	0
	Pasture	3.8	774	311	52%	2,929	1,176	60%	1,176	0
	Range	20.8	14	11	10%	287	230	20%	230	0
	Barren	0.7	925	925	28%	630	630	0%	630	0
	Urban	0.2	106	106	1%	25	25	0%	23	1
	Wetland	0.0	-	-	0%	-	-	0%	-	0
	Subtotal	*28.4*	163	80	*100%*	*4,635*	*2,266*	51%	*2,265*	*1*
18	Crop	0.1	3,655	920	0%	251	63	75%	63	0
	Fallow	0.0	229	46	0%	1	0	80%	0	0
	Forest	8.1	10	10	0%	84	84	0%	84	0
	Orchard	0.0	180	73	0%	0	0	60%	0	0
	Pasture	6.9	296	119	4%	2,028	817	60%	817	0
	Range	64.5	335	272	84%	21,593	17,539	19%	17,539	0
	Barren	0.8	2,790	2,790	10%	2,109	2,109	0%	2,109	0
	Urban^3	0.1	1,644	1,644	1%	161	161	0%	161	0
	Wetland	0.0	0	0	0%	0	0	0%	0	0
	Subtotal	*80.3*	326	259	*100%*	*26,228*	*20,775*	21%	*20,775*	0
19	Crop	0.5	1,586	377	1%	859	204	76%	204	0
	Fallow	0.1	130	26	0%	13	3	80%	3	0
	Forest	16.7	16	16	1%	267	267	0%	267	0
	Orchard	0.0	432	173	0%	5	2	60%	2	0
	Pasture	1.5	1,540	623	3%	2,252	910	60%	910	0
	Range	89.2	283	229	66%	25,214	20,413	19%	20,413	0
	Barren	2.8	3,148	3,148	29%	8,812	8,812	0%	8,812	0
	Urban^3	0.1	941	941	0%	126	126	0%	126	0
	Wetland	0.0	-	-	0%	-	-	0%	-	0

	Subtotal	*110.9*	338	277	*100%*	*37,548*	*30,738*	18%	*30,738*	*0*
TOTAL	Crop	1.5	1,135	274	1%	1,647	397	76%		
	Fallow	0.6	151	30	0%	91	18	80%		
	Forest	25.5	14	14	1%	352	352	0%		
	Orchard	0.9	171	69	0%	154	62	60%		
	Pasture	12.1	596	240	5%	7,209	2,903	60%		
	Range	174.4	270	219	71%	47,093	38,182	19%		
	Barren	4.2	2,727	2,727	21%	11,551	11,551	0%		
	Urban	0.5	674	674	1%	312	312	0%		
	Wetland	0.0	0	0	0%	0	0	0%		
	TOTAL	***219.7***	***311***	***245***	***100%***	***68,411***	***53,778***	21%		

[1]: based on existing load; [2]: metric tonnes; [3]: Occurs outside a designated "urban boundary"; therefore not a WLA

Table 3 - TMDLs for Corralitos/Salsipuedes Creek Subwatershed (including Rider Creek)

Modeled Subbasin	LANDUSE	AREA (sq mile)	Existing Sediment Load Rate (t/sq mile/yr)	TMDL Sediment Load Rate (t/sq mile/yr)	% Contribution to Sediment Load [1]	Existing Sediment Load (t[2])	TMDL Sediment Load (t[2])	% Reduction	LA	WLA
3	Unpaved Road	0.2	4,065	-	0%	785	-	100%	-	0
	Crop	0.0	1,765	410	0%	83	19	77%	19	0
	Forest	16.0	282	282	50%	4,528	4,526	0%	4,526	0
	Mine	0.0	1,530	313	0%	12	2	80%	2	0
	Orchard	1.9	2,386	955	20%	4,510	1,805	60%	1,805	0
	Pasture	1.3	1,423	610	9%	1,830	784	57%	784	0
	Range	6.9	212	172	13%	1,464	1,185	19%	1,185	0
	Barren	0.0	2,661	2,661	1%	97	97	0%	97	0
	Urban	1.2	477	477	6%	563	563	0%	391	172
	Wetland	0.0	1	1	0%	0	0	0%	0	0
	Subtotal	*27.6*	*503*	325	100%	*13,872*	*8,982*	*35%*	*8,811*	*172*
4	Crop	0.4	6,946	1,533	23%	2,532	559	78%	559	0
	Forest	5.4	2	2	0%	10	10	0%	10	0
	Orchard	0.9	3,135	1,255	48%	2,901	1,161	60%	1,161	0
	Pasture	0.4	1,550	673	12%	668	290	57%	290	0
	Range	14.8	14	11	7%	210	168	20%	168	0
	Barren	0.0	1,651	1,651	2%	55	55	0%	55	0
	Urban	0.8	215	215	7%	164	164	0%	52	112
	Wetland	0.2	-	-	0%	-	-	0%	-	0
	Subtotal	*22.9*	*286*	*105*	*100%*	*6,539*	*2,407*	63%	*2,295*	*112*
TOTAL	Unpaved Road	0.2	4,065	-	0%	785	-	100%		
	Crop	0.4	6,353	1,404	5%	2,615	578	78%		
	Forest	21.4	212	212	40%	4,538	4,536	0%		
	Mine	0.0	1,530	313	0%	12	2	80%		
	Orchard	2.8	2,632	1,053	26%	7,411	2,965	60%		
	Pasture	1.7	1,455	626	9%	2,499	1,074	57%		
	Range	21.7	77	62	12%	1,674	1,354	19%		
	Barren	0.1	2,176	2,176	1%	152	152	0%		

	Urban	1.9	374	374	6%	727	727	0%		
	Wetland	0.2	0	0	0%	0	0	0%		
	TOTAL	***50.5***	***404***	***226***	***100%***	***20,411***	*11,389*	***44%***		

[1]: based on existing load; [2]: metric tonnes

Table 4 - TMDLs for Rider Creek Subwatershed

Modeled Subbasin	**LANDUSE**	**AREA (sq mile)**	**Existing Sediment Load Rate (t/sq mile/yr)**	**TMDL Sediment Load Rate (t/sq mile/yr)**	**% Contribution to Sediment Load [1]**	**Existing Sediment Load (t[2])**	**TMDL Sediment Load (t[2])**	**% Reduction**	**LA**	**WLA**
Rider Creek	Forest	1.2	195	195	80%	234	234	0%	234	0
	Range	0.5	153	123	20%	73	58	20%	58	0
	Unpaved Road	0.0	9,382	-	0%	111	-	100%	-	0
	Subtotal	***1.7***	***248***	***174***	***100%***	***417***	***292***	***30%***	***292***	***0***

[1]: based on existing load; [2]: metric tonnes

Table 5 - TMDLs for Llagas Creek Subwatershed

Modeled Subbasin	LANDUSE	AREA (sq mile)	Existing Sediment Load Rate (t/sq mile/yr)	TMDL Sediment Load Rate (t/sq mile/yr)	% Contribution to Sediment Load [1]	Existing Sediment Load (t[2])	TMDL Sediment Load (t[2])	% Reduction	LA	WLA
5	Crop	5.1	216	44	6%	1,103	225	80%	225	0
	Forest	6.0	5	5	1%	31	31	0%	31	0
	Mine	0.0	11	2	0%	0	0	80%	0	0
	Orchard	26.4	35	14	9%	924	369	60%	369	0
	Pasture	4.6	23	9	1%	104	42	60%	42	0
	Range	29.6	97	78	59%	2,856	2,297	20%	2,297	0
	Barren	0.1	121	121	0%	14	14	0%	14	0
	Urban	11.4	83	83	24%	940	940	0%	153	787
	Wetland	0.0	0	0	0%	0	0	0%	0	0
	Subtotal	*83.2*	*72*	*47*	*100%*	*5,972*	*3,919*	*34%*	*3,132*	*787*
23	Crop	0.0	4,144	1,014	0%	3	1	76%	1	0
	Forest	10.8	27	27	6%	295	295	0%	295	0
	Orchard	0.0	1,346	539	0%	2	1	60%	1	0
	Pasture	0.0	12,122	5,105	1%	66	28	58%	28	0
	Range	8.5	663	542	88%	5,637	4,611	18%	4,611	0
	Barren	0.0	5,415	5,415	3%	130	130	0%	130	0
	Urban[3]	0.1	3,272	3,272	4%	201	201	0%	201	0
	Wetland	0.2	-	-	0%	-	-	0%	-	0
	Subtotal	*19.6*	*324*	*269*	*100%*	*6,333*	*5,266*	*17%*	*5,266*	*0*
TOTAL	Crop	5.1	216	44	2%	1,106	226	80%		
	Forest	16.9	19	19	4%	327	327	0%		
	Mine	0.0	11	2	0%	0	0	80%		
	Orchard	26.4	35	14	4%	926	370	60%		
	Pasture	4.6	37	15	1%	169	69	59%		
	Range	38.1	223	182	75%	8,493	6,908	19%		
	Barren	0.1	1,020	1,020	2%	144	144	0%		
	Urban	11.5	100	100	12%	1,141	1,141	0%		
	Wetland	0.2	0	0	0%	0	0	0%		
	TOTAL	***102.7***	***120***	***89***	***100%***	***12,306***	***9,185***	***25%***		

[1]: based on existing load; [2]: metric tonnes; [3]: Occurs outside a designated "urban boundary"; therefore not a WLA

Table 6 - TMDLs for Uvas Creek Subwatershed

Modeled Subbasin	LANDUSE	AREA (sq mile)	Existing Sediment Load Rate (t/sq mile/yr)	TMDL Sediment Load Rate (t/sq mile/yr)	% Contribution to Sediment Load [1]	Existing Sediment Load (t[2])	TMDL Sediment Load (t[2])	% Reduction	LA	WLA
11	Crop	1.1	1,390	289	5%	1,479	307	79%	307	0
	Forest	24.2	13	13	5%	304	304	0%	304	0
	Mine	0.0	177	38	0%	2	0	79%	0	0
	Orchard	3.5	460	184	10%	1,598	639	60%	639	0
	Pasture	2.3	406	163	6%	933	375	60%	375	0
	Range	22.7	255	208	70%	5,790	4,710	19%	4,710	0
	Barren	0.1	615	615	1%	61	61	0%	61	0
	Urban	1.1	317	317	5%	348	348	0%	209	139
	Wetland	0.0	-	-	0%	-	-	0%	-	0
	Subtotal	*54.9*	*191*	*123*		*10,514*	*6,744*	36%	*6,605*	139
22	Forest	22.1	31	31	8%	685	685	0%	685	0
	Range	9.5	943	778	87%	8,931	7,369	17%	7,369	0
	Barren	0.0	6,385	6,385	4%	308	308	0%	308	0
	Urban[3]	0.0	3,221	3,221	1%	71	71	0%	71	0
	Wetland	0.2	-	-	0%	-	-	0%	-	0
	Subtotal	*31.8*	*314*	*265*		*9,995*	*8,433*	16%	8,433	0
TOTAL	Crop	1.1	1,390	289	2%	1,479	307	79%		
	Forest	46.2	21	21	7%	989	989	0%		
	Mine	0.0	177	38	0%	2	0	79%		
	Orchard	3.5	460	184	4%	1,598	639	60%		
	Pasture	2.3	406	163	2%	933	375	60%		
	Range	32.2	458	376	80%	14,721	12,079	18%		
	Barren	0.1	2,513	2,513	2%	369	369	0%		
	Urban	1.1	374	374	3%	419	419	0%		
	Wetland	0.2	-	-	0%	-	-	0%		
	TOTAL	***86.7***	***236***	***175***	***100%***	***20,508***	***15,177***	**26%**		

[1]: based on existing load; [2]: metric tones; [3]Occurs outside a designated “urban boundary”; therefore associated load is LA

Table 7 - TMDLs for Upper Pajaro (Pacheco Creek)

Modeled Subbasin	LANDUSE	AREA (sq mile)	Existing Sediment Load Rate (t/sq mile/yr)	TMDL Sediment Load Rate (t/sq mile/yr)	% Contribution to Sediment Load [1]	Existing Sediment Load (t[2])	TMDL Sediment Load (t[2])	% Reduction	LA	WLA
1	Forest	26.3	20	20	4%	536	536	0%	536	0
	Range	40.6	358	290	96%	14,545	11,775	19%	11,775	0
	Wetland	0.1	0	0	0%	0	0	0%	0	0
	Subtotal	*67.0*	*225*	*184*	*100%*	*15,081*	*12,311*	18%	12,311	0
2	Crop	0.0	422	85	0%	0	0	80%	0	0
	Forest	9.1	26	26	4%	234	234	0%	234	0
	Range	18.5	419	339	95%	7,749	6,276	19%	6,276	0
	Urban[3]	0.1	1,370	1,370	2%	102	102	0%	102	0
	Subtotal	*27.6*	*292*	*239*	*100%*	*8,085*	*6,612*	18%	6,612	0
10	Crop	1.4	1,980	430	5%	2,752	597	78%	597	0
	Forest	26.4	16	16	3%	418	418	0%	418	0
	Orchard	3.7	602	241	7%	2,199	880	60%	880	0
	Pasture	4.5	1,989	853	30%	8,910	3,821	57%	3,821	0
	Range	34.0	247	199	53%	8,417	6,789	19%	6,789	0
	Barren	0.1	2,004	2,004	1%	140	140	0%	140	0
	Urban[3]	0.5	319	319	1%	175	175	0%	175	0
	Wetland	0.0	-	-	0%	-	-	0%	-	0
	Subtotal	*70.6*	*326*	*182*	*100%*	*23,012*	*12,820*	44%	12,820	0
TOTAL	Crop	1.4	1,979	430	2%	2,752	598	78%		
	Forest	61.8	19	19	4%	1,187	1,187	0%		
	Orchard	3.7	602	241	3%	2,199	880	60%		
	Pasture	4.5	1,989	853	12%	8,910	3,821	57%		
	Range	93.1	330	267	78%	30,711	24,840	19%		
	Barren	0.1	2,004	2,004	0%	140	140	0%		
	Urban	0.6	445	445	1%	277	277	0%		
	Wetland	0.1	0	0	0%	0	0	0%		
	TOTAL	***165.2***	***279***	***192***	***100%***	***46,178***	***31,742***	***31%***		

[1]: based on existing load; [2]: metric tones; [3] Occurs outside a designated "urban boundary"; therefore associated load is LA

Table 8 - TMDLs for Upper Pajaro (Santa Ana Creek)

Modeled Subbasin	LANDUSE	AREA (sq mile)	Existing Sediment Load Rate (t/sq mile/yr)	TMDL Sediment Load Rate (t/sq mile/yr)	% Contribution to Sediment Load [1]	Existing Sediment Load (t[2])	TMDL Sediment Load (t[2])	% Reduction	LA	WLA
9	Crop	7.4	1,292	276	17%	9,593	2,052	79%	2,052	0
	Forest	11.9	3	3	0%	40	40	0%	40	0
	Mine	0.1	196	41	0%	15	3	79%	3	0
	Orchard	2.7	544	218	5%	1,463	585	60%	585	0
	Pasture	25.5	630	258	54%	16,063	6,585	59%	6,585	0
	Range	68.3	44	35	20%	3,002	2,418	19%	2,418	0
	Barren	0.7	413	413	2%	285	285	0%	285	0
	Urban	3.8	63	63	2%	240	240	0%	79	161
	Wetland	0.0	-	-	0%	-	-	0%	-	0
	TOTAL	***120.4***	***255***	***101***	***100%***	***30,701***	***12,208***	**60%**	**12,048**	**161**

[1]: based on existing load; [2]: metric tones;

Table 9 - TMDLs for Lower Pajaro

Modeled Subbasin	LANDUSE	AREA (sq mile)	Existing Sediment Load Rate (t/sq mile/yr)	TMDL Sediment Load Rate (t/sq mile/yr)	% Contribution to Sediment Load [1]	Existing Sediment Load (t[2])	TMDL Sediment Load (t[2])	% Reduction	LA	WLA
6	Crop	6.1	97	20	44%	597	121	80%	121	0
	Forest	0.1	1	1	0%	0	0	0%	0	0
	Orchard	2.1	46	18	14%	96	38	60%	38	0
	Pasture	7.8	17	7	20%	136	55	60%	55	0
	Range	5.5	10	8	15%	52	42	20%	42	0
	Barren	0.2	39	39	2%	6	6	0%	6	0
	Urban	0.2	48	48	4%	10	10	0%	8	2
	Wetland	0.0	-	-	0%	-	-	0%	-	0
	Subtotal	*22.0*	*41*	*12*	*100%*	*898*	*272*	*70%*	*270*	*2*
7	Crop	1.2	673	146	35%	775	168	78%	168	0
	Forest	0.2	1	1	0%	0	0	0%	0	0
	Orchard	0.7	436	174	27%	325	130	60%	130	0
	Pasture	0.7	190	77	11%	131	53	60%	53	0
	Range	1.6	8	6	2%	12	10	20%	10	0
	Barren	0.1	443	443	6%	30	30	0%	30	0
	Urban	1.5	62	62	20%	95	95	0%	11	84
	Wetland	0.2	-	-	0%	-	-	0%	-	0
	Subtotal	*6.1*	*224*	*80*	*100%*	*1,368*	*486*	*65%*	*401*	*84*
8	Crop	6.3	977	212	39%	6,151	1,334	78%	1,334	0
	Forest	3.6	0	0	0%	2	2	0%	2	0
	Mine	0.2	998	205	1%	169	35	79%	35	0
	Orchard	2.7	690	276	21%	1,830	732	60%	732	0
	Pasture	4.1	336	137	16%	1,365	557	59%	557	0
	Range	11.8	4	3	1%	50	40	20%	40	0
	Barren	0.6	636	636	11%	372	372	0%	372	0
	Urban	1.3	289	289	11%	371	371	0%	302	69
	Wetland	0.0	-	-	0%	-	-	0%	-	0
	Subtotal	*30.6*	*337*	*113*	*100%*	*10,311*	*3,443*	*67%*	*3,374*	*69*
12	Crop	2.9	159	32	52%	456	93	80%	93	0

	Forest	0.1	0	0	0%	0	0	0%	0	0
	Orchard	1.0	75	30	17%	75	30	60%	30	0
	Pasture	3.8	29	12	25%	110	44	60%	44	0
	Range	1.0	8	6	3%	8	6	20%	6	0
	Barren	0.0	12	12	0%	0	0	0%	0	0
	Urban[3]	0.1	45	45	3%	6	6	0%	6	0
	Subtotal	*8.9*	*73*	*20*	*100%*	*655*	*179*	*73%*	*179*	*0*
13	Crop	4.0	182	37	50%	728	149	80%	149	0
	Forest	0.3	0	0	0%	0	0	0%	0	0
	Orchard	0.0	605	242	3%	24	10	60%	10	0
	Pasture	2.9	39	16	16%	114	46	60%	46	0
	Range	0.7	6	5	1%	4	3	20%	3	0
	Barren	0.1	281	281	9%	25	25	0%	25	0
	Urban	0.8	74	74	21%	62	62	0%	26	36
	Wetland	0.1	-	-	0%	-	-	0%	-	0
	Subtotal	*8.9*	*108*	*33*	*100%*	*958*	*295*	*69%*	*259*	*36*
14	Crop	1.1	940	205	35%	1,032	225	78%	225	0
	Forest	0.3	3	3	0%	1	1	0%	1	0
	Orchard	0.0	645	258	2%	25	10	60%	10	0
	Pasture	1.2	608	248	46%	724	295	59%	295	0
	Range	4.5	24	19	14%	108	87	20%	87	0
	Barren	0.0	449	449	1%	7	7	0%	7	0
	Urban[3]	0.1	188	188	3%	18	18	0%	18	0
	Subtotal	*7.2*	*265*	*89*	*100%*	*1,916*	*643*	*66%*	*643*	*0*
24	Crop	0.0	1,522	322	0%	34	7	79%	7	0
	Forest	5.6	10	10	3%	55	55	0%	55	0
	Pasture	0.2	547	221	2%	109	44	60%	44	0
	Range	8.4	257	212	91%	2,156	1,773	18%	1,773	0
	Barren	0.0	2,086	2,086	3%	60	60	0%	60	0
	Urban[3]	0.2	64	64	1%	12	12	0%	12	0
	Subtotal	*14.4*	*168*	*135*	*100%*	*2,425*	*1,951*	*20%*	*1,951*	*0*
TOTAL	Crop	21.6	453	97	29%	9,773	2,096	79%		
	Forest	10.2	6	6	1%	58	58	0%		
	Mine	0.2	998	205	0%	169	35	79%		

	Orchard	6.6	362	145	13%	2,375	950	60%	
	Pasture	20.7	130	53	15%	2,690	1,094	59%	
	Range	33.5	71	59	27%	2,391	1,962	18%	
	Barren	1.0	516	516	7%	500	500	0%	
	Urban	4.3	134	134	8%	574	574	0%	
	Wetland	0.3	-	-	0%	-	-	0	
	TOTAL	***98.2***	***189***	***74***	***100%***	***18,530***	***7,268***	61%	

[1]: based on existing load; [2]: metric tones; [3] Occurs outside a designated "urban boundary"; therefore associated load is LA